17th INTERNATIONAL SCHOOL ON QUANTUM ELECTRONICS

LASER PHYSICS AND APPLICATIONS

Book of abstracts

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SEVENTEENTH INTERNATIONAL SCHOOL ON QUANTUM ELECTRONICS
"LASER PHYSICS AND APPLICATIONS"
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BOOK OF ABSTRACTS

SEVENTEENTH INTERNATIONAL SCHOOL ON QUANTUM ELECTRONICS

"LASER PHYSICS AND APPLICATIONS"

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SCHOOL TOPICS

A. Laser - matter interactions
B. Laser spectroscopy and metrology
C. Laser remote sensing and ecology
D. Lasers in biology and medicine
E. Laser systems and nonlinear optics

The organizers are very pleased to acknowledge the co-operating organizations for their support of the school organization.
Special acknowledgments we address also to the industrial partners for their participation in the scientific exhibition.

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SCIENTIFIC EXHIBITION

INDUSTRIAL PRESENTATIONS

IP1

TRENDS IN FS AMPLIFIERS. NEW LEGEND/VITARA CEP TI:SAPPHIRE SYSTEM

Plamen Yankov

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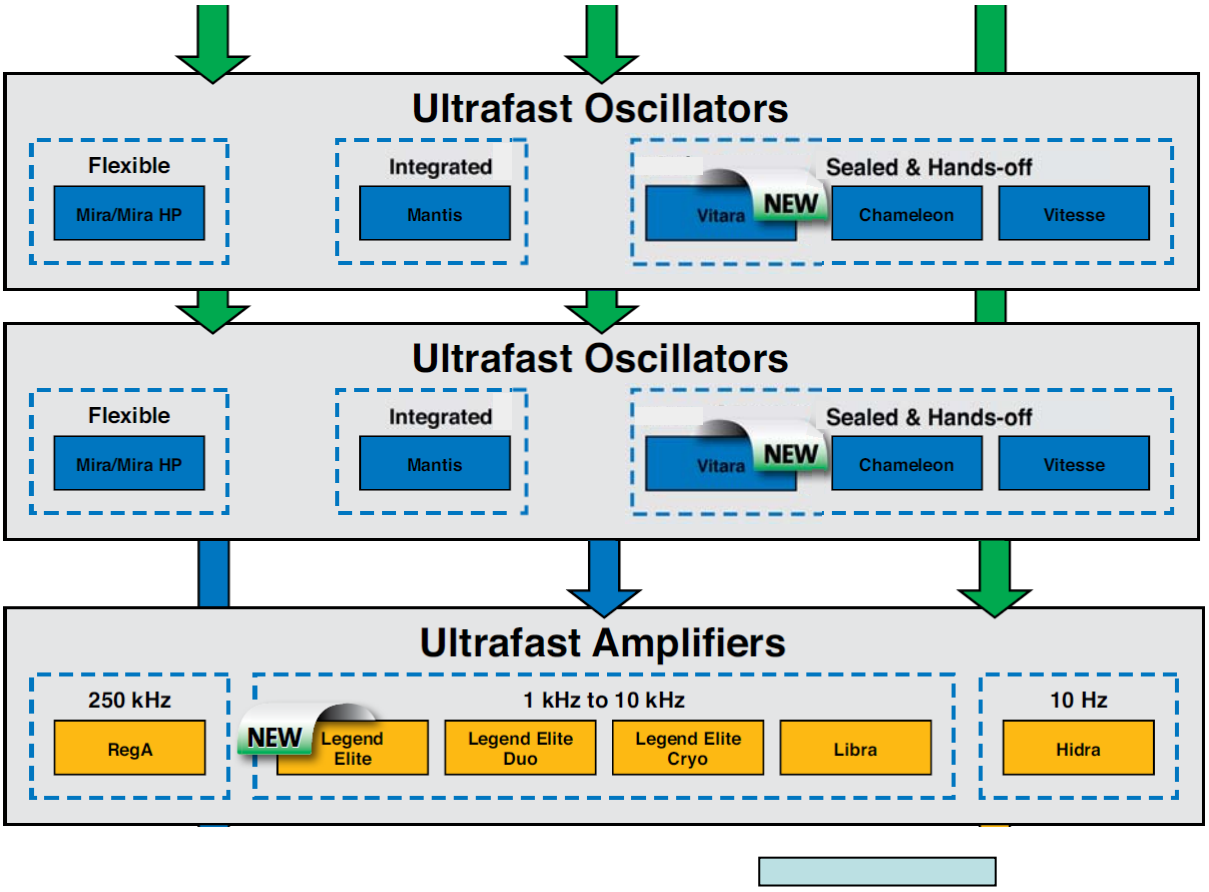
In this presentation we show the trends in the UF amplifiers with several examples for systems, which require very high stability for everyday excellent performance and hands-free operation.



IP2

UPCONVERSION FLUORESCENCE EMISSION OF Er3+/Yb3+- CODOPED THERMALIZED GLASS. KINETICS OF THE EXCITED STATES

P. Yankov[1], I. Gugov[2]

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The emission spectra of the upconversion fluorescence emission of thermalized Er/Yb doped glasses. The decay rates and excited states life times are measured at room temperatures. The kinetic scheme is derived by measuring independently the excited states life times of both excited ions.

IP3

LASERS FOR SCIENTIFIC CHALLENGES

Jan Schaefer

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Modern spectroscopic, atomic physics and quantum optics experiments have a high demand for tunable, narrow-linewidth laser sources at various wavelengths. Moreover, due to the increasing complexity of such experiments, high laser stability and hands-off operation is very important. TOPTICA Photonics serves these needs with its large portfolio of scientific tunable diode lasers covering almost the entire wavelength range from 205 to 2810nm.

The talk gives an overview over TOPTICA's research grade diode laser systems emphasizing how TOPTICA's "pro" technology leads to outstanding performance, stability and ease of use. Examples of standard and customized TOPTICA solutions are given for various cold atom and trapped ion experiments. Many such lasers are successfully used in laboratories worldwide.

SCIENTIFIC EXHIBITION

PRODUCTS PRESENTATIONS

PRODUCTS PRESENTATIONS

PP1

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•FIB (Focused Ion Beam System)
•FE-SEM (Field Emission Scanning Electron Microscope)
•SEM (Scanning Electron Microscope)
•Nano-Probing System
Spectra-Physics
•Laser equipment
Ophir
•Laser beam analytics
AFM: Asylum Research; Park Systems
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•High voltage piezoresponse force microscopy (PFM)
•Magnetic force microscopy (MFM)
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•Thermal Analysis DTA, DSC, TGA, TGA-DTA/DSC, TGA-EGA, TMA, TSC, 3D Calvet
•Calorimetry
•Microcalorimetry
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•High Pressure Differential Scanning Calorimetry (DSC) & Calorimetry
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- **Ultrahigh vacuum (UHV) pumps and components**
- **Molecular beam epitaxy systems**

PLENARY SESSION

INVITED LECTURES

INVITED LECTURES

LASER-MATTER INTERACTION

L1

THE SURFACE NANOSTRUCTURATIONS (POSITIVE OR NEGATIVE) BY MEANS OF NEAR FIELD ENHANCEMENT WITH NANOSPHERES

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Laser-matter interaction is a unique and simple approach to structure materials or locally modify their properties at the micro and nanoscale level [1]. Playing with the pulse duration and the laser wavelength, a broad range of materials and applications can be addressed. One can mention waveguide and microfluidic in dielectrics [2], Two-photon polymerization for the fabrication of 3D scaffolds [3], or UV photolithography in microelectronic industry.

Direct irradiation of surfaces with laser beam through a standard optical beam setup allows an easy and fast structuration of these surfaces in the range of few micrometers. Nano-patterning of surfaces requires sophisticated approaches which are time consuming and need expensive technologies. However, the irradiation of materials through an array of dielectric nanospheres provides a unique opportunity to break the diffraction limit and to realize structures in the range of hundred of nanometers [4]. This simple, fast and low-cost near-field nanolithography technique will be presented and discussed, as well as its great potential.

The theoretical aspects of the near-field enhancement effects underneath the particles have been studied with a simple model based on the Mie theory. The commercial FDTD software, Lumerical, has also been used to study the influence of the substrate and the surrounding media, on the energy profile of the photonic jet generated under the sphere. A specific study has been dedicated to the influence of the dispersion of the sphere diameter on the morphology of the ablation craters.

This technique has been used for patterning of glass and silicon, as well as bi-layer substrates (metal on glass, SiO_2 on Si). In the latter case, the process leads to the formation of a nanoporous membrane which has been used to realize an array of gold nanodots on silicon [5]. We have also performed Laser-Induced Forward Transfer (LIFT) [6] through a monolayer of spheres to print, in a single laser shot, an array of metallic nanobumps.

References:

[1] A. Kabashin et al., 'Nanofabrication with pulsed lasers', *Nanoscale Res. Lett.*, **5**, 454–463, (2010).
[2] A. Schaap, Y. Bellouard, T. Rohrlack, 'Optofluidic lab-on-a-chip for rapid algae population screening', *Biomedical optics express* **2** (3) pp. 658-664, (2011).
[3] I. Sakellari et al., 'Two-photon polymerization of titanium-containing sol-gel composites for three-dimensional structure fabrication', *Applied Physics A* **100** (2), pp. 359-364, (2010).

[4] D. Grojo et al. 'Monitoring photonic nanojets from microsphere arrays by femtosecond laser ablation of thin films', *Journal of Nanoscience and Nanotechnology* **11** (10), pp. 9129-9135, (2011).
[5] A. Pereira et al. 'Laser-fabricated porous alumina membrane (LF-PAM) for the preparation of metal nanodot arrays', *Small*, **4,** 572-575 (2008).
[6] L. Rapp et al., 'Pulsed-laser printing of silver nanoparticles ink: control of morphological properties', *Optics Express* **19** (22), pp. 21563–21574, (2011).

Acknowledgements: We thank French ANR agency for financial support through the FELINS-ANR-10-BLAN-946 project.

L2

INTERACTION OF LASER LIGHT WITH THE $A^{III}B^{VI}$ LAYERED SEMICONDUCTORS. NONLINEAR OPTICAL APPLICATIONS

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Low-dimensional materials and the materials sensitive to change of their dimensionality are highly interesting. Change in dimensionality have strong influence on their electronic, optical and nonlinear optical (NLO) properties. A class of $A^{III}B^{VI}$ materials (where A^{III}- is for *Ga*, *In*; B^{VI}- is for *S*, *Se*, *Te*) have layered (quasy two-dimensional) crystal structure. Bulk crystals of *GaSe* (gallium selenide) and other representatives of this group of materials are widely used as a NLO elements for frequency transformation of the laser lights. Main structural motive of $A^{III}B^{VI}$ crystals is a layer of atoms -*Ch-Me-Me-Ch*- (where *Ch*-, and *Me*-, is for chalcogenide and metal atoms, respectively). Depending on the number of layers per unit cell and their orientation, these materials may crystallize in different polytypes. 4 polytypes were described for *GaSe* [1]: i) the centrosymmetric β- type consisting of two layers and crystallizing in the D_{6h}^4 space group (SG); ii) the noncentrosymmetric ε- type conatins 2 layers and has SG D_{3h}^1; iii) γ- type, one layer, SG C_{3v}^5; iv) δ- modification, 4 layers, SG C_{6v}^4 [1].

One of the most prominent NLO material among $A^{III}B^{VI}$ group is *GaSe*, which is accepeted by the scientific community in the world as an ″outstanding NLO material or material with an outstanding NLO properties″. NLO properties of *GaSe* has been first investigated in 1972 and may be summurazed as follows [2]: i) very high NLO coefficient $d_{22} = 86 \pm 17$ pm/V; ii) wide transparency range of 0.7 - 18 μm with the linear absorption coefficient less than $\alpha \leq 0.3$ cm^{-1}; iii) high birefringence $\Delta n = n_o - n_e \approx 0.28$ ($\lambda = 1.06$ μm); iv) nonlinearity in the phase-matched direction: $d_{eff} = -d_{22}\cos\theta\sin 3\varphi$ ($e = e + o$) (where θ is angle between the wave vector k of the pump radiation and the optical c- axis of crystal and φ- is the angle between the crystal XZ and KZ planes); v) phase-matching angle θ for the second harmonic generation (SHG) at the pump wavelength $\lambda = 2.36$ μm is $\theta = 18^o40' \pm 10'$; $\theta = 10^o10' \pm 20'$ ($\lambda = 5.3$ μm); $\theta = 12^o40' \pm 20'$; ($\lambda = 10.6$ μm); vi) high value of the two photon absorption (TPA) coefficient ($\approx 10^{-7}$

cm/W at λ = 1.06 μm; vi) high power threshold for optical damage of ≈ 2 x 10^7 W/cm^2 (λ = 0.694 μm, τ_p = 25 ns), ≈ 3.5 x 10^7 W/cm^2 (λ = 1.06 μm, τ_p = 10 ns), ≈ 25 MW/cm^2 (λ = 9.3 μm, f = 20 Hz), ≈ 100 W/cm^2 (λ = 0.8 μm).

The NLO properties of $A^{III}B^{VI}$ bulk crystals and some of their solid solutions, perspectives for future research, applications in the THz range of spectra including nanoparticles are considered in the present article with emphasis on *ε- GaSe*.

References:

[1] K. Maschke and F. Levy, ″Landolt-Börnstein in Numerical Data and Functional Relationships in Science and Technology, New Series, Group III: Crystal and Solid State Physics″, Ed. by. S. Flügge, Springer, Berlin, (1983).

[2] G. Abdullalev, K. Allakhverdiev, L. Kulevskii, A. Prokhorov, E. Salaev, Savel'ev and V. Smirnov, ″Parametric conversion of infrared radiation in a GaSe crystal″, Sov. J. Quantum Electron., Vol. 5, No 6, 1228-1233 (1972).

L3

LASER ROUTE TO SCIENCE AND ENGINEERING ON NANOSCALE

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Processes and methods based on the application of laser irradiation and resulting in preparation of nanoscale objects and structures of controlled properties are discussed in this review. Objects of dimensions in-between the atomic and macromolecular scale evoke much interest and are intensively studied over last decades. This is because the processes and interactions of this size range determine the most important material properties such as thermal conductivity, magnetic permeability, optical response (color), etc. The research progress in this field benefits from the matured developments of the laser science and technology which is worth mention because of the 50th anniversary of the invention of the laser. Obviously, it is also enabled by newest developments in the structural and spectroscopic characterization techniques which make possible precise observations and are recently on the breakthrough towards the atomic scale resolution. Moreover, advanced modeling tools able to account so for quantum size effects as well as for macroscopic ones contribute to understanding of the small scale interactions and to engineering of the future, industrial level devices.

L4

FABRICATION OF PLASMONIC NANOSTRUCTURES AND OPTICAL DEVICES BY PULSED LASER ANNEALING

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The strong interaction of light with plasmonic nanostructures and the ability to tailor their optical properties can be utilised to form or enhance a variety of macro-scale to nano-optical devices. These include plasmonic coatings to enhance the efficiency of photovoltaics or LEDs, as substrates for chemical detection, in sub-wavelength optics, and super-lenses. To date a wide range of nanofabrication tools have been used to create bespoke plasmonic optical elements and coatings, but large scale fabrication has not been realised.

Here, we discuss the controllable nanostructuring of thin metal films by short (25 ns, 248 nm) and ultra-short (100 femtosecond, 800 nm) laser pulses across a wide range of fluences as a novel technique for the production of supported noble metal nanoparticles over large areas on glass, polymer and ITO substrates. We also introduce the laser-induced implantation of metal nanoparticles into the surface of glass substrates as a new method to produce robust optical coatings and fine-scale plasmonic optical devices. We discuss the differing mechanisms, relative merits and thermal budgets for laser nanostructuring with short and ultra-short pulses and demonstrate how the surface plasmon energy can be tuned via laser-induced alloying. Applications for these coatings in enhancing the efficiency of solar cells, as plasmonic optical elements and in chemical detection will be discussed.

L5

NANOSTRUCTURES ON LASER-BOMBARDED SURFACES AND THEIR CORRELATION WITH THE SHAPE OF THE ULTRASHORT LASER PULSE

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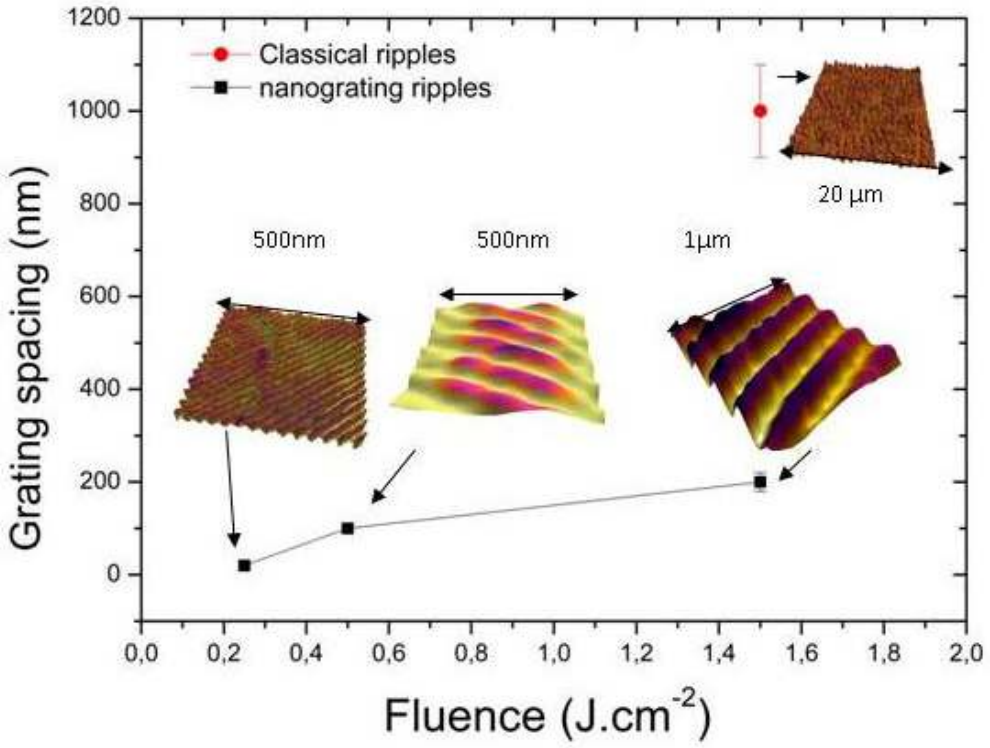
The formation of self-organized sub-wavelength ripples on the surfaces of many materials is one of the interesting and may be usable consequences of the interaction of materials with ultra short laser radiation. Here we discuss the observation of theses surface structures for 25 fs laser pulses at a central wavelength of 800 nm for different experimental conditions. I.e. for Al sub-wavelength gratings with periodicities ranging from 20 to 220 nm are found. For CaF2 the periodicity observed is closer to 625 nm. In case of Si, nano-gratings have a characteristic periodicity of 10–100 nm. The spacing of these gratings is 60 nm in case of CR-39. These features, which are significantly shorter than the incident laser wavelength are observed at an

irradiation fluence slightly higher than the ablation threshold regardless of the target material. In addition to these nano-ripples, classical or micro-ripples with an average spacing of 1–2 lm have also been observed on irradiated surfaces of Al and Si. These micro-ripples are characteristic for fluences higher than the ones required for nano-ripple-formation. It has been found that the formation of the laser-induced ripples is strongly dependent and quite sensitive to the incident laser fluence and the selection of material. Possible mechanisms and results of other groups will be put in perspective. Just to give an example, ultra-fast electronic and thermal processes related to the energy deposition mechanism during femtosecond laser ablation of CaF2 have been identified by means of Atomic Force Microscopy (AFM) and Raman scattering technique and will be discussed among others. Typical examples of periodic structures developing at different laser intensities on an Al surface are shown in the figure.



L6

ULTRAFAST PROCESSES IN SOLIDS AT THE NANOSCALE

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The high peak power and the short temporal duration of modern laser systems are valuable tools in the research on light-matter interactions in fundamental as well as applied and technological directions. In this presentation I will review recent work of ours with emphasis on physical mechanisms that take place at the nanoscale and in ultrashort temporal windows.

Firstly, I will review applications of laser-based time-resolved spectroscopy on the study of elementary excitations in solids and the subsequent ultrafast interactions that re-distribute the

absorbed energy within the electronic, vibronic and magnetic degrees of freedom of the solid at very small dimensions.

Secondly, I will summarize recent and ongoing research activities including, applications of ultrashort laser sources in the study of ultrafast electron and lattice dynamics in bulk and nano-structured solids, controlled surface modification at the micro- and nano-scale using irradiation with femtosecond laser pulses and an outlook relevant to the possibilities with temporally shaped laser pulses in the control of ultrafast processes in solids that can lead to tailored morphological properties, an important aspect for technological applications.

LASER SPECTROSCOPY AND METROLOGY

L7

VIBRATIONAL MECHANICS IN AN OPTICAL LATTICE: CONTROLLING TRANSPORT BY POTENTIAL RENORMALIZATION

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The control of transport is a recurrent topic in physics, chemistry and biology.

The typical scenario corresponds to particles diffusing on a periodic substrate, with transport controlled by the application of dc and ac external fields. The ultimate limit for the control of transport is often the impossibility of tuning the periodic potential, as it is usually the case in solid state.

In this work we provide a proof-of-principle of how this limitation can be overcome, and demonstrate theoretically and experimentally the control of a periodic potential amplitude via a strong high-frequency (HF) oscillating field. The potential is renormalized, with its amplitude controlled by the strength and frequency of the HF field. The mechanism underlying the potential renormalization is the so-called vibrational resonance, initially introduced and observed in bistable systems. Our experiment uses cold atoms in a dissipative optical lattice as a model system. However, the phenomenon demonstrated here is very general, and is relevant to any classical system of particles in a periodic potential. This may also offer a possibility of tuning the potential in solid state systems, where this is usually considered impossible. Combined with previous work which showed how ac fields can be used to control transport via dynamical symmetry breaking and tunnel coupling renormalization, the present work demonstrates that a complete control of transport can be achieved via ac fields.

References:

[1] A. Wickenbrock, P. C. Holz, N. A. Abdul Wahab, P. Phoonthong, D. Cubero, and F. Renzoni, Phys. Rev. Lett. **108**, 020603 (2012).

Acknowledgements: This work was supported by the Leverhulme Trust, the Ministerio de Ciencia e Innovación of Spain FIS2008-02873 (D. C.), and the DAAD (P. C. H).

L8

MOT FOR RADIOACTIVE ATOMS: OPTIMIZATION OF TRAPPING EFFICIENCY

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The set-up of a MOT is in general the first step in laser cooling experiments. During the last 20 and more years, a huge effort has been made to fix the best conditions for high trapping efficiency. Evidence of this activity is given by the very large number of papers that report a full analysis of problems and of their solution. More recently the possibility to work also with unstable isotopes gave to atomic physics new perspectives in the field of fundamental physics, but, at the same time it showed the need for further work on MOT efficiency. Goal of these experiments is, in general, a test of Standard Model. In these experiments the number of trapped atoms is a crucial parameter that depends, besides others, on production and decay rates.

We set up in INFN Legnaro National Laboratories a MOT working with Francium. The research project is aimed at the observation of parity non conservation. The effect is very weak so that a systematic optimization of all parameters is necessary. Main issues are: very poor production rate; losses on surface; surface passivation; ion neutralization; capture velocity; level scheme selection; laser excitation and others. The problems will be discussed and possible solutions will be presented.

An interesting issue is represented by the trapped atom number changes induced by a laser beam resonant with transitions both from ground and excited trap levels. Laser excitation outside the cooling scheme induces losses in the MOT population, while laser increases the trap population when tuned on transitions linked to the trapping cycle. The experiment is performed, so far, with a small number of trapped Rb atoms (100 to 10000). A discussion of our ability in manipulating the atomic population of different hyperfine states (HFS) is reported.

L9

ATOM-WALL INTERCTIONS AND THEIR ROLE IN THE SPECTROSCOPY OF SPATIALLY CONSTRAINED ATOMIC VAPORS

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Atom-wall interactions play an unexpectedly important role in the atomic spectroscopy. J.L. Cojan [1] was the first who observed and then interpreted the effects of the atom-wall interactions on the reflection spectra in the vicinity of the atomic spectral line. His observation was made on the mercury vapors of such a low concentration that the Doppler width was much larger than the homogeneous width of the atomic transition. Surprisingly, the width of the spectral line he observed in reflection was much smaller than the Doppler width. His explanation brought about a whole new branch of spectroscopy, i.e. stationary spectroscopy of transient polarizations. He pointed out that the atoms collide with the windows of a spectroscopic cell and, hence, their polarization may be destroyed. As a result, those atoms, that depart from the window posses a transient rather than the stationary polarization. This is the reason why their contribution to the reflected field differs from what was expected. Moreover, would the polarization be preserved the Doppler shifts of the atoms arriving at the surface and those atoms that leave the window surface are different anyway. Hence, the transient polarization is developed in this case too.

M. Ducloy [2] employed the tiny distortions of these narrow resonances in reflection spectra to measure for the first time the van der Waals constants in the excited atomic states. He pointed out that the atom-wall collision is a process that takes space and time rather than a sudden change of the atomic velocity. In simple terms there is a narrow slice of a nonresonant medium in an immediate proximity of the surface. As it was shown a little bit later [3] such a slice leads to the admixture of even and odd contributions to the line shape.

In our work [4] we considered reflection from a narrow slice of atomic vapors and found a manifold of spectral line shapes depending on the width of the vapor slice that have nothing in common with the Fabri-Perot resonances. It was not until the invention of an Extremely Thin Cell (ETC) by D. Sarkisyan [5] that the observation of these effects becomes possible in the optical domain. In this contribution we discuss the latest developments in the field.

References:

[1] J. L. Cojan, "A contribution to the study of the selective reflection of mercury resonance radiation from mercury vapour" Ann. Phys. (Paris), Vol. 9, 385-page, (1954).

[2] M. Oriá, M. Chevrollier, D. Bloch, M. Fichet, M. Ducloy, "Spectral observation of surface-induced van der Waals attraction on atomic vapor", Europhys. Lett. 14, 527 (1991).

[3] T. A. Vartanyan, F. Träger, "Line-shape of resonances recorded in selective reflection - influence of an antireflection coating" Opt. Commun., Vol. 110, No. 3-4, 315-320 (1994).

[4] T. A. Vartanyan, D.L. Lin "Enhanced selective reflection from a thin-layer of a dilute gaseous medium", Phys. Rev. A, Vol. 51, No 3, 1959-1964, (1995).

[5] D. Sarkisyan, D. Bloch, A. Papoyan, M. Ducloy. "Sub-Doppler spectroscopy by sub-micron thin Cs vapor layer", Opt. Comm., Vol. 200, 201-208, (2001).

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L10

SUB-DOPPLER OPTICAL RESOLUTION BY CONFINING A VAPOUR IN A NANOSTRUCTURE

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With the blossom of communication technologies, there is an urgent need to make frequency reference devices as compact as possible[1]. Recent advances[2-4] demonstrate that highly confined vapors still allow performing atomic or molecular physics. An issue is the ability to suppress the Doppler broadening in these systems. In particular, confinement is susceptible to reduce the Doppler broadening, through the Dicke narrowing[5], *i.e.* when the atomic free path is typically shorter than the wavelength. This narrowing, well-known in the *r.f.* domain, when buffer gas collisions restrict the atomic free motion, remains elusive in the optical domain, as a considerable buffer gas density would be needed at optical wavelengths.

Here, we report on experiments performed with a dilute alkali-metal (Cs) atomic vapor confined in the interstitial regions of an opal made of glass nanospheres (diameter d ~ 1μm, occasionally d ~ 400 nm). A thin opal has been deposited on one of the window of the cell by a layer-by-layer Langmuir-Blodgett technique, and we perform (FM) reflection spectroscopy on the doublet of Cs resonance lines (λ = 852nm and λ = 894 nm). We find that the reflection spectrum is sensitively sub-Doppler under a near normal incidence (~30 MHz width, *vs* a Doppler width ≥ 200 MHz). Also, in spite of a broadening with the incidence angle, a narrow structure remains observable for a large range of incidence angles (see fig.1). We interpret this last feature, observed in a fully linear regime, as a signature of the atomic response from the interstitial regions, through a Dicke narrowing allowed by wall collisions.

Presently, our work allows envisioning very compact sub-Doppler references, based upon weak (and hence hardly saturable) molecular lines, as a benefit of the intrinsic linearity of the method combined with the Dicke narrowing. The probed volume yielding a sub-Doppler response can be conceptually as small as several spheres (*i.e.* several λ^3), and the irradiation extremely focused. An extension to generic porous and scattering media seems feasible.

References:

[1] S. Knappe *et al.,* Appl. Phys. Lett., **85**, 1460 (2004).
[2] F. Benabid *et al.,* Nature, **434**, 488 (2005).
[3] T. Svensson *et al.,* Phys. Rev. Lett. **107**, 143901 (2011).

[4] S. Ghosh *et al.,* Phys. Rev. Lett. **97**, 023603 (2006).
[5] R.H. Dicke, Phys. Rev. **89**, 472 (1955).

Acknowledgements: Work performed in the frame of the ANR project Mesoscopic gas 08-BLAN-0031, and bilateral programmes ECOS-Sud U08E01 (with Uruguay) and CNRS PICS #5813 (with Russia). The opal was prepared at CRPP-Bordeaux by S. Ravaine team.

