Quantum dots interfaced with alkali atoms: filtering, delaying and quantum interfering single photons

S. L. Portalupi[1], H. Vural[1], J. Maisch[1], S. Kern[1], J. H. Weber[1], M. Jetter[1], J. Wrachtrup[2], R. Löw[3], I. Gerhardt[2], and P. Michler[1]

[1] Institut fr Halbleiteroptik und Funktionelle Grenzflchen, Center for Integrated Quantum Science and Technology (IQST), and SCoPE, University of Stuttgart,
[2] 3. Physikalisches Institut and Center for Integrated Quantum Science and Technology (IQST), and SCoPE, University of Stuttgart, and Max Planck Institute for Solid State Research,
[3] 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology (IQST), and SCoPE, University of Stuttgart

Hybrid quantum systems rely on the possibility to interface elements from complementary fields: only the best properties from all components can then be utilized, overcoming the limitation of each field. Semiconductor quantum dots (QDs) are well known and widely used as sources of bright, pure and highly indistinguishable on-demand single photons. Despite, a crucial limitation is given by the relatively short coherence time. This can be overtaken by interfacing them to alkali atoms, which display a longer coherence time and will benefit from the superior properties of QD-based non-classical light sources [1]. As example of an efficient QD-to-atom interface, we recently demonstrated the filtering of two consecutive single photons generated from a resonantly excited QD by using a Cs-based Faraday anomalous dispersion optical filter (FADOF) [2]. The Mollow triplet sidebands were tuned on resonance with the Cs-D1 transition and simultaneously filtered with more than 10% transmission. All other spectral components were suppressed below the noise level. In the present study [3], we take a step further by using a warm Cs vapor to realize a variable optical delay. An extensive study on the effects of vapor temperature on the achievable delay has been conducted using single photons with several different linewidth stemming from different QDs. A record delay of 28 ns was achieved for almost 100% of the transmitted photons. Autocorrelation measurements proved that an ideal $g^{(2)}(0) \approx 0$ is fully preserved after the interaction with the atomic vapor. Furthermore, we measured the Hong-Ou-Mandel visibility under several different conditions using the atomic vapor as variable delay line. By delaying both successively emitted photons, the photon indistinguishability is fully preserved, indicating no decoherence induced by the photon-atom interaction. In order to get closer to a realistic quantum network scenario, one photon is then sent through the atomic delay and then let it interfere with a non-delayed photon. In this case, only a small degradation of the two-photon interference visibility is observed, attributed to the photon wavepacket dispersion gained during the delay-based storage. This effect is fully explained via theoretical simulations and the fundamental photonic properties in realizing a hybrid quantum system are then discussed. This result opens the door to implement a vapor-based quantum memory for highly indistinguishable photons from a quantum dot.

References

[1] N. Akopian, *et al.*, Nat. Photon. **5**, 230-233 (2011).
[2] S.L. Portalupi, *et al.*, Nat. Commun. **7**, 13632 (2016).
[3] H. Vural, *et al.*, Optica **5**, 367 (2018).