Challenges and Opportunities for Free Space Elastic Optical Networking (FS-EON)

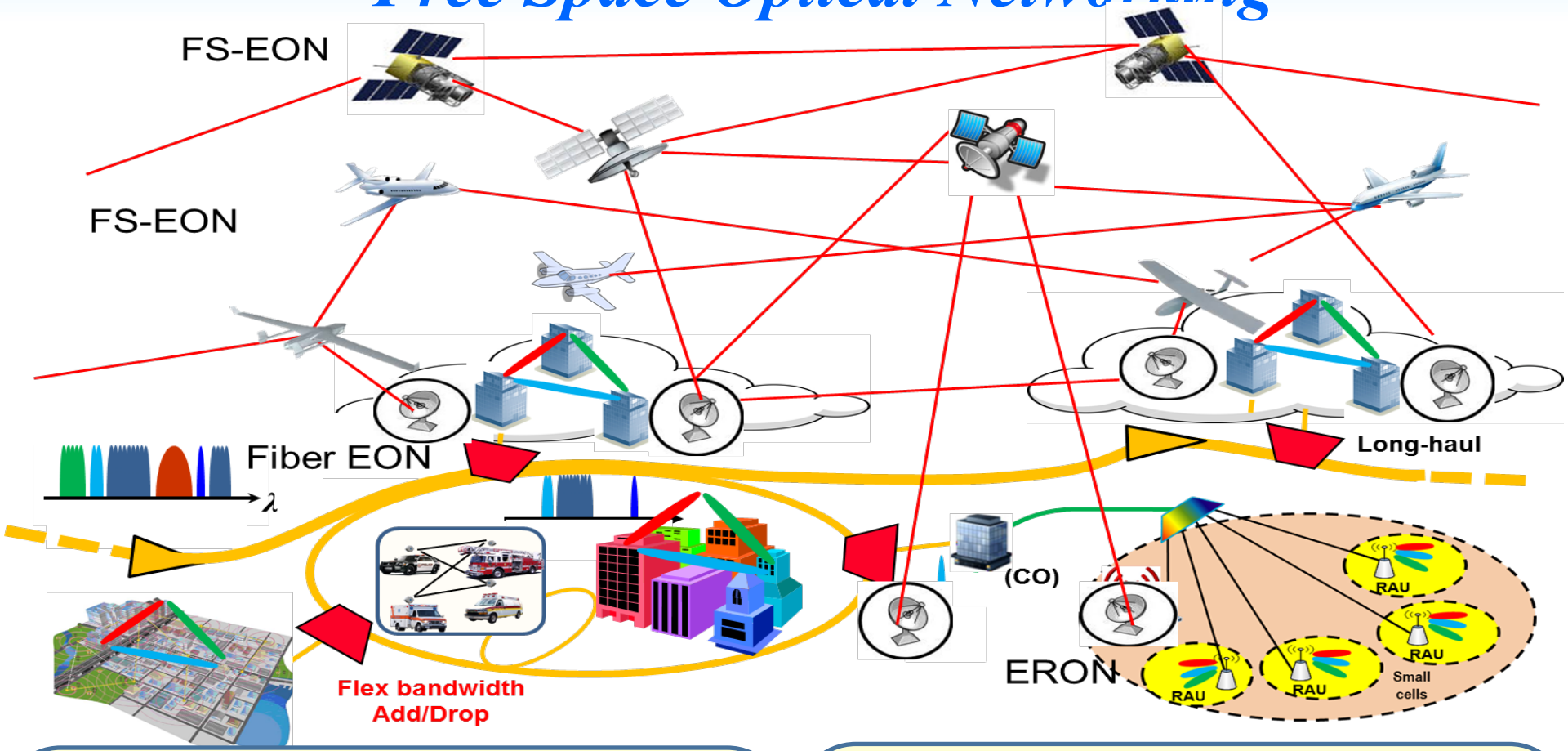
S. J. Ben Yoo

Roberto Proietti, Alberto Castro

Department of Electrical and Computer Engineering
University of California, Davis
sbyoo@ucdavis.edu
http://sierra.ece.ucdavis.edu

