Simulation of Optical Properties of Nanohole Droplet-Etched GaSb/AlGaSb Quantum Dots for Telecommunication Spectral Range

Robert Matysiak[1,2], **Markus Peil**[3], **Joonas Hilska**[3], **Teemu Hakkarainen**[3,4], **Anna Musiał**[1] **and Michał Gawełczyk**[2]

[1] *Department of Experimental Physics, Wrocław University of Science and Technology, Poland*

[2] *Institute of Theoretical Physics, Wrocław University of Science and Technology, Poland*

[3]*Optoelectronics Research Centre, Physics Unit, Tampere University, Finland*

[4]*Tampere Institute for Advanced Study, Tampere University, Finland*

Security of the classical cryptography is based on the complexity of mathematics behind it, while the security of the quantum one is guaranteed by the fundamental laws of quantum mechanics. For achieving functional and secure transmission of quantum information, using e.g. the widely known BB84 protocol for quantum key distribution, non-classical sources of single photons (SPS) are needed. Additionally, their emission wavelength has to match the third transmission window to take advantage of the low-loss transmission via existing fiber-based infrastructure. The most promising option for this purpose is the usage of epitaxial semiconductor quantum dots (QDs) [1]. Over the last two decades, droplet-epitaxy etched almost strain-free GaAs/AlGaAs QDs have been shown to provide unmatched optical quality (e.g., QD ensemble homogeneity, purity and indistinguishability of Fourier-limited single-photons, photon pair entanglement fidelity), but emitted photons are not at telecom wavelengths [2]. Recently, (In, Ga)As QDs have been suggested as potential SPS at telecom C-band frequencies [3]. We propose alternative material platform for 3rd telecom window, namely type I GaSb QDs on AlGaSb surface grown in the same droplet-epitaxy etching scheme. Thus combining QDs growth proven advantageous for QD optical quality at shorter wavelengths and maturity of GaSb platform in terms of methodology for device integration on the Si platform. There are strong indications that such QDs may serve as high-quality SPS working at the third transmission window [4]. To obtain the theoretical predictions of the QDs' optical properties, we use a custom state-of-the-art software employing a multi-band theoretical $\mathbf{k}\cdot\mathbf{p}$ framework [5]. We may take into account the impact of strain and piezoelectric effects included up to second order in strain tensor elements, spin-orbit coupling and arbitrary external fields in our simulations. Based on large-scale simulations over wide multidimensional parameter space, we are able to estimate the optimal QD parameters providing the best possible optical properties of GaSb QDs. This constitutes important feedback for guiding the growth of better QDs to further enhance the last achievements [6] and data basis for comparison with results of optical experiments. It also provides important insight into description of electronic structure and fundamental optical properties for this novel type of QDs.

This work was financed by FiGAnti project funded within the QuantERA II Programme that has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 101017733 and National Science Centre, Poland- project 2023/05/Y/ST3/00125.

[1] X. Zhou, L. Zhai, and J. Liu, Photonics Insights, **1**, R07 (2022).
[2] S. F. C. da Silva et al., Appl. Phys. Lett., **119**, 120502 (2021)
[3] D. Deutsch et al., AIP Advances **13**, 055009 (2023)
[4] J. Michl et al., Adv. Quantum Technol., **6**, 2300180 (2023)
[5] K. Gawarecki, Phys. Rev. B, **97**, 235408 (2018),
[6] J. Hilska, A. Chellu, and T. Hakkarainen, Crystal Growth & Design, **21**, 1917 (2021)