REPORT FOR DOCTORAL THESIS (ADRIÀ GRABULOSA)

30 November 2023

The Ph.D. thesis of Mr. Adrià Grabulosa is based on three published peer-reviewed articles and contains sufficient high-level content to warrant application for the doctorate. The thesis comprises six chapters, encompassing the research background and original publications. The PhD thesis is well-organized, written in a clear and concise manner, and includes an appropriate number of sources in the bibliography.

Strengths of his work and original contribution to its field

Undoubtedly, the 3D printing photonic technologies addressed by Adrià Grabulosa are promising for the next-generation 3D photonic circuits with high scalability and high-density integrability. One of the most unique strong points of his dissertation is that he established a printing technique for the basic optical components, such as 3D waveguides and optical splitters, required for 3D optical interconnections. The unique printing technologies merge the two polymerization processes, one-photon (OPP) and two-photon-polymerization (TPP), and significantly reduce printing time, compared to the conventional process using only TPP. This enabled the creation of very long 3D optical waveguides. Moreover, he designed and printed a unique 1-to-M optical splitter with low coupling loss and a broadband splitting ratio, which is highly promising for 3D optical network topologies. Interestingly, he successfully coupled a 3D optical waveguide with quantum dot microlaser arrays, introducing several innovations. The unique 3D printing photonic technology established by Adrià Grabulosa has a strong impact on the field of neuromorphic computing and optical integrated circuits.

Review report

The thesis comprises six chapters. It presents 3D printed photonic components essential for 3D photonic integrated circuits in upcoming neuromorphic computing. Leveraging CMOS-compatible materials and processes using OPP and TPP, it is demonstrated how the 3D photonic components facilitate extensive interconnections, addressing challenges in current 2D/2.5D integration technologies.

Chapter 2 presents a groundbreaking printing approach, flash-TPP, which merges TPP and OPP, reducing printing time by approximately 90%. This approach employs distinct strategies for various sections of photonic integrated circuits, ensuring high-resolution printing of waveguide cores and uniform cladding layers. This results in low-loss and stable optical performance over extended periods.

Chapter 3 showcases the accomplishment of broadband and low-loss adiabatic 1-to-M splitters using flash-TPP. The 3D splitters enable efficient splitting/combining of optical signals and will be essential for building 3D optical network topologies.

Chapter 4 demonstrates the development of air-cladding waveguides, offering the potential for higher integration density with increased optical confinement. Compared to polymer-cladding waveguides, these waveguides enable smaller bending radii and compact footprints, emphasizing their potential for high-density photonic integrations.

Chapter 5 introduces an innovative integration of quantum dot micro-lasers and 3D photonic waveguides in a hybrid platform, which is important for future all-optical neural networks. This unique approach demonstrates efficient emission collection using flash-TPP lithography.

Chapter 6 provides the summary and perspectives.

In summary, the Ph.D. thesis represents original and high-level technological work, generating significant new knowledge and technologies in the field of 3D photonic integration. The unique methodology has been scientifically described. The conducted experiments are well-organized, and the results are effectively presented. The explanations provided are both reasonable and appropriately focused on relevant topics. The thesis demonstrates his excellent skills and the high quality of his work, as evidenced by three first-authored peer-reviewed publications in reputable journals.

Therefore, I recommend the Ph.D. thesis of Mr. Adrià Grabulosa for defense.

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