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Abstract Book

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1. ASTROPHYSICS

1.1. Vikram Kumar Jaiswal, CFT PAN

Modeling Light Echoes in Active Galactic Nuclei (AGN)

Light echo measurement (continuum reverberation mapping) is one of the pivotal methods to study the accretion disk with a micro-arcsecond resolution, which is highly unlikely to obtain from any current telescopes. The "Lamp-Post Model (Martocchia & Matt 1996)" successfully explains the observed delayed UV and optical correlation in active galactic nuclei(AGN). In this model, the disk reprocesses the highly ionized photon from the corona into UV/optical light but with a delay. This delay incorporates the combined light travel time from the lamp to the disk and the disk to the observer, and the response function captures this information. I will discuss the response function for different wavelengths and the delay versus wavelength plot. Along with this, I will present my research based on artificial stochastic light curves for the primary source of radiation; And I will address the issue of how the contribution from the Broad Line Region (BLR) affects the results.

1.2. Anjitha John William Mini Lathi, CFT PAN

Deep learning based photometric redshifts of galaxies in Kilo-degree survey

One of the biggest challenges in astronomy is to measure distances to celestial objects. This is especially the case for far-away galaxies, which are millions and billions of light years from us. The traditional observational technique to measure galaxy distances is by obtaining their electromagnetic spectra - detailed decomposition of the light arriving to us - and computing the so-called redshift, related to the expansion of the Universe. However, exact redshifts can only be obtained for a small percentage of all observed galaxies. In the era of O(10^8) galaxy samples, other techniques of distance estimation are being developed, and among them are those using machine learning to estimate the redshift from galaxy images at different “colors” - different electromagnetic wavelengths or frequencies. For many years now methods such as artificial neural networks have been used for that purpose, and they have relied on post-processed, summary information about galaxies, in the form of galaxy fluxes measured for the different colors. However, more precise information about galaxy distances can be extracted directly from their full images, which encode many features lost in the post-processing (“data reduction”). This is where deep learning techniques excel and

in my talk I will show how we employ convolutional neural networks to estimate redshifts from state-of-the-art observational data.

1.3. Feven Markos Hunde, CFT PAN

Cosmic web topology and the characteristics of dark matter subhaloes

The cosmic web, a complex network of thin walls, elongated filaments, and dense clusters enclosing empty voids, provides a map of the universe's dark matter density distribution. Dark matter haloes are structures that form and grow due to the gravitational instability caused by initial density perturbations in the cosmic field, varying in their characteristics, such as mass and contained galaxies, depending on their location within the cosmic web. By studying the effect of the cosmic web environment on subhalo properties, like subhalo velocity function, radial distribution, and others including subhalo mass function, we can gain insights into the impact of location in the cosmic web environment on parent haloes and the galaxies they contain. Although there is some evidence that the features of dark matter haloes differ based on their cosmic web location, understanding the relationship between the properties of dark matter subhaloes and their cosmic web location remains elusive. In this study, we explore the subhalo mass function, velocity function, radial distribution, and other intrinsic properties of dark matter subhaloes through zoom-in N-body simulations. Our findings highlight the influence of parent halo properties and cosmic web location on subhalo properties, shedding light on the connection between the cosmic web and dark matter subhaloes.

1.4. Gursharanjit Kaur, CFT PAN

Target selection for 4MOST WAVES-wide via automated classification

The WAVES survey of the 4MOST has a key science goal of testing the dark matter paradigm. This will be achieved by measuring redshifts of 1.6 million galaxies with two sub-surveys "wide" and "deep". The surveys will be both flux-limited and redshift limited. The WAVES-wide survey intends to target ≈ 0.9 million galaxies with Z band (central wavelength 0.88 µm) magnitude $Z \lesssim 21.1$ mag and a redshift $z \lesssim 0.2$. For the WAVES-deep, the conditions are $Z \lesssim 21.25$ mag and $z \lesssim 0.8$. The selection of galaxies with desired completeness for spectroscopic redshift measurements without a prior idea of the redshift is challenging. The general solution to such a problem is the photometric redshift estimation using the magnitude and color measurements of the target. However, such estimates typically have errors of $\sigma z \gtrsim 0.02$ which might be too large for efficient target selection. Our research intends to use machine learning classification to predict the probability of a source falling

within the redshift limit as required by the WAVES survey, rather than estimate each object's photometric redshift. This way, each potential target will have a probability attached that it lies below the required redshift threshold, which will help optimise the survey planning. We use supervised machine learning algorithms such as random forest, our data being ugriZYJHKs broad-band photometry from KiDS+VIKING, as well as ancillary VST+VISTA observations. The redshift label for calibration is derived from an extensive sample of spectroscopic redshifts including wide-angle and deep surveys overlapping with KiDS and the ancillary fields. Our current results indicate that we should be able to achieve the completeness of 90% of the targets with our methodology which is close to the survey success criteria.

1.5. **Bestin James, CFT PAN**

Black hole outflows initiated by accretion of large-scale magnetic fields

Black holes attract gaseous material from the surrounding environment, and at the same time can be permeated by magnetic fields of external origin. Magnetic pressure acts against the accretion and it can lead to magnetically arrested accretion state. Once the accretion rate diminishes, the magnetic field lines can push the plasma clumps away from the black hole. In this talk, we discuss predictions for outflows that emerge primarily along the equatorial plane of the black hole rotation and above it. To this end, we evolve the initial configuration of accreting plasma and uniform magnetic field in the force-free limit using our version of the general relativistic magnetohydrodynamic code HARM. We notice how the magnetic lines of force start accreting with the plasma while an equatorial intermittent outflow develops and goes on ejecting some material away from the black hole.

2. TOPOLOGY

2.1. **Md Shahin Alam, IF PAN**

Anomalous properties of magnetic Weyl semimetal CeAlSi

Magnetic Weyl semimetals have attracted significant attention due to their fascinating transport properties owing to their nontrivial band structure. Especially large anomalous Hall and anomalous Nernst signals are frequently reported, which allow for a comprehensive study of anomalous transport properties. CeAlSi exhibit ferromagnetic ordering below TC < 8.5 K and crystallize in a non-Centro symmetric space group offering both approach, either broken inversion symmetry or broken time reversal symmetry to

generate the Weyl points. We measured the anomalous Hall conductivity (σ_ij^A) for two different orientations of the magnetic field (B), namely σ_yz^A for B || a and σ_xy^A for B || c, where a is magnetically easy and c is hard axis. In the magnetic phase σ_xy^A and σ_yz^A turn out to be of opposite sign. The sign change of the anomalous Hall effect was originated from shifting of the Weyl point along ΓX direction due to reconstruction of the band structure driven by spin reorientation. Above the Curie temperature σ_yz^A decreases, whereas σ_xy^A increases and reaches maximum at T ≈ 170 K. We also observed the anomalous contribution in the Nernst conductivity (α_xy^A) measured for B || c. In the magnetic phase, α_xy^A/T steeply increases as temperature decreases and above TC slowly decreases with temperature. We were able to recreate the temperature dependences of σ_xy^A and (α_xy^A)/T in the paramagnetic phase using a single band toy-model assuming a non-zero Berry curvature in the vicinity of the Weyl node. Large σ_xy^A and non-vanishing α_xy^A in the paramagnetic phase of CeAlSi appear to be consequences of the fact that the Fermi level lies close to the band crossing point.