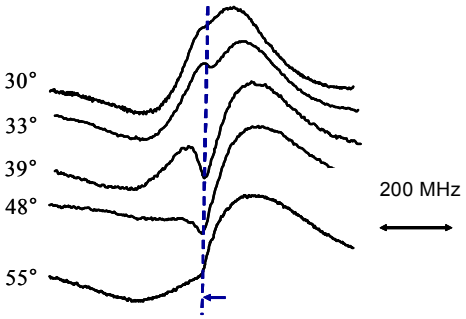

Fig.1: *FM reflection spectrum (TM polarization) as a function of the external incidence angle at the interface (D_1 Cs line, 10 layers of 1 μm opal). The dashed line indicates the center of an auxiliary saturated absorption spectrum.*

LASER REMOTE SENSING AND ECOLOGY

L11

SYNERGY OF GROUND-BASED AND SPACE LIDAR AND RADIOMETER SYSTEMS FOR MONITORING OF LONG RANGE POLLUTION TRANSPORT IN ATMOSPHERE

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Long range pollutants transport from remote sources makes significant impact on changing of the air quality in the European regions. Just in atmosphere pollutions propagates in the most rapid way, and local ecological catastrophes take on global character.

Union of remote sensing and local measuring data, space observations and modelling of air mass transport provides necessary prerequisites to monitor pollution spreading and its effect estimation on the regional ecological conditions. Ground-based remote sensing networks and satellite sensors contribute to the main part of data measured and allow the features of pollution transport to be operatively discovered. Basically, the object of the monitoring is particular matter suspended in the air.

Global Sun-radiometers network AERONET, regional lidar networks EARLINET and CIS-LiNet carry out regular aerosol observations over European area.

The Aerosol Robotic Network (AERONET) of ground-based sun/sky-scanning radiometers [1] provides reliable information about columnar aerosol properties in more than 200 world-wide distributed locations. AERONET directly measures aerosol optical thickness and retrieves detailed microphysical properties (including particles, sizes, absorption, index of refraction etc.) of aerosol in the entire atmospheric column from direct and diffuse radiation measurements [2].

The information about vertical variability of aerosol is obtained from lidar sounding. The European Aerosol Research Lidar Network (EARLINET) [3] and lidar network in the Former SU countries CIS-LiNet [4] provide measuring altitude profiles of aerosol backscatter and extinction coefficients.

Nowadays, a new technique of combined lidar and Sun-radiometer data processing is developed with the aim to establish routine coordinated lidar and Sun-radiometer observations of atmospheric aerosols over European area and abroad. Synergy of multiwavelenth lidar and Sun-radiometer techniques and implementation of the method at the combined lidar and radiometer EARLINET/AERONET stations allows the new type of network data being a full set of optical parameters of the aerosol layer to be obtained.

Developing and implementation of combined lidar and radiometer sounding of atmospheric aerosol, as well as application of networks measured data and satellite observations for monitoring process of long range pollution transport in the East European regions are the topic of the presentation.

LASERS IN BIOLOGY AND MEDICINE

L12

OPTICAL TWEEZERS AND CELL BIOMECHANICS IN MACRO- AND NANO-SCALE

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The dramatic expansion of both experimental and theoretical research efforts utilizing optical tweezers indicates the increased importance that this technology has found in the revolutionary fields of physics, biology, chemistry, genetics, medicine and micromechanics. Optical traps or tweezers are non-invasive tools which are developed using a laser beam for manipulation of matter in micro-and nano-cosmos. Optical tweezers are used to speed up, slow down, divert, or trap of small particles. Moreover, optical tweezers can be used along with other tools/techniques (laser scalpel and ablation, laser induced fluorescence, atomic force microscopy) for a variety of applications. Among them, optical tweezers have been used as a tool for detecting red blood cells diseases. Using linearly polarized light, we have induced rotation, to plasmodium infected red blood cells (iRBCs) and to normal cells RBCs [1]. Difference in their rotational speeds was observed and this could be exploited for the high throughput diagnosis of malaria. Recently, we have also studied the effect of optical forces on red blood cells in isotonic and hypertonic buffer solutions and their behaviour in the optical trap was analyzed in combination with the dielectrophoresis method. RBCs can experience rotational torque with a linearly polarised beam if they are handled by beams with elliptical focus spot profile. A modified optical trapping laser beam, a "line optical tweezers" system, was used as a tool for deformation and angular momentum transfer by photons of the beam in

biological samples, especially on birefringent permeable structures such as erythrocytes and liposomes, causing micro-elongations. Line optical tweezers proved to be an essential tool for inducing at the same time folding and stretching of more than one RBC and measuring their bending modulus. Another interesting cell model for biomechanical measurements is liposomes. Liposomes and nanoparticles applications in health care include mainly their ability to carry drugs and genes inside the human body for therapeutic purposes. Optical tweezers could be used to optimize the encapsulation efficiency of the drug in the carrier and the modification of its release from the system, by measuring their biophysical parameters. By measuring the line optical trap forces and the reversible liposome deformation induced by laser tension, the shear modulus, μ, of giant egg yolk phosphaditycholine liposomes stained with methylene blue (a photosensitizer) is numerically approached [2]. Interesting dynamic shape deformations were observed in nanometric scale including budding transitions and fissions of the liposomal membrane leading to liposomal tubular structures.

References:

[1] K. Bambardekar, A.K. Dharmadhikari, **"**Measuring erythrocyte deformability with fluorescence, fluid forces, and optical trapping" J. Biomed. Optics 13:6: 064021 (2008).
[2] E. Spyratou, M. Makropoulou, A.A. Serafetinides, "Line Optical Tweezers: A tool to investigate stained liposomes transformations and to determine shear modulus", Coll. Surf. A 349, 35-42, (2009).

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L13

ARTIFICIALLY DESIGNED PLASMONIC STRUCTURES FOR PHOTONIC AND BIOSENSING APPLICATIONS USING LASER TECHNIQUES

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The interaction of light by small metal nanoparticles (NPs) has been an active area of research for over a century and has recently given raise to the field of "plasmonics" with promising applications not only in photonics but also in sensors, biology or biomedicine. The surface plasmons/polaritons associated to these NPs lead to specific optical response (surface plasmon resonance) and an enhancement of the electromagnetic field in the neighborhood of the NPs. More recently, the use of sophisticated lithographic techniques has given access to plasmonic systems in which surface plasmons interact over two different scales leading to new interesting phenomena and opening new possibilities. The control of the size, shape and organization of the nano-objects is essential for tailoring their response to the application envisaged. This presentation will show how laser techniques can offer alternative routes to produce these artificially designed structures with several attractive features. Two approaches for producing structures spread in large areas (few mm^2) will be described. The first one is pulsed laser deposition and it will be shown how 1D or 3 D organization of plasmonic nano-objects can be achieved, the dimensions of the nano-object and their spacing being typically in the few nm range. The second one is laser interferometry that allows producing 1D or 2D

patterns having a wide range of motives and periodicities ranging from hundreds of nanometers to tenths of micrometers. Examples of applications of some of these nanostructured plasmonic structures in photonics and biosensing will be shown.

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LASER SYSTEMS AND NONLINEAR OPTICS

L14

FASCINATION LASER: A MOST WONDERFUL INSTRUMENT TO CHECK AND CONTROL MOLECULES, CLUSTERS AND EVEN THE ATMOSPHERE

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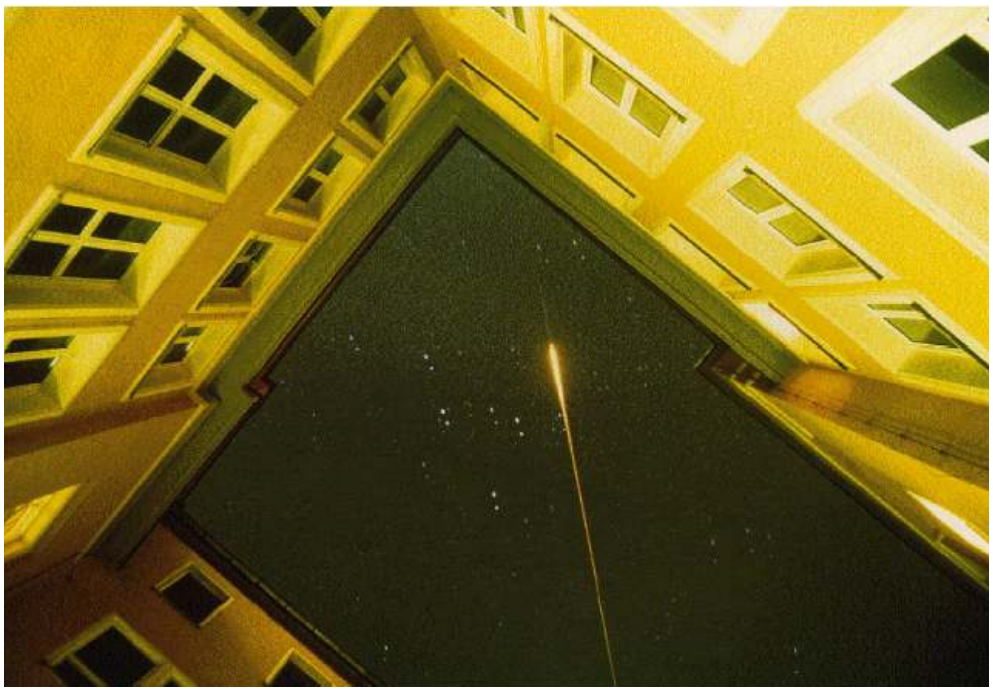

The advent of tuneable lasers has not only revolutionized the field of modern spectroscopy, it has also led to the development of ultrafast laser sources, which allow the real time observation of dynamic molecular processes like rotations and vibrations, electronic transitions, ionisations, fragmentations and even reactions. These processes can optically be controlled and optimized by using spectrally well sequenced light pulses (optimum control). During the lecture the basic principles of laser physics will be demonstrated and a Nitrogen laser will be built, which will then be used to pump a tuneable dye laser. Then examples of

spectroscopic applications will be provided reaching from multi photon ionisation experiments to LIDAR remote analysis of the atmosphere.

Based on the principle of tuneable lasers it was possible to develop new ultrafast and ultra-intense laser sources, which are able to generate fascinating non-linear optical processes. When for example launching them into air, white light emitting plasma filaments or even bundles of those are generated (see picture above). Under well-chosen conditions these bundles may extend even over kilometer lengths. Very interesting properties result from the electrical conductivity of these filament bundles. They do not only allow to guide and control electric discharges; they even provide a realistic chance to control lightning. Another still unexplored, but quite relevant effect resulting from the plasma character of filaments is the formation of droplets along their path. The effect is similar to the formation of droplets in a Wilson-type fog chamber; it is very promising and can well become a new and important tool in atmospheric research and for the prevention of hail.

L15

TAILORING AND APPLICATIONS OF INTENSE FEMTOSECOND THZ SOURCES

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The far-infrared region of the electromagnetic spectrum ranging from 0.1 to 10 THz, known as Terahertz radiation, has become the last years an extremely attractive research field for scientists from various disciplines, including chemistry, metamaterials science, biology and medicine. The THz spectrum provides rich information of low frequency vibrational modes such as crystalline lattice or inter-molecular vibrational modes, hydrogen bonding stretches, and large-scale motions of an entire macromolecule or motions of particular subunits which occur on a sub-picosecond to tens of picosecond time scales. All these low lying frequencies are essential for several physical and chemical processes and their position and strength are highly sensitive to small conformational changes of a molecule and its environment.

Here we will discuss the evolutions related to ultrashort THz sources with emphasis on our advances towards the generation of table-top intense THz sources based on laser filaments [1]. We will present effective ways to control the THz radiation properties, through filamentation tailoring [2] or tunable THz metamaterials [3], and discuss applications in spectroscopy and nonlinear THz optics – a research field in its birth.

References:

[1] J. M. Manceau, M. Massaouti, and S. Tzortzakis, "Strong terahertz emission enhancement via femtosecond laser filament concatenation in air," Opt. Lett. 35, 2424-2426 (2010).

[2] J.-M. Manceau, M. Massaouti, and S. Tzortzakis, "Coherent control of THz pulses polarization from femtosecond laser filaments in gases," Opt. Express 18, 18894-18899 (2010).

[3] N.-H. Shen, M. Massaouti, M. Gokkavas, J.-M. Manceau, E. Ozbay, M. Kafesaki, T. Koschny, S. Tzortzakis, and C. M. Soukoulis, "Optically Implemented Broadband Blueshift Switch in the Terahertz Regime," Phys. Rev. Lett. 106, 037403 (2011).

L16

ULTRASHORT LASER PULSE FILAMENTATION WITH AIRY AND BESSEL BEAMS

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Keywords: nonlinear propagation, Airy / Bessel beams, ultrashort laser pulse filamentation

Ultrashort laser pulse filamentation denotes a peculiar nonlinear propagation regime reported since 1995 [1]. The beam first shrinks upon itself to form a narrow intense core, surrounded by an extended region of laser radiation which constitute an energy reservoir able to feed the intense core and sustain propagation over extended distances. Competing nonlinearities severely reshape the pulse in the spatial, temporal and spectral domains leading to various spectacular phenomena such as conical emission [2]. Of particular importance is the spontaneous reshaping of the pulse into an apparently diffraction- and dispersion-free conical wave, then acting as an attractor for the filamentation dynamics [3,4]. We report results on the nonlinear propagation of ultrashort laser pulses when the beam is not initially Gaussian, but preliminarily reshaped into a one-dimensional diffraction-free or a two dimensional quasi diffraction-free Airy beam.

In one transverse dimension, we investigate light bullets in the form of nonlinear Airy beams. For paraxial propagation, we show the existence of diffraction-free nonlinear Airy beams sustained by a balance between diffraction, third-order (Kerr) nonlinearity and nonlinear losses, in one transverse dimension. Numerical simulations and experiments confirm a stable nonlinear propagation of these stationary nonlinear Airy beams up to a maximum intensity

[5]. We then extend this analysis to the nonparaxial propagation regime and provide nonlinear counterparts of the diffraction-free solutions discovered in Refs [6,7].

In two transverse dimensions, we investigate from numerical simulations and experiments the nonlinear dynamics of finite energy (truncated with a diaphragm) intense Airy beams in Kerr ionizing media. We show that Airy beams with high powers in the main lobe generate multiple filaments induced by Kerr and multiphoton nonlinearities, which only locally follow the properties of the input Airy beam. We analyze the effects of initial Airy lobe size, power and size of the truncating diaphragm. We show that the nucleation of new filaments and their interaction, depends on these parameters. New filaments affect the transverse acceleration of the main Airy lobes, which is otherwise governed by the size of the main lobe. The size of the truncating diaphragm allows for controlling the propagation distance over which the energy flux that features the Airy beam acceleration is sustained.

A regime of stationary propagation is retrieved for powers in the main Airy lobe below a critical threshold. In this case the transverse acceleration of the Airy peak is preserved as in one dimension and stationary propagation is sustained by a continuous energy flux to the main Airy lobe from it neighbors, similarly to the mechanism sustaining nonlinear Bessel beam propagation.

References:

[1] A. Braun et. al., Opt. Lett. **20**, 73 (1995).
[2] A. Couairon and A. Mysyrowicz, Phys. Rep. **441**, 47 (2007).
[3] D. Faccio et al. Opt. Express **16**, 1565 (2008).
[4] P. Polesana et al., Phys. Rev. Lett **99**, 223902 (2007).
[5] A. Lotti et al., Phys. Rev. A **84**, 021807 (2011).
[6] L. Froehly et al., Opt. Express **19**, 16455 (2011).
[7] I. Kaminer et al., Phys. Rev. Lett. **108**, 163901 (2012).

L17

NONLINEAR OPTICAL PROPERTIES OF CHIRAL MATERIALS

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Chiral materials exist in two forms that are mirror images of each other, referred to as enantiomers. In general chirality is equivalent to the absence of mirror planes of any order and chiral molecules and materials show optical activity effects such as circular dichroism (CD) and optical rotation (OR). Circular dichroism is the different absorption of left- and right-hand circularly polarized light and optical rotation is the rotation of the plane of polarization of linearly polarized light that travels through a chiral sample. Both CD and OR originate from a different refractive index for left- and right-hand circularly polarized light and are linear optical effects. Optical activity effects however, can also be observed in nonlinear optical processes [1]. For example, it has been shown that chiral materials show a different efficiency in second-harmonic generation when illuminated with circularly polarized

light of different handedness and also circular dichroism in other multiphoton processes has been observed [2]. Furthermore, these nonlinear optical activity effects have not only been used to study chiral materials, but also artificial nanomaterials have been demonstrated to show very unusual nonlinear optical effects [3].

In this talk, we will give an overview of several nonlinear optical processes in which chirality plays a crucial role, and present some of our most recent results in this field.

References:

[1] T. Verbiest, K. Clays, V. Rodriguez "Second-Order Nonlinear Optical Characterization Techniques: An introduction", CRC Press, Boca Raton (2009).
[2] C. Toro, L. De Boni, N. Lin, F. Santoro, A. Rizzo, F.E. Hernandez, Chem. Eur. J., Vol. 16, 3504-3509, (2011).
[3] V.K. Valev *et al*, Nano lett., Vol. 9, 3945-3948, (2009).

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POSTER SESSIONS

PRESENTED CONTRIBUTIONS

A - *LASER –MATTER INTERACTIONS*

PA1

MULTIPHOTON-AVALANCHE IONIZATION INSIDE N-DOPED SILICON BY TIGHTLY FOCUSED NEAR-INFRARED LASER PULSES

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We investigate the origin and localization of non-linear absorption when femtosecond laser pulses are tightly focused inside n-type doped silicon. In the experiments, we use an OPA femtosecond laser system to access wavelengths in the near-infrared domain where the optical radiation energy is below the band gap energy of silicon. At 1.3μm, we find intrinsic and low-doped silicon substrates are fully transparent to low light intensity (Fig 1). With focused nanojoule pulses, the intensity in the focal region is sufficient to initiate non-linear absorption. Since the energy deposition is confined in the focal region, the approach must make possible true-3D direct micromachining inside semiconductor materials which would be impossible at the fundamental wavelength of Ti:Sapphire laser systems.

We measure and characterize transmitted pulses interacting with silicon wafers of several doping concentrations. We find the non-linear contribution to absorption does not depend on initial concentration of free-electrons up to 10^{16}.cm^{-3} as it would be predicted with an important contribution of avalanche ionization [1]. To confirm the independence of the non-linear absorption to free-carrier initially present, we perform also a double-pulse experiment where a pre-pulse creates charge pairs and we compare the second transmitted pulse to a typical single pulse experiment.

We also perform Z-scan absorption measurements and single pulse material damaging experiments above breakdown threshold. Both methods are used to locate the energy deposition in the substrates as a function of pulse energy. Under specific conditions, we find the energy deposition can remain confined in micron-scale regions. The high degree of control and the independence on doping are major assets for future micromachining technology developments inside silicon.

Reference:

[1] I. Bogatyrev, D. Grojo, Ph. Delaporte, S. Leyder, M. Sentis, W. Marine, T.E. Itina, "Non-linear absorption of 1.3-μm wavelength femtosecond laser pulses inside semiconductors: FDTD-TTM combined computational study", J. Appl. Phys. 110, 103106 (2011).

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PA2

IN SITU SYNTHESIS OF HYBRID INORGANIC-ORGANIC NANOCOMPOSITE COATINGS BY NOVEL LASER ADAPTIVE ABLATION DEPOSITION TECHNIQUE

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A novel approach for *in situ* synthesis of hybrid inorganic-organic nanocomposite coatings by new modification of Pulsed Laser Deposition technology called Laser Adaptive Ablation Deposition (LAAD) is presented. Hybrid nanocomposite coatings including Mg- Rapamycin and Mg- Desoximetasone were produced by UV TEA N_2 laser under low vacuum (0.1 Pa) and room temperature onto substrates from SS 316L, KCl and NaCl. The laser fluence for Mg alloy was 1,8 J/cm^2 and for Desoximetasone 0,176 J/cm^2 and for Rapamycin 0,118 J/cm^2 were respectively. The three- dimensional two segmented single target was used to adapt the interaction of focused laser beam with inorganic and organic material. Magnesium alloy nanoparticles with sizes from 50 nm to 250 nm were obtained in organic matrices. The morphology and topology of nanocomposites films were studied by Bright field/ Fluorescence optical microscope and Scanning Electron Microscope (SEM). Fourier Transform Infrared (FTIR) spectroscopy measurements were applied in order to study the functional properties of organic component before and after the LAAD process. Energy Dispersive X-ray Spectroscopy (EDX) was used for identification of Mg alloy presence in hybrid nanocomposites coatings. The precise control of process parameters and particularly of the laser fluence adjustment enables transfer on materials with different physical chemical properties and *in situ* synthesis of complex inorganic- organic nanocomposites coatings.

References:

[1] G. Kikelbick Introduction to Hybrid materials: Synthesis, Characterisation and Applications, Weinheim, Wiley-VCH Verlag GmbH, (2007).

[2] F. E. Kruis, H. Fissan and A. Peled, "Synthesis of nanoparticles in the gas phase for electronic, optical and magnetic applications – a review", J. Aerosol. Sci., 29, 511–535 (1998).

[3] G. B. Blanchet, C. R. Fincher, C. L. Jackson, S. I. Shah and K.H. Gardner, "Laser Ablation and the Production of Polymer Films", Science, 262, 719-721, (1993).

[4] A. Pique, R. A. McGill, D.B. Chrisey. et al, "Growth of organic thin films by the matrix assisted pulsed laser evaporation (MAPLE) technique", Thin Solid Films, 1, 536-541, (1999).

[5] D. Bubb, S. O'Malley, Antonacci, D. Simson. and R. McGill, "Matrix assisted laser deposition of absorbent using on infrared laser", J. Appl. Phys., 95, 2175-2178, (2004).

[6] S. Eliezer, N. Eliaz, E. Grossman et al, "Synthesis of nanoparticles with femtosecond laser pulses", Phys. Rev. B, 69, 1411-1419, (2004).

[7] C. N. Alfonso, J. Solis, R. Serna, et al, Proc. SPIE Vol.3618, 453-464, (1999).

[8] S. Amoruso, R. Bruzzese, M. Vitiello, N. Nedialkov, P. Atanasov, "Experimental and theoretical investigation of femtosecond laser ablation of Al in vacuum", J. Appl. Phys., 98, 1-7, (2005).

[9] M. Ziberman, A. Kraitzer, O. Grinberg, J.J. Elsner, "Drug-eluting medical implants", Handb. Exp. Pharmacol., 197, 299-341, (2010).

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PA3

INVESTIGATION OF NEW STYLBAZOLIUM DYE THIN FILMS DEPOSITED BY PULSED LASER DEPOSITION

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Organic dyes, such as stylbazolium salts are new promising materials for photonic applications. The successful deposition of thin films of stylbazolium dye (E)-1-ethyl-4-(2-(4-hydroxynaphthalen-1-yl)vinyl) quinolinium bromide, by means of Pulsed Laser Deposition (PLD) technique and its large nonlinear optical parameters, measured by the SHG, Z-scan and THG techniques, inspire us to continue these investigations [1]. In present work we report for analysis of thin films and targets from new dye of the same series E-4-(2-(4-hydroxynaphthalen-1-yl)vinyl)-1-octylquinolinium iodide (Dye 1), deposited by means of PLD technique, using high power UV TEA N_2 laser. The thin films are deposited onto substrates – KBr, 316L SS alloy, optical glass and aluminum foil. The thickness of the deposited films ranges between 80 - 300 nm, measured by interferometric method. The deposited films were characterized by FTIR spectroscopy, Bright field microscopy, Fluorescence microscopy and Atomic Force Microscopy (AFM) analysis. Comparative FTIR spectroscopic study of films and targets showed small differences between deposited films and native materials – targets. The films have been found to be homogeneous and without any cracks and droplets on the surfaces from AFM results. The present study demonstrates the ability of PLD technique to provide thin films from new stylbazolium dyes with good quality in respect to their potential applications as NLO organic materials on different type of substrates.

Reference:

[1] H. El Ouazzani, S. Dabos–Seignon, D. Gindre , K. Iliopoulos, M. Todorova, R. Bakalska, P. Penchev, S. Sotirov, Ts. Kolev, V. Serbezov, A. Arbaoui, M. Bakasse, B. Sahraoui, "Novel styrylquinolinium dye thin films deposited by pulsed laser deposition for nonlinear optical applications", J. Phys. Chem. C**,** 116, 7144−7152, (2012).

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PA4

HYBRID NANOCOMPOSITE COATINGS FROM METAL (Mg, Fe)-DRUG IN SITU DEPOSITED ONTO MEDICAL IMPLANTS BY LASER ADAPTIVE ABLATION DEPOSITION TECHNIQUE

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Drug-eluting medical implants are active implants that create and healing effects. The current requirements for active medical coatings for Drug-eluting medical implants are to be biocompatible, biodegradable, polymer free, mechanically stable and enable a controlled release of one or more drugs and a defined degradation. This brings hybrid nanocomposite coatings into focus especially in the field of cardiovascular implants. We studied the properties of Metal (Mg, Fe)-Paclitaxel coatings obtained by novel Laser Adaptive Ablation Deposition Technique (LAAD) onto cardiovascular stents from 316 L stainless steel material. Comparative measurements were made of the morphology and topology of hybrid, polymer free nanocomposite coatings in situ deposited by LAAD and polymer-drug coatings deposited by classical spray technique. The morphology and topology of coatings were studied by Bright field / Fluorescence optical microscope and Scanning Electron Microscope (SEM). Metal nanoparticles with sizes from 40 nm to 230 nm were obtained in drugs matrices. Energy Dispersive X-ray Spectroscopy (EDX) was used for identification of metal presence in hybrid nanocomposites coatings. The new technology opens up possibilities to obtain new hybrid nanocomposite coatings with applications in medicine, pharmacy and biochemistry.

References:

[1] M. Moravej and D. Mantovani, "Biodegradable Materials for Cardiovascular Application: Interest and New Opportunities", Int. J. Mol. Sci., 12, 4250- 4270, (2011).

[2] L. Raber, St. Windecker. "Current status of drug-eluting stents", Cardiovasc Ther, 29, 176 -189, (2011).

[3] Al. Saez, R. Moreno, "Everolimus – eluting coronary stents", Med. Device: Evidence and Research, 3, 51- 56, (2010).

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PA5

ULTRAFAST SYNTHESIS OF METAL OXIDE AND DIAMOND LIKE CARBON THIN FILMS BY Yb^+ FIBER LASER ABLATION

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Metal Oxide (MO_x, M: Titanium, Magnesium) and Diamond-Like Carbon (DLC) thin films were synthesized by Pulsed Laser Deposition (PLD) at room temperature, and low vacuum of 2 Pa for MO_x and vacuum of 4.10^{-3} Pa for DLC films, respectively. A fiber based Ytterbium (Yb^+) laser operating in the nanosecond regime at a repetition rate of 20 kHz was used as an ablation source for the first time. Dense and smooth thin films with a thickness from 120 to 360 nm and an area of up to 10 cm^2 were deposited on glass and stainless steel substrates at high growth rates up to 2 nm/s for a laser fluence of 10-12 J/cm^2. The thin films synthesis was compared for two fiber laser modes of operation, at a repetition rate of 20 kHz and with an additional modulation at 1 kHz. The characteristic morphology, chemical composition and structure of the obtained thin films were evaluated using Optical Microscopy, Scanning Electron Microscopy (SEM), Energy Dispersive X-Ray Spectroscopy (EDX) and Raman spectroscopy. The morphology of the MO_x thin films and the deposition rate strongly depend on the fiber laser mode of operation for the same processing conditions. Very smooth surfaces were obtained for the metal oxide thin films deposited at lower deposition rates in the modulation mode at 1 kHz. The effect of the substrate on the DLC film structure was studied. The films deposited on dielectric substrates were identified as typical tetrahedral (ta-C) DLC with high sp^3 content. DLC films on metal substrates were found typical a-C amorphous carbon films with mixing sp^2/sp^3 bonds. The surface morphology of the DLC films was homogenous for both laser modes.

References:

[1] E. Gray, B. Luan, "Protective coatings on magnesium and its alloys - a critical review", J. Alloy Compd. Vol. 336, 88–113, (2002).

[2] F. Witte, "The history of biodegradable magnesium implants": a review Acta Biomater. Vol.6, 1680–1692, (2010).

[3] R.K. Roy, K.R. Lee," Biomedical Application of Diamond-Like Carbon Coatings: A Review", J. Biomed. Mater. Res. Part B: Applied Biomaterials, 72-84, (2007).

[4] J. M. Lackner, W. Waldhauser, R. Ebner, B. Major and T. Schöberl, **"**Pulsed laser deposition of titanium oxide coatings at room temperature-structural, mechanical and tribological properties", Surf. Coat. Tech., Vol. 180, 585-590, (2004).

[5] E. G. Gamaly, A. V. Rode and B. Luther-Davies, "Ultrafast ablation with high-pulse-rate lasers. Part I: Theoretical considerations", J. Appl. Phys. 85, 4121-4213, (1999).

[6] W. McLean, B.E. Waener, M.A. Havstad, M. Balooch, " Rapid Growth of Diamond Like Carbon films by Cooper Vapor Laser Ablation", Reprint UCRL-JC – 118841,L-19399-1, Materials Research Society, SF,CA, (1995).

