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Evaluation Report of the PhD thesis:

"Heterogeneous integration of InAs/InP quantum dots with photonic integrated circuits operating at 1550 nm" by Marek MIKULICZ.

I very much appreciated reviewing the PhD thesis by Marek Mikulicz. The thesis consists of four technical chapters wherein the original activity is illustrated and discussed, one introductory chapter and one final chapter for conclusions. The thesis addresses a relevant topic in integrated photonics, i.e. the physical coupling of light sources suitable for application in quantum regimes and Silicon photonic structures for guiding, filtering, and generally manipulating optical signals on chip. Two key integration strategies are followed—direct bonding and micro-transfer printing (μTP)—for coupling InAs/InP quantum dots (QDs) to photonic integrated circuits (PICs), particularly optimized for the telecom C-band.

In Chapter 1, a comprehensive overview of quantum photonic integrated circuits (qPICs) is provided. Specifically, it focuses on the challenge of integrating III-V quantum dots onto Si-based photonic platforms, which are known to lack embedded light emitters. It introduces key concepts such as excitonic complexes, Purcell enhancement in photonic crystal cavities, and silicon-on-insulator (SOI) platforms. The fundamental physics and growth technology of quantum dots is remarkably described. Related to this, absorption/emission properties from the excitonic landscape within confined semiconductors is nicely introduced and projected towards the main goals of the thesis. The concept of photonic cavities in 2D photonic crystals, linear beams or multilayered pillars is also introduced, wherein the Q factor and the modal volume are seen to be directly involved into the Purcell effect. Probably, few mentions about experimental approaches to measure Purcell factors could make the overall description more complete. I spotted a typo at pag.38: "phonons" instead of "photons". Worth of appreciation the detailed description of the experimental setups and DAQ procedures (including the active stabilization of the microscope-based acquisitions) used in this thesis.

Chapter 2 reports on the fabrication methods employed to obtain the integrated photonic circuits with embedded quantum sources. Description includes lithography (optical and e-beam), thin-film deposition, and both dry (ICP-RIE) and wet etching techniques. The μTP method is presented as a deterministic and high-throughput pick-and-place approach, enabling sub-100 nm alignment accuracy for integrating QD-containing nanobeams onto various substrates. The author also characterizes stress and alignment marks (AMs), and quantifies process parameters using SEM, AFM, and ellipsometry. The text is accurate and complete, providing all necessary details to replicate the results.

Chapter 3 deals with an example of direct bonding technique applied to an InP tapered waveguide containing InAs/InP quantum dots, contacted to a Si waveguide. An outcoupling grating is also provided. The design of the device has been performed by means of FDTD modelization. Fabrication steps are described in detail and the device performances are quantified experimentally. This activity is original and published on Optics Express in 2024.

One of the two examples of micro-transfer technique is illustrated in Chapter 4, where InAs/InP quantum dots are integrated within a photonic crystal cavity on the end facet of a single mode fiber. The devices are tested at 15 K using time-resolved and second-order correlation (HBT) setups. Results include $g^2(0) = 0.27$

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under pulsed excitation and emission linewidth < 0.5 nm, verifying true single-photon behaviour and long-term optical stability, with emission in the telecom C-band. It would be interesting to investigate possible polarization-dependencies of the cavity-coupled emitted light.

As a second example of micro-transfer technique, InP nanobeams (i.e. one-dimensonal cavities) containing quantum dots are contacted onto an SOI chip with Si guides, as illustrated in Chapter 5. The cavity mode resonance peak is close to 1550 nm, thus relevant for telecom use. Detailed analysis of optical coupling, mode overlap, and emission tuning with temperature is presented. Finally, SiN guides and metallic contacts are also explored to test the efficacy of the developed transfer technique.

Chapter 6 provides an effective outline of the main findings presented in the thesis.

The PhD candidate has actively engaged in an international collaborative network. Content from this thesis appear on three widely-accepted peer-reviewed international journals. Additionally, the candidate contributed to other six articles, whose content is not included in the thesis. Results are relevant to both scientific advancements and technological innovation. The breadth and depth of this work make it a comprehensive, high-quality thesis that significantly contributes to the field and showcases the candidate's strong expertise in nano-fabrication and experimental optics.

It is apparent that the candidate has placed considerable time and effort in advancing technological knowledge targeting quantum photonic devices in the near-infrared. The candidate's maturity is evidenced by the extended and detailed introduction on basically all aspects related to this topic.

All presented results are thoroughly supported, with data handled carefully and in accordance with scientific integrity. The research makes effective use of documentation, references, and relevant scholarly literature, which are well integrated into the thesis. The work is well-cited, includes useful figures and illustrations, and is generally very clear. The scientific level and originality of this entire work is high and there is no doubt that this work will contribute to advance fabrication technology aimed at quantum optical communications and processing devices -as outcasted in the introduction.

The candidate is first author in all three articles presented, thus demonstrating relevant, independent contribution to the published works.

In conclusion, this thesis is evaluated as excellent and fully deserving to be awarded with the PhD title. The thesis is recommended for a public oral PhD defence without minor revisions.

Sincerely,

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