INTERNATIONAL CONFERENCE ON NANOPHOTONICS, METAMATERIALS AND PHOTOVOLTAICS

ICNMP-2018

ICNMP/18
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ORGANIZATION AND COMMITTEE

ORGANIZERS

Havana University, Havana, Cuba

Stoletovs Vladimir State University, Vladimir, Russia

Russian Quantum Center, Moscow, Russia

PROGRAM COMMITTEE

Professor Alexey Kavokin, CNR-SPIN, Russian Quantum Center;

Professor Carlos Trallero Giner, University of Havana;

Professor Carlos Cabal Mirabal, Medical Bio-Physics Research Center;

Professor Aldo Di Carlo, University of Rome II;

Doctor Stella Kutrovskaya, Vladimir State University and Russian Quantum Center.

CONFERENCE TOPICS

- ✓ *Nanophotonics*
- ✓ *Metamaterials*
- ✓ *New functional materials for electronics and photonics*
- ✓ *Hybrid and conventional photovoltaics*
- ✓ *Light-matter interactions in solids*
- ✓ *Nonlinear and atomic optics*
- ✓ *Quantum cryptography*
- ✓ *Quantum communications*
- ✓ *Quantum simulations*
- ✓

SPECIAL SESSIONS:

- ✓ The light-matter interactions in cold atom arrays (Chaired by Professor Georgy Shlyapnikov, Paris-Orsay University, France)
- ✓ Applications of nanophotonics and metamaterials in medicine and biology(Chaired by Professor Carlos Cabal Mirabal, Medical Biophysics Center of Santiago de Cuba)

CONFERENCE PROGRAM

27th of January – for those who are in Havana:
Dinner party at the apartment of Prof. Carlos Cabal Mirabal,
The Director of the Medical Bio-Physics Center of the Oriente University Santiago de Cuba.
Please come at 21.00 to
Calle E 21 y 23 Number 517 entre 21 y 23 apto 10C Vedado, Havana
Hometelephone: 53 7 8366846, mobile: 5 4631819

28th of January – Departure to Santiago de Cuba

20.00 Welcome Dinner at Setos de Cuba
Avenida Manduley 154, Santiago de Cuba, Cuba
+53 5 3552204

29th of January
Medical Bio-Physics Center, Santiago de Cuba
Ave. Patricio Lumumba S/N Santiago de Cuba

10.00 - 10.10 Open ceremony.

10.10 - 11.30 – Plenary talks
10.10 - 10.50 **A vision of science in Cuba. Steps and path**
Prof. Carlos Cabal-Mirabal, Medical Bio-Physics Research Center, Santiago de Cuba, Cuba
10.50 - 11.30 **Light-emitting nanoantennas**
Dr. Sergei Makarov, ITMO University, the Department ofNanophotonics and Metamaterials, Saint Petersburg, Russia

11.30 - 12.00 Coffee break

12.00 - 13.30 – Session 1
12.00 - 12.30 **Vertical and lateral GaN nanowires**
Prof. Galia Pozina, Linköping University Department of Physics, Chemistry and BiologyLinköping, Sweden
12.30 - 13.00 **Topological edge-state engineering with high-frequency electromagnetic radiation**
Dr. Ivan Iorsh, ITMO University,Laboratory of light-matter coupling in nanostructures, Saint Petersburg, Russia
13.00 - 13.30 **One-dimensional optical Tamm plasmons**
Dr. Igor Chestnov, Stoletovs Vladimir State University, Vladimir, Russia

13.30 - 15.30 Lunch break
Lunch will be served at Setos Cuba,
Avenida Manduley 154, Santiago de Cuba, Cuba
+53 5 3552204

15.30 - 16.00 – Session 2

15.30 - 16.00 **High-Q states in subwavelength dielectric resonators as a result of strong light-light interaction**

Dr. Andrey Bogdanov, ITMO University, the Department of Nanophotonics and Metamaterials, Saint Petersburg, Russia

30th of January – excursion day.
Meeting at the entrance of the Melia Santiago hotel at 9.00 a.m.
Visits to the Castillo del Morre, Museum of Pirats,
Lunch at the Creole restaurant, visit to the Grave stone of Fidel Castro,
Visit to Santiago Rum factory with rum testing.
18.00 - 20.00 Round table.

31st of January Medical Bio-Physics Center, Santiago de Cuba
Ave. Patricio Lumumba S/N Santiago de Cuba

10.10 - 11.30 – Plenary talks

10.10 - 10.50 **Disordered quantum systems with long-range hops**

Prof. Georgy Shlyapnikov, International Center for Quantum Optics & Quantum Technologies Limited Liability Company, Many-body theory group, Moscow, Russia

10.50 - 11.30 **Optical microcombs**

Prof. Mikhail Gorodetskiy, Lomonosov Moscow State University, Moscow, Russia

11.30 - 12.00 Coffee break

12.00 - 13.30 – Session 4

12.00 - 12.30 **Light and superconductivity**

Prof. Alexey Kavokin, St-Petersburg State University, Spin Optics Laboratory, Saint Petersburg, Russia

12.30 - 13.00 **Laser synthesis of long linear carbon chains for photonic applications**

Dr. Stella Kutrovskaya, Stoletovs Vladimir State University, Vladimir, Russia

13.00 - 13.30 **Industry QKD test with polarization states**

Dr. Yuri Kurochkin, International Center for Quantum Optics &Quantum Technologies Limited Liability Company, Quantum Optics group, Moscow, Russia

13.30 Lunch
Lunch will be served at Setos Cuba,
Avenida Manduley 154, Santiago de Cuba, Cuba
+53 5 3552204

then free time until the Social dinner
Social dinner at Setos Cuba (starting at 19.45)
Avenida Manduley 154, Santiago de Cuba, Cuba
+53 5 3552204

1st of February
Medical Bio-Physics Center, Santiago de Cuba
Ave. Patricio Lumumba S/N Santiago de Cuba

10.10 - 11.30 – Plenary talks
10.10 - 10.50 **Tunable and Unconventional Photovoltaics in Organic-Inorganic and Hybrid Perovskites**
Prof. Anvar Zakhidov, The University of Texas at DallasAlan G. MacDiarmid NanoTech Institute, Dallas, USA
10.50 - 11.30 **Cuban MR project. Some results and experiences**
Prof. Carlos Cabal-Mirabal, Medical Bio-Physics Research Center, Santiago de Cuba, Cuba

11.30 - 12.00 Coffee break

12.00 - 13.40 – Session 5
12.00 - 12.30 **Clustered bimetallic structures with variable optical and electronic properties**
Dr. Alexey Kucherik, Stoletovs Vladimir State University, Vladimir, Russia
12.30 - 13.00 **Zitterbewegung of exciton-polaritons**
Dr. Evgeny Sedov, University of Southampton,Physics and Astronomy School
Highfield, Southampton, UK
13.00 - 13.40 **Enhancement of magnetic resonance imaging with metamaterials: from concept to human trials**
Prof. Pavel Belov, ITMO University, the Department of Nanophotonics and Metamaterials, Saint Petersburg, Russia

