Book of Abstracts

24th
edition of the

Physics of Light–Matter Coupling in Nanostructures

9–13 April 2024
Tbilisi (თბილისი) Georgia

Foreword by the Conference Chair

Dear conference participant,

in this booklet you will find a collection of abstracts submitted to the 24th edition of the international conference on Physics of Light-Matter Coupling in Nanostructures. This conference has been organised every year since 2000, and it has visited many countries in Europe, Asia and Americas, including France where it started, Italy, Greece, United Kingdom, Germany, Russia, China, Japan, Mexico, Cuba, Columbia and now Georgia.

Thinking of special features of this conference series, I would like to emphasize its somewhat old-fashioned family-like spirit, which did not help it to become financially successful or exceedingly attractive for students, industries and mass media, but which made it very special and, I would say, also famous in a relatively small scientific community of people who value informal discussions over a glass of wine, in-depth conversations during conference excursions and brilliant brain-storms at conference dinners.

From this point of view, Tbilisi seems to us one of the most suitable venues for PLMCN conferences: the city of great cinema and delicious food, the country famous for its hospitality, the land of most welcoming people who generously share their enormous cultural heritage virtually with any non-indifferent stranger following the noble ancient traditions of magnificent Caucuses.

The first full-size edition of the PLMCN after the dark years of global pandemic, the PLMCN-2024 has all chances to remain in history as a forum where the great ideas and breathtaking discoveries that will make everyone's life better sooner or later have come public.

I full-heartedly wish this conference to carry on forever, as, for me, it implements all the good that science may offer: good discussions with good friends over good dinners!

Have a great PLMCN!

Prof. Alexey Kavokin

Welcome

address by the Rector of GTU

Georgian Technical University is a scientific, research, educational and cultural center of national importance, a leading engineering and technological university in the region. During all these years, the university has established itself as a drivetrain of the best academic traditions and, at the same time, an innovative institution in the field of education. Currently, the Georgian Technical University implicates 13 faculties, 15 research institutes and modern laboratories operating within the university. In the recent history of Georgia, Georgian Technical University has always been and is a forge of highly qualified professionals in the country, who made a worthy contribution to the development of the country's economy with high-level knowledge and the use of the modern technology. Researchers of the Georgian Technical University and, most importantly, students together with their supervisors, successfully participate in such global international collaborations and projects as the European International Center for Nuclear Research (CERN), Switzerland - experiments ATLAS, CMS; High Energy Accelerator Research Organization (KEK), Japan - COMET experiment; FermiLab, USA - experiment DUNA; Julich Research Center, Germany; Helmholtz Center Dresden-Rossendorf (HZDR), Germany and many others. It is important, that this cooperation becomes more intensive every year and moves to a qualitatively higher stage. As a Rector of Georgian Technical University, my principal aim is to encourage and support the latest research initiatives and innovations, to position the university as a driving force of technological progress and advancement in the country and the world. In this context, it’s noteworthy that Georgian Technical University hosts a regular conference in the field of physics: "International Conference on Physics of Light-Matter Coupling in Nanostructures". This forum is a good opportunity for scientists in the abovementioned field to meet, share research outcomes and establish new scientific collaborations. I hope that the scientific contacts established within the conference will significantly contribute to the dissemination of new ideas, close cooperation between Georgian and foreign scientists and the implementation of international joint projects. We are grateful to the invited speakers, presenters and authors, participants and organizers for their contributions.

Rector of Georgian Technical University,
Academician David Gurgenidze

Introduction
by the Chair of the Program Committee

We live in increasingly troubled times, where dialogue, exchanges and arguments are, in all things, becoming more difficult and bitter. Confrontation has, at the same time, always been at the heart of the scientific progress, which, since it is a creative one, is intrinsically tainted with a component of ego and conflict, if not resentment. Scientists are known to be only admirative of people who have been long time dead. Fierce animosity has opposed geniuses and dilettantes alike on the problems and epochs they had in common. This was recorded already between Cardano and Tartaglia even before their solutions to the cubic equation had been in their respective works. The disputes between Newton and everybody else are even more famous, as is the hatred between Tesla and Edison who both refused the Nobel prize if it was to be jointly awarded. What is less famous is even more exacerbated, as is this comment from Schrödinger on the work of Heisenberg, that we prefer to leave untranslated: «*Jetzt benützen die verdammten Göttinger meine schöne Wellenmechanik zur Ausrechnung ihrer Scheiß-Matrixelemente*.»

Organizing a conference in Georgia in today's circumstances has not been a pedestrian journey. Inviting speakers exerted a rich and varied gamut of reactions, spanning the whole range of emotions, from mere worries and dismay to shock and outrage passing by fear and silence. It also, to be sure, generated a lot of excitement and interest, curiosity and dare. The PLMCN has always been a particular conference that embraces the Human (more than Social) component of Science: it understands that disagreement, opposition and even quarrels are unavoidable in any ambitious endeavor but that those are to be embraced and put in perspective, encouraged even, although in a fruitful and constructive way, so that distance grows between people's understandings, but shrinks between those who form them. It achieves this miracle by bringing us together, and, ideally, in off-the-beaten-track remote locations where the creative mind can be both challenged and inspired, not only by our peers, but also by the peculiarities of an exceptional venue. In this way, the PLMCN has brought its guests at the top of a volcano, in the embargoed Havana and in a multitude of islands. It also puts a peculiar emphasis on exquisite food, accompanying drinks of various alcoholic content and jovial atmosphere, shared by people who would not usually distinguish themselves for their social appetite. Its famous full-day excursion in lavish locations allows everybody, not only to reflect on our place and privilege as explorers of all things, but also to establish new contacts and discussions that extend beyond the seminar room, heartened by natural wonders.

This is the quarter-century edition of the PLMCN. My personal trajectory in Science has been rythmed by these events and also moulded by the founder of the Series, Prof. Alexey Kavokin, who imbues everything he does with his sui generis style. I have been raised scientifically with the PLMCN who was born at the top of the Puy-de-Dôme in Clermont-Ferrand in 2000 (I was myself born at the foot of the same volcano a few decades earlier). I met Alexey at this time and decided to change field from corpuscular physics to much less sexier (for a student) semiconductor physics, from a lecture he gave on *an important result of quantum theory*, the Bloch theorem, of which he commented that this would be a great achievement since nobody in the room knew anything about quantum theory or about theorems. I approached him during my Diplôme d'Études Approfondies (the old French name for what is now known, even in France, as a "Master") for a research project and he gave me on the spot the problem of scattering two excitons. This was much more interesting, important and personal than the Fortran calibration routines for a recluse component of scintillators developped for CERN. I am still working on it to this day. Instead of going to CERN like other students of my speciality, I thus went to the PLMCNs: in Acireale, Saint-Petersburg, Glasgow, La Habana...

Georgia—the land that created wine and its very own alphabet—and Tbilisi, one of the few remaining authentic gems of civilization, with its wooden balconies suspended to timeless brick buildings, could not have been better picked to celebrate twenty-five years of PLMCN, away from the worn-out usual locations, protected from video-conferencing and far from the anxiety and time-pressure of the daily life of overly busy scientists. It offers, instead, the gift of a week of immersion in slow-paced talks, with plenty of time for exchanges, comments and discussions. Some of those will be recorded for posterity in our Proceedings, as a snapshot of what our community had to say and to reply on its State of the Art. Others will be left to the discretion of coffee and Churchkhela, Saperavi or Chacha (ჭაჭა) as the only testimonies of the more confidential, deepest or trite exchanges. As the main actors of this most noble cause of the scientific spirit—preserving itself of consensus, boredom and the banal—we have you, the readers of this Program Book, making alive the event with some of the other most interesting, innovative, prolific, undaunted and visionary scientists of the Physics of Light interacting with Matter. We could assemble such a spectacular and unique composition of speakers from around the World, welcoming both the most prestigious, established and famous speakers, along with more junior, active and early-stage Researchers, thanks to the commitment and support from our Program Committee, itself also a composition halfway between a dream and a pantheon; we even got close of having one member win the Nobel prize on the fly! I am thankful to all our colleagues for their support and dedication, in particular to Prof. Nori for his unfaltering support and constant advices as the tedious and constantly transmuting process took place. Our program has known ups and downs, but despite difficulties, calendar clashes, accidents, surgeries, even Nobel prize concurrence déloyale, it succeeded in providing what we were aiming for: attracting exceptional people, and bathing them in the true spirit of the PLMCN: შენს პირს შაქარი!

Long live to this conference; from its first quarter-century, that it may carry on till PLMCN100. We will not enjoy it ourselves but we can also wish for, and foremost: long live Alexey! It will remain a great privilege to witness all that you will still bless the World with!

Алексей, спасибо за 25 лет PLMCN!

Fabrice P. Laussy

Program Committee


Fabrice Laussy (Chair)


Franco Nori


Maurice Skolnick


Yasuhiko Arakawa


Cristiano Ciuti


Jonathan Finley


Christian Schneider


Mikhail Glazov


Brian Gerardot


Daniele Sanvitto


Gloria Platero


Antonio Fernández Domínguez


Pavlos Lagoudakis


Natalia Berloff


Carlos Duque


Hui Deng


Alejandro González Tudela


Zhanghai Chen


Mikhail Portnoi

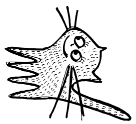

Said Rahimzadeh-Kalaleh Rodriguez


Hai Son Nguyen


Arturo Camacho Guardian


Daniele Barettin


Nina Voronova



KEYNOTES Speakers

Jeremy BAUMBERG

Pavlos LAGOUDAKIS

Päivi TÖRMÄ

INVITED Speakers

Boris ALTSHULER

Alexey KAVOKIN

Georgi SHLYAPNIKOV

Zhiliang YUAN

Alberto AMO

Sebastian KLEMBT

Pavlos Savvidis

Elena del Valle

Nikita KAVOKINE

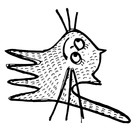
Anton NALITOV

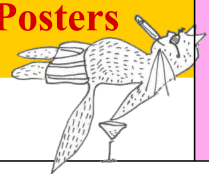
Ivan SAVENKO

Gia PETRIASHVILI

PROGRAM at a glance

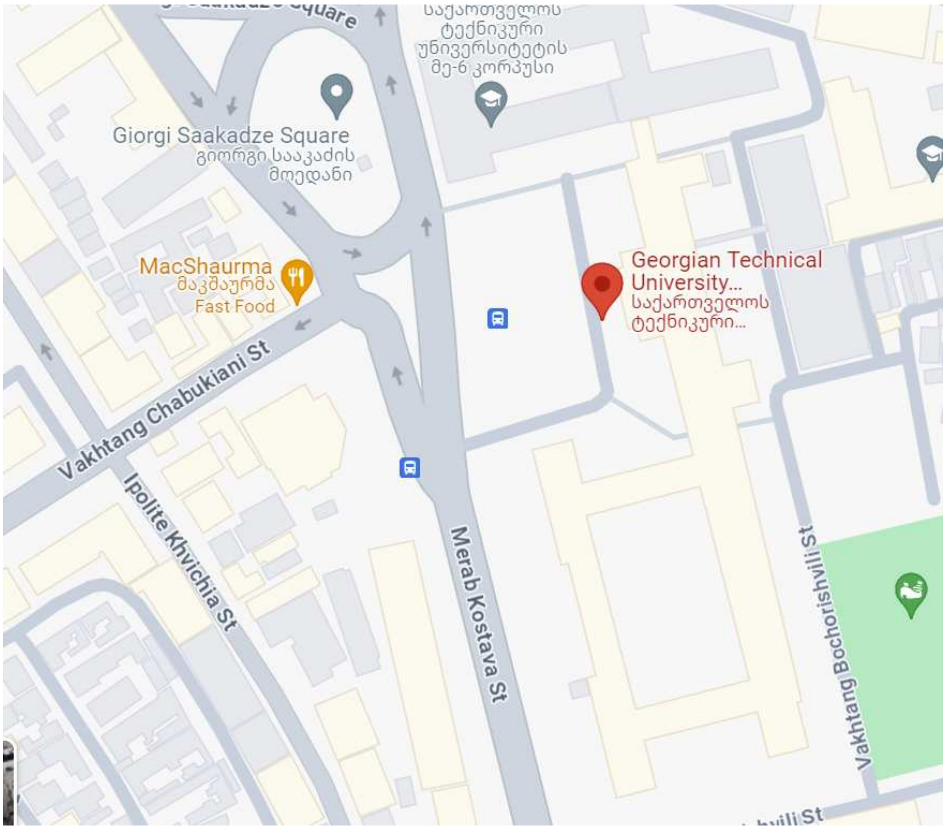
Time	8 Monday	9 Tuesday	10 Wednesday	11 Thursday	12 Friday	13 Saturday
8:00						
9:00	8:40	Opening	Lagoudakis	9:30	Baumberg	Törmä
		Coffee Break	Coffee Break		Coffee Break	Coffee Break
10:00 11:00	10:00	S1 Polaritonic	S4 Many-body	Mtskheta-Jvary Monastery	S7 Quantum Hydrodynamics	S10 Exotic Matter
12:00 13:00	12:00	LUNCH	LUNCH	Svetitskhoveli Georgian Wine degustation	LUNCH	LUNCH
14:00 15:00	13:30	S2 Quantum Correlations	S5 Phase Transitions	Traditional Georgian Banquet **PLMCN** **EXCURSION**	S8 Photonic Lattices Round Table	S11 Spin & Vortices
	15:30	Coffee Break	Coffee Break		Coffee Break (photo)	Coffee Break
16:00 17:00	16:00	S3 Single Photons	S6 Quantum Circuits		S9 Materials	S12 Devices Closing Session
18:00	18:00	Cocktails *with* **Posters**				
19:00			Keynotes & Invited speakers Dinner		**Conference Dinner** Announcements	

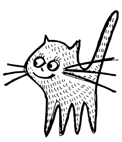




Conference Venue

Georgian Technical University (GTU),
Kostava st. N77, 0171, Tbilisi, Georia
Administrative building, III floor



Organizers

Giuseppe ERAMO
President of MIFP

David GURGENIDZE
Rector of GTU

GTU Organizing Committee

Prof. David Gurgenidze	Rector of GTU
Prof. David Tavkhelidze	Head of the Science and Innovation Department of GTU, Co-Chairman of the conference
Prof. Akaki Giginashvili	Head of the Physics Department of GTU
Prof. Gia Petriashvili	Head of Thermo & Photochromic Structures Laboratory of the Institute of Cybernetics
Prof. Zviad Tsamalaidze	Director of the institute of Quantum Physics of GTU
Prof. Tamara Iominadze	Dean of IT and Control System Faculty of GTU
Prof. Zurab Gudavadze	Advisor to the Rector
Prof. Konstantin Basilashvili	Advisor to the Rector

MIFP local assistants

Dr. Ia Trapaidze	Georgian State Electrosystem
Eng. Nino Dolidze	SCADA system specialist, "Energo-pro Georgia"

Scientific Secretary

Vasil SAROKA

The PLMCN 2024 is my first organizational experience of a high-level grand-scale scientific conference. It was a great privilege to be among the first to read fresh-baked incredible scientific research submitted as abstracts for evaluation. It has been a pleasure to communicate and interact with a well-organized and diligent audience of PLMCN participants. Concurrently, it has also been a huge responsibility to be the primary person behind such important procedures as keynote and invited speaker selection and abstract evaluation by the Program Committee. I must note that in preparation for the PLMCN-2024, mostly due to encouragement of the Program Chair, a few digital innovations were implemented that made process paperless, joyful, hustle-free, straightforward, and even playful. I am sure this was not the last thing in ensuring the exceptional quality of the PLMCN-2024 scientific agenda. Speaking of science, the vibrant field of polaritonics has never been my major. As condensed matter theoretical physicist I primarily built my profile around carbon-based nanostructures – such as carbon nanotubes, graphene nanoribbons, and graphene superlattices – and their low-energy physics including THz properties. However, by lucky coincidence polaritonics is the only field where I have practical experimental laboratory experience. Back in 2011, being a fifth-year student of my alma mater – Belarusian State University – I participated in IAESTE UK Exchange program that allowed me to spend two incredible months in the hybrid photonic laboratory of Prof. Pavlos Lagoudakis at the University of Southampton. Therefore, I had a genuine interest in following the research submitted for evaluation as abstracts. All Keynotes are of exceptional quality, but, of course, I was happy to see that Prof. Lagoudakis had been selected by most votes to be one of the Keynote speakers at the PLMCN 2024. In my opinion, the definite highlight of this year PLMCN is higher order topological phases of matter in photonics crystals and polaritonic lattices which have become wonderful tools to go beyond solid-state technology and synthetic chemistry limitations opening new horizons for device applications.

Contacts

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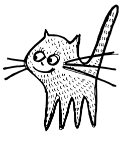


თბილისი

Tbilisi is the capital and the largest city of Georgia (population of ~1.2 million people), lying on the banks of the magnificient Kura River before it flows into the Caspian sea. Tbilisi was founded in the fifth century AD by Vakhtang I of Iberia, and since then has served as the capital of various Georgian kingdoms and republics. Between 1801 and 1917, Tiflis was the seat of the Caucasus Viceroyalty, governing both the northern and the southern parts of the kingdom. Because of its location at the crossroads between Europe and Asia, and its proximity to the lucrative Silk Road, Tbilisi has always been throughout history a medley of multicultural, ethnic and religious encounters, giving rise to a truely unique language and alphabet, gastronomy and architecture, the latter being an eclectic mix of medieval, neoclassical, Beaux Arts, Art Nouveau, Stalinist and Modern structures. Tbilisi is thus like no other place on the globe and a fitting destination for the quarter-century edition of the PLMCN, which has visited some of the most beautiful places on the planet.

Etymology

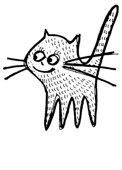
The name Tbilisi derives from Old Georgian Tbilisi: the place of warmth was therefore given to the city because of the area's numerous sulfuric hot springs. Time after time, most other languages have subsequently adopted the new name form, but some languages, such as Turkish, Persian, Greek, Spanish, and German, have retained a variation of *Tiflis*.

Geography

Tbilisi is located in the South Caucasus and it lies in Eastern Georgia on both banks of the Kura River (locally known as Mtkvari). The elevation of the city ranges from 380-770 metres above sea level (1,250-2,530 ft) and has the shape of an amphitheatre surrounded by mountains on three sides. To the north, Tbilisi is bounded by the Saguramo Range, to the east and south-east by the Iori Plain, to the south and west by various endings of the Trialeti Range.

