

COBRA long wavelength active-passive monolithic photonic integration technology platform

Citation for published version (APA):

Latkowski, S., van Veldhoven, P. J., D'Agostino, D., Rabbani Haghighi, H., Docter, B., Thijs, P. J. A., Ambrosius, H. P. M. M., Williams, K. A., Bente, E. A. J. M., & Smit, M. K. (2016). COBRA long wavelength active-passive monolithic photonic integration technology platform. In *Proceedings of 18th European Conference on Integrated Optics (ECIO), 18-20 May 2016, Warsaw, Poland* (pp. 1-2). Article o-38 s.n.. <http://www.ecio-conference.org/wp-content/uploads/2016/06/ECIO-o-38.pdf>

Document status and date:

Published: 01/01/2016

Document Version:

Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

www.tue.nl/taverne

Take down policy

If you believe that this document breaches copyright please contact us at:

openaccess@tue.nl

providing details and we will investigate your claim.

COBRA long wavelength active-passive monolithic photonic integration technology platform

S. Latkowski^{1*}, P.J. van Veldhoven¹, D. D'Agostino¹, H. Rabbani-Haghighi¹, B. Docter³, P. Thijs¹, H. Ambrosius¹, K. Williams¹, E.A.J.M. Bente¹ and M. Smit¹

¹COBRA Research Institute, Eindhoven University of Technology, De Zaale, 5612 AJ, Eindhoven, The Netherlands

²EFFECT Photonics B.V., Torenallee 20, Eindhoven, The Netherlands

*S.Latkowski@tue.nl

Standardized, generic photonic integration technologies [1] enable low-cost design and prototyping of photonic integrated circuits (PIC) realizing complex functionalities for a particular application on a chip scale. The range of potential applications for such photonics integration technology platforms [1] is currently restricted by the accessible wavelengths bands. All of the currently available and mature technology platforms offer their functionalities at wavelengths at around 1.5 μm . This wavelength range corresponds to the c-band in the area of telecommunications and consequently the majority of the application specific photonic integrated circuits (ASPIC) being realized target this area [1]. In order to extend the reach to other fields of applications and broaden a potential market for such generic photonic integration technologies the range of accessible wavelengths has to be diversified [2], [3]. The mid-infrared range beyond 2 μm is particularly attractive for gas sensing applications due to presence of strong absorption lines of many gas species for example: acetone, ammonia, carbon dioxide, water vapor, formaldehyde, diethylamine, ethylamine, methylamine and others. Development of a long-wavelength, monolithic, active-passive integration technology on indium phosphide (InP) substrate was undertaken at the COBRA Research Institute in order to extend the potential of the already existing technology at 1.5 μm .

The COBRA active-passive generic integration scheme relies on a limited set of predefined functionalities which are provided in the form of building blocks (BB). These BBs are realized in one of two types (active or passive) of vertical layer-stack epitaxial cross-sections combined on a common substrate via butt-joint integration [1].

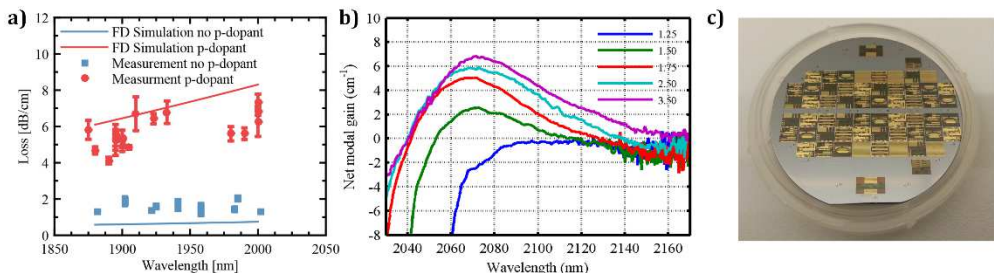


Fig. 1 (a) Propagation losses in passive waveguides at long wavelengths. (b) Net modal-gain measured from semiconductor amplifier sections based on strained quantum wells and fabricated using non-optimized ridge waveguide geometry i.e. 500 nm thick and 2 μm wide c) A photograph of the fabricated multi-project wafer (MPW) containing 8 different designs.