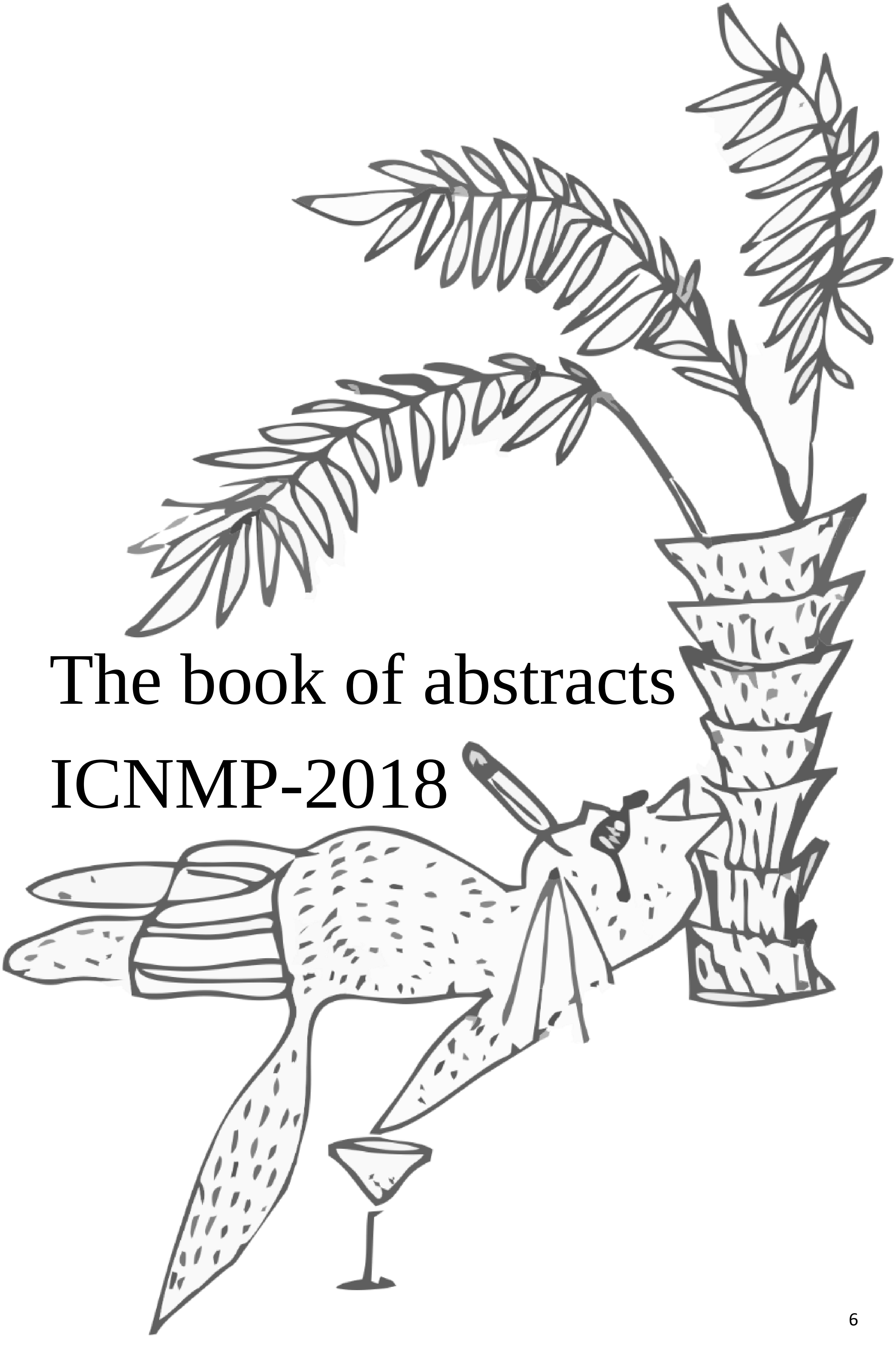
13.30 - 15.30 Lunch
Lunch will be served at Setos Cuba,
Avenida Manduley 154, Santiago de Cuba, Cuba
+53 5 3552204

15.30 - 16.30 Poster session
17.00 - 20.00 Project meeting

21.00 Meeting at the entrance of Melia Santiago hotel.
The night at La Tropicana Cabaret
Autopista Nacional, Km 1 1/2, Santiago de Cuba+53 22 642579

2nd of February
Medical Bio-Physics Center, Santiago de Cuba
Ave. Patricio Lumumba S/N Santiago de Cuba
10.00 - 12.00 - Lab tour
12.00 - Closing ceremony

The book of abstracts ICNMP-2018



1. VERTICAL AND LATERAL GAN NANOWIRES

G. Pozina

Department of Physics, Chemistry and Biology (IFM), Linköping University, S-581 83 Linköping, Sweden

Nanowires (NW) based on GaN and related III-N alloys have a huge potential for innovative semiconductor devices such as high-power high frequency field effect transistors, lasers and light emitting diodes. In recent years many advantages have been made in development of nanowires in the form of nano-pillars using vapor-liquid-solid growth mechanism, or by magnetron sputter epitaxy. Such technology allows fabrication of high quality NW exhibiting excellent electric and optical properties, even in the case of substantial mismatch of the layer parameter between NW and substrate material, and allows fabrication of III-V NWs on Si substrates [1]. Development of the technology of nanowire fabrication pave the way for the substitution of so–called “top-down” approach implying the growth of planar structures followed by etching of unwanted parts of the structures with “bottom-up” approach when the functional elements are grown in its final form. A “bottom-up” approach of fabrication of lateral GaN NWs utilizes patterning of the substrate using focused ion beam etching followed by epitaxial overgrowth technique. Although the approach is very attractive, there is a significant complicity in the production of high quality NWs associated with an enhanced growth rate in selective MOVPE. To obtain a high crystal quality lateral GaN NWs, the mechanism behind the increased growth rate has to be understood. Here, we present results of the recent studies of high crystal quality lateral GaN NWs produced by optimized MOVPE process.

[1] M. Forsberg, E.A. Serban, C.-L. Hsiao, M. Junaid, J. Birch, G. Pozina. Sci.c Reports **7**, 1170 (2017).

2. HIGH-Q STATES IN SUBWAVELENGTH DIELECTRIC RESONATORS AS A RESULT OF STRONG LIGHT-LIGHT INTERACTION

Andrey Bogdanov[1,2], Kirill Koshelev[1,3], Sergey Gladyshev[1], Zarina Sadrieva[1], Mikhail Rybin[1,2], Kirill Samusev[1,2], Mikhail Limonov[1,2], Yuri Kivshar[1,3]

[1]*Department of Nanophotonics and Metamaterials, ITMO University, St Petersburg 197101, Russia,*
[2]*Ioffe Institute, St Petersburg 194021, Russia,*
[3]*Nonlinear Physics Centre, Australian National University, Canberra ACT 2601, Australia*

The trapping of light in localized modes is extremely important for a vast variety of applications in photonics governing both transport and localization of waves [1,2]. We demonstrate a novel mechanism for achieving giant Q factors for isolated subwavelength dielectric resonators by realizing the regime of bound states in the continuum (BIC). Despite BICs are a mathematical abstraction, they can be realized in real structures in the form of quasi-BIC modes (or supercavity modes [3]) with finite but large values of the Q factor, being only limited by the resonator size, absorption, or surface roughness.

We use both scattering spectrum calculations and the eigenmode analysis to reveal the existence of avoided resonance crossings between Mie-like and Fabry-Perot-like modes of a single dielectric nanodisk which manifest themselves because of strong mode coupling in accord with the Friedrich-Wintgen mechanism. Each of avoided resonance crossings describes formation of a high-Q mode. We reveal a close relationship between the Q factor and the Fano asymmetry parameter in strong coupling regime. We analyze the avoided resonance crossing by fitting the scattering spectrum to the Fano formula and show that the Fano asymmetry parameter becomes singular at the frequency of the quasi-BIC modes. The results of fitting procedure are in excellent agreement with the eigenmode calculations.

