Book of Abstracts
INTERPHOTONICS 2023

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APRIL 13-19, 2023

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Marek Godlewski	Polish Academy of Sciences, Poland
Ludmil T. Benov	Kuwait University, Kuwait
Sergey Klimonsky	Lomonosov Moscow State University, Russian Federation
Rodion Reznik	Saint-Petesburg State University, Russian Federation

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Victor Koledov	Kotel'nikov Institute of Radioengineering and Electronics Russian Academy of Sciences, Russia
Yahia CHERGUI	University of Boumerdes, Algeria

PLENARY SPEAKERS

Id-635

Applications of AES, XPS and TOF SIMS to Phosphor Nanomaterials

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Abstract: Luminescent compounds and materials have numerous uses. The emission properties, whether of a fast decay rate fluorescent material or a slow decay rate phosphorescent material, are defined by the chemical composition and the physical structure of the luminescent material. Surface characterization and optical characterization techniques play a vital role in the complete understanding of the luminescent properties of phosphor nanomaterials. Auger electron spectroscopy (AES), X-ray photo electron spectroscopy (XPS), time of flight scanning ion mass spectrometry (TOF SIMS), Photoluminescence (PL) and cathodoluminescence (CL) are used to characterize different phosphor materials. The crystal field that is determined by the environment in the host material in combination with the various dopant ions with the correct valence state can be used to obtain emissions from the Ultraviolet (UV) to the infra-red (IR) wavelength ranges. Phosphor materials have been successfully used to improve the efficiency of various applications. Nanoparticles both undoped and doped with different rare earth elements were synthesized by several synthesized techniques. The defects incorporated into the bulk material play an important role in the emission efficiency and colour scheme. XPS in combination with PL can be used to identify some of these defects in the material. Degradation of the different phosphors during prolonged electron/photon bombardment also played a vital role in their possible applications. The combination of CL, PL, AES and XPS techniques helps to determine the mechanisms behind the degradation. A small number of impurities in the chemicals used during synthesis can play a large role in the final emission intensity and colour of the phosphor materials. TOF SIMS can point out these impurities. Examples of different phosphor materials with different applications such as Solid-State Lighting will be shown.

Keywords: Surface characterization, phosphors, luminescence materials, degradation, defects

Acknowledgment: The authors are highly thankful for the support provided by the South Africa Research Chair Initiative of the Department of Science and Technology (No. 84415), extending financial support from the University of the Free State to carry out the research work.

PLENARY SPEAKERS

Id-672

Laser and Additive Technologies for Industrial Application of Production and Repairing of Terrain, Marine and Aeronautical Engineering

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Abstract. Due to the unique set of physical properties of laser radiation and the specifics of its interaction with matter, laser technologies are widely used in many science-intensive and high-tech industries, such as: medium and heavy mechanical engineering, energy, shipbuilding, aerospace, automotive, etc. Large penetration depth and high processing speed are indisputable technical and economic advantages of laser and laser-arc welding of structural materials. In addition, the small volume of the melt pool and the high rates of physical and chemical processes make it possible to join materials that were previously considered non-weldable by fusion welding, including dissimilar, multicomponent, high-entropy and other alloys. The development of surfacing technologies allows not only modifying the surface of products, or restoring their geometry, but also creating them from the ground up using additive manufacturing methods. In this case, the idea of creating products with functionally graded properties, including topologically optimized design, can be realized. The paper shows the results of research and development in the field of the listed laser technologies introduced to industry.

Keywords: Laser welding, hybrid laser-arc welding, laser cladding, laser metal deposition, industrial application

Acknowledgment: The research was funded by the Ministry of Science and Higher Education of the Russian Federation as part of strategic academic leadership program “Priority-2030”, strategic project “Industrial digital technologies” (contract № 075-15-2021-1206 dated 30.09.2021).

PLENARY SPEAKERS

Id-674

An Overview and the Future Directions for Distributed Fiber Optic Sensing Systems

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Abstract. Distributed Fiber Optic Sensing (DFOS) systems transform passive fiber optic cables into active environmental sensors, that can detect external vibrations, strain and temperature along kilometers long fiber cables. Due to their unique properties, DFOS systems have many applications and advantages over competing technologies. In this talk we will focus on the challenges and applications of DFOS systems using outdoor grade telecom fiber networks instead of standard indoor or some specialty fiber cables. In more detail, we will focus on applications such as real time traffic monitoring, infrastructure health monitoring, and rain detection.

