SAND2016-5839C

Compound Semiconductor Integrated Photonics for Avionics

Anna Tauke-Pedretti
Sandia National Laboratories, P.O. Box 5800, Albuquerque, NM 87185
ataukep@sandia.gov

Abstract: This talk will focus on recent work done at Sandia National Laboratories in compound semiconductor integrated photonics relevant to avionics. Two technologies will be presented: Sandia's InP-based photonic integrated circuit platform which enables highly functional circuits and advanced heterogenous integration for microscale photovoltaic systems.

1. InP-based Photonic Integrated Circuit Technology

Photonic integration allows for advancements in system performance and photonic circuits with new capabilities, such as timing sensitive or low latency circuits, as well as reductions in SWaP and packaging costs, while increasing reliability. In particular, monolithic integration reduces the number of sensitive optical on-off chip coupling interfaces which reduces coupling losses and increases the mechanical robustness, as opposed to discrete components. Monolithic photonic integration with the InGaAsP materials system is particularly attractive since it enables an integrated light source as well as high performance active elements including modulators, amplifiers and detectors.

We have developed a fundamental capability in InP-based PICs that enables the monolithic integration of a diverse set of lasers, modulators (both phase-based and absorption-based), photodetectors, amplifiers (both high-gain and high-saturation power varieties) and routing waveguides, in addition to electrical passive components such as resistors, capacitors, and transmission lines. The foundation of the capability is quantum-well-intermixing which enables the realization of multiple bandedges to be formed across the wafer with very low optical reflections (<1 dB) at the interfaces [1], coupled with simple blanket MOCVD regrowths. Using a catalyst, the QWI process takes advantage of the metastable interface between quantum well and barrier layers to interdiffuse well and barrier atomic species and thereby blue-shift the quantum well energy levels. This process can be controlled to allow different degrees of intermixing in selected parts of the wafer. This allows the bandedge to be tailored to the specific device, for instance as-grown quantum wells could be used for gain sections in lasers and amplifiers, moderately blue-shifted regions used for electroabsorption modulators (EAMs), and strongly intermixed quantum wells (blue-shifted >35 nm) used for passive waveguides, mirrors and phase shifters. A blanket MOCVD regrowth is typically used after intermixing to add the top p-type cladding and contact layer. Additional blanket regrowths can be used to add versatility in device design and therefore improve the device performance, an example of this is the regrowth of a set of quantum wells above the waveguide core which enables high-saturation-power semiconductor optical amplifiers (SOAs).

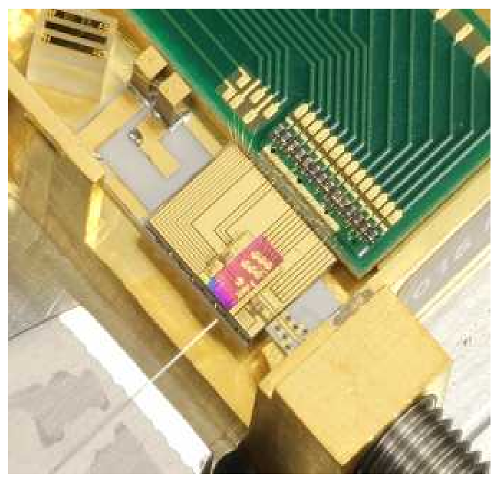

Figure 1: Optical image of an optical RF channelizing chip. The laser in the lower right generates an optical CW signal which is modulated by an EAM generating sidebands with RF data. This data is channelized using the three pole ring filters. There is a single pole filter coupled to the back laser facet to monitor the laser wavelength.

The PIC platform allows for high performance components including >40 Gbps EAMs (electroabsorption modulators) and photodetectors [2], <1 GHz passband optical filters and wavelength-tunable lasers with >40 dB side mode suppression ratio on a single monolithic chip. This variety of devices enables the creation of unique, highly-functional PICs.

A tunable optical-RF channelizing filter array for RF optical signal processing was demonstrated [3]. A photo of the chip is shown in Figure 1. This circuit consists of an integrated laser, 20 GHz EAM, and cascaded ring filters.

The filters include both an optical amplifier to offset the passive loss and optically transparent regions which are used to tune the filters over 12 GHz through current injection resulting in a 3.5 GHz linewidth for a three-pole filter.

3. Microscale photovoltaics

Microsystems Enabled Photovoltaic (MEPV) systems have recently been a focus of our research at Sandia. These systems use small solar cells (50-500 um in diameter) to reduce overall system costs and increase performance. These cells can be used Among the benefits of using the MEPV approach is reduced material requirements of concentrating optics, increased optical acceptance angle, increased shading tolerances due to interconnection designs, and reduced cell material consumption. One of the goals of MEPV is the design of concentrator systems with a large field of view and thin optics so the balance of systems (BOS) components are comparable to flat plate systems rather than the higher costs of traditional concentrator system components.

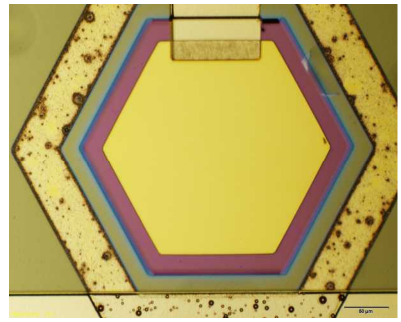

Figure 2: InGaAs microscale photovoltaic cell bonded to Si

Some implementations of the MEPV concepts require novel multijunction cells. Most notably combining Si cell junctions and III-V junctions. Various methods of integrating these photovoltaic junctions have been explored and multijunction photovoltaic cells results utilizing a wafer bonding approach for integration will be presented.

Acknowledgements

Part of this work was supported by the U.S. Department of Energy's Laboratory Directed Research and Development (LDRD) program at Sandia National Laboratories. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

References

[1] E.J. Skogen, J.S. Barton, S.P. DenBaars, and L.A. Coldren, "A Quantum-Well-Intermixing Process for Wavelength-Agile Photonic Integrated Circuits," IEEE Journal of Sel. Topics in Quantum Electronics, Vol. 8, No. 4, 863-869 (2002).

[2] E.J. Skogen, G.A. Vawter, A. Tauke-Pedretti, C.R. Alford, M.E. Overberg, and C.T. Sullivan, "Integrated Guided-Wave Photodiode Using Through-Absorber Quantum-Well-Intermixing", IEEE Photonics Technology Letters, 25, (17), pp.1684-1686 (September 1, 2013).

[3] A. Tauke-Pedretti, G.A. Vawter, G. Whaley, E. Skogen, M. Overberg, G. Peake, C. Alford, D. Torres, J.R. Wendt, and F. Cajas, "Photonic Integrated Circuit for Channelizing RF Signals," CLEO, San Jose, June 2013.

[4] E.J. Skogen, G.A. Vawter, A. Tauke-Pedretti, G.M. Peake, M.E. Overberg, C.R. Alford, D.L. Torres, and C.T. Sullivan, "Optical AND and NOT Gates at 40 Gbps Using Electro-Absorption Modulator/Photodiode Pairs," Photonics Society Meeting, Denver, November 2010