We have predicted theoretically the existence of quasi-BICs in the simplest object – a single subwavelength dielectric nanodisk in free space without any additional tweaks. For dielectric nanodisk resonator made of silicon, we have shown that strong mode coupling can lead to the values of the Q-factor about 200. We have analyzed the effect of material losses and revealed that high values of the Q factor could be achievable in experiment. Our findings make evident the counterintuitive fact that the electromagnetic energy could be confined with high-Q dielectric resonators even in a strongly subwavelength regime.

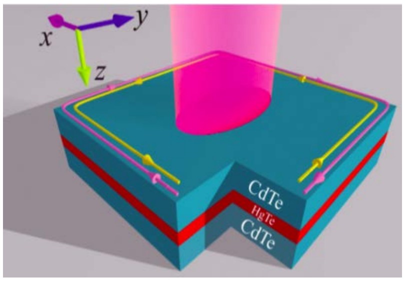
[1] A. Kodigala, T., Nature **541**, 196-199 (2017).
[2] M. L. Brongersma, Y. Cui, and S. Fan, Nat. Mater. **13**, 451 (2014).
[3] M. Rybin and Y. Kivshar, Nature (London) **541**, 164-165 (2017).

3. TOPOLOGICAL EDGE-STATE ENGINEERING WITH HIGH-FREQUENCY ELECTROMAGNETIC RADIATION

M. Hasan, D. Yudin, I.V. Iorsh*, I.A. Shelykh

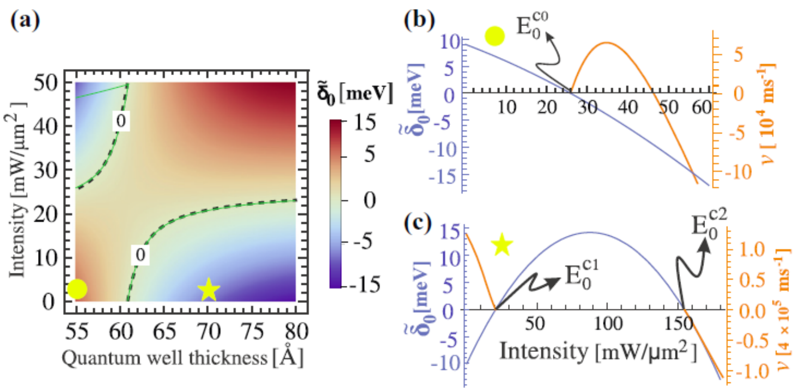
ITMO University, Saint-Petersburrg, Russia.

We outline here how strong light-matter interaction can be used to induce quantum phase transition between normal and topological phases in two-dimensional topological insulators. We consider the case of a HgTe quantum well, in which band inversion occurs above a critical value of the well thickness, and demonstrate that coupling between electron states and the **E** field from an off-resonant linearly polarized laser provides a powerful tool to control topological transitions, even for a thickness of the quantum well that is below the critical value.



Geometry of the system under consideration.

We also show that topological phase properties of the edge states, including their group velocity, can be tuned in a controllable way by changing the intensity of the laser field. These findings open up the possibility for new experimental means with which to investigate topological insulators and shed new light on topological-insulator-based technologies that are under active discussion.



Light-induced phase transitions under off-resonant pumping with electromagnetic radiation. (a) The phase diagram of the system, revealing transitions between topologically trivial and nontrivial states depending on quantum well thickness and the intensity of the light. There exist two types of phase transitions as a function of the intensity of the electromagnetic field: (b) band insulator to topological insulator and (c) topological insulator to band insulator to topological insulator.

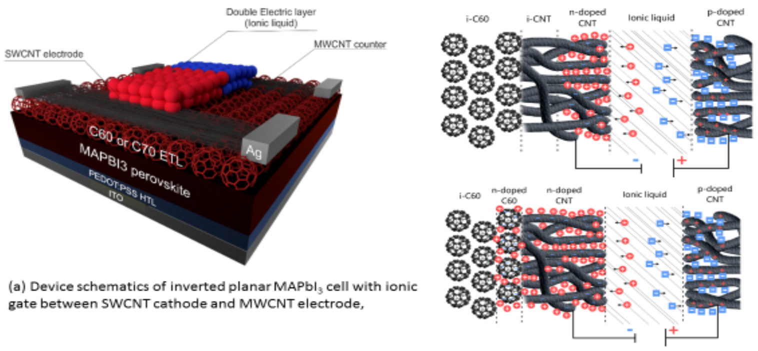
4. TUNABLE AND UNCONVENTIONAL PHOTOVOLTAICS IN ORGANIC AND HYBRID PEROVSKITE PV

Anvar Zakhidov[1,2], Danila Saranin[3], Pavel Voroshilov[1]

[1]ITMOUniversity, St. Petersburg, Russia,
[2]University of Texas at Dallas, USA [3]NUST MISIS, Moscow, Russia

The concept of a tunable photovoltaic (PV) cell is introduced on the example of the organic donor acceptor heterojunction with ionically gated charge collector, extended to perovskite PV. This type of tunability is demonstrated and further developed to incorporate the n-or p-type doping of the transport layers in PV. As known conventional solar cells are silicon p-n junction photodiodes that generate photocurrent upon light, and they cannot be tuned once created. In this talk we show that molecular, organic and hybrid perovskite PV can be improved by tuning them to p-i-n type solar cells, just by ionic gating. So an electrolyte or ionic liquid can be added adjacent to the cathode (e.g. made of porous CNT) of OPV, In our proof of concept studies, we have used CNT also as a counter-electrode. CNT can be easily doped by electrochemical double layer charging. Our design allows the organic transport layers adjacent to porous MWCNT cathode to be further n-doped at higher gate bias U_g and this ETL doping provides not only a better ohmic contact with CNT cathode of n-doped fullerene organic layer (as shown at Fig. below), but this process reconfigures the OPV from undoped D-A type BHJ to n-i, or more correctly heterojunction of the: A(n)-A(i)-D(i) type. So the internal build-in electric fields appear at n-I interface increasing the PV performance. As known the hybrid perovskites of CH3NH3PbI3 type that have revolutionized the field of PV solar cells reaching the record efficiencies over 23 % cannot be easily doped to create p-i-n structures. However using the introduced concepts of ionic gating we show that perovskite PV cells can become tunable and even reconfigurable via ions involvement. We further prove that similar type of ionic modulation is taking place in all real MAPbBr3 type devices due to internal diffusion of ions, composing the perovskite. We show that the exposure of Pero-PV to external bias turns it into LED by ions internal diffusion and formation of charge injecting contacts.

Tunable perovskite solar cells via ionic gating of carbon nanotube at interface on C60/70 layer and further n-doping of C60 by ions



(a) Device schematics of inverted planar $MAPbI_3$ cell with ionic gate between SWCNT cathode and MWCNT electrode,

5. MICRODEVICES INTEGRATION BASED ON LOCAL LASER DENSIFICATION OF POROUS GLASSES

Veiko V.P.[1*], Zakoldaev R.A.[1], Segeev M.M.[1], Sivers A.N.[1], Antropova T.V.[2], Itina T.E. [1,3], Hongfeng Ma[3], Kudryashov S.I. [1,4]

[1] *ITMO University, Kronverkskiy prospect 49, 197101 St. Petersburg, Russia*
[2] *Grebenshchikov Institute of Chemistry of Silicates, Russian Academy of Sciences, 2 Makarova nab., 199034, St. Petersburg, Russia*
[3] *Hubert Curien Laboratory, UMR CNRS 5516/UJM/University of Lyon, Bat. F, 18 rue du Pr. Benoit Lauras, 42000 Saint-Etienne, France*
[4] *Lebedev Physical Institute, Leninskiy prospect 53, 119991 Moscow, Russia*
**e-mail: vadim.veiko@mail.ru*

Polymeric porous media seems to be a perspective matrix for the creation of integrated microdevices, which are used in various fields of research, mostly in analytical chemistry [1]. However, for many photonics, MOEMS and other applications optically transparent and physically stable matrices are highly valuable [2]. Porous glass (PG) is in many respects optimal as a matrix for impregnation by the reagent and analyte due to its high adsorption capacity, as well as chemical and mechanical resistance, electrical and thermal strength, etc. [3].