Keywords: Fiber Optics, Distributed Fiber Optic Sensing, Distributed Acoustic Sensing, Smart city, Rain detection

INVITED SPEAKERS

Id-636

Fluorescent Markers for Early Detection of Cancer

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Abstract: Nanoparticles of wide band gap oxides (ZnO and ZrO_2) are used as fluorescence markers (FMs) allowing early detection of cancer. Several types of FMs were tested by us as discussed in [1] and other groups. The new generation of FMs, developed by us, is based on ZnO and ZrO_2 nanoparticles doped with rare earth ions. These nanoparticles are selected due to their bio-neutrality. Rare earth doping of the markers results in an efficient and spectrally sharp photoluminescence (PL) in a visible light spectral region. Relatively bright PL is observed, without any blinking and photo-bleaching.

We propose a new way of introducing FMs to organisms. Since direct injection to a blood system may be dangerous – FMs can aggregate blocking blood circulation, intra-gastric (IG) method was tested by us. This is innovative method of introducing of markers to organisms. After IG introduction, FMs penetrate and gradually accumulate in tumors, including the difficult to diagnose and treat lungs tumor.

Tests were performed to check selectivity of our method. It turned out that blood - lungs barrier is very tight. FMs cannot enter to healthy cells but easily penetrate membrane for the region of tumor. An effective trafficking of FMs to the areas of lung cancer was thus observed, whereas surrounding tissue was impermeable for nanoparticles. The data obtained confirm 100% selectivity of the method. This shows a high potential of studied FMs in direct tracing of the extent of cancer spread in lungs.

Importantly, FMs developed by us can also be used as MRI contrast agents. Moreover, we performed tests of using developed FMs as transport agents. FMs were used to selectively introduce a given medicine to area of tumor. A directed therapy is thus possible.

Keywords: Oxides, Nanoparticles, Fluorescence Labels, MRI, Cancer.

INVITED SPEAKERS

Id-638

Weed Control with A 2 µm Fiber Laser: How Does the Laser Beam Affect Non-Target Organisms?

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Abstract: Herbicide use has resulted in increasing problems with herbicide-resistant weeds and unwanted contamination of the environment. Substitution of herbicides by mechanical weed control increases the risk of soil erosion and deterioration of soil particles, harms soil organisms and beneficial insects, and provides poor results for in-row weeding.

Therefore, there is a need to develop more sustainable weed control means. Using small autonomous vehicles equipped with lasers could be a sustainable and eco-friendly alternative to replace or supplement herbicide application and mechanical weed control in both conventional and organic farming. Furthermore, laser beams are based on electricity, which can be produced from non-fossil fuels and could contribute to reducing CO_2 emissions from agriculture production.

Deep learning methods have been developed to locate and identify weed and crop plants to target and deliver laser energy with autonomous vehicles. The laser should only be directed towards weeds and kill the weed plants in their early growth stages. Therefore, the field area exposed for weed control can be reduced substantially compared to commonly used methods that may expose the whole field for treatment. Consequently, the risk of affecting non-target organisms is significantly reduced, and the soil will be kept undisturbed in the area, avoiding triggering new cohorts of weed seeds to germinate.

In this presentation, we discuss the advantages and disadvantages of using laser beams for weed control and give examples of how a 2 µm fiber laser used to control weeds affects living organism as worms and seeds in the soil and insects on the soil surface.

Keywords: Eco-Friendly Weed Control, Environmental Impact, Risk-Assessment.

INVITED SPEAKERS

Id-646

Site-Specific Delivery of Photo-Generated Cytotoxic Species

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Abstract: Oxygen-derived reactive species (ROS) have been implicated in the etiology of a wide array of human diseases, including cancer, but are also widely used for cancer eradication. Hydrogen peroxide, hydroxyl radical, and singlet oxygen ($^1O_2$), are commonly produced by anticancer therapeutics and are responsible not only for destruction of malignancies, but also for unwanted side effects. The best way to increase the efficacy of the treatment and limit its side effects, is to deliver the damaging agent to a specific target. Photodynamic therapy (PDT), which combines the use of three harmless components, a non-toxic, light-absorbing pigment, a photosensitizer (PS), visible light, and atmospheric oxygen, provides excellent opportunities for selective destruction of unwanted cells and tissues by localized production of cytotoxic species. Upon illumination, photo-excited PSs generate $^1O_2$ and radicals, which have short life and small diffusion distances in biological environment, thus limiting the damage to the close proximity of the PS. Cancerous cells commonly display altered metabolism and preferential uptake of certain compounds, among them porphyrins, and preferential accumulation of porphyrins in cancerous tissues is the basis for their selective cytotoxic action.

