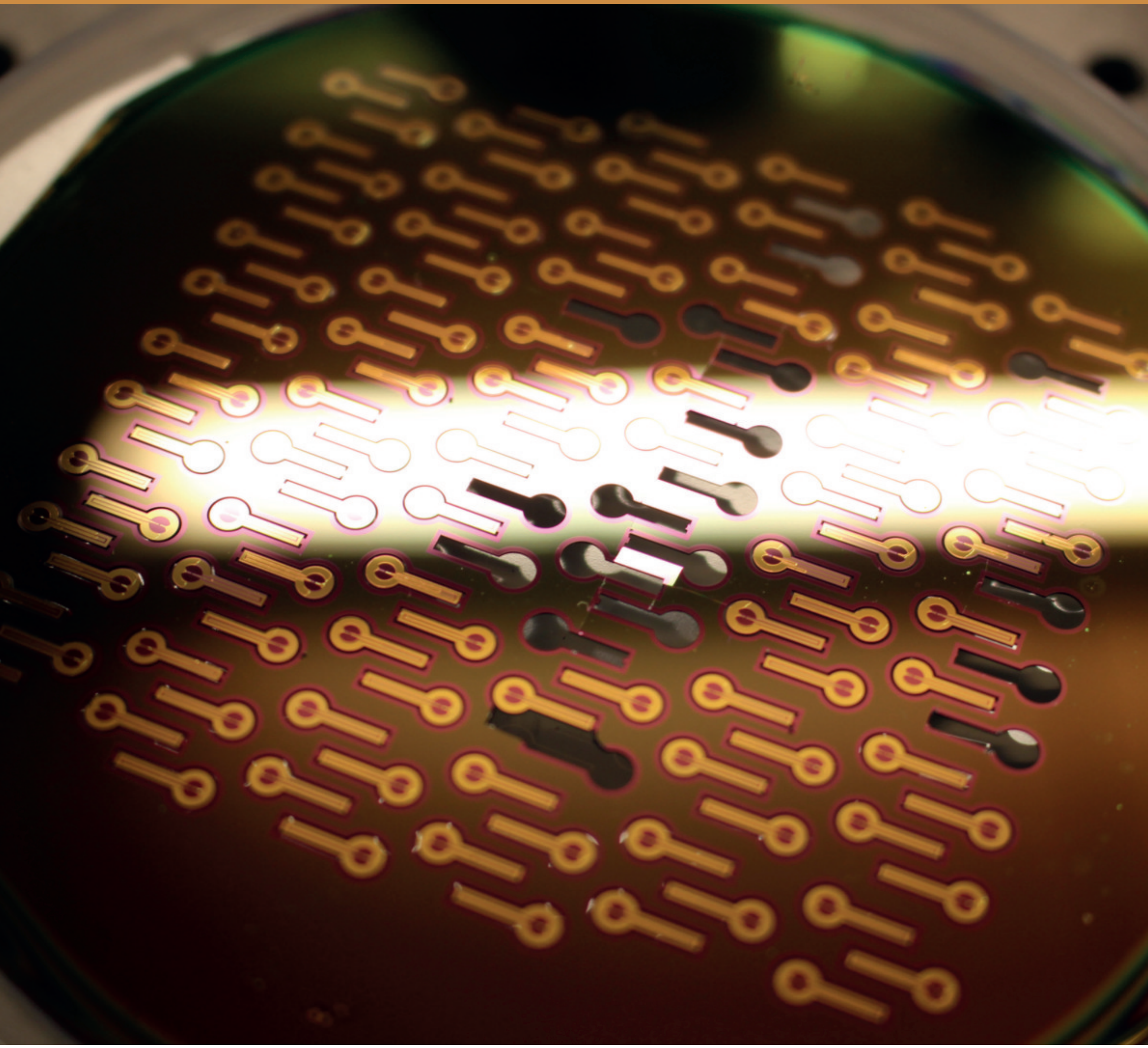
THE BIG IMPLICATIONS OF QUANTUM OPTICS AT THE NANOSCALE



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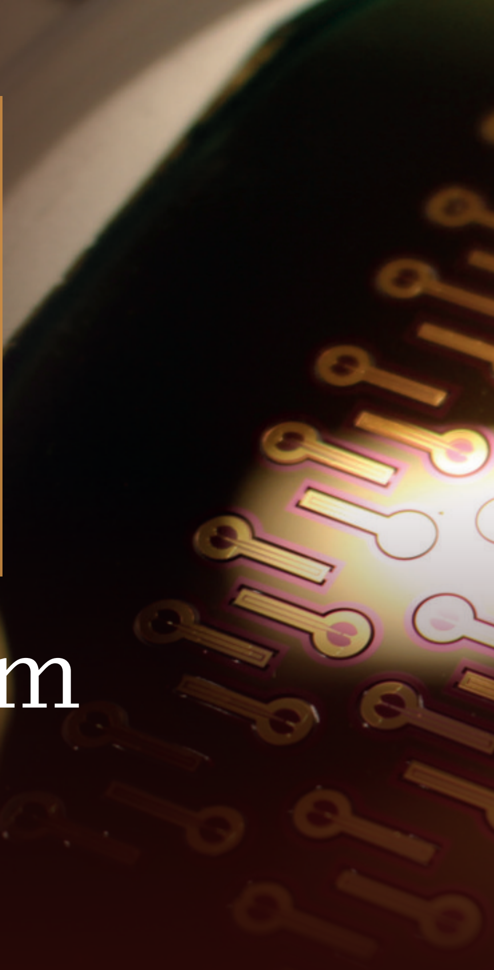


Impact Objectives

- Create and shape a research community by establishing a fruitful and successful interaction among scientists and engineers from academia, research centres and industry, focusing on quantum science & technology, nanoscale optics & photonics, and materials science
- Promote and coordinate forefront research in nanoscale quantum optics through a competitive and organised network
- Define new and unexplored pathways for deploying quantum technologies through nanophotonics devices within the European Research Area

A collaborative platform for understanding quantum phenomena

*The Core Group of the **COST Action MP1403 Nanoscale Quantum Optics**, chaired by **Professor Mario Agio** and **Professor Irene D'Amico**, is coordinating a network of experts who are working to explore and identify new opportunities to deliver quantum technologies through nanophotonic devices. Below, they share some thoughts on how the team's work could lead to improved economic growth and security in Europe*


