FORTH-QuTech kick-off meeting
11-13 June 2025

Scientific program and Book of Abstracts

We are currently experiencing a wave of quantum revolution that enables quantum technologies to build on the foundations of quantum mechanics and information science. Quantum mechanics underpins our comprehension of the microscopic realm, while information science forms the backbone of today's ubiquitous communication and information processing systems. The symbiosis of these fields brings about Quantum Technologies including quantum information processing, secure communications, quantum simulations and quantum enhanced sensing and metrology.

A Center for Quantum Science & Technologies (FORTH-QuTech) has been recently established at the Foundation for Research and Technology-Hellas (FORTH). FORTH-QuTech aims to develop new tools for groundbreaking investigations across various basic research and technology disciplines and to generate new knowledge in the understanding of quantum phenomena. Specifically, FORTH-QuTech aims to form a critical mass of researchers from various disciplines to develop new paradigms, knowledge and understanding while dealing with: photonic, atomic, molecular and condensed matter systems for quantum information science (processing, communication, sensing, metrology, simulation, design of quantum algorithms and hybrid (quantum-classical) systems for computing and simulations).

The aim of the kick-off meeting is:
I) To inform the international and the national community, about a) the creation of FORTH-QuTech and the importance of quantum technologies, and b) the large number of high quality researchers and the state-of-the art research conducted in quantum technologies at FORTH and in Greece.

II) To enrich the vision of FORTH-QuTech and the Greek research community, with the current developments in quantum technologies.

III) To strengthen the possibility of national and international collaborations between the various research groups.

This kick-off meeting will bring together leading experts to enlighten the current status an future prospects of quantum technologies, focusing on the following three key themes:

1: Quantum technologies in EU: Current status and future steps
2: Quantum computation, simulation and cryptography
3: Quantum light, many-body physics and sensing

SCIENTIFIC COORDINATORS & ORGANISERS

Paraskevas Tzallas,
(IESL - FORTH & Coordinator of FORTH - QuTech)

David Petrosyan,
(IESL - FORTH)

Giorgos Vasilakis,
(IESL - FORTH)

FORTH-QuTech kick-off meeting 11-13 June 2025

- Location of the Welcome reception & Lab tour on **11th of June: FORTH central building**
- Location of the kick-off meeting on **12th, 13th of June: ENISA building**

Scientific Program

Wednesday 11 June			
13:00-16:00	Welcome reception	Registration, drinks and food (Location: FORTH central building)	
16:00-18:00	Lab tour	Labs tour at FORTH Institutes (Location: FORTH central building)	
Thursday 12 June			
Chair: G. Vasilakis (IESL)			
09:20-09:25	Vasilios Charmandaris	Chairman, Board of Directors, FORTH, GR	Introduction to FORTH
09:25-09:30	Emmanuel Stratakis	Deputy Director of IESL, GR	Introduction to IESL
09:30-09:40	Paraskevas Tzallas	FORTH-QuTech Coordinator, GR	Introduction to FORTH-QuTech
09:40-10:25	**Tommaso Calarco (Plenary)**	**Forschungszentrum Jülich, DE**	**Quantum technologies in EU: Current status and future steps**
10:25-11:00	*Coffee break*		
Chair: G. Stamatiou (ICS-FORTH)			
11:00-11:45	**Eugene S. Polzik (Plenary)**	**Niels Bohr Institute, DK**	**Beyond standard quantum limits: Quantum Mechanics in a Quantum Reference Frame**
11:45-11:55	George Vasilakis	IESL-FORTH, GR	Quantum Magnetometry at IESL-FORTH
11:55-12:05	David Petrosyan	IESL-FORTH, GR	Quantum simulations of strongly interacting few- and many-body systems at IESL-FORTH
12:05-13:20	*Lunch*		
Chair: H. Kondylakis (ICS-FORTH)			
13:20-14:05	**Frank Leymann (Plenary)**	**University of Stuttgart, DE**	**Quantum Software: An Architectural Perspective**
14:05-14:25	George Stamatiou	ICS-FORTH, GR	Hybrid Quantum-Classical Adaptive Computing Systems
14:25-14:45	Dimitrios Angelakis	TU Crete (Chania), GR & CQT, SG	Qubit efficient quantum computing and applications
14:45-15:10	*Coffee break*		
Chair: D. Petrosyan (IESL)			
15:10-15:55	**Radim Filip (Plenary)**	**Palacký University Olomouc, CZ**	**Non-Gaussian quantum physics**
15:55-16:05	Paraskevas Tzallas	IESL-FORTH, GR	Quantum light and Technologies at IESL-FORTH
16:05:16-15	Von Klitzing Wolf	IESL-FORTH, GR	BEC and Matterwaves at IESL-FORTH

16:15-16:35	Emmanuel Paspalakis	UoP, GR	Quantum Technologies at Univ. of Patras
16:35-17:30	Poster Session*	Poster presentations of key activities of FORTH Institutes (not necessarily related to Quantum Technologies)	
17:30-18:15	FORTH Director, Directors of FORTH Institutes, FORTH-QuTech "task force", and Plenary speakers		Round table discussion
	DINNER		
Friday 13 June			
Chair: von W. Klitzing (IESL)			
09:15-10:00	**Eleni Diamandi (plenary)**	**CNRS, Sorbonne Univ., Paris, FR**	**Quantum Cryptography: Current Status and Future Perspectives**
10:00-10:10	George Nikolopoulos	IESL-FORTH, GR	Quantum communication and Cryptography at IESL-FORTH
10:10-10:30	Haridimos Kondylakis	ICS-FORTH, GR	Query Optimization exploiting Quantum Computing
10:30-11:20	*Coffee break*		
Chair: G. Nikolopoulos (IESL)			
11:20-12:05	**Morgan W. Mitchell (plenary)**	**ICREA & ICFO, Barcelona, ES**	**Quantum sensing of magnetic fields: quantum limits of existing methods and prospects for new technologies**
12:05-12:20	Ioannis Kominis	UoC, GR	Quantum biology and sensing at Univ. of Crete (Heraklion)
12:20-12:40	Panagiotis Dimitrakis	IQCQT, GR	Quantum Technologies in IQCQT-Demokritos, Athens
12:40-13:50	*Lunch*		
Chair: G. Zacharakis (IESL)			
13:50-14:35	**Pavlos Savvidis (plenary)**	**Westlake Univ., Hangzhou, CN & IESL-FORTH, GR**	**Quantum Light and Fluids: Applications in Photonic Simulation and Annealing**
14:35-14:45	Nikos Pelekanos	UoC & IESL-FORTH, GR	Practical Single-Photon Emitters based on InAs Quantum Dots
14:45-14:55	Georgios Kavoulakis	HMU,GR	Quantum Technologies in Hellenic Mediterranean University
14:55-15:05	Spyros Sotiriadis	IESL-FORTH & UoC, GR	Entanglement in a quantum many-body system
15:05-15:10	Paraskevas Tzallas	IESL-FORTH, GR	Closing remarks

Poster presentations will be available throughout the duration of the kick-off meeting.

Abstracts

Lectures

Quantum Technologies in the EU: Current Status and Future Steps

Tommaso Calarco*
Forschungszentrum Jülich GmbH, Peter Grünberg Institute, Quantum Control (PGI-8), 52425 Jülich, Germany
*e-mail address: t.calarco@fz-juelich.de

The European Union is entering a decisive phase in its quantum journey, marked by an ambitious vision to achieve technological sovereignty and scientific excellence in quantum technologies. Building upon the achievements of the Quantum Flagship and numerous national initiatives, the EU has now laid the strategic foundations for the next phase through the European Quantum Declaration, together with all of its Member States. The recently announced European Quantum Strategy, and the forthcoming Quantum Act, will aim to unify and accelerate the development of quantum science and technology across Member States, with coordinated investments in research, infrastructure, education, and innovation.

This talk will offer an overview of the current status of quantum technologies in Europe from a scientific perspective. It will highlight the role of European research institutions, collaborative R&D projects, and emerging quantum ecosystems. Looking ahead, the talk will discuss how the strategic initiatives now underway—especially those to be formalized under the Quantum Act—will shape research agendas, technology roadmaps, and funding opportunities. Particular emphasis will be placed on how the scientific community can contribute to and benefit from these coordinated efforts.

Plenary, 12 May, 11:00

Beyond standard quantum limits: Quantum Mechanics in a Quantum Reference Frame

Eugene S. Polzik
Niels Bohr Institute, Copenhagen University
*e-mail address: polzik@nbi.dk

A question of the limits of the measurement precision has always been one of the central topics in quantum mechanics. A special case based on the measurement relative to a quantum reference frame has been introduced and explored. It has been shown that in a suitable reference frame the accuracy of measurements of spin projections and mechanical motion are not limited by the uncertainty principle [1]. The development of this field dubbed "measurements in the negative mass reference frame" or "quantum mechanics free subspaces" has led to several potential applications. In the talk I will introduce the concept of a reference frame with an effective negative mass or frequency which forms the basis for such measurements. Experiments where a macroscopic object and a reference frame are driven deep into entangled quantum regime will be reviewed, including observation of a trajectory of motion in a quantum reference frame with, in principle, unlimited accuracy [2] and applications of those ideas to magnetometry [3] and gravitational wave detection [4].

References

[1] *Nature*, **413**, 400 (2001); *Nature*, **547**, 191 (2017).
[2] *Nature Phys.* (2020) 10.1038/s41567-020-1031-5.
[3] *Phys. Rev. Lett.*, **104**, 133601 (2010).
[4] *Phys. Rev. Lett.* **121**, 031101 (2018); arXiv:2412.11824, to appear in *Nature* (2025).

Quantum Magnetometry at IESL-FORTH

G. Vasilakis*
Foundation for Research and Technology-Hellas, Institute of Electronic Structure & Laser, GR-70013 Heraklion (Crete), Greece.
*e-mail address: gvasilak@iesl.forth.gr

Keywords: atom-light interaction, spin noise

Quantum aspects of atom–light interactions have been a central topic in physics since the early days of quantum mechanics. Recent technological advances have transformed the atom–light interface into a powerful platform for precision measurements at or beyond classical limits. In this talk, I will present ongoing work in my group aimed at studying, understanding, and characterizing quantum features of light interacting with warm atomic spin ensembles, with particular interest in their potential for quantum-enhanced magnetometry.

Invited, 12 May, 11:55

Quantum simulations of strongly interacting few- and many-body systems

D. Petrosyan*
Foundation for Research and Technology-Hellas, Institute of Electronic Structure & Laser, GR-70013 Heraklion (Crete), Greece.
*e-mail address: dap@iesl.forth.gr

Keywords: quantum gates, quantum simulations, Rydberg atoms

Cold atoms trapped in optical lattices or arrays of microtraps represent a very clean yet controllable quantum system to simulate and study few- and many-body physics. Supplemented by laser excitation to the strongly-interacting Rydberg states, neutral atoms can implement high-fidelity quantum gates and realize large-scale quantum simulators.

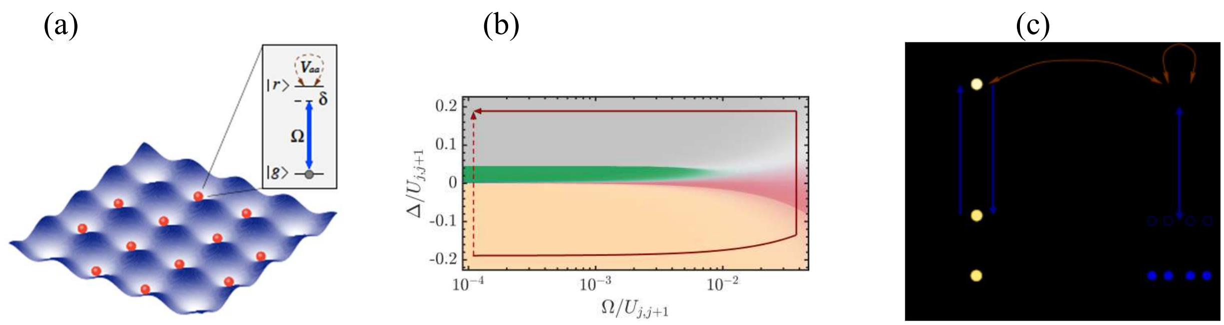


Fig. 1 (a) Cold neutral atoms in a lattice trap laser excited from the ground $|g\rangle$ to the strongly interacting Rydberg state $|r\rangle$. (b) Phase diagram of the quantum Ising model realized by the laser-controlled atoms in a lattice. (c) Level scheme of atoms to realize a multiqubit quantum CNOT_k gate between one Cs and $k \geq 1$ Rb atomic qubits.