2.2. **Pardeep Kumar Tanwar, IF PAN**

Gravitational anomaly in antiferromagnetic topological Weyl semimetal NdAlSi

Quantum anomalies are the breakdowns of classical conservation laws that occur in the quantum–field theory description of a physical system. They appear in relativistic field theories of chiral fermions and are expected to lead to anomalous transport properties in Weyl semimetals. This includes a chiral anomaly, which is a violation of the chiral current conservation that takes place when a Weyl semimetal is subjected to parallel electric and magnetic fields. A charge pumping between Weyl points of opposite chirality causes the chiral magnetic effect that has been extensively studied with electrical transport. On the other hand, if the thermal gradient, instead of the electrical field, is applied along the magnetic field, then as a consequence of the gravitational (also called the thermal chiral) anomaly an energy pumping occurs within a pair of Weyl cones. As a result, this is expected to generate anomalous heat current contributing to the thermal conductivity. We report an increase of both the magneto-electric and magneto-thermal conductivities in the quasi-classical regime of the magnetic Weyl semimetal NdAlSi. Our work also shows that the anomalous electric and heat currents, which occur due to the chiral magnetic effect and gravitational anomalies, respectively, are still linked by a 170 years old relation called the Wiedemann-Franz law.

3. MAGNETISM

3.1. Jaydeb Dey, IF PAN

Helical magnetic structure of nanolaminated Mn2GaC MAX phase films

Mn2GaC, a magnetic Mn+1AXn (MAX) phase material, grown as nanolaminated hetero-epitaxial thin films crystalizes in the hexagonal structure (space group P6_3/mmc), with the hexagonal c-axis along the film normal. It is magnetically ordered with the critical temperature of the order-disorder transition at 507 K. At around 214 K this compound undergoes a first order phase transition, and the magnetic structure below the transition point turns out to be complex. The reported results of unpolarized neutron reflectometry experiments have shown the features of antiferromagnetic order with periodicity of two unit cells, in consistence with the AFM[0001]_4^A structure proposed from the theoretical calculations [1]. On the other hand, a nonzero magnetic remanence suggested long range ferromagnetic correlations [2]. The NMR experiments on the 69Ga, 71Ga and 55Mn nuclei performed in this work made it possible to propose the magnetic structure that reconciles the contradictory literature reports. The data were taken at 4.2 K in presence of the external in-plane field varying from 0 upto 5.5 T. The in-depth analysis of the experimental results have shown a helical magnetic structure consisting of the ferromagnetically coupled Mn-C-Mn slabs that are twisted across the Ga layer by 167˚ with respect to the next Mn-C-Mn slab. Therefore, the magnetic structure presents a spiral propagating along the out-of-plane direction (c-axis) with a pitch of about 14 lattice constants[3].

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3.2. Arathi Moosarikandy, IF PAN

Temperature Dependence of Spin Pumping in Ni81Fe19/Pt, Ni81Fe19/SnTe and Ni81Fe19/ Pb1-xSnxSe bilayers

Spin transport between Ferromagnetic (FM)/Normal metal (NM) interfaces has been widely studied in the recent years due to their applications in Spintronics and dissipation less electronics. Spin pumping is one of the prominent methods used to inject pure spin current from a ferromagnetic material to a normal metal, where it can be detected as a charge current via the Inverse Spin Hall Effect. Heavy metals such as Pt and Topological materials such as Bi2Se3 have been widely studied as efficient materials for spin-charge interconversion due to the presence of spin orbit coupling and topologically protected surface states. Topological crystalline insulators such as SnTe and Pb1-XSnXSe are also promising materials for future spintronics applications because of the presence of surface states protected by the mirror symmetry of the crystal in addition to the strong spin-orbit coupling present in them. We systematically studied the spin-pumping effect in a series of Ni81Fe19/Pt, Ni81Fe19/SnTe, Ni81Fe19/ Pb1-xSnxSe bilayers by comparing the broadband ferromagnetic resonance (2-20 GHz) and electrically detected Inverse Spin Hall Effect (ISHE) experiments with respect to temperature (300-4K). We compare the observed ferromagnetic resonance fields, amplitude, and linewidths of the materials as a function of frequency and temperature to determine spin mixing conductance, spin current density, and spin hall angle values.

3.3. **Kausik Das, IF PAN**

Monte Carlo simulations of magnetic properties in (Ga,Mn)N layers

Here we investigate, both numerically and experimentally, the thermodynamic properties of diluted ferromagnetic semiconductor $Ga_{1-x}Mn_xN$. The MBE grown ferromagnetic $Ga_{1-x}Mn_xN$ layers, with x ranging between 3% and 7%, are studied by a superconducting quantum interference device (SQUID). The Curie temperature (Tc) of investigated material has been estimated by thermoremanent (TRM) and zero-field-cooling (0FC) measurements. In order to analyze the experimental data, an atomistic spin model has been proposed. The model takes into account the Zeeman interaction as well as both trigonal and Jahn-Teller anisotropies [1]. A large simulation box, with few thousand Mn ions coupled by ferromagnetic interaction $-J_{ij}S_iS_j$ taken up to 14th neighbors has been employed. First, the standard Monte Carlo (MC) Metropolis method is used [2] to determine the steady state and Tc. MC is universally accepted method for studying the static properties of the various systems, where dynamics is not required. In order to simulate the dynamical properties of the system, a new modified MC algorithm, known as step Monte Carlo (sMC) [3], is utilized. The obtained results have been compared with stochastic Landau-Lifshitz-Gilbert (sLLG) simulations and experimentally observed data.

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3.4. **Amar Fakhredine, IF PAN**

Spontaneous anomalous Hall effect in $SrIrO_3$ (111) thin film

The transition metal oxide $SrIrO_3$ is a nonsymmorphic crystalline symmetry-protected nodal-line semimetal in its bulk Pnma crystal structure[1,2]. When going to the thin film limit, this system becomes an antiferromagnetic insulator with a weak ferromagnetism which occurs due to the spin-canting [3,4]. Using density functional theory, we show that we can obtain the ferromagnetic phase in $SrIrO_3$ only in the face-shared octahedra that are formed by the IrO_3 atoms. We also show that the collinear ferromagnetism cannot be stabilized in the corner-shared phase. We obtain that $SrIrO_3$ with the face-shared octahedra is a Stoner ferromagnet with its magnetization along the c-axis. Finally, we observe a huge orbital magnetic moment of the same order of magnitude as that of the spin magnetic moment.

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3.5. **Sana Zakar, IF PAN**

Magnetic and magnetotransport properties of diluted magnetic semiconductor (Ge1-x-ySixMnyTe) crystals

IV-VI materials doped with magnetic impurities hold potential for spintronic applications particularly by integrating the memory component within the semiconducting matrix. This work intends to investigate the carrier mediated magnetic interactions in GeTe lattice alloyed with Mn ions. We present Ge1-x-ySixMnyTe bulk crystals by altering their chemical composition in the range $0.056 \leq x \leq 0.10$ and $0.0036 \leq y \leq 0.046$. The magnetic phase transition temperature rises from Tc = 25 K to about 160 K for the highest Mn content. The analysis of inverse of susceptibility with modified Curie-Weiss law finds ferromagnetic-like interaction in the alloys. The magnetically glassy samples were interpreted with frequency dependent susceptibility. This identified scaling parameter, R = 0.2 - 0.6 which indicate the formation of clusters in the glassy samples. Finally, the temperature and concentration dependence of anomalous Hall Effect (AHE) is interpreted in terms of extrinsic scattering mechanisms.