In the present research, a method of laser-induced formation of a through densified region inside of PG (like the physical relief of the density of a silica framework) is proposed. The formed regions of monolithic (fully or partially collapsed pores), formed with a certain period, can be play a role of molecular barriers with a selective permeability to molecules adsorbed in the pores of the PG. Local laser inner densification inside the PG plates was conducted under the action of ultrashort laser pulses (λ = 515 nm, E_p = 1 - 2 μJ, τ = 200 fs, ν = 500 kHz) [4]. The molecular barrier was densified from the surface by the action of CO_2 laser radiation (λ = 10.6 μm, τ = 190 μs, q = $2.8 \cdot 10^4$ W/cm^2).

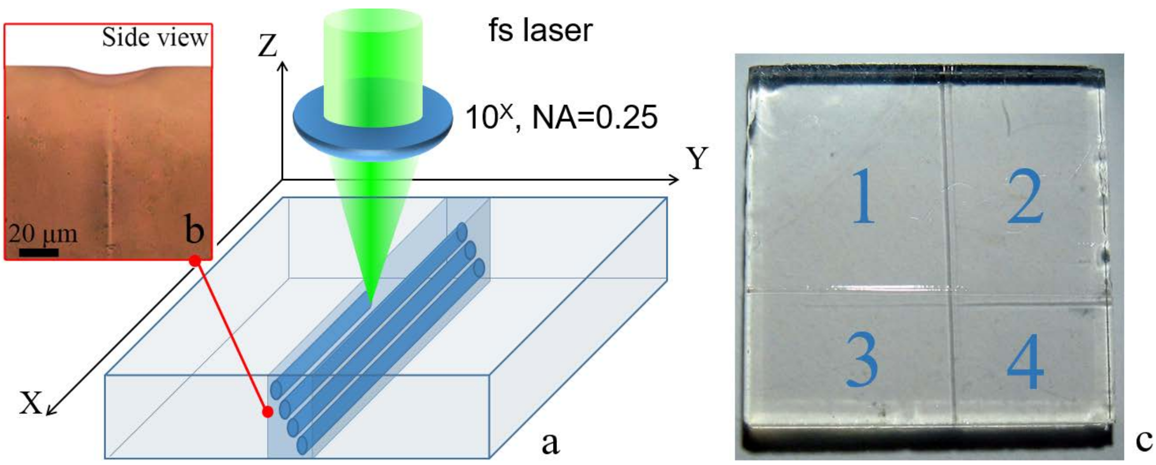


Fig.1 Schematically view of PG inner densification and fabrication of molecular barrier (a); the side view of a barrier (b) and its general view of a few independent cells inside of PG plate

The reported study was financially supported by the Ministry of Education and Science of the Russian Federation, research agreement №14.587.21.0037 (RFMEFI58717X0037).

[1] Hopwood, A.J., et al., Integrated microfluidic system for rapid forensic DNA analysis: sample collection to DNA profile. Analytical chemistry, 2010. 82(16), p. 6991-6999.

[2] N.A Esikova, et.al., Study Features of the Change of the Fluorescence Signal of the Sensor Element Based on Porous Glass on the Concentration of Labeled Insulin. Glass Physics and Chemistry. 2015, 41(1), p. 89–92.

[3] Reisfeld, R., et al., Porous glasses as a host of luminescent materials, their applications and site selective determination. Journal of Luminescence, 2016. 169, Part B: p. 440-444.

[4] Veiko, V. P, et al., (2016). Femtosecond laser-induced stress-free ultra-densification inside porous glass. Laser Physics Letters, 13(5), 055901.

6. LIGHT AND SUPERCONDUCTIVITY

A.V. Kavokin

Spin Optics Laboratory, St-Petersburg State University, 1, Ulianovskaya, St-Petersburg, Russia

We consider theoretically a two dimensionalFermi gas of electrons (2DEG) interacting with a Bose-Einstein condensate(BEC) of excitons or exciton-polaritons. This situation may be realisedexperimentally if a quantum well (QW) containing a 2DEG is separated by athin and high potential barrier from QWs containing excitons. There is nooverlap of exciton and electron wave-functions, but both types ofquasiparticles may efficiently interact if the excitons possess non-zerodipole moments in normal to the QW plane direction. This is the case, inparticular, in biased coupled QWs or in QWs with a built-in piezo-electricfield. Summing the Feynman diagrams of electron-exciton scattering in therandom phase approximation we show that due to scattering between bosonsand fermions attractive interactions are induced both in the Fermi sea andin the Bose gas. These interactions have an important effect on the energyspectra of both systems. The dispersion of excitations of the exciton BEC develops a roton minimum. The width of the roton gap may be tuned bychanging the barrier thickness between 2DEG and BEC or changing theconcentration of excitons. At certain conditions, the energy of the rotonminimum may go below the energy of the exciton BEC which manifests the collapseof the condensate and formation of spatially localised exciton droplets. Thecritical temperature of the Berezinsky-Kosterlitz-Thouless transition in theexciton system decreases in the presence of 2DEG and vanishes at somecritical coupling strength [1].

Attractive interactions in the 2DEGinduced by coupling with excitons may result in formation of the Cooperpairs and superconductivity. We compute the electron-electron interaction potential and resolve the gap equation by iterations. We show that the strength of Cooper coupling and, as aconsequence, the value of superconducting gap and the critical temperaturemay be tuned in large limits by tuning the exciton concentration by means ofresonant optical pumping in microcavities. This effect may pave way to (high temperature)superconductivity in semiconductor heterostructures [2].

Finally, I will discuss the interplay between exciton- and phonon-mediated superconductivity in hybrid semiconductor-superconductor structures and show that a resonant enhancement of the critical temperature for superconductivity may take place in such structures is a certain relation between coupling parameters and Debye temperature is verified.

This work was carried out in the framework of the joint Russian-Greek project supported by Ministry of Education and Science of The Russian Federation **(project RFMEFI61617X0085)**

Работа была выполнена в рамках выполнения совместного Российско-Греческого проекта, поддержанного Министерством Образования и Науки Российской Федерации (проект № RFMEFI61617X0085)

[1] I.A. Shelykh, T. Taylor and A.V. Kavokin, Phys. Rev. Letters, **105**, 140402 (2010)**.**
[2] F.P. Laussy, A.V. Kavokin and I.A. Shelykh, *Phys. Rev. Lett.***104**, 106402 (2010).