I will outline some of our recent research on quantum gates [1,2] and simulations [2,3] with Rydberg atoms in a lattice.

References

[1] D. Petrosyan, S. Norrell, C. Poole, M. Saffman, "Fast measurements and multiqubit gates in dual species atomic arrays", *Phys. Rev. A* **110**, 042404 (2024).
[2] G. Doultsinos, D. Petrosyan, "Quantum gates between distant atoms mediated by a Rydberg excitation antiferromagnet", arXiv:2408.11542 [quant-ph]
[3] A. F. Tzortzakakis, D. Petrosyan, M. Fleischhauer, K. Mølmer, "Microscopic dynamics and an effective Landau-Zener transition in quasiadiabatic preparation of spatially-ordered states of Rydberg excitations", *Phys. Rev. A* **106**, 063302 (2022).

Plenary, 12 May, 13:20

Quantum simulations of strongly interacting few- and many-body systems

Frank Leymann *
IAAS, University of Stuttgart.
*e-mail address: frank.leymann@iaas.uni-stuttgart.de

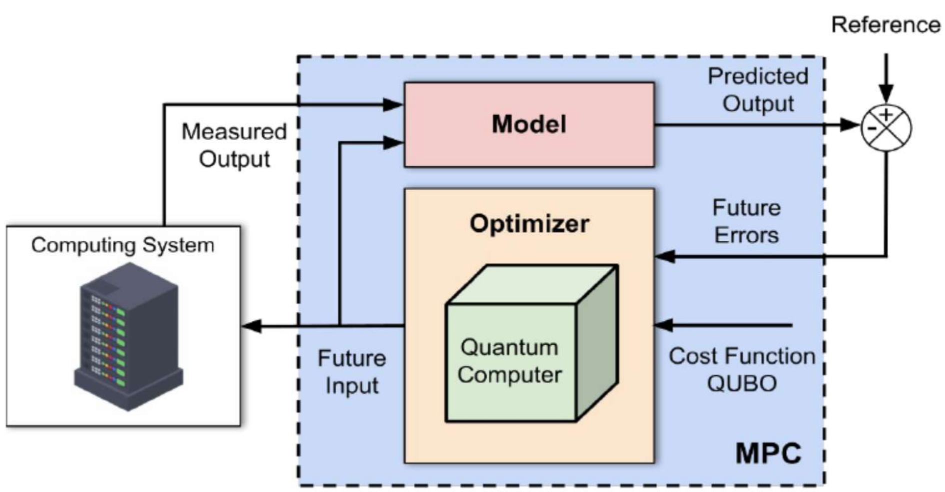
This talk will sketch the essentials of quantum computing technology from a software perspective. We will discuss properties that make quantum computing so interesting for applications. But quantum computing is radically different from classical computing such that new approaches for building software that encompass quantum computing is needed. We will sketch such differences and suggest a first attempt of a lifecycle of quantum software that evolved from projects the speakers are engaged with. Also, some building blocks of a corresponding development environment and execution infrastructure will be discussed that have been developed in projects. Selective areas that demand significant research will be pointed to.

Hybrid Quantum-Classical Adaptive Computing Systems

G. T. Stamatiou*
Foundation for Research and Technology-Hellas, Institute of Computer Science, GR-70013 Heraklion (Crete), Greece
e-mail address: stamatiou@ics.forth.gr

Keywords: quantum optimization, model predictive control

As adaptive computing systems grow in complexity and responsiveness requirements, we aim for efficient, real-time control mechanisms. Predictive control strategies such as Model Predictive Control (MPC) offer a powerful optimization-based framework for dynamic system regulation, but the computational demands increase with system complexity and longer prediction horizons. This talk explores a hybrid quantum-classical computing approach that leverages quantum optimization algorithms to solve the core optimization problem in MPC, making advanced control feasible. We present two case studies: the stabilization and control of an unstable queueing system [1] and the dynamic resource management of an Internet server [2]. Our results show that the quantum solution shows potential improvement over the classical solution for longer prediction horizons. However, we also highlight key trade-offs such as solution variance, QPU access time, and network latency that influence the real-time control. These insights position hybrid quantum-classical systems as a promising direction for next-generation adaptive infrastructures.



References
[1] G. T. Stamatiou, K. Magoutis, “Quantum-Enhanced Control of a Tandem Queue System”, VALUETOOLS 2023. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, vol 539. Springer, Cham. (2024) https://doi.org/10.1007/978-3-031-48885-6_7

[2] E. Papageorgiou, G. T. Stamatiou and K. Magoutis, "Model Predictive Control of Internet Servers using Quantum Annealing," 2024 IEEE International Conference on Autonomic Computing and Self-Organizing Systems (ACSOS), pp. 151-156, (2024) https://ieeexplore.ieee.org/document/10771442

A summary of our efforts in my group and some ideas forward towards a concentrated national quantum effort in Greece

Dimitris Angelakis[1,2*]
[1]*IQCQT Demokritos, Athens, Greece*
[2]*TUC Chania (Crete), Greece*
*e-mail address: dimitris.angelakis@gmail.com

I will present our recent efforts in showcasing quantum supremacy in driven many-body systems in analog quantum simulators settings. The work is based on complexity theory arguments and supports earlier intuitions and heuristic claims, that is indeed computational hard to simulate complex quantum dynamics. Our result opens the path for a multitude of analog platforms to showcase and benchmark quantum supremacy, including cold atoms, ions and superconducting qubits. The connection was made via showing that sampling from the output distribution of thermalizing driven many-body systems is P hard and the hardness is connected with the quantum phase matter is in. Recently, in collaboration with the cold atom group at USTC, an experiment has been performed where some of our predictions were implemented in cold atom setup. In the second part of the talk, if time, I will discuss some of our recent works in improving quantum approximate optimization algorithms for industrial applications using a novel encoding we have developed. The approach allows solving QUBO problems for up to 4000 classical variables, pushing the state of the art with NISQ devices by almost two orders of magnitude. Two real world examples will be discussed, in route optimization and financial transaction optimization using real world use cases.

Beyond science, I will also present some ideas on how we plan to shape the new quantum institute in Demokritos as well as the plans to collaborate at the national level to push Hellenic quantum science and technology to the next level.

Quantum non-Gaussian states of light and atoms

R. Filip*
Department of Optics, Faculty of Science, Palacky University, 17. listopadu 1192/12, 77146 Olomouc, Czech Republic.
*e-mail address: filip@optics.upol.cz

Keywords: bosonic quantum technology, quantum non-Gaussian states

The bosonic systems currently have revolutionary applications in all pillars of quantum technology. They stimulate further studies of the fundamental features of bosonic states. The talk will present an overview of the theoretical and experimental development of quantum non-Gaussian states of many bosons, their generation, manipulation, detection, identification, scalability, and applications for different experimental platforms: nonlinear optics and cavity QED, microwaves in superconducting circuits, and mechanical motion of trapped ions and nano-oscillators. The particular focus will be on conclusive benchmarking and scalability of quantum non-Gaussian states of light, microwaves and mechanics in recent experiments.

Quantum Light and Technologies (*Q-light*) at IESL-FORTH

P. Tzallas[1,2,3*]

[1]*Foundation for Research and Technology-Hellas, Institute of Electronic Structure & Laser, GR-70013 Heraklion (Crete), Greece.*

[2]*Center for Quantum Science and Technologies, FORTH, 70013 Heraklion, Crete, Greece*

[3]*ELI-ALPS, ELI-Hu Non-Profit Ltd., Dugonics tér 13, Szeged, H-6720 Hungary*

*e-mail address: ptzallas@iesl.forth.gr

Keywords: strong laser physics, high harmonic generation, quantum optics, quantum light

Non–classical and entangled light states are of fundamental interest in quantum mechanics and they are a powerful tool for the emergence of new quantum technologies. The development of methods that can lead to the generation of such light states is therefore of high importance. Recently, we have demonstrated that intense laser–matter interactions can serve towards this direction. Specifically, we have shown how the use of fully quantized approaches in intense laser–matter interactions and the process of high harmonic generation [1-8], can lead to the generation of high photon– number non-classical and entangled states from the far–infrared (IR) to the extreme–ultraviolet (XUV) [6]. Here, I will summarize these developments and potential future directions of non-classical light engineering using strong light fields with the potential application in ultrafast and quantum information science. These findings represent a significant advance in the development of novel quantum nonlinear spectroscopy methods [9], which exploit the interplay between the quantum properties of light and those of matter—a central objective of the *Q-light* laboratory at IESL-FORTH [10–12].

References

[1] N. Tsatrafyllis, et al., *Nat. Commun.* **8**, 1 (2017)
[2] N. Tsatrafyllis, et al., *PRL* **122**, 193602 (2019).
[3] M. Lewenstein, et al., *Nat. Phys.* **17**, 1104 (2021).
[4] J. Rivera-Dean, et al., *Phys. Rev. A* **105**, 033714 (2022).
[5] P. Stammer, et al., *PRL* **128**, 123603 (2022).
[6] P. Stammer, et al., *PRL* **132**, 143603 (2024).
[7] J. Rivera-Dean arXiv:2409.02016
[8] P. Stammer arXiv:2410.15503
[9] Th. Lamprou, et al., PRL **134**, 013601 (2025).
[10] P. Stammer, et al., *PRX Quantum* **4**, 010201 (2023).
[11] U. Bhattacharya, et al., *Rep. Prog. Phys.* **86**, 094401 (2023).
[12] Th. Lamprou, *et al., J. Phys. B* (in press 2025).

Cretan Matterwaves and Space Optics

A. Aretaki[1,2], E. Blavakis[1,2], M. Chairetis[1], P. Examilioti[1,2], M. Georgousi[1,2], K. Makris[1,3], A. Oikonomou[1,3], V. Pareek[1,3], V. Pathak[1,3], V. P. Veettil[1,3], R. P. Thampy[1,3], P. R. Antunez[1], D. Papazoglou[1,3], and W. von Klitzing[1*]

1. *Foundation for Research and Technology-Hellas, Institute of Electronic Structure & Laser, GR-70013 Heraklion (Crete), Greece.*
2. *Department of Physics, University of Crete, -70013 Heraklion (Crete), Greece*
3. Department of Materials Science and Engineering*, University of Crete, -70013 Heraklion (Crete), Greece*

* e-mail address: wvk@iesl.forth.gr

Keywords: Quantum Sensing, Matterwave Interferometry, Matterwave Optics, Space Instrumentation.

In this presentation, I will give an overview over the activities of the quantum-activities of the Cretan Matterwaves and Space Optics groups. Which range from the first fully coherent matterwave guides [0] and matterwave lensing down to pico-kelvin temperatures [4] to technology developments for space-based atom-quantum sensors for (CARIOQA-PMP [5]). I will also touch upon our current large-scale proposals such as the proposed gravitational wave detector Elgar [1], a mission proposal to test Einstein's weak Equivalence principle in space (STE-QUEST) [2] and gravity mapping of Mars using atom interferometry (MaQuIs) [3].