Professor Mario Agio, Professor Irene D'Amico

The COST Action Nanoscale Quantum Optics (NQO) investigates quantum phenomena in nanophotonics systems. Can you explain a little more about the project?

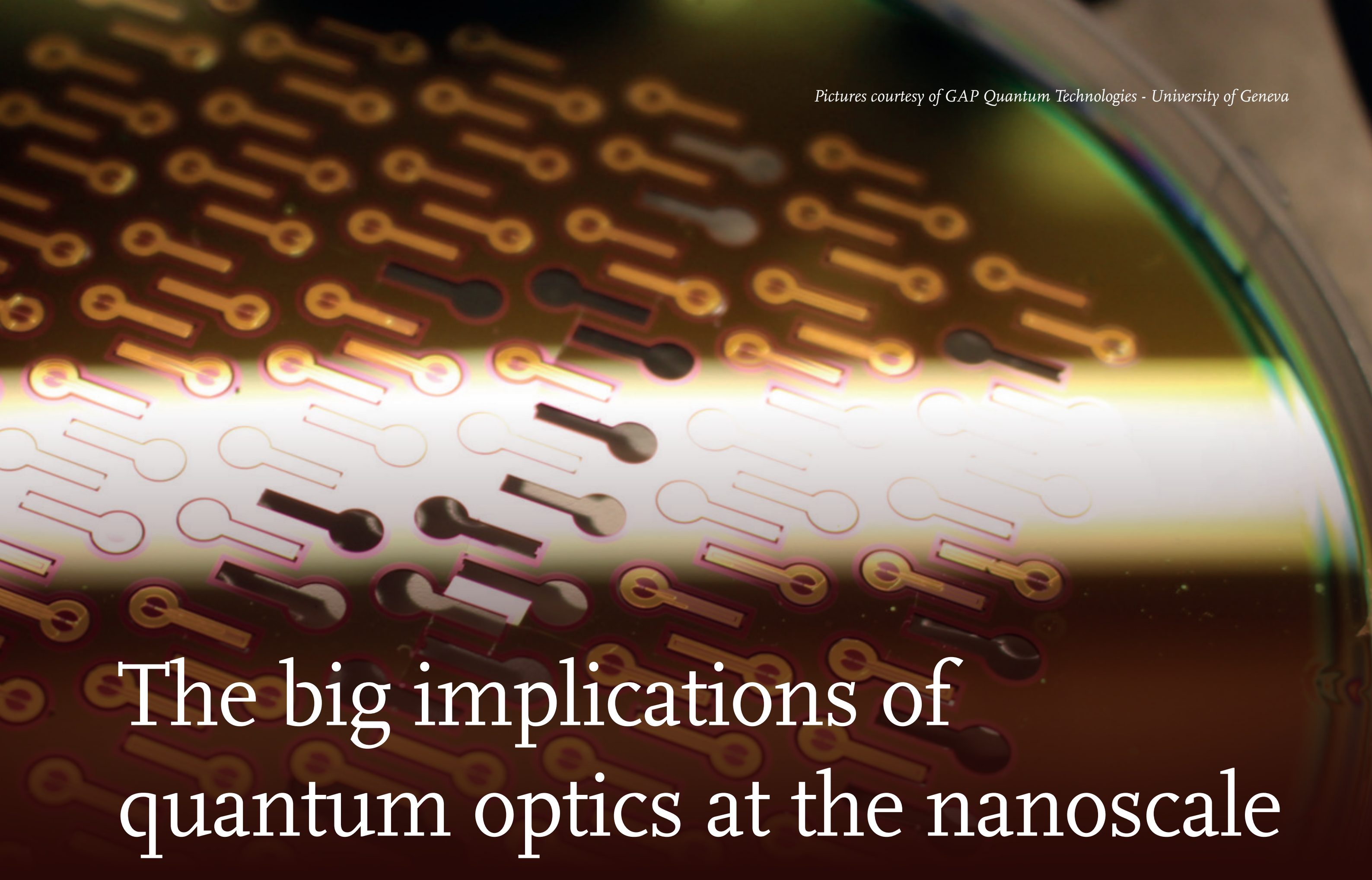
MA: We address a wide range of quantum effects in many different nanophotonics systems. For instance, we are exploiting the latest advances in the nanoscale control of optical fields to strongly enhance the interaction of photons with single quantum emitters. In doing so, we address some major roadblocks for a practical implementation of quantum information devices, for example by exploring the use of the emerging area of quantum plasmonics. These involve, for example, the production of scalable hybrid quantum systems that feature lifetime-limited transitions above cryogenic temperatures, and are able to generate an efficient stream of indistinguishable single photons. In this framework, the COST Action will perform a comparative study of single-photon sources.

