Interfacing Quantum Dot Single-Photon Emitters with Cesium Atomic Vapor

Hala Said[1]* , Esteban Gómez-López[1] , Moritz Meinecke[2] , Karol Winkler[2] , Jonathan Jurkat[2] , Tobias Huber-Loyola[2] , Sven Höfling[2] , Jisoo Kim[2] , Markus A. Schimdt[2], and Oliver Benson[1] .

[1*] *Institut für Physik, Humboldt-Universität zu Berlin, 12489, Berlin, Germany*

[2] *Technische Physik, University of Würzburg, 97074, Würzburg, Germany*

[2] *Institute of Photonics and Quantum Electronics, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany*

[2] *Department of Fiber Photonics, Leibniz Institute of Photonic Technology, Jena, 07745, Germany*

Quantum dot–based single-photon sources (SPS) are promising candidates for scalable quantum networks due to their ability to generate bright, on-demand single photons with high purity and indistinguishability [1]. Embedding quantum dots in micropillar cavities significantly enhances light extraction and collection efficiency, which is critical for practical quantum networks and linear optical quantum computing [2]. To enable synchronization of local operations and long-distance quantum communication, interfacing solid-state single-photon emitters with atomic systems such as cesium vapor cells is highly desirable. In such systems, variable optical delay lines can be implemented using slow-light effects [3], while long-lived spin-wave excitations enable photonic storage in atomic ensembles [4]. In this work, we tune the emission of semiconductor quantum dots into resonance with the cesium D1 transition and investigate their interaction with a cesium vapor cell. The single-photon properties of the emitters are characterized using Hanbury Brown–Twiss (HBT) interferometry. This work provides insight into the interaction between solid-state single-photon emitters and atomic systems and establishes a platform for future investigations aimed at stabilizing quantum dot emission with atomic spectroscopy precision and realizing hybrid atomic–quantum dot interfaces for quantum memory applications.

References

[1] Vajner, D. A.; Rickert, L.; Gao, T.; Kaymazlar, K.; Heindel, T. Quantum communication using semi-conductor quantum dots. Adv.Quantum Technol.2022, 5, 2100116.

[2] Y.-M. He, et al., Deterministic implementation of a bright, on-demand single photon source with near-unity indistinguishability via quantum dot imaging, Optica 4, 802 (2017).

[3] Kroh, Tim, et al. "Slow and fast single photons from a quantum dot interacting with the excited state hyperfine structure of the Cesium D1-line." Scientific reports 9.1 (2019): 13728.

[4] Maaß, Benjamin, et al. "Storage of single photons from a semiconductor quantum dot in a room temperature atomic vapor memory with on-demand retrieval." Quantum Science and Technology (2025).