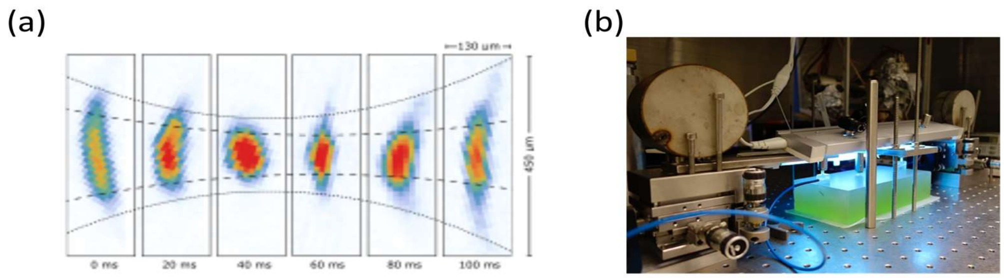


Fig. 1 (a) A matterwave focussing in a coherent matterwave guide. (b) Assembly of an ultra-stable optical breadboard for space missions.

References

[0] Saurabh Pandey et al. *Nature* **570 7760** 205--209 (2019)

[1] Benjamin Canuel et al. *Classical and Quantum Gravity* **37 22** 225017 (2020)

[2] Naceur Gaaloul et al. *STE-QUEST -- Space Time Explorer and QUantum Equivalence principle Space Test: The 2022 medium-class mission concept* (2022).

[3] L. Wörner et al. *Planetary and Space Science* **239** 105800 (2023).

[4] Saurabh Pandey et al. Phys. Rev. Lett. **126 17** (2021)

[5] https://carioqa-quantumpathfinder.eu and EU mission to map Earth's gravitational field using atom interferometry.

Invited, 12 May, 16:15

Quantum Science and Technologies at the University of Patras

E. Paspalakis[1*], I. Thanopulos[1], D. Stefanatos[1], S. G. Kosionis[1], S. Baskoutas[1], C. S. Garoufalis[1], I. Galanakis[1], C. Anastopoulos, and A. F. Terzis[2]

1. *Materials Science Department, School of Natural Sciences, University of Patras, Patras 265 04, Greece*
2. *Department of Physics, School of Natural Sciences, University of Patras, Patras 265 04, Greece*

*e-mail address: paspalak@upatras.gr

Keywords: Quantum theory, quantum control, quantum optics, coherent nonlinear optics in quantum structures, quantum dynamics, quantum nanostructures, quantum materials, open quantum systems, quantum decoherence, relativistic quantum information

In this talk, we present the research groups active in quantum science and quantum technologies at the School of Natural Sciences of the University of Patras, highlighting selected recent results (see, for example, Refs. [1-13]) and educational contributions in the field. These activities span over twenty years and are primarily based in the Departments of Materials Science and Physics.

In the Department of Materials Science, three research groups are active. The Quantum Technologies Theory and Simulations group includes four permanent members: E. Paspalakis, I. Thanopulos, D. Stefanatos, and S. G. Kosionis. Their research covers a broad range of topics, including quantum optics, quantum control, quantum information processing, quantum plasmonics, strong light-matter interactions at the nanoscale, quantum dynamics in molecular and nanoscale systems, quantum coherence and interference effects, coherent nonlinear optics in quantum structures, and quantum analogies in photonic systems. The Nanomaterials Theory group, with two permanent members, S. Baskoutas and C. S. Garoufalis, works mainly on electronic structure calculations of semiconductor nanomaterials, investigating their optical and electronic properties and applications in optoelectronics and quantum technologies. The Computational Quantum Materials group, led by I. Galanakis, uses first-principles band structure calculations to study the magnetic and electronic properties of quantum materials and nanomaterials, with particular emphasis on magnetic systems, and to explore their potential applications in spintronics, quantum devices, and magnetic memory technologies. In the Department of Physics, two groups are active. One, led by C. Anastopoulos, works on quantum foundations and quantum information theory, focusing on open quantum systems and decoherence, quantum measurement, quantum correlations, and relativistic quantum information. The second group, headed by A. F. Terzis, conducts research on quantum foundations, quantum optics theory, and the dynamics of nanoscale quantum structures. Beyond research, members of these groups have significantly contributed to education in quantum science and technologies. They have developed and taught new courses across the Departments of Materials Science, Physics, and Electrical and Electronic Engineering, and participate in the international Master's program in Quantum Computing and Quantum Technologies. They also support the field's development through the authorship of textbooks in quantum science and technologies [14-16].

References

[1] I. Thanopulos, V. Karanikolas, and E. Paspalakis, *Phys. Rev. A*, **106**, 013718 (2022).
[2] S.G. Kosionis, V. Yannopapas, and E. Paspalakis, *IEEE J. Sel. Top. Quant. Electron.*, **29**, 6700108 (2023).
[3] V. Evangelakos, E. Paspalakis, and D. Stefanatos, *Phys. Rev. A*, **108**, 062425 (2023)
[4] D. Koutromanos, D. Stefanatos and E. Paspalakis, *EPJ Quantum Technol.*, **11**, 85 (2024).
[5] I. Thanopulos, V. Karanikolas, and E. Paspalakis, *Nanophotonics*, **13**, 4545 (2024).
[6] H.R. Hamedi, V. Kudriašov, S.H. Asadpour, et al*., Phys. Rev. B*, **111**, 035415 (2025).
[7] D. Koutromanos, D. Stefanatos, and E. Paspalakis, *Comp. Phys. Commun.*, **310**, 109505 (2025).
[8] V. Evangelakos, E. Paspalakis, and D. Stefanatos, *Quantum Sci. Technol.*, **10**, 035024 (2025).
[9] C. S. Garoufalis, Z. Zeng, G. Bester, et al., *J. Phys. Chem. C*, **126**, 2833 (2022).
[10] C. S. Garoufalis, D. B. Hayrapetyan, H. A. Sarkisyan, et al., *Nanoscale*, **16**, 8447 (2024).
[11] C. Anastopoulos and B. L. Hu, *AVS Quantum Sci,* **4**, 015602 (2022).
[12] C. Anastopoulos, B. L. Hu, and K. Savvidou, *Ann. Phys*., **450**, 169239 (2023).
[13] D. Moustos and C. Anastopoulos, *Phys. Rev. D*, **110**, 024022 (2024).
[14] C. Anastopoulos, *Quantum Theory: A Foundational Approach*, (Cambridge University Press, 2023).
[15] E. Paspalakis, et al., *Introduction to Quantum Control*, in preparation, (2025).
[16] N. Iliopoulos and E. Paspalakis, *Introduction to Quantum Optics and Quantum Electronics* (in Greek), in preparation, (2025).

Plenary, 13 May, 09:15

Quantum networking resources and applications

Eleni Diamanti*
CNRS, Sorbonne University of Paris, France
* e-mail address: eleni.diamanti@lip6.fr

We discuss the main concepts, critical photonic resources, present efforts and challenges ahead aiming at the deployment of quantum communication networks at various stages of development, with both terrestrial and satellite links at a national and global scale. We present examples of applications of such networks spanning from ultrasecure communication to advanced cryptographic and communication protocols in distributed architectures.

Quantum Communication and Cryptography at IESL - FORTH

Georgios M. Nikolopoulos
Foundation for Research and Technology-Hellas, Institute of Electronic Structure & Laser, GR-70013 Heraklion (Crete), Greece.
*e-mail address: nikolg@iesl.forth.gr
Keywords: quantum communication, quantum cryptography, quantum key distribution, physical unclonable functions

In this short presentation, I will briefly describe our recent research activities in quantum communication and cryptography, which span a broad range of topics including the faithful transfer of quantum states in qubit networks, quantum key distribution, quantum one-way functions, physical unclonable functions, and various cryptographic protocols beyond key distribution.

References
[1] G.M. Nikolopoulos, "Quantum Diffie-Hellman key exchange", *APL Quantum* **2**, 016107 (2025).
[2] G. M. Nikolopoulos and M. Fischlin, "Quantum key distribution with post-processing driven by physical unclonable functions", *Appl. Sci.* **14**, 464 (2024).
[3] X.W. Wang *et al.*, "Experimental Boson Sampling Enabling Cryptographic One-Way Function", *Phys, Rev. Lett.* **130**, 060802 (2023).
[4] G.M. Nikolopoulos, "Cryptographic one-way function based on boson-sampling ", *Quant. Inf. Process.* **18**, 259 (2019).
[5] A. Gratsea *et al.*, "Photon-assisted quantum state transfer and entanglement generation in spin chains", *Phys. Rev. A* **98**, 012304 (2018).
[6] G. M. Nikolopoulos, "Continuous-variable quantum authentication of physical unclonable keys: Security against an emulation attack", *Phys. Rev. A* **97**, 012324 (2018).

Query Optimization Exploiting Quantum Computing

Haridimos Kondylakis*
Institute of Computer Science, FORTH & Computer Science Department, University of Crete, GR-70013 Heraklion (Crete), Greece
*e-mail address: kondylak@ics.forth.gr

Keywords: Data Management, Query Optimization, Quantum Computing

Quantum computing is a new computational paradigm that harnesses the computation power derived from the properties of quantum mechanics to perform calculations. Given the prevalence of big data now available both online and at the various industrial domains, and the hardness of the algorithms used for querying and analysing such data, researchers have already focused on solving theoretical problems using quantum computing, hoping that quantum advantages will be able to reduce complexity and produce overall more efficient systems. Despite the theoretical advancements in data management problems, currently, the exploitation and usage of quantum algorithms in practice for big data management remains largely in the sphere of imagination.

In talk we will present Dedalus, a new national project just funded, aspiring a leap forward by delivering a next-generation platform offering the best of both worlds, classical and quantum, effectively compartmentalizing big data algorithms into parts that can be solved by classical or quantum computing harnessing and combining the benefits of both worlds. Dedalus will deliver a novel hybrid query optimizer, exploiting quantum advantages for searching the large space of alternative execution plans, and exploring also indexing for harnessing quantum advantages. Further, Dedalus aspires to encapsulate selected algorithms and hybrid execution models through API calls, hiding from the programmers the peculiarities of the underlying architectures. Finally, the Dedalus approach will be validated by deploying the framework onto real QPUs and simulators and validating the results of the hybrid architecture and the tangible computation benefits offered.

Example References

[1] T. Lamprou et al., "Nonlinear optics using intense optical coherent state superpositions", Phys. Rev. Lett., 134, 013601 (2025).
[2]F. Trager, in Springer Handbook of Lasers and Optics 2nd edn, (Springer, 2012), pp223–251.
[3] J. Rivera-Dean, et al., "Quantum Optical Analysis of High-Order Harmonic Generation in Semiconductors", in High-Order Harmonic Generation in Solids (World Scientific, 2023) pp. 139–183, edited by P. Tzallas and M. Ciappina.

Plenary, 13 May, 11:20

Quantum sensing of magnetic fields: quantum limits of existing methods and prospects for new technologies

Morgan W. Mitchell[1,2*]

[1] *ICFO - Institut de Ciències Fotòniques, The Barcelona Institute of Science and Technology, 08860 Castelldefels (Barcelona), Spain*

[2] *ICREA - Institució Catalana de Recerca i Estudis Avançats, 08010 Barcelona, Spain*

*e-mail address: morgan.mitchell@icfo.eu

Precise measurement of magnetic fields is important in fields ranging from brain imaging to space exploration. Many magnetometry technologies have been developed for these many applications, including sensors using color centers in diamond, superconductors, and hot and cold atoms. Curiously, these quite different technologies achieve similar sensitivities when measuring a given volume of field. This so-called "Energy resolution limit" is not a true fundamental limit, but it is also very difficult to beat with existing technologies. This situation motivates the study of non-traditional sensing methods, including single ions, superconducting qubits, Bose-Einstein condensates, and levitated nano-magnets. I will discuss what is known about this quantum sensing problem, and if time permits, describe our work to develop non-traditional atomic magnetometers.

Quantum Sensing and Quantum Biology

I. Kominis*
Department of Physics, University of Crete, Heraklion 70013, Greece.
*e-mail address: ikominis@uoc.gr

Keywords: quantum sensing, magnetometry, quantum biology, biological magnetoreception

In this talk I will review our recent work on quantum sensing and quantum biology, which fields have crossfertilized each other over the last two decades. I will describe magnetic sensing using hot atomic vapors and radical-pair reactions. The latter are an ideal biochemical system demonstrating the premise of quantum biology, in short, because such reactions work like a quantum computer in vivo.