The legend of Tbilisi:

According to the legend, the king of ancient Iberia, Vakhtang I Gorgasali, once hunted in the forests near the first capital of Georgia - Mtskheta. After some time, he saw a pheasant, then shot and killed the bird. The king sent his falcon to find the prey. The falcon flew away, and after a while, the king lost sight of him. In search of the birds, Vakhtang Gorgasali with his hunters came upon the source and saw that both the falcon and the pheasant got into its waters. The source turned to be hot. And amazed with this find Vakhtang I decided to found here the city that would become the capital of Georgia, realizing the exceptional benefits of that unique location.



The relief of Tbilisi is complex: the part of the city which lies on the left bank of the Kura River extends for more than 30 km (19 mi) from the Avchala District to River Lochini. The part of the city which lies on the right side of the river, though, is built along the foothills of the Trialeti Range, the slopes of which in many cases descend all the way to the edges of the river. The mountains, therefore, are a significant barrier to urban development on its right bank. This type of a geographic environment creates pockets of very densely developed areas, while other parts of the city are left undeveloped due to the complex topographic relief. To the north of the city, a large reservoir (commonly known as the Tbilisi Sea) is fed by irrigation canals.

Essential Georgian

Hello:	Gamarjoba (ga-mar-jo-ba)
Thank You:	Madloba (mad-lo-ba)
Yes / No:	Ki / Ara
Excuse Me:	Ukatsravad (u-kats-ra-vad)
Please:	Tu Sheidzleba (tu she-id-zle-ba)
Wine:	Gvino (gvi-no)
Delicious:	Gemrielia (gem-ri-eli-ia)
Quantum field:	Kvanturi veli (kvan-tu-ri ve-li)
Goodbye:	Nakhvamdis (na-khvam-dis)

Mkhedruli

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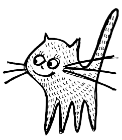

9 Tuesday

8:40	Conference Opening
	Coffee Break
10:00	S1 Polaritonic
12:00	LUNCH
13:30	S2 Quantum Correlations
15:30	Coffee Break
16:00	S3 Single Photons
18:00	Posters *with* Cocktail

S1: Polaritonic

Kavokin:	**Pathways of quantum polaritonics**
Ravets:	Eigenstate tomography and valley Hall effect in polariton lattices
Bennenhei:	Organic room-temperature polariton condensate in a higher-order topological lattice
Osipov:	Control of exciton-polaritons condensate's synchronization using resonant pumping

S2: Quantum Correlations

del Valle:	**A Tale of Two Photons**
Kuznetsova:	Two-photon spectroscopy of exciton states in perovskite nanocrystals
Zubizarreta Casalengua:	Quantum correlations of spatially extended quantum states
Balas:	Sub-µm Confinement of Polariton Condensate in He+ Implanted Microcavity

S3: Single Photons

Yuan:	**Resonance Fluorescence as Spontaneous Emission: No More No Less**
Mitryakhin:	Cavity-tuning single photon coherence in a monolayer-based single photon source
Laussy:	Perfect Photons
Posters:	5 min blitz presentation of selected posters

Kavokin

del Valle

Yuan

Pathways of quantum polaritonics

Alexey Kavokin

*School of Science, Westlake University, No.18, Shilongshan Road, Cloud Town, Xihu District, Hangzhou, China**

Abstract embargoed.

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Eigenstate tomography and valley Hall effect in polariton lattices

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Exciton-polariton lattices obtained by coupling excitons to cavity photons in semiconductor heterostructures are a platform of choice for investigating topological physics [1]. Due to their part-light part-matter character, exciton polaritons can indeed undergo spin-orbit coupling (photon part), while simultaneously experiencing time-reversal symmetry breaking as a consequence their susceptibility to magnetic fields (exciton part) [2-5]. This has enabled the study of variety of phenomena with exciton polaritons, such as Chern insulators, the quantum geometric tensor, the quantum spin Hall effect, the non-Hermitian skin effect, topological lasing, or topological gap solitons [6]. Importantly, the topology of a system is rooted in the structure of its eigenstates and how they wind in momentum space. Measuring the eigenstates of a polariton lattice is thus of prime importance when determining some of the topological properties associated to its energy bands. In this talk, I will report on our recent measurements of the Bloch eigenstates of a polariton honeycomb lattice. The eigenstates are encoded in the sub-lattice pseudo-spin, which we access through a series of interferometric measurements. This enables us to reconstruct the Berry curvature and quantum metric associated to each energy band of the lattice. Our tomography applies to lattices of any geometry and provides a valuable tool for future experiments in topological photonics and polaritonics.

References

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[2] I. Carusotto, and C. Ciuti, Rev. Mod. Phys. **85**, 299 (2013)
[3] T. Karzig, Charles-Edouard Bardyn, Netanel H. Lindner, and Gil Refael, Phys. Rev. X **5**, 031001 (2015)
[4] A. V. Nalitov, D. D. Solnyshkov, and G. Malpuech, Phys. Rev. Lett. **114**, 116401 (2015)
[5] S. Klembt, et al., Nature **562**, 552 (2018)
[6] D. Solnyshkov, et al., Optical Materials Express **11**, Issue 4, 1119 (2021)

Organic room-temperature polariton condensate in a higher-order topological lattice

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Organic molecule exciton-polaritons in photonic lattices are a versatile platform to emulate unconventional phases of matter at ambient conditions [1], including protected interface modes in topological insulators. Compared to cold atoms in optical lattices and exciton-polaritons in III-V semiconductors, which only operate at temperatures up to a few Kelvin, their main advantage are the less demanding experimental conditions at ambient temperature, which is enabled by the much larger excitons binding energy. In this work, we investigate bosonic condensation in the most prototypical higher-order topological lattice: a 2D-version of the Su-Schrieffer-Heeger (SSH) model (see top left panel in Fig. 1), supporting both 0D and 1D topological modes. We study fluorescent protein-filled [2], structured microcavities defining a staggered photonic trapping potential and observe the resulting first- and higher-order topologically protected modes via spatially resolved photoluminescence spectroscopy. We account for the spatial mode patterns by tight-binding calculations and theoretically characterize the topological invariants of the lattice. Under strong optical pumping, we observe bosonic condensation into the topological modes. Via interferometric measurements, we map the spatial first-order coherence in the protected 1D modes extending over 10µm [3]. Our findings pave the way towards organic on-chip polaritonics using higher-order topology as a tool for the generation of robustly confined polaritonic lasing states.

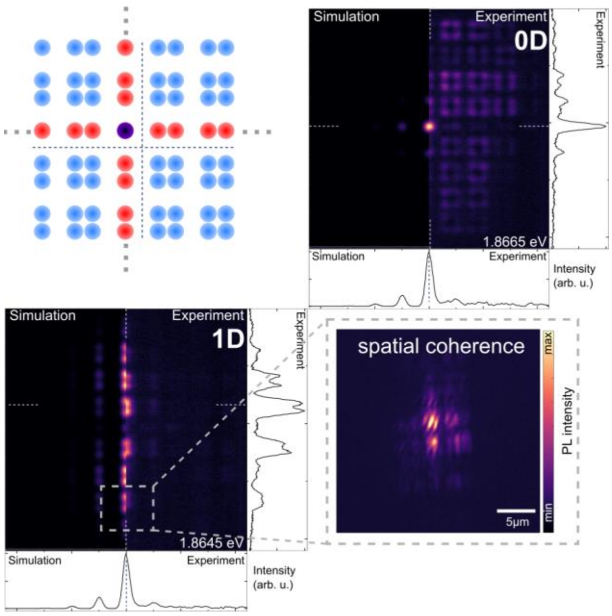

Fig. 1: 2D Su-Schrieffer-Heeger lattice with photoluminescence images and tight binding calculations of 0D and 1D defect states. Bottom right corner shows a spatial interferogram of the emission from a 1D mode.

References

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[2] C. Bennenhei, *et al.*, "Polarized room-temperature polaritons lasing in elliptical microcavities filled with fluorescent proteins" Opt. Mater. Express **13**, 2633-2643 (2023)

[3] C. Bennenhei, *et al.*, "Organic room-temperature polariton condensate in a higher-order topological lattice", arXiv:2401.06267, (2024)

Control of exciton-polaritons condensate's synchronization using resonant pumping

Alexey Osipov[a,b], Alexey Yulin[b], Olha Bahrova[a], Oleg Utesov[a] and Sergei Koniakhin[a]

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Exciton-polaritons are hybrid light-matter quasiparticles, which inherit useful properties both form excitons and light [1]. Experimental techniques for operating with exciton-polaritons have made a huge step last decade making exciton-polaritons perspective for applications and for experimental studying of fundamental physics. One of the crucial aspects in polaritonics is Non-equilibrium Bose-Einstein polaritonic condensation in non-resonantly optically pumped microcavities [2]. Spatially separated spots of condensates demonstrate rich synchronization dynamics [3], which has wide range of perspective applications. In particular, this mechanism was used as a basis for polaritonic simulators [4].

Nowadays, ways to control polariton's synchronization are actively studying. Including into the system additional resonant pumping was proposed as a perspective way to control condensates synchronization [5, 6]. In particular, in [5] a forced synchronization of two condensate spots with homogeneous coherent pumping was proposed. The main goal of our work is studying effects of coherent pumps on synchronization dynamics of incoherently pumped polaritonic condensates. We considered various configurations and geometries to study condensates synchronization properties and to discover various experimentally realizable setups. First, we studied synchronization of condensate in a ring shaped geometry under external coherent pumping. We demonstrated that in the case where vorticity of the coherent pump differs from the initial condensate's vorticity, kink-like condensate's phase profiles could be observed. We provided numerical and analytical description of the synchronization dynamics in such systems. In particular, we analyzed kink's dynamics in the presence of the perturbation potential demonstrating both its moving and localized regimes with respect to different potential strengths. Moreover, we observed multikink regimes occurring in such systems and studied its dynamics. Second, we considered synchronization of two distant condensates following the scheme from Ref. [7]. We considered forced synchronization by additional coherent and non-resonant pumping including synchronization temporal dynamics. In addition, we studied influence of momentum-depended damping on condensates synchronization [8] and observed suppression of synchronization at particular conditions.

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A Tale of Two Photons

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I will discuss quantum correlations and the possibility to tune them, from the simplest possible system: a qubit (or two-level system). I will review the emission from such a simple system in its simplest time-independent and stationary regime, also focusing on mere two-photon emission only [1]. Although "*as simple as possible*", I will then show that the "*but not simpler*" motto on this particular case is instructive as providing a new picture of multiphoton emission, independent from photoluminescence, that features a phenomenology that has escaped notice so far despite its considerable consequences for applications [2–5]. This picture consists of a systematic and comprehensive mapping of all the possible two-photon emission processes [6] (cf. Fig. 1). I will show how, in the landscapes thus defined, new patterns emerge that consist of lines of bunching and circles of antibunching. Those are explained by combining:

1. our now decade-old theory of frequency filtering, which links observables to the fundamental process of photodetection [7], and
2. our more recent theory of interferences of quantum fields [8, 9].

I will show how, brought together, these theories provide a comprehensive and analytical picture of two-photon emission, that can inspire and guide generalizations beyond the simplest cases that we will entertain in this talk [10].

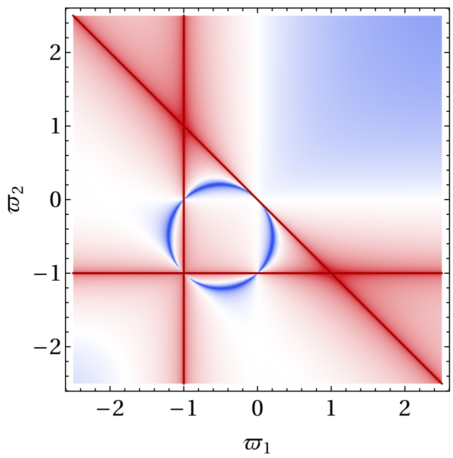

FIG. 1. The plot of $S(\varpi_1,\varpi_2)=\dfrac{(\varpi_1^2+\varpi_1+\varpi_2^2+\varpi_2)^2}{(\varpi_1+\varpi_2)^2(\varpi_1+1)^2(\varpi_2+1)^2}$. In my talk, I will explain how this relates to two-photon emission.

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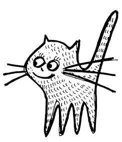

Two-photon spectroscopy of exciton states in perovskite nanocrystals

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Inorganic perovskite nanocrystals (NCs) demonstrate strong nonlinearity of their optical properties that has been revealed in the multiphoton excitation of photoluminescence (PL) [1-3]. Here we demonstrate the nonlinearity in the $CsPbBr_3$ and $CsPbI_3$ NCs grown in a glass matrix. The synthesis of the NCs was described previously [4]. The sample with the perovskite NCs was investigated by measuring the PL spectra and the PL excitation spectra under the excitation with the photon energies far below the exciton resonance. Figure 1 demonstrates main results obtained for the $CsPbI_3$ NCs. Similar results were obtained for the $CsPbBr_3$ NCs. The PL spectrum obtained at the low photon energy excitation is very similar with that obtained at the interband excitation. As the fixed excitation photon energy, the integral PL intensity nonlinearly increases with the excitation power that can be approximated by the power low, $I \sim P^{\alpha}$, with $\alpha > 1$. In particular, we found that $\alpha = 2.4$ for the $CsPbI_3$ NCs under their excitation with photon energy, $E_{exc} = 1.46$ eV. For the $CsPbBr_3$ NCs, $\alpha = 2.1$ under excitation with $E_{exc} = 1.55$ eV. So, the excitation process is mainly the two-photon one.

The two-photon absorption allows one to study the spectrum of the high-energy exciton and electron states tuning the photon energy of the excitation. Preliminary results for the two-photon PL excitation spectrum of the $CsPbI_3$ NCs are shown in the figure. As seen, the PL intensity increases with excitation photon energy. At the same time, there are some spectral features, which indicated increased two-photon absorption efficiency. We attribute them to transitions to excited exciton and/or electron states, whose energy is far above the bandgap of the perovskite. The obtained results will be compared with a theoretical modeling of electron band structure.

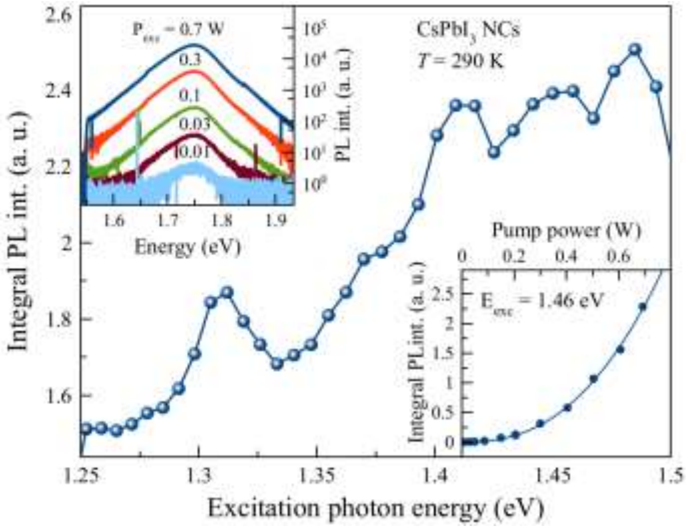

Figure 1: Two-photon PL excitation spectrum of the $CsPbI_3$ NCs. $P_{exc} = 0.6$ W, the laser pulse duration 200 fs, the diameter of caustics in the sample is of about 30 μm. Upper inset: PL spectra measured at the excitation photon energy 1.46 eV and different excitation powers. Lower inset: power dependence of the integral PL intensity (symbols) and the fit by function, $I = A^*P^{\alpha}$, with $\alpha = 2.4$ (solid line). $T = 290$ K.

The authors thank St. Petersburg State University for financial support under grants No. 94030557.

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Quantum Correlations of Spatially Extended Quantum States

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Quantum correlations are at the heart of both mysteries and resources of quantum effects. In Optics and other field that involve photons, they are typically studied in time [1, 2]. Here, we study correlations in space instead [3]. We focus on the particular case of vortices (Fig. 1) and study how various quantum states produce different spatial correlations at the multi-photon level, despite all being indistinguishable at the one-photon level (e.g., in luminescence). We find that the specificities of space as compared to time (2D in our case as opposed to 1D for time, possibility to go back and forth in space as opposed to flowing time, etc.) enrich considerably the already complex quantum-optical (temporal) paradigm. As examples of new phenomenology, even non-interacting systems—so pure wavefunction effects—result in two bosons exhibiting a bimodal distribution of their distances, opening the possibility for them to be found farther apart than two fermions, in opposition to the commonly-held view of bosons clumping up together. Would bosons be, however, prepared as coherent states, then their phase would allow them to get rid of such correlations. Scrambling the phase restores them. Fock bosons can also disguise their correlations to appear uncorrelated as would coherent states (or classical particles) be, but achieving this on average, since to do that, they instead exhibit even stronger single-shot correlations. Other curiosities, as well as applications, of spatial correlations will be discussed.

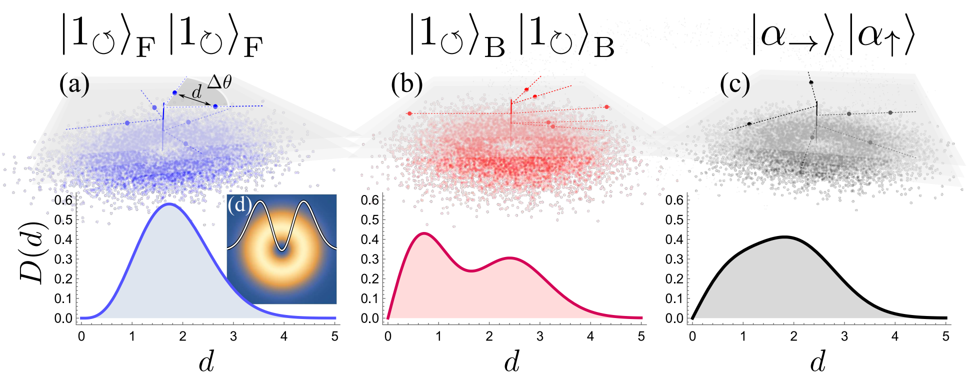

FIG. 1. Three vortices that are distinguishable in photoluminescence or other one-photon observables. In (a), two Fock fermionic vortices, in (b) two Fock bosonic ones and in (c), two coherent states with $|\alpha_{\leftarrow}|^2 = |\alpha_{\rightarrow}|^2 = 1$ but with Poissonian fluctuations of particle numbers. The distributions D of their distances d (or other two-particle properties) differ strikingly.