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PA6

STRUCTURAL, OPTICAL AND PHOTOELECTRICAL PROPERTIES OF A-SI:H FILMS TREATED BY FEMTOSECOND LASER PULSES

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Hydrogenated amorphous silicon (a-Si:H) has been attracting a lot of attention for the last several decades, because of its perspectives in thin film optoelectronics (e.g. solar cells, active matrix of liquid crystal displays). It combines low cost with a processing mechanism capable with large scale technologies. Low temperatures during the deposition process allow using inexpensive and low-melting substrates. The main issues with a-Si:H films is the high order of dangling bonds which act as recombination centers that strongly reduce the carrier lifetime and make the efficiency of the solar cell as low as around 10 %. Additionally, this initial efficiency will halfway decrease when exposed to sunlight which is known as the Staebler-Wronski effect (SWE) [1]. In order to reduce the SWE in solar cells, hybrid a-Si/nc-Si tandem modules have been developed. Such modules are able to achieve both higher efficiency and stability compared with single a-Si:H solar cells. For optimization of technological process of tandem solar cells production one can use a femtosecond laser-induced crystallization of a-Si:H thin films. The laser-based treatment of a-Si:H may solve its efficiency and stability issues in a one-step process.

a-Si:H 300 nm thick films were deposited onto quartz substrates using PECVD method. The a-Si:H film was deposited at a rate about 2 Å/s in an argon (Ar) diluted silane (SiH_4) environment at a substrate temperature of 180 ^oC. The samples were treated using a femtosecond Yb:KGW laser system. The laser system delivered pulses at a repetition rate of 200 kHz with a pulse wavelength of 1030 nm and a duration of 500 fs. The beam spot was circular with beam diameter of 15 μm on the film surface. To prepare the samples for measurements films were scanned by laser beam with the scanning speed of 5 mm/s. The scanning step was 2 μm. To carry out the electrical and photoelectric measurements aluminum contacts were deposited on the surface of prepared films. The gap between the contacts was perpendicular to the laser beam scanning direction. Distance between contacts and their length were 0.5 and 4 mm correspondingly. Averaged laser beam power was varied continuously from 25 to 100 mW.

We have investigated the effect of femtosecond laser treatment of hydrogenated amorphous silicon films on their structural, optical and electrical properties. When crystalline volume fraction of the treated samples was around 7% sufficient increase (by 4 orders of magnitude) of dark conductivity was observed. We have attributed such behavior to change in charge carrier transport mechanism from typical for amorphous to that for nanocrystalline. However, the shape of the spectral dependences of absorption coefficient of all investigated samples corresponded to that of a-Si:H. This question still remains uncertain and needs further investigation. It was also found that starting from some values of laser fluence the effect of spallation and film oxidation occurred.

References:

[1] D.L. Staebler, C.R. Wronski, "Optically induced conductivity changes in discharge-produced hydrogenated amorphous silicon" J. Appl. Phys., 51, 3262 (1980).

PA7

FABRICATION OF GOLD AND SILVER NANOWIRES BY PULSED LASER ABLATION IN DOUBLE DISTILLED WATER

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The experimental conditions were investigated enabling one to fabricate Ag and Au nanowires by pulsed laser ablation in water. Previous studies [1] have shown that it is possible to produce alternatively nanoparticles (or aggregates) or nanowires at certain wavelengths depending on the laser fluence. The aim of this work was to establish the boundary region where this transition takes place. Au or Ag discs immersed in double distilled water were used as targets. The second (λ_{SHG} = 532 nm) harmonic of a Nd:YAG laser system was utilized for both materials, while the third (λ_{THG} = 355 nm) harmonic was only used to produce different Au colloids. The values of the laser fluence for both wavelengths under the experimental conditions chosen were varied from several J/cm^2 to tens of J/cm^2. The optical extinction of the colloids in the UV-VIS region was measured to estimate the structure of the dispersed Au or Ag phase. Transmission electron microscopy (TEM) was applied to visualize the size and configuration of the colloidal particles. Their structure was determined by high resolution transmission electron microscopy (HRTEM).

References:

[1] A. S. Nikolov, N.N. Nedyalkov, R.G. Nikov, P.A. Atanasov and M.T. Alexandrov "Investigation of Ag nanoparticles produced by nanosecond pulsed laser ablation in water" Applied Surface Science 257, 5278–5282, (2011).

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PA8

Ag/ZnO MULTILAYER NANOCOMPOSITES PREPARED BY LASER METHODS

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The unique properties of semiconductor based nanocomposites make them attractive for potential applications in biomedicine, photocatalysis, and nanodevices instead of the single component materials. One of the approaches to develop novel materials and improvement of their functions is to combine two or more functional phases. This can be done by combining a nanosized metal and metal oxide semiconductor to improve their activities. The multilayer structures of Ag nanoparticles (NPs) and ZnO semiconductor are investigated and the results indicated that laser annealing of Ag layer in Ag/ZnO nanocomposites is a feasible method to tune the optical properties of ZnO nanostructures. Silver films were deposited by laser ablation in a vacuum chamber and subsequent laser annealing in air was applied for nanostructuring of the silver layers by a fixed number of laser pulses. The as-prepared silver nanoparticles were covered by a ZnO thin film using pulsed laser deposition at room temperature. For the preparation of the multilayer structure a layer-by-layer deposition was carried out alternating Ag nanoparticles with ZnO films in order to produce a multilayer structure. The morphology of the nanoparticles was characterized by scanning electron microscopy (SEM) and the mean size of the nanoparticles and size distribution were estimated. The interface mechanisms of the Ag-ZnO nanostructures were examined by using X-ray photoelectron spectroscopy (XPS). The transmission spectrum of the Ag nanoparticles was analyzed to confirm the plasmon resonance properties. The photoluminescent (PL) measurements were made under excitation at 325 nm. The emission depends on the geometrical parameters of the structure and the properties of the nanoparticles. The main task of this work is to find correlation between the structure of Ag nanoparticles array and its optical properties and to study of ZnO photoluminescence as a function of Ag nanoparticles array and the number of layers.

PA9

NEAR FIELD INTENSITY ENHANCEMENT AND LOCALIZATION IN NOBLE METAL NANOPARTICLE ENSEMBLES

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Theoretical analysis on the electromagnetic field properties in vicinity of noble metal nanostructures is presented. The study is done on the basis on numerical simulation using

Finite Difference Time Domain approach. The systems under consideration are two- and three-dimensional arrays composed of gold and silver nanoparticles. The near field intensity distribution and its enhancement are calculated for structures with a broad range of characteristics – particle size, inter-particle distance, size and shape of the array and at different conditions of the incident irradiation – wavelength, polarization, and geometry of excitation. This analysis is used to define the optimal parameters for such structures from the viewpoint of application in Surface Enhancement Raman Spectroscopy. Simulations of real structures obtained by laser annealing of thin noble metal film are also presented. The predicted efficiency in SERS applications at different conditions of the incident irradiation are confirmed experimentally.

PA10

FABRICATION OF METAL NANOROD SUBSTRATES FOR SERS APPLICATION

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Surface enhanced Raman scattering (SERS) is a powerful tool for investigation and structural characterization of interfacial and thin-films systems. In spite of its recent popularity, SERS does have limitations, including strict requirements that must be met in order to achieve optimal enhancement. One critical aspect of the technique involves the need for producing an ideal surface morphology on the SERS substrate for maximum enhancement.

In this work, our attention was focused on a fabrication method which allows production of reproducible and practical SERS-active substrates. Pulsed laser deposition (PLD) was used together with a glancing angle deposition (GLAD) technique in order to produce a suitable metal substrate for SERS application. During deposition, the angle between the incoming vapor from a noble metal target and the surface normal of the substrate is set to be greater than 75°. The main mechanisms that control the growth are the shadowing effect and surface diffusion. By varying the incident angle, laser fluence and substrate rotation rate, the size, shape and arrangement of the metal nanorods can be tailored for maximum SERS enhancement.

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PA11

INFLUENCE OF THE SIZE OF NANOPARTICLES DOPED IN SERIES OF AZOPOLYMERS ON THE PHOTOINDUCED BIREFRINGENCE

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In this paper we present a study of the photoinduced anisotropy in nanocomposite films of azopolymers doped with ZnO nanoparticles with different sizes – 50 and 100 nm. We have established that doping the azopolymers with 50 nm nanoparticles (NP) leads to a significant increase of the maximal value of the photoinduced linear birefringence (Δn_{max}) in comparison with non-doped samples.

According to our model, two mechanisms influence the dependence of Δn_{max} on the size of the ZnO NPs – the smaller the size of NPs, the larger is the free volume in the nanocomposite structure (higher surface/volume ratio and contact surface between the azo molecules and the nanoparticles) which enhances the mobility of the azochromophores and leads to increase of the birefringence. On the other side the increased scattering at larger size of the NPs reduces the transmitted intensity, hence the effective value of Δn_{max}.

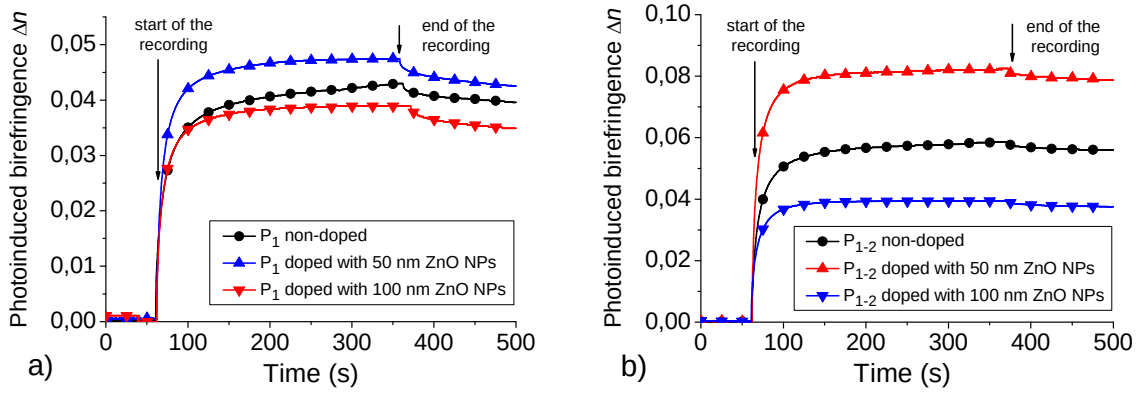

Figure 1. Time dependence of the photoinduced birefringence in two of the investigated azopolymers denoted as P_1 (a) and $P_{1\text{-}2}$ (b) doped with 50 and 100 nm sized ZnO nanoparticles.

As seen on Fig. 1, our experimental results indicate that doping with both 50 and 100 nm sized particles improves the response time, however the smaller size nanoparticles provide increase of Δn_{max}, as the 100 nm particles reduce the saturated value of the birefringence, due to the higher scattering.

PA12

LASING EFECTS ON OPTICALY PUMPED MICRO-DROPLETS

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In this paper we present lasing effect in pendant droplets having different volumes. The droplets were seeded with an organic dye (Rhodamine 6G – R6G) in ultrapure water at different concentrations and irradiated by pulsed laser beam emitted at 532 nm by a SHG Nd:YAG laser, (pulse time width 6ns, laser pulses repetition rate 10 pps, energy per pulse 330 kW/pulse).

The droplets were generated using a computer controlled system Hamilton Microlab 500. The liquid volumes pumped were typically 12.5 µl. This produced droplets with diameter of 3mm.

To observe the lasing emission we measured the laser induced fluorescence emitted by the droplets when excited at 532 nm. The fluorescence signal is collected by an optical fiber (1mm core), and analyzed with HR4000 Ocean Optics spectrometer (0.65mm resolution, 200-1100nm).We observed that the effect depends on several parameters, such as: the concentration of the Rh 6G in water; the droplet's volume; the interaction angle of the pumping laser beam with the droplet's surface.

By varying the concentration of the R6G in water we obtained the typical fluorescence broad band and a narrow peak assigned to the lasing effect. The best results obtained on the measured samples were at the R6G 10-3M concentration in ultra-pure water.

In order to study how the volume changes by evaporation of the droplets during irradiation, we measured the temperature variations of the pendant droplets following their resonant interaction with laser radiation emitted at 532nm. The droplet temperature was measured with the thermo-camera ThermaCAM® E45. Depending of the droplet dye concentration and irradiation time, the increase of the temperature was maximum 3°C.

References:

[1] V. Nastasa, M. Boni, I.R. Andrei, L. Amaral, A. Staicu, Pascu, M.L. Pascu, "Optical investigation of medicine solutions in micro-droplets form at interaction with laser radiation" Physical Chemistry of Interfaces And Nanomaterials X, Proceedings of SPIE, Vol. 8098, No 809815, (2011).

[2] V. Nastasa, V. Pradines, I. R. Andrei, M. Boni, M.L. Pascu "Studies about the generation and characterization of microdroplets with a controlled content", Optoelectronics and Advanced Materials-Rapid Communications Vol.4,page 1916-1919, (2010).

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PA13

EFFECT OF DUV AND VISIBLE LASER TREATMENT ON COPPER-MODIFIED POLY(3,4-ETHYLENEDIOXYTHIOPHENE) LAYERS FOR SELECTIVE DETERMINATION OF DOPAMINE IN THE PRESENCE OF ASCORBIC ACID

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Poly-3,4-ethylenedioxytiophene (PEDOT) stands out in the field of electronically conducting polymers for the possibility to obtain after modification exemplary properties suitable for applications in microelectronic, photovoltaic, sensing and catalytic devices. There are many ways for modification both the bulk and the surface of the polymer. The key for fine tuning of the surface properties is the development of corresponding treatments.

In our previous investigations [1,2] it is shown that deep ultraviolet (DUV) laser treatment of PEDOT with a Cu^+ Ne-CuBr laser, oscillating at 248.6 nm, results in a mild modification of the external polymer surface without affecting the bulk properties of the polymer. It was established that DUV irradiation activates significantly the copper electrodeposition and silver electroless precipitation on the irradiated PEDOT layer. A larger amount of silver and a highly homogeneous distribution over the entire visible surface were found on the DUV laser treated samples. The number density and amount of the electrodeposited copper particles increases twofold. The established DUV effect on PEDOT is important for potential application of metal-modified PEDOT layers for electrocatalytic purposes.

The goal of the present work is to study the effect of DUV laser treatment on copper-modified PEDOT layers for selective electrochemical determination of dopamine in the presence of ascorbic acid. It is established that the type (number, size, distribution) of the deposited Cu crystals is crucial for the sensitivity of the composite layers. The homogeneous distribution of copper crystals on the DUV irradiated PEDOT surface provides the possibility to determine dopamine in the nm concentration range in the presence of large excess of ascorbic acid. A comparative investigation on DUV Cu^+ Ne-CuBr laser and visible atomic Ne-CuBr laser treatment on copper-modified PEDOT layers is also undertaken, in order to understand and clarify the abovementioned influence of laser irradiation on PEDOT layer surface.

References:

[1] M. Ilieva, V. Tsakova, N. K. Vuchkov, K. A. Temelkov, N. V. Sabotinov, Journal of Optoelectronics and Advanced Materials, Vol. 9, p. 303, (2007).

[2] M. Ilieva, A. Stoyanova, V. Tsakova, N. K. Vuchkov, K. A. Temelkov, W. Erfurth, N. V. Sabotinov, Journal of Optoelectronics and Advanced Materials, Vol. 11, p. 1444, (2009).

PA14

INVESTIGATION OF OPTICAL PULSED DISCHARGE IN A SUPERSONIC AIR JET

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One of promising areas of study is the use of laser to control parameters of a supersonic air flow, solving the problems of aircraft aerodynamics, plasma chemistry, etc. Pulse periodic CO_2 laser with a pulse repetition frequency of 80 kHz and a power of 4.5 kW is described in [1,2]. The characteristics of the laser have allowed realize an optical pulsating discharge (ODA) in a supersonic flow for the first time and to determine the requirements for the gas density allowing achievement a high (60%) absorption of the radiation power into the flow. The use of ODA to study aerodynamics of aircraft is determined by the thermal structure of the wake formed by the interaction of ODA and supersonic flow. It was obtained the values of the average mas temperature of air along the heat wake after effect of ODA and distribution of stagnation pressure in the cross section of the jet and thermal wake [3].

The purpose of present research is study of microphysical and macrophysical of the heat wake by methods of high spatial and temporal resolution.

The study of dynamics of laser energy deposition in supersonic flow has shown that after the breakdown time of the order of 100 ... 150 ns, it is formed quasi-stationary discharge phase lasting about 1.5 ms, the existence of which depends weakly on the presence of air flow, and the frequency repetition of pulse duration. This phase of strong absorption, appears to be associated with the development of the ionization wave. Estimating the size of the formed cavity defined by the radius of inhibition gives the values of 5 .... 6. mm.

In order to determine the possibility of application of hot wire to study flow structure in the thermal wake of ODA preliminary measurements of flow characteristics behind the discharge were carried out. Spectra of fluctuations and the data on changing the flow parameters (mass flow rate and temperature) according to the time behind the discharge were obtained. It was established that there are cavities each of which is formed during the pulse in the zone of optical discharge, and which do not merge with one another. It is shown that at a pulse repetition rate about 50 kHz at a distance of 15 mm after the plasmoid a sequence of cavities in the flow with the characteristic size 5 ... 6 mm is observed in 15 mm from each other.

References:

[1] A. N. Malov, A. M. Orishich. V. B. Shulyat'ev "Powerful impulse-periodical CO_2 laser with mechanical Q-switch and its application for investigations in wind tunnels", Quantum Electronics, Vol. 41, No. 11, 1027-1032, (2011).

[2] A. N. Malov, A. M. Orishich, "Optical breakdown in supersonic air jet", Technical Physics Letters V 38, № 1, 70-73, (2012).

[3] A. N. Malov, A. M. Orishich, T. A. Bobarykina, V. F. Chirkashenko, "Investigation of the optical discharge and absorption of energy of a powerful pulse-periodic CO_2 laser in supersonic jet of air", Journal of Atmospheric and Oceanic Optics Vol.25., №3, 244-249, (2012).

PA15

TWO METHODS OF PUMPING FOR EXIMER LASER PULSE-STRETCHING

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Eximer laser emission (193 nm and less) is used in modern photolithographic technologies [1,2]. Strict requirements are imposed to these lasers. They must operate at kilohertzs pulse repetition rates; have high optical beam quality, defined by its homogeneity, divergence and radiation spectrum. Besides, they should be fail-safe and have relatively small sizes and weight. Pulse-stretching of the eximer laser is capable to solve some of these tasks [1]. It provides increasing of round-trips transits of radiation along the laser resonator, thereby improving space laser coherence, decreasing the spectrum line radiation and also prolonging the laser lifetime.

Two methods of laser pumping for radiation pulse-stretching are proposed in this work. In the case of low-power small ArF laser for this purpose we used a generator with a forming line and a system of a magnetic compression as a pumping source. The high voltage generator on a solid-state base, offered in work [3], used in the laser setup, allowed not only to improve output laser characteristics, but noticeably prolong the laser service time and considerably reduce its size and weight. In the case of powerful KrF laser we investigated laser pumping in a regime of periodically damping voltage at the discharge gap, realized by variation of an active media composition. For the first time pumping mode of periodically damping voltage at the discharge gap for increasing of eximer lasers radiation is used.

As a result experimental dependences of energy and pulse duration of the lasers radiation on pumping voltage, composition and pressure of gas mixtures at the discharge gap are obtained. ArF laser radiation with pulse duration of up to 18 ns and energy of 15 mJ is obtained, that is more than twice exceeds the laser pulse duration in the case of pumping without forming line. For KrF laser with the output energy of 40 mJ the duration of radiated pulses from 15 ns to 45 ns is obtained.

References:

[1] Hofmann T., Johanson B., Das P, "Prospects for long pulse operation of ArF lasers for 193 nm microlithography", Proceedings of SPIE, Vol. 4000, 511-518, (2000).

[2] Vartapetov S. K., Gryaznov O. V., Malashin M. V., Moshkunov S. I, Nebogatkin S. V., Khasaya R. R., Khomich V. Yu., Yamschikov V. A., "Electric-discharge VUV laser pumped by a solid-state generator", Quantum Electronics, Vol. 39, №8, 714-718, (2009).

[3] Gryaznov O. V., Ivanov E. V., Malashin M. V, Moshkunov S. I., Khomich V. Yu., "Pumping source for the eximer laser based on high voltage solid-state switch", Applied Physics, № 5, 32 – 34, (2008).

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PA16

STRUCTURE AND OPTICAL PROPERTIES OF TIO_2 THIN FILMS PREPARED BY PULSED LASER DEPOSITION

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Porous titanium dioxide nanostructures of large active surface are subject of concentrated research due to application potential in the photocatalysis and photovoltaics. Moreover, the synthesis of metal doped nanoparticles has provided a new way to tailor the optical and electronic properties of the TiO_2 semiconductor allowing for extension of its absorption band towards visible region and for new applications using nonlinear optical phenomena.

In this work the TiO_2 films were prepared by pulsed laser deposition (PLD) using a metallic Ti and also pressed nanopowder TiO_2 targets in the O_2 ambient gas. Thin films of titania were deposited on SiO_2 (001) and SiO_2 glass substrates at 300°C. Values of the laser fluency from the range of 1 – 5 J/cm^2 and the O_2 pressure of 0.1 – 2.2 Pa were selected. The μ-Raman and XRD analysess of the deposited films indicated both the presence of anatase and rutile crystalline phases. The crystallite dimensions were determined from the broadening of the anatase and rutile main peaks using the Scherrer equation and values between 6-17 nm and 5-21 nm were obtained for the anatase and rutile, respectively, depending on the process conditions. The band gap of 3.5-3.8 eV derived from absorption spectrum by means of the Kubelka – Munk relation was higher than that of 3.2 eV reported for anatase and this difference was ascribed to presence of the rutile crystallites. Porous films of highest anatase content were obtained by ablation of the TiO_2 target at moderate laser fluencies below 2 J/cm^2 and at oxygen pressure around 1.9 Pa. For samples produced under similar conditions from both targets the porous structure was revealed by the SEM observation and confirmed by the XEDS scans.

PA17

TIME RESOLVED LIPS FOR OBSERVATION OF MOLECULAR EMISSIONS

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In practical applications of Laser Induced Plasma Spectroscopy (LIPS) the presence of molecular bands is usually unwanted since it increases the spectral background and covers a wide spectral range masking atomic emission lines used in elemental analysis. On the other hand, molecular emission bands can provide important information on the chemical composition of the analyzed material. Under typical experimental conditions used in LIPS measurements, the molecular emission bands represent in part molecular arising from the ablated matter and in part small molecules forming in the plasma plume often with contribution from the surrounding medium, oxygen and nitrogen in the case of experiments performed in air. In this work we present experimental results from time-resolved LIPS analysis of calcium carbonate ($CaCO_3$) and calcium sulphate ($CaSO_4$). Using variable gate delay for recording emission spectra following laser ablation, molecular bands of CaO in the ranges of 540-560 nm and of 590-620 nm are resolved in time from the intense atomic emission lines of Ca. The use of a noble gas atmosphere suppressing the oxide formation processes of some radicals in the plasma was studied. The experimental results show that not only information on the elemental composition but also on the chemical structure of the investigated material can be concluded from time-resolved LIPS spectra. Application of this approach to the family of materials commonly characterized as "patinas" on archeological metal objects made of copper and copper alloys (e.g. copper carbonate, copper chloride or copper sulphide) represents a promising tool for the material and object identification which is inevitable in the conservation practice.

References:

[1] A. Portnov, S. Rosenwaks, I. Bar, "Emission following laser-induced breakdown spectroscopy of organic compounds in ambient air", Appl. Optics, Vol. 42, No 15, 2835-2842 (2003).

[2] D. P. Baldwin, R.W. Field, "Dispersed Laser Fluorescence Spectroscopy of the Perturbation Facilitated $B^1\Pi$-$b^3\Sigma^+$(1,1) Band of CaO", J. Mol. Spectrosc., 139, 77-83 (1990).

PA18

LASER NANOSTRUCTURING OF Au/Ag AND Au/Ni FILMS FOR APPLICATION IN SERS

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In this paper the results are presented on laser nanostructuring of Au/Ag and Au/Ni thin films. The fabrication of bimetal nanostructures is made on two steps. Initially, thin films are deposited on quartz substrates by classical pulsed laser deposition method. In order to produce

Au/Ag or Au/Ni thin films, targets with two metal sections are used in this technique. Thin films with different concentrations of the two metals are obtained by changing the area of the different sections of the target. The as prepared films are then annealed by nanosecond laser pulses delivered by Nd:YAG laser system operated at λ = 355 nm. It is found that the laser annealing may lead to nanostructuring of the films as at certain conditions the thin films are decomposed into a monolayer of nanoparticles with narrow size distribution. The performed EDX analyses indicate that the fabricated particles are composed by a bimetallic system of the basic metals used. The extinction spectra of the obtained structures show plasmon excitations as the resonance wavelength can be efficiently tuned in a wide range by changing the ratio of the basic metals in the films. The bimetal nanostructures are covered with Rhodamine 6G and then tested as active substrates for Surface Enhanced Raman Spectroscopy (SERS).

PA19

INVESTIGATION OF Au NANOPARTICLES PRODUCED BY LASER ABLATION OF SOLID TARGET IN WATER

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The method of pulsed laser ablation (PLA) of a solid target in liquid is applied in the present work in order to create Au nanoparticles (NPs). Au target was immersed in double distilled water, irradiated by the fundamental wavelength (λ=1064 nm) of a Nd:YAG laser system (10 Hz repetition rate, 15 ns pulse duration) and as a result Au colloids were produced. The dependence of certain characteristics of the NPs' as structure, phase composition, shape and size distribution on the production parameters (laser fluence and duration of the ablation process) was studied. The influence of the water level above the target surface (5, 10 and 15 mm) on the NPs prosperities was investigated. Optical transmission in the near UV and visible region of the obtained colloids and transmission electron microscopy (TEM) of properly prepared samples were used to assess the shape and size distribution of the Au NPs. The structure and phase composition of the nanoparticles produced were examined by means of high-resolution transmission microscopy (HRTEM) and selected-area electron diffraction (SAED).

PA20

LASER INDUCED CHANGES OF OPTICAL PROPERTIES OF OBLIQUELY DEPOSITED THIN CHALCOGENIDE FILMS

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The magnitude of the photo-induced changes of properties of thin chalcogenide films depends on the incident photon flux, penetration depth of the photons used for illumination and structure of the film. The segmental layers structures and in particular the columnar structure can play significant role in photo-induced changes produce the deformations from interlayer-typed during the light illumination [1,2].

The object of present work is the photo-induced optical changes in obliquely deposited thin As-S(Se)-Ge films. The influence of the deposition rate on the film's microstructure was investigated. The conditions for deposition coatings of with columnar structure were determined. Furthermore, the role of actual conditions of illumination on the magnitude of photo-darkening (the incident photon flux and the penetration depth of absorbed photons) is examined. The differences are observed in magnitude and in kinetics of photo-darkening which are tentatively attributed to different states excited by gap and over-gap photons of white light and monochromatic laser beam by "near gap" sub-gap photons and nanosecond impulse laser (Fig.1). It was found that the photo-induced changes in the thin film depend on light intensity due to of effect of annealing of the coating during the laser irradiation.

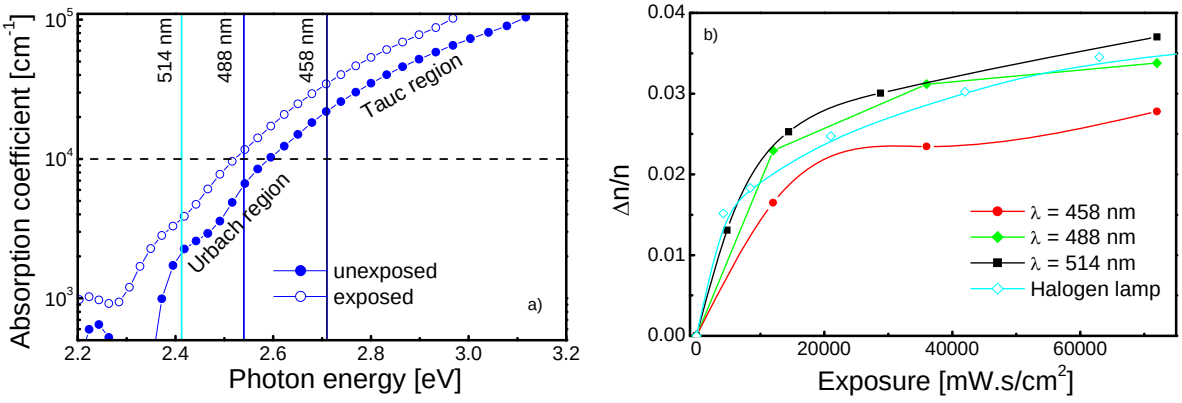

Fig.1. Absorption edge of thin As_2S_3 film before and after illumination (a); and kinetics of photo-darkening for white light (halogen lamp) and monochromatic light (b).

References:

[1] K. Tanaka, Photoinduced deformations in chalcogenide glasses: Scalar and vectoral, J. Optoelectron. Adv. Mater. Vol. 7, No. 5, 2571-2580, (2005).

[2] E. E. Khawaja1, S. M. A. Durrani1 and M. F. Al-Kuhaili, "Determination of average refractive index of thin CeO_2 films with large inhomogeneities" J. Phys. D: Appl. Phys. Vol. 36, 545–551, (2003).