Regarding quantum sensing with hot vapor magnetometers, and human-made quantum magnetometers in general, I will describe recent work connecting quantum thermodynamics with the ubiquitous energy resolution limit. I will then show what this limit can teach us about biological magnetometers developed by Nature. The discussion will lead to highlighting the scientific and technological potential of quantum biology, and its highly promising synthesis with modern quantum technology.

References

[1] I. K Kominis and E. Gkoudinakis, *PRX Life* **3**, 013004 (2025).
[2] I. K. Kominis, *Adv. Quantum Technologies* **8**, 2300292 (2025).
[3] I. K. Kominis, *Phys. Rev. Lett.* **133**, 263201 (2024).
[4] K. Mouloudakis et al., *Phys. Rev. A* **108**, 052822 (2023).
[5] K. Mouloudakis and I. K. Kominis, *Phys. Rev. A* **103**, L010401 (2021).
[6] I. K. Kominis, *Phys. Rev. Res.* **2**, 023206 (2020).

Invited, 13 May, 12:20

Quantum Technologies in IQCQT-Demokritos

Panagiotis Dimitrakis
IQCQT-Demokritos, Athens, Greece
e-mail address: p.dimitrakis@qi.demokritos.gr

Quantum Light and Fluids: Applications in Photonic Simulation and Annealing

P. G. Savvidis[1,2*]
[1]*Physics Department, Westlake University, Hangzhou, Zhejiang, China*
[2]*Institute of Electronic Structure and Laser, FORTH, 70013 Heraklion, Crete, Greece*
*e-mail address: p.savvidis@westlake.edu.cn

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.

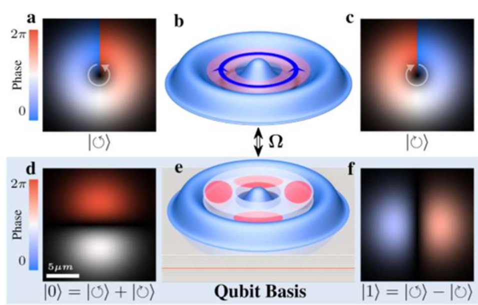


Fig. 1: Polaritonic qubit analog

References

[1] Y. Xue, et al., *Phys. Rev. Res.* **3**, 013099 (2021).
[2] A. Kavokin, et al., *Nat. Rev. Phys.* **4**, 435 (2022).
[3] J. Barrat, et al., *Science Advances* **10**, eado4042 (2024).
[4] T. Byrnes, K. Wen, and Y. Yamamoto, *Phys. Rev. A* **85**, 040306(R) (2012)

Practical Single-Photon Emitters based on InAs Quantum Dots

N. G. Chatzarakis[1,2], N. T. Pelekanos[1,2]
[1]*Department of Materials Science and Technology, University of Crete, 70013 Heraklion, Greece*
[2]*Microelectronics Research Group, IESL-FORTH, 71110 Heraklion, Greece*
*e-mail address: pelekano@materials.uoc.gr

We demonstrate single-photon emission in epitaxial strongly-confined piezoelectric (211)B InAs/GaAs quantum dots at the non-cryogenic temperature of 230 K, exploiting the enhanced exciton-biexciton splittings in the system. This is the highest operating temperature reported so far, for a single-photon emitter based on III-arsenide quantum dots. A determining factor toward this important result is the incorporation of the quantum dot layer in between GaAs/AlAs short-period super-lattices, improving drastically the carrier confinement and temperature stability of the dot emission, allowing the observation of distinct exciton and biexciton emission peaks up to 260 K and single-photon emission at a record-high temperature. We will also briefly discuss how to obtain similar operating temperatures using non-piezoelectric (100) InAs/GaAs quantum dots, as well as ongoing work on solution-processed colloidal InAs quantum dots.

Invited, 13 May, 14:45

Quantum droplets in mixtures of cold atomic gases

S. Nikolaou[1]**, M. Örgen**[2, 3]**, and G. M. Kavoulakis**[1, 2*]
1. Department of Mechanical Engineering, Hellenic Mediterranean University, GR-70013 Heraklion (Crete), Greece
2. HMU Research Center, Institute of Emerging Technologies, 71004 Heraklion, Greece
3. School of Science and Technology, Örebro University, 70182 Örebro, Sweden
*e-mail address: kavoulak@hmu.gr

Keywords: Cold atoms, superfluidity, nonlinear effects

Self-bound, macroscopic, droplets are often observed in various physical systems, with the most familiar example being that of water droplets. Furthermore, droplets appear on microscopic length scales, as e.g., in atomic nuclei, in semiconductors (electron-hole droplets), and in liquid-helium nanodroplets. In this talk I will present results on recent experimental [1] and theoretical work on "quantum" liquid droplets [2] in an ultracold mixture of bosonic atoms [3-7]. These are self-bound states, which become possible due to many-body effects stemming from quantum fluctuations [2]. Quantum fluctuations, which are typically very small, become significant in this system when two different species are mixed, and the couplings for inter- and intra-component interactions are tuned appropriately. I will first describe the basic physics of these systems. Then, I will present some recent experimental results. Finally, I will discuss the ground state and the rotational properties of quantum droplets which are confined in harmonic and in ring potentials.

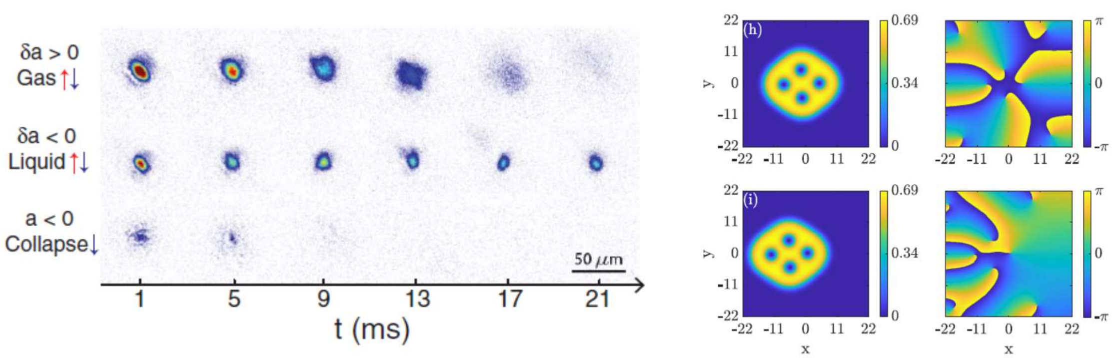


Fig. 1 Left plot: In situ density distribution of the atoms after the removal of the confinement [1]. Right plot: The density (left column) and the phase (right column) of a harmonically-trapped rotating quantum droplet, for two values of the angular momentum per particle, $L/N = 3.4$ (higher plot), and 5.0 (lower plot), respectively [5].

References
[1] C. R. Cabrera, et al., Science **359**, 301 (2018).
[2] D. S. Petrov, Phys. Rev. Lett. **115**, 155302 (2015).
[3] P. Examilioti and G. M. Kavoulakis, Journal of Phys. B **53**, 175301 (2020).
[4] L. Chergui, et al., Phys. Rev. A **108,** 023313 (2023).
[5] S. Nikolaou, G. M. Kavoulakis, and M. Ögren, Phys. Rev. A **108**, 053309 (2023).
[6] S. Nikolaou, G. M. Kavoulakis, and M. Ögren, Phys. Rev. A **110**, 043302 (2024).
[7] S. Nikolaou, G. M. Kavoulakis, and M. Ögren, Phys. Rev. A **109**, 043304 (2024).

Invited, 13 May, 14:55

Towards experimental observation of entanglement in a quantum many-body system

Spyros Sotiriadis[1,2*]
[1]*University of Crete, GR-70013 Heraklion, Greece*
[2]*Foundation for Research and Technology-Hellas, Institute of Electronic Structure & Laser, GR-70013 Heraklion (Crete), Greece*
*e-mail address: ssotiriad@physics.uoc.gr

Keywords: quantum simulation, ultracold atoms, quantum entanglement

Entanglement, a fundamental phenomenon in quantum physics, plays a crucial role in many-body systems, distinguishing quantum phases of matter, underlying the mechanism of thermalisation and determining the complexity of classical simulations. While entanglement has been observed in few-body experiments, its detection in many-body systems remains challenging as it requires full reconstruction of the quantum manybody state from measurements. In this talk, I will present a quantum state tomography technique that allows direct measurement of the von Neumann entropy, a key quantity for detecting entanglement in pure quantum states. By applying this method to a class of ultracold atom experiments, we verify theoretical predictions for the scaling of the von Neumann entropy in both thermal equilibrium and out-of-equilibrium dynamics.

References

[1] T. Schweigler, et al., *Nature Phys.* **17**, 559 (2021)
[2] M. Tajik, et al., *Nature Phys.* **19**, 1022–1026 (2023)
[3] M. Tajik, et al., *PNAS* **120**, e2301287120 (2023)
[4] S. Aimet, et al., arXiv:2407.21690

Posters

Poster #1

Multi-qubit gates between distant atoms in Rydberg quantum computers

A. Delakouras[1,2], G. Doultsinos[1, 2] and D. Petrosyan[1*]
[1]*Institute of Electronic Structure and Laser and*
Center for Quantum Science and Technologies, FORTH, 70013 Heraklion, Crete, Greece
[2]*Department of Physics, University of Crete, Heraklion, Greece*
*e-mail address: dap@iesl.forth.gr

We propose an efficient protocol to realize multi-qubit gates in arrays of neutral atoms. The atoms encode qubits in the long-lived hyperfine sublevels of the ground electronic state. To realize the gate, we apply a global laser pulse to transfer the atoms to a Rydberg state with strong blockade interaction that suppresses simultaneous excitation of neighboring atoms arranged in a star-graph configuration. The number of Rydberg excitations, and thereby the parity of the resulting state, depends on the multiqubit input state. Upon de-exciting the atoms with an identical laser pulse, the system acquires a geometric phase that depends only on the parity of the excited state, while the dynamical phase completely cancels. Using single qubit rotations, this transformation can be converted to the C*k*Z or C*k*NOT quantum gate for k+1 atoms. We also present extensions of the scheme to implement quantum gates between distant atomic qubits.

Poster #2

Quantum gates between distant atoms mediated by a Rydberg excitation antiferromagnet

G. Doultsinos[1,2] and D. Petrosyan[1*]
[1]*Institute of Electronic Structure and Laser and Center for Quantum Science and Technologies, FORTH, 70013 Heraklion, Crete, Greece*
[2]*Department of Physics, University of Crete, Heraklion, Greece*
*e-mail address: dap@iesl.forth.gr

We present a novel protocol to implement quantum gates between distant atomic qubits connected by an array of neutral atoms playing the role of a quantum bus. The protocol is based on adiabatically transferring the atoms in the array to an antiferromagnetic (AFM) -like state of Rydberg excitations using chirped laser pulses. Upon exciting and de-exciting the atoms in the array under the blockage of nearest neighbors, depending on the state of the two qubits, the system acquires a conditional geometric π-phase, while the dynamical phase cancels exactly, even when the atomic positions are disordered.

Poster #3

Polarization controllable laser using chiral metamaterials

I. Katsantonis[1*] **and M. Kafesaki**[1,2]

1. Foundation for Research and Technology-Hellas, Institute of Electronic Structure & Laser, GR-70013 Heraklion (Crete), Greece.

2. Department of Materials Science and Technology, University of Crete, 70013 Heraklion, Crete, Greece

*e-mail address: katsantonis@iesl.forth.gr

Keywords: chiral quantum metamaterials, circularly polarized laser, gain media

Polarization-controllable lasers, especially circular polarization (CP) lasers, are gaining significant prominence in the realm of light-matter interactions. They show great potential in applications such as spectroscopy, sensing, and display technology [1-2], including biophysics [3], and quantum optics [4].