4. THIN FILMS

4.1. Sameh Altanany, IF PAN

Vortex glass transition and thermal creep in Nb films

The vortex glass phase transition in disordered two-dimensional Nb films with different thickness was studied by measuring the temperature-dependent resistance and the current–voltage (IV) characteristics in perpendicularly applied magnetic fields. Analysis using standard nonlinear I-V scaling laws shows that the vortex glass transition has a non-universal nature since the scaling leads to a deviation from theoretical predictions. Comparison of our results with the standard strong pinning theory suggests that non-universality of the quasi two-dimensional vortex glass scaling may be generated by the presence of thermal creep effects. We believe that thermal creep in our films is primarily driven by the intrinsic features of the fractal superconductivity which is induced by structural disorder.

4.2. Krzysztof Golyga, IWC PAN

Growth of Niobium Nitride films on III-Nitrides by Molecular Beam Epitaxy

Niobium nitride (NbN) is a II-type superconductor which has metallic electrical properties in normal state and its critical temperature (Tc) is about 17 K. NbN crystallizes in cubic, tetragonal and hexagonal structures. Among them, the phase with the highest temperature of superconducting transition (Tc) is cubic one (δ) [1]. Recently it has been shown that rocksalt NbN can be epitaxially grown on hexagonal Ga-polar (0001) GaN substrates [2]. The phase of NbN can be determined by i.e. X-ray diffraction (XRD) symmetric coupled scans, XRD reciprocal space mapping and Tc measurements [1]. Because of GaN grown on NbN tends to be of N polarity [3] and also Ga creates an alloy with NbN [2], the preferable growth conditions are N-rich. It has been shown that GaN growth in N-rich conditions gives satisfying results only on N-polar substrates [4]. Therefore, it is crucial to have a good control of NbN growth on N-polar substrates in N-rich conditions. Obtaining such control opens perspective for new devices like good quality Josephson junctions. In this research work, the growth rate and conditions for growth of δ-NbN phase was tested on Ga-polar and N-polar GaN substrates by plasma-assisted MBE. As Nb source, the e-gun evaporation of Nb pellets has been used. The morphological and electrical properties of epitaxial NbN layers will be discussed.

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4.3. **Pushkar Joshi, IF PAN**

Spectroscopic signatures of energy transfer in inhomogeneous films of CuInS2 quantum dots

Energy transfer (ET) in colloidal quantum dot (QD) films has been a highly studied area in pursuit of applications such as solar cells. The size-dependent optical properties of QDs make them interesting candidates for such exploration. The environmentally safer QD materials such as CuInS¬2 (CIS) have not been explored as much as Pb and Cd chalcogenide QDs in this regard. The significant Stokes shift of CIS and the scope for changing its stoichiometry provide additional parameters that affect the ET efficiency. Here, we report the results of the steady-state photoluminescence (PL) and time-resolved PL (trPL) of films and solutions formed of an ensemble of CIS QDs highly inhomogeneous in PL energy. Comparison of the results between the film and solution samples unveils three signatures of ET in QD films: (i) the redshift of the PL spectrum: the peak PL energy of the QD ensemble redshifts from 1.78 eV in solution by over 50 meV on a film, (ii) the increase of the PL decay rate: the fastest PL decay in QD solution is two times faster than the slowest one whereas in film it is 10 times faster, and (iii) the presence of PL rise dynamics: at a low temperature of 25 K, the trPL intensity is seen to increase for about 150 ns before decaying at the smallest detection energy. We also discuss the ways to diminish or enhance ET, namely, increasing the inter-QD separation by encapsulating them with micelles or increasing the overlap between the PL spectrum of the donor QDs and absorbance spectrum of the acceptor QDs, respectively.

5. OPTICAL PROPERTIES

5.1. **Omer Farooq, IF PAN**

Investigation of Spectral Properties of Quantum Graphs and Microwave Networks

Quantum graphs provides efficient model systems for the experimental and theoretical study of closed and open quantum system with chaotic classical dynamics. They have been

widely used to model various physical systems, such as quantum wires and mesoscopic quantum systems. Microwave networks can be applied for experimental simulation of quantum graphs. Microwave networks allow the simulation of quantum systems described within the framework of the random matrix theory (RMT) by Gaussian orthogonal ensemble (GOE) and Gaussian symplectic ensemble (GSE) systems with preserved time reversal symmetry (TRS), and Gaussian unitary ensemble (GUE)−systems with broken TRS. Therefore, any theoretical or numerical results obtained for quantum graphs can be verified experimentally by using microwave networks. In present work, we will experimentally investigate the spectral properties of quantum graphs and microwave networks.

5.2. **Saranya Narayanan, IF PAN**

Luminescence study of LiGa5O8 :Mn powders

The development of impurity-doped phosphors has been continuously pursued versatile applications nowadays. In this work, LiGa5O8:Mn has been investigated by the mean of luminescence excitation spectra and luminescence decay kinetics. Upon 298 nm excitation, the phosphor exhibits strong photoluminescence (510 nm) which corresponds to the 4T1-6A1 transition of Mn2+ ions, probably in an environment - of tetrahedral symmetry. Mn4+ showed sharp emission lines observed in the region ~600-780 nm. Such sharp emissions are attributed to the Stokes and anti-Stokes 2Eg-4A2g transition in the Mn4+ ions. It exhibited different excitation spectra for different environmental symmetries of Mn4+ ions. The temperature-dependent photoluminescence (PL) measurement excellent agreement has been achieved if not only the optical phonon but also acoustic phonon contribution is taken into consideration in the conventional thermal quenching. Effects of hydrostatic pressure on the PL were studied using a diamond anvil cell up to 18GPa to characterize the Mn charge states and the changes in the electronic properties without a change of chemical composition.

5.3. **Joanna Olas, IF PAN**

Imaging the S0→S1 transition moments of single organic dye molecules in a crystalline matrix

Detection of single organic dye molecules has been a very important field of research for over 30 years, as it provides a sensitive nano-environment probe, without the need to average the results over the set of molecules. In this study, an attempt was made to visualize the direction of the S0→S1 transition in terrylene molecules (Tr) placed in the structure of naphthalene (N) and 2,3-dimethylonaphthalene crystals (23DMN). The direction of the observed transition reflects the direction of the long axis of the Tr molecule, so it is possible to obtain precise information about how the guest molecules integrate into the

host crystalline structure. It will be of particular interest for the 23DMN crystals, in which there is an orientation disorder in the direction of the methyl groups of the host molecules. Each guest molecule, Tr, has a slightly different environment in this crystal type, which should be reflected in the long axis direction of the guest molecules. For the purposes of this research, the confocal microscope, previously used for research at low temperatures, was rebuilt. Measurements are carried out at the room temperature, so a microscope with an immersion liquid (Nikon 60x / 1.40 Oil) was used. The crystalline sample (places on a slide) was moved in the X and Y axis by a piezo-scanner (PXY36 piezosystemjena). The beam of Light used for Tr molecules excitation was linearly polarized with its middle part obscured.

6. NANO-STRUCTURES

6.1. Priya Singh, IF PAN

Thermodynamics of Nanostructures at Low Temperatures

At the mesoscopic level, with the help of our experiments, we would like to inspect the energy exchange efficiency between two nanostructures mediated by the phonon emission channels. Usually, such processes are too rapid to be detectable. Our pioneering methodology provides enough temporal resolution to investigate their dynamics. At low temperatures testing a nanostructure involves inevitable dissipation. It accounts for not only the heating of the probed nanostructure but also affects remote devices on the same chip. However, the second effect was difficult to probe due to not appropriate experimental protocols. We send electrical pulses on the copper heater line and record temporal traces of the electron temperature at a fixed heating current IH (μA) using the calibration curve. From a device fabrication point of view, we use three-step electron beam lithography and electron beam evaporation. They allow us to make the Copper heater and Aluminium thermometers on the same chip. Our experiment will give qualitative insights into the efficiency of energy exchange between two galvanically isolated nanostructures mediated by the phonons.