B - *LASER SPECTROSCOPY AND METROLOGY*

PB1

PUMP-PROBE SPECTRA MODELED WITH INCLUSION OF A DIPOLE-COUPLED BUT NOT DIPOLE-PROBED *F'* STATE, FOR THE CASE OF ^{85}Rb [$5S_{1/2}(F)\leftrightarrow 5P_{3/2}(F')$] TRANSITIONS

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In Ref. [1] we reported spectra of a weak probe beam absorption registered with the probe frequency scanned across the ^{85}Rb [$5S_{1/2}(F=3)$-$P_{3/2}(F')$] resonances. The coupling beam frequency was set at a number of values in turn within a range embracing the [$5S_{1/2}(F=2)$-$5P_{3/2}(F')$] resonances. In that work our attention was mostly paid to the spectral features attributed by us to various levels'-fields' configurations in respect to $m_F\leftrightarrow m_{F'}$ transitions realized under the conditions of our experiment performed in an operating magneto-optical trap.

In the present work we concentrate on another aspect of pump-probe spectra of this kind, namely on the impact on the spectral features from a state in the upper (F') manifold, to which the coupling transition is dipole-allowed, but the probing one is dipole-forbidden. For ^{85}Rb D2 line, such state is $5P_{3/2}(F'=1)$, and the respective transitions are $5S_{1/2}(F=2)\leftrightarrow 5P_{3/2}(F'=3)$ (allowed) and $5S_{1/2}(F=3)\rightarrow 5P_{3/2}(F'=1)$ (forbidden). Generally, we refer to the conditions of the experiment described in Ref. [1], however we also extend the range of some parameters, *e.g.*, of Rabi frequency values.

In modeling the probe absorption spectra, we apply optical Bloch equations assuming a 5-level model, in which we adopt characteristics of the ^{85}Rb states $5S_{1/2}(F=2, 3)$ and $5P_{3/2}(F'=1, 2, 3)$. The state $5P_{3/2}(F'=4)$ is not taken into account as a non-coupled one and as being most distant in energy from the other F' states. The validity of the approach will be discussed and the results compared with the ones obtained by neglecting the state $F'=1$ in the model.

Reference:

[1] A. Żaba, E. Paul-Kwiek, M. Głódź, K. Kowalski, J. Szonert, S. Gateva, "Signatures of (m_F -$m_{F'}$) transitions in pump-probe spectra for cold ^{85}Rb atoms in MOT under strong ($5S_{1/2}$-$5P_{3/2}$) Λ-coupling explained *via* simple modeling", *article in preparation*.

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PB2

QUANTUM STUDIES OF REORIENTATION, ALIGNMENT AND COHERENCE EFFECTS IN ATOMIC COLLISION

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The collisional processes which occur in gases are of great importance in many areas of physics and chemistry. The experimentally determined cross-sections contain information about the atom-atom interaction and the collisional dynamic. In case of cell experiment the incident velocity direction is randomly oriented with respect to the quantization axis. In such experiment the multi-structure transition between magnetic sublevels, are not resolved. Thus the multi-structure averaged cross sections (ACS), $\overline{\sigma}(j_2 m_2 \leftarrow j_1 m_1)$, characterizing the collisional processes in gas cell can not be measured. Only crossed atomic beam experiments with laser pump-probe techniques explore directly the elementary processes of gas phase phenomena. Twenty years ago Driessen and Eno [1] have examined the explicit relation of the alignment curves obtained in three-vector correlation experiments by the Leone group [2] to the steady-selected scattering cross sections, called fundamental cross sections (FCS). There are two types of FCS multi-structure cross sections: conventional and coherence one. The conventional, real-valued cross section described population transfer for an individual $|j_1, m_1\rangle \rightarrow |j_2, m_2\rangle$ transition. The complex-valued coherence cross sections contain information about the atomic coherence of the initial and final states. The calculated alignment curves based on Czuchaj's potentials [3] agree quite well with the experimental ones. On the other hand those calculations show that the multi-structure cross sections are very sensitive to the detailed behaviors of the potential curves.

In this work the ACS and FCS have been put in terms of geometry-independent quantities. In case of ACS, the standard Grawert parameters are used. The equivalent expressions for the FCS are obtained where the introduced geometry-independent quantities are the generalization of well-known Grawert parameters [4]. The formulae introduced are used to find numerically the relationship between the ACS and FCS.

References:

[1] J. P. J. Driessn, L. Eno, "Three-vector correlation theory for orientation/alignment studies in atomic and molecular collisions", J. Chem. Phys. 97, 5532-5541 (1992).

[2] Ch. J. Smith, J. P. J. Driessn, L. Eno, S. R. Leone, "Laser preparation and probing of initial and final orbital alignment in collision-induced energy transfer Ca(4s5p, $^1P_1$) + He –> Ca(4s5p, $^3P_2$) + He ", J. Chem. Phys. 96, 8212-8224 (1992).

[3] E. Paul-Kwiek, T. Orlikowski, "Ouantum calculations of multi-structure cross-sections for the Ca(4s5p, $^3P_2 \leftarrow ^1P_1$) + He collisional process", Mol. Phys. 92, 781-792 (1997).

[4] E. Paul-Kwiek, "Generalization of Grawert parameters - quantum close-coupling calculations for Ba(6s6p, $^3P_2 \leftarrow ^1P_1$) + Ar inelastic collision", J. Phys. B. 35 175-189 (2002).

PB3

LIGHT-INDUCED ATOMIC DESORPTION FOR MINIATURIZATION OF MAGNETO-OPTICAL SENSORS

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There are many works on development of high sensitive alkali vapor magneto-optical sensors and their miniaturization for different applications. The reduction of the dimensions causes resonance width broadening and signal amplitude decrease. Antirelaxation coating of the cell walls removes the resonance broadening due to the collisions with the walls. The decrease in the resonance amplitude can be compensated by increasing the atomic density with the cell temperature using special high temperature antirelaxation coatings. An alternative way to increase the alkali atom density is by light-induced atomic desorption (LIAD). LIAD is a non-thermal process in which atoms adsorbed from a surface are released under illumination. It is investigated in various papers and has different applications - vapor density stabilization, MOT loading, surface nanostructuring etc.

In this work an investigation of the efficiency of LIAD in uncoated and with different coating Rb cells is presented, aimed at LIAD application for miniaturization of magneto-optical sensors. The transmission spectra on the D_2 line of Rb (780nm) are registered at different light intensity of the illuminating blue (460 nm) diode (Fig. 1).

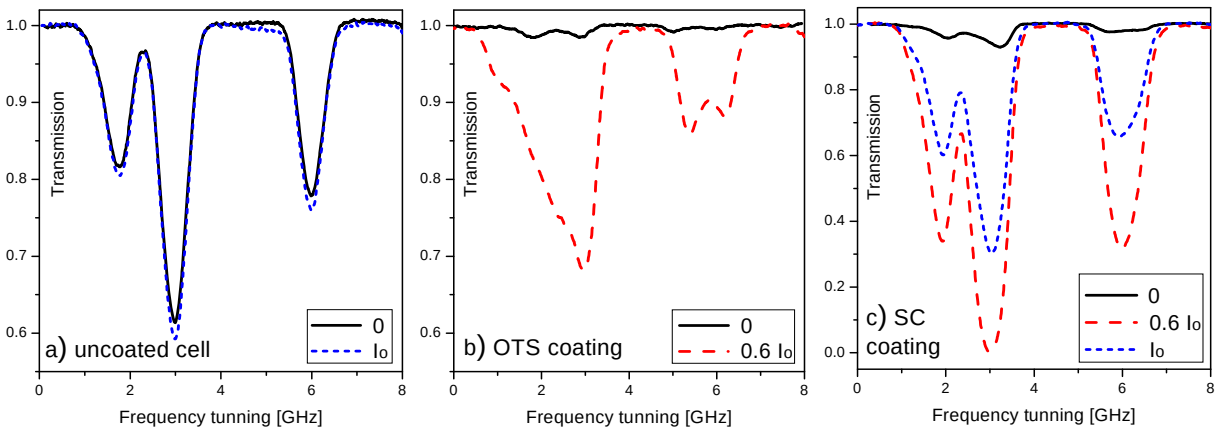

Fig.1. Transmission of 20μW Rb D2 line at different blue light intensities in:
(a) uncoated cell; (b) coated cell with good LIAD effect; (c) coated cell with very strong LIAD effect.

The measured spectra show that in all Rb cells (coated and uncoated) LIAD is detected – the transmission changes due to the different atomic densities. In uncoated cell (Fig.1a), the LIAD contribution is extremely small, while in coated cells the atomic desorption by the light depends dramatically on the coating (Fig.1b,c). The LIAD involvement can result in complete absorption on strong transitions (Fig.1c). However after reaching the maximum, the desorbed by the light atomic population strongly reduces with further enhancement of the blue light.

For magneto-optical sensors miniaturization the atomic density must be optimized keeping in mind that at low densities the relaxation processes are independent of the vapor density, while at high densities, the radiation trapping and atom-atoms collisions increase the relaxation rate.

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PB4

MONITORING OF BREAD COOLING BY STATISTICAL ANALYSIS OF LASER SPECKLE PATTERNS

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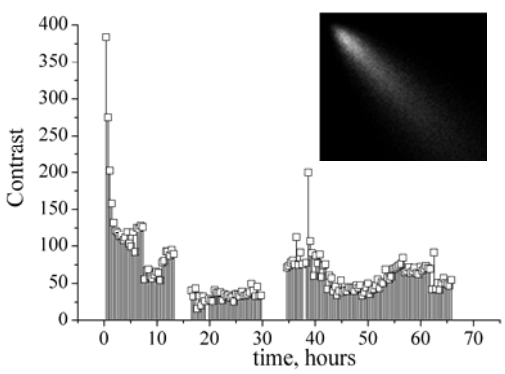
Physical or biological activity within a diffuse object leads to a randomly varying speckle pattern under coherent illumination. This phenomenon is used for non-invasive whole-field detection of processes in industrial or biological samples through statistical description of laser speckle dynamics [1]. A variety of statistical descriptors have been proposed both in spatial and frequency domains. The approach enables measurements with high spatial and temporal resolution without requirement for sophisticated equipment.



The paper gives the results of non-destructive monitoring of the important for the food industry bread cooling process by continuous automated acquisition of speckle patterns within a few days. The experiment was planned as a result of observation of outbursts of activity that occurred after its normal steep fall during the first several hours after the baking process [2]. In total, 72960 and 39680 images were recorded for two similar bread samples. Acquisition of data both in space and time by illumination of the sample with an expanded laser beam makes possible monitoring of activity in time over the whole bread surface. To process the data we built a gray-level co-occurrence matrix with 256 levels for the 2D images formed by using the central column of the acquired speckle patterns in time sequences with 256 images each [1]. The embedded figure presents variation of the inertia moment or contrast calculated from the obtained co-occurrence matrices; one of them is shown in the inset. Our second goal in the reported work was testing the quality of processing by a structure function, ***S***, which we introduced in [2] as an effective estimator for the non-uniform intensity distribution over the sample. As a first step, we found the temporal variation of ***S*** within the whole observation period, *T*, by averaging over the entire sample's surface and performing calculations by dividing *T* in time sequences with 256 images each. As a second step, we found distribution of ***S*** over the sample surface at a given moment by averaging within a moving spatial window. In addition, we

determined the power Fourier spectrum of the inertia moment variation and observed small peaks corresponding approximately to periods 6, 10 and 15 hours as well as a comparatively larger peak corresponding to a period of 25 hours. By the performed unique monitoring of the dynamic speckle for a long period of time (3-7 days) we were able to detect long-period time oscillations of the parameters related to underlying processes within the bread samples.

References:

[1] Rabal, H. and R. Braga, "Dynamic Laser Speckle and Applications", Crc Press, Taylor&Francis Group, (2008).

[2] Stoykova E., B. Ivanov, M. Shopova, T. Liubenova, I. Panchev, V. Sainov, "Dynamic laser speckle for non-destructive quality evaluation of bread", Proc. SPIE 7747, 77470L-1-11, (2011).

PB5

DESIGN OF A PHOTOELASTIC MEASUREMENT OF PRINCIPAL STRESSES BY A PHASE- SHIFTING METHOD

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Photoelasticity is an accurate non-contact full-field polarization technique for analysis of stress distributions in mechanical components with a complicated geometry. A popular approach in the photoelastic stress analysis is capture of a set of fringe patterns in which preliminary known phase shifts are introduced by changing orientation of the polarizing optical elements. The pointwise nature of the phase-shifting method and its good sensitivity motivate the invention of various phase-shifting algorithms for static and dynamic mode of operation. Implementation of a particular phase-shifting algorithm determines to a large extent the design of the photoelastic optical set-up.

An arbitrary 3D photoelastic model can be considered as an elliptic retarder which, being a combination of a pure rotator and a linear retarder, is described by three optical parameters – relative phase retardation δ, primary θ and secondary η characteristic directions (azimuth and ellipticity angles, respectively). For characterization of surface principal stresses only the first two parameters are determined. This representation of the test object as well as derivation of the intensity equations at different phase steps of the photoelastic system involves analysis based on Jones matrices formalism. The aim of the present work is to develop a rationalized method for designing the set of the necessary phase shifts for implementation of the photoelastic-holographic measurement that is based on the introduction of the original "binary" algebra for calculation of Jones matrices. Such a method will strongly facilitate the comparison of the phase-shifting algorithms in order to choose the most effective one. The proposed method is verified by simulation of the photoelastic system based on expressions for the complex amplitude of the light beam passing through the different polarizing elements.

PB6

MISALIGNMENT ANALYSIS IN A PHASE-STEPPING ELECTRONIC SPECKLE PATTERN INTERFEROMETER FOR FULL-FIELD DISPLACEMENT MEASUREMENT

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Determination of strains, stresses and bending moments in experimental and fracture mechanics requires full field (in-plane and out–of-plane) displacement measurement. The effective means to perform this measurement is to apply digital electronic speckle pattern interferometry as a non-contact high-precision coherent optical method. Retrieval of the displacement vector and estimation of the derivatives of its components entail double symmetrical laser illumination of the tested object in two orthogonal planes and separate recording of the interference patterns corresponding to the different illumination directions. Processing of the data involves various modifications of the phase-stepping technique.

A compact and stable phase stepping four-channels one-beam interferometer for full field displacement measurement in static and "real time" operation mode can be built through incorporation of a four-exposure reflection holographic optical element, which reconstructs four reference planes under illumination with two pairs of laser diodes positioned in the horizontal and the vertical planes [1,2]. Interference and polarization filters ensure parallel data acquisition in the four separate channels of the system. Phase-stepping is performed by variation of the laser diodes currents. Experimental check of the system has been recently reported [2].

Such a multi-channel system is prone to misalignment errors and their estimation is crucial for its successful operation. The present work gives analysis of the error due to misalignment in illumination directions of the laser sources, i.e. due to small deviations in illumination angles in the four channels of the interferometer. As a first task, we focused on analysis of the experimental results obtained for the normal displacements in the horizontal plane under double symmetrical illumination before and after the change of the illumination angle in one of the channels. As a second task, the out-of-plane (normal) and in-plane components of the displacement vector for each point of the tested object (a dome) were retrieved. Computer simulation of the system was made for verification and estimation of the experiment results.

References:

[1] V. Sainov, A. Baldjiev, E. Stoykova, N. Berberova, patent application for useful model, № 2140 / 14.02.2012, Bulgarian patent office;

[2] V. Sainov, A. Baldjiev, E. Stoykova, **"**Full field displacement measurement by double symmetrical illumination with diode lasers through a pair of double exposure reflection holograms", Optics and Lasers in Engineering, sent for publication, (2012).

PB7

SUB-DOPPLER AND SUB-NATURAL WIDTH RESONANCES IN CS VAPOR CONFINED IN MICROMETRIC THICKNESS OPTICAL CELL

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The reduction of optical cell thickness L results in observation of new phenomena with L approaching the wavelength λ of the light. We describe the new thermalization behavior of excited state population, observed at the $F_g=4\rightarrow F_e=5$ transition (Cs, D_2 line – 5MHz Natural and 400MHz Doppler widths, λ=852nm, F_g/F_e – quantum numbers of the ground/excited state), in case of L=6λ cell. Electromagnetically Induced Transparency (EIT) resonance is also observed, for precise hyperfine transition matching. Two narrow-band diode lasers are used: (i) a pump one - with frequency fixed at the $F_g=3\rightarrow F_e=4$ transition and (ii) a probe laser tuned along the $F_g=4\rightarrow F_e=3,4,5$ transitions. The L=6λ cell is irradiated by both laser beams,

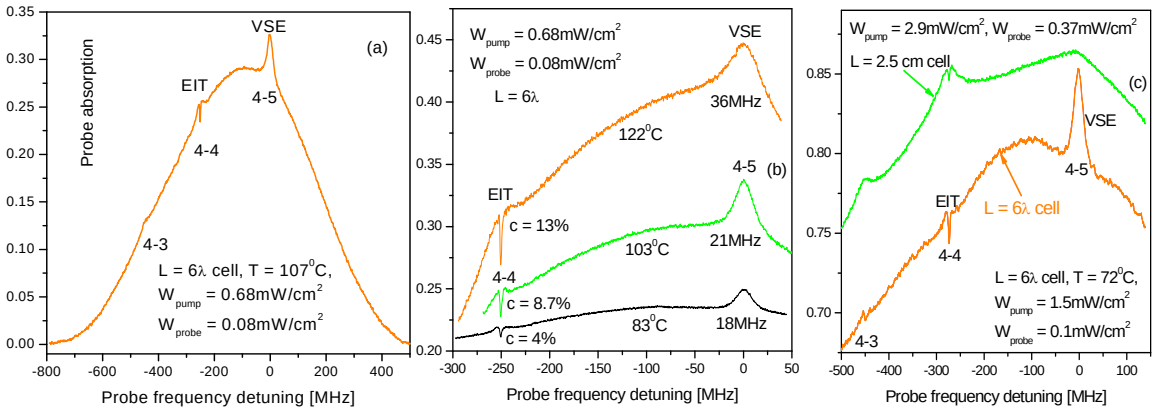

Fig.1 Probe absorption spectra for L = 6λ and L = 2.5cm cells: (a) EIT resonance at 4-4 transition and VSE resonance at 4-5 transition; (b)-EIT and VSE resonance behavior with atomic source temperature; (c) illustration of the striking difference between the thermalizations of atomic population selectively excited by the narrow-band pump beam, for the L = 6λ and L = 2.5cm cells. Atomic density: $2.3.10^{12} – 5.3.10^{13}$ at/cm^3.

in orthogonally to its windows. In Fig. 1, the main observations are shown.

EIT resonance is observed in the $F_g = 4 \rightarrow F_e = 4$ transition absorption, measured by the probe beam (Fig.1a). Narrow, high-contrast Velocity Selective Excitation (VSE) resonance occurs at the $F_g = 4 \rightarrow F_e = 5$ transition, attributed to accumulation (on the $F_g = 4$ level) of atoms flying orthogonally to laser beam by the pump laser. While the EIT resonance width stays constant (< 2MHz) with atomic source temperature, the VSE resonance suffers broadening (Fig.1b). The comparison of EIT/VSE resonance for L = 6λ and L = 2.5cm cells shows two unexpected results (Fig.1c): (i) despite the much higher rate of atomic collisions with the walls in the case

of L = 6λ cell, the width of the EIT resonance is similar for both cells; (ii) the termalization of selectively excited at the $F_e = 5$ level population for the L = 6λ cell is much lower than that observed in the L = 2.5cm cell. Physical processes behind the two effects will be discussed.

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PB8

VELOCITY SELECTIVE OPTICAL PUMPING RESONANCE SIGN REVERSAL

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The reduction of the thickness L of optical cells confining alkali atoms results in observation of sub-Doppler-width Velocity Selective Optical Pumping (VSOP) resonances, which can be easily registered by single beam spectroscopy. Here, we discuss the peculiarities in VSOP resonance behavior at the $F_g = 4 \rightarrow F_e = 3,4,5$ transition spectra of Cs atoms, confined in cell with L = 6λ, where λ = 852 nm and F_g/F_e – quantum numbers of the ground/excited state. For comparison, the conventional L = 2.5 cm cell spectrum is also presented. Distributed feedback (DFB) narrow-band diode laser is used, providing high resolution optical spectra (Fig.1).

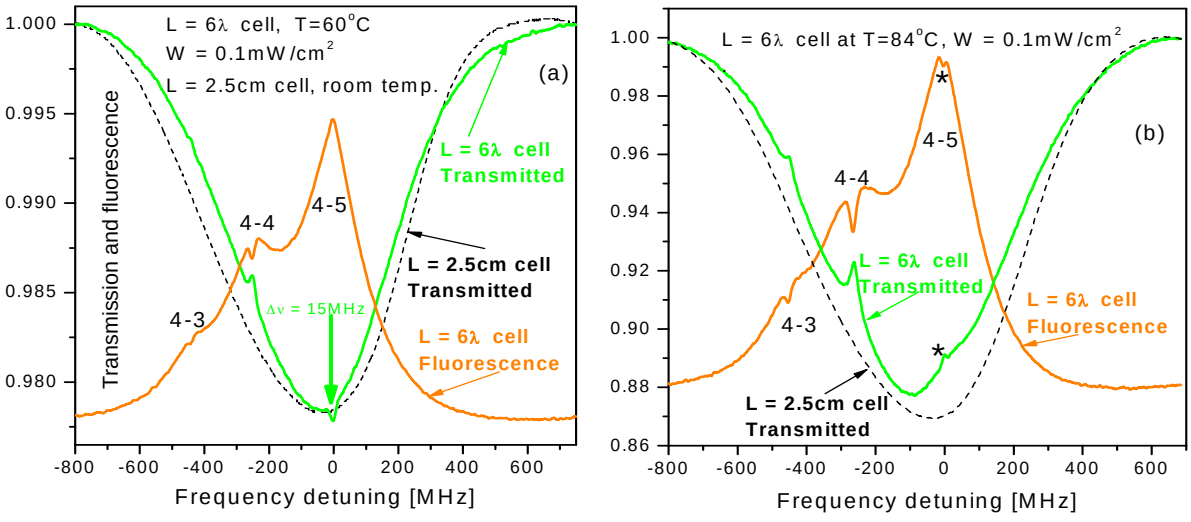

Fig.1 (a) Narrow VSOP resonances of different signs in the L = 6λ cell fluorescence and transmission spectra, for low atomic concentration ($9.2.10^{11}$at/cm^3) and very low light intensity – comparison with a conventional L = 2.5cm cell profile, where no sub-Doppler-width feature occurs; (b) Illustration of the bright resonance transformation into a dark one (denoted by asterisk) with atomic concentration enhancement ($5.2.10^{12}$at/cm^3), at the $F_g = 4 \rightarrow F_e = 5$ transition.

Like in previous studies the open $F_g = 4 \rightarrow F_e = 3,4$ transitions show reduced absorption (fluorescence), dark VSOP resonances whose contrast increases with atomic concentration.

However, in case of the closed $F_g = 4 \rightarrow F_e = 5$ transition the situation is different, the enhanced absorption (fluorescence), bright VSOP resonance reverses its sign with the atomic concentration. Theoretical study is in progress for clarifying the physical processes behind the resonance sign transformation. Density matrix formalism, taking into account the statistical tensors describing atomic population and longitudinal alignment, shows that the VSOP resonance sign reversal can be attributed to the efficiency reduction of population transfer by the spontaneous decay with atomic source temperature. The atomic population rate equations describe the resonance sign reversal with the involvement of the exited state depolarization.

Acknowledgements: This work was supported by the Bulgarian Science Fund (grant No: DO 02-108), as well as by a Marie Curie International Research Staff Exchange Scheme Fellowship within the 7th European Community Framework Programme.

PB9

BI-CHROMATIC SPECTROSCOPY IN MICROMETRIC OPTICAL CELLS

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The reduction of photonic sensor dimensions is of great importance. Here, we report new narrow features in the $F_g=4 \rightarrow F_e=3, 4, 5$ transition spectra of Cs atoms, confined in two optical cells with thickness L=6λ and L=700μm, where λ=852nm and F_g/F_e – quantum numbers of the ground/excited state. For comparison, the conventional L=2.5cm cell spectra are also presented. Two narrow-band diode lasers are used: (i) a pump one - with frequency fixed at the $F_g=4 \rightarrow F_e=5$ transition (Δ=0) or slightly detuned (Δ=31MHz) and (ii) a probe laser scanned along the $F_g=4 \rightarrow F_e=3,4,5$ transitions. Both laser beams are of linear and orthogonal to each other polarizations. In Fig. 1, the main observations are illustrated.

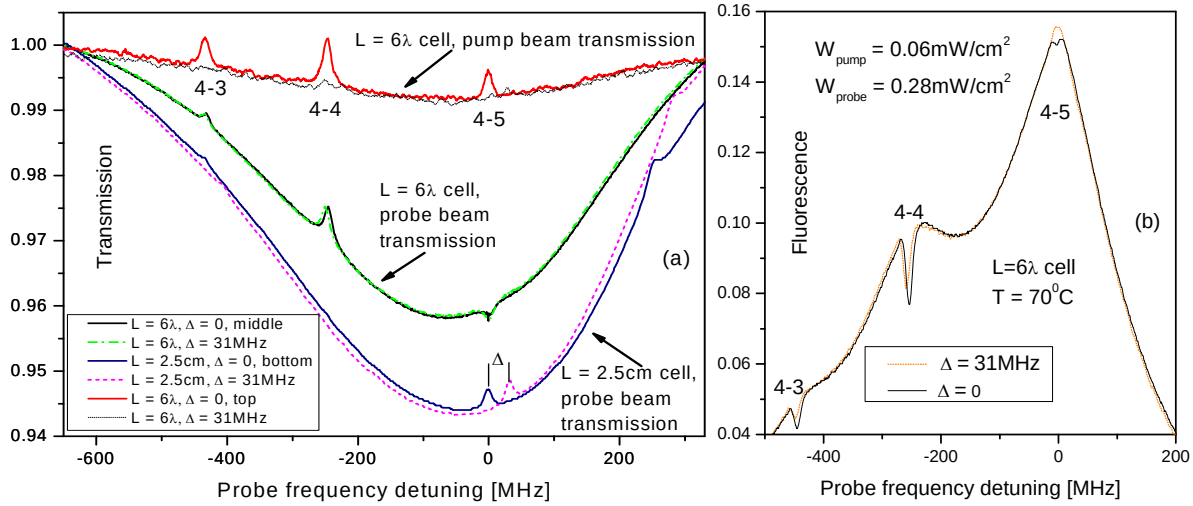

Fig.1 Probe transmission spectra for L = 6λ and L = 2.5cm cells: (a) transmission spectra for both cells, at two positions of pump frequency – (i) at exact resonance with the 4-5 transition, Δ = 0 and (ii) with small detuning from the resonance, Δ = 31MHz; (b) fluorescence spectra under the same conditions.

For the L=2.5cm cell transmission (Fig.1a, bottom), two curves are shown: (i) at Δ=0, a reduced absorption narrow feature occurs centered at the $F_g=4\rightarrow F_e=5$ transition and (ii) at Δ=31MHz, the narrow feature follows the pump frequency shift. The situation is completely different for the L=6λ cell (Fig.1a, middle curves), where the 3 sub-Doppler features of reduced/enhanced absorption do not change their positions when the pump beam frequency is shifted. In the micrometric cell, the narrow features are produced by the probe beam and are not sensitive to the low-intensity pump field. However, the fluorescence of the L=6λ cell is sensitive to the pump frequency shift: at Δ=0, a new dip is observed at the center of the $F_g=4\rightarrow F_e=5$ transition, while a Δ=31MHz shift transforms the dip into a peak. Very interesting is the transmission behavior of the pump beam, observed for a first time. Here, the Δ=0 condition produces very good contrast excited transparency resonances (Fig.1a, top curves), while only 31MHz pump detuning suppresses all 3 features. Physical processes behind the observed experimental features will be discussed.

Acknowledgements: This work is supported by the Bulgarian Science Fund (grant No: DO 02-108).

PB10

DETECTON OF SLOW ATOMS CONFINED IN A CESIUM VAPOR CELL BY SPATIALLY SEPARATED PUMP AND PROBE LASER BEAMS

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When an atom leaves a surface in an oblique incidence its velocity, with respect to the cell window normal, is governed by "cos theta" low [1]. For real "not perfectly" plane surfaces and when taking into account the attractive forces influencing the atomic flight such as electrostatic force and van der Waals attractive force, the existence of atoms with parallel velocity i.e. very slow along the normal (called here "slow atoms") is under question. To our knowledge this question is studied experimentally only seldom in literature [2].

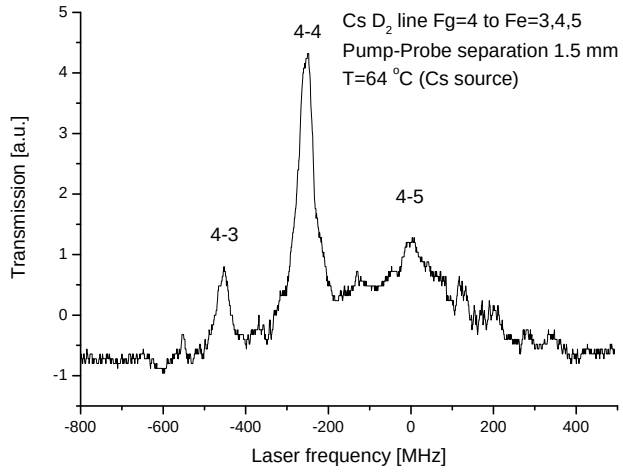

Figure 1. Probe beam transmission as a function of the laser frequency

The idea for an experiment as well as experimental results for detecting of "slow atoms" with normal velocity of 2 m/s appeared in [3]. This experimental statement allows one, changing pump-

probe separation to choose the highest velocity of the detected atoms for the given thickness. Measuring the height of the transmission peaks as a function of pump-probe separation gives the actual velocity distribution of the atoms flying under grazing incidence.