7. *ZITTERBEWEGUNG* OF EXCITON-POLARITONS IN SEMICONDUCTOR MICROCAVITIES

Evgeny Sedov, [1,2*] ***Yuri Rubo,*** [3,4] ***and Alexey Kavokin*** [1,5,6]

[1] *School of Physics and Astronomy, University of Southampton, Southampton SO17 1BJ, UK*
[2] *Stoletovs Vladimir State University, 87 Gorkii Street, 600000 Vladimir, Russia*
[3] *Instituto de Energías Renovables, Universidad Nacional Autónoma de México, Temixco, Morelos 62580, Mexico*
[4] *Center for Theoretical Physics of Complex Systems, Institute for Basic Science (IBS), Daejeon 34051, Republic of Korea*
[5] *CNR-SPIN, Viale del Politecnico 1, I-00133 Rome, Italy*
[6] *Spin Optics Laboratory, St. Petersburg State University, St. Petersburg 198504, Russia*
**Corresponding author: evgeny_sedov@mail.ru*

The *zitterbewegung* is an unexpected quivering motion of a Dirac particle around the ballistic trajectory. It was first theoretically predicted by Schrödinger for free relativistic electrons [1]. However, since then it has never been observed experimentally because of the very large frequency (of the order of 10^{20} Hz) and the extremely small amplitude (of the order of 10^{-10} m) of oscillations. Nevertheless, one was recently demonstrated that the effect of *zitterbewegung* is not only characteristic for free electrons but for systems with spectra possessing energy gaps, e.g. electrons in the solid state with the Rashba and Dresselhaus spin-orbital coupling [2], Bose-Einstein condensates of ultracold atoms [3], ions [4], graphene and carbone nanotubes [5], binary photonic crystals [6] and ordinary sonic crystals [7]. In this work, we have theoretically predicted the *zitterbewegung* of the pseudospin-split condensate of exciton polaritons in a 2D microcavity with embedded quantum wells under the effect of the splitting of longitudinal and transverse polariton modes (LT splitting), see Fig. 1. We have demonstrated that the polariton condensate possesses a wavy trajectory resulting from the effect of the precession of the polariton pseudospin around the LT-splitting-induced effective magnetic field on the motion of the polariton wave packet. We have shown that properties of the *zitterbewegung* of exciton polaritons can be tuned by the control parameters including the LT splitting constant, the wave vector and the width of the resonant optical pump. With the optimized parameters, the *zitterbewegung* is manifested on the length scale of tens of micrometers.

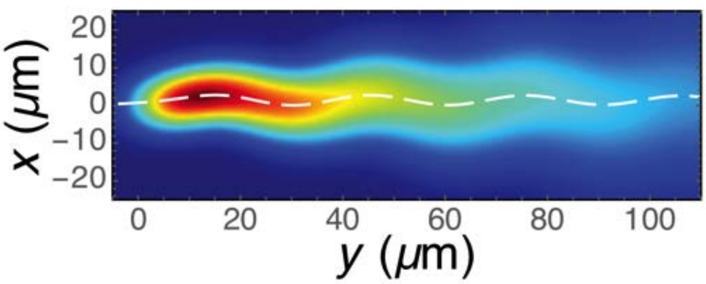


Fig. 1. The spatial distribution of the polariton condensate intensity in the steady state.

[1] E. Schrödinger, Sitz. Preuss. Akad. Wiss. Phys.-Math. **24**, 418 (1930).
[2] J. Schliemann, D. Loss, and R. M. Westervelt, Phys. Rev. Lett. **94**, 206801 (2005).
[3] C. Qu, C. Hamner, M. Gong, C. Zhang, and P. Engels, Phys. Rev. A **88**, 021604 (2013).
[4] R. Gerritsma, *et al.*, Nature (London) **463**, 68 (2010).
[5] T. M. Rusin and W. Zawadzki, Phys. Rev. B **76**, 195439 (2007).
[6] F. Dreisow, *et al.*, Phys. Rev. Lett. **105**, 143902 (2010).
[7] Y. Wang, *et al.*, Physics Letters A **374**, 4933 (2010).

8. LIGHT-EMITTING NANOANTENNAS

Sergey V. Makarov

ITMO University, Kronverkskiy prospect 49, Saint Petersburg, Russia

A driving force for nanophotonics is the discovery of new materials to improve existing concepts or enable new applications. One of the most recent conceptual shift was related to the replacement of metallic nanoparticles by all-dielectric ones (e.g., silicon, GaAs, etc.) bringing a novel opportunities for light manipulation at nanoscale [1]. The next step is to further expanding the range of materials. This report reviews the state-of-the-art in all-dielectric nanophotonics, including recent results on photonic crystals, metasurfaces, and nanoantennas made of organic-inorganic perovskites [2], as well as their implementation in optoelectronic devices. Finally, we compare efficiencies of light-emitting nanoantennas made of different materials.

[1] Kuznetsov, Arseniy I., Andrey E. Miroshnichenko, Mark L. Brongersma, Yuri S. Kivshar, and Boris Luk’yanchuk. "Optically resonant dielectric nanostructures." Science 354, no. 6314 (2016): aag2472.

[2] Tiguntseva, Ekaterina, George P. Zograf, Filipp E. Komissarenko, Dmitry A. Zuev, Anvar A. Zakhidov, Sergey V. Makarov, and Yuri S. Kivshar. "Light-Emitting Halide Perovskite Nanoantennas." Nano letters (2018). Doi: 10.1021/acs.nanolett.7b04727

9. INDUSTRY QKD TEST WITH POLARIZATION STATES

A. Duplinskiy[1,2], V. Ustimchik[1,3], A. Kanapin[1,4], V. Kurochkin[1] And Y. Kurochkin[1]

[1]*Russian Quantum Center (RQC), Business Center Ural, 100, Novaya Street, Skolkovo, Moscow Region, 143025, Russia*

[2]*Moscow Institute of Physics and Technology, 9 Institutskiy per., Dolgoprudny, Moscow Region, 141700, Russia*

[3]*IRE RAS, Mokhovaya St, 11 – 7, Moscow, 125009, Russia*

[4]*Lomonosov Moscow State University, GSP-1, Leninskie Gory, Moscow, 119991, Russia*

In this work we present the quantum cryptography demonstration in the Moscow urban fiber. We use one way polarization optical scheme [1]. Polarization encoding is common for free space applications, since the atmosphere, unlike optical fiber keeps polarization stable. However polarization drift in the fiber quantum channel (QC) can be overcome with the help of polarization stabilization techniques. Moreover this problem is not unique for polarization schemes – most phase encoding QKD setups also require polarization states recovery because active modulators usually polarization dependent.

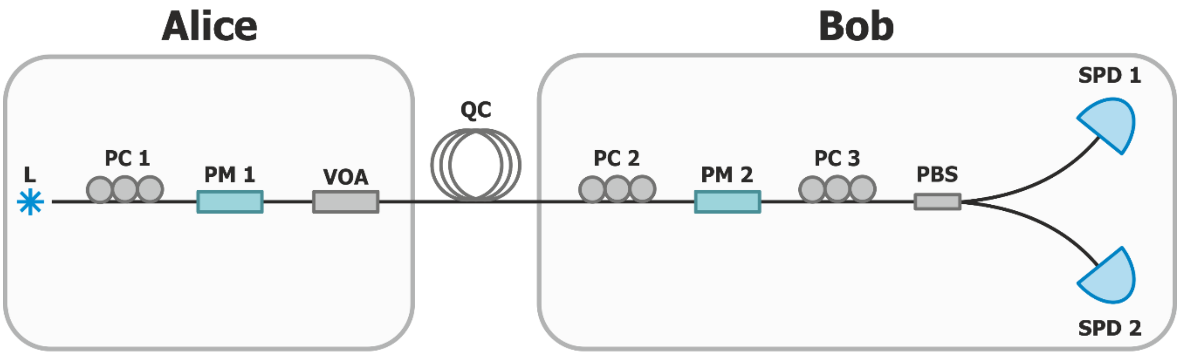


Fig. 1. QKD optical scheme for BB84 protocol with polarization encoding. Laser source (L) emits polarized optical pulses at 1550 nm. Polarization controller (PC 1) rotates the polarization state so that the amplitudes along the crystal axes of Alice's phase modulator (PM 1) are equal to each other. This allows Alice to encode bits of the secret key in the SOP with the help of the modulator. To weaken the pulse a variable optic attenuator (VOA) is used. The intensity is reduced to calibration or key generation level, depending on the operation mode. After the quantum channel (QC), the 2nd polarization controller (PC 2) compensates SOP drifts and rotates it so that polarization components along lithium niobate crystal axes switch places, compensating the birefringence of $LiNbO_3$. Bob's modulator PM 2 is used for basis selection. Finally, polarization controller PC 3 converts SOPs for polarization beam splitter (PBS) to distinguish states with the help of single-photon detectors (SPD1, SPD2). Standard single-mode fiber is suitable for all elements included, however three polarization controllers are used.

