Chiral light-matter interaction in deterministically fabricated quantum dot waveguides

Paweł Mrowiński,[1,*] Peter Schnauber,[1] Philipp Gutsche,[2] Arsenty Kaganskiy,[1] Johannes Schall,[1] Sven Burger,[2] Sven Rodt[1] and Stephan Reitzenstein[1]

1 Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany
2 Zuse Institute Berlin, Takustraße 7, 14195 Berlin, Germany
**Permanent address: Laboratory for Optical Spectroscopy of Nanostructures, Department of Experimental Physics, Faculty of Fundamental Problems of Technology, Wrocław University of Science and Technology, Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland*

Quantum dots embedded into waveguides can exhibit directional emission and non-reciprocal transmission on a single-photon level via chiral light-matter interactions. This type of interaction is highly interesting from a fundamental physics point of view and has high relevance also for the realization of large-scale on-chip quantum circuits [1,2]. In this work, we study directional emission of a single InGaAs quantum dot (QD) in a ridge waveguide (WG) structure with bottom AlGaAs/GaAs DBR mirror. The QD is pre-selected and deterministically integrated into the WG by using in-situ electron-beam lithography (see Fig 1a), providing a positioning accuracy of 30-40 nm, as described in [3,4]. We fabricated a series of WG structures containing single QDs under variation of the lateral displacement in the waveguide to explore the position dependence on directional emission. Directional propagation is demonstrated by recording polarization resolved photoluminescence in the presence of an external magnetic field applied in Faraday configuration. A significant contrast of 90 % between light emitted by the left/right outcoupling element is observed for right/left circularly polarized QD emission from a charged exciton of a QD with highly off-center position. This result clearly indicates chiral coupling in this determinsitcally faricated QD-waveguide system (see Fig 1b). Furthermore, we study in detail the contrast vs QD position and we obtain good agreement with the calculated dependence obtained by finite element method (JCMwave) modelling which reveals strong impact of higher order guided modes in our multimode waveguide system. Finally, by using again the JCMwave software, we analyze numerically the crossed-waveguide system to realize non-reciprocal on-chip single-photon devices in the future.

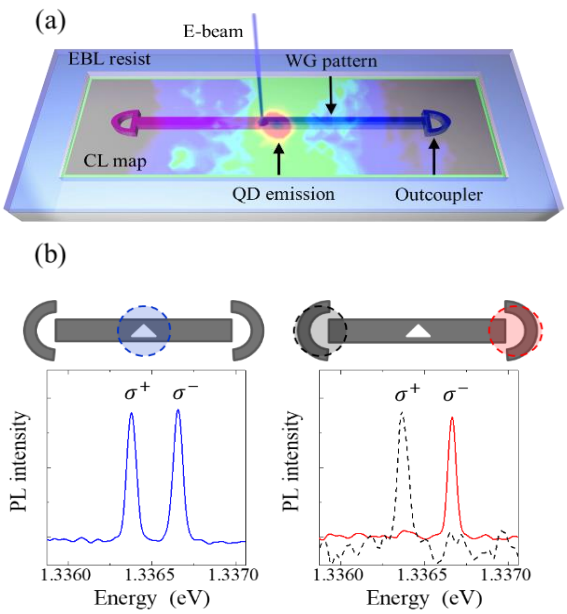

Fig. 1 a) Schematic demonstration of the fabrication process of deterministic quantum dot waveguide structures fo studying chiral coupling. b) PL results prooving highly directional emission for the off-center QD position.

[1] P. Lodahl et al., Nature 541, 473 (2017)
[2] R. J. Coles et al., Nat. Commun. 7, 11183 (2016)
[3] P. Schnauber et al., Nano Lett. 18, 2336 (2018)
[4] P. Mrowiński et al arXiv:1902.01905