CP laser generation requires both a gain medium and a chiral response. Natural chiral materials typically exhibit weak chiral response, directing the investigations to artificial chiral nanostructures. These include three-dimensional chiral metamaterials [5]. These nanostructures significantly enhance interactions between CP light and matter, opening up exciting possibilities for diverse applications [1,2]. Notably, there is a growing demand for ultra-compact chiral light sources that can provide a substantial degree of circular polarization of the emitted wave, for a wide range of applications.

In this study, we introduce a chiral metamaterial design that utilizes twisted isotropic crosses. We validate its ability to control CP laser emission through numerical simulations. By adjusting the incident polarization angle, we can modulate the chiral response, effectively interacting with the optical gain band to demonstrate various laser emission characteristics. Our active chiral metamaterial system offers an innovative approach to designing circularly polarized emission lasers, eliminating the need for expensive and labor-intensive fabrications processes.

In Figure 1 we show the unit cell of the proposed chiral metamaterial structure, formed by a pair of twisted crosses embedded in a dielectric host, with a square periodicity of α=300 nm, length l=100 nm and host refractive index n=1.41. The metallic crosses are made of Silver with response described by Drude model: $\varepsilon(\omega)=\varepsilon\infty-\omega p2/(\omega2+i\omega\gamma)$ with $\varepsilon\infty$=9.07, $\omega p=2\pi\times2159$ s-1 and $\gamma=2\pi\times25$ s-1. The gain material is formed by doping the dielectric host with dyes, and its atomic response is described by a four-level system [5] as shown in Figure 1.To comprehend the underlying lasing process, initially, we excite the gain molecules using a continue pump wave with a central frequency of $\omega b=2\pi\times335$ s-1. We calculate the E- /RCP and E+/LCP as a function of time and frequency. Observing the results presented in Figure 1 (c)-(d), the target lasing mode is predominantly dominated by right-handed circular polarization (RCP/-), while the emission of left-handed circular polarization (LCP/+) is negligible. By pumping the two crosses across the diagonal of the xy-plane, we gain additional control over the lasing polarization. Specifically, when the angle φ=45 deg, the main lasing mode is predominantly dominated by (LCP/+) radiation, while the emission of (RCP/-) is reduced to the noise level. This analysis highlights our successful demonstration of an almost pure circularly polarized emission laser.

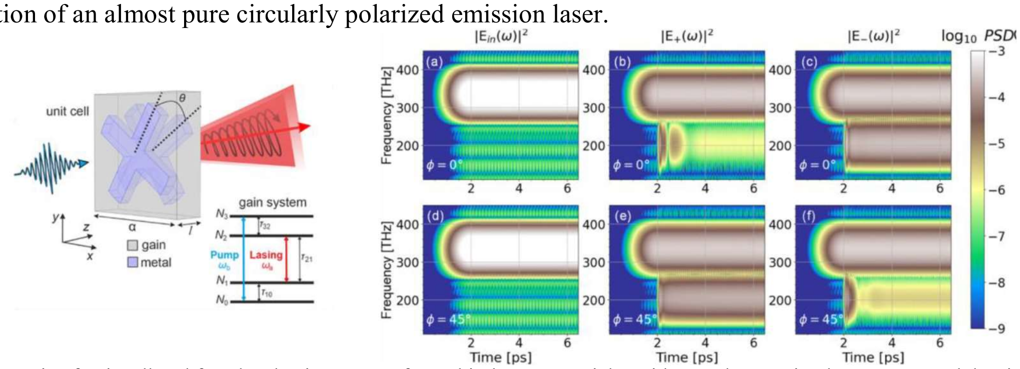


Fig. 1 Schematic of unit cell and four-level gain system of our chiral metamaterial. Incident and transmitted power spectral density from the chiral structure for incidence of a linearly polarized CW of different polarization angles, φ.

References

[1] H. H¨ubener, *et al.*, Nature Materials, 20, 438 – 442 (2021).

[2] M. Lindemann, *et al.*, Nature, **568**, 212 – 215 (2019).

[3] R. Naaman, Y. Paltiel, and D. H. Waldeck, *Annual Review of Biophysics*, **51**, 99-114 (2022).

[4] I. Thanopoulos *et al.*, *Chem. Phys. Rev.*, **390**, 228-235 (2004).

[5] I. Katsantonis, et al.,. *ACS Photonics* **2025**, *12*, 71– 78,

Poster #4

Electrical Resistivity Tomography: A versatile method to image and monitor subsurface processes

N. Papadopoulos

Foundation for Research and Technology-Hellas, Institute for Mediterranean Studies, Lab of Geophysical Satellite Remote Sensing and Archaeoenvironment, GR-7410 Rethymno (Crete), Greece.

*e-mail address: nikos@ims.forth.gr

Keywords: FEM modeling, least square inversion, array optimization, Mediterranean

Over the last three decades, Electrical Resistivity Tomography (ERT) has been transformed into a widely used geophysical method for approaching several different near-surface applications. This was boosted by the improvement of the hardware's capabilities, the development of multichannel resistivity systems and the compilation of automated modelling and reconstruction algorithms to image and monitor the subsurface electrical resistivity properties [1].

The Finite Element method is used to numerically solve the Poisson's differential equation that governs the current flow and the behaviour of the electric potential into the ground. The Galerkin weighted residual approach is applied to minimize the error between the approximated and real potential resulting in the solution of a linear system integrating the nodal coordinates, the element conductivities, the current sources and boundary terms. The algorithms to reconstruct the actual subsurface resistivity are based on a non-linear iterative least-square approach with smoothness constraints to account for the ill-condition, instability and non-uniqueness of the inverse problem [2].

Although two dimensional (2-D) ERT approaches are nowadays routinely applied in approaching diverse environmental, hydrogeological and archaeological problems, they underperform in cases of complicated stratigraphy and intense inhomogeneity of the subsurface resistivity distribution. Thus, significant research efforts have been placed on proposing and investigating the resolving capabilities of different measuring and processing strategies to map the underground resistivity structure within a three-dimensional (3-D) context [3].

The actual implementation of a 3-D ERT experiment involves the arrangement of a number of electrodes on the nodes of a regular or irregular grid. The total number of the linear independent apparent resistivity measurements is an exponential function of the electrodes that are simultaneously connected to any multiplexed and multichannel resistivity instrument, rendering the data collection practically impossible, even for an array composed of a relatively small number (~50) of electrodes. A step forward to exploit the full capability spectrum of the modern acquisition instruments incorporated experimental optimization methods based on the resolution and Jacobian (sensitivity) matrices, to select electrode arrays that maximize the resolving capabilities of the inversion images [4].

Within this international research framework, the GeoSat ReSeaArch Lab has placed significant effort on defining the optimum and practical survey measuring strategies, in developing fast and memory efficient inversion algorithms and proposing experimental design techniques to automatically extract optimized array configurations resulting in improved resolution with respect to commonly used arrays. These developments will be demonstrated through various examples signifying the efficiency of ERT in illuminating the spatial and temporal subsurface resistivity changes attributed to specific structures and processes in Eastern Mediterranean [5].

References

[1] Loke, M.H., et al., 2013 *Journal of Applied Geophysics* 95, 135-156.
[2] Papadopoulos, N.G, et al., 2011 *Geophysical Prospection*, 59, 557-575.
[3] Papadopoulos, N.G, et al., 2007 *Near Surface Geophysics*, 5, 6, 349-362.
[4] Loke, M.H., et al., 2015 *Near Surface Geophysics*, 13, p.505-517.
[5] Papadopoulos, N. 2019 *AGU Fall Meeting* 2019, San Francisco, USA

Spin-noise spectra acquired with stroboscopically modulated probe-light

V. Koutrouli*, M. Mylonakis, G. Vasilakis
Foundation for Research and Technology-Hellas, Institute of Electronic Structure & Laser, GR-70013 Heraklion (Crete), Greece.
*e-mail address: vkoutrou@iesl.forth.gr

Keywords: Spin noise, quantum magnetometry, atom light interactions

Atomic-optical magnetometers have reached a level of sensitivity limited by quantum effects. One quantum noise source that can potentially affect the sensitivity of such magnetometers is known as back-action noise. This arises from the coupling of light quantum polarization-fluctuations with the measured atomic-spin system. Stroboscopic modulation of probe intensity at twice the Larmor frequency can circumvent the back-action noise [1]. Besides the noise reduction, eliminating back-action noise paves the way for engineering spin-squeezed states, which can further enhance the sensor's sensitivity [2].

We investigate spin-noise spectra acquired using stroboscopically modulated probe light in cells with sub-mm2 cross sections. Our focus is on buffer-gas-free atomic ensembles, where the hyperfine structure in the excited state is resolvable, and the second-rank tensor interaction of light with atoms cannot be ignored. We find that the AC Stark shift, along with residual optical pumping caused by the off-resonant probe light, substantially alter the spin-noise spectrum, deviating markedly from a simple Lorentzian profile. This deviation is particularly pronounced when measuring spin-noise spectra in the thermal state and should be considered when evaluating the threshold for spin-squeezing.

References
[1] G. Vasilakis, *et al.*, *Phys. Rev. Lett.*, **106**, 1 (2011).
[2] G. Vasilakis *et al.*, *Nat. Phys.*, **11**, 389 (2015).

Poster #6

Retrieving Optical Information in Nonlinear Chaotic Systems using Neural Networks

P. Konstantakis[1,2], M. Manousidaki[1], S. Tzortzakis[1,2,*]

1. Institute of Electronic Structure and Laser, Foundation for Research and Technology Hellas (FORTH), N. Plastira 100, Heraklion, 71110, Crete, Greece

2. Department of Materials Science and Technology, University of Crete, Heraklion, 70013, Crete, Greece

**e-mail address:* stzortz@iesl.forth.gr

Keywords: optical encryption, nonlinear optics, chaotic systems, neural networks

Free-space laser communication through scattering media, where the scattering of light can significantly degrade the quality of communication, has garnered significant attention in recent years. In this work, we unveil a novel application of Neural Networks to recover information from optical holograms subjected to total distortion within a highly nonlinear and turbulent liquid medium (Fig.1).

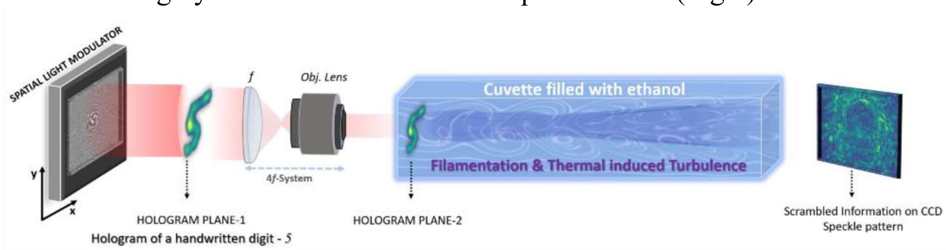


Fig. 1 Experimental setup for the generation of handwritten digit holograms and the delivery of this information through a filamentation-induced turbulent liquid medium.

Utilizing three distinct types of neural networks, we effectively reconstructed the original beam profile from intricate speckle patterns, mitigating the adverse impacts of nonlinear propagation and turbulence (Fig.2) [1].

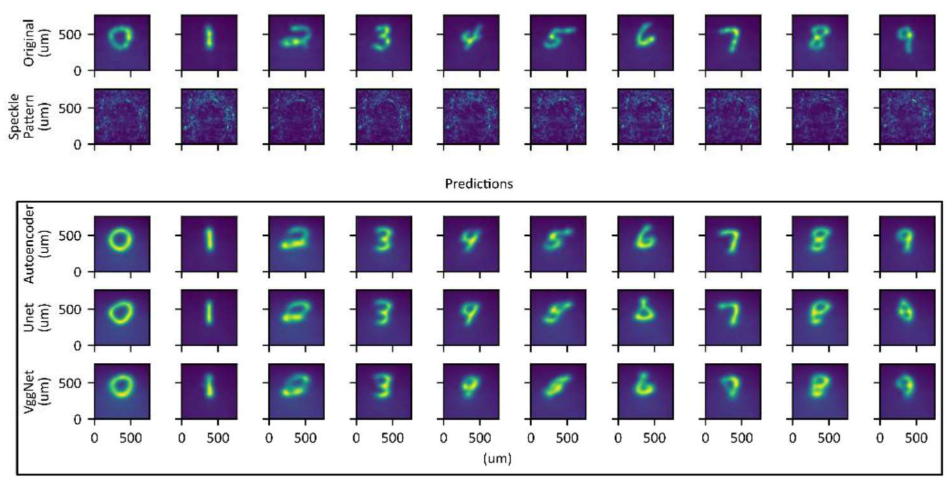


Fig. 2 Reconstruction of holograms from the validation dataset for all numbers from 0 to 9 using three different neural network architectures.