The parameters of the QKD setup implementation are as follows: number of pulses in train 9.82×10^4, repetition rate of pulses in train 312,5 MHz, detectors efficiencies are 10% and

6.4% (for SPD1 and SPD2, respectively; see Fig. 1), detectors dead time 5 μs, dark count probability 3×10^{-7}, fiber channel losses 14.05 dB in the channel of 25 km length (which corresponds to ≈ 70km of standard fiber-optic communication line with 0.2dB/km losses), and additional losses on Bob's side 6 dB. The resulting raw key generation rate in our experiments is about 2 kbit/s. After realization of the QKD session, we realize the standard sifting procedure and post-processing procedure [2].

The result key is used in the standard encryption device to change key every 400 seconds.

We acknowledge support from S.V. Lebed' and S.K. Kuznetsov as well as colleagues from Amicon for the help in realizing this experimental work. The work was supported by the Russian Science Foundation (Grant No. 17-71-20146).

[1] A. Duplinskiy, V. Ustimchik, A. Kanapin, V. Kurochkin, and Y. Kurochkin, Opt. Express 25, 28886 (2017).
[2] E.O. Kiktenko, A.S. Trushechkin, Y.V. Kurochkin, and A.K. Fedorov, J. Phys. Conf. Ser. 741, 012081 (2016).

10. LASER SYNTHESIS OF LONG LINEAR CARBON CHAINS FOR PHOTONIC APPLICATIONS

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Synthesis of new carbon form is an actual task of modern nanotechnology. Laser methods for the synthesis of nanostructured carbon allows varying the composition and morphology of the structures obtained according to the experiments conditions. In our experiments, we demonstrate the synthesis of carbyne with the irradiation of the colloidal system obtained during laser ablation of a target schungite in water. The experiments suggest that a change in the conditions of exposure (the exposure time and the energy of the impact) by YAG:Nd laser with a pulse duration of 100 ns leads to the formation of structures with the carbyne structures.

The laser irradiation of the carbon targets allows to realize different ways of the phase transformation solid-liquid-vapor in dependence on the sample heating speed and on the environmental properties [1, 2]. The use of millisecond lasers results in melting of the surface of the target and synthesis of carbyne. During the laser ablation the quazicontinuous regime of laser irradiation allows us to synthesize carbon clusters [3]. The size of carbon clusters depends on power density of the laser radiation. During the laser irradiation in liquid it is possible to obtain special media parameters for carbon modification with different allotropic forms [4]. There are theoretical and experimental results about carbyne synthesis under the nanosecond pulse duration laser radiation, then it results in splitting of graphite layers and formation of linear carbon chains [5].

[1] Mel'nichenko V.M., Sladkov A.M., Nikulin Yu.N., Uspekhi khimii, 51, 736 (1982).
[2] Asinovskiy E.I., Kirilin A.V., Kostanovskiy A.V. UFN, 172, 931 (2002).
[3] N. E. Kask, E. G. Leksina, S. V. Michurin and G. M. Fedorov Fractal Nanostructures Arising under the Ablation of Graphite and Silicon by Millisecond-Laser Radiation// Laser Physics, 2008, Vol. 18, No. 6, pp. 762–767.
[4] Antpov A.A., Arakelian S.M., Garnov S.V., Kutrovskaya S.V., Kucherik A.O., Nogtev D.S., Osipov A.V. Quantum Electronics, 45, 731 (2015)
[5] Pan B., Xiao J., Li J., Liu P., Wang C., Yang G. Science Advances, 1, e1500857 (2015).

11. CLUSTERED BIMETALLIC STRUCTURES WITH VARIABLE OPTICAL AND ELECTRONIC PROPERTIES

A.A. Antipov, D.N. Bukharov, S.M. Arakelyan, S.V. Kutrovskaya, A.O. Kucherik, A.V. Osipov, A.V.Istratov, T.A. Vartanyan and T.E. Itina

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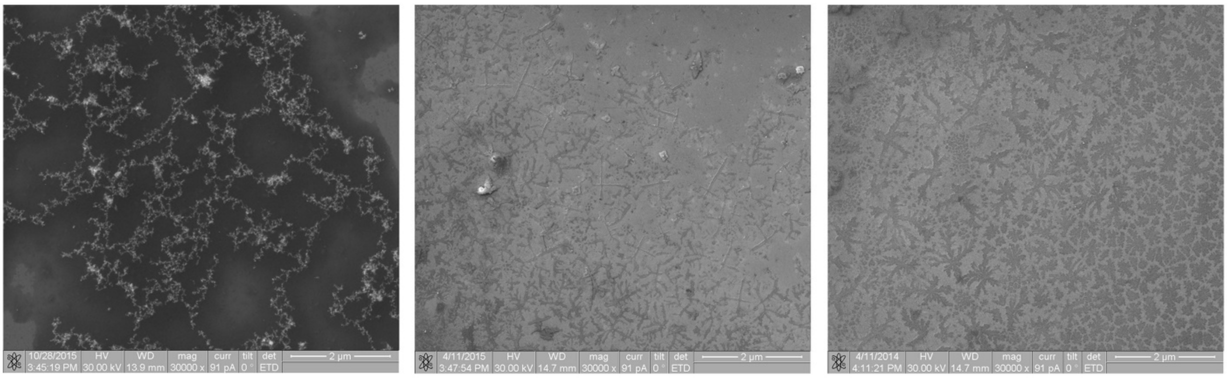
Efficient synthesis of thin films with controlled optical properties is a key issue in modern photonics. In particular, possibilities of plasmon-assisted light manipulations by using nanoparticles and nanostructures currently attract considerable attention enabling various applications and opening new research area [1]. Drop deposition of the colloidal particles on glass substrate represents, furthermore, a promising solution to this challenging problem. The optical properties of these films are dominated by a set of plasmonic effects and strongly depend not only on the composition of the film but also on its morphology. In the case of the structures composed of nanoparticles, such parameters as spacing and ordering of nanoparticles define the local field enhancement to be observed either for distinct resonance frequencies or in a much wider spectral ranges [2, 3]. Furthermore, if nanoparticle spacing is comparable with its sizes, optical properties of the random structures can considerably differ from that of the ordered ones. In the case of the thin bimetallic films, one can expect even more complicated optical properties [4].

Deposition of bimetallic thin films

Gold and silver particles were formed as a result of CW laser irradiation (power 30 W, laser spot diameter 100 μm) of a target in water [5]. The target was scanned by a laser beam with a velocity of 100 μm/s; the total exposure time was 30 min. After laser irradiation, the solution was exposed to ultrasound for 10 min and then separated on a CM-6M centrifuge. The particle sizes in the colloidal solution was investigated by dynamic light scattering method with a Horiba LB-550 particle-size analyzer. They appear to be in the range from 5 to 10 nm. A mixture of silver and gold colloidal solution with the weight ratio of 1:1 was prepared by vigorous stirring..

