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INTEGRIERTE QUANTENPHOTONIK

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PhD Thesis (Doctoral Dissertation) Report on

"InAs/InP quantum dots for telecom quantum photonics"

by

Paweł Holewa

Single photon emitting devices are a core research activity within the fields of quantum optics and optical quantum information processing. The later includes both optical communication as well as quantum simulation. Despite a long quest for optimizing single photon emitters, still today not all required parameters regarding efficiency and quality of the emitted quantum states come close to the theoretically predicted values. Over the past years, however, significant progress has been made regarding the efficiency and indistinguishability, yet only allowing a few groups world-wide to develop sources in the telecom C-band, the main frequency band for classical communication due to the minimal losses occurring through propagation in optical fibers. This low loss is similarly and possibly even more important for quantum communication, hence single photon sources at 1550 nm have a significant technological implication.

In his *Doctoral Dissertation,* Paweł Holewa develops recipes for the growth of such sources, implements methods for the integration of such sources in optical devices for the improvement of efficiency, and characterizes in detail the optical properties of the grown single photon emitters. The emitters are based on the InAs/InP material heterosystem.

The *Doctoral research work* is distributed between the *Nonlinear Quantum Photonics Group in the Department of Experimental Physics at Wrocław University of Science and Technology* and the *Nanophotonic Devices Group in the Department of Electrical and Photonics Engineering at the Technical University of Denmark.*

The *Doctoral Dissertation* is a combination of a compact introductory section and cumulative work; in part I, the dissertation introduces the overall and theoretical background and introduces the methods, and then lists in part II the five included peer-reviewed publications. In addition, extensive Supplementary Materials belonging to several of the published papers are also addended.

Before introducing the research work in form of the published articles, Paweł Holewa spends chapter 1 on motivating in detail his research work, giving a nice overview of past and present state-of-the-art. This includes information on quantum communication, the background of epitaxial quantum dots, and photonic structures to enhance light-matter interaction.

In chapter 2, Paweł Holewa addresses the theoretical background of both the growth physics as well as the physics of quantum light. He begins with aspects growing material with MOVPE and details the growth of quantum dots and in particular the state of the art in droplet epitaxy. He covers exitonic states, their modelling and experimental aspects. Finally, he introduces single photon properties and the interaction of emitters with optical cavities.

In chapter 3, Pawel Holewa describes his experimental tools, including the growth and processing of the investigated materials. In addition, the details of the optical systems used for the analysis of photonic states terminates the background section.

In chapter 4, Pawel Holewa summarizes the 5 published, and in the thesis included, manuscripts. He organizes his research motivation along three objectives. In Objective 1, he aims at establishing an optimized growth strategy for low-density InAs/InP QDs with emission in the telecom band. He focuses on understanding their optical properties and on enhancing the QD in-plane symmetry. In Objective 2, he develops and introduces of a wafer-bonding platform for combining different materials to enable tailoring of QD emission properties and the broadband enhancement of photon collection efficiency. In Objective 3, he develops methods to localize the spatial position of QDs for fabricating nanocavities at their respective position and investigates the optical properties of the cavity-coupled QDs.

In this chapter, Pawel Holewa also includes statements on his contribution to each individual published work. This section clearly indicates that he has significantly contributed to these works. He is even named the corresponding author in several works, supporting that he was the drive and responsible main person. His broad type of contributions range from optimizing growth of quantum dots, modelling of electronic structures, optical spectroscopy of quantum dots and cavity-quantum dot structures, software control design, data analysis, data interpretation, to writing and defending the included manuscripts.

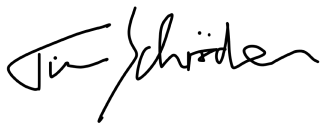
The compact introductory section is very nicely written, and despite its introductory character includes all required background information. Compared to other cumulative works, this introductory section is rather detailed and beyond the expectation regarding the content, supporting the impression from his pure scientific publications that Pawel Holewa has developed to a well-trained and careful young researcher that can well communicate relevant scientific and technological aspects to the reader. One nice detail I would like to mention is that, to make the most important concepts easily accessible to the reader, Pawel Holewa uses "boxes", which emphasize important aspects of the most important concepts. These six boxes include "objectives of the thesis", "MOVPE growth", "k*p modelling", "selection rules", "correlation function", and "cavity coupling" and guide the reader through the different sections.

In part II of the thesis, Pawel Holewa prints the published manuscripts. Besides the excellent 5 published works included in his dissertation, Pawel Holewa has also published 3 more peer-reviewed papers and has contributed to 7 more works as co-author. Together, this makes a contribution of 15 peer-reviewed manuscripts to the solid-state community and is remarkable at this early stage of the career. For the evaluation of the thesis, however, only the 5 included manuscripts are considered.

In summary, Pawel Holewa's thesis part I is very clearly and well written, contains all information required to follow the experiments in part II in a compact fashion, and in part II presents excellent scientific results. The research work has been published in several very well-established physics journals including solid publications in PRB and PR Applied, and high-impact publicaitons in Nanophotonics and ACS Photonics, and a preprint work on the arxiv server.

Overall, Pawel Holewa's scientific contribution spans from designing and developing improved quantum dot growth methods, the analysis and interpretation of their properties, to the demonstration that the fabricated quantum dots and photonic systems might have a relevance for future quantum technologic applications. It is not one explicit achievement that distinguishes the thesis from Pawel Holewa compared to other PhD works, but it is the collection of results and the mastering of a broad range of techniques that support the excellent universal expertise of the candidate.

I therefore recommend to **award the doctoral degree with the highest distinction** to the candidate Paweł Holewa for his PhD thesis "InAs/InP quantum dots for telecom quantum photonics".



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