Our results showcase the remarkable potential of combining laser filamentation with artificial neural networks to facilitate the transfer and retrieval of information.

References

[1] P. Konstantakis, M. Manousidaki, and S. Tzortzakis, *Optica* **12**, 131 (2025).

Poster #7

Polymeric photonic integrated circuits fabricated via Multiphoton Lithography

S. Papamakarios[1,2*], E. Marakis[1], T. Amory[3], I. Zacharakis[1], M. Farsari[1]

1. Foundation for Research and Technology-Hellas, Institute of Electronic Structure & Laser, GR-70013 Heraklion (Crete), Greece.

2. University of Athens, Physics Department, Athens, Greece

3. Telecom St-Etienne, Saint Etienne, France

*e-mail address: spapamakarios@iesl.forth.gr

Keywords: Multiphoton Lithography, Direct Laser Writing, PICs, Photonics, Simulations

Photonic Integrated Circuits (PICs) are the evolution of electronic circuits which up today are being used for significant number of computational tasks. PICs offer larger bandwidth and lower energy per bit, making them the ideal candidates to replace electronics. Although, they still show limitations due to the planar geometries that are being used. Here, we propose a new approach where we can use the vertical interconnections of such PICs, employing true 3D architectures with multi-layer circuits that can empower the computational power and be used in biosensing, tensor calculations and programmable circuits.

We create a pipeline where we theoretically study different 3D freeform geometries that can be used for such 3D PICs, through WaveSim[1]—a voxel-native solver that directly incorporates fabrication-induced distortions. WaveSim supports demanding computational tasks through domain decomposition and GPU acceleration, making the simulation of 3D PICs way faster than other techniques. For the fabrication of such devices, we employ Multi-photon Lithography (MLP)[2], which is a true 3D printing process relying on Direct Laser Writing (DLW), using a layer-by-layer approach. MPL takes into advantage non-linear effects and can reach to a resolution of a few tens of nm. Photosensitive materials are used for the creation of the architectures, mostly dielectrics, with the most used one for our case to be SZ2080[3], a hybrid Zr-based photoresist well known for its chemical, mechanical and optical properties.

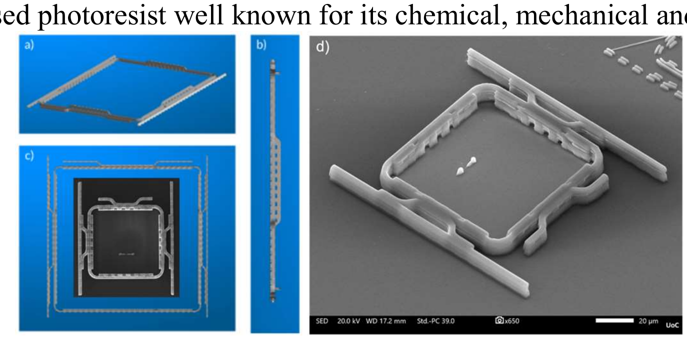


Fig. 1 Pilot Cube architecture demonstrating 3D photonic routing.. (a-c) Schematic representation of the Cube architecture, (d) SEM image of the Cube fabricated at FORTH.

Our main studied case is the **Cube** (Fig.1a), which can be used for volumetric tensor operations due to its 3D elevated design, taking into advantage the vertical interconnections that we were able to build using MPL (Fig.1c,d). The Cube can potentially be used for programmable matrix operations (using phase changing materials) as a reprogrammable photonic processor[4].

References

[1] G. Osnabrugge et al., J Comput Phys 322, 113 (2016).

[2] Papamakarios, Savvas, et al., ACS photonics 12, 1, 87–97 (2024),

[3] A. Ovsianikov et al., ACS Nano 2, 2257 (2008).

[4] N. Farmakidis et al., Nature Reviews Electrical Engineering 1, 358 (2024).

Atomically Engineered 2D MXenes for Ultrafast Nonlinear Optical Applications

M. Stavrou[1*], B. Chacon[2], M. Farsari[1], A. M. Pappa[3], L. G. Delogu[4], Y. Gogotsi[2], and D. Gray[1]
[1]Institute of Electronic Structure and Laser, Foundation for Research and Technology-Hellas, 70013 Heraklion, Greece
[2]A. J. Drexel Nanomaterials Institute and Department of Materials Science and Engineering, Drexel University, Philadelphia, PA 19104, USA
[3]Department of Biomedical Engineering Khalifa University of Science and Technology, Abu Dhabi 127788, UAE
[4]Department of Biological Sciences, Khalifa University of Science and Technology, Abu Dhabi 127788, UAE
*e-mail address: m.stavrou@iesl.forth.gr
Keywords: MXenes, nonlinear optics, ultrafast spectroscopy

Materials exhibiting strong nonlinear optical (NLO) properties along with fast carrier recovery have fostered significant advancements in photonic devices, enabling the development of ultrafast lasers, optical limiters, optical switches, modulators, photodetectors, and more. Among these materials, transition metal carbides, nitrides, and carbonitrides (MXenes), characterized by the general formula Mn+1XnT*x* (where M is a transition metal, X is C or N, and T*x* represents surface terminated groups such as -OH, -O, or -F), are particularly attractive for such applications due to their exceptional NLO response, broadband absorption, ultrafast carrier relaxation, and resistance to radiation and heat.

The present study provides, for the first time, comprehensive insight into the ultrafast NLO response and carrier dynamics of two kinds of MXene nanosheets, Ta4C3T*x* and ordered-phase Mo2Ti2C3T*x*, using Z-scan and pump-probe optical Kerr effect (OKE) techniques under 515 and 1030 nm laser pulses. The measurements show that both MXenes reveal exceptional saturable absorption properties (i.e., nonlinear absorption coefficient β, modulation depth αs, and saturable intensity *Is*) under visible laser irradiation. Additionally, strong reverse saturable absorption was observed, resulting in very efficient optical limiting under infrared laser irradiation. Among the two MXenes, Mo2Ti2C3T*x* exhibited the strongest NLO response under both excitation wavelengths, attributed to charge transfer between Mo and Ti layers in the MXene structure. As shown in Fig. 1, the NLO response of the studied MXenes surpasses all previously studied MXenes (e.g., Ti3C2, Ti3CN, and Nb2C) and most other 2D nanomaterials (e.g., graphene, graphene oxide, WS2, silicon nanosheets, and black phosphorus), attaining exceptionally high third-order susceptibility (*χ(3)*) values on the order of 10-13 esu.

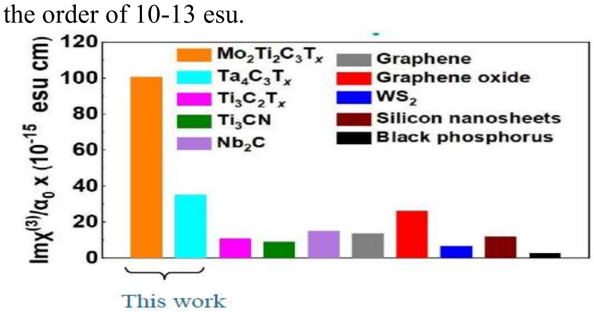


Fig. 1 Comparison of the figure of merit Im*χ(3)* values (i.e., Im*χ(3)* normalized by the linear absorption α0) of Mo2Ti2C3T*x* and Ta4C3T*x* with those of other 2D materials.

Beyond their superior NLO performance, ultrafast spectroscopy studies revealed rapid relaxation of hot carriers due to carrier-carrier and phonon scattering, as well as electron-hole recombination. The measured relaxation constants of ~300 fs and ~3 ps for both MXenes are comparable to or significantly lower than those of previously studied 2D materials. The findings of the present work position Ta4C3T*x* and Mo2Ti2C3T*x* MXenes among the most promising NLO materials currently known, underscoring their potential for applications in advanced photonic and optoelectronic technologies, including laser systems, optical protection devices, photodetectors and telecommunications.

References

[1] M. Stavrou, et al., "Emerging Ta4C3T*x* and Mo2Ti2C3T*x* MXene Nanosheets for Ultrafast Photonics", *Adv. Optical Mater.*, 2403277 (2025)

Poster #9

Simulating Waves with Convergent Born Series

I. Stergou[1]*, E. Marakis[1], I. M. Vellekoop[2], V. Sarantos[3], I. Zacharakis[1]

[1] *Foundation for Research and Technology-Hellas (FORTH), Institute of Electronic Structure & Laser, Laboratory for Biophotonics and Molecular Imaging (LBMI), Heraklion, Crete, Greece.*

[2] *Biomedical Photonic Imaging Group, Faculty of Science and Technology, University of Twente, Enschede, Netherlands.*

[3] *RayFos Ltd., Basingstoke, United Kingdom.*

*e-mail address: i.stergou@iesl.forth.gr

Keywords: Wave Simulations, Convergent Born Series

Modern photonics, acoustics and quantum technologies demand precise, predictive models that reveal information before prototypes are built. Full-wave solvers give that preview, compressing design cycles from weeks to hours and exposing physics that simplified formulas overlook. Conventional numerical methods like FDTD and PSTD require fine spatial and temporal grids, leading to prohibitive runtimes, accumulation of phase errors, and heavy memory demands. The Convergent Born Series (CBS) [1] outperforms these by iteratively solving frequency-domain Helmholtztype wave equations. Benchmarks show CBS runs orders of magnitude faster, achieves near–machine precision accuracy, uses significantly less memory, and effortlessly handles large-scale, realistic experimental domains that are unreachable with established solvers. CBS already serves optical and seismic [2] problems. At LBMI, we have demonstrated CBS capacity for large simulation domain in waveguide design for integrated optics allowing 3D coupling for light, making it an ideal platform for quantum optics experiments and applications [3]. We have also adapted the CBS algorithm to work for acoustic simulations in the constant density regime. Working towards a variable-density acoustic solver is our next step, which will enable us to simulate acoustic wave scattering at speeds and scales that no other solver can match.

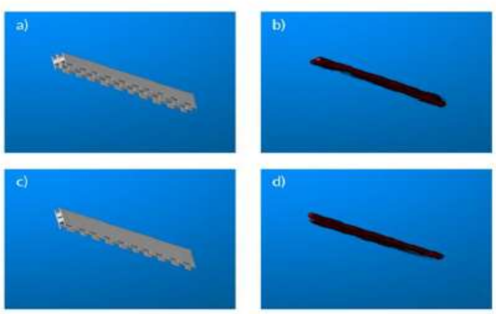


Figure 1 *Design and simulated field distribution of 3D freeform directional couplers. (a) Geometry of a horizontally aligned coupler with elevated-core waveguides placed side-by-side. (b) Simulated optical intensity profile for the structure in (a), showing periodic energy oscillation between the two guides. (c) Geometry of a vertically aligned coupler, with stacked waveguides and index-balancing supports. (d) Corresponding field distribution for the structure in (c), illustrating controlled interlayer power transfer through vertical coupling.*

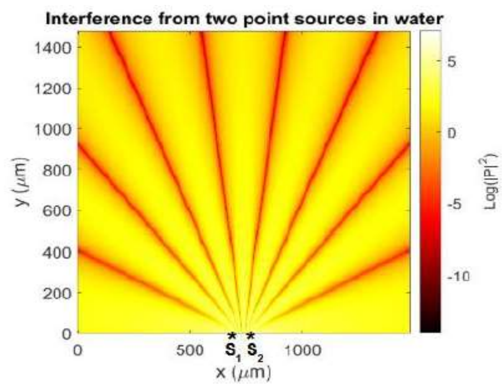


Figure 2 2D log-scale intensity of two-source interference pattern in water at 50 MHz.

