SYPQ 1: Symposium: The Rise of Photonic Quantum Technologies – Practical and Fundamental Aspects

Within the so-called second quantum revolution many research fields undergo a transition from basic research in solid-state physics and quantum optics towards applications of photonic quantum technologies, which will prospectively have a large impact to our future daily life. In this light, our Symposium brings together leading experts and early career scientists from different fields, reporting their recent progress on quantum technologies. The topics will illuminate practical but also fundamental aspects at the intersections between the fields of semiconductor and solid-state physics, spin systems, quantum optics, quantum communication, and quantum computing.

Organizers: Tobias Heindel (TU Berlin), Kai Müller (TU München), Nadezhda Kukharchyk (Walther Meißner Institute, Garching)

Time: Friday 10:00–12:45 Location: Audimax 2

Invited Talk SYPQ 1.1 Fri 10:00 Audimax 2

Quantum dots operating at telecom wavelengths for photonic quantum technology — •Simone Luca Portalupi — IHFG-University of Stuttgart

In recent years, strong efforts have been made in order to realize out-of-the-lab demonstrations using quantum science. In particular, the broad range of photonic quantum technologies became highly attractive for the real world implementation of quantum information, quantum communication and quantum network tasks. Long distance realizations would benefit from the possibility of using photons as carriers of information. For these purposes, the use of quantum light in the so-called telecom O- (centred around 1310 nm) and C-band (centred around 1550 nm) would have the advantages of experiencing minimal photon wavepacket dispersion and absorption. Semiconductor quantum dots are considered one of the most appealing sources of quantum light, in particular the ones based on the GaAs material system. In this talk, we will discuss the techniques that can be employed to realize In(Ga)As/GaAs quantum dots emitting in the telecom O- and C-bands [1]. Furthermore, we will discuss advanced fabrication techniques [2] and optical resonators that can be employed to sensibly enhance the source brightness and performances, even operating at liquid nitrogen temperature [3].

[1] S. L. Portalupi, et al., Semicond. Sci. Technol. 34, 053001 (2019)
[2] M. Sartison, et al., Appl. Phys. Lett. 113, 032103 (2018)
[3] S. Kolatschek, et al., arXiv:2107.03316 (2021)

Invited Talk SYPQ 1.2 Fri 10:30 Audimax 2

Photonic graph states for quantum communication and quantum computing — •Stefanie Barz — Institute for Functional Matter and Quantum Technologies, University of Stuttgart, Germany — Centre for Integrated Quantum Science and Technologies, University of Stuttgart, Germany

Multipartite entanglement and, in particular, graph states are useful resources both for quantum computing and quantum communication, especially in networked settings.

In this talk, I will show a few examples where multipartite entanglement offers an advantage over classical or bipartite approaches.

In particular, I will present how photonic graph states can serve as a resource for computation and, vice versa, how computation can be used as a tool to test certain states.

Furthermore, I will show how graph states offer an advantage for communication protocols, in particular in networked settings and where one aims at keeping the identity of the communicating parties private.

I will present implementations of these concepts and discuss challenges in scaling up photonic quantum technologies.

Invited Talk SYPQ 1.3 Fri 11:00 Audimax 2

Rare-earth ion doped solids at sub-Kelvins: practical and fundamental aspects — •Pavel Bushev — JARA-Institute for Quantum Information (PGI-11), Forschungszentrum Jülich, 52425 Jülich

Rare-earth ion-doped solids are promising candidates with a great variety of potential applications in quantum information processing and quantum communication. Due to the existence of addressable and long-lived transitions at microwave and optical frequencies these materials might be deployed as quantum memories in circuit QED, quantum memories for itinerary optical photons, and as quantum transducers between microwaves and light. Some of the above-listed applications require the use of ultra-low temperatures, i.e. $T < 0.1$ Kelvin. At this temperature, one may expect the resolving of single microwave photons at GHz frequency as well as the increase of spin and nuclear coherence times. In my talk, I will review the experimental state-of-the-art and discuss practical and fundamental aspects of the deep freezing of spin-doped solids.

15 min. break.

Invited Talk SYPQ 1.4 Fri 11:45 Audimax 2

Quantum Light and Strongly Correlated Electronic States in a Moiré Heterostructure — •Brian Gerardot — Institute for Photonics and Quantum Sciences, Heriot-Watt University, Edinburgh, UK

The unique physical properties of two-dimensional materials, combined with the ability to stack unlimited combinations of atomic layers with arbitrary crystal angle, has unlocked a new paradigm in designer quantum materials. For example, when two different monolayers are brought into contact to form a heterobilayer, the electronic interaction between the two layers results in a spatially periodic potential-energy landscape: the moire superlattice. The moire superlattice can create flat bands and quench the kinetic energy of electrons, giving rise to strongly correlated electron systems. Further, single particle wave packets can be trapped in the moire potential pockets with three-fold symmetry to form quantum dots which can emit single photons. Here I will present magneto-optical spectroscopy of MoSe2/WSe2 heterobilayer devices with a small relative twist. I will discuss moire-trapped inter-layer excitons, which can emit quantum light, and intra-layer excitons, which are sensitive to a large number of strongly correlated electron and hole states as a function of fractional filling.

Invited Talk SYPQ 1.5 Fri 12:15 Audimax 2

Quantum communication in fibers and free-space — •Rupert Ursin — Institute for Quantum Optics and Quantum Information - Vienna of the Austrian Academy of Sciences, Austria — Quantum Technology Laboratories GmbH, Vienna, Austria

Quantum communication is by far the most technically advanced and mature field within the emerging field of quantum technologies. It gained a lot of attention over the recent years because of the remarcable achievements in China on satellite links and in fibre based communication networks. I will present the quantum links we've successfully implemented from the Chinese satellite MICIUS to an optical ground station in Graz, Austria. Then I will present our effort to build scalable quantum networks on deployed fibres in the city of Bristol, UK and a quantum link between Malta and Italy on a submarine optical fibre cable. Last but not least I will present the recent efforts to built very bright entangled photon sources and preliminary results from an international collaboration to connects the Central European capital cities around Vienna with quantum optical fibre links.