Different cellular organelles and structures show dramatic differences in sensitivity to ROS. Location and extent of the ROS-induced damage in turn determine the fate of the cell and the mechanism of cell death. The mode of cell death in turn defines the overall response of the organism. This makes subcellular localization of a PS a key tool for control of the treatment outcome. The properties of a PS, including site-specific delivery of cell-damaging species, can be adjusted by modifications of the PS molecule. Porphyrin-based PSs and their metal complexes allow for endless modifications, whose nature affects singlet oxygen quantum yield, cellular uptake and subcellular distribution of the PS. Chelation of different metal ions by the porphyrin core directly affects singlet oxygen quantum yield, while modifications at the periphery of the tetrapyrrole ring control the uptake and allocation of PSs to subcellular organelles. Lipophilicity, overall charge and its distribution, three-dimensional shape of the molecule, its flexibility, bulkiness, and size, are the key features that control PS subcellular localization. In biological systems, however, where PSs are subjected to the action of enzymes, reactive metabolites, endogenous biological chelators and reducing or oxidizing agents, their physicochemical and photosensitizing properties are affected. Therefore, photo-physical features alone cannot unambiguously predict the anticancer efficacy of a PS. The spatial distribution

of the PS, the nature of the environment, the inherent stability of a metal complex and interactions with biomolecules and other cellular components, are among the key factors controlling the PDT efficacy.

Keywords: Photodynamic Therapy, Photosensitizer, Metalloporphyrin, Singlet Oxygen, Cancer

INVITED SPEAKERS

Id-651

End-To-End Lıne Control For Optıcal Quantum Key Dıstrıbutıon

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Abstract. We propose a novel approach to optical quantum key distribution (QKD) in which the end-to-end physical control of the transmission line allows for precise estimation of any potential leakage caused by an eavesdropper. This enables the users appropriately adapt the parameters of the bit-encoding quantum states to make them indistinguishable for the eavesdropper. Our approach enables the use of optical amplification to extend the range of QKD over long distances. We delve into the intricacies of designing secure amplification-based repeaters, and demonstrate a special line configuration rendering near all losses in the quantum channel impenetrable to the intruder.

Keywords: Quantum Key Distribution, Optical Amplification, Coherent States, Reflectometry.

INVITED SPEAKERS

Id-652

III-V nanowires with Quantum Dots on Silicon

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Abstract: Combination of nanowires (NWs) with quantum dots (QDs) are promising building blocks for future optoelectronic devices, in particular, single-photon emitters. The most studied epitaxially grown QDs are self-assembled, i.e., grown by island nucleation in the Stranski-Krastanov growth mode. The size, shape, and density of self-assembled QDs can be controlled by changing of the growth parameters such as substrate temperature, growth rate and growth time, but in the end it is a self-organized strain induced process and controlling the properties of the array independently is a challenging task. QDs in nanowires have, in contrast, shown great potential as a highly controllable system. The diameter, height, and density of the QDs are defined by the NW diameter, the growth time, and the NW density, respectively, and can be chosen more predictable. Due to a very efficient strain relaxation on the free sidewalls, coherent growth can be much easier realized in the NW geometry, where a small footprint is dictated by a metal catalyst particle assisting the NW growth via the vapor-liquid-solid (VLS) mechanism [1]. Moreover, it has recently been shown that [111] grown nanowires, especially heterostructured, are ideal candidates for the generation of entangled photon pairs [2].