References

[1] G. Osnabrugge et al., *J. Comput. Phys.* **322**, 113 (2016).

[2] X. Huang et al., *J. Geophys. Eng.* **17**, 277 (2020).

[3] M. Makris et al., *Phys. Rev. Lett.* (in press, 2025).

Poster #10

Cavity enhanced quantification of optical thickness

Vinay Pareek[1,2], Dimitris Papazoglou[2,1], and Wolf von Klitzing[1*]
1. Foundation for Research and Technology-Hellas, Institute of Electronic Structure & Laser, GR-70013 Heraklion (Crete), Greece.
2. Department of Materials Science and Engineering, University of Crete, 70013, Heraklion, Greece
**e-mail address: wvk@iesl.forth.gr*
Keywords: Imaging technique, Phase measurement, Optical thickness, Cavity enhancement, Microscopy

Imaging is a vital tool in research and applications which provides key insights to improve our understanding of various samples ranging from biological cells to ultra-cold atom-quantum systems. Conventional imaging techniques face challenges when imaging samples have a weak optical response. Here we demonstrate that this weak optical response can be amplified in an imaging optical cavity by forcing the light to interact with the sample many times before detection. Multiple sample interaction in an optical cavity permits extremely sensitive measurements such as measuring trace amounts of gas in the atmosphere but the cavity needs to be restricted to a single mode [1]. However, Imaging requires a full set of transverse modes in order to represent any spatial variations. In a perfectly degenerate cavity all the transverse modes are resonant at the same frequency. Since these modes form a complete basis set of the real space, this allows the imaging of a sample (optically thin) with arbitrary spatial distribution. By introducing such a sample in such a degenerate cavity, any optical perturbation it induces can be decomposed into transverse modes of the cavity. At each round trip in the cavity the light is perturbed in precisely the same way as during the first interaction, effectively amplifying the effect of the perturbation. Previously, imaging using a cavity was either done by spatially scanning across modes [2] or to increase the contrast with low finesse [3]. Another way to understand this is that under certain circumstances a degenerate cavity images the sample back onto itself in each round-trip.

Here, we present a technique to measure the absolute optical thickness over a wide field of view using a degenerate confocal cavity. Any sample-induced phase perturbation in the cavity results in a shift of resonant frequency for that region, which is measured and converted to optical thickness as shown in Fig.1 b). With this method we achieve a resolution in optical path difference of less than 5 nm with a transverse spatial resolution of 8 um. Fig.1a) shows a simplified schematic describing the technique, 1b) and (c) illustrates the cavity response with and without a dielectric inside the cavity. Figure 1d) and e) displays the phase thickness measured (in nm) of a USAF resolution pattern phase target and a HfO2 micro dot.

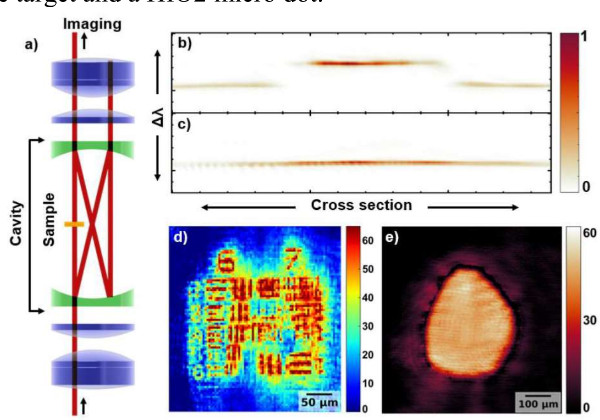


Fig. 1 (a) Simplified layout of the setup. (b) and (c) cavity response with and without a dielectric in the cavity. d) and e) Optical thickness (in nm) of USAF target phase sample and HfO2 micro dot.

References
[1] Lee, D-H., et al. Applied Physics B 74 (2002): 435-440.
[2] Mader, Matthias, et al. *Nat. Commun.* 6.1 (2015): 7249.
[3] Israel, Yonatan, et al. *Optica* 10.4 (2023): 491-496.

Poster #11

Quantum Memory Prototype for Space: Laser system overview

M. Georgousi[1,2,*], P. R. Antunez[1], A. Oikonomou[1], R. Thampy[1], K. Makris[1], W. von Klitzing[1]
1. Foundation for Research and Technology-Hellas, Institute of Electronic Structure & Laser, GR-70013 Heraklion (Crete), Greece.
2. University of Crete Department of Physics, GR-71003 Heraklion (Crete), Greece.
**georgousi@iesl.forth.gr*
Keywords: quantum memory, space optics, laser system, magneto-optical trap, miniaturization

A key element in quantum technology is the distribution of quantum entanglement over large distances. This can be applied in network connections between quantum computers [1], remote quantum sensing and quantum key distribution. Since quantum states of light cannot be amplified using the conventional ways, long distance fiber communications are limited due to the fiber attenuation. In order to surpass such limits, free-space transmission can be done via satellites. A link between two ground stations via a satellite allows to increase the communication distance. This requires a quantum memory, which is able to store a quantum state, such as a photon, and allows on-demand retrieval of the quantum state [2]. This way, a satellite network for quantum key distribution could be established using quantum memories as repeater stages [3]. In order to serve adequately as a quantum memory for repeater stages on satellite missions, the memory must fulfil certain specifications, especially regarding the storage time, storage fidelity and storage efficiency [2]. Furthermore, from a systems perspective, one requires that the quantum memory must only use a limited amount of budget, in terms of *energy*, *mass*, *volume,* and *cost*, when it is foreseen as a product manufactured in larger quantities, e.g. for large satellite constellations for quantum key distribution. The current technology platforms for quantum memories under investigation are quite diverse, spanning from solid-state devices (such as rare-earth ion doped crystals, defect centers in diamond, quantum dots in other semiconductors), over single-trapped atoms, to room-temperature and cold atomic gases [4-6]. The technology of cold atomic gases (in a magneto optical trap - MOT) as quantum memory are quite promising.

The department for Integration of Micro- and Nanosystems at DLR-QT (Ulm, Germany) is developing a miniaturized MOT (chamber, vacuum system, Rubidium source), for single-photon detection and storage. The laboratory version of the laser light distribution and conditioning system is already successfully developed by Space Optics Lab (SOL-IESL) and installed at DLR-QT. It consists of 3 main light beams, for frequency stabilization (lock-in), the cooling beam, and the imaging system. It is comprised of 6 fiberized modules: Master Laser, Spectroscopy (lock-in), Tapered Amplifier/EOM (repumper and amplification), double-pass AOM (frequency detuning), single-pass AOM (intensity control) and a double-pass AOM (imaging). The second version will follow, with the manufacturing of two space qualified modules: the Beam-Conditioning Board (BCB), and the Rubidium-Spectroscopy Reference Board (RRB). Space verification tests (subsystem and system) will take place in TESAT (Backnang, Germany).

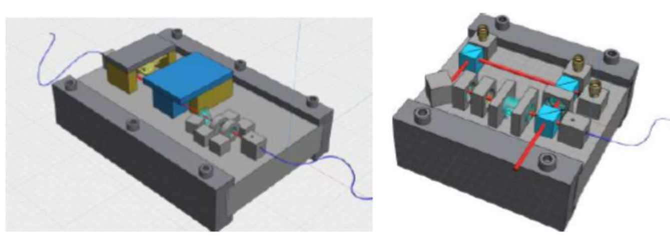


Fig. 1 (a) Beam-Conditioning Board (b) Rubidium-Spectroscopy Reference Board

References

[1] A. Broadbent, J. Fitzsimons, and E. Kashefi, *2009 50th Annual IEEE Symposium on Foundations of Computer Science*, Atlanta, GA, USA, 2009, pp. 517–526.
[2] C. Simon *et al., Eur. Phys. J. D*, 58, 1 (2010).
[3] J. Wallnöfer *et al., Commun Phys*, 5 (2022).
[4] B. Zhao *et al., Nat. Phys.*, **5**, 95 (2009).
[5] A. I. Lvovsky, B. C. Sanders, and W. Tittel, *Nat. Photon*, 3, 706 (2009).
[6] Y. O. Dudin, L. Li, and A. Kuzmich, *Phys. Rev. A*, 87 , 2013.

Poster #12

Development and Optimization of a Laser System for Bose-Einstein Condensate Experiments

K. Makris*, A. Oikonomou, V. K. Pathak, V. P. Veetil, R. P. Thampy, P. Rivero-Antunez and W. Von Klitzing

Foundation for Research and Technology-Hellas, Institute of Electronic Structure & Laser, GR-70013 Heraklion (Crete), Greece.

*e-mail address: kostasmakris@iesl.forth.gr

Keywords: BEC, laser system

Traditional free-space optical setups often face challenges related to alignment sensitivity and susceptibility to environmental fluctuations, which can compromise experimental consistency. In this, work, I introduce the development and optimization of a robust fiber-based laser system designed for Bose-Einstein Condensate (BEC) experiments. Our system incorporates single-pass and fibered double-pass acousto-optic modulators (AOMs) alongside an electro-optic Modulator (EOM), facilitating precise control over the laser beam's frequencies, intensity and phase. Using multiple fiber-coupled breadboards, we simplify the construction, increase the stability against fluctuations and greatly improve the serviceability of the system.

A key component is the fibered Tapered Amplifier system, engineered to amplify the laser beam while preserving beam quality, thereby ensuring the requisite optical power for subsequent experimental stages. Additionally, we have designed and constructed a fibered optical distribution board that accurately directs laser light to various optical elements essential for both two-dimensional (2D) and three-dimensional (3D) magneto-optical traps (MOTs). This fiber-based approach simplifies alignment, enhances stability and ensures consistent beam modulation, which is crucial for efficient cooling and trapping of atoms. By emphasizing simplicity and robustness, our design significantly improves the performance and reliability of BEC laser systems. We operated the system for up to three months without requiring any human intervention (other than switching it on and off), thus demonstrating its stability and reliability in long-term experimental settings. This work highlights the critical role of well-engineered laser infrastructure in advancing ultra-cold quantum gas research.

Poster #13

Quantum-limited Measurement and Control of Atom Number in Ultracold Ensembles

P. Rivero-Antúnez*, A. Oikonomou, K. Makris, R. Thampy, V. Pathak, M. Chairetis, W. von Klitzing

Foundation for Research and Technology-Hellas, Institute of Electronic Structure & Laser, GR-70013 Heraklion (Crete), Greece.

*e-mail address: privero@iesl.forth.gr

Keywords: Quantum metrology, Atom number squeezing, Non-destructive measurement

We propose a robust and fundamentally optimal method for real-time measurement and control of atom number in ultracold atomic ensembles with precision beyond the atom shot-noise limit. The technique relies on off-resonant, dispersive light-atom interaction to map the atom number onto the polarization state of light, enabling non-destructive measurements with minimal impact on coherence and temperature. Atom number control is achieved by strategically utilizing the weak probe-induced atom loss, monitored and optimized via real-time Kalman filtering. This approach turns measurement back-action into a resource, leading to number-squeezed Bose-Einstein condensates and accelerating experimental repetition rates. The method paves the way for enhanced performance in atomic clocks, inertial sensors, gravimetry, magnetometry, and quantum technologies.