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Sub-μm Confinement of Polariton Condensate in He^{+} Implanted Microcavity

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Engineering of the energy potential landscape by either direct optical excitation patterning or lithographic etching techniques in planar microcavities (MCs) allows for the direct control of exciton-polariton condensates. Often, such manipulation aims for planar confinement in arbitrarily shaped potentials that give rise to lower condensation threshold and improved coherence[1], and/or topological[2] effects depending on their shape and size. Recently Focused Ion Beam implantation has been shown to alter the photonic and the excitonic[3] resonances of semiconductor MCs. In this study, to achieve higher lateral resolution and proximity to the quantum well excitons, we employ high energy He ion implantation of an MBE grown GaAs/AlGaAs "half-microcavity" sample, followed by post growth deposition of dielectric top DBR. On these structures we demonstrate lateral confinement of polariton condensates within annular shaped implanted regions shown in Figure 1 with sizes ranging from sub-μm to several μm. The trapped condensate exhibits discrete spectrum, lower threshold, and reduced blueshift due to minimal overlap with the excitonic reservoir. Spatial resolution of such implantation technique is in the order of several nanometers [4] while dose density allows precise control on the energy shifts. The combination of high resolution and non-binary potential shifts pave the way for the design of intricate devices ranging from interacting single-photon emitters to quantum simulators.

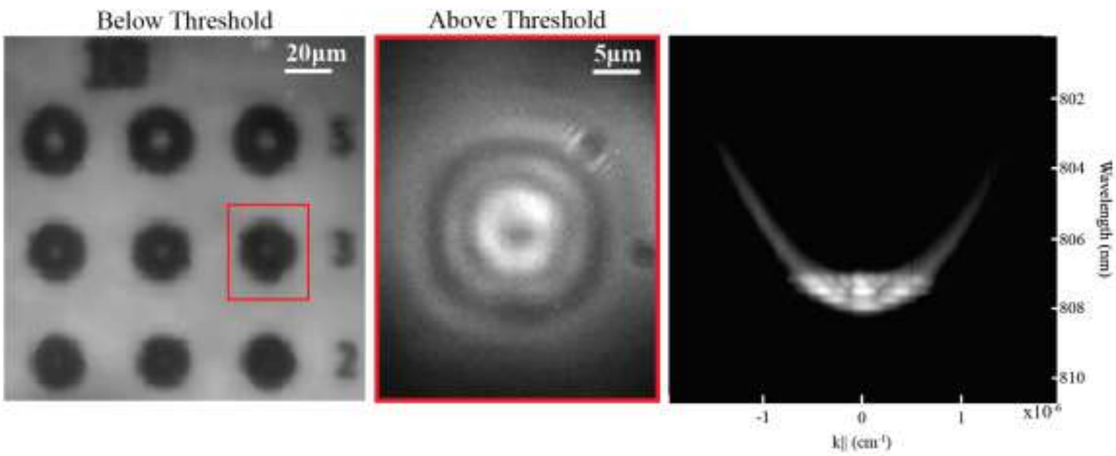

Figure 1. PL quenching at He^{+} implanted pattern on QWs (left).Polariton condensate trapped within the dosed region(middle). Angle resolved spectrum of "middle" (right).

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Resonance Fluorescence as Spontaneous Emission: No More No Less

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Under weak continuous-wave excitation (Heitler regime), resonance fluorescence (RF) spectrum of a quantum two level emitter (TLE) consists of a laser-like sharp peak superimposed upon a broadband pedestal. These distinctive spectral features were generally interpreted in literature [1] as the TLE serving merely as a passive scattering site in the former or undergoing actual (incoherent) absorption and re-emission process in the latter. However, this interpretation implicitly treats photons with convenience as waves for the scattering as opposed to particles for the absorption and re-emission, and thus lacks a unified picture. Bringing in scientific rigor, López Carreño et al. [2] recently derived through field decomposition that the interference of the coherent and incoherent RF components is the key to observation of photon antibunching in the RF (see [3,4] for follow-up experiments). Implying existence of higher-order scattering processes, their work has further stimulated interesting experimental discussion on the simultaneous scattering of two photons by an atom [5]. We point out that the wave-particle boundary is rather blurred along this line of discussion. Application of spectral filtering [5] reveals already wave-aspect properties of photon and thus precludes discerning simultaneity of multi-photon scattering which requires treating them as particles.

In this work, we propose and experimentally verify a model in which a quantum emitter and its spontaneous emission enter entanglement in time degree of freedom [6]. We treat the emitted photons strictly as particles, i.e., spontaneously emitted one at a time and with bandwidth governed by the emitter's excited-state lifetime. The model involves no higher-order scattering processes, nor does it need to distinguish between coherent scattering and incoherent absorption/re-emission processes. All there is in the RF is spontaneous emission. From the entanglement, we have theoretically derived the excitation power dependencies, with the strongest effects measurable at the single-photon incidence level, of the first-order coherence of the RF as a single entity and the second-order correlation function of just the broadband component. In laboratory, we confirm the model by reproducing its predictions on the RF from a high-quality semiconductor quantum dot micro-pillar device.

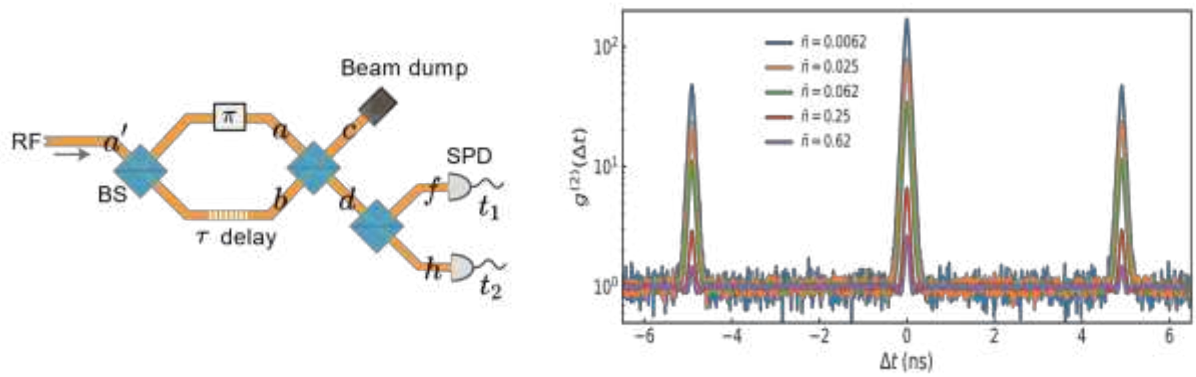

Fig. 1: (left) Experimental setup; (right) Auto-correlations measured for the AMZI-filtered output under different excitation fluxes.

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Cavity-tuning single photon coherence in a monolayer-based single photon source

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Recently, mono- and bi- layers of transition metal dichalcogenides (TMDC) have shown to host single photon emitters in crystalline defects. This, along with the low-cost and ease of TMDC integration into photonic structures, makes this class of materials a promising candidate for quantum applications.

In this work, we show a highly performant single photon source based on a WSe_2 monolayer integrated into a low-Q cavity featuring two freely movable mirrors (sketched in Fig. 1a). Provided by the design, the cavity allows for high extraction efficiency of 65% (comparable to the state-of-the-art), *in-situ* cavity-emitter matching and tunability of the radiative rate via Purcell effect (Fig. 1b). We perform Hanbury-Brown-Twiss (HBT, Fig. 1d) and Hong-Ou-Mandel (HOM, Fig. 1e) measurements revealing high single-photon purity ($g^{(2)}(0)$ = 4.7 ± 0.7%) and signature of quantum interference with the visibility of 2% limited by the resolution of the setup and the emitter coherence [1]. We further investigate the emitter coherence via first-order correlation measurements with a Michelson interferometer. As the result, we show that it is possible to use cavity system to suppress the contribution of emitter-phonon coupling and improve the overall coherence of the single photon source [2].

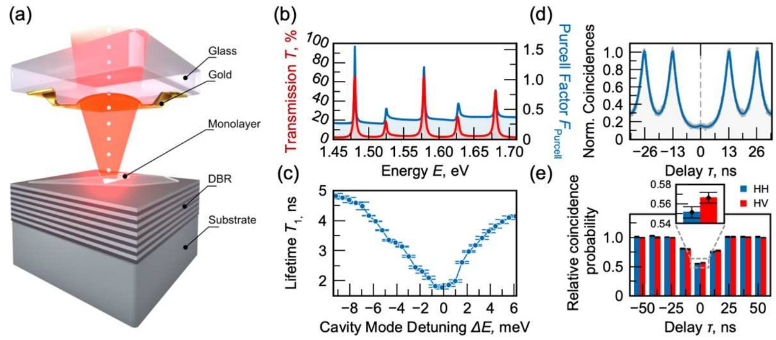

Fig: (a) Sketch of an open microcavity with an embedded monolayer. DBR − distributed Bragg reflector. (b) Transmission and Purcell factor of the open cavity system. (c) Cavity mode detuning dependent radiative lifetime. (d) $g^{(2)}$ function of single photons measured in a HBT experiment with 76.2 MHz pulsed excitation. (e) $g^{(2)}$ function in a HOM setup between orthogonally polarized (HV, fully distinguishable) and parallelly (HH) polarized photons for 1.1 ns post-selection time window.

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Perfect Photons

E. Zubizarreta Casalengua, E. del Valle and Fabrice P. Laussy

TUM – UAM – ICMM

While we all know about perfect conductors and perfect fluids—although we call them "super" instead of "perfect"—the much more straightforward concept of *perfect single-photon emission* is discussed in the literature only in engineering terms of asymptotically approaching an inaccessible ideal. This is strange because if there is something that embodies the notion of a gap, this is precisely the quantum of excitation, that separates the vacuum from the excited state as quantumly as possible. So it should be easy to produce perfect single photons.

In this talk, I will explain the fundamental reason why perfection is not of this (photonic) world, due to emission needing its at-least-equally important companion of detection. I will show that the popular mechanism for single-photon emission is indeed doomed to failure for the same reasons than those understood by Bortkiewicz to cause casualties from horsekicks in the Prussian army, and that this realization traces the road toward genuine, or perfect, single-photon emission. I will demonstrate a simple mechanism which can be described fully analytically and that considerably enlarges the realm of single-photon emitters towards perfect Single-Photon Sources (SPS). A compelling manifestation is that such sources acquire the characteristics of pulsed single-photon emission, except that there is no outside intervention to rythm their repetition cycle, that is instead developed self-consistently.

Furthemore, the statistical properties of such single-photon emitters are nothing like what has ever been seen by quantum opticians, but are on the other hand commonplace in condensed matter physics, where they describe liquids. We thereby speculate that there is an hitherto overlooked connection between textbook thermodynamics and quantum optics, where a typical SPS is a (temporal) gas whereas a perfect SPS is a thick liquid (not able to crystallize completely since time is one-dimensional). Our discussion calls to reconsider criteria for single-photon sources as the rate of change of their two-photon coincidence suppression with respect to the inverse detection time. It should also invite resourceful solid-state and material physicists to implement our mechanism to liquefy photons (albeit in time).

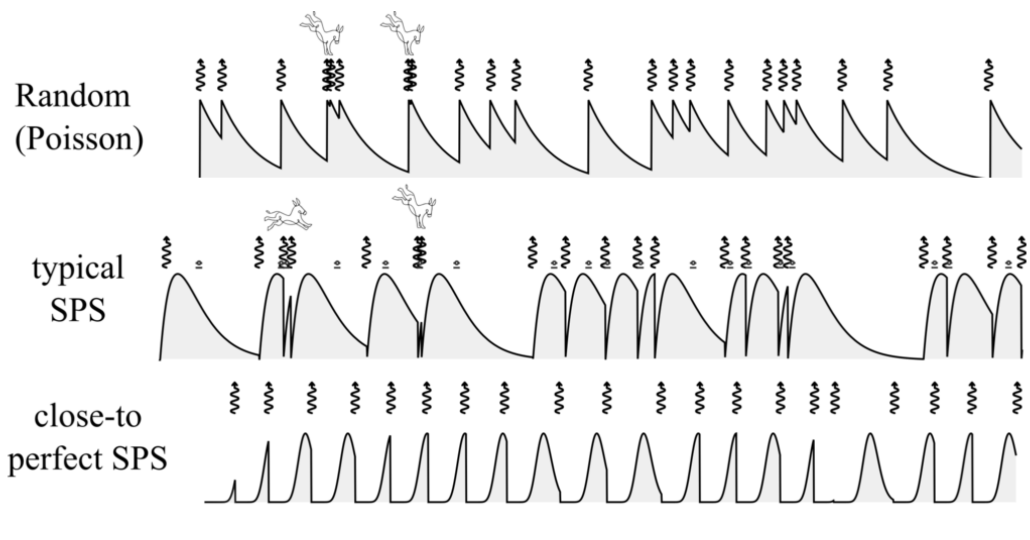


FIG. 1. Top: a random stream (uncorrelated emissions). Middle: a typical Single-Photon Source, with Poisson bursts that spoil the process and Bottom: a new mechanism revealing the essence of perfect single-photon emission.

Time	10 Wednesday
8:40	Lagoudakis
	Coffee Break
10:00	S4 Many-body
12:00	LUNCH
13:30	S5 Phase Transitions
15:30	Coffee Break
16:00	S6 Quantum Circuits
19:00	Keynotes & Invited speakers Dinner

Keynote:

Pavlos Lagoudakis

Polariton Computing:
from digital logic to analogue simulation

S4: Many-body

Altshuler:	**Are we on the way to room temperature superconductivity?**
Glazov:	Control of excitonic properties in 2D semiconductors by light-matter coupling
Fainberg:	Hartree method for calculation of exciton-polariton luminescence and exciton superfluorescence
Grudinina:	Thermal and dark-exciton contributions to interactions in polariton systems

S5: Phase Transitions

Shlyapnikov:	**Quantum advantage and novel transitions in disordered quantum systems**
Voronova:	Dipolar exciton BEC – dipolariton BEC tunable first-order phase transition
Fainstain:	Exciton-polariton Continuous Time Crystal with an Optomechanical Clock
Litvyak:	Nuclear spin clusters emerging in absorption spectra in CdTe at zero and low magnetic fields

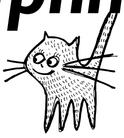
S6: Quantum Circuits

Petriashvili:	**Liquid Crystals and Nanostructure Synergy for the Development of Green Technology**
Barzanjeh:	Nonclassical radiation and amplification from superconducting quantum circuits
Ugulava:	Resonance Effect of a Radio Frequency Field on the Rotational Diffusion of Magnetic Nanoparticles
Siltanen:	Quantum master equation approach to polariton dynamics in organic light-emitting diodes

Altshuler

Shlyapnikov

Petriashvili



Polariton Computing: from digital logic to analogue simulation

Prof Pavlos Lagoudakis

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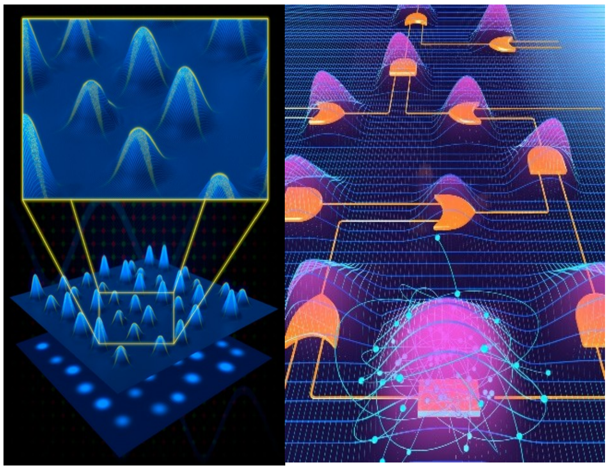
Modern digital computers have changed our lives in a variety of ways, but the technology on which they are built is rapidly reaching a hard limit due to inherent quantum effects. Two of the main pillars of our modern digital computers are the electronic transistor and the von-Neumann computer architecture. While the von-Neumann architecture established the physical separation of computing tasks like storage and processing, transistors are the fundamental building blocks in digital computers. The drive for faster and more powerful computers can be realised by increasing the number of transistors in a processor and the clock frequency. However, Moore's law will soon come to an end, whilst the breakdown of Dennard's scaling law means that clock frequencies have remain unchanged since 2006. This leads to the pressing quest to develop new kinds of transistors and alternative computing architectures that could one day lead to more efficient computers.

In our labs, we combine state-of-the-art photonic structures and light emitting semiconductor materials in which light and matter fuse to form new types of particles called polaritons. In a sense, polaritons bridge the fields of electronics and photonics by controlling the amount of light vs matter in these hybrid particles. At high densities, polaritons undergo 'condensation' forming micron scale droplets of liquid-light, with all particles within the droplet being coherent and indistinguishable from one another. In this seminar, I will describe the fundamental properties of such liquid-light droplets, aka polariton condensates, and their applications both in analogue (simulators) [1-4] and digital (logic) computing [5-6].



Schematics of (a) a liquid light analogue simulators, (b) liquid light circuit for digital computing

Prof Pavlos Lagoudakis graduated from the University of Athens, Greece. He received his PhD from the University of Southampton and worked as a postdoctoral researcher at the Ludwig Maximilian University of Munich. In 2006, he joined the faculty of the University of Southampton. In 2016, he joined Skoltech where he setup and heads the Laboratories for Hybrid Photonics. His research spans the fields of photonics, strong light-matter coupling, semiconductor, and condensed matter physics.

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Are we on the way to room temperature superconductivity?

Boris Altshuler

Columbia University

The speaker will discuss his recent extension of the Migdal-Eliasberg theory and its application to hydrides.

Control of excitonic properties in 2D semiconductors by light-matter coupling

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Bright excitons in semiconductors are characterized by two key parameters: the optical transition energy and radiative decay rate. In two-dimensional semiconductors the exciton transition energies lie in the range of 1.5 – 2.2 eV and exciton radiative decay rates are on the order of 1 ps^{-1}.

Here we demonstrate theoretically and illustrate the predictions experimentally that exciton optical transition energies and radiative decay rates can be efficiently tuned in van der Waals heterostructures with atomically thin transition metal dichalcogenides (TMDCs). Typical van der Waals heterostructure consists of a monolayer (ML) or bilayer (BL) TMDC encapsulated in hexagonal boron nitride (hBN) and deposited on top of the SiO_2/Si substrate. In such structures multiple reflections of light from interfaces modify the density of states of photonic modes are generally result in the Purcell effect: modification of the exciton radiative decay rate compared to that in the free space, and Lamb shift: variation of its optical transition energy due to coupling between the exciton with the vacuum fluctuations of electromagnetic field.