These BBs can be combined into large complexity topologies to realize an application specific system on-chip or in other word an ASPIC. The development process of the

COBRA long-wavelength technology included modifications of the vertical cross-sections of the active and passive layer-stacks and adaptations of all BBs to realize all basic functionalities at longer wavelengths. The studies and early stage experiments have shown that at longer wavelengths an increase in the propagation losses and lower gain values shall be expected as presented in the Fig. 1(a) and Fig. 1(b) respectively. In order to reduce propagation losses due to overlap with highly doped cladding layers the thickness of the wave guiding layer was increased to 625 nm with further adjustment of the ridge wave-guide (RWG) structures in lateral direction. A new optically active core based on low temperature (560 °C) strained multi quantum wells (InGaAs) has been developed to realize the BBs which provide with on-chip means of light generation and an optical gain (semiconductor optical amplifiers) or absorption (photodiodes, saturable absorbers).

These research and development efforts have enabled fabrication of the first long-wavelength multi-project wafer (MPW) run. The wafer processing was carried using cleanroom facilities of Nanolab@TU/e [4]. The 2" MPW wafer shown in Fig.1 (c) included 8 designs from 5 different users and projects, including two unique monolithically integrated tunable lasers with a large tuning range in the 2 μm wavelength window [5], [6].

Acknowledgement

The authors would like to acknowledge support for the presented work from the STW Technology Foundation project LWAVETECH, the IOP Photonic Devices project TULGAS and the EU FP7 Integrated Project Paradigm.

References

- [1] M. Smit, et al. *An introduction to InP-based generic integration technology*, Semicond. Sci. Technol., vol. 29, no. 8, p. 083001, Jun. 2014.
- [2] K. Scholle, S. Lamrini, and P. K. and P. Fuhrberg, *2 μm Laser Sources and Their Possible Applications*, Feb. 2010.
- [3] G. Roelkens, U. Dave, A. Gassenq, N. Hattasan, C. Hu, B. Kuyken, F. Leo, A. Malik, M. Muneeb, E. Ryckeboer, D. Sanchez, S. Uvin, R. Wang, Z. Hens, R. Baets, Y. Shimura, F. Gencarelli, B. Vincent, R. Loo, J. Van Campenhout, L. Cerutti, J.-B. Rodriguez, E. Tournie, X. Chen, M. Nedeljkovic, G. Mashanovich, L. Shen, N. Healy, A. C. Peacock, X. Liu, R. Osgood, and W. M. J. Green, *Silicon-Based Photonic Integration Beyond the Telecommunication Wavelength Range*, IEEE J. Sel. Top. Quantum Electron., vol. 20, no. 4, pp. 394–404, Jul. 2014.
- [4] *NanoLab@TU/e*. [Online], Available: <http://www.tue.nl/en/research/research-institutes/research-institutes/nanolabtue/>. [Accessed: 13-May-2015].
- [5] D. D'Agostino, S. Tahvilli, L. Sylwester, P. J. Veldhoven, H. Rabbani-Haghighi, C. Jin, B. Docter, H. Ambrosius, E. Bente, D. Lenstra, and M. Smit, *Monolithically Integrated Widely Tunable Coupled Cavity Laser Source for Gas Sensing Applications around 2.0 μm Wavelength*, Advanced Photonics 2015 (2015), paper JT5A.1, 2015, p. JT5A.1.
- [6] S. Latkowski, D. D'Agostino, P. J. van Veldhoven, H. Rabbani-Haghighi, B. Docter, H. Ambrosius, M. Smit, K. Williams, and E. A. J. M. Bente, *Monolithically integrated tunable laser source operating at 2 μm for gas sensing applications*, in Photonics Conference (IPC), 2015, 2015, pp. 535–536.