

# Martijn J. R. Heck

Eindhoven University of Technology, Eindhoven, the Netherlands

## Where is the laser in heterogeneous integration?

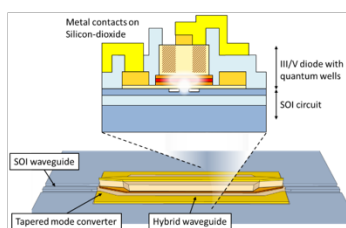
Photonic integrated circuits (PICs) have been around for decades, enabling first our telecom networks, then our datacenter interconnects, and now slowly pushing into chip-to-chip communications. Whereas initially indium phosphide (InP) PICs were mostly used, the need for higher volumes and lower cost led to a push into silicon photonics, where the existing semicon infrastructure could be leveraged. However, physics prevents (efficient) lasing in silicon, so the InP-based laser is still needed.

The open question is how the InP laser can best be combined with silicon or silicon nitride based photonics, to keep the manufacturability and scalability of a silicon substrate. Various heterogeneous integration techniques have been proposed, developed and even put into the market, such as InP die [1] and wafer [2] bonding on silicon, and micro-transfer-printing [3]. Such techniques also allow for the heterogeneous integration with silicon electronics [4].

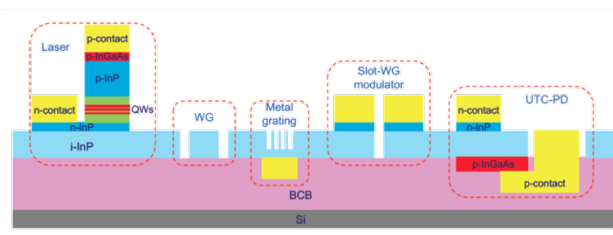
In this talk I will first give an overview of the needs: what do we expect from the laser? Then I will discuss the pros and cons of the various heterogeneous integration methods, specifically aimed towards the laser. I will highlight that there is no conclusive answer yet, which leaves the floor open for discussion.

### References

- [1] Heck et al., IEEE Journ. of Sel. Top. in Quant. Electr., vol. 19, no. 4 (2013).
- [2] Reniers et al., Chips vol. 4, no. 3 (2025).
- [3] Roelkens et al., APL Photonics vol. 9, no. 1 (2024).
- [4] Yao et al., Journal of Lightwave Technology vol. 39, no. 4 (2021).

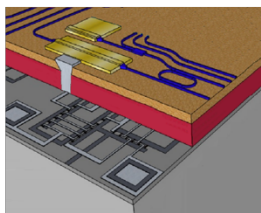


*UCSB – InP die bonding on Si*

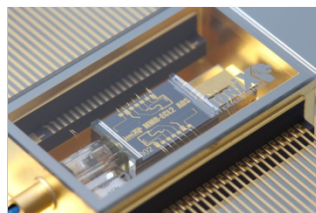


*TU/e – InP wafer-scale membrane bonding on Si*

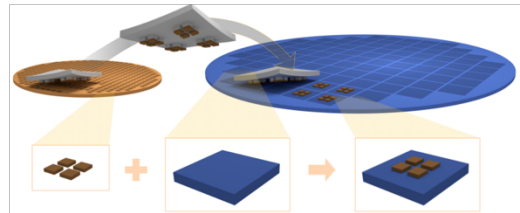
*TU/e – InP wafer-scale membrane bonding on BiCMOS*



*LioniX – hybrid SiN integration with SOA*



*imec-Ghent – III/V micro-transfer printing on Si and SiN*



**Fig. 1:** Overview of various heterogeneous integration techniques, such as InP-on-silicon die bonding (top left), InP membrane on insulator, IMOS (top right), InP photonics on BiCMOS electronics wafer bonding (bottom left), hybrid integration (bottom center), and micro-transfer printing of InP on silicon (bottom right).