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To whom this may concern

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Date	Our reference	Your reference
June 11, 2025	N/A	N/A

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Report on PhD thesis M. Mikulicz

Dear colleague,
In the following I am reporting my findings on the PhD thesis of Mr. Marek Mikulicz, entitled *"Heterogeneous integration of InAs/InP quantum dots with photonic integrated circuits operating at 1550 nm".*
The first chapter presents an extensive introduction to the work. In the beginning, the contributions of the author and of his coworkers are clearly listed, which makes it easy to identify his role in the work. The final intended application (quantum simulations and computing using quantum photonic integrated circuits – qPICs) is briefly explained. Here it would have been useful to include more specific references to the computation paradigms introduced in the last years and currently pursued at industrial scale (e.g. by PsiQuantum), besides the initial quantum gate proposals. A detailed and useful introduction to the growth and physics of quantum dots (QDs) is provided, with a minor confusion between homogeneous and inhomogeneous broadening in Fig. 1.2. The discussion of strong coupling in par. 1.5.4 would have been better coupled to the discussion of the Purcell effect in par. 1.5.6.1 and the definition of the strong coupling regime is not completely correct. Overall, the first chapter provides a good introduction to the work and a solid basis for the thesis.
Chapter 2 provides a detailed description of the fabrication methods, including the working principle of the different processing and inspection equipment. The specific recipes used in the work are described and motivated, which will represent a very useful reference for other researchers working in the field. This chapter shows that the PhD candidate has fully mastered the methods used to fabricate the devices developed in the course of the work.
Chapter 3 presents the heterogeneous integration of the III-V sources on silicon. The design and related simulated performance are first presented, based on previous work in the same group. This shows a quite promising performance, although some design choices (such as the thickness of the III-V layer) are not fully justified. The experimental results show convincing evidence of single-photon emission from single excitons in InAs/InP QDs, using a heterogeneously integrated InP/Si waveguide structure. This is an exciting development in view of the integration of single-photon sources on silicon photonics quantum circuits. The purity of the single-photon emissions is affected by the background emission and could be improved by using (quasi)resonant pumping. It would also be interesting to consider a waveguide-based excitation schemes.
Chapter 4 reports the characterization of a photonic crystal cavity with embedded QDs, micro-transfer-printed to an optical fiber. This is an interesting configuration in view of the realization of compact, fiber-coupled single-photon sources. Encouraging evidence of Purcell enhancement and single-photon emission is

provided. A more detailed discussion of the expected and experimental properties of the cavity-fiber structure would have been useful in order to gauge the real potential of this approach
In chapter 5, several fabrication tests and experiments involving heterogeneous integration by microtransfer printing are presented. First, a nanobeam photonic crystal cavity transferred on a silicon waveguide is discussed. Cavity modes and single-QD emission are observed, and evidence for Purcell-enhanced emission on resonance with top excitation/collection is provided (although in my view the measurements do not allow a reliable estimation of the Purcell factor). Secondly, nanobeam photonic crystal cavities are transferred to SiN waveguides. A potentially interesting side-docking technique is also introduced, which would improve the positional accuracy of the transfer. In this part, some relevant details about the waveguide structure and the intended coupling mechanism are not given. Thirdly, a new approach to define contacts on photonic crystal nanobeams is presented, which appears very promising for controlling the emitter's properties with an electric field. The accuracy of the microtransfer printing process is then studied in detail, revealing an impressive placement uncertainty of below 70 nm. Lastly, the possibility of automated microtransfer printing is experimentally demonstrated, achieving a throughput of 90 devices per hour and a success rate of 90%, which are quite promising for the early stage of the technology.
Chapter 6 summarizes the main findings of the work.
Overall, this manuscript demonstrates the high potential of heterogeneous integration and microtransfer printing for integrated quantum photonics, through a wide range of design approaches, fabrication methods and experiments, and therefore contributes to the state of the art in the field. The thesis is clearly written and the main conclusions are justified. I therefore approve the thesis and recommend that the candidate is admitted to the defense.

Sincerely,

Andrea Fiore
Professor

Enclosures
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