Workshop on Free Space Optical Networks
Arlington, VA
July 13th-14th, 2017

Free Space Optical Networking



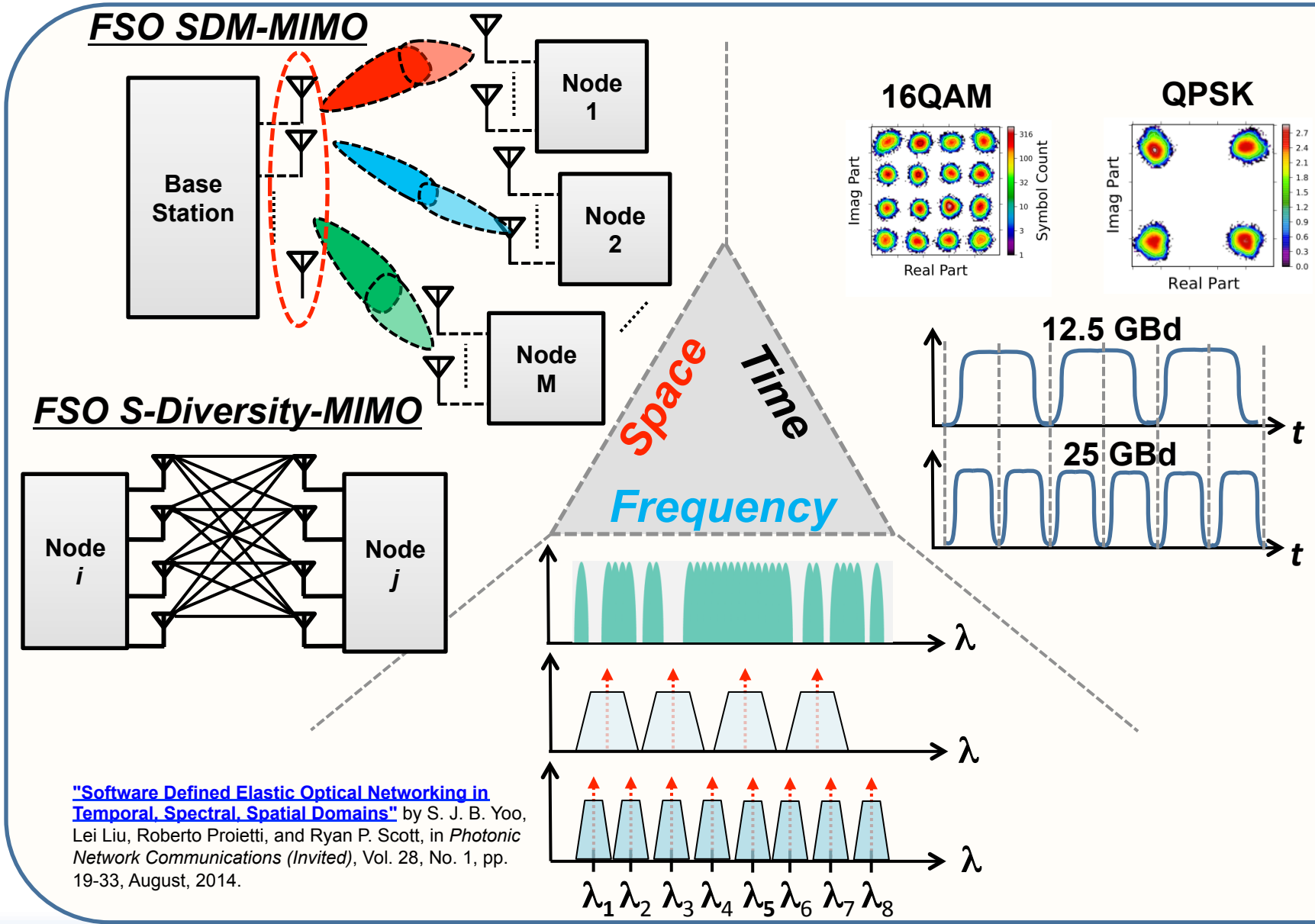
FSO Challenges

1. turbulence and scintillation
2. photon-starved LR communications
3. costly transceivers with point/steer
4. Multi-domain resource control/manag
5. Heterogeneous interfaces
6. Mobility management and handover