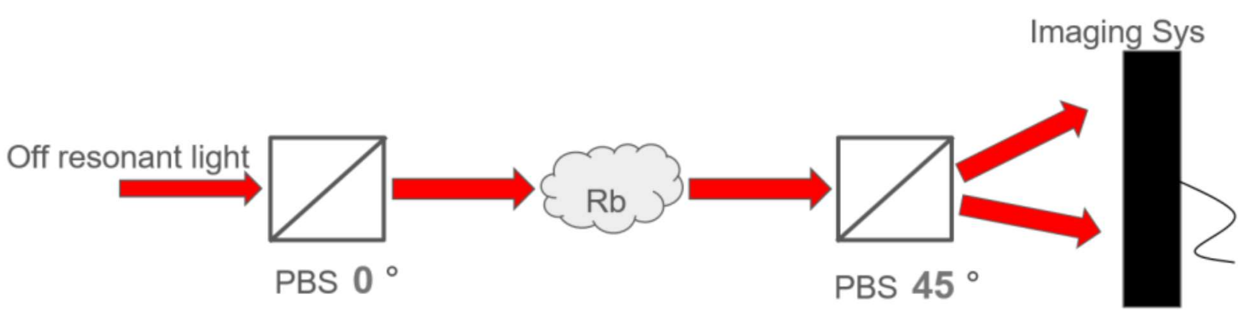


Fig. 1 The atom number is mapped to the polarization state of light. The measurement is non destructive and will lead to a number squeezed state of BEC. This measurement is used to control the atom number by using a feedback mechanism.

Poster #14

Generation of optical Schrödinger "cat" states using intense laser-matter interactions and applications in non-linear optics

N. Tstarafyllis[1,2], Th. Lamprou[1,2], K. Deeksha[1,2] and P. Tzallas[1,2,3*]

[1]*Foundation for Research and Technology-Hellas, Institute of Electronic Structure & Laser, GR- 70013 Heraklion (Crete), Greece.*

[2]*Center for Quantum Science and Technologies, FORTH, 70013 Heraklion, Crete, Greece*

[3]*ELI-ALPS, ELI-Hu Non-Profit Ltd., Dugonics ter 13, H-6720 Szeged, Hungary.*

e-mail address: ptzallas@iesl.forth.gr

Intense laser-matter interactions give rise to high harmonic generation (HHG), a process in which low-frequency photons from a driving laser field are converted into higher-frequency photons. HHG has driven significant advances in atomic, molecular, and optical (AMO) physics, as well as in attosecond science [1]. Traditionally, it has been modeled using classical or semi-classical frameworks [2], which neglect the quantum nature of light. Recent fully quantized treatments [3–7] have demonstrated that conditioning measurements on the HHG process can lead to the generation of optical Schrödinger "cat" states and entangled light states. This work highlights results on high-photon-number optical "cat" states and their significance in nonlinear optics [8].

References

[1] P. Agostini, F. Krausz and A. L'Huillier Nobel prize in physics 2023

[2] K. Amini, *et al.*, *Rep. Prog. Phys.* **82**, 116001 (2019) (and references therein).

[3] U. Bhattacharya, *et al.*, *Rep. Prog. Phys.* **86**, 094401 (2023).

[4] Th. Lamprou, *et al., JPB: Atomic, Molecular and Optical Physics* (in press 2025).

[3] M. Lewenstein, *et al.*, *Nat. Phys.* **17**, 1104 (2021).

[4] J. Rivera-Dean, *et al.*, *Phys. Rev. A* **105**, 033714 (2022).

[5] P. Stammer, *et al.*, *PRL* **128**, 123603 (2022).

[6] P. Stammer, *et al., PRX Quantum* **4**, 010201 (2023).

[7] U. Bhattacharya, *et al., Rep. Prog. Phys.* **86**, 094401 (2023).

[8] Th. Lamprou, *et al., PRL* **134**, 013601 (2025).

Poster #15

Engineering of Optical Ground Stations for Satellite Optical Communication

P. Examilioti, D. Papazoglou, and W. von Klitzing 1,21,31*

1. Foundation for Research and Technology-Hellas, Institute of Electronic Structure & Laser, Heraklion (Crete), Greece.

2. Hellenic Mediterranean University, Heraklion (Crete), Greece

3. Department of Materials Science and Engineering, University of Crete, Heraklion, Greece

*e-mail address: wvk@iesl.forth.gr

Optical communications is a transformative technology for scientific, commercial, and defense applications. Compared to radio-frequency (RF) communications, it can offer higher bandwidth, lower power consumption, and reduced size and mass of transceivers. Using narrow, directed beams can, in principle, provide higher link security, and by using quantum communication, even provide absolute physical security. This work aims to provide and implement key technologies that address the main challenges for optical communication links between Earth and satellites on the ground segment, with application on the Optical Ground Station (OGS) of Skinakas Observatory. A bidirectional optical link with a satellite in a Low Earth Orbit (LEO) will be performed for the first time in Greece. It will also make a significant contribution to the progress of optical communication links, both for quantum communication purposes, rendering the link physically secure, and deep space links, enabling future scientific missions aspiring to perform experiments at the edge of our solar system.

Unveiling Asymmetric Topological Photonic States in Anisotropic 2D Perovskite Microcavities

E. G. Mavrotsoupakis[1,2,3,4*], L. Mouchliadis[1,4], JH. Cao[3,5], M. C. Chairetis[1,2], M. E. Triantafyllou-Rundell[2], E. C. P. Macropulos[2], G. G. Paschos[3], A. Pantousas[2], HY. Liu[6], A. V. Kavokin[3,5], H. Ohadi[7], C. C. Stoumpos[2,8], P. G. Savvidis[3,4]

1. Institute of Electronic Structure and Laser, FORTH, Heraklion, Crete, Greece
2. University of Crete, Department of Materials Science and Engineering, Heraklion, Crete, Greece
3. Westlake University, Department of Physics, Hangzhou, People's Republic of China
4. Center for Quantum Science & Technologies, FORTH-QuTech, Crete, Heraklion, Greece
5. Abrikosov Center for Theoretical Physics, MIPT, Dolgoprudny, Moscow, Russia
6. Tongji University, School of Physics Science and Engineering, Shanghai, China
7. University of St. Andrews, School of Physics and Astronomy, St. Andrews, UK
8. Photonics of Crystals Laboratory, Saint Petersburg State University, St. Petersburg, Russia
*e-mail address: emmavro@physics.uoc.gr

Keywords: Polaritonics, perovskites, topological photonics

Photonic Rashba-Dresselhaus (RD) coupling in anisotropic microcavities offers a compelling platform for realizing unconventional topological states with nonzero Berry curvature [1,2]. In this study, we explore a self-assembled two-dimensional (2D) hybrid structure composed of anisotropically oriented organic/inorganic halide perovskite layers [3] confined within a microcavity. The strong optical anisotropies of these perovskite systems, driven by significant refractive index contrasts and robust excitonic resonances at room temperature [4], enable the emergence of synthetic magnetic fields that mediate photonic and polaritonic interactions. The interplay between polarization-dependent modes and spatial inversion symmetry breaking gives rise to strong photonic RD spin-orbit coupling (SOC) [5], leading to distinct modifications in band topology and energy dispersions. These effects result in the formation of unconventional topological features, including nonzero Berry curvature and off-axis diabolical points, within the photonic and polaritonic bands. Our findings reveal the critical role of optical anisotropies in engineering synthetic gauge fields for light, providing a versatile approach for designing photonic systems with novel topological properties. By leveraging the unique properties of halide perovskites and their ability to support room-temperature excitons, this work advances the development of polaritonic platforms for applications in topological photonics and spinoptronics.

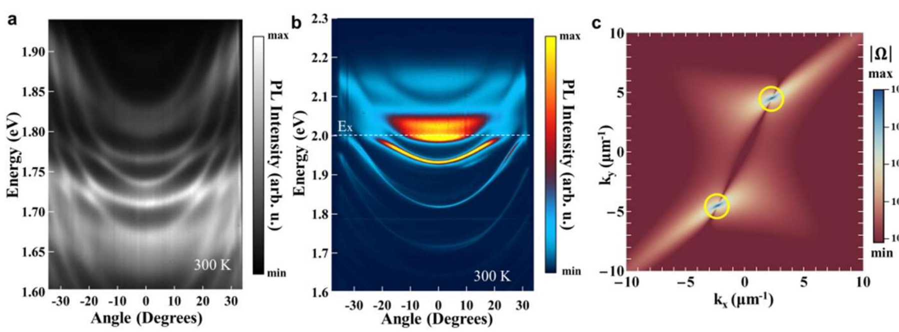


Fig. 1: (**a**) Photonic interaction and (**b**) strong coupling of perovskite microcavities. (**c**) Calculated Berry curvature and diabolical points.

References
[1] K. Łempicka-Mirek et al, Sci. Adv. **8**, eabq9952 (2022).
[2] L. Lu et al, Nature Photon **8**, 821–829 (2014).
[3] C. C. Stoumpos et al, Chem. Mater. **28**, 2852–2867 (2016).
[4] D. B. Mitzi et al, IBM J. Res. Dev. **45**, 29–45 (2001).
[5] A. Kavokin et al, Phys. Rev. Lett. **95**, 136601 (2005).

Notes........................

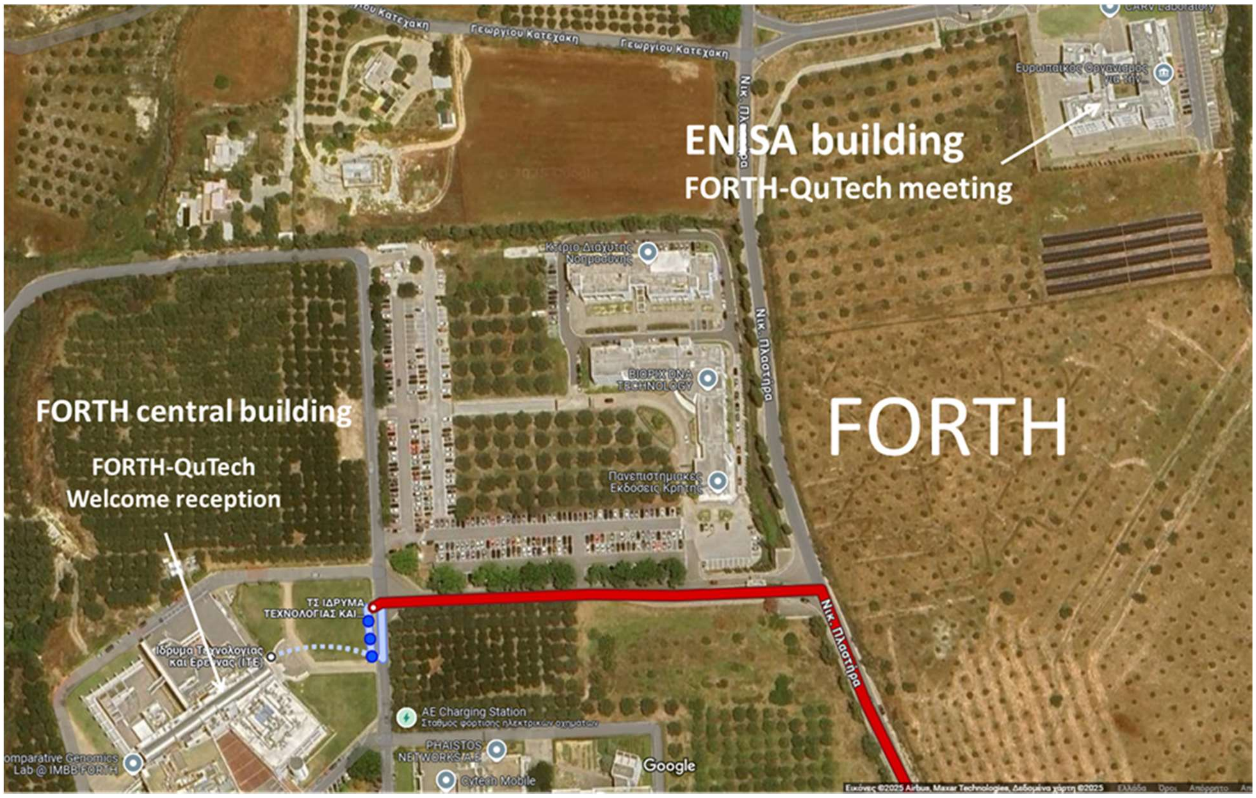
Notes........................

Notes........................

Notes.........................

Notes.........................

Map


ENISA building
FORTH-QuTech meeting
FORTH central building
FORTH-QuTech
Welcome reception
FORTH
Γεωργίου Κατεχάκη
Νικ. Πλαστήρα
AE Charging Station
Google