Experimentally, all the samples in the present work were grown by molecular-beam epitaxy (MBE). For GaAs/AlGaAs, InGaAs/AlGaAs, InGaAs/GaAs and InAsP/InP material systems, different growth conditions were applied, but the strategy was the same: we have used Au-assisted growth of the NWs on Si(111) substrate, firstly we grew the AlGaAs, GaAs or InP base of the NW, secondarily, the nanoinsertions with lower bandgap, or QD, was formed and we end the structure with the core with the same material as the base. In case of GaAs/AlGaAs NWs it was found that during the growth spontaneous, independently on the Al fraction, core-shell structures with lower aluminum content in the cores are formed. Optically, our growth method results in the formation of GaAs QD in a AlGaAs NW having very narrow spectral linewidth (< 10ueV), single-photon emission in the wavelength range 750 – 820 nm in dependence on the QD growth recipe. Moreover, the emission wavelengths al-lows one to design light emission devices in a red range by simply changing of the Al fraction in AlGaAs NWs. In case of InAsP/InP NWs it was found that using a special procedure of substrate preparation immediately before the growth made it possible to obtain a nanowire coherency with the substrate of nearly 100%. A high-intensity emission from nanostructures was observed at a wavelength of ~1.3 μm at room temperature. In addition, NWs with QDs based on other systems of materials were synthesized and their physical properties were studied. Thus, the grown nanostructures with controlled properties are promising for creating applications in the field of quantum informatics, cryptography,

and telecommunications.

Keywords: Semiconductors, Nanowires, Quantum Dots, Molecular-Beam Epitaxy, Silicon.

Acknowledgement: This work was done under financial support of St. Petersburg State University under research grant № 94031047.

REGULAR SESSIONS

Id-637

Numerical Simulations of Electronic Transport in Type II Superlattice Device

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Abstract: Numerical simulations of electronic transport in superlattice (SL) p-i-n diode are reported. Due to the unique features offered by SL material like e.g. tuneable gap, high absorption coefficient and low tunnelling currents the SL-based devices receive growing interest as photodetectors of mid-infrared radiation. On the theoretical side the SL-based devices are usually modelled with the semi-classical methods in which the superlattice is treated as a bulk material with effective parameters extracted from the kp analysis. As there is little justification for such an approach, an attempt is made to model SL-based device with a quantum method. Namely, the nonequilibrium Green's function (NEGF) method is applied to the two-band kp model of InAs/GaSb SL p-i-n diode. In this method apart from the quantum phenomena which are directly included in the formalism through the device Hamiltonian, also the phase breaking mechanisms are accounted for through scattering selfenergies. The analysis takes into account the scatterings on rough interfaces, which is elastic in nature, and scattering with phonons, both acoustic and optical, which is inelastic. Equation of the formalism are self-consistently solved in the real space giving at the output the Green's functions (GFs) which are the functions of the 4 parameters, namely: two position coordinates (z, z'), the in-plane momentum modulus (k), and the total energy (E). From these functions the physical quantities such density of states, carries and currents (resolved in z, k and E) were estimated. Results of these simulations will be presented. The focus is paid to band-to-band (btb) tunnelling with the aim to validate the equations used for its semi-classical description. The results of calculations presented in Figure 1 demonstrate that in the SL-based diode the btb tunnelling occurs only at certain values of the in-plane momentum, k, at which electronic and hole sub-bands cross. This is in contrast to the bulk materials, where there is a continuous range of such k-values. The simulations reveal much more differences. Accordingly, care must be taken when applying the semi-classical models in order to describe btb tunnelling in SL-based devices.

Keywords: Type II Superlattice; Electronic Transport; Nonequilibrium Green's Function.

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REGULAR SESSIONS

Id-645

Quantum Key Distribution Over Global Distances by Using Quantum Thermodynamics Restrictions

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Abstract. One of the key practical challenge for quantum cryptography is secret key distribution over long distances. Unfortunately, in conventional approach there is a fundamental Pirandola-Laurenza-Ottaviani-Banchi (PLOB) bound [1] on secret key rate without quantum repeaters, which are far from practical use as they manipulate fragile entangled states. Otherwise, one can use trusted nodes along the line, and ensure their security by the classical methods, which nevertheless significantly decreases the overall security. Other technologies like, e.g., Twin-Field QKD, are not scalable.

In our work [2], we consider an alternative approach to quantum key distribution which is based on the restrictions of quantum thermodynamics. As it was shown recently ([3], [4]), only a negligible fraction of photons from natural losses in optical fiber can be collected effectively to obtain information. This result implies that one can relax a traditional assumption of conventional quantum key distribution that the eavesdropper gets all the information from the channel losses.