We perform calculations of the Purcell factors and Lamb shifts using two approaches. First one is fully quantum electrodynamical and based on the secondary quantization of the field in van der Waals heterostructures. Second one is semiclassical based on the solution of the Maxwell equations for the electromagnetic field together with the equation of motion for excitonic polarization. We demonstrate equivalence of the approaches in our case.

We illustrate our findings by experimental results obtained at INSA-Toulouse [1,2]. To detect the Purcell effect and Lamb shift, the exciton fine structure in atomically thin WSe_2-based van der Waals heterostructures has been investigated. The energy splitting Δ between the bright and dark exciton is measured by photoluminescence spectroscopy. It is shown that Δ can be tuned by a few meV as a result of a significant Lamb shift of the optically active exciton that arises from emission and absorption of virtual photons triggered by the vacuum fluctuations of the electromagnetic field. Strong variations of the bright exciton radiative linewidth as a result of the Purcell effect. All these experimental results illustrate the strong sensitivity of the excitons to local vacuum field fluctuations.

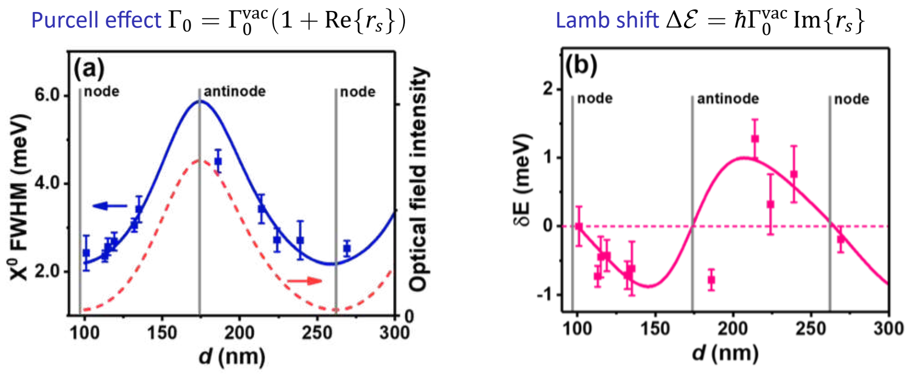

Fig. 1. Measured (symbols) and calculated (solid line) variation bright exciton linewidth (a) and δE, the bright-dark exciton splitting (b) as a function of the hBN thickness *d*. See Refs. [1,2] for details.

This work was supported by the RSF project 23-12-00142. We are grateful to L. Ren, C. Robert, D. Lagarde, B. Urbaszek, T. Amand, and X. Marie for discussions.

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Hartree method for calculation of exciton-polariton luminescence and exciton superfluorescence: Stokes shift, motional narrowing, non-Markovian Fano resonances, and high-temperature superfluorescence in hybrid perovskites

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Recently, Frenkel exciton polaritons (EPs) in organic materials and biological structures have drawn considerable interest due to their Bose-Einstein condensation, low-threshold polariton lasing, and polariton chemistry in microcavities. However, theoretically describing EP luminescence in molecular systems is challenging, as both the interaction with the radiation field and electron-vibrational interaction are strong in this case. In this work, using a realistic non-Markovian theory to describe the polariton-molecular vibration interaction, we calculated polariton luminescence on a polariton basis [1]. Employing the multiconfiguration Hartree approach, we derived nonlinear equations of motion for the polariton wavefunction, where the vibration degrees of freedom interact with the polariton quantum field through the mean-field Hartree term [2].

The Stokes shift and broadening of polariton luminescence spectra strongly depend on the exciton fraction of the EP, which is a function of frequency. We considered a single-mode microcavity. It is commonly thought that polariton states form when the Rabi splitting between the upper and lower polariton branches far exceeds broadening of the molecular resonances. In contrast, our non-Markovian theory [1] demonstrates the key features of Fano resonance in polariton luminescence when the Rabi splitting is comparable to the inhomogeneous broadening of molecular spectra. Additionally, we predicted motional narrowing of the EP luminescence spectrum in the microcavity. Our theory captures how the Stokes shift impacts polariton luminescence spectra. This provides a basis for the heuristic model used in experimental work [3], which qualitatively explains the larger Stokes shift in resonant cavities filled with R6G:PMMA compared to the same dye-doped films deposited on glass. Furthermore, our theory [2] explains the narrowing of the R6G:PMMA luminescence spectrum in a cavity relative to the spectrum of the same film on glass [3].

In light of the recent discovery of high-temperature superfluorescence (SF) in hybrid perovskite thin films [4,5], we have extended our multiconfiguration Hartree approach for polaritons [2] to model SF of quasi-2D Wannier exciton systems coupled to LO phonons in polar crystals. We calculated the interaction Hamiltonian for this system. Our work sheds light on the mechanism underlying the high-temperature SF in hybrid perovskite thin films. We show that in the superradiant state at zero wave vector, the LO phonon-exciton Frohlich interaction is nullified. For small deviations from the superradiant state, a new state emerges that is quadratic in the deviation. This new state retains superradiant properties, however, the optical transition frequency now depends on the amplitude (a non-isochronous system). In other words, the superradiant properties of the coherent state in hybrid perovskite thin films are stable under the perturbation caused by the LO phonon-exciton Frohlich interaction. Therefore, a prerequisite for the high-temperature SF in hybrid perovskite thin films is the formation of Wannier excitons interacting with the LO phonons via Frohlich interaction.

This work elucidates the conditions that allow coherent states to retain their superradiant properties at high temperatures, providing guidance for designing new quantum technologies.

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Thermal and dark-exciton contributions to interactions in polariton systems

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In this work we study bosonization in the electron-hole-photon system with the exciton pairing channel within the description based on the equilibrium path integral approach. Being originally developed for excitons [1], it allows among other things to take into account finite temperatures when considering interactions. In contrast to the standard exciton case, the presence of photons in the polariton system modifies interactions between electrons and holes within the excitons and hence the Wannier equation, leading to the so-called 'flexible' exciton regime when the Rabi-splitting is not negligible compared to the exciton binding energy.

To get insight into the possible explanation of experimentally-observed large saturation nonlinearity in polariton systems based on transition-metal dichalcogenide crystals (TMDC) [2, 3], we restrict ourselves here to the trivial limit of $T = 0$ and the 'rigid' (as opposed to flexible) *1s*-exciton state to calculate the exciton-exciton and saturation interaction matrix elements (see Fig. 1), and examine the dark exciton states which are self-consistently introduced in the exciton-photon action by considering spins of electrons and holes. Thus, the contributions of dark excitons to the upper- and lower-polariton blueshifts are estimated and are shown to reduce the Rabi-splitting with increasing density of the system (including the dark-exciton density). Our analysis qualitatively clarifies giant polariton nonlinearities in TMDCs, which may be due to the dark states and hence do not suppose the occurrence of the giant saturation constant g_{sat}, not "destroying" the hydrogenic nature of excitons in TMDCs. We reveal that large nonlinearity due to saturation in TMDCs potentially corresponds to the influence of dark exciton states, which also contributes to assisted exciton-photon coupling.

This work is funded by the Russian Science Foundation grant No. 24-22-00426 (https://rscf.ru/project/24-22-00426/).

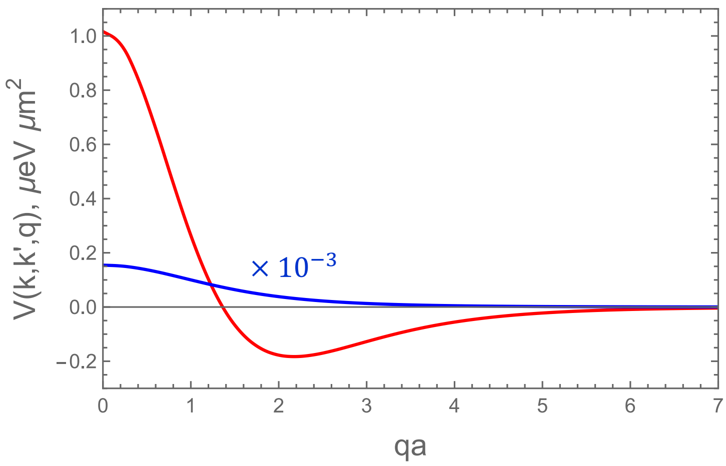

Fig. 1: Matrix elements V(**k**, **k'**, **q**) at $\mathbf{k} \approx \mathbf{k}'$ of exciton-exciton (red) and saturation (blue) interactions versus exchange momentum **q** calculated for MoS_2 monolayer.

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Quantum advantage and novel transitions in disordered quantum systems

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I first focus on single particle problems, in particular on dipolar excitations in a disordered lattice. This can be randomly spaced polar molecules, with one of them excited to the first rotationally excited state so that the rotational excitation can be transferred to other molecules and thus propagate in the system. It will be shown that there are bands of extended non-ergodic states and transitions between such states as well as transitions from extended non-ergodic states to ergodic ones. The identification of these novel phase transitions will then be discussed. I then turn to many-body problems, in particular to the one-dimensional Hubbard model in the lattice with on-site disorder. It will be shown that there are bands of extended non-ergodic states, transitions between such states and transitions from extended non-ergodic states to localized states. The discussion of this system will be linked to the problem of quantum advantage. Thus, in contrast to the situation a decade ago, when practically all extended states in disordered systems were considered as ergodic and only one (Anderson) transition between extended ergodic and localized states was discussed, we now have systems with bands of extended non-ergodic states and a set of novel phase transitions.

Dipolar exciton BEC – dipolariton BEC tunable first-order phase transition

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We study dipolariton Bose-Einstein condensation (BEC) and the excitation spectra in a wide single quantum well embedded in a microcavity, in the presence of relatively weak transverse electric fields (enough create the exciton dipole, at the same time not precluding the strong coupling and polariton BEC formation) [1]. We show that a fine control over the single-particle dispersion, interparticle interactions, and excitation spectrum can be acquired when one additionally applies in-plane magnetic field. Our theory predicts the existence of two minima on the lower branch of the polariton dispersion, which can be tuned at fixed fields strengths by a purely polaritonic control parameter, namely the photon-exciton detuning. The competition between these two minima gives rise to the tuneable first-order phase transition between the polariton Bose-Einstein condensate and that of excitons. We predict that such dipolar condensate in both regimes exhibits a roton-maxon character of the excitation spectrum, never before observed for polaritons. Our proposal opens opportunities towards manipulating the superfluid properties and dipole-dipole correlations of polariton condensates.

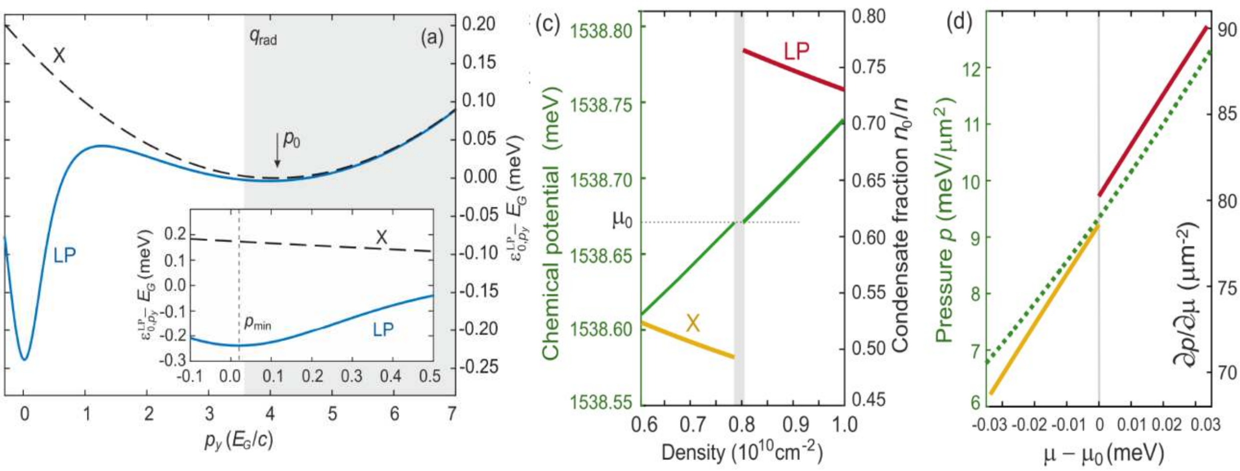

Figure: (a) Exemplary single-particle dispersions of excitons and lower polaritons vs p_y at $p_x = 0$ in a wide QW (L = 30 nm) in transverse electric field 4.2 kV/cm and in-plane magnetic field 3 T, with Δ = 10 meV. The inset shows the magnified view of the near-zero region, revealing the polariton minimum shifted from $p = 0$. (c) Chemical potential μ (left axis) and condensate fraction n_0/n (right axis) across the transition. μ_0 indicates the chemical potential at the transition. (d) Pressure and its derivative with respect to chemical potential vs $\mu - \mu_0$. While the pressure is continuous at the transition, its derivative exhibits a discontinuity, indicating the first-order transition type. For (b,c), B = 3T, E = 5.9 kV/cm, d/e = 8.5 nm, detuning Δ = 10 meV. The shaded area in (c) shows the transition region n ∈ [0.7862, 0.8027].

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Exciton-polariton Continuous Time Crystal with an Optomechanical Clock

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Time crystals broadly refer to the spontaneous breaking of time translation symmetry in quantum systems paralleling the similar concept of spatial symmetry breaking evidenced in crystalline matter [1]. In this context, so-called discrete time crystals (DTCs) have been demonstrated in diverse physical systems including cold atoms, magnons in superfluid ^{3}He, nuclear spins, photonic devices, and quantum computer qubits. DTC behavior is typically evidenced by the emergence of period doubling upon a time-dependent external drive. Very recently also continuous time crystals (CTCs) have been proposed in dissipative quantum systems perturbed from their equilibrium with a time-independent drive. Here, we reveal, through both ultra-high resolution spectroscopy and time-resolved spatial first-order coherence function $g^{(1)}(r,\tau)$ experiments, that the exciton-polariton ground state in a trap can develop a non-linear self-sustained dynamics, intimately affected by mechanics in ways that expose characteristics of both CTCs and DTCs. At low continuous, linearly polarized and non-resonant excitation powers (P_{cw}), a single confined level of the trap is observed. On increasing P_{cw} a Bose-Einstein condensation occurs at a threshold P_{th}. This is signaled by a strong non-linear increase in the level occupation, accompanied by a narrowing of the line down to a fraction of a GHz (coherence times of a few nanoseconds), as well as by an energy blue-shift determined by polariton-polariton and polariton-reservoir exciton-mediated interactions. On further increasing P_{cw} a series of striking qualitative changes occur. First, a spontaneous splitting of lines is observed, attributed to the σ polarization degree of freedom of the condensate. This splitting, together with the emergence of equispaced sidebands, manifests a self-sustained Larmor precession of the polariton-condensate pseudo-spin degree of freedom (evidence of a CTC). Second, on augmenting P_{cw} non-linearities induce an increase of the Larmor frequency, until it approaches the frequency (or a subharmonic) of a mechanical vibration confined to the same trap and strongly coupled to the polariton-field [2]. This resonance launches a self-sustained coherent mechanical wave [3] that back-acts on the polariton condensate locking the Larmor frequency at $\nu_m \sim 20$GHz (stabilized CTC). And third, on further increasing the polariton population the emergence of sidebands separated by $\nu_m/2 \sim 10$GHz signal a period doubling respect to the self-induced mechanical drive (DTC with continuous drive). Non-Hermiticity, non-linearity, and dissipative coupling between the polariton pseudo-spin states are shown to be critical ingredients for the observation of the spontaneous breaking of time-symmetry in such a many-body quantum system [4].

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Nuclear spin clusters emerging in absorption spectra in CdTe at zero and low magnetic fields

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For semiconductor structures in the absence of external magnetic fields nuclear spin system is characterized by internuclear spin-spin interactions, such as dipole-dipole and indirect (exchange and pseudodipolar) interactions [1]. For materials, isotopes of which have the value of nuclear spin more than ½, nuclear spins can also interact with electric field gradients (quadrupole interaction). All types of these internuclear spin-spin couplings manifest itself in nuclear magnetic resonance (NMR) spectra. Shape of NMR spectrum is determined by both Zeeman and nuclear spin-spin interactions, therefore strongly depending on the nuclear spin properties of the semiconductor under study [2,3].

In our work we present experimental manifestation of internuclear spin-spin interactions in radio-frequency absorption spectra of optically cooled nuclear spins of a CdTe/CdZnTe single quantum well in zero and low external magnetic fields. In such heterostructure quadrupolar interaction is absent and natural abundance of nuclear isotopes with nonzero spin is very low. The manifestation of such properties of the nuclear spin system was expected to be seen in absorption spectra.

In absorption spectra at zero external magnetic field, we observed three narrow low-frequency peaks and high-frequency "tail" (Fig. 1, blue dots). To explain the nature of these peaks, we developed a model of non-interacting nuclear spin clusters consisting of different numbers of spins. We based our model on the results of a previous work [3] where spin-spin interactions in CdTe appear as satellites to Zeeman absorption lines in high magnetic fields. We have concluded, that for description of absorption peaks observed in our experiments, five nuclear spin clusters should be taken into account (Fig. 1, green line). It should be noted, that our nuclear spin cluster model describes also spectra in external magnetic fields, in which nuclear spin-spin satellites appeare.

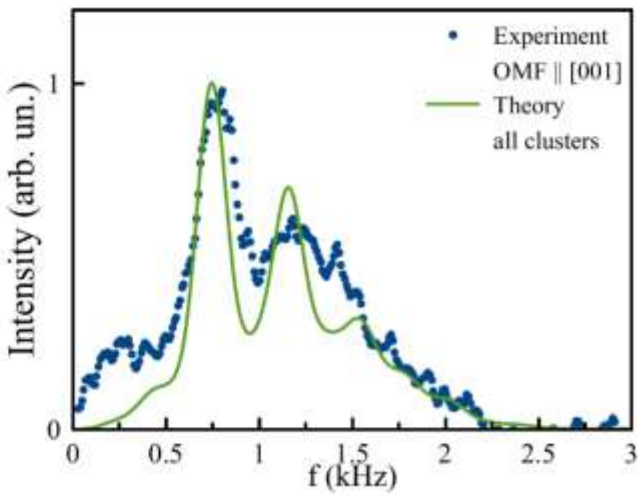

Fig. 1: Calculated in a nuclear cluster model (greed curve) and experimental measured (blue dots) absorption spectra in zero external magnetic field for CdTe heterostructure.