We have formed clustered films by method of drop deposition [6]. The basic concept of this method is the deposition of a small-radius (10 μm) drop of colloidal solution combining with the pinning effect. The particles are deposited on the contact area of the droplet with the substrate placed on the thermostabilized table at the temperature of about 80°C. The area of droplet doesn't change during the evaporation processes, because of an additional energy barrier, which impedes the interface displacement. In this case, the surface tension forces, which tend to make a drop spherical, dominate over the gravitational forces, which tend to flatten the drop. The dynamics of drop spreading is determined by the following factors: surface tension, wetting, viscosity, thermal conductivity, and ionic bonds [6]. Thus, when the particle concentration in a drop is relatively low, the particle deposition can be described similar to the behavior of an isotropic medium. As an example, Fig. 1 shows the deposited layers for different concentration of colloidal system.

For metal particles, we can control the cluster morphology at slow deposition process [6]. A more detailed analysis of the film morphology reveals a variety of aggregate shapes. Some of them gain typical fractal shapes which are shown in Figure 1.



a) b) c)

Fig. 1. Three different morphologies of the obtained fractal aggregates: (a) -“dendrites” configuration; (b) -“brunches” configuration; and(c)-“snowflakes” configuration.

The optical properties of deposited films

Transmittance spectra strongly depend on the aggregate shape. There is a periodical variation ranges in the transmission spectra of all films at the wavelength of the plasmon resonance of gold (500-540 nm) and silver (390-420 nm). The behavior of bimetallic films transmission spectra is more complicated at the wavelength of the plasmon resonance of silver nanoparticles. Additionally, Figure 2 illustrates this dependence for three typical fractal aggregate configurations shown in Figure 1.

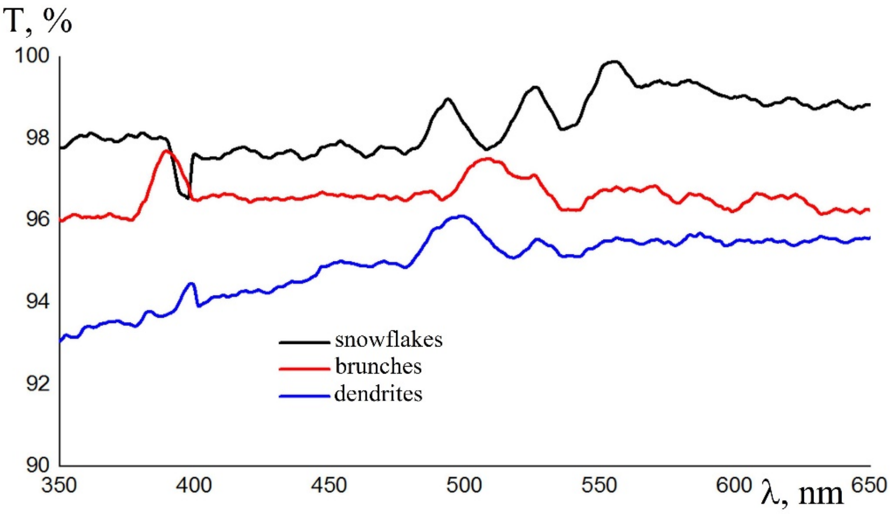


Fig. 2. Measured transmittance spectra of fractal aggregates shown in Figure 2.

We have presented an efficient method of the drop deposition of bimetal island films. The possibility of the formation of the clustered films of gold and silver nanoparticles with controlled morphology is demonstrated. The experimental data on optical properties of nanostructured bimetallic clustered films has been obtained. We have demonstrated that the properties of the island films depend on its morphology.

[1] Genov, D.A., Sarychev, A.K., Shalaev, V.M., Wei, A. "Resonant Field Enhancements from Metal Nanoparticle Arrays," *Nano Letters*, Vol. 4, № 1, 153–158, 2004.

[2] Mayer, C., Palkovits, R., Bauer, G., and Schalkhammer, T., "Surface enhanced resonance of metal nano clusters: a novel tool for Proteomics," *Journal of Nanoparticle Research*, Vol. 3, № 5, 359–369, 2001.

[3] Bakhti, S., Tishchenko, A.V., Zambrana-Puyalto, X., Bonod, N., Dhuey, S. D., Schuck,P. J., Cabrini, S., Alayoglu, S., and Destouches N., "Fano-like resonance emerging from magnetic and electric plasmon mode coupling in small arrays of gold particles," *Scientific Reports*, Vol 6, Article ID 32061, 2016.

[4] Tlahuice-Flores, A., "Optical properties of thiolate-protected $Ag_nAu_{25-n}(SCH_3)_{18}$-clusters,"*Journal of Nanoparticle Research*, Vol. 15, Article ID 1771, 2013.

[5] Arakelyan, S.M., Veiko, V.P., Kutrovskaya, S.V., Kucherik, A.O., Osipov, A.V., Vartanyan, T.A., Itina, T.E., "Reliable and well-controlled synthesis of noble metal nanoparticles by continuous wave laser ablation in different liquids for deposition of thin films with variable optical properties," *Journal of Nanoparticle Research*, Vol. 18, Article ID 155, 2016.

[6] Antipov, A. A., Arakelyan, S. M., Vartanyan, T. A., Itina, I. E., Kutrovskaya, C. V., Kucherik, A. O., Sapegina, I. V., "Optical properties of nanostructured gold–silver films formed by precipitation of small colloid drops," *Optics and Spectroscopy*, Vol. 119, № 1, 119-123, 2015.

12. TAILORING OF THE OPTICAL RESPONSE OF HYBRID GOLD-SILICON CLUSTERS

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Light scattering by micro- and nano-particles is used in multiple photonic applications, e.g. in nano-antennas. One of the important challenges on a way to optimization of such nano-antennas is constituted by the Ohmic losses that are very high at the optical frequencies in Nobel metals (gold, silver) that are promising due to their plasmonic properties. The optical absorption and high Ohmic losses result is a significant heating that negatively affects the performance of metallic nano-antennas. On the other hand, dielectric and semiconductor nanostructures are usully characterized by much lower losses that makes them suitable candidates for nano-antenna applications, potentially. In particular, it has been theoretically predicted [1] and experimentally demonstrated that silicon nanoparticles of a diameter of 100 and 200 nm possess well-resolved dipole resonances in the visible frequency range [2]. The interplay between electric and magnetic multipole resonances in silicon nanoparticles leads to a number of new effects such as the self-focusing of radiation and suppression of the back scattering. Combining the characteristics of Nobel metal and silicon nanoparticles one can potentially take advantage of the specific optical properties of both of them. In this context, hybrid silicon-metal nanoparticles are especially promising as they allow tailoring of the optical properties, plasmon resonances, electric and magnetic interactions for multiple photonic applications.

The development of fabrication techniques that would enable a high-precision control over the nanoparticle (NP) parameters is very important in this context. The method of laser ablation in a liquid phase [3, 4] offers a possibility to control the average size and shape of the synthesized particles by a proper choice of the irradiation conditions (pulse duration, energy density etc.). Low optical losses in silicon NPs are crucial for their applications in photonics, in particular as building blocks for metamaterials and metasurfaces. For these applications it is also important to be able to engineer the near field emission of silicon NPs. This work is aimed at the experimental demonstration of such tailoring and enhancement of the near field emission of silicon NPs by covering them by small-size golden NPs. Golden shells trigger a strong nanoantenna effect induced by the Purcell enhancement of radiation that strongly affects the near field emission of silicon.