We present here experimental results for detecting of "slow atoms" in a thin cell (thickness 19 micrometers). The cell is specially designed with roughness of the sapphire windows surface 5 nm and deviation from a perfectly planar surface not more than 100 nm over 1 mm (10^{-4} radians as angle). The experiment is performed on Cs D_2 line (see figure 1). A systematic measurement is done when detecting atoms with normal velocity of about 3 m/s for estimation the influence of the atomic concentration (broadening, velocity changing collisions) over the signal characteristics (amplitude and width).

References:

[1] V. Bordo and H. Rubahn, Phys. Rev. A, 60, 1538, (1999).
[2] D. Grischkowsky, Applied Physics Letters **36**, 711, (1980).
[3] S. Briaudeau, et al, J. Phys. IV France **10**, 145 (2000).

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PB11

SIMULTANEOUS OBSERVATION OF N- AND EIT- RESONANCES IN 40-MICRON THIN CELL FILLED WITH Rb AND BUFFER GAS

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In recent years there was high interest for the fascinating properties of Coherent Population Trapping (CPT), Electromagnetically-Induced Transparency (EIT) and of Electromagnetically-Induced Absorption (EIA) processes. These phenomena attract much attention because of their significance for various applications in metrology, magnetometry, optical storage etc [1]. Recently, it was revealed that so-called *N*-resonance [2] is a promising alternative to CPT-(EIT)- and EIA- resonances. The main advantage of the process includes the technically easier formation of high-contrast sub-natural *N*-resonance.

We report simultaneous observation of N- and EIT- resonances formation using Rb micrometric –thin cells (MTC) filled with 150 Torr of buffer gas neon with the thickness *L* vary in the range of 1μm - 50μm. For N- and EIT- resonances formation in Λ-system two lasers are used: the probe (with tunable frequency), and the coupling (with the fixed frequency) with $\lambda \approx 795$ nm wavelength and 1MHz- line-width. Although, the best parameters of N-resonance could be obtained for a cell thickness ~ 1cm [2], however use of MTC with the thickness as low as 30-40 μm still allows us to obtain a good contrast and narrow line-width. The probe frequency is scanning within Rb, D_1 line, 5 $S_{1/2} \rightarrow 5P_{1/2}$ transitions, while the

coupling frequency is fixed. The *N*-resonance demonstrates sub-natural increase of the probe absorption and is formed when probe frequency ν_{P1} is resonant with ^{85}Rb, Fg=3 $\rightarrow 5P_{1/2}$ transition while for the coupling frequency the condition $\upsilon_C = \nu_{P1} + \Delta_1$ (Δ_1=3036 MHz) must be fulfilled. The EIT- resonance demonstrates sub-natural reduction of the probe absorption and is formed when ν_{P2} is scanning within ^{87}Rb, Fg=2 $\rightarrow 5P_{1/2}$ and for the same coupling frequency the condition $\upsilon_C = \nu_{P2} + \Delta_2$ (Δ_2=6835 MHz) must be fulfilled. The frequency distance between N- and EIT-resonances is equal to Δ_2-Δ_1=3799 MHz.

Comparison of *N*- and EIT-resonance formation in thin cells will be presented. As it was demonstrated in [3], the reduction of the thickness *L* down to 800 nm still allows one to detect of 40% contrast EIT-resonance, meanwhile *N*-resonance contrast obtained under identical conditions for the thickness *L* below 5 μm is of 1 %. However, a drawback of EIT is that its amplitude in the case of micrometric- thin cells use strongly depends on the detuning Δ of the coupling frequency from the appropriate intermediate level, and for Δ>100 MHz the EIT amplitude strongly reduces, while the line-width strongly increases [3]. As to *N*-resonance its amplitude is less sensitive to the value of the coupling frequency detuning.

References:

[1] M. Fleischhauer, A. Imamoglu, and J. P. Marangos, Rev. Mod. Phys. 77, 633-673 (2005).
[2] I. Ben-Aroya, G. Eisenstein, Optics Express 19, 9956 (2011) (see references therein).
[3] A.Sargsyan et al., Appl. Phys. B. Lasers and Optics, 105, 767 (2011).

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PB12

TOTAL INTERNAL REFLECTION FLOURESCENCE CROSS CORRELATION SPECTROSCOPY - EXPERIMENTAL STUDY OF BOUNDARY SLIP PHENOMENON

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Fluorescence Correlation Spectroscopy (FCS) is a versatile tool to study the dynamic behavior (diffusion, particle concentration, reaction kinetics etc) of single molecules, macromolecules and nanoparticles in solution. The method detects and analysis the minute fluctuations of the fluorescent light originating from an extremely small detection volume (<1 μm^3). The fluorescent tracers excitation is done using a laser beam, strongly focused to a diffraction limited focal volume by a high numerical aperture objective. In order to limit the detection volume also in axial direction, a confocal pinhole is introduced in the image plane, which

blocks all light not coming from the focal region. In this way improving significantly the S/N ratio.

An important application of FCS, due to its high sensitivity and spatial resolution, is to measure and profile fluid velocity in microchannels. However, the technique suffers from limited axial resolution (~1 μm) when monitoring flow velocity in proximity to an interface and measuring the so called slip length. In order to overcome this drawback the so called Total Internal Reflection Fluorescence Correlation Spectroscopy (TIR-FCS) was proposed as an extension of the classical FCS technique. In TIR-FCS the excitation of the fluorescent species is done by the evanescent wave that is formed when TIR takes place on the interface between two media with different refractive indices. As this evanescent field has a very short penetration depth (50-250 nm) TIR-FCS offers a significant improvement in the z-axis resolution, as compared to the conventional confocal FCS and allows studies in a very proximity of a solid surface.

In the present contribution a new experimental method called Total Internal Reflection Fluorescence Cross Correlation Spectroscopy (TIR-FCCS) is described. It is a method that we developed to probe the hydrodynamic flows near solid surfaces, and to measure the so called slip length with nanometer resolution (~5-10 nm). The time-resolved fluorescence intensity signals from two laterally shifted observation volumes, created by two confocal pinholes, are independently measured and recorded. The auto- and cross-correlations of these signals provide important information for the tracers motion within the studied liquid fluid. Since this motion is affected by the magnitude of the flow and slip length, extracting the latter becomes possible. We used as tracers fluorescent quantum dots and measured the slip length value on hydrophilic as well as hydrophobic surfaces. The measurements showed that the slip, on either surface, did not exceed 10-15nm.

References:

[1] S. Yordanov, A. Best, H.-J. Butt, K. Koynov, "Direct studies of liquid flows near solid surfaces by total internal reflection fluorescence cross-correlation spectroscopy", Optics Express, 17, 23, 21149-21158, (2009).

[2] R. Schmitz, S. Yordanov, H. J. Butt, K. Koynov, and B. Duenweg, "Studying flow close to an interface by total internal reflection fluorescence cross-correlation spectroscopy: Quantitative data analysis", Phys. Rev. E, 84, 6, 066306(1)-066306(16), (2011).

PB13

INFLUENCE OF QUANTUM DOTS SIZE ON THE SPECTRUM OF FLUORESCENCE

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At the present time phosphors labels are used to mark highly esteemed archeological and art objects. They are commonly based on organic dyes or luminescent microparticles doped with

rare earths. However, they have some significant shortcomings: a low quantum yield, complex sources of radiation, fast fading and other. These disadvantages are avoided in semiconductor nanocrystals (quantum dots) [1], which make semiconductor phosphors the optimal material for creating fluorescent labels.

In this report, the luminescent properties of quantum dots (QD) of various sizes and concentrations were investigated. Two QD solid solutions with particle size: 2.5 nm in the first composition and 5 nm in the second composition were prepared.

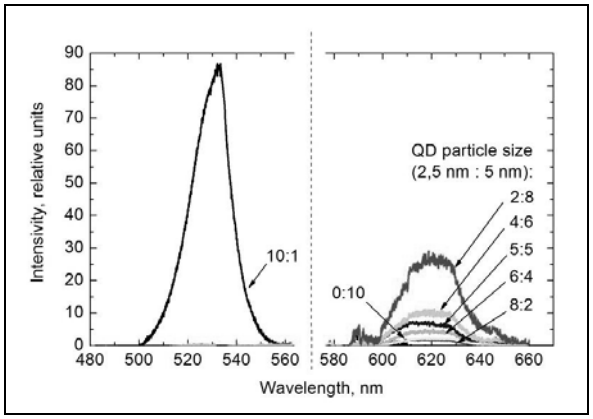

Figure 1. The fluorescence spectrum of the investigated quantum dots.

It was found that large dimension QD extinguish the luminescence of the QD of smaller dimensions very effectively. For 4:1 ratio between the compositions containing particles of 2.5 nm and 5 nm (extinction coefficients of the two compositions are equal), the luminescence of the QD with dimension 2.5 mm is suppressed or gone out totally. Phosphor labels based on QD must consist of QD with equal dimensions.

References:

[1] A.V. Baranov, V.G. Davydov, A.V. Fedorov, H.W. Ren, S. Sugou, and Y. Masumoto. Heterostructure optical phonons in dynamics of quantum dot electronic excitations: new experimental evidences. Proceedings of SPIE 5023, 247-250 (2003).

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PB14

POLARIZATION CHARACTERISTICS OF THE NONLINEAR MAGNETO-OPTICAL RESONANCES OBSERVED IN FLUORESCENCE IN PARAFFIN-COATED ^{87}Rb CELL

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The ultra-narrow resonances, achieved in coherent spectroscopy of alkali atoms, originate from the destruction of the laser-induced coherence in the ground state. Anti-relaxation cell coating preserves the created coherence and the resonance narrows almost by two orders of magnitude. The long lifetime of the coherent state makes possible transfer of coherence by multi-photon processes due to the mixing of the contribution of polarization moments with different rank [1]. The ground state coherence is transmitted from the laser field to the upper level.The competition between .processes with different rates leads to new structures in the magneto-optical resonance. This complex signal is observed in the fluorescence as Coherent population trapping in Hanle configuration.

The polarization characteristics of the fluorescence signals are measured and analyzed in order to obtain the contribution of the polarization moments having different rank to the fluorescent signal. The experiment is performed on the D1 ^{87} Rb line, F=2→F=1 transition in a paraffin coated cell.

Program for numerical modelling of this experiment, based on the irreducible tensor operator formalism is applied [2]. The results of the modelling are compared with the measured ones at different experimental conditions.

References:

[1] S. Gateva, E. Alipieva, E. Taskova, G. Todorov, "Coherent population trapping resonance structure in paraffin-coated Rb vacuum cells" Proceedings of SPIE - 7747, art. No. 77470G, (2011).

[2] V. Polischuk, V. Domelunksen, E. Alipieva , G. Todorov **"**Modelling of nonlinear interaction of Rb^{87} atoms with polarized radiation", Bulg.J. Phys. **39** 150-164(2012).

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PB15

FIBERIZED FLUORESCENT DYE MICROTUBES

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The development of miniature tunable fiber-compatible or all-fiber dye lasers has exhibited a considerable growth in recent years. The basic idea is their use in microfluidics and biosensing technologies [1]. Capillary tubes and the holes of photonic crystal fibers have been a natural choice for inserting fluorescent organic dyes so as to obtain a lasing effect [2]. Also the construction of an opto-fluidic ring laser has been studied [3].

In the present work we study the effect of the length of fluorescent dye-filled micro-capillaries on the fluorescence spectra. Two types of micro-capillaries have been studied: a 200 m inner

diameter PolyMicro capillary with transparent coating and a 125m inner diameter glass tube. The tubes were filled with solutions of R6G dissolved in ethanol and glycerine. The intensity and the spectral widths (Fig.1) have been found to vary considerably depending on the length of the micro-capillary in case of side laser excitation at 532 nm. The receiving fibers were either 9/125 m or 50/125 m core/cladding diameter optical fibers.

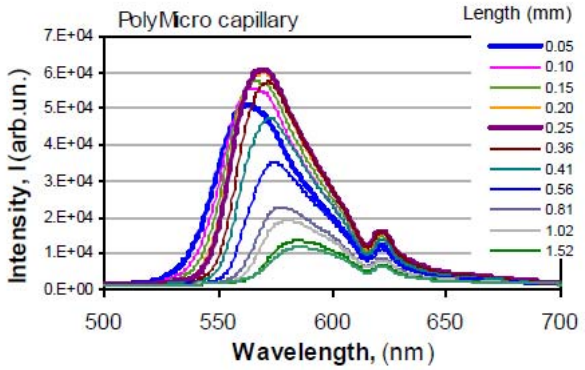

Fig. 1. Fluorescence spectra of R6G solution in glycerine for different capillary lengths.

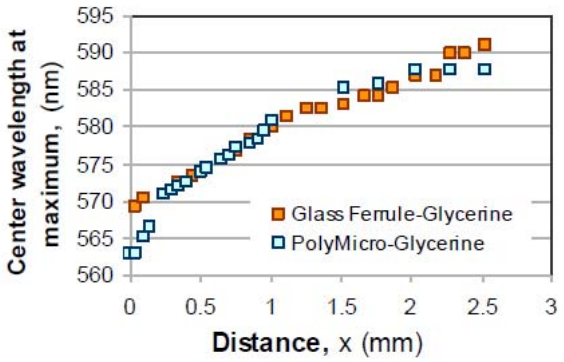

Fig. 2. Center-wavelength shifts vs. distance between pumping and detection position (length)

The dependence of the center wavelength vs. the length of the section between excitation and detection fiber is presented in Fig. 2. Figures 1 and 2 show that maximum fluorescence and largest spectral widths are observed for a sample length of about 0.25 mm for the used concentration. This means that miniature small-size tunable fiberized dye lasers can be developed using available micro-optic components.

References:

[1] Y. Chen, L. Lei, K. Zhang, J. Shi, L. Wang, H. Li, X. Zhang, Y. Wang, H. Chan, Optofluidic microcavities: Dye-lasers and biosensors, Biomicrofluidics, Vol. 4, 043002-1-14 (2010).

[2] A. Turnbull, I. Samuel, Fluidic fibre dye lasers, Vol. 15, No. 7, Opt. Express, 3962-3967, (2007).

[3] S. Shopova, H. Zhou, X. Fan, P. Zhang, Optofluidic ring resonator based dye laser, Appl. Phys. Lett., Vol. 90, 221101, (2007).

PB16

SPECKLE SUPPRESSION IN PATTERN PROJECTION PROFILOMETRY WITH A THIN SINUSOIDAL PHASE GRATING BY LED ILLUMINATION

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Pattern projection profilometry is a well-established method in optical metrology for distant capture of 3D objects. The information is retrieved from the phase of the deformed fringe pattern formed by imaging the object onto a CCD camera after projection of a structured light pattern onto its surface. A variety of phase retrieval algorithms requires projection of sinusoidal fringes. Thin diffraction sinusoidal gratings under coherent plane-wave or divergent illumination are a suitable choice for outdoor implementation of the method when the portability and compactness of the profilometric system are crucial requirements. These gratings, which can be recorded as a hologram onto a photosensitive material [1] or reproduced by a spatial light modulator [2], provide high-visibility sinusoidal fringes with negligible higher-frequency content in a large measurement volume under laser illumination.

The aim of the present study is speckle suppression in the fringes projected with a sinusoidal phase grating (SPG) with spacing, L, modulation parameter, m, and transmission $\tau(x) = \exp[jm\sin(2\pi x/L)]$, where x is the lateral coordinate, by using LED illumination [3]. Speckle noise is a serious drawback of the laser projected fringes. Its reduction by sophisticated digital filtering of the recorded fringes may not always guarantee acceptable level of accuracy. We solve the task of speckle suppression by analysis of the contrast (visibility) and the frequency content of fringes projected by the SPG under multi-wavelength illumination by solving the Fresnel diffraction integral for a point source illumination in paraxial approximation. The lateral fringe spacing does not depend on the wavelength of the illuminating light. It has an impact on the locations and number of the Talbot planes, where self-imaging of the grating occurs, and on variation of the contrast and the frequency content of fringes along the distance from the grating, as is shown in Fig.1 for L=0.025cm and m=0.3. The Talbots planes should be strictly avoided because the self-image of the grating is a zero-contrast pattern (Fig.1). To decrease their number and to increase the available volume with good-quality fringes we apply divergent illumination. We verified the obtained results by experiments with a thin holographic grating recorded on a silver-halide holographic plate and a LCoS generated grating for illumination with a LED and a multi-mode laser diode.

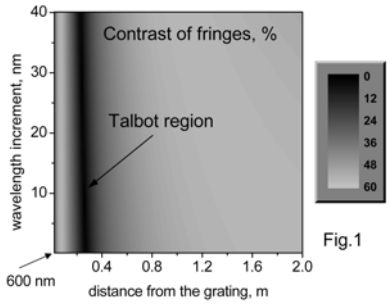

Fig.1

References:

[1] E. Stoykova, G. Minchev, and V. Sainov, "Fringe projection with a sinusoidal phase grating", Appl. Opt. 48, 4774-4784, (2009).

[2] N. Berberova, E.Stoykova, V.Sainov, "Generation of sinusoidal fringes with a holographic phase grating and a phase-only spatial light modulator", Phys. Scr. T147, (2012).

[3] F. Yaraş, H. Kang, and L. Onural, "Real-time phase-only color holographic video display system using LED illumination," Appl. Opt. 48, H48-H53, (2009).

PB17

INVESTIGATION OF 2D AND 3D COLOR GAMUT CHANGES BASED ON REFLECTANCE SPECTRA OF PRINTED IMAGES IN DEPENDENCE OF THE STANDARD ILLUMINANTS FOR LWC PAPER

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The main goal of this study is investigation of 2D and 3D color gamut changes depending on different standard illuminants based on spectral reflection of printed images for LWC /lightweight coated/ paper. The graphically presentation of color gamut – 3D and 2D gives us valuable and comprehensive information for colors, that can be reproduced in the specific conditions. Presentation and analyses of tree dimensional (3D) gamut surface, gives general and important information for the asymmetric color body. Two dimensional (2D) gamut presentation at different cross-section of CIE L* coordinate, gives more detailed information for analyses and comparison. For better assessment of changes in color gamuts, the surface area of 2D and volume of 3D color bodies were calculated for each standard illuminant. For the experiment have been chosen the most commonly used in practice standard illuminants – CIE D50, CIE D65, CIE A, and CIE Fluorescent illuminants –F2, F7 and F11. A test form has been made by specialized software. The test form contains big number of control strips, components and test chart with more over 1000 color patches. The all used patches contain different percent combinations of Cyan (C), Magenta (M), Yellow (Y) and Black (K). The paper, printing inks and printing press used in the experiment are some of most commonly used in practice. A series of spectral measurements have been performed for the printed test charts for each standard illuminant.

The results are important from scientific and practical point of view. For first time via experimental research in real production conditions, were made 3D and 2D comparison of color gamuts volumes and color gamut surface areas for different standard illuminants. The differences between volumes are very important from practical point of view, because the volume of gamuts for each standard illuminant is one of the most important factors, that impact on human perception and print quality.

The results of this research can be used for simulation and prediction of color accuracy of reproduction and for foresight of the reflectance spectra of printed images depending on standard light source.

References:

[1] R. Balasubramanian, E. Dalal, "A method for quantifying the color gamut of an output device", Proc. SPIE Vol. 3018, 110–116, (1997).

[2] I. Farup, J. Y. Hardeberg, A. M. Bakke, S. Kopperud, A. Rindal, "Visualization and interactive manipulation of color gamuts", Proc. IS&T and SID's, Volume: 9, Issue 5, 250–255, (2002).

[3] N. Neophytou, K. Mueller, "Color-Space CAD: Direct Gamut Editing in 3D", IEEE, vol. 28, no., 3, 88-98, (2008).

PB18

STUDY OF THE EFFECT OF GRAY COMPONENT REPLACEMENT LEVEL ON REFLECTANCE SPECTRA AND COLOR REPRODUCTION ACCURACY

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The aim of this study is investigation of gray component replacement (GCR) levels on reflectance spectrum for different overprints of the inks and color reproduction accuracy. In multicolor printing, the black ink is used to reduce the technological expense of printing with three chromatic colors, to reproduce the gray tones using predominantly black ink and also, primarily, in order to stabilize the printing process making it less sensitive to variations in the individual process colors. There are several methods for generation and controlling the amount of substitution of chromatic colors – cyan, magenta and yellow with black ink. The most commonly implemented method in practice for generation of achromatic composition is gray component replacement (GCR). The experiments have been performed in real production conditions with special test form generated by specialized software.

The measuring of reflection spectrum of printed colors, gives a complete conception for the effect of different gray component replacement levels on color reproduction accuracy. For better data analyses and modeling of processes, we have calculated (converted) the CIEL*a*b* color coordinates from the reflection spectra data. The assessment of color accuracy by using different GCR amount has been made by calculation of color difference ΔE_{ab}^*. In addition for the specific printing conditions we have created ICC profiles with different GCR amounts. A comparison of the color gamuts has been performed. For a first time a methodology is implemented for examination and estimation of effect of GCR levels on color reproduction accuracy by studying a big number of colors in entire visible spectrum. Implementation in practice of the results achieved in this experiment, will lead to improved gray balance and better color accuracy. Another important effect of this research is reduction of financial costs of printing production by decreasing of ink consumption, indirect reduction of emissions during the manufacture of inks and facilitates the process of deinking during the recycling paper.

References:

[1] H. Kipphan, "Handbook of Print Media, Technologies and Production Methods", Springer-Verlag Heidelberg, Berlin, (2001).

[2] T. Bugnon, M. Brichon, R.D. Hersch, "Model-based deduction of CMYK surface coverages from visible and Infrared spectral measurements of halftone prints", Proc. SPIE Vol. 6493, 649310-1 - 649310-10, (2007).

PB19

INVESTIGATION OF EFFECT OF DIFFERENT TOTAL AREA COVERAGE VALUES OF INKS ON REFLECTION SPECTRA AND COLOR GAMUT

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The paper presents investigation of the effect of different values of total area coverage of inks (TAC) on reflection spectra and color gamut. Total area coverage is the maximum total dot percentage of cyan, magenta, yellow and black ink used in the darkest areas and generally depends on the printing process and the type of paper. Total area coverage is a key factor for achieving of maximal volume of color gamut, especially in dark areas. Theoretically, the maximal amount of process inks is 400%, but in practice that will cause problems with ink trapping, decreasing of adhesion of inks layers, drying troubles, etc. The reflection spectra of color surfaces in entire visible spectrum are used for determination the effect of different values of TAC. For study the effect of TAC values on color gamut, we have used special test form that contains many components for process control and simulation - control strips and test charts with over 1500 color patches. According to measurement of reflectance spectrum of test charts, we have compared the color gamuts with different values of TAC. By this way we have obtained comprehensive information of all colors, which could be reproduced in the specific conditions. In addition we have converted the reflection spectra data to CIEL*a*b* coordinates, and we have calculated the color difference ΔE^*_{ab} to determine the effect of TAC on color reproduction accuracy.

The main goal of this study is development of methodology, which gives objective and analytical assessment, for determining the optimal value of total area coverage (TAC). A practical implementation of the correct and optimal value of total area coverage should improve the printability, better ink layers adhesion, biggest number of trapping values and reduce the quantity of process inks. The optimal value of the TAC determined by this new methodology helps to achieve a significant reduction of ink cost and a maximal color gamut volume, i.e. improve the quality of printed image and reduce financial costs.

References:

[1] G. Sharma, Digital Color Imaging Handbook, CRC Press, (2003).

[2] T. Bugnon, M. Brichon, R.D. Hersch, "Model-based deduction of CMYK surface coverages from visible and Infrared spectral measurements of halftone prints", Color Imaging XII: Proc. SPIE Vol. 6493, 649310-1 - 649310-10, (2007).

PB20

DARK STATE FORMATION IN THREE-LEVEL LADDER SYSTEM IN Na SUPERSONIC ATOMIC BEAM

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In the present communication, we present experimental demonstration of realization of "dark state" by means of strong coupling of atomic Na hyperfine energy levels. A strong laser field P couples the $3S_{1/2}$, F″=1 (or F″=2) and the $3P_{1/2}$, F′=1,2 hyperfine levels with Rabi frequency Ω_P, leading to the formation of three laser-dressed states [1]. The dressed states are probed by scanning a weak probe field S across the $3P_{1/2}$, F=1,2→$7D_{3/2}$ transition (Fig.1). The experiment is performed in a supersonic atomic beam with counter-propagating S and P laser fields, and the fluorescence from the $7D_{3/2}$ is registered by a photon counter. The excitation spectrum of the $7D_{3/2}$ state consists of an intense central peak with side peaks with much smaller intensities (Fig.2). The increase in Ω_P leads to (almost) no change in the position of the main peak, while the side peaks are shifted further apart. The results are confirmed by our theoretical model based on the density matrix equations of motion, with good agreement with the experimental data. These observations are explained in the dressed-states picture of the three level system consisting of Na ground state hyperfine level F″=1 or F″=2 (depending on P-field detuning) with the F′=1,2 levels of $3P_{1/2}$ coupled by Ω_P. Following the analysis of Fano [2], we show that the intermediate level obtained in the dressed-state picture is weakly affected by the magnitude of Ω_P, thus it can be considered as weakly coupled to the P-field. This "gray" state evolves into a dark state at high Ω_P.

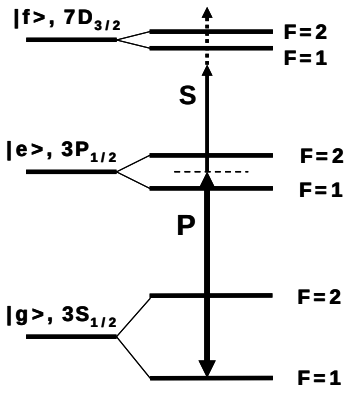

Fig.1. Na energy levels involved.

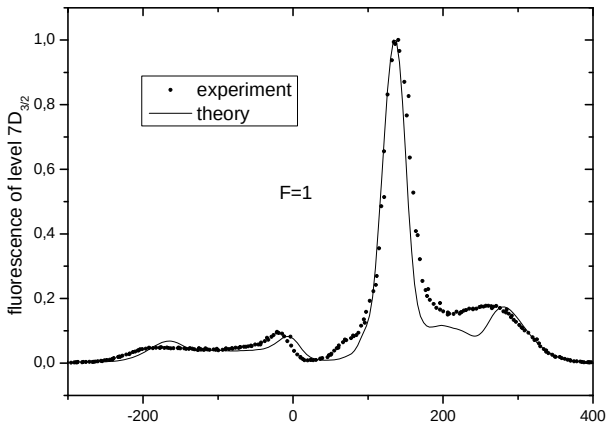

Fig.2. 7D3/2 fluorescence vs the probe laser detuning.

References:

[1] C. Cohen-Tannoudji, S. Reynaud, "Dressed-atom description of resonance fluorescence and absorption spectra of a multi-level atom in an intense laser beam" J. Phys. B – At. Mol. Phys. 10, 345-363, (1977).

[2] U. Fano, "Effects of configuration interaction on intensities and phase shifts", Phys. Rev. 124, 1866-1878, (1961).