The authors acknowledge Russian Science Foundation, Grant No. 22-42-09020.

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Liquid Crystals and Nanostructures Synergy for the Development of Green Technology

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Solar energy is the most abundant of all energy resources and can even be harnessed in cloudy weather. It is estimated that the intensity of the sun, irradiated on one square meter of the earth, is equal to about 1000 watts. Globally, this amount of radiation could generate 85,000 terawatts, while the total energy currently consumed worldwide is 15 terawatts. There are several methods and tools based on converting the intensity of solar radiation into electrical energy. The most common are solar cells, or photovoltaic cells, which convert solar energy into electrical energy. Of these, silicon-based solar cells are the most common. However, they have several disadvantages, such as the thickness of the photosensitive layer, complex manufacturing technology, high cost, and the temperature dependence of converting light into electricity. One of the new types of promising converters is the dye-sensitized solar cells (DSSCs) [1], which are being actively investigated to improve their parameters. Currently, acid/alkaline-based organic and inorganic liquids are being used as electrolytes in DSSCs, however, they have many drawbacks, such as volatility, environmental pollution, high probability of electrolyte leakage, and temperature dependences of light-temperature conversion efficiency.

We have developed a new type of DSSC that uses liquid crystal (LC) material as the electrolyte for the first time. By replacing the LC electrolyte the parameters of DSSC were significantly improved. In particular, LC is environmentally friendly, non-volatile, and does not require deep insulation. Besides, the efficiency of converting light into electricity increases with increasing temperature. It has a long service time and, a wide operating temperature range, and the manufacturing technology is simple and cheap. Another advantage of the proposed LC electrolyte-based DSSC is that it acts as a rechargeable battery, which makes such light-to-electricity conversion and energy storage devices particularly promising. Unlike traditional silicon-based solar cells, DSSCs are less sensitive to the incident angle of light. This characteristic makes them more effective in capturing sunlight during different times of the day and under various weather conditions.

Solar concentrators [2] are a new and improved method of concentrating solar radiation. A new type of solar radiation concentrator using titanium dioxide nanoparticles has developed. The incoming light is scattered by the plasmonic nanoparticles and then guided to the window edges, where solar cells are placed in series. These cells form a PV system that can significantly enhance power conversion efficiency. Unlike existing solar concentrators, the proposed solar concentrator utilizes visible and infrared parts of solar irradiation. Using the proposed technology will reduce the part of traditional sources of electricity generation that cause environmental pollution.

Fig. 1 Solar concentrator deposed with plasmonic nanoparticles

Acknowledgment: This work was supported by Shota Rustaveli National Science Foundation of Georgia, project number FR-22-2543

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Nonclassical radiation and amplification from superconducting quantum circuits

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Parametric amplifiers with noise characteristics at the quantum limit play a central role in quantum processors [1], offering significant applications across various quantum systems. In the microwave frequency range these amplifiers enable precise, fast, and high-fidelity single-shot measurements of superconducting qubits [2], ensembles of spins [3], quantum dots [4], and nanomechanical resonators [5]. Furthermore, the utilization of near-quantum-limited amplifiers has created new experimental avenues for producing nonclassical radiation, including single and double-mode vacuum squeezing with applications in weak measurement, Axion dark matter detection and quantum illumination and radar [6].

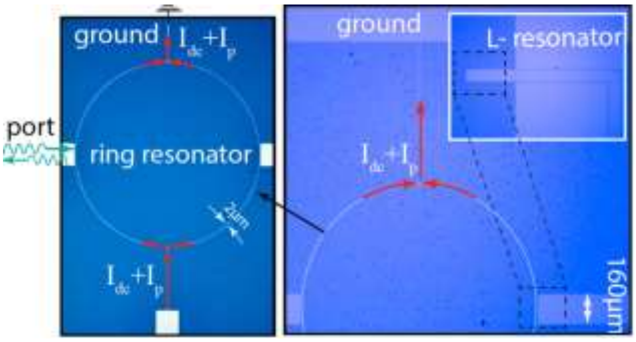

Fig. 1: A ring resonator with a 1.3 mm diameter and a 2 μm pitch is connected capacitively to an auxiliary resonator. A separate line provides the pump and DC current from the device's bottom, flowing through the ring.

Parametric amplification, primarily developed using Josephson junctions, has evolved into the leading technology for highly effective microwave measurements within quantum circuits. Despite their significant contributions, these amplifiers face fundamental limitations, such as their inability to handle high powers, sensitivity to parasitic magnetic fields, and particularly their limitation to operate only at millikelvin temperatures. To tackle these challenges, here we experimentally develop a novel quantum-limited amplifier based on superconducting kinetic inductance and present an extensive theoretical model to describe this nonlinear coupled-mode system. Our device surpasses the conventional constraints associated with Josephson junction amplifiers by operating at much higher temperatures up to 4.5 K. With two distinct spectral modes and tunability through bias current, this amplifier can operate selectively in both single and double-mode amplification regimes near the quantum noise limit. Utilizing a nonlinear thin film exhibiting kinetic inductance, our device attains gain exceeding 50 dB in a single-mode and 32 dB in a double-mode configuration while adding 0.35 input-referred quanta of noise. Importantly, this amplifier eliminates the need for Josephson junctions, resulting in significantly higher power handling capabilities than Josephson-based amplifiers. It also demonstrates resilience in the presence of magnetic fields, offers a straightforward design, and enhances reliability. This positions the amplifier as a versatile solution for quantum applications and facilitates its integration into future superconducting quantum computers.

We additionally observe stationary emission of path-entangled microwave radiation from our device, squeezing the joint field operators near 3 decibels below the vacuum level. Such quantum correlations are important for quantum-enhanced detection and provide direct evidence of the non-classical nature of the radiation emitted for the quantum circuits.

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Resonance Effect of a Radio Frequency Field on the Rotational Diffusion of Magnetic Nanoparticles

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The work investigates the rotational-stochastic dynamics (rotational diffusion) of magnetic suspension nanoparticles, created by random collisions of nanoparticles with liquid molecules. The flow of root-mean-square fluctuations of rotational motion acquires the character of periodic motion at large times. The frequency of this motion is due to the cyclicity of the angular variables of the nanoparticles and is proportional to the Brownian relaxation rate. It is shown that with the help of a weak radio-frequency field resonant with this periodic motion, it is possible to increase the average rotation speed. It is also shown that by selecting the parameters of the resonant field, it is possible to achieve a stationary deviation of the magnetic moments of nanoparticles by the desired angle.

Quantum master equation approach to polariton dynamics in organic light-emitting diodes

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Organic light-emitting diodes (OLEDs) have redefined lighting with their superior efficiency, durability, and energy savings. OLEDs emit light evenly across surfaces, offering unparalleled design flexibility for curved displays, flexible screens, and lighting panels. However, only 25 % of the electronic states of an OLED can emit light upon electrical excitation, limiting the overall luminous efficiency, especially in ambient lighting applications [1].

Strong light-matter coupling, achieved by confining light within OLEDs using mirrors, generates polaritons—hybrid light-matter states—which could activate the remaining 75 % electronic states. Recent studies have focused on intramolecular processes like reverse inter-system crossing (RISC) [2, 3]. However, it is debatable whether RISC only gets diluted due to the collective nature of polaritons and any enhancement in emission is actually due to Purcell enhancement. Hence, more comprehensive models are needed that also take into account intermolecular processes such as triplet-triplet annihilation (TTA).

Here, we present a phenomenological quantum master equation model that explains electrical excitation, different decay channels, ISC, RISC, and TTA. The model correctly produces the widely used classical rate equations and predicts dilution of triplet-polariton RISC. Our work helps to better understand the rich dynamics occurring in polariton OLEDs and paves the way for more advanced hybrid light-matter technologies.

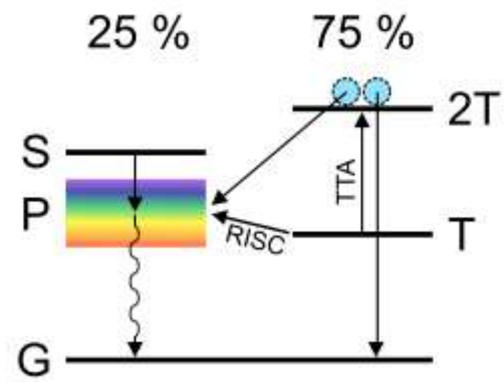

Fig. 1: A simplified energy diagram of an organic molecule upon electrical excitation. S = singlet, T = ttiplet, P = (lower) polariton, G = ground state.

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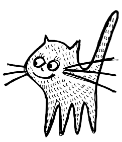


Time	12 Friday
8:40	Baumberg
	Coffee Break
10:00	S7 Quantum Hydrodynamics
12:00	LUNCH
13:30	S8 Photonic Lattices
14:40	Round Table
15:30	Coffee Break (photo)
16:00	S9 Materials
19:00	Conference Dinner / Announcements

Keynote:

Jeremy Baumberg

How emitters work when inside cavities shrunk to the picoscale

S7: Quantum Hydrodynamics

Klembt:	**Topological physics with light: Topological edge and corner modes in polariton lattices**
Zanotti:	Long-range & ballistic propagation at room temperature of 75% excitonic fraction polaritons in perovskite metasurface
Keijsers:	Photon superfluidity through dissipation
Mouchliadis:	Nonzero Berry curvature and Rashba-Dresselhaus effects in 2D perovskite microcavities

S8: Photonic Lattices

Amo:	**Localisation induced by drive and dissipation in photonic lattices**
Muñoz de las Heras:	Non-linear-enabled localization in driven-dissipative photonic lattices

Round Table

Controversies, consensus, past & future of light-matter coupling in nanostructures

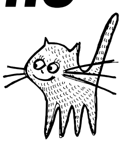
S9: Materials

Savvidis:	**Prototype Polariton Superfluid Qubit Analog in an Annular Trap**
Sundar Paul:	Local tuning of Rydberg exciton energies in nanofabricated Cu2O pillars
Paschos:	Strong-coupling utilizing 2D organic-inorganic halide perovskite crystals in Microcavity
Shahnazaryan:	Electrostatic control of nonlinear polaritons in a monolayer semiconductor

Klembt

Amo

Savvidis



How emitters work when inside cavities shrunk to the picoscale
KEYNOTE

by

Jeremy J. Baumberg

Jeremy John Baumberg, FRS, FInstP (born 14 March 1967) is a British physicist who is Professor of Nanoscience in the Cavendish Laboratory at the University of Cambridge, a Fellow of Jesus College, Cambridge and Director of the NanoPhotonics Centre.

Baumberg was born on 14 March 1967. He was educated at the University of Cambridge where he was an undergraduate student of Jesus College, Cambridge and awarded a Bachelor of Arts degree in Natural Sciences in 1988. He moved to the University of Oxford where he was awarded a Doctor of Philosophy degree in 1993. During his postgraduate study he was a student of Jesus College, Oxford and supervised by John Francis Ryan where his doctoral research investigated nonlinear optics in semiconductors.

Following his PhD, Baumberg was a visiting IBM Research fellow at the University of California, Santa Barbara (UCSB) from 1994 to 1995. He returned to the UK to work in the Hitachi Cambridge Lab from 1995 to 1998 before being appointed Professor of Nano-scale Physics at the University of Southampton from 1998 to 2007 where he co-founded Mesophotonics Limited, a Southampton University spin-off company.

Baumberg's research is in nanotechnology, including nanophotonics, plasmonics, metamaterials and optical microcavities. He is interested in the development of nanostructured optical materials that undergo unusual interactions with light, and his research has various commercial applications.

His early work led to the development of a number of pioneering experimental techniques. His research has been funded by the Engineering and Physical Sciences Research Council (EPSRC) and the Biotechnology and Biological Sciences Research Council (BBSRC).

Baumberg appeared in the documentary The Secret Life of Materials in 2015 and a Horizon documentary about Schön scandal first broadcast in 2004. He is the Author of "*The Secret Life of Science: How It Really Works and Why It Matters*" and a co-author of "*Microcavities*".

Topological edge and corner modes in polariton lattices

Sebastian Klembt
Chair for Applied Physics, Julius-Maximilians-University Würzburg & Würzburg-Dresden Cluster of Excellence ct.qmat

Topological Photonics is an emerging and novel field of research, adapting concepts from condensed matter physics to photonic systems adding new degrees of freedom. Here, topology has emerged as an abstract, yet surprisingly powerful, new paradigm for controlling the flow of light [1]. As such, it holds great promise for a wide range of advanced applications. Photonic lattice devices are generally used to emulate lattice Hamiltonians and a brief introduction focussing on group III-V microcavities will be given [e.g. 2]. Using high-quality vertical resonators, exciton-polaritons – hybrid states of light and matter – can emerge in the strong coupling regime. By choosing precise lattice geometries we are able to tailor optical band structures realizing novel photonic lattice. The specific geometry as well as the hybrid light-matter nature allow for ways to break time-reversal symmetry and implement topologically non-trivial systems. Starting from discussing zero-dimensional defects in one-dimensional lattices [3,4] and one-dimensional edge modes in 2D-lattices [5], I am going to discuss the emergence and properties of so-called corner modes. These fully localized 0D-topological defects in a two-dimensional lattices are studied in the breathing Kagome as well as the two-dimensional Su-Schrieffer-Heeger lattice [6]. Lastly, I will discuss ways to introduce a spin degree of freedom into the (bosonic) polariton system, by using the circular polarization degree of freedom as pseudo-spin [7]. In collaboration with the team of Prof Tim Liew, we show first indications of an artificial gauge field, emulating spin quantum Hall-like behaviour in the polarization selective propagation of polaritons in a lattice [8].

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Long-range and ballistic propagation at room temperature of 75% excitonic fraction polaritons in perovskite metasurface.

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Behaving as superlative non-linear photons due to their hybrid nature, exciton-polaritons represent a fruitful ground for studying quantum fluid of light and realizing prospective all-optical devices. However, achieving macroscopic propagation of polaritons with a high excitonic fraction at room temperature remains very challenging. Indeed, most room temperature excitonic materials exhibit lower quality compared to the conventional GaAs platform of cryogenic polaritons, resulting in significant nonradiative losses and localized disorder structures that can induce backscattering in polariton propagation. Moreover, the thermal broadening of excitonic resonance at room temperature severely hinders the macroscopic propagation of highly excitonic polaritons.

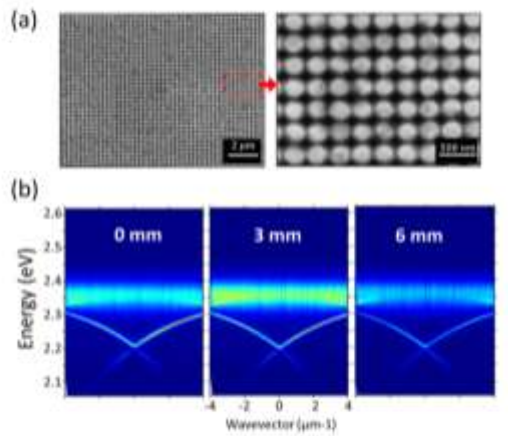

Figure 1. (a) SEM image of the perovskite metasurface. (b) Angle-resolved emission of polaritonic modes at different locations on the sample

Here, we report on experimental studies of exciton-polariton propagation at room temperature in resonant metasurfaces made from a sub-wavelength two-dimensional lattice of perovskite pillars. The metasurface is fabricated by direct thermal imprinting on a thin film of perovskite. The fabricated structure exhibits homogeneous patterns over square centimeters, exhibiting the same polaritonic modes with a remarkable Rabi splitting in the 200 meV range at room temperature (see Fig. 1). Most importantly, we demonstrate ballistic propagation of polaritons over hundreds of micrometers at room temperature, even with a large excitonic component of up to 75% (see Fig. 2). This long-range propagation is enabled by the high homogeneity of the metasurface and by the large Rabi splitting, which completely decouples polaritons from the phonon bath at the excitonic energy. Our results propose a new approach to study exciton-polaritons and pave the way toward large-scale and low-cost integrated polaritonic devices operating at room temperature.

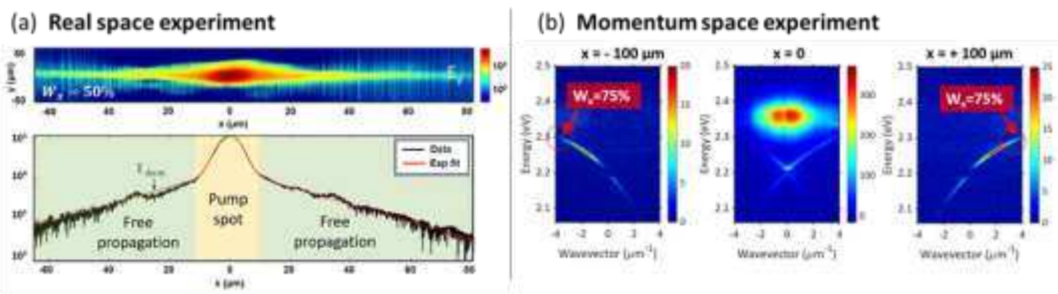

Figure 2. (a) Spatial-resolved emission corresponding to excitonic fraction 75%. (b) Angle-resolved emission measured at different propagation positions. The absence of the excitonic reservoir and uncoupled excitons signals at x = ±100 µm allows clearer observation of polariton narrowing near excitonic energy, signature of thermal broadening quenching.

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Photon superfluidity through dissipation

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Superfluidity - frictionless flow - has been observed in various physical systems such as liquid helium, cold atoms, and exciton-polaritons [1,2,3]. Superfluidity is usually realized by cooling and suppressing all dissipation. Here we challenge this paradigm by demonstrating signatures of superfluidity, enabled by dissipation, in the flow of light within a room-temperature oil-filled cavity. Dissipation in the oil mediates effective photon-photon interactions which are non-instantaneous and nonlocal. Such interactions were expected to severely limit the emergence of superfluidity in conservative photonic systems [4]. Surprisingly, when launching a photon fluid with sufficiently high density and low velocity against an obstacle in our driven-dissipative cavity, we observe a record suppression of backscattering (see Fig. 1). Our experiments also reveal the reorganization dynamics of photons into a superfluid, and a qualitatively changing behavior of the optical phase as light propagates around the obstacle. The phase is locked between the laser and the obstacle, but evolves with the intensity in the wake of the obstacle where superfluidity breaks down. Using a generalized Gross-Pitaevskii equation for photons coupled to a thermal field, we model our experiments and elucidate how the non-instantaneous and nonlocal character of the interactions influences superfluidity. Beyond providing a first demonstration of cavity photon superfluidity, and of any superfluid both at room temperature and in steady state, our results pave the way for probing photon hydrodynamics in arbitrary potential landscapes using structured mirrors.

