SYPD 1: Solid-state quantum emitters coupled to optical microcavities

Time: Monday 16:30–18:30 Location: AKjDPG-H17

Invited Talk SYPD 1.1 Mon 16:30 AKjDPG-H17

Fiber-based microcavities for efficient spin-photon interfaces — •David Hunger — Physikalisches Institut, Karlsruher Institut für Technologie, Karlsruhe, Germany

Optical microcavities are a powerful tool to enhance light-matter interactions and offer the potential to realize efficient interfaces for spins and photons. To achieve large cavity enhancement on a flexible platform, we have developed microscopic Fabry-Perot cavities based on laser-machined optical fibers [1]. We employ such cavities to realize efficient readout of individual solid-state quantum emitters such as NV centers in diamond [2,3] and rare earth ions [4,5,6], with the goal to realize a quantum repeater for long-distance quantum communication, and optically addressable multi-qubit registers as quantum computing nodes. [1] Hunger et al., New J. Phys. 12, 065038 (2010) [2] Kaupp et al., Phys Rev Applied 6, 054010 (2016) [3] Benedikter et al., Phys Rev Applied 7, 024031 (2017) [4] Casabone et al., New J. Phys. 20, 095006 (2018) [5] Casabone et al., Nature Commun. 12, 3570 (2021) [6] Serrano et al., Nature, in print (arxiv:2105.07081)

Invited Talk SYPD 1.2 Mon 17:00 AKjDPG-H17

A fast and bright source of coherent single-photons using a quantum dot in an open microcavity — •Richard J. Warburton — Department of Physics, University of Basel, Switzerland

A semiconductor quantum dot is a potentially excellent source of single photons: billions of photons per second can be created; the interaction with phonons is relatively weak such that successively emitted photons exhibit a high degree of two-photon interference. Significant challenges are to create an efficient source, and to reduce the noise such that photons created far apart in time also exhibit a high degree of two-photon interference. We show how these challenges can be met by embedding a gated quantum-dot in an open microcavity.

In our gated devices, quantum dots exhibit near transform-limited linewidths, both at wavelengths in the near infrared (920–950 nm) and in the near-red (around 780 nm). A microcavity is constructed using a planar semiconductor bottom mirror (part of the semiconductor heterostructure) and a curved top mirror. With a very high-reflectivity top mirror, a single quantum-dot enters the strong-coupling regime of cavity-QED with a cooperativity exceeding 100. Clear vacuum Rabi-oscillations are observed. With a modest-reflectivity top mirror, an efficient single-photon source is demonstrated. The end-to-end efficiency, the probability of creating a single photon at the output of the experiment's final optical-fibre following a trigger, is 57%; the photon purity $(1 - g^{(2)}(0))$ is 97.9%; the two-photon interference visibility is 97.5% and is maintained even on interfering photons far apart in time (1.5 μs in the experiment).

Invited Talk SYPD 1.3 Mon 17:30 AKjDPG-H17

New host materials for individually addressed rare-earth ions — •Sebastian Horvath, Salim Ourari, Lukasz Dusanowski, Christopher Phenicie, Isaiah Gray, Paul Stevenson, Nathalie de Leon, and Jeff Thompson — Department of Electrical and Computer Engineering, Princeton University, Princeton, New Jersey 08544, USA

Erbium ions in crystalline hosts, which have an optical transition at 1.5 μm, are promising as single photon sources and quantum memories for quantum repeater networks operating directly in the telecom-band. Rare-earth ions can be incorporated into a wide range of host materials; however, the choice can dramatically impact the spin and optical coherence properties. Two key factors determining these properties are the presence of species with a magnetic dipole moment, as well as the point-group symmetry of the substitutional site. From this we develop a set of design principles for an optimized host material, which leads us to a detailed investigation of the hosts MgO and CaWO4. Single erbium ions were isolated using heterogeneously integrated silicon photonic crystal cavities, and both the optical and spin properties were probed using single shot readout. With this approach, we have studied sources of decoherence for both Er:MgO and Er:CaWO4, and developed materials processing techniques to improve the performance of this platform. I will discuss refinements to our design considerations developed from our results to date and share the current status of our single erbium ion platform for the efficient generation of spin-photon entanglement.

Invited Talk SYPD 1.4 Mon 18:00 AKjDPG-H17

A multi-node quantum network of remote solid-state qubits — •Ronald Hanson — QuTech and Kavli Institute of Nanoscience, Delft University of Technology, The Netherlands

Future quantum networks [1] may harness the unique features of entanglement in a range of exciting applications. To fulfill these promises, a strong worldwide effort is ongoing to gain precise control over the full quantum dynamics of multi-particle nodes and to wire them up using quantum-photonic channels.

Here, we present our most recent work on the realization and application of a three-node entanglement-based quantum network based on diamond NV centers. We demonstrate several quantum network protocols without post-selection: the distribution of genuine multipartite entangled states across the three nodes, entanglement swapping through an intermediary node [2], and qubit teleportation between non-neighbouring nodes [3]. This work establishes a novel platform for exploring, testing, and developing multi-node quantum network protocols and a quantum network control stack [4]. Moreover, we will discuss future challenges and prospects for quantum networks, including the role of next-generation integrated devices.

[1] Quantum internet: A vision for the road ahead, S Wehner, D Elkouss, R Hanson, Science 362 (6412), eaam9288 (2018). [2] M. Pompili, S.L.N. Hermans, S. Baier et al., Science 372, 259-264 (2021). [3] S.L.N. Hermans, M. Pompili et al., arXiv:2110.11373 (2021). [4] M. Pompili, C. Delle Donne et al., arXiv:2111.11332 (2021).