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PB21

SUB-DOPPLER VELOCITY SELECTIVE EXCITATION RESONANCES IN MICROMETRIC OPTICAL CELL

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Conventional optical cells (of cm size), containing Cs vapor exhibit spectral profiles, which are convolution of 5 MHz natural and 400 MHz Doppler widths (D_2 line). Reduction of optical cell thickness L results in sub-Doppler width (SDW) resonances with L approaching the wavelength λ of the light. Here we report high-contrast Velocity Selective Excitation (VSE) resonance of SDW at closed $F_g = 4 \rightarrow F_e = 5$ transition (λ = 852nm, F_g/F_e – quantum numbers of the ground/excited state), for L = 6λ cell. Two narrow-band diode lasers are used: (i) a pump one with frequency at the $F_g = 3 \rightarrow F_e = 4$ transition and (ii) a probe - tuned along

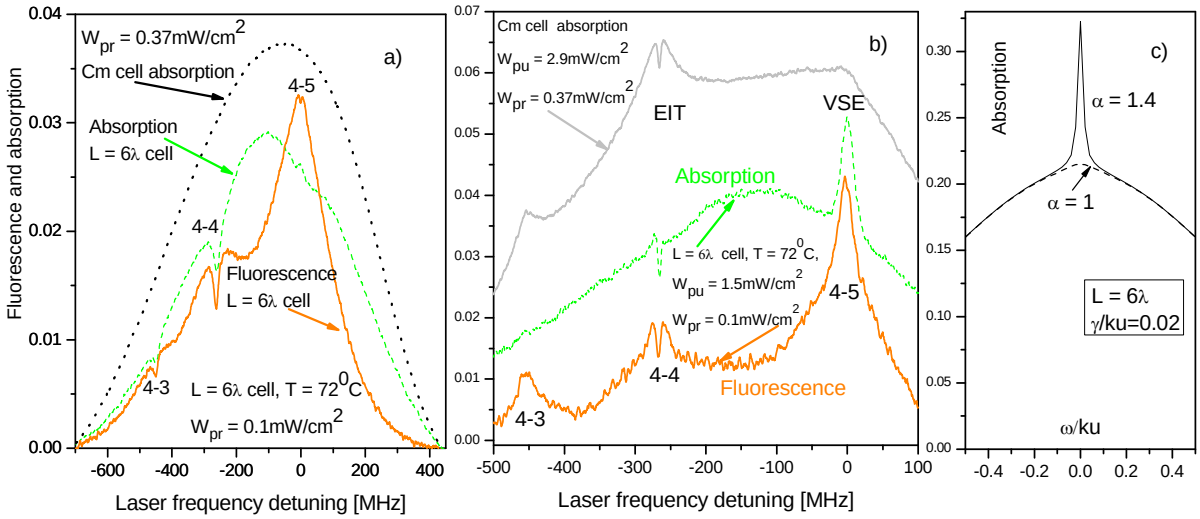

Fig.1 (a) Experimental probe absorption and fluorescence spectra for L = 6λ and L = 2.5cm cells – pump laser is off; (b) Experimental Electromagnetically Induced Transparency (EIT) resonance at 4-4 transition and VSE resonance at $F_g = 4 \rightarrow F_e = 5$ transition: illustration of the striking difference between VSE resonance profiles observed in L = 6λ and L = 2.5cm cells - probe and pump lasers on; (c) theoretical simulation of absorption, for closed transition (α = 1) and for some flow of additional atoms to the two-level system (α = 1.4).

the $F_g = 4 \rightarrow F_e = 3,4,5$ transitions. The $L = 6\lambda$ cell is irradiated by both overlapped laser beams, in orthogonal to its windows direction. In Fig.1, the main observations are shown.
Single beam spectroscopy (Fig.1a) demonstrates principle difference between L = 2.5cm cell, showing no SDW structure and $L = 6\lambda$ one with SDW (~ 12MHz) resonances at each hyperfine transition. The pump-probe approach results in EIT resonance (~ 2 MHz) observed at the 4 - 4 transition (Fig.1b). The VSE resonance (of~ 18MHz) at 4 - 5 absorption (Fig.1b) is due to the atomic population accumulation on the $F_g = 4$ level: the pump laser excites to $F_e = 4$ level those atoms flying orthogonally to the beam, which further decay to $F_g = 4$ level. Surprisingly, the comparison of VSE resonance for $L = 6\lambda$ and L = 2.5cm cells shows that atomic termalization at the $F_e = 4, 5$ levels is much lower for the $L = 6\lambda$ cell than that for the L = 2.5cm cell. Preliminary theoretical simulation (Fig.1c) for two-level atoms with atomic income from outside of the system shows similar feature for the $L = 6\lambda$ case.

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C- *LASER REMOTE SENSING AND ECOLOGY*

PC1

LIDAR OBSERVATIONS OF HIGH-ALTITUDE AEROSOL LAYERS (CIRRUS CLOUDS)

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Aerosols, clouds and aerosol-cloud interactions are recognized as key factors influencing the climate. Clouds are the primary modulators of the Earth's radiative budget. They contribute differently to short-wave and long-wave radiation depending on their type, altitude, thickness, particle size, etc. In this work we present an excerption from regular lidar investigations of atmospheric aerosols, performed in Sofia lidar station at Institute of Electronics – Bulgarian Academy of Sciences (IE-BAS) within the frame of European project EARLINET (European Aerosol Research Lidar Network, FP6, http://www.earlinet.org). The paper focuses on the detection of high-altitude aerosol layers, situated in altitude range of 6 km÷16 km, with thickness about 200 m÷5000 m and varying optical characteristics. On the basis of the generally adopted classification of cirrus clouds, high values of the retrieved aerosol backscatter coefficient profiles and optical density and the results of Angshtrom-exponent estimation, we conclude that the observed dense aerosol layers are cirrus clouds.

Lidar measurements are performed with an aerosol lidar, equipped with Nd:YAG laser at wavelengths 532 nm and 1064 nm, recently developed in Laser Radar Lab of IE-BAS. Lidar data is presented in terms of vertical atmospheric backscatter coefficient profiles. We employed HYSPLIT (HYbrid Single-Particle Lagrangian Integrated Trajectory) backward trajectories and DREAM (Dust REgional Atmospheric Model) forecasts to analyze the lidar profile outlines and characterize the events during which cirrus cloud samples were observed. It was remarked that most of the cirrus clouds observation were combined with a long-way Saharan dust transport over Sofia lidar station.

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PC2

REMOTE MONITORING OF AEROSOL LAYERS OVER SOFIA DURING SAHARA DUST TRANSPORT EPISODE (APRIL, 2012)

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In this work we present results of lidar remote sensing of aerosol layers in the atmosphere above Sofia during an episode of Sahara dust transport, 02-07 April, 2012. The investigations were made using two lidar system, one equipped with a CuBr-vapor laser, emitting at wavelength 510.6 nm, and second one - with Nd:YAG laser, at wavelengths 1064 nm and 532 nm. The results of lidar measurements are presented in terms of vertical atmospheric backscatter coefficient profiles and color maps of the aerosol stratification evolution. The involved into discussions ceilometer data (CHM 15k ceilometer) and satellite data from CALIPSO lidar, enhance the synergy of observations. Conclusion about atmospheric aerosol's origin was made upon analyses of the information of weather-forecast maps provided by the Atmospheric Modelling and Weather Forecasting Group of NTUA and the Forecast system of Barcelona Supercomputing Centre, which are accessible via Internet. Additional information was provided by calculations of the backward air mass trajectories, using online software of NOAA about HYSPLIT model (HYbrid Single-Particle Lagrangian Integrated Trajectory). The comparison between the data from the two lidars and the ceilometer showed similar behavior of aerosol layers development in the atmosphere above Sofia.

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PC3

RAYLEIGH-FIT APPROACH APPLIED TO IMPROVE THE REMOVAL OF BACKGROUND NOISE FROM LIDAR DATA

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A procedure to approach synthesized profile of lidar returns from hypothetical Rayleigh atmosphere to real lidar data is described in this work. The procedure is used in the preprocessing of lidar data to determine the magnitude of background noise which should be removed before to start an inversion processing (by Klett, or Fernald algorithm) for to retrieve atmospheric backscatter or extinction profiles. Some applications of Rayleigh-fit procedure on real lidar data are discussed. After removing the background noise from lidar data the atmospheric backscatter profiles at two near laser wavelengths 510.6 nm and 578.2 nm (CuBr-vapor laser) was calculated. The ratio of these two backscatter profiles was used as justification of the results of Rayleigh-fit procedure for background noise removal.

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PC4

A STUDY OF THE RESPONSE OF INTERMODAL INTERFERENCE PATTERNS AT A FIBER COUPLER OUTPUT

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In this paper we derive interference equations and present theoretical models for a variety of cases of interfering mode pairs: non-degenerate and non-degenerate; non-degenerate and degenerate as well as degenerate and degenerate even/odd LP modes assuming a Gaussian approximation and an identical polarization. For 2x2 fiber couplers of different coupling ratios and single mode at 1310/1550nm, we measure the coupling ratio in a few mode regime of operation at 650nm and record the pattern distributions. We find a very good correspondence between theoretical and experimental results which will be used for optimizing a CCD array used for the analysis of the external disturbances along an optical fiber intrusion sensor.

PC5

CHARACTERIZATION OF ATMOSPHERIC PROPERTIES BY COMBINED USE OF TWO-WAVELENGTH- AND RAMAN LIDAR MEASUREMENTS

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Multi-wavelength lidar measurements offer the opportunity various optical and micro-physical characteristics (such as backscatter- and extinction coefficients, Ångström exponents, particle size distribution, etc.) of the atmospheric molecules and aerosols to be determined and

profiled with high spatial- and temporal resolution[1]. Raman lidar data, combining both the elastic- and inelastic light-scattering sensitivity, provide independent evaluation of some atmospheric parameters (extinction/backscatter, optical depth, lidar ratio), considerably increasing by this manner the reliability and accuracy of the quoted above retrievals[2]. In this work we take advantage of the combined use of two-wavelength- and Raman lidar probing to characterize atmospheric properties at altitudes of up to the low stratosphere (≤16 km). Measurements are carried out in Sofia, Bulgaria, by using simultaneously the three channels of a combined aerosol-Raman lidar[3] based on Nd:YAG laser transmitter. The two elastic-scatter (aerosol) channels are operated at 1064 nm and 532 nm whereas the Raman channel detects inelastic-scatter lidar returns at 607 nm. Results obtained in a 3-day period (28-30.11.2011) are presented and discussed. Series of time-averaged height profiles and histograms of the backscatter coefficient and integral backscatter at 1064 nm and 532 nm are displayed and commented, as retrieved by using the Klett-Fernald method for solving the lidar equation. The big spectral distance between the two used wavelengths allows one to distinguish between the fine-mode and coarse-mode aerosol fractions and to follow their behavior in terms of spatial distributions and temporal dynamics. In order to characterize the dominating aerosol particle size, height profiles of the backscatter-related Ångström exponent (BAE) are presented and analyzed. Assumptions concerning the type and origin of the detected aerosols are made. Colormap evolutional diagrams in height-time coordinates are shown, revealing the minute-scale temporal dynamics of atmospheric characteristics over the measurement time periods. Results of parallel Raman lidar measurements at 607 nm are also presented. The high spectral noise discrimination level of 10^8 in the lidar's Raman channel provided reliable detection of Raman lidar returns from distances of up to 8 km. Vertical profiles of the aerosol extinction- and backscatter coefficients, as well as of the lidar ratio, are retrieved from Raman data to altitudes of up to near 5 km, limited by the 32°-slope-angle sounding. These are used for calibration and correction of the backscatter vertical profiles retrieved by Klett-Fernald method in whole accessible height range of 16 km. Obtained results show the effectiveness of using 3-channel lidar probing, as performed at two distant spectral lines in the visible and IR for aerosol channels and a Raman one in between, resulting in more reliable and accurate determination and profiling of optical and microphysical atmospheric characteristics.

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References:

[1] A.K. Jagodnicka, T. Stacewicz, G. Karasiński, M. Posyniak, S.P. Malinowski, "Particle size distribution retrieval from multiwavelength lidar signals for droplet aerosol", Appl. Opt., Vol. 48 (4), B8-B16 (2009).

[2] A. Ansmann, M. Riebesell, and C. Weitkamp, "Measurement of atmospheric aerosol extinction profiles with a Raman lidar", Opt. Lett., Vol. 15(13), 746-748 (1990).

[3] Z.Y. Peshev, A.D. Deleva**,** T.N. Dreischuh, D.V. Stoyanov, "Dynamical characteristics of atmospheric layers over complex terrain probed by two-wavelength lidar," Proc. SPIE Vol.7747, paper # 77470U (2011).

PC6

AEROSOL OPTICAL DEPTH, WATER VAPOR CONTENT AND OZONE MEASUREMENTS OVER SOFIA (BULGARIA)

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This paper presents the results from a study related to the optical and physical characteristics of atmospheric aerosol, precipitable water and variation of near ground and total ozone column over Sofia (Bulgaria). Compact five-channel hend-held Microtops II sun photometer and ozone monitor were used to measure aerosol optical depth (AOD), water vapor content (WVC) and total ozone column (TOC) over urban area [1]. Aerosol optical depth and precipitable water vapor amount are two physical parameters for characterizing atmospheric aerosol. Atmospheric aerosol is important component of global climate system and plays an important role in the Earth - Atmosphere system's radiation budget. Total ozone in the atmosphere modifies the intensity and spectral composition of the solar ultraviolet radiation reaching Earth's surface [2].

In the present investigations the results from two experimental campaigns carried out in two periods from 07.06.2011 to 18.06.2011 (hereafter summer campaign) and from 22.10.2011 to 04.11.2011 (hereafter winter campaign) are presented. Few different types of AOD and WVC behavior are observed. TOC contents measured by MicrotopsII at Sofia are in agreement with those retrieved from the long-term (1997-2008) database statistics acquired from the satellite measurements.

During the summer campaign the AOD values at wavelength λ=500nm changed between τ_a=0.16 and τ_a=0.5 and WVC values varied in the range from 1.65cm to 2.35cm. The TOC content varied in the range from 280 DU to 330 DU. During the winter campaign the AOD at wavelength λ=500nm had values from τ_a=0.20 to τ_a=0.40 and WVC values varied in the range from 0.54cm to 0.80cm. The TOC content varied in the range from 250DU to 270DU. The summer values of aerosol optical depth, water vapor content and total ozone column are higher than those obtained during the winter measurements over the region of Sofia (Bulgaria).

References:

[1] N. Kolev, P. Savov, E. Donev, D. Ivanov, T. Evgenieva, V. Grigorieva, I. Kolev, "Boundary Layer Development and Meteorological Parameters Impact on the Ground Level

Ozone Concentration Over an Urban Area in a Mountain Valley (Sofia, Bulgaria)", Int. J. Rem. Sens., Vol 32, No 24, 8915-8933, (2011).

[2] V. Grigorieva, N. Kolev, E. Donev, D. Ivanov, B. Mendeva, T. Evgenieva, V. Danchovski, I. Kolev, "Surface and total ozone investigations in the region of Sofia, Bulgaria", Int. J. of Rem. Sens., Vol 33, No 11, 3542-3556, (2012).

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EFFICIENCY OF THE DETERMINATION BY THOMSON SCATTERING LIDAR OF THE ELECTRON TEMPERATURE AND CONCENTRATION AND THE PRESSURE IN THERMONUCLEAR PLASMAS

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Effective observation and control of the fusion process is possible only on the basis of effective thermonuclear plasma diagnostics involving the determination with high accuracy and (spatio-temporal) resolution of the electron temperature T_e and concentration n_e and the pressure P in the reactive zone. Because of the high characteristic temperatures [~10^8 K] and pressures [~10^5 Pa] in this case, the only effective methods for diagnostics turn out to be the contactless, passive and active optical or microwave ones. Among these, the Thomson-scattering-based lidar-type methods are especially appropriate for simultaneous determination of electron temperature and concentration, and respectively pressure profiles in fusion plasmas. The routine approach usually used for this purpose is based on log-linear or non-linear fit of the experimentally-obtained, relativistically-thermally-broadened lidar-return spectra to the corresponding theoretical expression [1,2]. Effective and fast methods have also been developed for measuring T_e on the basis of the unambiguous temperature dependence of the "center-of-mass wavelength" of the lidar-return spectrum and of the ratio of the return-signal powers of two spectral regions [2].

The important problem about the determination of the statistical error in the determination of the electron temperature and concentration has been concerned in [1,2]. In paper [1], considering the fitting approach, the errors in the determination of T_e and n_e are derived analytically without taking into account the statistical correlation between the estimates of the fitting parameters obtained by least-squares procedures.

The main purpose of the present work is to derive analytical expressions of the statistical errors in the determination by least-squares fitting of the electron temperature and concentration and the pressure in thermonuclear plasmas, taking into account the correlation between the estimates of the fitting parameters. Another purpose of the paper is to perform computer statistical modeling for validation of the obtained analytical expressions. As a result of the investigations performed, analytical expressions of the afore-mentioned errors have been obtained. They show, e.g., that at concentration of 8×10^{19} $m^{-3}$and temperatures between 1 keV and 6 keV, the relative errors of measuring T_e, n_e, and P are below 3% and increase

with increasing the temperature above 6 keV. The results from the statistical modeling confirm in general the theoretical results.

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References:

[1] M. Mattioli, R. Papoular R, Plasma Physics 17**,** 165 (1975).
[2] L. Gurdev, T. Dreischuh, D. Stoyanov, Proc. SPIE 7027, 702711 (2008).

PC8

FAST COMPUTATION OF RADIATION TRANSFER THROUGH THE ATMOSPHERE FOR COMPLEX ALGORITHMS OF LIDAR&RADIOMETER DATA PROCESSING

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We present results on development of analytical approximate techniques to simulate polarized radiation multiple scattering in the atmosphere with underlying surface. These analytical techniques, being perfected, will be incorporated into an originating lidar&radiometer inversion algorithm to provide real time data processing.

An important line of investigations and predictions of environmental climatic and ecological changes is the distant monitoring of atmospheric aerosols. Of particular interest are the results of distant atmospheric aerosols sounding at the combined lidar and sun-radiometer stations. Currently, for processing joined lidar&radiometer data the researchers from the Institute of physics of NAS in Minsk (Belarus) and from Laboratory of atmospheric optics of Lille University 1 (France), and as well from some other scientific centers develop a new inversion program package which is distinctive in including a very complex procedure of retrieval of aerosol microphysical parameters from sun-radiometer measurements [1]. To simplify performance of the retrieval we develop fast analytical techniques for evaluating measured radiation parameters formed on multiple scattering in the atmosphere.

Solution of the vector radiation transfer equations (VRTEs) describing process of polarized radiation multiple scattering in the atmosphere is sought. The atmosphere is modeled by a plane-parallel infinitely lengthy layer of not large optical thickness illuminated at the top by an infinitely wide light beam. The Earth surface is generally bi-directional, but now only Lambertian reflectance is dealt with. Light transfer is supposed to occur due to molecular and aerosol constituents of the atmosphere. With employing approximations, namely, delta-approximation of the phase function, idea of approximate solution of "the atmospheric task"

from [2] combined with a small-angle method, we deduce analytical solutions of the VRTEs that will allow fast computation being performed in the iterative inversion procedure.

Based on the developed approach, we have obtained analytical solutions of equations of radiative transfer in the atmosphere for a number of cases of geometry and sought-for quantities. Created analytical computation algorithms have been tested by means of computed data comparisons with results of solutions by numerical methods and also with measurements by radiometer of sky radiation distributions in the almucantar taken from AERONET sites, and good agreement of data from different methods have been got.

References:

[1] O. Dubovik and M. King, "A flexible inversion algorithm for retrieval of aerosol optical properties from Sun and sky radiance measurements", J. Geophys. Res., Vol. 105(D16), P. 20673-20696, (2000).

[2] V.V. Sobolev, "Transfer of Radiant Energy in Atmospheres of Stars and Planets", Chapter 10, State Publishing House of Technical Theoretical Literature, Moscow, (1956).

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D - *LASERS IN BIOLOGY AND MEDICINE*

PD1

THE IMPACT OF MYOGLOBIN ON THE EFFICIENCY OF THE THERAPEUTIC EFFECTS OF LOW INTENSITY LASER RADIATION

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The results of development of the theoretical model of the effect of laser radiation on the gas exchange processes in biological tissues and its application in photobiology and photomedicine are presented. Laser-induced tissue oxygenation and its role in the biomedical processes are discussed. It is shown that synchronous photodissociation of blood oxyhemoglobin and muscle oxymyoglobin may provide a possible maximal level of tissue local oxygenation directly at the zone of irradiation. The criteria for the selection of the parameters of laser radiation for its effective use in phototherapy are considered.

PD2

VENOUS SATURATION AND BLOOD FLOW BEHAVIOR DURING LASER-INDUCED PHOTO-DISSOCIATION OF OXYHEMOGLOBIN

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The knowledge of relative oxyhemoglobin concentration (saturation) in arterial (SaO_2) and venous blood (SvO_2) is of considerable interest both in general diagnostic purposes and measurements of intensity of cerebral oxygen metabolism. Simultaneous measurement of these quantities provides possibility of evaluating the state of oxygen utilization in various tissues, especially in the brain.

Using own technique of non-invasive measurement of SaO_2 and SvO_2 [1-3] we continued studies of the laser-induced photodissociation of oxyhemoglobin in arterial blood. Reduction of SaO_2 by 1.5 % to 2 % during irradiation of third phalanx of a finger with 15 mW He-Ne laser was observed. At the same time the duration of cardiocycle is changed from 0.85 sec before to 0.77 sec after irradiation. Also some decrease in signal constant component was observed that can be explained by an increasing of blood flow into the irradiated field.

The study was carried out in the frame of State Agency on Science, Innovations and Informatization of Ukraine.

References:

[1] M. M. Asimov, R. M. Asimov, A. N. Rubinov, S. A. Mamilov, Yu. S. Plaksiy, "High sensitive pulseoximeter-spectrophotometer for laser optical dosimetry in biology and medicine", Proceeding of SPIE, Vol. 6251, pp. 147-154 (2006).

[2] S. S. Yesman, S.A. Mamilov, M.M. Asimov, A.I. Gisbrecht, "Noninvasive methods of measuring oxygen saturation in venous blood", Journal of Applied Spectroscopy, V.78, Number 3, pp 406-413 (2011).

[3] M. M. Asimov, R. M. Asimov, A. N. Rubinov, S A. Mamilov, S. S. Esman, Yu. S. Plaksiy, "Laser-optical method of stimulation of cell metabolism and its biomedical applications", Proceeding of SPIE, Vol. 6594, pp. 431-438 (2007).

PD3

THE EFFECT OF LASER RADIATION ON THE STABILITY OF OXYHEMOGLOBIN MOLECULS TO THE POISIONING ACTION OF CHEMICAL ECOTOXICATS

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The results of investigations the effect of laser –induced conformational changes in structure of blood hemoglobin is presented. Effect of stabilization of hemoglobin molecules to toxic action of different chemical ecotoxicants by low intensity laser radiation is observed. The mechanism of this phenomenon connected with the energy transformation of laser radiation absorbed by hem groups in blood molecules is discussed. It is shown that laser radiation changes conformational structure of hemoglobin α and β protein chains towards stable form to the toxic effect of chemical ecotoxicants. This phenomenon significantly increases the thermal and chemical stability of adult hemoglobin. Different applications of obtained experimental results in clinical practice are discussed.

PD4

IN VITRO STUDY OF CYTOTOXICITY OF SUBSTANCES, USED BY PHOTODYNAMIC THERAPY IN DENTISTRY

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More frequently observed bacterial strains, resistent to antimicrobial drugs, leads to development of new methods of antimicrobial therapy. Photodynamic therapy (PDT) with photosensitizers is an alternative method, which can destroy bacteria, fungi, viruses, protozoa.

The aim of our study was *in vitro* investigation of cytotoxicity of different photosensitizers /Zn-1, Zn-2, Ga-phthalocyanine complexes and FotoSan/ on fibroblast cell cultures.

There were used fibroblast cell lines Balb/c 3T3 (clone 31), treated as follows:
1. Group 1-Zn-1 complex + laser irradiation /λ=632 nm, t=10 min, 20 J/cm^2/
2. Group 2- Zn-2 complex + laser irradiation /λ=632 nm, t=10 min, 20 J/cm^2/
3. Group 3- Ga complex + laser irradiation /λ=632 nm, t=10 min, 20 J/cm^2/
4. Group 4 - FotoSan + laser irradiation /λ=632 nm, t=10 min, 20 J/cm^2/
5. Group 5 - Dark control
6. Group 6 - Light control

Eight different concentrations of each substance were prepared /10- 0,125 μM/. Results were reported on Balb/c 3T3 Neutral Red Uptake test (3T3 NRU test).

In our investigation was found that cytotoxicity in Group 2, 3, 4 by all used concentrations was under 50 %. In Group 5 and 6 no diversions were found. By Group 1 concentration under 1 μM showed permissible cytotoxicity /under 50%/, so they can be applied in dental practice.

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PD5

INVESTIGATION OF PHOTOTOXICITY OF LASER IRRADIATION

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Many researches demonstrate biostimulating effect of laser light on cell proliferation. The effect is dependent on absorbed light energy. Every human tissue manifests individual translucence, according to their optical characterization.

The aim of our *in vitro* study was investigation of phototoxicity of laser light with different wavelength on fibroblast cell cultures.

There were used fibroblast cell lines Balb/c 3T3 (clone 31), treated as follows:

1. Group 1- Laser irradiation / λ=632 nm, t=1 min and 3 min/
2. Group 2 - Laser irradiation / λ=1064 nm, t=1 min and 3 min/
3. Group 3 - Laser irradiation / λ= 2940 nm, t=1 min and 3 min/
4. Group 4 - Control group

All groups were divided into two subgroups:

a/ direct irradiation

b/ irradiation through dentin sections 1mm thick.

Results were reported on Balb/c 3T3 Neutral Red Uptake test (3T3 NRU test).

For investigated irradiation time no one group showed phototoxicity. There was found that laser light, with indicated wavelengths, can stimulate cell proliferation.

Acknowledgements: The National Science Fund, Bulgaria for Grants (DO - 02-177/08) is gratefully acknowleged.

PD6

COMPARATIVELY STUDY OF THE Nd:YAG LASER THERAPY AND THE PHOTODYNAMIC THERAPY WITH PHTALOCYANINES – NEW METODS FOR DESINFECTION OF ROOT CANALS

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The aim of the study was an investigation of the effect of a few new methods against microbial biofilms, grown in root canals.

The 345 extracted human single-root teeth, after cleaning from the organic material and sterilization, were infected with bacterial suspensions of representatives of Gram-positive and Gram-negative pathogens and a fungus *Candida albicans* and the samples were cultivated 48 hours to form biofilm. The biofilm formation and the effect of Nd:YAG laser and photodynamic therapy (PDT) were detected by two methods: before and after treatment from every root canal were counted the generations of microbial cells in the biofilm on the petri

dish by standart dilution method (counting CFU/ml) and some samples of the teeth were undergoing to the scanning electron microscopy before and after therapy. The teeth were divided in two groups – the first: teeth treated with Nd:YAG laser; the second: teeth treated with PAD.

The strongest antibacterial activity was shown by PDT with phthalocyanine zinc II complex (ZnPCMe) against *Enterococcus faecalis* and *Staphylococcus aureus.* The Gram-negative bacteria and *Candida albicans* were 10-000 times more resistant than the Gram-positives. The eradication of *Pseudomonas aeruginosa* in the biofilm wasn't achieved by Nd:YAG laser and PDT.

The newly used photosensitizer ZnPCMe demonstrated a powerful antimicrobial activity against the most frequent pathogens in endodontic infections and suggested that PDT could play an important role against the bacterial biofilm in the root canals.

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PD7

GALACTOPYRANOSYL CONJUGATION TO ZN(II) PHTHALOCYANINES FOR SELECTIVE PHOTODYNAMIC THERAPY

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Photodynamic therapy (PDT) is well accepted as palliative, non-invasive and local curative procedure in oncology. PDT involves application of non-toxic compound (PS), which by presumption localizes selectively in the tumor cells than in the surrounding normal cells. Upon irradiation the absorbed by the PS light initiates processes that lead to PS in a singlet excited state, which relaxes to a singlet ground state by fluorescence emission or to the low energy triplet state by intersystem crossing. Further on, energy transfer from the triplet state to the molecular oxygen or electron/proton transfer to the surrounding biomolecules results in singlet oxygen formation or other reactive oxygen species which induce tumor damage.

Galactopyranosyl conjugation to Zn(II) phthalocyanines (GalPcs) leads to essential differences in the properties of the singlet and the triplet states in comparison to the unsubstituted Zn(II) phthalocyanines. The galactopyranosyl moiety improves the dye solubility in biocompatible solvents and after addition of Cremophore EL monomerization occurres. GalPcs were evaluated with relatively low fluorescence quantum yields (0.06-0.21)

as compared to ZnPc (0.18-0.23), but with fast photooxidation of the probe-scavenger of singlet oxygen with quantum yields of 0.26 to 0.49 vs. 0.56 for ZnPc in DMF as solvent.

The subcellular localization in MDA-MB-231 breast tumor cells was observed after incubation with GalPcs and ZnPc without light exposure. Upon irradiation with red light (LED 635 nm) the low-intensity fluorescence signal of GalPcs as compared to ZnPc was recorded. A re-localization of tested phthalocyanines into cellular compartments was not observed post-irradiation. Photocytotoxicity studies in MDA-MB-231 and Balb/c 3T3 (clone 31) cell lines revealed the role of galactopyranosyl conjugation on to Zn(II) phthalocyanine for a selective PDT process.

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PD8

IN VITRO STUDY OF THE ANTIMICROBIAL EFFECT ON STR.MUTANSBACTERIA-REFERENCE STRAIN, OF LICENSED FOR CLINICAL USE PHOTOSENSITISERS AND SYNTHESISED BY US METALPHTALOTZIANINI

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In recent years photosensitisers (PS) were successfully applied in endodontics and periodontology as a powerful tool for disinfection. Good results were obtained also in teeth whitening. More importantly there is an ongoing research in the fields of dental caries prevention.

To investigate the *in vitro* antimicrobial effect (bactericidal and bacteriostatic) of licenced for clinical use photosensitisers (methylene blue, erythrosine, photosan?) and created by us 3 types of metalphtalotzianini on the reference strain Str. mutans.

Bacterial suspension at a density of 10^9 cells / ml is prepared. For the needs of Antimicrobial photodynamic therapy is used a bacterial suspension at a density of 10^6 cells / ml. An incubation mixture of 1 ml. bacterial suspension (10^6 Cl./ml.) and the corresponding PS is prepared, thus achieving a final concentration of 3S 1-6 μl. Controls are as follows: bacterial suspension in the dark; bacterial suspension with irradiation, bacterial suspension + FS in the dark. Sample: bacterial suspension + FS + irradiation. For irradiation of the mixture (bacterial suspension + FS) after incubation in the dark 15 min into 200 μl., placed in wells of microtransitional plate (96 wells) and 15 min illuminated with a diode laser with a wavelength of 600 nm. There are also cultures from controls and samples after preliminary 10-fold dilutions (10^6; 10^5; 10^4; 10^3; 10^2) in trays with medium. 6 samples and controls for each test FS after 24 h incubation at 37 º C are reported. This number is needed for statistical analysis.