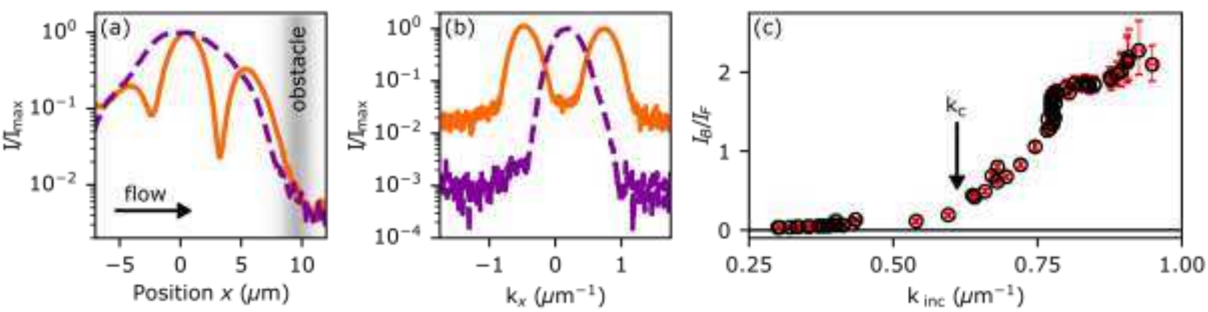

Fig. 1: Suppression of backscattering and existence of a critical velocity for superfluidity. This figure shows experimental results obtained when launching a photon fluid onto an obstacle in an oil-filled planar Fabry-Pérot cavity. (a) Normalized measured transmitted intensity along flow axis at low and high photon density, as solid and dashed curves respectively. At low density, light backscattered by the obstacle interferes with the incident light, which modulates the intensity in space. At high density, these interference fringes vanish since backscattering from the obstacle is fully suppressed. (b) Momentum-space measurements corresponding to (a), evidencing a full suppression of the backscattering peak initially at $k_x \sim -0.5\ \mu m^{-1}$. (c) Backward-to-forward scattering ratio when slowly increasing the fluid mean incident momentum k_{inc}. These measurements demonstrate the existence of a critical momentum k_c, and hence critical velocity, for superfluidity.

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Nonzero Berry curvature and Rashba-Dresselhaus effects in 2D perovskite microcavities

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In crystals lacking inversion symmetry, the spin-orbit interaction can be exploited to emulate artificial gauge fields describing the movement of electrons through an effective magnetic field [1]. Gauge fields due to photonic spin-orbit coupling play a central role in a number of exciting phenomena, giving rise to topological effects such as nonzero Berry curvature [2]. In this work, we realize an artificial gauge field for light in planar microcavities containing highly anisotropic 2D perovskite crystals characterized by large linear birefringence. The combination of TE-TM polarization splitting and the material's anisotropy leads to the interaction between photonic modes, realizing characteristic Rashba-Dresselhaus photonic spin-orbit coupling with the emergence of an effective magnetic field (Fig. 1a) and nonzero Berry curvature (Fig. 1b). These phenomena are described by an effective Hamiltonian for a general birefringent material inside a microcavity and can be utilized for the design of artificial gauge fields in photonic systems.

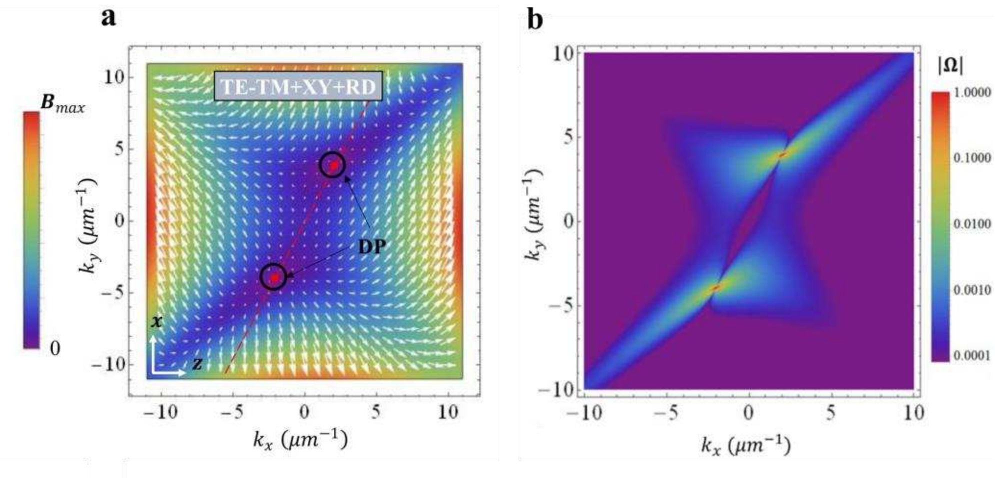

Fig. 1: **(a)** Effective magnetic field due to TE-TM splitting, XY splitting and RD interaction of two cavity modes. The effective magnetic field vanishes at the diabolical points (red dots) on the momentum plane. **(b)** Calculated Berry curvature for a system of RD interacting cavity modes with TE-TM and XY splittings.

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Localisation induced by drive and dissipation in photonic lattices

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The engineering of localised modes in photonic structures is one of the main targets of modern photonics. An efficient strategy to design these modes is to use the interplay of constructive and destructive interference in periodic photonic lattices. This mechanism is at the origin of defect modes in photonic bandgaps, bound states in the continuum and compact localised states in flat bands. In this presentation we show that in lattices of lossy resonators made of coupled semiconductor micropillars, the addition of external optical drives with controlled phase enlarges the possibilities of manipulating interference effects and allows designing novel types of localised photonic responses [1]. We show that light can be localised down to a single site of a photonic lattice in a fully reconfigurable manner. Nonlinear effects allow enhancing the localization effects [2,3].

The localized modes reported here are fully reconfigurable and have the potentiality of enhancing nonlinear effects and of controlling light–matter interactions with single site resolution.

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Non-linear-enabled localization in driven-dissipative photonic lattices

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Spatial photon localization holds great significance for the control of light-matter interactions, showcasing fundamental implications in quantum information, communication, and simulation. A recent experimental work [1] has shown how driving lossy photonic lattices with multiple, spatially separated, laser spots can produce localization with dynamically tunable spatial dependence. However, an important drawback of this method is that it only works for specific combinations of laser frequencies and/or distant spots. Here, we examine this localization regime in the presence of standard optical Kerr non-linearities, such as those found in polaritonic lattices, and show that they stabilize driven-dissipative localization across frequency ranges significantly broader than those observed in the linear regime, as shown in Figure 1. Moreover, we demonstrate that, contrary to intuition, in most situations this driven-dissipative localization does not enhance non-linear effects like optical bistabilities, due to a concurrent reduction in overall intensities. Nevertheless, we are able to identify certain parameter regions where non-linear enhancement is achieved, corresponding to situations where emission from different spots constructively interferes [2].

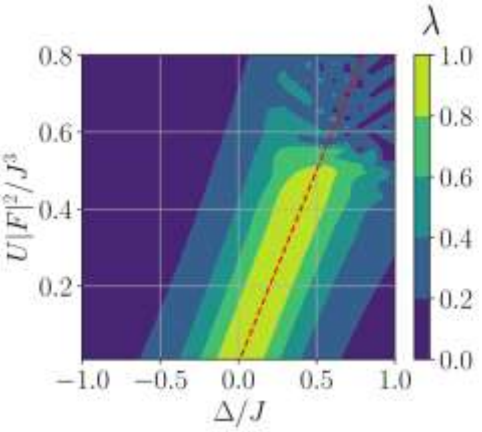

Fig. 1: Localization in a 1D photonic crystal lattice driven by two coherent pumps separated by two sites. The figure shows the fraction of localized light with respect to the total intensity inside the lattice λ as a function of the pump amplitude $|F|^2$ (normalized in units of the Kerr non-linearity strength U and the tunneling rate J) and the pump-resonator detuning Δ. The red dashed line indicates the $\Delta=U|F|^2/J^2$ dependence of the region showing the largest localization.

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Prototype Polariton Superfluid Qubit Analog in an Annular Trap

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Exciton-polaritons are hybrid light-matter quasi-particles resulting from the strong coupling of semiconductor excitons and microcavity photon. Being bosons polaritons can exhibit macroscopic spatial coherence and form out-of-equilibrium condensates exhibiting superfluid behavior when pumped above threshold. A promising recent theoretical proposal for polaritonic qubit utilizes split-ring polariton-condensate in an annular ring involving quantized circular currents[1,2]. This system relies on the formation of vortices in superfluids arising from the quantization of circulation, where the phase accumulation around a supercurrent loop can only take discrete values. Closely related physics governs the principles of operation of superconducting flux or phase qubits involving superconducting loops interrupted by Josephson junction.

Here we show that, under appropriate conditions, optically trapped out-of-equilibrium polariton condensates can populate two well-characterized states corresponding to the clockwise and counterclockwise circulating currents. We demonstrate coherent coupling between these states, due to the partial reflection of the circulating superfluid from a weakly disordered laser potential or an external control laser beam, while simultaneously maintaining long coherence times. We can control the coupling and thereby the energy splitting between the two eigenmodes of the system. Inspired by the theoretical proposal to realise qubit analogs and quantum computing with two-mode BECs[4], we formally identify the two polaritonic eigenmodes with the basis states of a qubit. Supplemented with controllable coupling between individual polaritonic qubits, such systems hold great potential for simulating a subset of quantum algorithms that do not rely on entanglement.

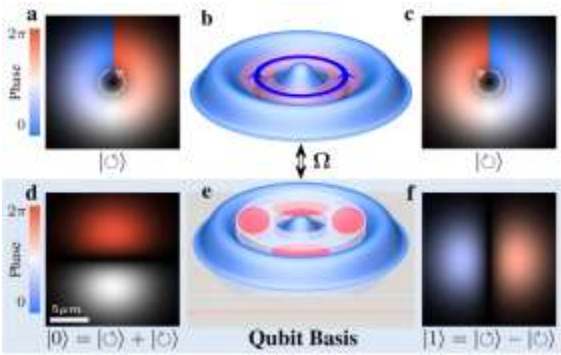

Figure 1: Polaritonic qubit analog

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Local tuning of Rydberg exciton energies in nanofabricated Cu_2O pillars†

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High lying Rydberg excitons in Cuprous Oxide (Cu_2O) feature giant optical nonlinearities. To harness these nonlinearities for quantum applications, the confinement must match the Rydberg blockade radius, which in Cu_2O could be as large as a few microns. Through this work, in a top-down approach, we show how exciton confinement can be realised by focused-ion-beam etching of a polished bulk Cu_2O crystal (see Fig. 1) while preserving the excitonic properties. The etching of the crystal to micron sizes allows for tuning the energies of Rydberg excitons locally, and precisely, by optically induced temperature change. These results pave the way for exploiting the large nonlinearities of Rydberg excitons in micropillars for fabricating non-classical light sources, while the precise tuning of their emission energy opens a viable pathway for realizing a scalable photonic quantum simulation. The recent development in exploring the strong light matter coupling for the micropillar cavities as a testbed for quantum correlations will also be discussed.

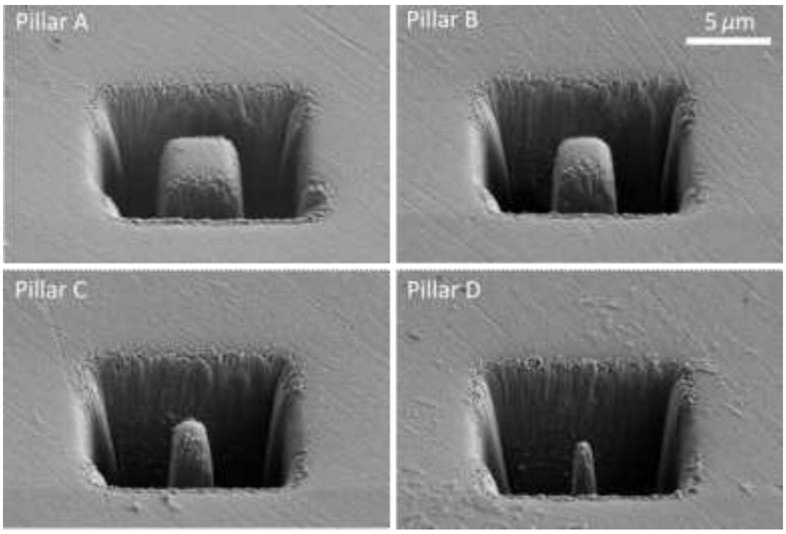

Figure 1: SEM images of the four micropillars constructed using FIB technique.

Strong-coupling utilizing 2D organic-inorganic halide perovskite crystals in Microcavity

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In recent years, 3D and 2D halide perovskite crystals used as active medium in polariton microcavities have shown immense potential for room temperature operation of optoelectronic devices due to their large exciton binding energies [1], oscillator strength [2], efficient photoluminescence and bandgap-tunability [3]. In this study, we use Ruddlesden–Popper organic-inorganic 2D halide perovskites solutions $(BA)_2(MA)_2Pb_3I_{10}$ incorporated in a prefabricated microcavity to investigate light-matter interactions in the strong-coupling regime. Microcavities with precisely controlled cavity thickness are fabricated by wafer-bonding two high reflectivity dielectric mirrors onto which desired thickness slabs of Cu are deposited. [4].When perovskite solution is injected through the side of the cavity, capillary forces drag the solution inside the microcavity spacer, forming optical quality 2D perovskite crystals of controlled thickness and large lateral dimension >100μm.

Furthermore, we show that such microcavities can exhibit strong-coupling regime (Fig1. c) which persists up to room temperature. The observed Rabi splitting is consistent with the previous observation of strong coupling in similar materials. Large size of the 2D perovskite crystals in combination with their high uniformity open new opportunities for their use in real world polaritonic devices at room temperature, while being cost-effective and easy to fabricate offer additional advantage over CVD and MBE grown heterostructures.

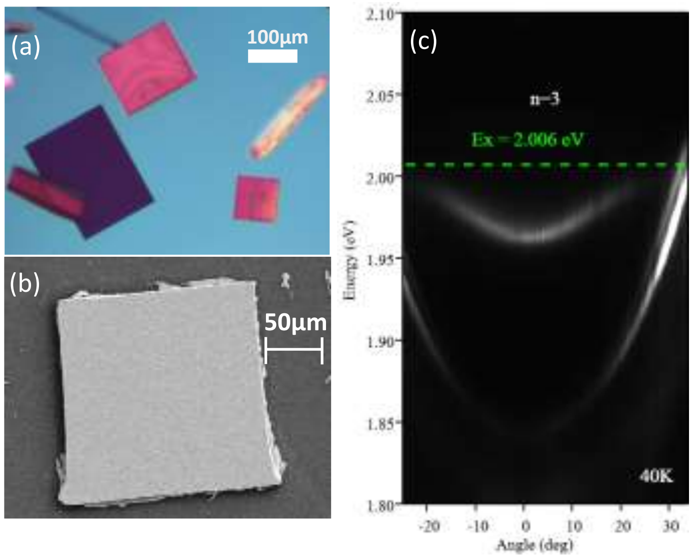

Fig. 1: (a) Optical microscope image of perovskite crystal between two quartz glasses. (b) SEM image of perovskite crystal. (c) Strong coupling in optical microcavity.

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Electrostatic control of nonlinear polaritons in a monolayer semiconductor

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We address experimentally and theoretically the time resolved dynamics of excitons polaritons in the $MoSe_2$ atomic monolayer in photonic crystal cavity, formed by substrate periodic grating. The photoluminescence spectra in TM polarization shows two exciton and two trion peaks, corresponding to Ta_2O_5 and empty regions of the substrate. The respective polariton spectra thus consists of 5 branches. We apply a near-resonant pulsed excitation at a given wavevector in the reflection geometry. We found a pump fluence-dependent significant blueshift of both upper and lower exciton-polariton resonances, demonstrating a sublinear behavior at high excitation regime. The results of theoretical modelling of polariton blueshift are in good agreement with the experimental data (see Fig. 1).

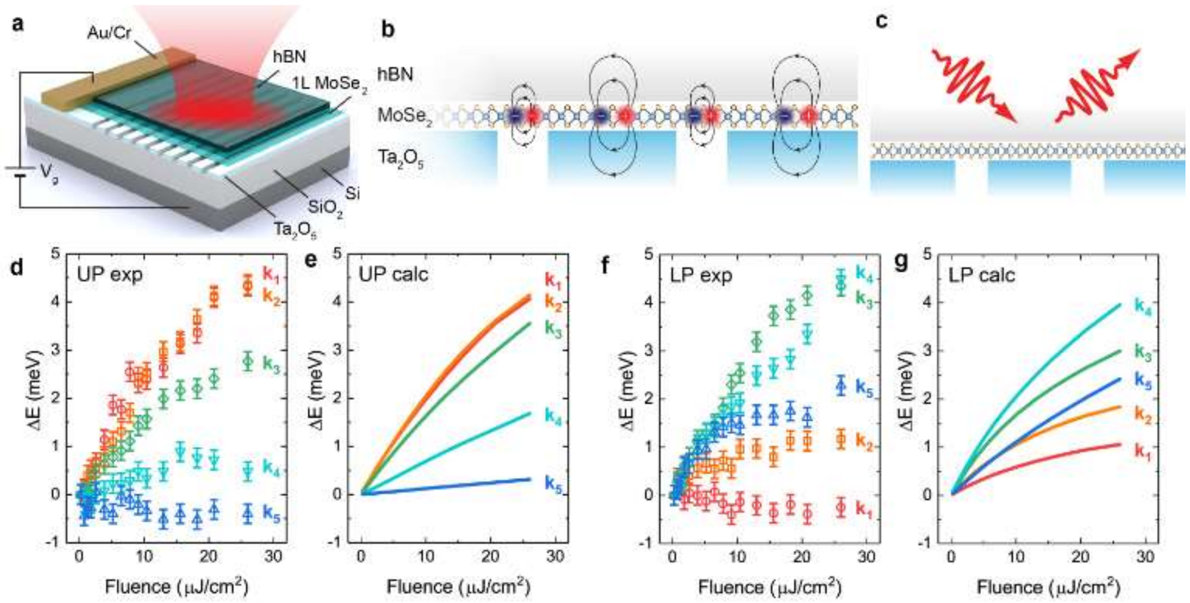

***Fig. 1**: **a** Schematic of the studied device. **b** Schematic illustration of the 2 spatially localized exciton species formed in $MoSe_2$ due to periodic modulation of the dielectric environment. **c** Schematics of polariton resonant excitation by femtosecond laser pulses and detection in the reflection geometry. **d** Experimentally measured, and **e** theoretically calculated fluence-dependent spectral shifts of upper polariton energy for excitation at different wavevector. **f**, **g** The same for lower polariton branch.*

We found that the modulating of gating field has a minor impact on exciton-polariton fluent-dependent nonlinear response. We further consider the quench of trion-polariton Rabi splitting at high excitation regime. Contrary to exciton-polaritons, the trion-polariton nonlinear response is strongly dependent on gating field, as the latter determines the free carrier density, and, consequently, the phase space available for trion excitation [1].