We show that this paradigm shift enables us to reach global distances in quantum key distribution with no compromises on security. The only thing that we sacrifice is what can be called ``channel device independence'', thus our proposition is more device-dependent than the PLOB-restricted ones. We discuss the concepts of quantum cryptography and practical aspects for the difference between the security and device independence.

Keywords: Quantum Key Distribution; Quantum Cryptography; Quantum Thermodynamics; Long-Distance Quantum Cryptography; Quantum Amplifiers.

REGULAR SESSIONS

Id-653

Existing Qkd Protocols Enhancement via Continuous Monitoring of Artificial Leakages in the Transmission Line

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Abstract: In conventional quantum cryptography paradigm, the eavesdropper (Eve) is seen as capable of exploiting all the losses from the quantum channel. This puts a strong restriction on the number of photons in the transmitted quantum states: too high intensities cause the increase of lost photons, which Eve may exploit to extract a significant amount of information about the key. We apply close quantum mechanical examination (namely, the Holevo bound) to the information that can be extracted from the photons scattered at quenched disorders of the optical fiber. The study demonstrates that to sabotage the security of quantum communication, the eavesdropper has to cover an unfeasible length of the fiber with quantum Maxwell demon-like detection devices.

Based on this principle, we enhance the existing QKD protocols' key generation rates and communication distances by increasing the signal's average photon number and continuous monitoring of information leaks in the quantum channel. Precise estimation of the information available to the eavesdropper in any quantum cryptography scenario allows for the less destructive reduction of the key length during the privacy amplification procedure. The proposed approach results in the boost of the key generation rates by an order of magnitude for BB84, COW, DPS and other existing QKD protocols.

Keywords: Quantum Cryptography; Scattered Photons; Holevo Bound; Privacy Amplification.

REGULAR SESSIONS

Id-654

On the Securıty of a Long-Dıstance Quantum Key Dıstrıbutıon Protocol Utılızıng Optıcal Amplıfıers

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Abstract. Quantum key distribution (QKD) protocols providing unconditional security are applicable only at relatively short distances due to the rapid signal decay in quantum channels. Optical amplifiers installed along the transmission line in order to compensate for the natural losses could represent a solution. Yet, in the conventional quantum cryptography framework, the intensities of signal states are relatively low, and the signal gets suppressed by the spontaneous emission of the amplifiers' medium. Treating quantum communication as a physical process, we narrow the range of feasible eavesdropping attacks -- this opens the possibility of utilizing high intensities and, hence, optical amplifiers.

We design an exemplary prepare-and-measure QKD protocol exploiting optical coherent states and examine its security via upper-bounding the information available to a potential eavesdropper creating artificial signal leakages. The provided analysis addresses the correlations induced by optical amplifiers between the eavesdropper and the legitimate receiver. In addition, we propose an effective post-selection strategy to eliminate the correlations' influence. Using numerical optimization, we determine the optimal parameters of the protocol's experimental setup and estimate the achievable secret key generation rates. The study results show that the proposed protocol is unprecedentedly efficient on global distances over thousands of kilometers.

Keywords: Quantum Key Distribution, Optical Amplifiers, Quantum Correlations, Spontaneous Emission, Post-Selection Procedure..

REGULAR SESSIONS

Id-671

Impact of Laser Surface Texturing in Sustainability at Homes: Improvements in Energy Efficiency for Tumble Dryer Machines

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Abstract: Over the last decade, laser surface texturing (LST) has emerged as one of the leading processes for surface engineering and the enhancement of surface functionality for a wide range of applications. PROMETHEUS, a European Horizon 2020 funded project, covers the development of high-speed texturing of metal surfaces using a purpose-built Direct Laser Interference Patterning (DLIP) system, incorporating integrated surface monitoring. The PROMETHEUS system is being explored by Arçelik, one of the consortium members, for applications on energy-efficient household appliances requiring high-quality surface finishes. For this purpose, Arçelik is interested in applying the PROMETHEUS technology to create textures exhibiting super-hydrophobic properties for heat pump tumble dryers. The heat exchanger of the Arçelik's dryer incorporates aluminum fins where super-hydrophobic textures (θc >150°) are being investigated for reducing energy consumption. Preliminary studies were carried out at AIMEN's laboratories in Spain, on aluminium fins having textured areas of 100 mm2. Initial results have achieved a water droplet contact angle higher than 160° after applying a low-temperature annealing process at 200 °C for 6 hours. While these initial annealed surfaces continued to exhibit θc > 160° for periods of up to 30 days after processing, the hydrophobic performance deteriorated in a simulated operating environment, depending on the drying conditions set by the test simulator. The investigation of producing enhanced textures using the PROMETHEUS DLIP laser system is currently underway at the Manufacturing Technology Centre, in England to develop and enhance the texture performance and durability of the textured surfaces.