FS-EON Opportunities

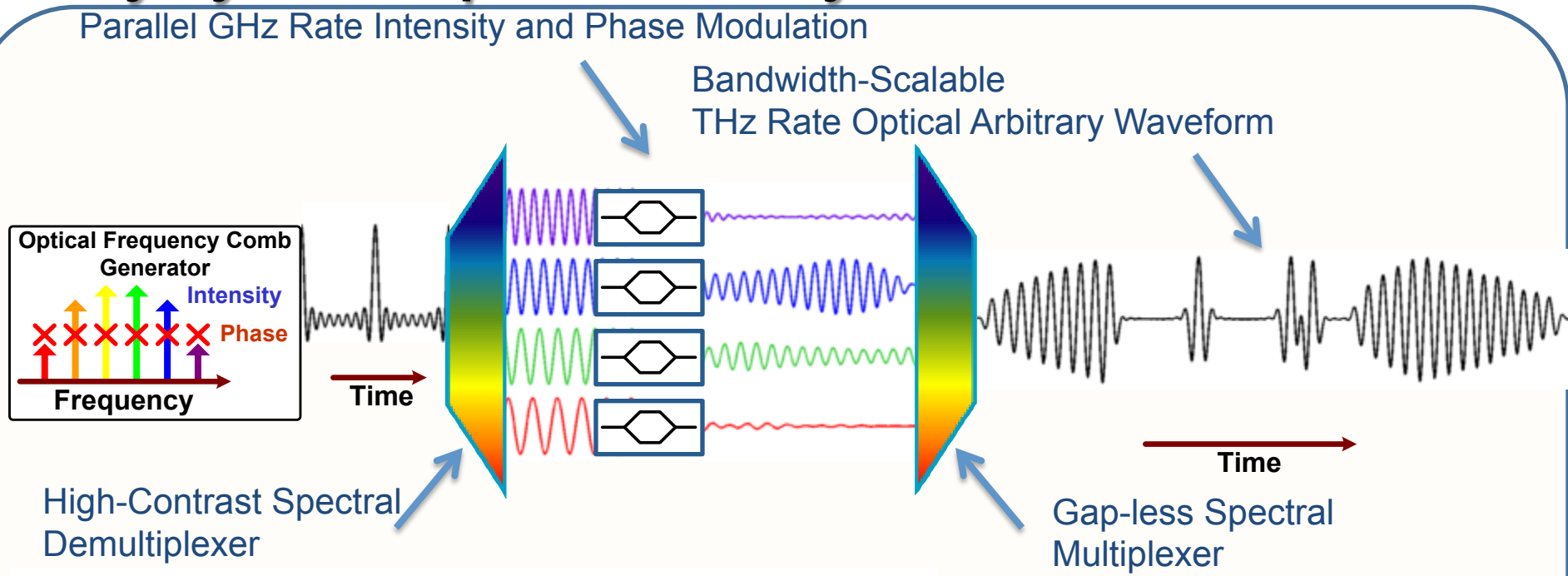
1. Optical MIMO and novel coding
2. Spatial and spectral diversity
3. OAWG-OAWG PIC with phase array
4. Broker-plane across multi-domain
5. Unified cross-layer protocol
6. Hierarchical cognitive agents