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Time	13 Saturday
8:40	Törmä
	Coffee Break
10:00	S10 Exotic Matter
12:00	LUNCH
13:30	S11 Spin & Vortices
15:30	Coffee Break
16:00	S12 Devices
17:30	Closing Session

Keynote:

Päivi Törmä

Bose-Einstein condensation and topological photonics in plasmonic lattices

S10: Exotic Matter

Kavokine:	**Quantum nanofluidics: from Coulomb drag to hydroelectric power**
Gavreev:	Data-driven identification and prediction of non-Markovian quantum dynamics
Kervalishvili:	Development of Laser Plasma Method for Spintronics and Spinquant 2D Structures
Tiukhova:	Low-temperature processing for blade-coated perovskite solar cells

S11: Spin & Vortices

Nalitov:	**Optically trapped polariton vortices**
Chestnov:	Exceptional-point-enforced vorticity of a trapped polariton condensate
Gnusov:	Spin precession resonance in a stirred exciton-polariton condensate
Kozlov:	Spin memory manifestation in polarization noises of polariton lasers

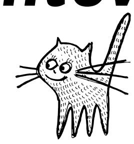
S12: Devices

Savenko:	**A theory for superconducting photodiode**
Kachlishvili:	Scanning system based on an innovative spectrometer — “ANTIDRON”
Tsulukidze:	Novel optical device: Time-resolved spectral monitoring of health

Kavokine

Nalitov

Savenko



Bose–Einstein condensation and topological photonics in plasmonic lattices
KEYNOTE

by

Päivi Törmä

Päivi Törmä is a Finnish physics professor at Aalto University. She works in the fields of quantum many-body physics, superconductivity, and nanophotonics.

Päivi Törmä graduated with a master's degree from the University of Oulu and the University of Cambridge. She earned a PhD in theoretical physics from the University of Helsinki in 1996, under the supervision of Stig Stenholm. She worked as a postdoc at the University of Ulm in the group of Wolfgang Schleich, and as a Marie Curie Fellow at the University of Innsbruck in the group of Peter Zoller. In 2001 she became a professor at the University of Jyväskylä, Finland. She moved to Aalto University (at that time Helsinki University of Technology) in 2008, and was an invited guest professor at ETH Zurich in 2015. Päivi Törmä has served the academic community by leading the Nanoscience Centre at University of Jyväskylä 2002-2005, as director of the Academy of Finland Centre of Excellence in Computational Nanoscience 2013-2017, vice chair of the Academy of Finland board 2010-2014, and member of the Research and Innovation Council chaired by the prime minister of Finland 2007-2015. Since 2017 she is the chair of the Millennium Technology Prize International Selection Committee.

Quantum nanofluidics: from Coulomb drag to hydroelectric power

Nikita Kavokine

Liquids are usually described within classical physics, whereas solids require the tools of quantum mechanics [1]. We have shown that in nanoscale channels, this distinction no longer holds. At these scales, the liquid flows become intertwined with electron dynamics in the channel walls, resulting in a wealth of phenomena beyond the reach classical fluid mechanics. I will discuss, in particular, our recent results on the coupling of liquid flows with electric currents in the channel walls [2], and implications for hydroelectric energy conversion at the nanoscale.

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Data-driven identification and prediction of non-Markovian quantum dynamics

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Understanding the influence of an environment on quantum dynamics is crucial for further progress in the development of controllable large-scale quantum systems [1]. However, non-Markovianity, i.e., effects of memory, is one of the most challenging problems towards the proper description of the open quantum systems. Since building a precise analytical or numerical description of open quantum dynamics from the first principles is a notoriously difficult problem, a solution to this problem can be addressed by building a precise data-driven model of open quantum dynamics based on experimentally observed data. Inspired by recent advances in data analysis and machine learning, we suggest a data-driven approach to the analysis of the non-Markovian dynamics of open quantum systems.

Our method takes a dataset consisting of measured noisy quantum trajectories as input. By reconstructing their minimal r-dimensional Markovian embedding [2] (Fig.1) our method captures the most important characteristics of open quantum systems, such as the effective dimension of the environment, eigenfrequencies of the joint system-environment quantum dynamics. Markovian embedding also allows the prediction of quantum dynamics as well as the reduction of noise in measured quantum trajectories.

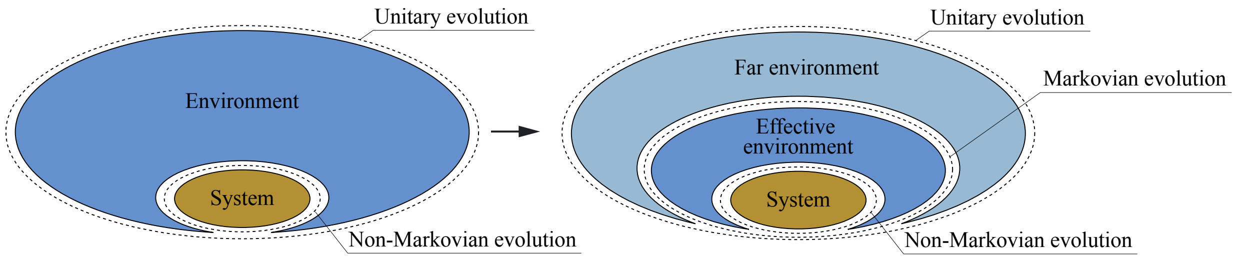

Fig. 1: Illustration of the Markovian embedding for the system interacting with the environment.

Our approach has a number of remarkable features:

1. Markovian embedding provides an interpretable model of open quantum dynamics, which gives insights into the properties of the environment.
2. Markovian embedding reconstruction procedure relies on matrix decompositions guaranteeing convergence to the optimal solution.
3. Our approach is equipped with an automatic model selection module that corresponds to the best machine-learning practices.
4. Proposed method can be applied to large datasets and complicated dynamics.

Note that all of the previously proposed methods do not combine the same features simultaneously.
The research is supported by the Russian Science Foundation (Grant No. 19-71-10092) and Russian Roadmap on Quantum Computing (Contract No. 868-1.3-15/15-2021, 5 October 2021).

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Development of Laser Plasma Method for Spintronics and Spinquant 2D Structures Preparation

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The convergence between quantum materials properties and prototype quantum devices is especially apparent in the field of 2D materials, which offer a broad range of material's properties, high flexibility in fabrication pathways and the ability to form artificial states of quantum matter. Along with the quantum properties and potential of 2D materials as solid- state platforms for quantum dot qubits, single photon emitters, superconducting qubits and topological quantum computing elements it is necessary to select the best method of preparation spinqubit nanosystems.

Based on difference from conventional electronics which uses the electron's charge degree of freedom for information processing, spintronics is devoted to incorporating the electron's spin degree of freedom. In an ideal situation, there will be purely spin current and no charge current in the spintronic circuit, thus practically no heat will be created and wasted. Meanwhile, information will be transmitted at a high speed owing to the spin coherence effect.

In linear optical quantum computing the basic building blocks are beam splitters, half- and quarter-wave plates, phase shifters, etc. The main characteristic of photonic computing process is the effect of nonlinearity of computation. Design of photonic computing devices which was inspired by the theoretical Ising model is based on lasers, mirrors, and other optical components commonly found on an optical table.

Perfection and ultra-purity are not the only parameters characterized material usefulness for quantum devices. Modification of material properties by different structural nonperfections (structural defects: impurities, isotopes, etc.) is the smart instrument for regulation of their characteristics.

Along with the quantum properties and potential of 2D materials as solid- state platforms for quantum- dot qubits, single- photon emitters, superconducting qubits and topological quantum computing elements it is necessary to select a the best method of their preparation.

Potential of laser plasma process for 2D materials preparation, particularly its usefulness for organization of nanostructures applicable in spintronic and quantum computing devices nowadays is actively developing. Laser plasma formed under the ionizing effect of powerful laser radiation on the thing. The usage of resonance light heat creates the opportunity to energize the selected atoms as well as their groups (assemble) and to produce plasma with the necessary properties relevant to structures which must be prepared.[1].

We are looking for further development of LP processes aim of preparation the next (higher) level of spintronic structures based on diluted semiconductors. Our works shown that the LP method and technology is very useful for preparation of a new highly effective multiqubit elements. [2]

Finally, when we are choosing the particles for quantum computing we should consider that the candidate for a qubit generally needs to have the quantum properties of superposition and entanglement. There a are also the main technical requirements of quantum computation which are: scalable physical systems with well characterized qubits (Zeeman Splitting); long decoherence time higher than gate operation one; existence of qubits at the ground state; set of quantum gates; measurement capabilities, etc. Leptons – fermions (electrons, protons, neutrons, muons, tauon and even neutrinos) as we know have that kind of properties. Concerning the photons – bosons particles with frequency-dependent energy collecting into the same energy state (Bose-Einstein condensation), they also could acting as a qubits because of polarization effects they characterized. The usefulness the other boson particles as quantum information carriers is the very interesting task for current and future research works.

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Low-temperature processing for blade-coated perovskite solar cells

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Halide perovskite is considered a promising photovoltaic material owing to high charge-carrier mobility, extended carrier lifetime, substantial absorption coefficient and defect tolerance. The power conversion efficiency (PCE) of small-area perovskite solar cells (PSCs) has escalated from 3.8% to exceeding 26 % [1]. Moreover, their potential lies in ability to be fabricated on glass or plastic substrates offering advantages such as lightweight, portability, and suitability for integration on curved surfaces. These low-cost and efficient PSCs hold great promise for commercial applications. Various printing methods consider to be advanced preparation processes that align well with large-scale manufacturing to achieve superior quality upscaled perovskite films.

However, operational layers on plastic substrates require annealing at temperatures lower than 150 ºC. This demands meticulous fabrication of charge transporting layers and absorber films to maintain high output performance.

In this work we made complex investigation for the modification of PSCs with increased active area manufactured by blade coating method. The aqueous dilution concentration of SnO2 nanoparticles was optimized, high-temperature spray-pyrolysis deposition of a compact TiO_2 layer was eliminated from the solar cell architecture and organic compounds TBAI, PEG10K were added to stabilize the ETL/perovskite interface.

The impact of the modification on the output characteristics of solar cells was estimated under the light of a solar simulator. The benefits for the used methods of growth halide PSCs were discussed.

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Optically trapped polariton vortices in the non-adiabatic regime

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Persistent quantum vortices can emerge spontaneously in out-of-equilibrium polariton condensates. Optically induced annular polariton traps, produced by incoherent excitonic gases, present a peculiar platform for creating and controlling such vortices. This talk will overview some effects involving optically trapped polariton vortex dynamics in the vicinity of the condensation threshold, where the excitonic reservoir cannot be adiabatically eliminated, including control over vortex topological charge [1], topological states [2] and a reach diagram of nonlinear transitions [3].

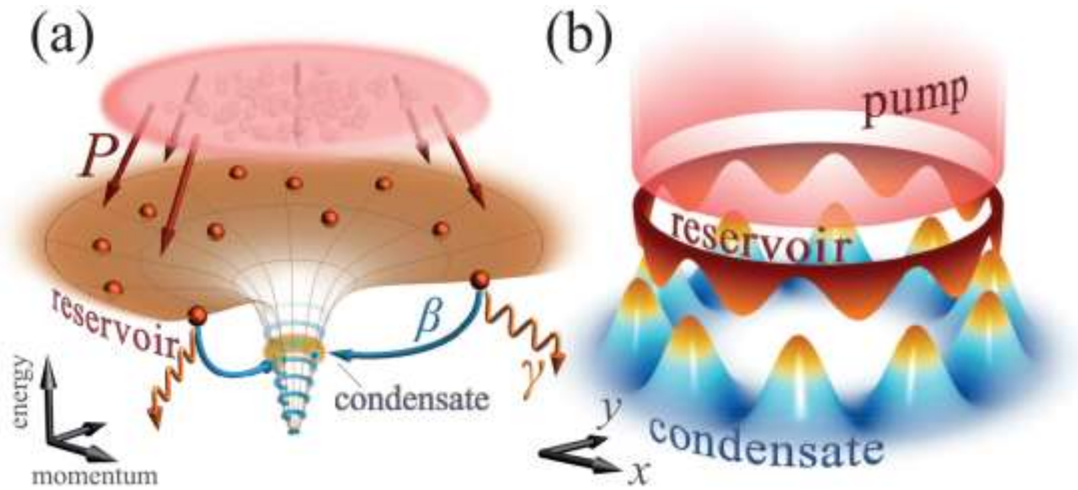

Fig. 1: (a) Momentum-space representation of the non-resonantly excited polariton condensate. The reservoir of high-momentum states of the lower polariton dispersion branch are created from the continuum of free carriers (dim red cloud) generated under high-energy laser radiation. Due to phonon-mediated cooling, these exciton-like particles (red beads) accumulate near the region of the dispersion inflection from where they can be scattered (blue arrows) to the discrete set of leaky polariton modes (blue-shaded levels) that arise from the spatial quantization in the trap. The mode with the fastest net gain rate (not necessarily the lowest in energy) accumulates a microscopically large number of particles thereby manifesting formation of the condensate (glowing yellow level). (b) A sketch of the burner-shaped polariton condensate created with a ring-shaped optical pump. The density of the ridged reservoir is shown upside down.

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Exceptional-point-enforced vorticity of a trapped polariton condensate

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Formation of quantized vortices is a spectacular manifestation of macroscopic coherence in quantum fluids. Being a fingerprint of equilibrium systems such as superfluid helium and ultracold dilute gases, this phenomenon also occurs in their open counterparts, namely off-resonantly driven polariton condensates. Because of their intrinsically non-Hermitian nature, polaritons localized in the trap support spontaneous nucleation of vortices whether they correspond to the ground state or not. However, in the circularly symmetric trap configuration, polariton vortices appear with a randomly selected handedness i.e. without preferred rotation direction.

Manipulation of vorticity direction requires an explicit breaking of the chiral symmetry meaning inequivalence of the clockwise and counterclockwise rotations. The existing symmetry breaking approaches include rotation of the optical trap [1,2] or an intricate sculpting of the pump pattern with imposed chirality [3]. In this talk we describe a simple approach which enables ultimate control over vortex handedness and formation probability. It needs only an annular optical trap with a weakly elliptical contour and a coaxial potential with an angle-dependent landscape. The proposed method takes advantage of the peculiar eigenvalue structure at the non-Hermitian singularities called exceptional points (EPs). Manipulating the pump ellipticity and its rotation angle relative to the conservative potential, one can bring polariton condensate to the EP where a pure vortex state with the given handedness is created with unit probability. Inversion of the pump orientation flips the vortex rotation direction.

Quite unexpectedly, we observe that polariton self-interactions enhance functionality of the proposed scheme. In particular, in the linear limit, vortices with integer orbital angular momentum (OAM) are excited only directly at the EP while the vortex quality rapidly decreases away from the EP. However, with the increase of the pump amplitude, the vortices with almost integer OAM appear within a large region of the parameter space around EP. Additionally, we reveal the existence of the robust time-periodic phase at the parity-time symmetric configuration of the trap orientation. In contrast with the previous theoretical [4] and experimental [5] findings, this oscillating state emerges in the low-pumping regime directly at the condensation threshold.

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Spin precession resonance in a stirred exciton-polariton condensate

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Driven spin precession is a standard tool to manipulate the spin state for different applications. Among others, the oscillating magnetic or optical fields at a specific frequency and amplitude are shown to drive the spin into the required state [1] for the realization of quantum gates.

Here, we discover the driven spin precession in exciton-polariton condensate featuring unprecedented spin coherence [2]. Utilizing the beating note of two nonresonant excitation lasers shaped with spatial light modulators we create a rotating optical trap [3,4] of a broken axial symmetry for polaritons (see Fig.1(a)), which causes the condensate spin to rotate in-step [2,5]. At GHz stirring frequencies, we reveal a resonant behaviour of the spin precession. The driven precession becomes amplified when the external stirring frequency matches exactly the condensate internal Larmor precession frequency. In fact, the trap acts as a rotating in-plane magnetic field, so the observed phenomena could be considered a driven-dissipative quantum fluidic analog of the Nuclear Magnetic Resonance effect. We find the resonance by sweeping both stirring frequency and pump polarisation ellipticity (see Fig.1(b)), which defines the frequency of the self-induced Larmor precession. At resonance, the spin oscillations are incredibly stable, with the spin dephasing time exceeding 170 ns, that is and by the order of magnitude larger than the previously reported value [6] and limited only by the stability of the excitation lasers. Furthermore, from the envelope of the precession resonance curve, we estimate its spin coherence time (T2). Our observations are supported by numerical simulations of the Gross-Pitaevskii equation.

The achieved control over the spin degree of freedom of polariton condensate opens new perspectives for their utilization in future spinoptronic devices [7], the addressable control of the spin in the extended arrays of condensates and as coherent light sources with polarization oscillations. The notable advantage of polaritons is the utilization of all-optical techniques for spin manipulation.

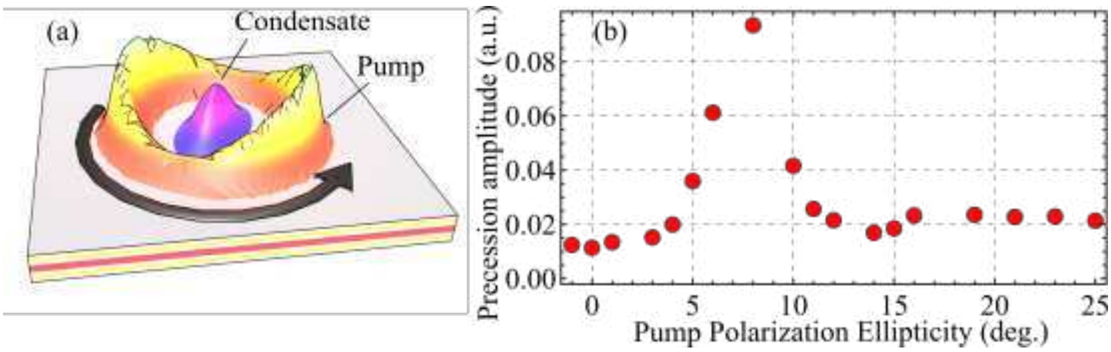

Fig. 1 (a) Schematic of the rotating excitation laser profile (red-to-yellow color scale) and polariton condensate distribution (blue-to-purple color scale). (b) Driven spin precession amplitude (measured as a range of the cross-correlation function of horizontal and vertical linear polarization components of the condensate emission at big (~15ns) time delay of the HBT interferometer) plotted as a function of pump polarization ellipticity (angle of the quarter waveplate in the excitation path).