6.2. Wiktoria Zajkowska, IF PAN

Crystallization and characterization of ZnO//FeGa nanowires for nano-devices applications

The hybrid core-shell nanowires (H-NWs) with piezoelectric material cores (e.g. ZnO (0001)) and magnetostrictive alloy shells (FeGa) can be used as nano-devices controlled by external electric and magnetic fields. Both piezoelectric and magnetostrictive properties altered e.g. by mechanical deformation at the core-shell interface and can generate a magnetic field around H-NW under the influence of voltage, and vice versa. This means that such

nanoobjects are sensitive to fluctuations of the environmental electromagnetic field. In the case of ZnO, the H-NWs cores are crystallized on an a-sapphire substrate using the modified carbothermal method. Vertically oriented nanowires with lengths of 20-100 µm and average diameters of 90-700 nm were obtained. As-grown NWs underwent the shell growth deposition in the two ways: using MBE technique and magnetron sputtering. In this way, ZnO//FeGa H-NWs with continuous polycrystalline shells and half-shells were obtained. NWs were coated with about 5 nm Pt or Al protection layer. The quality of the H-NWs was examined by TEM imaging which evidenced that the shells have a textured polycrystalline structure and some grains have an epitaxial relation to the monocrystalline, crystallographically perfect core.

6.3. **Ajeesh Kumar Somakumar, IF PAN**

Pressure-induced emission colour tuning of ZnS: Mn2+ nano phosphor

Transition metal-doped, luminescent Zinc Sulphide (ZnS) semiconducting nanoparticles have potential applications in the biological field and optoelectronic devices. The Manganese (Mn2+) doped ZnS sample was synthesized by a simple chemical precipitation technique. The sulphide nano phosphor was characterized utilizing SEM, Raman, ambient and high-pressure photoluminescence and decay measurements using diamond anvil cells (DAC) etc. The SEM results also show the formation of well-dispersed particle structures throughout the sample. The photoluminescence studies in the Vis-NIR range were done at ambient & high-pressure conditions. The synthesized phosphor has an orange luminescence band centred around 600 nm related to the 4T1 → 6A1 transition under ambient conditions and it shifted towards higher wavelengths with the increase of pressure and completely quenched at 16.41 GPa due to the phase transition. The decay time analysis confirms that the phosphor has a milliseconds lifetime at ambient conditions. The overall results point towards the potential emission colour-tuning application of ZnS: Mn2+ phosphor with pressure.

7. SEMICONDUCTORS 1

7.1. **Mahwish Sarwar, IF PAN**

Post-implantation Defect Accumulation in Crystal Lattice of β-Ga_2O_3 Implanted with Yb ion

Gallium oxide (Ga_2O_3) is an ultra-wide bandgap semiconductor of interest for many applications, including optoelectronics. Undoped Ga_2O_3 emits light in the UV range that can be tuned to the visible region of the spectrum by rare earth dopants. Ytterbium may further

enhance the span of applications due to emission in the infrared region of the spectrum. Ion implantation is a renowned doping technology used for the alteration of material properties. Despite many advantages of this technique, it could lead to lattice damage and defect accumulation which need to be studied thoroughly as these factors strongly influence the material properties. Our previous work, where we studied structural defects and recovery of the crystal lattice of β-Ga_2O_3 after Sm implantation and post-implantation annealing, indicates that the damage of the crystal lattice after implantation is not typical and needs further investigations. In the present study, the (-201) orientated β-Ga_2O_3 single crystals were implanted with Yb ions fluences ranging from $5x10^{11}$ to $5x10^{15}$ atoms/cm^2. Channeling Rutherford backscattering spectrometry (RBS/c) was used to study modification of the crystal lattice induced by ion implantation and annealing. The RE depth profile was analyzed by the SIMNRA calculations, while the McChasy simulations were used to quantify the defect distributions. The obtained accumulation curve reveals the two-step damage process. From the fluence of $5x10^{13}$ /cm^2, the damage of the Ga_2O_3 lattice starts to increase very fast, reaching the amorphization level for the Yb ion fluence of $1x10^{14}$ /cm^2. The new form of defect that is created on the highest level is found to be annealing resistant.

7.2. **Vasyl Stasiv, IF PAN**

Chemical Tuning and Temperature Behavior of Mn4+ Photoluminescence in Ga_2O_3–Al_2O_3 Alloys

In this study, we carried out a detailed investigation of the photoluminescence of Mn4+ in Ga_2O_3–Al_2O_3 solid solutions as a function of the chemical composition, temperature. For this purpose, a series of (Al1–xGax)2O3:Mn4+,Mg phosphors (x = 0, ..., 0.1.0) were synthesized and characterized for the first time. A detailed crystal structure analysis of the obtained materials was done by the powder X-ray diffraction technique. The results of the crystal structure and luminescence studies evidence the transformation of the ambient-pressure-synthesized material from the rhombohedral (α-type) to monoclinic (β-type) phase as the Ga content exceeds 15%. Spectroscopic features of the Mn4+ deep-red emission, including the temperature-dependent emission efficiency and decay time. The luminescence properties of this material were compared with β-Ga_2O_3:Mn4+. Finally, we evaluated the possibility of application of the studied phosphor materials for low-temperature luminescence thermometry.

7.3. **Sania Dad, IF PAN**

Surface and Structural Analysis of (110)-grown Pb1-xSnxTe Topological Crystalline Insulator

The novel class of semiconductors namely topological crystalline insulators (TCIs) is a rapidly developing research area of modern solid state physics. In these materials, surface electron states with Dirac dispersion relation are formed on certain high symmetry surfaces. Pb1-

xSnxTe alloy has been experimentally discovered as a member of TCIs family in the previous decade. It exhibits topological phase transition above a critical concentration of Sn ($x \geq 0.36$ at LHe temperature). Theoretical predictions of band inversion at high symmetry L point in the Brillouin zone, and experimental evidence for topologically protected states on (001) and (111) surfaces of Pb1-xSnxTe alloy have already been proclaimed in literature. However, (110)-oriented Pb1-xSnxTe has not been studied experimentally in this context yet. We have grown thin layers of Pb1-xSnxTe solid solution by molecular beam epitaxy (MBE). To our knowledge the growth of Pb1-xSnxTe in the (110) orientation has not been reported so far. We have found that direct growth on epi-ready GaAs(110) substrates resulted in non-uniform layers with mixed (100) and (111) orientations. To get around this problem we have used hybrid substrates with thick CdTe(110) buffer grown in separate MBE system. The layers have been investigated by several characterization techniques such as energy dispersive X-ray fluorescence, atomic force microscope, X-ray diffraction and, high resolution transmission electron microscopy which reveals the (110)-orientation of Pb1-xSnxTe. Angle-resolved photoemission experiments are underway to identify topologically protected surface states on the Pb1-xSnxTe(110) surface.