How is it hoped that exploiting the laws of quantum physics will help ensure the wellbeing, economic growth and security of Europe?

MA: NQO will address scientific issues that are at the forefront of research and shape a research community. Important scientific achievements are expected from the cross-fertilisation of cutting-edge research. Furthermore, this strategy has the potential to generate disruptive technology and give rise to intellectual property and start-up companies. These will create scientific and industrial leadership as well as long-term competitiveness in, but not limited to, information and communication technology, sensing and metrology, and energy efficiency within the European Research Area.

Collaboration clearly plays an important role in the success of this project. What does each collaborator bring to the table and how does that benefit the research being conducted?

IDA: The main purpose of NQO is to provide a platform where scientists and engineers can jointly analyse the state-of-the-art and define coordinated efforts capable of generating new approaches to existing problems to go beyond the current limits. This requires gathering a network of experts from the different communities of nanophotonics, quantum optics, quantum physics and materials science and providing them with means to effectively interact through the exchange of human resources and access to research infrastructure, joint meetings and a coordinated but flexible work plan. Furthermore, our COST Action aims at achieving a critical mass of scientists and engineers who are able to involve early end users concerning innovation and education in a forefront research field. The improved know-how in this domain will open up new areas of research with relevance to physics, optics and photonics, materials science, and spectroscopy.



Pictures courtesy of GAP Quantum Technologies - University of Geneva

The big implications of quantum optics at the nanoscale

***Nanoscale Quantum Optics** is a four-year COST Action that aims at promoting and coordinating research in this exciting field through a competitive and organised network. Investigating quantum phenomena in nanophotonics systems is the first step towards developing novel technologies with real-world applications*

The nanoscopic scale refers to structures that have a length scale that is incredibly small. Indeed, a nanometre is a billionth of a metre and, at such scales, physical phenomena defy the conventional understanding derived from classical physics. Given this, researchers around the world are investigating a multitude of potential applications for nanoscience.

One branch of enquiry related to the nanoscale is concerned with nanophotonics, which is the study of the behaviour of light on the nanometre scale. Such is the broad potential for nanophotonics systems, the Nanoscale Quantum Optics (NQO) COST Action has been established with a view to exploit quantum phenomena. This work has seen the creation of the NQO community, which is composed of a significant number of scientists and engineers from academia, research centres and industry, all focusing on quantum science and technology, nanoscale optics and photonics, and materials science. 'In addition to addressing the fundamental challenges associated with nanoscale quantum optics, the community hopes to contribute to the discovery of novel phenomena, and define new routes for applications in fields such as information and communication technology, sensing and metrology, and energy efficiency,' explains Action Chair Professor Mario Agio.