Here we report on the synthesis of hybrid gold-silicon NPs by laser irradiation of colloidal solutions [5]. The increase of the optical near field magnitude in the emission of the NPs is observed and interpreted in terms of the redistribution of the near-field scattering intensity due to the nanoantenna action by gold nanoparticles. The spontaneous ordering of NPs in the course of their deposition allows for the formation of thin films that may be used for creation of metasurfaces suitable for controllable manipulation of the transmission and reflectivity of light [6,7]. These results pave the way to applications of hybrid gold-silicon NPs in optical integrated circuits combining functions of generation, transmission and detection of optical signals.

[1] Evlyukhin AB, Reinhardt C, Seidel A, Luk'yunchuk BS, Chichkov BN. Optical response features of Si-nanoparticle arrays. Phys. Rev. B.2010; 82 (4): 045404.

[2] L. Shi, T. U. Tuzer, R. Fenollosa, and F. Meseguer, Adv. Mater. 24, 5934 (2012).

[3] KuzminP. G., Shafeev G.A., Bukin V.V. et al Silicon Nanoparticles Produced by Femtosecond Laser Ablation in Ethanol: Size Control, Structural Characterization, and Optical Properties J. Phys. Chem. C, 114 (36), 15266-15273 (2010)

[4] Zywietz U, Reinhardt C, Evlyukhin AB, Birr T, Chichkov BN. Generation and patterning of Si nanoparticles by femtosecond laser pulses. Appl. PhysA,2014, 114:45-50.

[5] Liu P, Chen H, Wang H, Yan J, Lin Z and Yang G. Fabrication of Si/Au core/shell nanoplasmonic structures with ultrasensitive surface-enhanced raman scattering for monolayer molecule detection. J. Phys. Chem. C. 2015; 119(2), 1234-1246.

[6] Yu, N.; Capasso, F. Flat optics with designer metasurfaces. Nat. Mater. 2014, 13, 139−150.

[7] AntipovAA, ArakelyanSM, VartanyanTA, ItinaTE, KutrovskayaSV, KucherikAO et al. Optical properties of nanostructured gold-silver films formed by precipitation of small colloid drops.OptSpectrosc. 2015; 119 (1): 119-123.

13. A VISION OF SCIENCE IN CUBA. STEPS AND ROADS

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A briefly overview of the History of Cubans science, in connection with the science's knowledge revolution is evaluated. A concise analysis of the weaknesses, threats, strengths and opportunities of the science, technology and innovation in Cuba at the present stage and its future projection is presented. Some steps and paths to undertake transformations in order to enhance their economic, social, sovereignty and culture contributions for the Cuban nation are suggested. The demographic reality, the geographic characteristics, the social justice and the sovereignty, between others, as challenges to the social and economic development is presented. The knowledge society, the development of the innovation, science and technology are illustrated as opportunities to the Cuban society. A discussion related of the influence of the international environment as well as the possible action to attenuate it effects is presented. The Russian science contribution in the development of Cuban science and technology is declared.

14. CUBAN MR PROJECT

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Cuban´s experiences concerning to the calculation, design, construction and validation Magnetic Resonance (MR) technology is presented in the context of the celebration of the 70 Anniversary of the discovery of the MR and 25 Anniversary of the opening of Medical Biophysics Center of the University of Oriente, Santiago de Cuba. Cuban MR Technology includes MR relaxometer, Magnetometers and MR imaging (MRI) whole body machines. The MR relaxometers and MRI systems were development in ending of the 80 ties and introduced in several Cuban's hospitals where were working during more than 12 years.

The Cuban MR project includes the research in quantitative MR associated with molecular, preclinical and clinical studies of significant diseases and drugs development is presented. MR "in vitro" and "in vivo" studies of Sickle Cell disease, the Diabetic Foot Ulcer, the Brain Tumor Response and the Magnetic Nano Particles Pharmacokinetics, are presented as example. Furthermore, contributions and restrictions of MR to diagnostic and optimization of therapeutic pathways are discussed in these concrete cases.

Others principal outcomes of this project are presented.

15. OPTICAL MICROCOMBS

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The advent of microresonator-based Kerr combs opens a path to novel applications where traditional optical frequency combs requiring bulky apparatus can hardly be used. In this case, frequency comb is formed in optical ring-type or whispering-gallery microresonator spontaneously due to four-wave mixing cascaded processes. Though initial expectations were somewhat mitigated by intrinsic chaotic character of first-generation combs, it was shown that coherent mode-locked combs which are associated with self-supporting femtosecond optical pulses (solitons) are still possible without significant additional efforts on different platforms.

Recent theoretical and experimental results in soliton combs from the Russian Quantum Center are reported. Key advantages of microresonator-based frequency combs are their compact form factor, high power per comb line, and ability to access microwave repetition rates, relevant for many application including high capacity telecommunications or microwave photonics. It was also revealed that coherent Kerr combs are possible not only for anomalous group velocity dispersion necessary for bright optical solitons but also in normal dispersion systems using the so-called “platicons” – solitonic like flat-topped waveforms. This opens the ability to generate coherent combs in the UV or mid IR spectral range with the gain bandwidth limited only by the transparency window. Recently demonstrated microresonator-based dual frequency combs open the possibility to transfer optical spectral measurements to radio-frequency domain. New experimental methods of Kerr soliton generation using cheap regular wide spectrum multifrequency diode laser self-injection-locked high-Q microresonator will be discussed.

The work was supported by the Russian Science Foundation project #17-12-01413

16. DISORDERED QUANTUM SYSTEMS WITH LONG-RANGE HOPS

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I will first give a brief overview of localization properties of quantum systems in disorder, with an emphasis on ultracold atoms/molecules in random systems. Here, since the appearance of the idea of localization of particles in random potentials [1], for more than 50 years it was thought that all extended states are ergodic (except for a single point of mobility edge in three dimensions), and there is only one disorder-related phase transition, namely localization-delocalization (insulator-conductor) transition. However, it has been recently shown that there can be a band of extended non-ergodic (multifractal) states in an artificial Bethe lattice [2]. I then demonstrate that the bands of non-ergodic extended states exist in a physical system of dipolar excitations propagating via long-range hops ($1/r^3$) among polar molecules that are randomly pinned in a three-dimensional optical lattice [3]. We are thus really facing a problem of a new phase transition, that is the transition between extended ergodic and non-ergodic states. I will give supporting arguments that this is a phase transition, not a crossover.

I then turn to a similar one-dimensional system, where the long-range hops behave as $1/r^a$, with a that can be even smaller than 1. Such a system can be realized for trapped ions with laser-driven interactions. Suprisingly, almost all single-particle states in this system are localized for any a>0 [4]. Moreover, there is a property of duality: most of the localization properties in the system with a<1 are the same as those in the system with the exponent 2-a [4]. We are thus having a new class disordered quantum systems.

[1] P.W. Anderson, Phys. Rev. 109, 1492 (1958).
[2] A. De Luca, B.L. Altshuler, V.E. Kravtsov, and A. Scardiccio, Phys. Rev. Lett. 113, 046806 (2014).
[3] X. Deng, B.L. Altshuler, G.V. Shlyapnikov, and L. Santos, Phys. Rev. Lett. 117, 020401 (2016).
[4] X. Deng, V.E. Kravtsov, G.V. Shlyapnikov, and L. Santos, arXiv:1706.04088.

CONTENTS