Keywords: Laser surface texturing, aluminum, hydrophobic texture, heat pump, tumble dryer, energy efficiency

POSTER SESSIONS

Id-669

Synthesis of the Chromium Compound Based on Petroleum Raw and Analysis by X-Ray

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Abstract: Many reactions of modern organic chemistry rely on heterogeneous catalytic systems, as they are superior to homogeneous catalysts in their simplification of the technology of use. They are easy to separate from the reaction zone by filtration or centrifugation, they can be reused many times and their cost is significantly low. In [1], data on the use of metal oxides as catalysts for organic synthesis are summarized. We have proposed the synthesis of chromium-containing compounds based on petroleum raw materials by the CVD method. The sample was synthesized under conditions of supply of argon and hydrogen in a ratio of 2:1, for 4-8 hours, at a temperature of 400-800°C. Gas supply rate: Ar = 0.2 l/min; H_2 = 0.1 l/min.

The phase composition and microstructure of the obtained sample were determined by X-ray diffraction using XRD TD3500 (China), using CuKα radiation and a nickel filter. X-ray phase curves were taken by the Bragg-Brentano method at room temperature in the range of angles 5-84^o at 2θ (2-theta). The average grain size was estimated from the width of the diffraction patterns using the Debye–Scherer formula: $d = k\lambda/\beta\cos\theta$, where d is the average crystallite size, λ is the radiation wavelength λ(CuKα) = 1.54051 Å, β is the peak width at half maximum, θ is the diffraction angle, k = 0.9.

As a result of the research, it was determined that the studied sample has a crystalline shape and a rhombohedral structure consisting of Cr_2O_3 oxide.

It can be seen from the figure that the greatest intensity is observed in the angles between the directions of the incoming and outgoing beam in the values: 24.482(2θ) – 3.6330(d(E)); 33.588(2θ) -2.6660(d(E)); 36.191(2θ) - 2.4800(d(E)); 54.865(2θ)- 1.6720(d(E)).

Keywords: Chromium Compound, Synthesis, X-Ray.

ALL SUBMISSIONS & TOPICS

Topics	Submissions
Optical Materials and Applications	Id 635 - Applications of AES, XPS and TOF SIMS to phosphor nanomaterials
High Power Laser Technology, Ultrafast Optics and Applications	Id 672 - Laser and Additive Technologies for Industrial Application of Production and Repairing of Terrain, Marine and Aeronautical Engineering
Optical Sensors	Id 674 - An Overview and the Future Directions for Distributed Fiber Optic Sensing Systems
Biophotonics	Id 636 - Fluorescent Markers for Early Detection of Cancer
	Id 638 - Weed control with a 2 μm fiber laser: How does the laser beam affect non-target organisms?
	Id 646 - Site-Specific Delivery of Photo-Generated Cytotoxic Species
Optical and Quantum Communications	Id 651 - End-To-End Line Control For Optical Quantum Key Distribution
	Id 652 - III-V Nanowires with Quantum Dots on Silicon
	Id 645 - Quantum Key Distribution Over Global Distances By Using Quantum Thermodynamics Restrictions
	Id 653 - Existing Qkd Protocols Enhancement via Continuous Monitoring of Artificial Leakages in the Transmission Line

	Id 654 - On the Security of a Long-Distance Quantum Key Distribution Protocol Utilizing Optical Amplifiers
Photodetectors	Id 637 - Numerical Simulations of Electronic Transport In Type II Superlattice Device
Green Photonics, Energy and Related Technologies	Id 671 - Impact of Laser Surface Texturing in Sustainability At Homes: Improvements In Energy Efficiency For Tumble Dryer Machines
	Id 669 - Synthesis of the Chromium Compound Based on Petroleum Raw And Analysis by X-Ray