7.4. **Syed Shabhi Haider, IF PAN**

$LiTaO_3$:Pr: A Smart Optical Material for Remote Stress Sensing Applications

In this oral presentation, we briefly demonstrates mechanoluminescence (ML) phenomena and ML experimental setups, while specifically talk about the ML properties of $LiTaO_3$ samples (S1, S2 and S3) doped with variable percentage (1%, 3% and 5%) of praseodymium that have been experimentally examined by dissimilar mechanical stimuli based ML setups. Initially, luminescence properties of synthesized samples that performed in visible region were discussed, revealed identical photons emission in all samples at two different energy bands 510 and 616 nm wavelengths associated with $^3P_0$ to $^3H_4$ and $^1D_2$ to $^3H_4$ transitions states of Pr^{3+}, respectively. Afterward, we presents the ML results of prepared samples that scrutinized by impact induced ML (I-ML) setup at different kinetic energies (250 to 290 mJ) demonstrates ultrafast remote sensing of applied mechanical impact with good signal retentivity. Furthermore, stress induced ML measurements were exhibited at various stress application rates (200 to 600 mm/min) under maximum 9% and 14% deformation conditions. The extracted result validates the perfect superposition of detected time dependent ML intensity curves with applied mechanical force signal. Among all of them, S3 have prominent and extraordinary ML intensity with small back ground persistence luminescence due to appropriate traps formation and less luminescence centers. This novel study proposed $LiTaO_3$:Pr as a suitable candidate for ultrafast, sensitive and remote detection of diverse mechanical impact or stress in numerous engineering and medical application.

Acknowledgement

This work was supported by the National Science Center Poland Grant 2019/33/B/ST8/02142.

7.5. Mikołaj Chlipała, IWC PAN

Enhanced injection efficiency in double-color III-Nitride LEDs

Introduction

III-nitride possess several unique qualities which allowed them to make the world brighter, but uniqueness is not always beneficial as in the case of III-nitrides. Uniaxial nature of the wurtzite crystal leads to strikingly large electric polarization fields. For light-emitting diodes (LEDs), this phenomenon, along with the high acceptor ionization energy, causes low injection efficiency and uneven carrier distribution for multiple quantum well (QW) devices [1, 2]. Though, built-in polarization can also be added as a valuable design parameter.

In this work, we explore the carrier distribution in standard Ga-polar LED, where built-in polarization ( ) is parallel to current flow ( ) and, less standard case, where its antiparallel. The latter one mimics an N-polar alignment but still uses a Ga-polar substrate. This is accomplished by utilizing a bottom tunnel junction (BTJ), which enables the inversion of the sequence of the p and n layers while altering the direction of current flow in relation to the inherent polarization [3]. To probe the carrier distribution two, color coded QWs are used in alternating sequence.

Experimental

Four LED structures were grown on free-standing Ga-polar GaN substrate using plasma assisted molecular beam epitaxy. Each has a 2.6 nm double QW, one emitting at a lower wavelength using In0.17Ga0.83N and the other emitting at a longer wavelength using In0.22Ga0.78N. Their sequence is varied. According to the sequence of the corresponding QWs along the growth direction, we denote each structure BG or GB, where B is for blue QW and G for green. Two of the samples have a top TJ (TTJ) construction and active region order BG and GB. These represent a standard approach to the GaN based LEDs where is parallel to . The following two LEDs include a bottom TJ below the active region with QW in order BG and GB. These represent the case where is antiparallel to . Each TJ consists of 15 nm In0.15GaN layer with Ge and Mg doped halves. The TJ allows termination of the LEDs with n-type layer, which offers low resistivity and uniform current spreading. Samples were co-processed into LEDs with mesa sizes ranging from 100x100 µm2 to 350x350 µm2.

Results

We observe that luminescence from QW closest to the p-type dominates spectra for samples with top TJ regardless of the In concentration. In this case, the hole mobility is the largest bottleneck limiting the recombination in QW further away from the p-type [4]. In contrast, light originating from the green QW (the one with the highest In content) dominates spectra for samples with bottom TJ. The built-in polarization prevents, both electrons and holes from escaping the QW, and this effect is stronger for QW with higher In content (i.e green). For BTJ GB LED this leads to negligible recombination in blue QW, which is further away from p-type, as holes are unable to reach the second QW. Whereas, for BTJ BG LED, at low current density, recombination occurred only in the green QW showing that second, high built-in field in green QW acts as an effective electron blocker, preventing electrons from overflowing it and reaching the blue QW.

Moreover, BTJ LEDs have lower turn-on voltage than standard and TTJ LEDs due to the absence of the usual barriers for current injection [3]. Noticeable light emission at 546 nm occurs at voltages as

low as 2.20 V. All samples exhibit a smooth surface evaluated by atomic force microscopy (AFM).
Conclusion
The findings demonstrate how the inversion of the current flow direction relative to the built-in field causes a change in carrier transport and distribution between double QW. In contrast to conventional LEDs, BTJ LEDs' QW prevents carriers from escaping, enhancing injection efficiency.

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8. BIOPHYSICS

8.1. Midhun Anila, IF PAN

Coarse-grained molecular dynamics of intrinsically disordered proteins

Intrinsically disordered proteins (IDPs) at physiological conditions have no stable structure in extended parts of their polypeptide chains. We use molecular dynamics (MD) methods to study conformations and interactions of IDPs. Since IDPs typically exhibit large conformational fluctuations on time scales of microseconds or longer, we use coarse-grained (CG) models, where groups of atoms are represented by single beads, which significantly reduces the computation time. Firstly, we employ our locally developed CG Cα-based model [1] to study aggregation of α-synuclein. In particular, we investigate how α-synuclein aggregation depends on protein concentration and temperature. Secondly, use Martini 3 model [2] to determine the conformational ensemble of galectin-3. We follow the approach of Thomasen et al. [3] and rescale water-protein interactions to obtain a conformational ensemble consistent with data from small angle X-ray scattering experiments.

8.2. Barbara Klepka, IF PAN

Coral polyanionic protein-mediated formation of calcium carbonate spherulites

Increased concerns about rising temperatures and ocean acidification are spurring scientists to investigate how it can affect the processes ensuring the survival of marine organisms. One of such vital processes is biomineralization, however, still little is known about the molecular mechanisms behind it. Coral acid-rich proteins (CARPs) are postulated to be involved in the process of skeleton formation. So far, only four CARPs have been cloned and shown to induce the formation of aragonite crystals under conditions which do not allow for spontaneous precipitation. Our goal is to elucidate what protein-mediated transient phases appear prior to the fully grown CaCO3 crystals, how are polyanionic proteins distributed within the crystals and what is their role in vitro in the formation of spherulitic structures of calcium carbonate, which were identified in the coral skeleton. We cloned for the first time

two novel CARPs from Acropora millepora – secreted acidic protein 1A (SAP 1A) and aspartic and glutamic acid-rich protein (AGARP). By means of i.e. fluorescence correlation spectroscopy, confocal imaging and SEM we aim to decipher the early stages of the CARP-mediated nucleation pathway.