By exploiting the laws of quantum physics, the NQO community envisages the development of a means of ensuring the wellbeing, economic growth and security of Europe. It is hoped that the resultant advances will have positive implications for state-of-the-art technology and applications, and be of immediate interest to industry. 'For instance,' observes Agio, 'the development of highly efficient single-photon sources on demand and photon-number-resolved detectors would have impact in the field of secure quantum communication.' He adds: 'Switches that operate at few-photon levels could drastically mitigate the high energy required for optical communication and computation in supercomputers, as well as playing a major role in the reduction of worldwide energy requirements in information and communications technologies.' Agio further notes that new approaches to single-molecule detection and quantum-enhanced measurements will expand the capabilities of sensors, thereby opening new avenues within the fields of metrology, security and safety.

INTERRELATED WORKING GROUPS

To achieve its aims, the COST Action is composed of four Working Groups (WGs) that function alongside each other, on both independent and interrelated levels. WG1 (led by Professor Christophe Couteau and Dr Félix Bussières) is concerned with aspects such as advancing nanoscale control of optical fields, strongly enhancing the interaction of quantum systems, and investigating novel materials such as graphene. WG2 (led by Professor Walter Pfeiffer) is investigating topics such as ultrafast single-photon non-linearities; a direction that could lead to ultrafast optical switching with energies down to very few attojoules. WG3 (led by Professor Thomas Durt and Dr Branko Kolaric) is focused on quantum coherence in nanoscale systems, a phenomenon that lies at the heart of quantum science and technology, representing the basis for advancing quantum computing, metrology and energy transfer. Finally, WG4 (led by Professor Peter Rabl and Professor Dimitris Angelakis) concerns many-body effects, such as the

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The NQO community is working on a scientific and technological roadmap which will be available in spring. You can request a copy by emailing cost-nqo@uni-siegen.de. The roadmap will also be available at http://www.cost-nqo.eu/support/documents/, and a new LinkedIn Group Nanoscale Quantum Optics at https://www.linkedin.com/groups/13505932 has recently been created.

study of polaritonic effects in nanostructures to attain quantum correlations between light and matter, even in the presence of fast dephasing processes. ‘Importantly, to facilitate the scientific exchange of ideas and discoveries – and to establish a common ground between the researchers and engineers – overlaps between the WGs are actively encouraged,’ says Agio.

From the beginning of the project, the Action has involved industries. ‘Now the number of companies has grown and started to form a pool focused on quantum technologies’, says Dr Felix Bussières, senior scientist at the University of Geneva and ID Quantique SA, and Chair the NQO Advisory Board on Industry. ‘Our aim is to further strengthen cooperation with industry, especially start-ups, and organise dissemination activities devoted to policy makers.’

SUPPORTING YOUNG RESEARCHERS AND ENCOURAGING GENDER EQUALITY

Other key considerations of this COST Action centre on early stage researchers (ESRs) and achieving gender balance. In educating and training ESRs, the output of future leaders and a highly skilled workforce is assured, one that will be capable of meeting the ever-increasing demands of a fast-growing and strategic research field on a global scale. Dr Andre Xuereb and Professor Humeyra Caglayan are NQO’s ESR Advisors and they always have gender balance in mind. ‘There is commonly more gender balance among ESR, so it is essential that we keep gender balance in mind when planning ESR activities,’ explains Xuereb. ‘We are trying to give equal opportunities to young female researchers in the involvement of the activities.’

Dr Ruth Oulton, the Gender Balance Advisor to NQO, hopes to have a positive impact on gender equality by taking steps to promote dialogue amongst the scientists and engineers involved in the Action. ‘There are many reasons for the large gender imbalance in this area of technology, from lack of girls taking up STEM subjects in schools, to the leaky pipeline of women leaving careers in STEM subjects,’ explains Oulton. ‘I have implemented several courses of action during the NQO project. One of the most important aspects is to ensure dissemination of information.’

An initial survey of attitudes towards gender equality in STEM was distributed among those involved in NQO, which revealed that there was a lack of knowledge about the proven effects of implicit bias against gender equality, and about the latest research into gender inequality in STEM. Importantly, there is little on how to correct it. Accordingly, Oulton hopes to have gathered insights into effective ways of tackling gender issues in the COST Action community and, by conducting another survey at the close of NQO, it will be clear whether the actions taken have worked.

A LARGE SUPPORTIVE COMMUNITY

The involvement of a very large and very international community (about 500 members from 40 countries, including 28 COST Countries) in the Action is something the team are proud of. ‘Indeed, such a substantial involvement has enabled the NQO community to speak with a single, authoritative voice,’ says Action Vice-Chair Professor Irene D’Amico. Moreover, Bussières explains that they carried out a survey prepared by a market research company on behalf of a start-up company that originated from members of the Action: ‘All members had the opportunity to participate in the survey and help shape a new market for quantum technologies (QT). Members of the Action founded a number of start-up companies on QT, which shows that the combination of quantum physics and nanophotonics has the potential to create totally new products and markets.’

Project Insights

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