Elastic Optical Networking in Temporal-Spectral-Spatial Domains

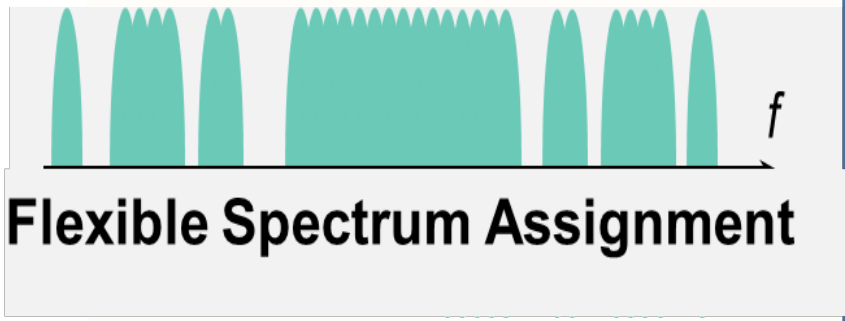


"Software Defined Elastic Optical Networking in Temporal, Spectral, Spatial Domains" by S. J. B. Yoo, Lei Liu, Roberto Proietti, and Ryan P. Scott, in *Photonic Network Communications (Invited)*, Vol. 28, No. 1, pp. 19-33, August, 2014.

Free-Space Elastic Optical Networking using by Dynamic Optical Arbitrary Waveform Generation

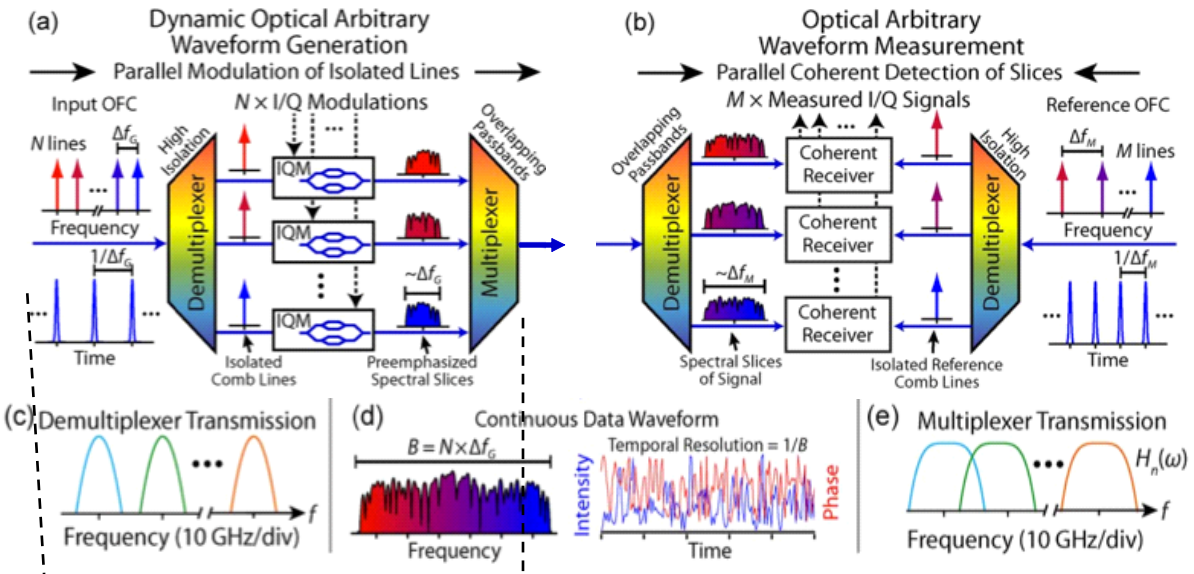


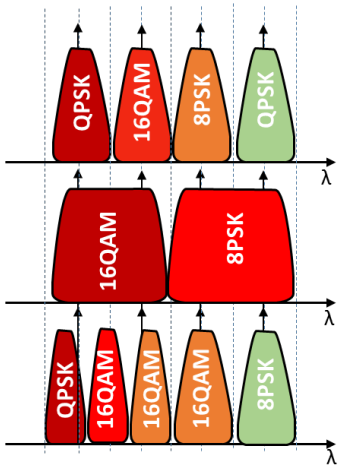
- **Fourier Synthesis of Arbitrary Waveforms scaling to Terahertz BW using simple CMOS speed electronics**
- **Flexible spectrum & modulation format assignments**
- **Flixible grid spacing**
- **Low PAPR and Pre-Comp/Post-Comp**
- **Photonic Integrated Circuit construction**