8.3. **Pamela Smardz, IF PAN**

Disulfide Bonds in Lipid Transfer Proteins - Molecular Dynamics studies

Disulfide bonds are one of the most common types of post-translational modification found in proteins (Feige, 2018) and are covalent bonds formed between sulphur atoms of the two cysteine side-chains, which can be located in the same protein molecule (intramolecular) or between two different protein molecules (intermolecular). Disulfide bonds are an essential feature of many proteins and their formation can have a significant impact on protein structure, stability, activity, and function. For a long time, it was believed that the main function of the disulfide bonds is to stabilise protein structure, however, not always lack of the disulfide bond decreases protein stability or the formation of the additional disulfide bond increases it. Our area of particular interest is the study of biologically important proteins that possess native disulfide bonds. For example, Lipid Transfer Proteins (LTPs) are a family of proteins found in land plants that have been involved in a wide range of biological processes, including lipid metabolism, signalling, and stress responses (Salminen, Blomqvist and Edqvist, 2016). Despite their importance, the precise function of LTPs in vitro remains largely unknown (Missaoui et al., 2022). To gain a better understanding of the role of disulfide bonds in LTPs, we used all-atom and coarse-grained molecular dynamics simulations, like in our previous studies of Ribonuclease A (Smardz, Sieradzan and Krupa, 2022), that allowed us to study the behaviour of proteins and their interactions with other molecules in various environments, such as in different salinity, temperature, pH or within a proximity of a membrane. Our studies demonstrated that in the absence of any disulfide bonds, the LTP protein maintains its overall shape, with the most notable difference being an increased flexibility of the C- and N-termini. Intriguingly, the presence of a single specific disulfide bond can stabilize the structure more than certain combinations of two or even three disulfide bonds, indicating that their roles within a protein may vary. Studies conducted under harsh conditions (e.g., thermal stress) reveal a more prominent impact of disulfide bonds on LTP stability, suggesting that their function may be more closely related to stress- and enzymatic-protein destabilization and digestion than to maintaining stability under standard physiological conditions.

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8.4. **Nguyen Van Hung, IFPAN**

Antibodies bind to Spike protein to prevent SARS-CoV-2 entering the human cell

The global spread of COVID-19 has devastated health systems and economies worldwide. While the use of vaccines has yielded encouraging results, the emergence of new variants of SARS-CoV-2 shows that combating COVID-19 remains a big challenge. One of the most promising treatments is the use of not only antibodies but also nanobodies. Using molecular dynamics simulations, we investigated the binding affinity of antibodies and nanobodies to the SARS-CoV-2 receptor binding domain. We found that the combination of antibody and antibody as well as antibody and nanobody can significantly improve their neutralizing ability through binding to the SARS-CoV-2 spike protein. Importantly, these combinations have also proven as an excellent solution for the treatment of some SARS-CoV-2 dangerous variants such as the Alpha, Beta, Gamma, Delta, and Omicron.

9. INVITED TALK

9.1. **Professor Izabella Grzegory**

GaN : High Pressure Crystal

10. Quantum Physics

10.1. **Maciej Marciniak, CFT PAN**

Super-Tonks-Girardeau quench in the extended Bose-Hubbard Model

One of the most intriguing features of diluted ultracold quantum gases is the so-called super-Tonks-Girardeau (sTG) effect. This phenomenon, observed in quasi-one-dimensional systems of strongly interacting bosons, implies that the quench from highly repulsive to highly attractive short-range interactions does not lead to the collapse of the system - the gas remains stable for a long time. In my talk, I am going to generalize this problem and address the question of the existence of the sTG states in systems with both local (which are assumed to be strong) and non-local interactions and show that when these two interactions compete with each other, the outcome of the quench of local forces may be

much more drastic in comparison to the case with short-range interactions only. In the particular example of the extended Bose-Hubbard model, it can lead to the destruction and evaporation of self-bound structures formed by the particles.

10.2. **Tae-Hun Lee, CFT PAN**

Objectivity in a simple harmonic oscillator in spin environment

We investigate the objective properties of a simple harmonic oscillator interacting with the collections of 1/2 spin environments. The classicality can be achieved in a particular quantum state, a so-called spectrum broadcast structure (SBS). We assume that the quantum state of the harmonic oscillator is close to a classical state. The measures for the SBS, identified with a decoherence factor and a generalized overlap (fidelity), are calculated in asymptotic limits in couplings and time to show how the SBS state can be realized.

10.3. **Oskar Slowik, CFT PAN**

The efficiency of universal sets of quantum gates

Currently available quantum computers, so called Noisy Intermediate-Scale Quantum (NISQ) devices, are characterized by relatively low number of qubits and moderate gate fidelities. In such scenario, the implementation of quantum error correction is impossible and the performance of those devices is quite modest. In particular, the depth of circuits implementable with reasonably high fidelity is limited, and the minimization of circuit depth is required. Such depths depend on the efficiency of the universal set of gates S used in computation. In this talk I will explain how one can bound the efficiency of such universal sets and discuss some results obtained in our group.

10.4. **Sarath Prem, IF PAN**

Longitudinal coupling between electrically driven spin-qubits and a resonator

At the core of the semiconducting spin qubits success is the ability to manipulate them electrically, enabled by the spin-orbit interactions. However, most implementations require external magnetic fields to define the spin qubit, which in turn activate various charge noise mechanisms. Here we study spin qubits confined in quantum dots at zero magnetic fields, that are driven periodically by electrical fields and are coupled to a mi- crowave resonator. Using Floquet theory, we identify a well-defined Floquet spin-qubit originating from the lowest degenerate spin states in the absence of driving. We find both transverse

and longitudinal couplings between the Floquet spin qubit and the resonator, which can be selectively activated by modifying the driving frequency. We show how these couplings can facilitate fast qubit readout and the implementation of a two-qubit CPHASE gate. Finally, we use adiabatic perturbation theory to demonstrate that the spin-photon couplings originate from the non-Abelian geometry of states endowed by the spin-orbit interactions, rendering these findings general and applicable to a wide range of solid-state spin qubits.

[1] S. Prem, M. M. Wysokĭ nski, and M. Trif, arXiv: 2301.10163 (2023).

11. SEMICONDUCTORS 2

11.1. **Jerzy Plesiewicz, IWC PAN**

Formation and electronic properties of EE1 trap level after 1.5-MeV electron irradiation in homo-epitaxial n-GaN layers grown by MOVPE

We report and compare the results of the formation and electronic properties of the electron traps in MOVPE (metal–organic vapor-phase epitaxy) n-GaN samples grown on highly doped Ammono-GaN as well as in the same GaN material but exposed to high energy 1.5 MeV electron irradiation. In addition to the commonly observed deep levels in GaN such as E1 (0.25 eV) and E3 (0.56 eV), we found that 1.5-MeV electron irradiation introduces two new electron traps, EE1 and EE2, with electronic levels located around 0.14 and 0.98 eV below conduction band (EC), respectively. In the case of EE1 level, a strong influence of the electric field present in the space charge region on the electron emission rate is observed which in turns can suggest donor type character of this trap level. Additionally, we observed that strong electric field as high as 2x105 V/cm can significantly lower activation energy of EE1 level to the value of 0.095 eV. A series of DLTS measurements carried out for different filling times revealed high complexity of the EE1 trap level structure since at least three contributors have been observed in DLTS spectra. Finally, the DLTS analysis of electron irradiated samples allowed us to estimate the average production rate for EE1 trap level to 0.126 cm-1 for n-GaN material grown on Ammono-GaN substrate.

11.2. **Abinash Adhikari, IF PAN**

Bandgap study of {CdO/MgO} superlattice structure

The development of superlattice structures (SLs), using the molecular beam epitaxy (MBE) technique is challenging but meaningful work for technological advancement in semiconductor industries. Here, in this work, short-period SLs composed of alternate CdO and MgO layers were grown on r-plane sapphire substrate using the plasma-assisted molecular beam epitaxy (PA-MBE) technique. The thickness of the structure was estimated from the basis of growth conditions. The sublayer thickness of CdO and MgO were found to be 4 monolayers each. High-resolution transmission electron microscopy (HR-TEM) image confirmed the separation of Mg and Cd elements and a distinct interface between CdO and MgO layers. The optical investigation was carried out using UV-Vis spectroscopy at room temperature. Using the Tauc relation, the direct bandgap was estimated to be around 2.75 eV. The pressure-dependent optical absorption studies were performed using a double-gasket diamond anvil cell (DAC). It has been observed that the optical absorption, associated with direct bandgap of SLs has been shifted toward higher energy with applied hydrostatic pressure in DAC. The bandgap of SLs was varied from 2.76 to 2.87 eV with applied pressure varied from 0 to 5.9 GPa. The pressure coefficient for the direct bandgap of SLs was found to be 26 meV/GPa. The obtained experimental result was supported by theoretical results obtained using density functional theory calculations. The volume deformation potential was estimated using the empirical rule. We believe that our findings may provide valuable insight for a better understanding of {CdO/MgO} SLs toward their future applications in optoelectronics.