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Spin memory manifestation in polarization noises of polariton lasers

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In recent decades, spin noise spectroscopy has occupied an important place in experimental magnetic resonance physics [1,2]. Due to the fact that SNS is a polarimetric method, this made it possible to expand the field of SNS to a number of “non-magnetic” physical systems, the properties of which also appear in light that fluctuates in polarization. For example, as in the case of emission from a condensate of polaritons [3,4].

In this work, we investigated the noise of a polariton condensate that was formed in a sample [5] with a resonator width of 3/2 λ. The condensate was excited by a non-resonant continuous laser with a power up to 10 times the threshold power. A strong dependence of Faraday rotation noise (FRN) and ellipticity noise (EN) on the polarization of the pump laser was discovered. Faraday rotation noise and ellipticity noise were recorded using spin noise spectroscopy techniques in the zero-frequency region.

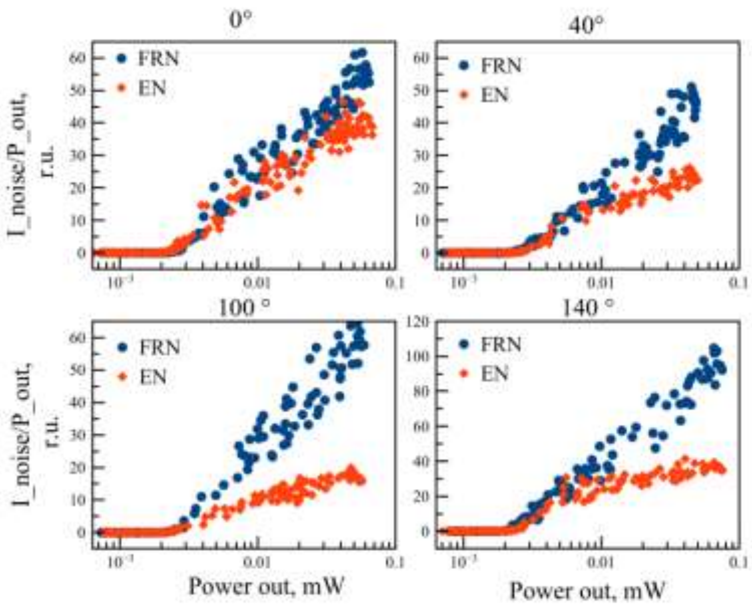

Fig. 1 Dependence of the normalized polarization noise power on the radiation power at different angles of the polarization plane of the exciting light.

The work was financially supported by RSF grant No. 21-72-10021.

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A theory for superconducting photodiode

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Diodes providing the electric current rectification effect are fundamental for quantum logic. We propose a superconducting device based on electromagnetic field-induced transport in two-dimensional superconducting thin films and monolayers at finite temperatures: a 2D superconducting photodiode. A microscopic first-principal theory shows that an external electromagnetic field's frequency and polarization can control the Cooper pairs' current.

This research aligns with the recent study of the superconducting diode effect [1]. We propose the photodiode, which (i) allows for optical control of the signal propagation in the system and (ii) is magnetic field-free, as opposed to the superconducting diode, where the magnetic field is necessary. The frequency of the control field depends on the superconducting gap. For conventional superconductors, it lies in terahertz (THz) and sub-terahertz regions. However, the effect we propose is general as it does not impose any substantial restrictions on the material or the frequency of the field, which can vary in quite a broad range. Moreover, this theory can be used for any 2D superconductors, including conventional and high-temperature superconductors.

Absorption of a uniform electromagnetic field with a frequency larger than the superconducting gap is forbidden in pure superconductors. Finite absorption can occur only if electron scattering by impurities is considered. In recent works [2-4], the issue of absorption of EM radiation in isotropic superconductors with built-in superconducting currents was studied. We are constructing a theory of the nonlinear response of isotropic 2D superconductors in the presence of a built-in constant supercurrent at various frequencies and temperatures.

The proposal for superconducting photodiode opens a route towards low-energy, small-scale electronics, nearly no dissipation thanks to the superconducting properties of the system, miniaturization (small-scale) of the devices, fast switch, and phase coherence due to the presence of the superconducting condensate, which, in turn, can provide high sensitivity.

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Scanning system based on an innovative spectrometer - "ANTIDRON"

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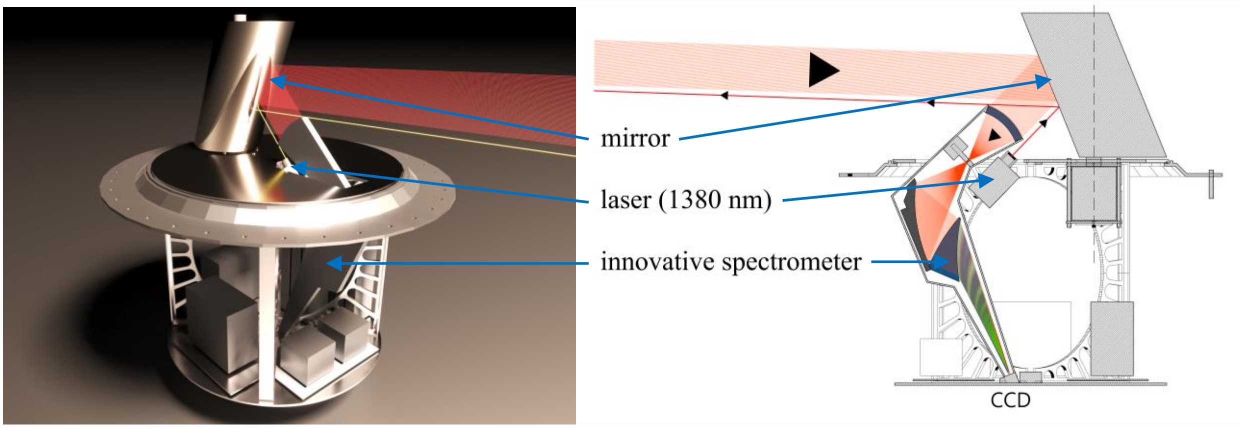

Fig. 1: The left figure presents a 3D visualization of the scanning system concepts, while the right figure depicts a cross-section.

Recent events underscore the escalating threat posed by small drones, eluding detection and identification through conventional radar systems. Beyond the military context, small drones introduce potential threats in terms of terrorism and reconnaissance.

We have developed the theory of an innovative spectrometer [1] that can be optimized for a diverse range of optical and spectroscopic applications. One of these applications involves addressing the challenge of detecting small-sized and elusive FPV (First-Person View) drones at distances of approximately 500 m. On one hand, developing a real-time scanning device that surveys the sky within a 500 m radius using a specialized laser apparatus presents no significant challenges. On the other hand, several non-trivial problems emerge: a) The reflected signal from small and camouflaged objects is exceedingly weak; b) the solar background is significantly brighter; c) precise isolation of the faint reflected signal from the solar background is essential.

For example, calculations indicate that utilizing a 1000 W (1380 nm) laser for hemispherical dome scanning, factoring in reflections from a drone with 4% reflectivity and an effective reflection area of 4 sq.mm within a 1/500-second interval, yields approximately 1/13,000,000,000 of the initial power, considering atmospheric absorption and scattering. Detecting these signals demands a sophisticated solution.

In theory, in the approximation of linear optics (which in turn implies both geometric and wave approximations), the innovative spectrometer has the highest possible transparency (sensitivity) and almost unlimited resolution, which allows it to be optimized for this kind of optical tasks. The problem is that the correct interpretation of the signal in this spectrometer strongly depends on the collimations of the signal itself. The more the signal is collimated, the more correctly it will be identified. Fortunately, the smaller and farther the target is, the more collimated the reflected signal is.

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Novel optical device II : Time – resolved spectral monitoring of health

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Photoplethysmography (PPG) is conventionaly used technique used for observing cardiovascular regulations, PPG showcases modulations of the reflected intensity of broadband visible light. We have developed software that connects to the spectrometer, capturing signals, thereby introducing a novel approach to photoplethysmography through the observation of signals across various wavelengths.

In many cases, the length of the data prevents the use of linear methods, necessitating the processing of large amounts of data. Linear methods, such as spectral methods (Fourier, wavelet, and correlation analysis), are typically employed for handling stationary signals, where statistical characteristics remain constant over time. But in real-life scenarios, signals of natural procceses (medical, biology, geophysics and econometrics) are typically non-stationary, meaning that nonlinear methods such as reccurence quantification analysis (RQA) and informational entropy analysis are needed for their accurate parametrisation. Informational methods have demonstrated interesting results while analysing biomedical signals and they can serve as predictors for chatastrophic events.

We processed simulated PPG signals, highlighting the capability of informational methods in capturing phase transitions. Additionally, we employed Recurrence Quantification Analysis (RQA), known for its effectiveness in analyzing short, nonstationary signals. RQA values provided a detailed parameterization, enabling the detection of anomalous fluctuations. The variation in determinism and entropy that we showcased further confirms the effectiveness of our method.

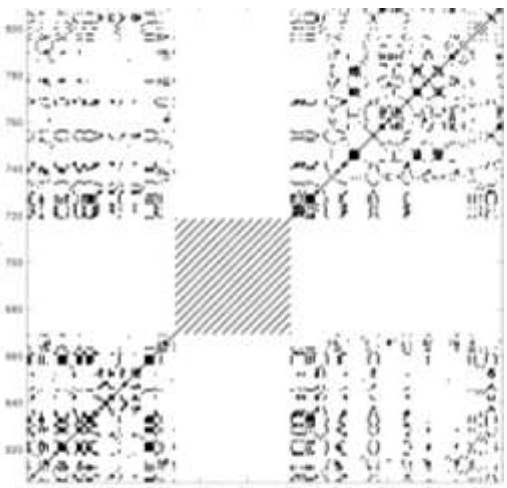


Fig.1 Reccurence plot of RR intervals from Simulated signal

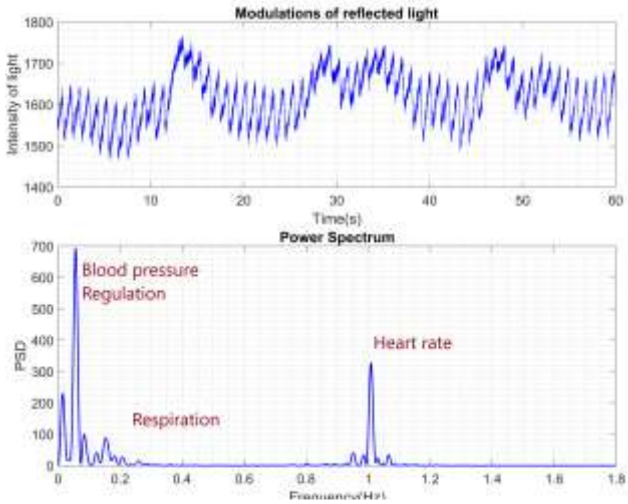
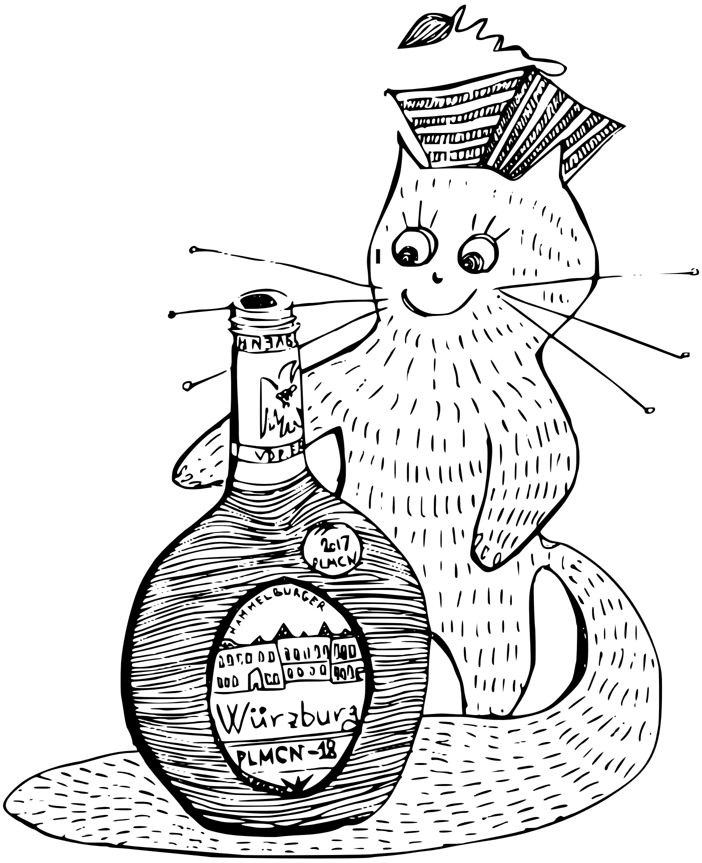


Fig.2 Reflected intensity modulations of the green ligth and it's power spectrum



Posters

Novel optical device I : spectral monitoring of disease

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Non-invasive spectrophotometric methods are widely used and recognized approaches in medical applications for diagnostics and health monitoring. Devices we use are compact and cost-effective (as showcased in fig2) what makes this methods pratical for implementation.

We developed innovative approach (devices + methods) combining set of instruments, which is characterized by its flexibility and remote operability, making it suitable for a wide range of settings, from clinical environments to home-based monitoring.

Diffuse Reflectance Spectroscopy (DRS) is a method that uses reflected light from the tissue to analyse composition of this tissue itself. Spectra taken from the patients gives us information about optical charachteristics of the tissue we are examining. Therefore any deviation from the normal spectra would indicate certain health problems that need to be adressed. DRS can also assess Ankle Brachial index as a division of spectras from fingertip and toe. Thus we will have not only one value of the ABI but set of the values at different wavelengths. We've taken spectras and spectral ABI-s from patients with angiology problems before and after surgeries, examining and monitoring success of treatment. Said results has been compared to the analytical models and the monte carlo simulations of the spectra, which were fitted to the experimental results, this not only helps us to analyse spectra but also showcased robustness of our approach.

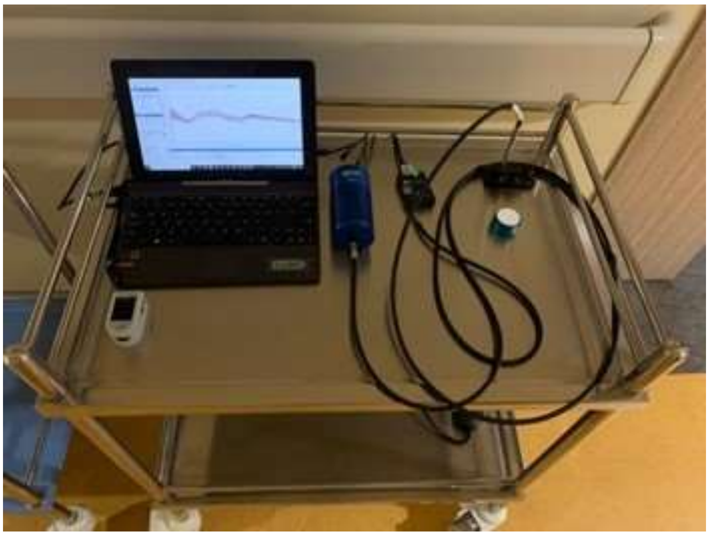

Fig. 2 Clinical set-up

Anisotropic localized plasmons of gold nanoclusters on GaP(001) surface

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Semiconductor-base surface structures with nanoclusters of noble metals supporting localized plasmons are of great interest for practical applications and also for fundamental investigating the interaction between localized plasmons and electronic states of semiconductors. Our article reports on the preparation and test optical studies of Au/GaP structures with surface gold nanoclusters. To prepare the structure, we developed a chemical procedure in which GaP(001) surface initially undergone to chemical etching in orthophosphoran acid H_3PO_4. Then the etched surface is treated by 0.2ml water solution of $HAuCl_4$, the latter treatment leads to chemical precipitation of a gold from solution onto the semiconductor surface.

Optical investigation of the prepared Au/GaP structures is carried out by method of reflectance anisotropy (RA) spectroscopy. Such a method measures as a function of the wave length the normalized difference of relectvities for linear polarization of incident light along to orthogonal surface axes. It has been shown RA spectroscopy can be used for detection of anisotropic localized plasmons of metal nanoclusters [1].

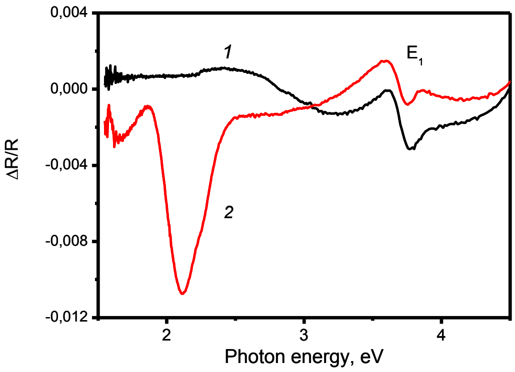

Fig.1 Reflectance anisotropy spectra of *1*- GaP(001) surface after etching, *2*- after chemical deposition of gold.

Fig. 1 presents the obtained RA spectra. RA spectrum *1* in Fig.1 measured after etching of GaP surface exhibits a weak spectral feature corresponding to optical bulk transition E_1 in GaP crystal. After chemical deposition of gold film, a strong resonant line appears at energy of 2.1 eV in RA spectrum curve *2*. This line is attributed to the localized anisotropic plasmons of gold nanoclusters which formed as a result of chemical gold deposition. The found plasmon anisotropy unambiguously proves that the formed by chemical deposition Au clusters have anisotropic shape. The shape anisotropy of gold nanoclusters, can arise, in turn, due to multiple anisotropic micropits appearing on surface of GaP(001) substrate as a result of its chemical etching. Such the pits have a shape of rectangular, the long side of which is oriented along [110] direction of GaP(001) surface. Apparently, gold atoms precipitating from solution preferentially aggregate in such pits and are therefore elongated along [110] direction.

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