Examination of the number of the colonies that have grown in Petri dishes serves to analyze the effect of the FS subject of our study. The control samples made in dark and toxicity only during and after radiation treatment with laser show a minor/weak antimicrobial effect. The samples of bacterial suspension + PS + diode laser irradiation showed, on the contrary, strong antibacterial effect on Str. Mutans with small differences in all tested PSs.

The so executed/conducted microbiological testing demonstrated that the six tested PS put under activation with a laser diode show strong antimicrobial effect in the strain of reference of Str. Mutans, with some small differences between the tested FS. Toxicity in dark use on this microorganism is to be neglected.

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PD9

STUDY OF THE PENETRATION OF IR AND VISIBLE LASER RADIATION IN HUMAN TEETH – DETERMINATION OF THE ABSORBED AND SCATTERED PARTS

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The penetration of laser radiation in human teeth is essential for estimation of the intensity and the dose of energy for the therapeutical process. The accumulation of the experimental data from the investigations, related with this problem, is of scientific and especially, of direct practical interest [1, 2]. We have developed a specialized laser and thermo-electronic experimental set up to study the diffusing penetration of the laser beam and to obtain (using the experimental data) separately the coefficient of the absorption and the coefficient of the scattering of the laser. We create the prism-selected flashlamp pumped Nd:YAG laser that emits tunable at the series of lines (1.06, 1.32, 1.34, 1.36, 1.44 μm) and also simultaneously in two chosen line of this sequence of lines. We use also high-power He-Ne laser (~70 mW). The cases of the penetration in pure dental tissue and in the complex of the both are investigated. We have used a cube formed, with sequence of thickness and well defined teeth's samples, specially prepared by the dental medicine specialists. Our measurements permit to obtain and we present the series of systematized date about: 1) the spatial distribution of the intensity in the cross-section of the penetrated light intensity schematically, the principle of this type of measurement is illustrated on Fig.1 and Fig.2 (practical realization, He-Ne laser).The principle of the technique used is the following:

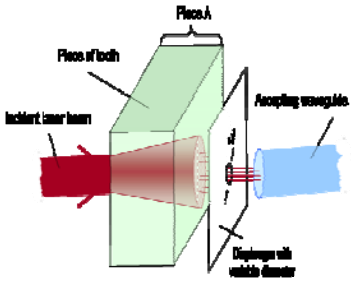

Fig.1 Schematic - with the changeable diaphragms

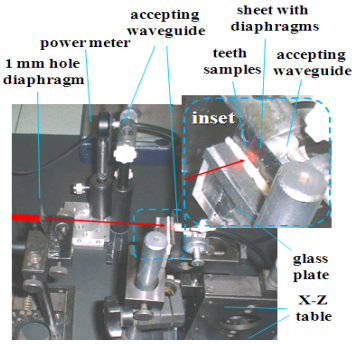

Fig.2 Variant of practical realization with variable diameter fibres

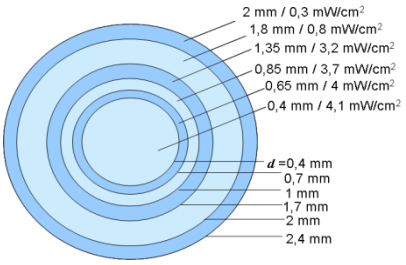

Fig.3 Illustration of the measured power density distribution

Closely to the tooth's sample, the illuminated part is screened by a black screen with the sequence of holes in line, thus forming the diaphragm with variable aperture. (0.4-2 mm) and followed by the large optical fiber. 2) As a main result: having by the measurement the illuminated and the passed laser energy, the heating of the teeth's samples and theirs thermal capacity, we have obtained separately the coefficients of the absorption and of the scattering..

References:

[1] J. J. Bosch, J. R. Zijp, "Optical properties of dentin in Dentine and Dentine Reactions in the Oral cavity" eds. ILR Press, Oxford, 59-65, (1987).

[2] P. Uzunova, Tz. Uzunov, S. Rabadgiiska, N.Kaimakanova, M.Nenchev, "Analysis of the penetration of the laser radiation in dental tissue", J. of Tech. Univ.-Sofia, Plovdiv, Vol. 16, 297- 301, (2011) and the literature cited therein.

PD 10

SURFACE MODIFICATION OF COLLAGEN-BASED BIOMATERIAL INDUCED BY PULSE WIDTH VARIABLE FEMTOSECOND LASER PULSES.

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The ability to produce idealized cellular constructs is essential for understanding and controlling intercellular processes and ultimately for producing engineered tissue replacements. Preliminary results have been obtained on collagen modification by irradiation with single and multiple pulses of femtosecond laser with variable pulse durations. Irradiation of collagen thin film by single pulses of femtosecond duration results in creation of foam layer with micrometer thickness. The structure and thickness of the layer strongly depends on the number of the applied laser pulses. The surface properties of collagen thin films before and after Ti-sapphire irradiation with 800 nm were investigated by means of the technique Field

Emission Scanning Electron Microscope (FESEM). Based on the FESEM results, it was possible to identify an energy density range as the ablation threshold for collagen thin films. The laser-induced foam formation was characterized over the intensity range 3 – $4.2x10^{11}$ W/cm^2. The results of the field emission scanning electron microscopy, showed that by tailoring the laser pulse duration, was improved the uniformity of the pore network. Examination of the interaction of ultra-short laser pulses with collagen films is useful for controlling the chemical and microstructural modification of the created foam layer.

References:

[1] S. Lazare, V. Tokarev, A. Sionkowska, M. Wisniewski, "The Influence of KrF Excimer Laser Irradiation on the Surface of Collagen and Collagen/PVP Films" Appl. Phys. A81, 465-470, (2005).

[2] A. Vogel, J. Noack, G. Hüttmann, G. Paltauf, "Mechanisms of femtosecond laser nanoprocessing of biological cells and tissues." Journal of Physics 59, 249–254, (2007).

[3] S. H. Chung, E. Mazur, "Femtosecond laser ablation of neurons in *C.elegans* for behavioral studies"Appl Phys A 96, 335–341, (2009).

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PD11

OPTICAL FORCE MEASUREMENTS AND ATOMIC FORCE MICROSCOPY OF STAINED LIPOSOMES

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Liposomes are the most attractive nanoparticles as drug carriers in nanomedicine and pharmaceutical technology. They are spherical lipid structures composed of one or more lipid bilayers which enclose aqueous spaces. Their properties depend on their lipid composition, size and the preparation method, which affect their physical behaviour and consequently their effectiveness. Novel biophotonic techniques for manipulation and characterization of drug delivery nanosystems in cancer therapy have been developed; among them are optical tweezers and Atomic Force Microscopy (AFM).

In our work, Egg-yolk phosphaditycholine liposomes loaded with Methylene blue (MB) were studied for optical manipulation. Methylene blue stands as an interesting potential photosensitizer, candidate for improving the efficacy of photodynamic therapy (PDT) as it can be located in the aqueous compartments of neutral or positively charged liposomes. The optical forces exerted on liposomes were measured experimentally by dielectrophoretic method. Dielectrophoretic forces were used to calibrate our optical trap system and to observe liposomes behaviour, considering that the optical trap force depends essentially on the liposome composition and the membrane refractive index. Atomic Force Microscopy was

used to provide information regarding the morphology, size distribution and liposome elasticity or rigidity.

References:

[1] A. S. L. Derycke, P.A.M. de Witte, "Liposomes for photodynamic therapy" Adv. Drug. Del. Rev. 56, 17–30, (2004).

[2] E. Papagiakoumou, D. Pietreanu, M. I. Makropoulou, E. Kovacs, A.A. Serafetinides, "Evaluation of trapping efficiency of optical tweezers by dielectrophoresis" J. Biomed. Opt. 11, 014035–014042, (2006).

[3] E. Spyratou, E. A. Mourelatou, M. Makropoulou, C. Demetzos, "Atomic Force Microscopy (AFM): A tool to study the structure, dynamics and stability of liposomal drug delivery systems", Expert Opinion on Drug Delivery, 6, 305-17, (2009).

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PD12

NEAR INFRARED OPTICAL TWEEZERS AND NANOSECOND LASER ABLASTION ON YEAST AND ALGAE CELLS

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In recent years, biophotonic applications of lasers in optical trapping and manipulation of microparticles or cells and sub cellular structures have gained remarkable interest in biomedical research and nanomedicine. The combination of optical trapping with laser micro-ablation opens new areas in micro- and nano-surgery. It is generally accepted that laser ablation, based on photochemical or photothermal processes, requires efficient absorption of light by the biological molecules or by the intrinsic water molecules. In addition, the absorption of ultraviolet light by biomolecules can lead to photochemical bond breakage, or heating. Although the principles and the mechanisms of pulsed laser ablation have been well described for macroscopic interventions, the microbeam operation under microscope guidance necessitates further investigation.

In this work, we present the research and development efforts towards a pulsed ultraviolet microbeam laser system (at λ=337 nm), the design and realization efforts towards an infrared laser trapping system (a cw Nd:YAG laser at λ=1064 nm) and the results obtained on yeast cells and algae by the combined set-up. The choice of these two cellular samples is imposed by the following reasons: a) the yeast cells have been long time considered as invaluable experimental organisms due to their simplicity of genetic manipulation and dissection molecular mechanisms, b) the small filamentous brown algae are present on all coasts of temperate climate zones and it is one of the rare brown algae which is resistant to copper. We investigated the optical dissection of the cell versus the presence of optical trap forces and the presence of rhodamine dye, a well known photosensitizer. We observed that as the power of the laser optical trap increased the ablation threshold decreased. Although the wavelength of

1.06 μm is generally used for optical trapping, because biological samples are transparent for wavelengths near 1.0 μm, ensuring the lowest rate of absorption and minimimal changes in the sample, one should be careful during the sample exposure to the laser trapping power, to avoid heating of the cell. We estimated the minimum energy of the microbeam for optical dissection of yeast cell under the influence of optical trapping forces as lower as 3 μJ, while in the presence of rhodamine as lower as 2 μJ, due to singlet oxygen production. Although the chosen concentration of rhodamine did not affect the viability of cells, the combination with the microbeam reduced the ablation threshold. We characterized the laser ablation of the cell walls and the resulting cavitation as a result of plasma formation *via* a cascade ionization process, which creates shock waves due to their occurrence only in nanosecond pulse mode irradiation. Lastly, using the techniques of optical microsurgery without influence of optical forces, we demonstrated that the minimum energy value for sub cellular dissection on an algae cell is ten-times higher. It is important to note that in the sub-cellular structure of algae there is an empty place into the cell, a "vacuole" between the organelles. The existence of this empty place is favor to create shock waves which affect the ablation threshold. We calculated that, for pulse energy of 27 μJ, the pressure per unit mass is equal to 250 GPa/mass and this value is sufficient to introduce shock waves into cytoplasm.

References:

[1] Greulich KO, Pilarczyk G, Hoffmann A, Meyer Zu Hörste G, Schäfer B, Uhl V, Monajembashi S., "Micromanipulation by laser microbeam and optical tweezers: from plant cells to single molecules", Microscopy 198, 182-187 (2000).

[2] Kotsifaki, D., Makropoulou M., and Serafetinides, A.A., "Ultra-violet laser microbeam and optical trapping for cell micromanipulation", Proc. SPIE, 6535, DOI: 10.1117/12.741079 (2007).

PD13

UV LASER ABLATION PATTERNS IN INTRAOCULAR LENSES

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In modern intraocular lens (IOL) fabrication, new diffractive multifocal lenses have been developed providing good distant and near vision. Currently available intraocular lenses are manufactured from silicone and acrylic, both rigid (e.g. PMMA) and foldable (hydrophobic or hydrophilic acrylic biomaterials), behaving different mechanical and optical properties. In an attempt to design new diffractive–refractive multifocals, the use of laser technology for IOL customization is proposed. Apodized patterns could be created by using a UV solid state laser for ablation of circular diffractive step heights from the centre to the periphery of IOLs. The aim of this work is to investigate the effect of UV laser radiation on intraocular lens polymer surfaces as an alternative method to conventional surface shaping techniques for IOLs customization. Laser ablation experiments were performed on commercially available hydrophobic and hydrophilic acrylic IOLs with different UV laser radiation parameters. The

laser source was the 5th harmonic of a Q-switched Nd:YAG laser (λ=213 nm) and the IOLs were placed perpendicular to the incident laser beam. Circular arrays of holes were drilled on the polymer surface, covering the centre and the peripheries of the IOL. The morphology of the ablated IOL surface was examined first with a conventional optical microscope (Leitz GMBH Wetzlar) and finally with a scanning electron microscope (SEM, Fei - Innova Nanoscope) at various numbers of laser pulses, different focal length and laser fluencies. Quantitative measurements of ablation rates were performed with a contact profilometer (Dektak-150), in which a mechanical stylus scanned across the surface of gold-coated IOLs (after SEM imaging) to measure variations in surface height. The laser induced surface modification and the ablation rates between hydrophobic and hydrophilic IOLs are discussed. Laser interaction with IOLs depends on optical and mechanical material properties, in addition to laser radiation parameters. The exact ablation mechanism is still under discussion. Some polymer materials, depending on their properties, are more susceptible to the photothermal mechanism than the photochemical one or *vice versa*. In summary, every IOL polymer exhibits specific attributes in its interaction with the 5rd harmonic of Nd:YAG laser.

References:

[1] Spyratou E., Asproudis I., Tsoutsi D., Bacharis K., Moutsouris K., Makropoulou M., Serafetinides A.A., "UV laser ablation of intraocular lenses: SEM and AFM microscopy examination of the biomaterial surface", Applied Surface Science, Vol. 256, p. 2539 - 2545, doi:10.1016/j.apsusc.2009.10.101, (2010).

[2]. Spyratou E., Makropoulou M. and Serafetinides A.A., "Study of visible and mid-infrared laser ablation mechanism of PMMA and intraocular lenses: experimental and theoretical results", Lasers in Medical Sciences, 23, p. 179-188, DOI 10.1007/s10103-007-0468-4, (2008).

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PD14

EVALUATION OF FAST AND ULTRA FAST LASER BEAM INTERACTION WITH OLD CORRODED COINS

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This work presents experimental results of the fast and ultra fast laser beam interaction with old corroded coins and diagnostically investigates the best laser cleaning conditions for the

specific samples examined. These samples are old corroded coins of the 19th-20th century of very well known metal composition.

Besides the established use of lasers, emitting pulses of fast - nanosecond duration, for laser cleaning applications of corroded metals [1], ultra fast – picosecond and femtosecond lasers present an interesting possibility for demanding conservation cases [2,3]. For example, previous use of femtosecond lasers in ablation processes exhibited extremely high spatial resolution, minimum thermal damage and reduced photochemical effects [4]. Recently experiments comparing laser ablation of silver plated coins by femtosecond and nanosecond pulses have been performed and reported [5]. Our comparative experiments with ns, ps and fs beams confirmed the established capabilities of the fast ns pulses and the potential of the ultra fast ps and fs pulses, in coins cleaning and indicated further experimental efforts and diagnostic evaluation before one can draw definite conclusions on the comparison between the ultra fast (ps, fs) or fast (ns) pulse superiority.

The main aim of this work was the detailed investigation, via controlled ablation, of the ns, ps and fs pulse duration cleaning of the corrosion layer, found in old corroded coins. This was achieved with: i) a Nd:YAG-5w laser at 213 nm (pulse duration 6ns, repetition rate 1 Hz) and a Nd:YAG-w laser at 1064 nm (pulse duration 6ns, repetition rate 1 Hz), ii) a Nd:YAG-4w at 266 nm (pulse duration 155 ps, repetition rate 10 Hz) and iii) a Ti: Sapphire laser at 785 nm (pulse duration 150 fs, repetition rate 1 kHz). The cleaning results on the corrosion areas were characterized by high resolution optical microscopy, by SEM-EDX and by XRD. *Via* these techniques, the effect of the laser fluence and of the number of pulses, on the removal efficiency of the various corrosion products, was obtained. The details of this systematic experimental investigation and of the evaluation results will be presented.

References:

[1] E. Drakaki, A. G. Karydas, B. Klinkenberg, M.Kokkoris, A.A. Serafetinides, E. Stavrou, R. Vlastou and Ch. Zarkadas, Appl. Phys. A 79, 1111–1115, (2004).

[2] T. Burmester, M. Meier, H. Haferkamp, S. Barcikowski, J. Bunte, and A. Ostendorf, Proceedings of the International Conference LACONA V Lasers in the Conservation of Artworks-Springer Proceedings in Physics, 100, 61–69, Germany (2005).

[3] Pouli, P, Bounos, I, Georgiou, S, Fotakis, C & Doulgeridis, M, 6th International Congress on Lasers in Conservation of Artworks, Book of Abstracts, Academy of Fine Arts, Vienna, pp.67, 2005.

[4] A.A. Serafetinides, Proc. SPIE 3571, 61-71, Tenth International School on Quantum Electronics: Laser Physics and Applications, (1999).

[5] Serafetinides AA, Drakaki E, Fabrikesi E, M. Kandyla, I. Zergioti, C. Vlachou-Mogire, Thomson RR, Kar AK, Boukos N, Karydas AG, Proc. SPIE, 7391:73910P, (2009).

PD15

LIGHT-INDUCED AUTOFLUORESCENCE AND DIFFUSE REFLECTANCE SPECTROSCOPY OF CUTANEOUS TUMORS – CLINICAL STUDY

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Optical spectral modalities applied in recent clinical trials for early diagnosis of skin pathologies allow broadening of possibilities for development of cutaneous malignancies precise non-invasive detection technique. Light-induced autofluorescence spectroscopy (LIAFS) is a very attractive tool for early diagnosis of cancer due to its high sensitivity, easy-to-use methodology for measurements, lack of need for contrast agents' application on the tissue under investigation, possibilities for real time measurements and noninvasive tumor detection [1,2]. It allows differentiation on the base of differences in biochemical content and metabolic state of the pathology. However, when the lesion is highly pigmented the obtained fluorescence signal is too weak to be used for diagnostics [3]. Diffuse reflectance spectroscopy is applied for the melanin-pigmented cutaneous pathologies, including malignant melanoma, as well combination of two spectral techniques allow increasing of the diagnostic accuracy in general for all pathologies investigated.

Our investigation is a part of a clinical trial for introduction of optical biopsy spectral diagnostic system for skin cancer detection. We apply autofluorescence and diffuse reflectance spectroscopy to several different classes of malignant non-melanoma cutaneous lesions. Initially, patients were classified visually and dermatoscopically using ABCD criteria by experienced dermatologist (E.P. and/or P.T.). Second step was detection of their lesion' and surrounding normal skin autofluorescence using different excitation wavelengths, namely 365, 385, and 405 nm. Reflectance spectroscopy is applied in broad spectral region – from 400 to 900 nm. In the end for every lesion histological examination is used as a "gold standard" for all our investigations.

The spectra and dermatoscopic evaluations were obtained from more than 350 patients up to now. Spectral properties of variety of benign cutaneous lesions are also evaluated for development of more precise discrimination algorithms for diagnosis of cancer lesions. Spectra from normal skin are used for comparison and evaluation of alterations occurred in lesions investigated. Results of these spectroscopic investigations will be presented in our poster report.

References:

[1] S. Svanberg, "Environmental and medical applications of photonic interactions", Physica Scripta Vol. T110, 39-5, 1 (2004).

[2] J. Bigio, J.R. Mourant, "Ultraviolet and visible spectroscopy for tissue diagnostics: fluorescence spectroscopy and elastic-scattering spectroscopy", Phys. Med. Biol. Vol. 42, 803-812, (1997).

[3] L. Bachmann, D.Zezell, A.da Costa Ribeiro, L.Gomes, A.Ito, "Fluorescence spectroscopy of biological tissues – a review", Appl. Spectr. Rev. Vol. 41, 575-593, (2006).

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PD16

LASER-INDUCED BREAKDOWN SPECTROSCOPY OF CARIES

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One of the most exciting potential growth areas for lasers in dentistry is diagnostics. Recently optical approaches (such as laser – or light-induced fluorescence spectroscopy (LIFS), Fourier-transform infrared reflectance spectroscopy (FTIR), laser-induced break-down spectroscopy (LIBS), diffuse–reflectance spectroscopy (DRS)) to enhance the early detection of dental decay have become a "hot" topic [1,2]. In fact carious decay usually develops as a tiny area of demineralization on the enamel, which could be detected by element analytic techniques such as LIBS. That demineralization can quickly turn into a large lesion inside the tooth, it is often discovered too late to prevent the kind of decay that leads to cavities. The same optical detection approaches could be used for monitoring of the caries removal using laser ablation or drilling techniques [3].

Therefore, the major line of our investigations is related to the development of a methodology for real-time optical feedback control during selective ablation of tooth tissues using LIBS. Tooth structures with and without pathological changes are investigated in vitro and their element analysis is compared to differentiate major changes, which occur during tooth carious process and growth. This would permit the dentist to follow normal drilling procedures while obtaining automatic, real-time information about the composition of the sample area and the status of ablation. The first comments about experimental combination of spectral detection of tooth lesions and following laser ablation appear in a form of scientific investigation [2].

Additional to the major aimed results, related to development of smart feedback spectral system during dental treatment of carious lesions, our investigations could be useful for the development of alternative to existing on the market devices for initial diagnosis of tooth pathologies, with possibility to differentiate initial demineralization from pre-carious conditions, different pre-carious and carious stages of the lesions, and to differentiate these major disorders from other tooth pathologies, such as odontolithiasis, fluorosis, etc. in measurement mode, working in real time. We expect that this system could have improved sensitivity and specificity parameters for tooth lesion type determination.

References:

[1] D. Fried, "Optical Methods for caries detection, diagnosis and therapeutic intervention", in Biomedical Photonics Handbook, editor Tuan Vo-Dinh, CRC Press (2003).

[2] F. Krause, A. Braun, G. Lotz, S. Kneist, S. Jepsen, J. Eberhard, "Evaluation of selective caries removal in deciduous teeth by a fluorescence feedback-controlled Er:YAG laser in vivo", Clin. Oral Invest., Vol. 12, 209–215, (2008).

[3] E. Surmenko, V. Tuchin, T. Sokolova, A. Kishen, "Spectroscopic research of processes of demineralization and remineralization of dental enamel", Almanac of clinical medicine, Vol. 12. pp.39, (2006).

Acknowledgements: This work was supported by the National Science Fund of Bulgaria of the Ministry of Education, Youth and Science under grant DO-02-112/08 "National Center on Biomedical Photonics" and under grant BIn-14/07 "Inactivation of pathogenic bacteria in periodontal diseases – fluorescence diagnostics and photodynamic therapy".

PD17

ENDOGENOUS AND EXOGENOUS FLUORESCENCE OF GASTROINTESTINAL TUMORS – INITIAL CLINICAL OBSERVATIONS

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The limitations of standard endoscopy for detection and evaluation of cancerous changes in gastrointestinal tract (GIT) are significant challenge and initiate development of new diagnostic modalities. Therefore many spectral and optical techniques are applied recently into the clinical practice for obtaining qualitatively and quantitatively new data from gastrointestinal neoplasia with different level of clinical applicability and diagnostic success. One of the most promising approaches is fluorescence detection using naturally existing fluorescent molecules or added fluorescent markers. In this report we will discuss clinical applicability of both these diagnostic spectral modalities for GIT cancer detection.

Investigations presented are a part of our initial clinical experience during trial procedure for introduction of spectroscopic diagnostic system for gastrointestinal tumors in the clinical practice of University Hospital "Queen Giovanna - ISUL". For fluorescence measurements of gastrointestinal pathologies excitation sources at 405 and 530 nm are applied. Optical fiber probe, consisting of 6 emitting fibers and one collecting fiber, is applied through instrumental channel of the endoscope for detection of tumors *in vivo*. When *in vitro* samples are investigated similar 7-fibers probe is applied on the samples excised during surgical procedures for tumors' removal. For all pathologies investigated using exogenous fluorescent detection, as a fluorescent marker is used Protoporphyrin IX. Initially 5-ALA is applied orally – as a water solution (20 mg/kg dose) for the gastrointestinal lesions. After 6 hours exogenous fluorescence detection of accumulated in the pathologies protoporphyrin IX was carried out.

Both kinds of spectra – autofluorescence signals and protoporphyrin IX signal are recorded and stored using a fiber-optic microspectrometer (USB4000, Ocean Optics, Dunedin, FL, USA). A personal computer is used to control the system and to store and display the data using the specialized microspectrometer software OOI Base ("Ocean Optics", Inc., Dunedin, FL, USA). Normal tissue fluorescence was used in both localizations as a basis for comparison with the pathologies observed.

In the case of esophageal and stomach tumors the autofluorescence spectra of the lesion area are not significantly different by shape and intensity from the surrounding normal mucosa. Some additional absorption of hemoglobin is observed in lesion' areas, but false-positive results in this case are observed when inflammatory tissues have place as well.

Autofluorescence results gives high sensitivity (>90%), but extremely low specificity (~55-60%), which is not acceptable for a technique, which must improve the diagnostic accuracy of initial tumor detection and evaluation of tumor borders and spreading lesions in the mucosa investigated. These drawbacks are overloaded when exogenous fluorophore 5-ALA/PpIX is applied. Sensitivity and specificity observed for both localizations – esophageal and stomach carcinoma lesions exceed 90%, which make the exogenous fluorescence diagnosis of gastrointestinal tumors and useful tool for clinical practice.

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E - *LASER SYSTEMS AND NONLINEAR OPTICS*

PE1

THREE-PHOTON ABSORPTION MEASUREMENT OF BAC-M AN EFFICIENT REAGENT FOR THREE-PHOTON INDUCED PHOTOGRAFTING

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Arylazide derivatives have been widely used for surface modification via photografting. In this contribution we explain how the order of nonlinear absorption in BAC-M was determined and then the 3PA cross section for this compound has been investigated applying the open aperture (OA) Z-scan technique.

We employed an ultrashort laser system producing 25 fs pulses at a repetition rate of 1 kHz with the wavelength centred at 798 nm [1]. Fig. 1(a) shows the Z-scan experimental data and two different fit curves assuming two-photon absorption (2PA) (solid violet line) and 3PA (solid red line). Comparing these two fit curves reveals the predominance of 3PA in BAC-M.

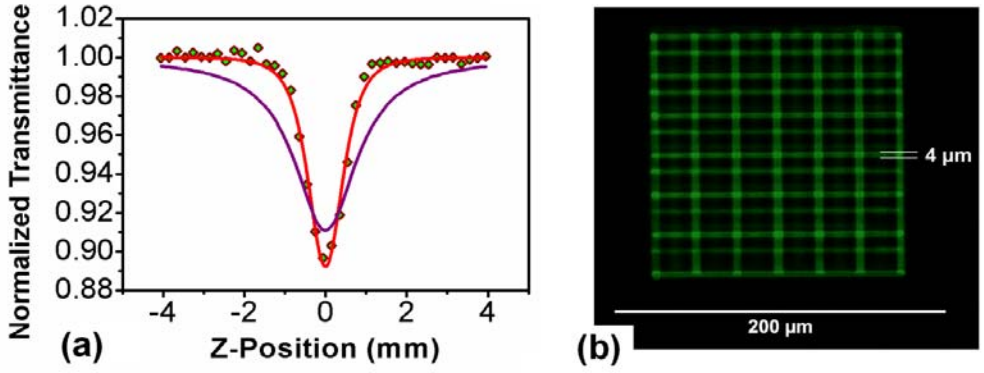

Fig.1. (a) Z-scan of a 0.2 mm thick cell filled with BAC-M, (b) A 150µm large woodpile pattern indicating a resolution of around 4µm.

The 3PA cross section σ_3 was obtained 4.8×10^{-78} ($cm^6.S^2$). In the next step we tested the efficiency of BAC-M molecule for photografting. Fig. 1(b) shows a 150µm large woodpile pattern realized with photografting of BAC-M via 3PA.

References:

[1] A. Ajami, W. Husinsky, R. Liska, and N. Pucher, "Two-photon absorption cross section measurements of various two-photon initiators for ultrashort laser radiation applying

the Z-scan technique," Journal of the Optical Society of America B: Optical Physics 27, 2290-2297, (2010).

PE2

DEVELOPMENT OF APPROACH FOR COMPETITIONLESS GENERATION OF A CHOSEN PAIR OF TWO LINES OR TWO CHOSEN MODES IN FLASH-LAMP PUMPED AND DIODE PUMPED SOLID-STATE LASERS

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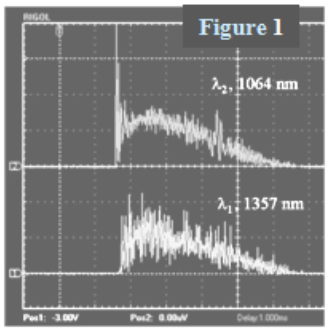
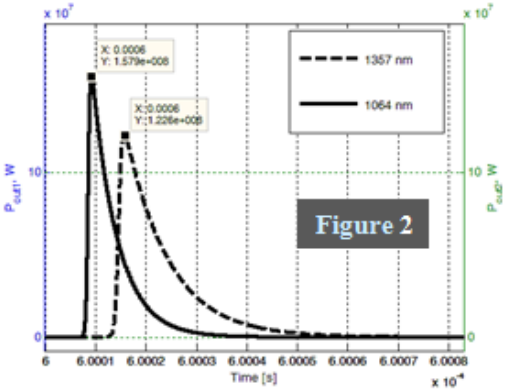
On the base of our previous experience [1-3], we have developed an original technique on the example of single Nd:YAG laser crystal to obtain a simultaneous or in controlled sequence generation at two chosen lasing lines (pair-combination of two lines from the possible generating lines - 1.06 μm, 1.32 μm, 1.34 μm,1.36 μm and 1,44. μm; after frequency doubling – green and red colors combination) and without limiting process of the wave-competition. The laser can operate also at two chosen modes, with equal frequencies and different frequency distance that the standard for a single cavity lasers (c/2L). Our solution is based on the use of generations in two separate parts of the single Nd:YAG crystal with single flash-lamp or diode pumping arrangement (more efficiency at two closely disposed parts). The generation is in two closely disposed prism selected-tuning resonators (for the single-mode case with introduced glass-lame Fabry-Perot interferometers).