11.3. **Anastasia Lysak, IF PAN**

Structural and optical properties of Eu-doped Zn(Mg)O/Cd(Zn)O superlattices

Today, the development of modern optoelectronic devices cannot be imagined without oxide wide bandgap semiconductor materials (ZnO, CdO, GeO2, In2O3, etc). Doped with rare earth (RE) ions ZnO, as well as ternary alloys e.g ZnCdO and ZnMgO, are being actively investigated due to changes in the optical, structural, electrical and magnetic properties and improved emission. ZnO as WBGS can act as a candidate host for doping with trivalent Eu ions. In this work, we present the results of the investigation of the structural and optical properties of in situ Eu3+ doped quasi alloys {ZnCdO/Zn(Mg)O}22 SLs with varied Cd and Mg content in sublayers. The structures were grown on (10-10) m-plane sapphire substrate (Al2O3) by plasma assisted molecular beam epitaxy method. To study the thermal stability and effect on optical properties of the structures the SLs were annealed. Structural, morphological and optical properties of the deposited structures have been studied by using X-ray diffraction (XRD), Secondary-Ion Mass Spectrometry (SIMS), cathodoluminescence (UV) and UV-Vis spectroscopy. The band gap energy showed a strong dependence on the concentration of Cd and Mg in the as grown structures. The XRD pattern of as grown SLs

indicated hexagonal crystal structure. Studies of the CL spectra for in situ Eu-doped {Zn(Mg)O/ZnCdO}m SLs showed at room temperature emission bands at ~615±2 nm, due to the 5D0 – 7F2 intra-4f-shell transition of Eu ions. The highest intensity of the 5D0 – 7F2 peak was observed after annealing.

Polish National Science Center, Grants No. 2019/35/B/ST8/01937, and 2021/41/B/ST5/00216.

11.4. **Juby Alphonsa Mathew, IF PAN**

Europium-doped ZnMgO alloy as perspective material for red light sources

Oxide-wide-bandgap semiconductors are suitable hosts for rare earth ions owing to their availability at low cost, ease of synthesis, chemical stability, and, above all, due to the tunability of their optical and electrical properties. The structural characteristics of Eu-doped ZnO structures have been investigated extensively for the past few decades. However, it is known that the bandgap of Zn1-xMgxO increases with the Mg alloying content, x. The photo-excitation-emissions of Eu ions are expected to be modified when doped inside a tunable wide-bandgap material like Zn1-xMgxO. Our studies showed that the optical activity of Europium is increased by an order of magnitude when around 10% fractional Mg is alloyed to ZnO in comparison to Eu doped pure ZnO matrix. In this project, Eu-doped Zn1-xMgxO thin films of various Mg contents were grown on a-Al2O3 substrates via plasma-assisted Molecular Beam Epitaxy. XRD measurements revealed the hexagonal structure of Eu-doped Zn1-xMgxO films except in one with ~46% Mg content, where both hexagonal and cubic phases were found. XPS analysis showed that Eu exists in 3+ and 2+ charge states. Energy gaps of ZnMgO: Eu thin films were determined from transmission measurements. We show that red emission due to the 5D0 - 7F2 transitions of Eu3+ is effectively controlled by bandgap engineering through Mg alloying. In Zn1-xMgxO alloys with fractional Mg contents above x= ~ 22% transitions from higher energy levels 5D3, 5D2, and 5D1 of Eu3+ are observed. We suggest that the increased PL efficiency is due to the strong localization of excitons and increased oscillator strength in Zn1-xMgxO random alloys that highly enables the energy transfer to Eu ions.

12. DROPLETS

12.1. Russel Kajouri, IF PAN

Unidirectional Droplet Propulsion onto Gradient Brushes Without External Energy Supply

Durotaxis motion due to stiffness gradient is a process in which an agent, e.g. a droplet or a cell, exhibits a unidirectional movement without consuming the energy of an external source. In our recent research, we describe the possibility of durotaxis motion of polymer-brush substrates and its dependence on various parameters. We also explain the mechanism of this phenomenon.

12.2. Kwasi Nyandey, IF PAN

Tracking the evolution of radius of levitated shrinking micro-droplet: an exercise in deep learning

Characterization of micro-droplets using light scattering phenomena has been the subject of several researches because they are ubiquitous and their applications extend beyond scientific purpose. However, throughout literature, fast recognition and characterization of micro-droplets (into for example their radius/size parameter or evaporation rate) still face problems of accuracy and processing delays. We have carried out an exercise in deep learning to; (1) characterize micro-droplets into appropriate radius range within a wider range of 1 – 30µm and (2) track the radius evolution of evaporating micro-droplets of Diethylene glycol (DEG). We achieved this by generating theoretical light scattering patterns of evaporating/shrinking micro-droplets using Mie theory and training convolution neural network on such scattering patterns. The trained network was then used to recognize and classify experimentally recorded light scattering patterns. Preliminary results show very good trends of the rate of evolution of the radius of the droplet. With such complete results it will enable, simultaneously, the accurate and fast prediction of micro-droplet radius and time evolution [1], [2]. Further developments of this method, (we anticipate) will enable the online tracking, fast investigations of the state of droplet surface layer [1], formation [3], transitions and folding or breaking [3], [4]. Hence we analyze our methodology, preliminary results, problems and future work.

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12.3. **Luis Carnevale da Cunha, IF PAN**

Thermal fluctuation driven breakup and formation of satellite droplets

The breakup of liquid threads into smaller droplets is a fundamental problem in fluid dynamics. Through many-body dissipative particle dynamics, we estimate the characteristic wavelength of the breakup process driven by thermal fluctuations. This wavelength correlates with the Ohnesorge number, aligning with stability analysis findings. Furthermore, we observe a power-law decay in the number of satellite droplets when considering the product of the Ohnesorge and Thermal capillary numbers. In contrast, the main droplets' overall size exceeds expectations based solely on the characteristic wavelength due to asynchronous breakup. We also show that the formation of satellite droplets stems from the advection of pinching points toward the main droplets in a remaining thinning neck. This occurs when the fluid's velocity gradient exhibits two maxima.

