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Heterogeneous Silicon Photonics for High Performance Computing

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Abstract – The demand for high-speed and low-cost short-distance data links, and eventually for chip-level optical communications, has led to great efforts to develop high density photonics integrated circuits (PICs) to decrease the link power consumption and unit price. Optics offers unique opportunities for reducing energy in information processing and communications while simultaneously resolving the problem of interconnect bandwidth density inside machines [1]. In order to proceed on this route, the integration platform is experiencing significant transitions from the group III-V semiconductor materials, such as InP or GaAs, to silicon that is commonly used in EIC industry. The transition is motivated by the availability of cheap material and the mature CMOS fabrication techniques inherited from electronic industry. A number of components required for optical links have been demonstrated on silicon platform, including low-loss waveguides, modulators, and photo-detectors. However, silicon is not a good material for light emission due to its indirect band-gap nature. The poor radiative recombination efficiency prohibits an on-chip laser source or optical amplifier. This is a major obstacle for fully integrated high density photonic integrated systems. We address said problem with heterogeneous integration first proposed by Fang et. al [2]. The maturity of such approach has been proven with Intel and Juniper shipping 100G transceivers and demonstrating 400G transceivers.

We utilized heterogeneous silicon photonics in realization of a network-on-a-chip [3] which comprised of eight dense wavelength division (DWDM) nodes, each comprising of eight transceivers with total capacity of 2.56 Tbps (8x8x40 Gbps, OOK). The capacity can be further increased by optimizing the on-chip losses to address SNR and optimizing bandwidth of individual components to increase link analog bandwidth >60 GHz. Individual components with such bandwidths have already been demonstrated. The combination of bandwidth and SNR increase along with introduction of additional channels would boost the total capacity to beyond 15 Tbps (8 nodes, 16 wavelengths, 60 Gbaud/s, PAM4). Previous example addresses short link lengths and potential chip-to-chip or even on-chip communication. The heterogeneous technology is poised to revolutionize yet another field, that of coherent communications due to extreme spectral purity of widely-tunable sources. The underlying low-loss silicon waveguide platform allows for extremely low linewidths with sub-40 kHz integrated linewidths recently demonstrated with fully-integrated heterogeneous silicon lasers that can readily be mass produced.

[1] D. A. B. Miller, "Attojoule Optoelectronics for Low-Energy Information Processing and Communications," Jour. of Light. Tech., 35(3), 346-396, 2017.

[2] A. W. Fang et al., "Electrically pumped hybrid AlGaInAs-silicon evanescent laser," Opt. Express 14(20), 9203-9210 (2006).

[3] C. Zhang et al., "8×8×40 Gbps fully integrated silicon photonic network on chip," Optica 3, 785-786 (2016)

Bio – Tin Komljenovic received his M.Sc. and Ph.D. degrees in electrical engineering from Faculty of Electrical Engineering and Computing, University of Zagreb in 2007 and 2012, respectively. During his Ph.D. he was a visiting researcher at IETR, University of Rennes. His current research interests include integrated photonic circuits, tunable optical sources and LIDAR. He has authored or coauthored over 70 papers and 7 patents. Currently he is working as a Project Scientist at University of California, Santa Barbara pursuing research in photonic integration. Dr. Komljenovic is a recipient of the EuMA young scientist prize and Marie Curie FP7 grant.