The operation of this laser was developed both theoretically and with practical realization, both in free lasing and in Q-switched regime. To generate at any desired pair of the given up lines we employ a single prism-shock frustrated total reflection or opto-mechanical Q-switches. For the theoretical study we have adapted the rate differential equations system to obtain the optimum conditions for desired operation. Typical experimentally obtained simultaneous generation at the 1.06 μm and 1.38 μm in free running regime is given in Figure 1. In Figure 2 are plotted the theoretically obtained curves for simultaneous Q-switching operation at this two wavelengths.





The advantages in comparison with system of two separated and coupled Nd:YAG lasers are: i) simplicity of the developed laser devices ii) essentially low prices and iii) high efficiency due to the pumping of single active volume with the given energy.

Such lines-tunable and two-wavelength laser devices is of interest for scientific applications, for metrology, for wavelength testing and study of non-linear effects in optical fiber.

References:

[1] M. Deneva, E.Stoykova, M.Nenchev,R.Barbe, J.C.Keller, "Diode laser emission, spectrally fixed at atomic absorption line" Optics&Laser Technology,Vol.42, 301-307, (2010).

[2] Y. Louyer, J.-P. Wallerand, M. Himbert, M. Deneva, M. Nenchev, "Two-wavelength passive self injection controlled operation of a diode pumped cw Yb:doped crystal lasers", Appl. Optics, Vol. 42, № 27, 5463-5476, (2003)**.**

[3] M. Gorris-Neveux, M. Nenchev, R. Barbe, J-.Keller, "A two-wavelength, passively self-injection locked, CW Ti:Al_2O_3 laser", IEEE J. Quant.Electron., Vol.31(7), 1253-1260, (1995).

PE3

EXPERIMENTAL VERIFICATION OF FOCUSABILITY OF COHERENT ANNULAR LASER BEAMS

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Experiments are carried out to verify issues of a two-dimensional Fast Fourier Transform simulation of coherent pure (dark) annular beams by focusing a full-coherency copper vapor laser beam which is being diffracted beforehand on an annular aperture. The beam pattern at focal plane (aka far-field pattern) is a central peak and concentrical rings around it. In the course of simulation we calculate the fraction of the central peak power to the whole power of beam that gives a notion of power spread within the focal spot. This fraction is a function of beam annularity i.e. 'inside diameter /outside diameter' ratio. The experimentally-measured dependence of the central peak power to the whole power of beam versus the annularity of pure annular laser beams was the major target of the report. That dependence was necessary to verify the issues of a two-dimensional Fast Fourier Transform simulation of coherent pure (dark, zero-intensity core) annular flat beams done before [1-3].

We found that from the five experimental points (in reality, five different annular slits) four of them are within 16% error as to the simulated dependence which is tolerable in such a measurement. Further improvement of simulation is envisaged to reduce that discrepancy.

References:

[1] D. N. Astadjov, "Fourier Transform of Annular Beams", http://arxiv.org/ftp/arxiv/papers/0904/0904.1911.pdf, (2009).

[2] D. N. Astadjov, "Energy Focusability of Annular Beams", AIP Conf. Proc., Vol. 1203, 472-476, (2010).

[3] D N Astadjov and S V Nakhe, "CuBr laser beam transformations", Journal of Physics: Conference Series**,** Vol. 253, 012076 (2010), doi:10.1088/1742-6596/253/1/012076

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PE4

SPATIAL COHERENCE OF LOW-COST λ532NM GREEN LASERS

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We report for first time, to our best knowledge, experimental results of the degree of spatial coherence of a λ532 nm laser source (of a DPSS type - frequency doubled Nd: YVO4 laser). The tested device was a low-cost (< 30 €) λ532 nm (30 mW) laser [1] and its spatial coherence was measured by reversal shear interferometers [2,3] developed in our laboratories not so long ago. The degree of a full-sized non-apertured laser beam turned out to be quite high *viz.* up to 0.6 which is comparable with the degree of spatial coherence of λ=510 nm copper lasers we had measured repeatedly last decade [3,4].

Although such pointer-style green lasers as low-end laser sources are no good for operations requiring high precision and reliability, they can be a useful low-cost tool for preliminary examinations in some areas of research.

References:

[1] http://www.skylaser.cn

[2] O. Prakash, R. Mahakud, H. S Vora and S. K. Dixit, "Cylindrical-lens based wavefront-reversing shear interferometer for the spatial coherence measurement of UV radiations", Opt. Eng., Vol.45, No.5, 055601-1-6, (2006).

[3] D. N. Astadjov, L. I. Stoychev and N. V. Sabotinov, "Improvement of CuBr Laser Coherence Properties", Proc. SPIE, Vol. 6252, 625229-1-5, (2006).

[4] O. Prakash, P. K. Shukla, S. K. Dixit, S. Chatterjee, H. S. Vora and R. Bhatnagar "Spatial coherence of generalised diffraction filtered resonator copper vapour laser, Appl. Opt.,Vol. 37**,** 7752, (1998).

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PE5

A SYSTEM FOR GENERATION OF COHERENT HIGH – ORDER HARMONIC LIGHT AT VACUUM ULTRAVIOLET WAVELENGTHS

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A compact femtosecond laser system for high-order harmonic generation is developed. Intense ultrashort-pulse pump light generated by a kilohertz Ti:sapphire laser amplifier system (3 mJ, 45 fs, 800 nm) is focused in a thin 150 -m inner-diameter hollow waveguide filled with noble gas argon. Gas pressure variations between 10 and 80 Torr allow obtaining of phase matching in the hollow waveguide and generation of high-order harmonic light at vacuum ultraviolet wavelengths. The whole system is maintained under vacuum to prevent generated light from strong absorption losses. Because of its laser light characteristic properties generated harmonics could be used in coherent diffractive imaging of nano-objects and for observation of dynamical processes.

References:

[1] A. Rundquist, C. G. Durfee III, Z. Chang, C. Herne, S. Backus, M. M. Murnane, H. C. Kapteyn, "Phase-matched generation of coherent soft x-rays", Science, 280, 1412-1415, (1998).

[2] C. G. Durfee III, A. Rundquist, S. Backus, C. Herne, M. M. Murnane, H. C. Kapteyn, "Phase matching of high-order harmonics in hollow waveguides", Phys. Rev. Lett., 83, 11, 2187-2190, (1999).

[3] R. A. Bartels, A. Paul, H. Green, H. C. Kapteyn, M. M. Murnane, S. Backus, I. P. Christov, Y. Liu, D. Attwood, C. Jacobsen, "Generation of spatially coherent light at extreme ultraviolet wavelengths", Science, 297, 376-378, (2002).

[4] J. Spence, "Harmonic pictures in a flash", Nature, 449, 553-554, (2007).

[5] T. Popmintchev, M-C. Chen, P. Arpin, M. M. Murnane, H. C. Kapteyn, "The attosecond nonlinear optics of bright coherent x-ray generation", Nature Photonics, 4, 822-832, (2010).

[6] H. N. Chapman, K. A. Nugent, "Coherent lensless x-ray imaging", Nature Photonics, 4, 833-839, (2010).

[7] R. L. Sandberg, A. Paul, D. A. Raymondson, S. Hadrich, D. M. Gaudiosi, J. Holtsnider, R. I. Tobey, O. Cohen, M. M. Murnane, H. C. Kapteyn, C. Song, J. Miao, Y. Liu, F. Salmassi, "Lensless diffractive imaging using tabletop coherent high-harmonic soft-x-ray beams", Phys. Rev. Lett., 99, 098103(4), (2007).

[8] R. L. Sandberg, C. Song, P. W. Wachulak, D. A. Raymondson, A. Paul, B. Amirbekian, E. Lee, A. E. Sakdinawat, C. La-O-Vorakiat, M. C. Marconi, C. S. Menoni, M. M. Murnane, J. J. Rocca, H. C. Kapteyn, J. Miao, "High numerical aperture tabletop soft xray diffraction microscopy with 70-nm resolution", PNAS, 105, 1, 24-27, (2008).

[9] J. R. Fienup, "Phase retrieval algorithms: a comparison", Appl. Opt., 21, 15, 2758-2769, (1982).

[10] V. Elser, "Phase retrieval by iterated projections", J. Opt. Soc. Am. A, 20, 1, 40-

55, (2003).

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PE6

LASER CHARACTERIZATION OF THE DEPTH PROFILE OF COMPLEX REFRACTIVE INDEX OF PMMA IMPLANTED WITH 50 KEV SILICON IONS

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Being of importance for integrated optics, optoelectronics and optical communications, the depth profile of the complex refractive index of silicon ion (Si^+) implanted polymethylmethacrylate (PMMA) is studied, in particular PMMA implanted with Si^+ ions accelerated to a relatively low energy of 50 keV and at a fluence of 3.2×10^{15} cm^{-2}. The ion-modified material in the near(sub)surface layer of a thickness of about 100 nm is optically characterized by reflection ellipsometry measurements at a wavelength of 632.8 nm (He-Ne laser). The results obtained for the in-depth distribution of the real and imaginary parts of the complex refractive index of Si^+-implanted PMMA are compared with calculations by discrete multilayer model using data from photometric reflectance measurements at different angles of incidence [1].

Related to the index depth profile of Si^+-implanted PMMA, the change in the profile of the reflected laser beam due to the strong laser-induced thermo-lensing in reflection [2,3] is analyzed upon illumination with cw Nd:YAG laser (wavelength 532 nm, optical power 20 mW). The effect can be used to characterize the laser-induced change of the refractive index of this ion-implanted plastic and, thereby is of a special interest for related applications.

References:

[1] H. Y. Stoyanov, I. L. Stefanov, G. G. Tsutsumanova, S. C. Russev, G. B. Hadjichristov, "Depth-profiled characterization of complex refractive index of ion implanted optically transparent polymers using multilayer calculations and reflectance data", Vacuum, Vol. 86, No. 12, 1822-1827, (2012).

[2] G. B. Hadjichristov, I. L Stefanov, B. I. Florian, G. D. Blaskova, V. G. Ivanov, E. Faulques, "Optical reflectivity study of silicon ion implanted poly(methyl methacrylate)", Appl. Surf. Sci., Vol. 256, No. 3, 779-786, (2009).

[3] I. L. Stefanov, V. G. Ivanov, G. B. Hadjichristov, "Laser-induced thermo-lens in ion-implanted optically-transparent polymer", Proc. SPIE Vol. 7501, eds. S. M. Saltiel, A. A. Dreischuh, I. P. Christov, art. no. 75010Q, 1-9, (2009).

Acknowledgements: This work was supported by the National Science Fund of Bulgaria, grant No. DRNF-02/8-2009.

PE7

AC CONDUCTIVITY OF THE Si-LiNbO$_3$ HETEROSTRUCTURES GROWN BY ION SPUTTERING METHOD

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Lithium niobate is a perspective material for integral electronics due to its remarkable nonlinear optical and electrooptical properties. Deep understanding different electronic phenomena is vital for successful creation various electronic devices because of its influence on switching and other process.

Dc conductivity of the (100)Si-LiNbO$_3$ heterostructures grown by ion beam sputtering method and conductivity after thermal annealing (TA) have been studied in [1]. In this work ac conductivity of the same heterostructures has been studied. Our study research demonstrates that ac conductivity of as-grown Si-LiNbO3 heterostructures at the range of temperatures from 30° C to 100° C is described by the following power law: $\sigma = A(T)\cdot\omega^s$. Here A is a frequency-independent value, $\omega=2\cdot\pi\cdot\nu$ is frequency (in our experiment $\nu = 20\div10^5$ Hz). Study of the temperature dependence of power factor s(T) pointed up that the correlated barrier-hopping (CBH) conductivity [2] is realized in the given frequency range. Fig.1 shows the experimental dependence ln(σ) versus ln(ω) and the theoretical one for as-grown Si-LiNbO$_3$ heterostructures in the framework of CBH model. Taking into account this model we have estimated concentration of traps D in the band gap of LiNbO3 and an average potential barrier height W which is overcome by electrons in the hopping process.

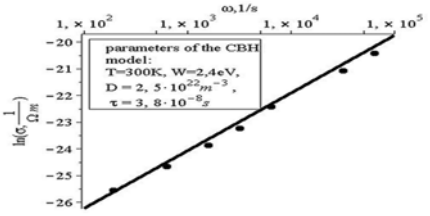

Fig.1. Ac conductivity of the Si-LiNbO3 heterostructures at T=300K (dots – experiment, line – CBH model).

As heterostructures after TA are concerned, their ac conductivity is determined by two mechanisms. First of them is resonance tunneling through charge centers in the LiNbO3 layer and the second one is hopping conductivity over the traps in the band gap of LiNbO3 layer. It

has been established that increase of temperature higher than 60°C leads to predominate of hopping conductivity in studied heterostructures in the frequency range from 500 to 10^5 Hz.

References:

[1] V. M. Ievlev, M. P. Sumets, A. V. Kostyuchenko "Effect of Thermal Annealing on Electrical Properties of Si-LiNbO3" Materials Science Forum, 700, 53-57, (2011).

[2] S. R. Elliott, Phil. Mag. "A theory of a.c. conduction in chalcogenide glasses" B 36 1291 (1977).

PE8

NONLINEAR REGIME OF PROPAGATION OF FEMTOSECOND OPTICAL PULSES IN SINGLE-MODE FIBER

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In the present work is being reviewed the evolution of one-dimensional femtosecond optical pulses with large spectral bandwidth in a single-mode fiber. The corresponding scalar nonlinear amplitude equation is used which describes the propagation of such pulses. It significantly differs from the ordinary Nonlinear Schrodinger equation. It appears that non-linear term oscillates at a frequency proportional to the difference between the group and phase velocity of the pulse. This equation includes a term containing the first order of dispersion of the group velocity and the second derivatives of the coordinate z and the time t. It is assumed that the losses in the fiber are not significant and they will not be counted. An accurate analytical solution of this equation is found. It describes the evolution of soliton-like pulses in single-mode fiber. This soliton has different characteristics from those of the soliton obtained by solving the nonlinear Schrodinger equation.

PE9

BRANCHING OPTICAL SIGNALS BY FRACTIONAL VORTEX DIPOLES

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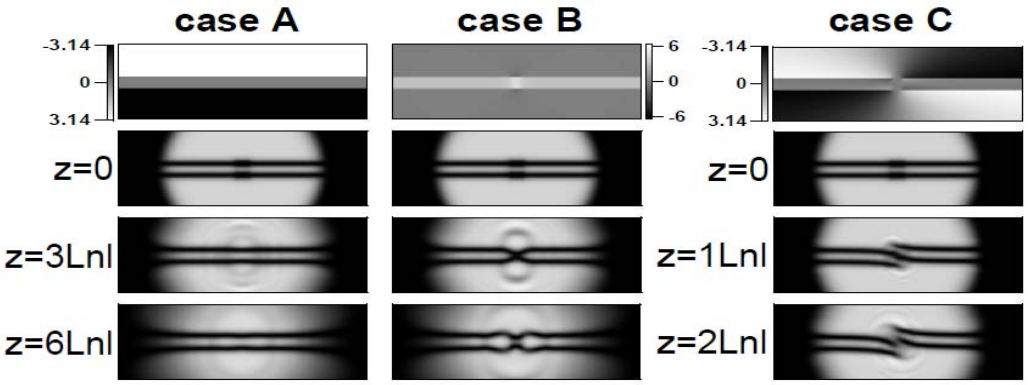
Similar to dark beams with a finite length, semi-infinite dark beams carrying phase dislocations, where step - and screw - like phase profiles are combined, tend to move in transversal direction with respect to their background beam. In addition, they develop a snake-like instability and optical vortices detach from their bending ends.

Here we numerically analyze two different nontrivial interaction schemes between ordered semi-infinite fractional vortex dipoles (FVDs) in a local self-defocusing nonlinear medium (NLM) and model the branching and routing of probe beams inside the optically- induced reconfigurable interconnects. The first interaction scenario modeled is collinear - i.e. both the dark (pump) and the bright (probe) beam propagate in parallel through the NLM. In the second scenario the probe beams propagate perpendicular to the propagation direction of the dark beams, i.e. parallel to the dark beams themselves. We simulated each interaction scheme for three possible cases:

Case A: Pair of two parallel one-dimensional dark beams with purely one-dimensional phase dislocations of magnitude π.

Case B: Pair of two inline semi-infinite FVD beams for which the overlapping FVDs have *opposite* helicities, whereas the two pairs have *opposite* phase distributions.

Case C: Pair of two inline FVD beams for which the overlapping semi - infinite FVDs have *equal* helicities, whereas the two pairs of semi-infinite FVDs have phase distributions with the *same* gradients.



We found appropriate conditions for controlling the process of crossing dark beams in a way suitable for probe-beam cross-switching. Depending on their phase profiles, four parallel semi-infinite fractional vortex dipoles aligned to initially form two dark stripes can evolve into two different cross-connects able to partially redirect collinearly- and perpendicularly-propagating probe optical beams at different branching efficiencies.

Acknowledgments: This work was supported by the NSF-Bulgaria (grants *DO*-02-0114/2008 and *DRNF*-02–8/2009), and by the DFG in the framework of Forschergruppe 532 "Nichtlineare raum-zeitliche Dynamik in dissipativen und diskreten optischen Systemen".

PE10

FOUR-WAVE FREQUENCY MIXING OF PUMP BEAMS CARRYING MULTI-CHARGED OPTICAL VORTICES: STEP TOWARDS SINGULAR OPTICAL (SUPER)CONTINUUM

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Optical vortices (OVs) are singular optical beams with a spiral phase dislocation in their wavefront. When two pump beams at the frequencies ω_1 and ω_2 interact in a Kerr-type nonlinear medium, the four-wave mixing process (FWM) results in the generation of new distinct sum and difference frequency components at the output. Importantly, the FWM is expected to preserve the topological charge of the OVs, and thus it can be employed for the generation of white-light vortices, in contrast to the vortex propagation in a Raman nonlinear medium. However, as the FWM process is accompanied by noticeable spatial nonlinear instabilities due to self- and cross-phase modulation, the phase information in the newly generated frequency components may be destroyed. Therefore, it is important to reveal the possible regimes where the FWM process will dominate nonlinear instabilities, leading to the stable generation of white-light optical vortices.

Here we expand our earlier studies and analyze numerically the process of FWM with multi-charged optical vortices involving phase-matched FWM interactions of the type $\omega_s=\omega_1+\omega_2-\omega_j$. Our model is based on a set of ten coupled nonlinear partial differential Schrödinger-type equations for the ten equally-spaced frequency components ω_j (j= 1,...,10), which take into account two-dimensional beam diffraction, FWM effect, as well as self-phase modulation and cross-phase modulation effects. At the input of the nonlinear medium, two pump beams are launched at the frequencies located in the center of the spectrum, ω_p (p = 5 and p = 6), and the resulting system of equations is solved using the beam propagation method. Particularly, when one of the pump beams carries a single charge OV and the other one is a doubly-charged OV, our numerical simulations predict generation of signal beams ω_s (s = 1..4 and s = 7..10) carrying multi-charged OVs. Examples for signal waves s=4 and s=7 generated in the first cascade of the FWM process are shown in Fig. 1. Generally, the numerical data confirm that the transformation rule for the OV topological charges follows the rule for the conversion of their frequencies.

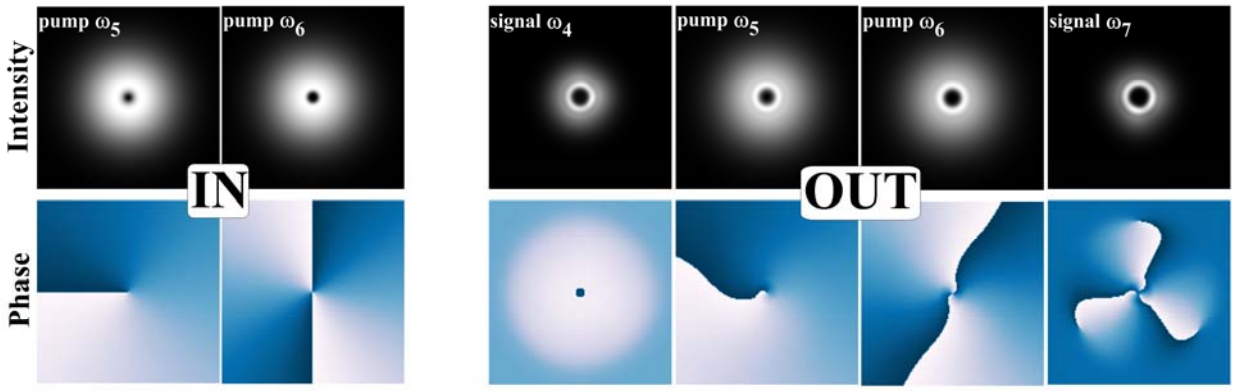

Fig. 1. Numerical results. Intensity (upper row) and phase (lower row). Left frames – pump waves at the input of the nonlinear medium (NLM). Right – pump beams and probe beams generated in the first cascade of the FWM process at the output of the NLM.

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PE11

CASCADED ULTRASHORT OPTICAL VORTEX FOUR-WAVE MIXING

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We have experimentally investigated the process of nonlinearly mixing different optical vortex beams in a Kerr medium. Due to self-phase modulation and degenerate four-wave mixing, both spectral broadening and transfer of topological charge (TC) into emerging spectral satellites takes place. Starting with a FWHM bandwidth of 43nm, vortices can be observed within >200nm after nonlinear propagation. For the first time, the TC of the generated vortex cascade is measured.

Four-wave mixing is a third order nonlinear process, where four optical fields interact in a nonlinear Kerr medium: $\omega_d = \omega_a + \omega_b - \omega_c$. If two or more fields possess the same frequency, the process is called degenerate. Energy conservation dictates the resulting photon energy when combining any three of those pump beams and leads to spectral satellites $\omega_n = \omega_0 - n\Delta\omega$. This process can continue if the intensity is still sufficiently high, leading ultimately to a frequency comb spaced at the difference frequency $\Delta\omega = \omega_0 - \omega_1$ between the input fields.

Topological charge m – as a form of angular momentum – has to obey the same conservation laws. For two pump beams with different central wavelengths and TCs m_0, m_1, the TC of the emerging spectral satellites can be calculated from the relation $m_n = m_0 - n\Delta m$ with $\Delta m = m_0 - m_1$. Fig. 1 shows this process schematically for the mixing of a Gaussian beam $m_0 = 0$ with a vortex beam $m_1 = +1$.

We have conducted experiments that use a broadband femtosecond laser pulse to generate such a nonlinear vortex beam cascade. Despite notable instabilities from energy redistribution due to self-focussing, and subsequent vortex decay, the total topological charge follows the expected law. Such a method can be used as a new source of arbitrary vortex beams, and has implications on currently proposed data transmission schemes using topological charge as information carriers.

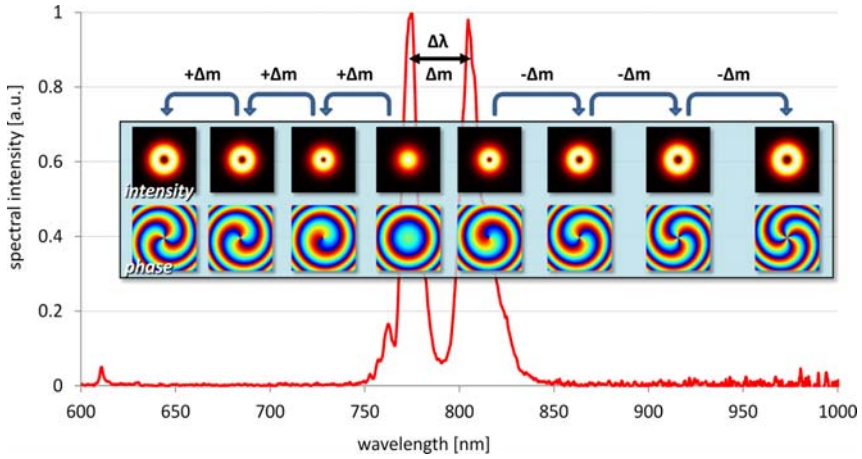

Fig. 1. Numerical results. Intensity (upper row) and phase (lower row). Left frames – pump waves at the input of the nonlinear medium (NLM). Right – pump beams and probe beams generated in the first cascade of the FWM process at the output of the NLM.

Acknowledgements: This work was supported by the NSF-Bulgaria (grants DO-02-0114/2008 and IRNI-17/2007), by the DFG in the framework of Forschergruppe 532 "Nichtlineare raum-zeitliche Dynamik in dissipativen und diskreten optischen Systemen", and by the Australian Research Council through Discovery and Linkage International projects.

PE12

COMPARATION BETWEEN TWO MODELS OF FILAMENTATION – BASIC AND IONIZATION FREE MODEL

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The basic model of filamentation is created on a generalization of the one parochial amplitude equation, which including of addition mixed (z, t) second derivative term, nonlinear Kerr term, higher order Kerr terms, nonlinear addition to the group velocity term, ionization and multi-photon absorption. Firstly, we compare the linear part of this basic model which the linear part the ionization free model and a significant difference in the spectral characteristic

is observed when a fs pulse is investigated simultaneously in both models. Dimensionless analysis, provided on the basic model point that the higher order Kerr terms, nonlinear addition to the group velocity term, ionization and multi-photon absorption are negligible for pulses with intensities of order of $10^{12}\ W/cm^2$ - a typical value for single stable filament. On the base on the comparation with the experiments on filamentation, we point, that the ionization free model more accurate presents the recent experimental results, than the basic model.

PE13

BRIGHT BEAM SELF-FOCUSING INITIATED BY SINGULAR DARK BEAMS

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Propagation of optical beams in nonlinear media (NLM) has been a subject of continuing interest for more than four decades, partially due to the possibility for creation of reconfigurable waveguides through the intensity-dependent refractive index change. Particular interest in singular dark beams (optical vortices, one-dimensional dark beams and ring dark waves) is motivated by their ability to propagate as dark spatial solitons or dark solitary waves and to induce gradient optical waveguides in bulk self-defocusing NLM. Necessary (but not sufficient) condition for this is to propagate them in a self-defocusing NLM, in which the dark beam diffraction is compensated for by the medium's nonlinearity. In contrast, the positive Kerr nonlinearity leads to (accelerated) dark beam broadening and energy density redistribution on the host background beam. As a result, self-focusing of the bright structures on the background could be intentionally and controllable initiated.

In this work we study by computer simulations the initial stage of bright background beam self-focusing initiated by the energy density redistribution due to the presence of optical vortex and/or ring dark wave. Local self-focusing Kerr nonlinear medium is considered. When a single ring dark wave is nested on the background, ring radius-to-width ratio Δ=2 (Fig. 1a) promises up to 4 times peak intensity increase at a propagation distance of 2 dark beam diffraction lengths (Fig. 1b). Δ=6 seems adequate when flat-toped super-Gaussian beam is desired (see Fig. 2a,b).

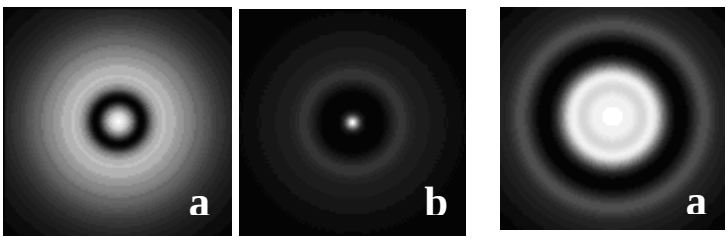

Fig. 1. Initial Gaussian background beam

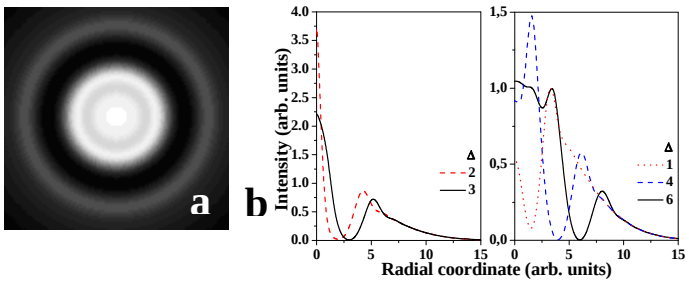

Fig. 2 (a) Nonlinear background beam reshaping into super-

with a ring dark wave nested on it **(a)** and **(b)** intentionally self-focusing peak at $z/L_{diff}=2$. Peak intensity increase equal to 4.04.

Gaussian for initial ring radius-to-width ratio $\Delta=6$. **(b)** Cross-sections of the intentionally self-focused beams by single ring dark waves with different Δ. Nonlinear propagation distance $z/L_{diff}=2$.

Self-focusing in bright rings of different radii and even in two coaxial rings (at $\Delta=3$) is observed when initially optical vortex and ring dark wave are simultaneously nested on the background. The detailed numerical analysis of the evolution of azimuthal perturbations confirmed the physical intuition that self-focusing rings of small radii suffer much less (when at all) from ring filamentation, because the spatial frequency of the perturbations on the inner rings appear higher than the critical one.

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