13. EMITTERS AND SENSORS

13.1. **Muhammed AKTAS, IWC PAN**

P-Cladding Layer Utilizing Polarization Doping for Nitride Emitter

Nitride-based semiconductors play a crucial role in modern optoelectronics, particularly in the fabrication of white LEDs and UV-violet-blue-green laser diodes. The success of nitride semiconductor technology is based on the fabrication of bipolar devices, where p-type material is doped with Mg acceptors. Several studies have demonstrated that Mg is an optimal solution. However, there are certain drawbacks associated with the use of Mg acceptors. For instance, Mg acceptors have high ionization energies, which are close to 160-

200 meV for GaN and 630 meV for AlN. A high ionization energy has a significant impact on the hole concentration, leading to low free hole concentration. Additionally, the hole concentration changes significantly with temperature, which can cause issues in driving LEDs and lasers at cryogenic temperatures. The spontaneous and piezoelectric polarizations of nitride-based semiconductors can help overcome doping problems. In nitride heterostructures, dielectric polarization gradients create polarization charge density, thereby allowing for the formation of a free carrier gas (electron or hole). This effect is referred to as polarization doping. A significant advantage of polarization doping is that it can be controlled by adjusting the polarization gradients and layer thicknesses, thereby allowing for the formation of a relatively high hole concentration. Moreover, carriers are not affected by temperature, making it easier to use devices at cryogenic temperatures. In this study, we investigated the optoelectronic properties of LED and LD structures with polarization-doped p layers. The electrical characterization of the LED structure showed that polarization doping can easily match the conventional Mg-doped structure. At cryogenic temperatures, the LED was successfully driven, and we did not observe substantial hole freeze-out down to 20K. For the LD structure, we designed a symmetrical structure and used an Mg-doped electron blocking layer (EBL) to improve the injection efficiency. For the top metal contact, GaN subcontact doping with Mg is indispensable for lowering the metal-semiconductor Schottky barrier. After coating the facets, the measurements showed that the threshold current of the laser fluctuated from 50 mA to 80 mA in different chips at room temperature in the CW mode. The applied voltage changed between 4.3 – 4.5V, and the slope efficiency was approximately 0.3-0.4 W/A. In future work, the structure should be adjusted to improve injection and slope efficiency.

13.2. **Aleksandr Cherniadev, IWC PAN**

Integrated CMOS Resonator-Based Sensing for the THz frequency range

A wide range of materials and biomolecules exhibit unique spectral "fingerprints" in the terahertz frequency range, making highly sensitive spectroscopic tools necessary for probing the properties of 2D materials and for many biological applications, such as single molecule detection. Silicon complementary metal–oxide–semiconductor (CMOS) technology provides a compact, integrated solution for a near-field sensor. This work explores the physics of coupled resonators in such integrated semiconductor systems and studies resonance shift-based near-field sensing. We experimentally validated our sensor using water and ethanol as test subjects, and our simulations predict a sensitivity level of pL for our devices.

13.3. **Oliwia Golyga, IWC PAN**

Ion implantation and electrochemical etching as steps towards DFB lasers

For some particular purposes, such as gas detection, atomic clocks, interferometry, a single wavelength operation is required, therefore, a diffraction grating is added to the distributed feedback (DFB) laser structure. Its high coupling depends on the overlap of the optical mode with the grating and on the contrast of refractive index (Δn) of the two materials building the grating. In this work we present a method for the fabrication of buried periodic air-GaN channels located inside GaN structures. Our solution benefits from high refractive index contrast between air and GaN and also provides high overlap of the optical mode with the grating because it is buried under the active region. The proposed method is based on selective ion implantation and consecutive electrochemical etching (ECE). We created a mask using photolithography to define the grating geometry and then selective Si ion implantation was conducted with energy of 100keV and dose 2.6·1015 cm-2. After the implantation, a 100 nm GaN cap was grown by plasma-assisted molecular beam epitaxy (PAMBE). In order to activate the implanted ions samples were annealed in 4 different temperatures (1100°C, 1200°C, 1300°C and 1400°C) for 5 minutes. Then ECE was carried out at 8 V for 120 min. We present optical microscopy (OM) and scanning electron microscopy (SEM) images which show the formed air channels.

Starting time	Monday, June 5th			
7:00	**Departure from IFPAN**			
9:30	**Opening**			
9:45	1.1.	Vikram Kumar Jaiswal	ASTROPHYSICS	Bestin James
10:00	1.2.	Anjitha John William Mini Latha		
10:15	1.3.	Feven Markos Hunde		
10:30	1.4.	Gursharanjit Kaur		
10:45	1.5.	Bestin James		
11:00	Q & A 1			
11:15	**Coffee Break 1**			
11:30	2.1.	Md Shahin Alam	TOPOLOGY	Pardeep Kumar Tanwar
11:45	2.2.	Pardeep Kumar Tanwar		
12:00	Q & A 2			
12:15	**Coffee break 2**			
12:30	3.1.	Jaydeb Dey	MAGNETISM	Manasa Manasa
12:45	3.2.	Arathi Moosarikandy		
13:00	3.3.	Kausik Das		
13:15	3.4.	Amar Fakhredine		
13:30	3.5.	Sana Zakar		
13:45	Q & A 3			
14:00 – 15:15	**Lunch**			
15:30	4.1.	Sameh Altanany	THIN FILMS	Jaydeb Dey
15:45	4.2.	Krzysztof Golyga		
16:00	4.3.	Pushkar Joshi		
16:15	Q & A 4			
16:30	**Break**			
16:45	5.1.	Omer Farooq	OPTICAL PROPERTIES	Kwasi Nyandey
17:00	5.2.	Saranya Narayanan		
17:15	5.3	Joanna Olas		
17:30	Q & A 5			
End of Day 1 - **Supper**				

Starting Time	**Tuesday, June 6th**			
8:00 – 9:15	**Breakfast**			
9:30	6.1.	Priya Singh	NANO-STRUCTURES	Syed Shabhi Haider
9:45	6.2.	Wiktoria Zajkowska		
10:00	6.3.	Ajeesh Kumar Somakumar		
10:15	Q & A 6			
10:30	**Coffee Break**			
10:45	7.1.	Mahwish Sarwar	SEMICONDUCTORS 1	Omer Farooq
11:00	7.2.	Vasyl Stasiv		
11:15	7.3.	Sania Dad		
11:30	7.4	Syed Shabhi Haider		
11:45	7.5	Mikołaj Chlipała		
12:00	Q & A 7			
12:15	**Coffee Break**			
12:30	8.1.	Midhun Anila	BIOPHYSICS	Abdul Khaliq
12:45	8.2.	Barbara Klepka		
13:00	8.3.	Pamela Smardz		
13:15	8.4	Nguyen Van Hung		
13:30	Q & A 8			
14:00 - 15:15	**Lunch**			
16:00	9	Professor Izabella Grzegory	INVITED TALK	PROF. LUKASZ KILANSKI
16:45-17:00	Q & A 9			
End of Day 2- **Supper**				

Starting Time	**Wednesday, June 7th**			
8:00 – 9:15	**Breakfast**			
9:30	10.1.	Maciej Marciniak	QUANTUM PHYSICS	Aleksander Sanjuan C.
9:45	10.2.	Tae-Hun Lee		
10:00	10.3.	Oskar Slowik		
10:15	10.4	Sarath Prem		
10:30	Q & A 10			
10:45	**Coffee Break**			
11:00	11.1.	Jerzy Plesiewicz	SEMICONDUCTORS 2	Muhammed AKTAS
11:15	11.2.	Abinash Adhikari		
11:30	11.3.	Anastasia Lysak		
11:45	11.4	Juby Alphonsa Mathew		
12:00	Q & A 11			
12:15	**Coffee Break**			
12:30	12.1.	Russel Kajouri	DROPLETS	Amar Fakhredine
12:45	12.2.	Kwasi Nyandey		
13:00	12.3.	Luis Carnevale da Cunha		
13:15	Q & A 12			
14:00 – 15:15	**Lunch**			
15:30	13.1.	Muhammed AKTAS	EMITTERS AND SEN-SORS	Joanna Olas
15:45	13.2.	Aleksandr Cherniadev		
16:00	13.3.	Oliwia Golyga		
16:15	Q & A 13			
End of Day 3				
17:00 Departure from Zegrze				