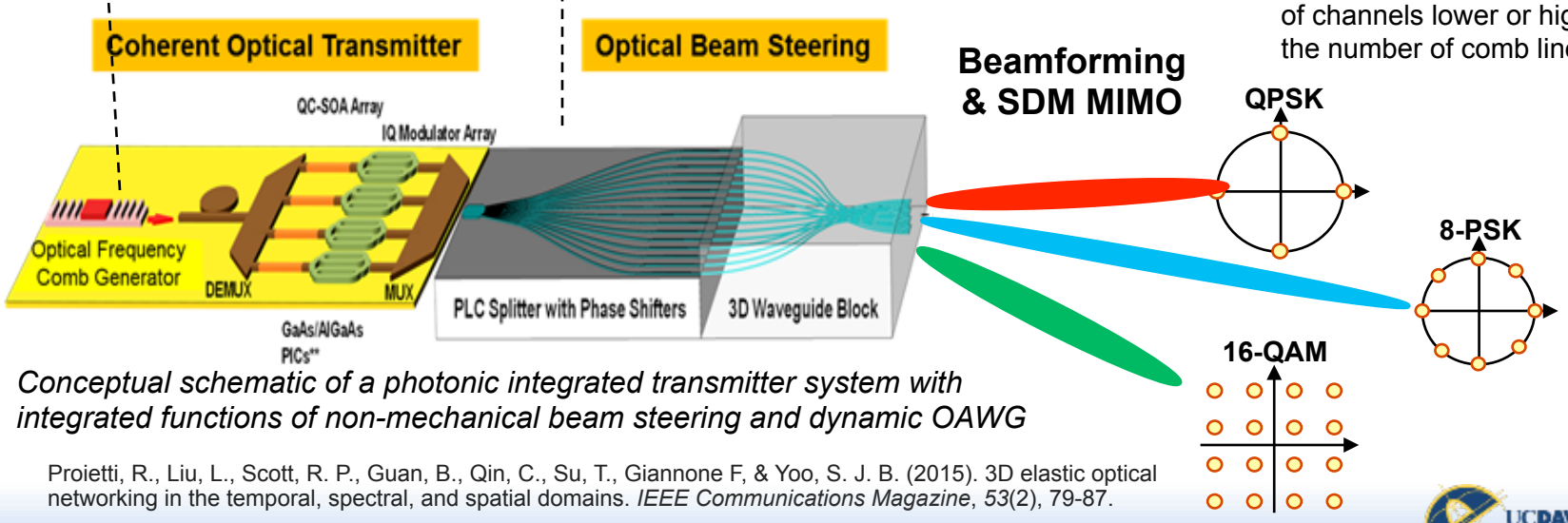
"Terahertz Information and Signal Processing by RF-Photonics" by S. J. B. Yoo, Ryan P. Scott, David J. Geisler, Nicolas K. Fontaine, and Francisco M. Soares, in *IEEE Transactions on Terahertz Science and Technology (Invited)*, Vol. 2, No. 2, pp. 167-176, March, 2012.

FS-EON Sliceable Bandwidth Variable Transponder based on Dynamic OAWG & OAWM





Multiple channels generated with one DOAWG-based SBVT with four comb-lines (spectral slices). DOAWG allows to group the comb-lines to generate a number of channels lower or higher than the number of comb lines

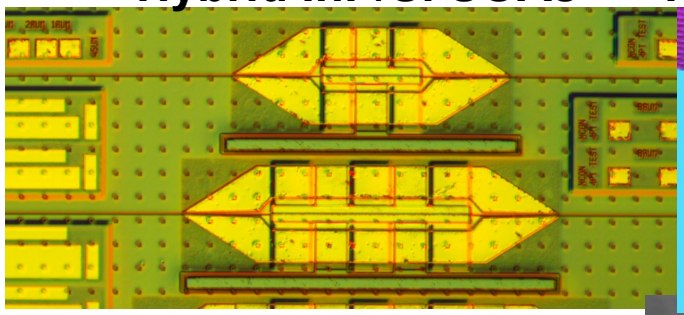


Conceptual schematic of a photonic integrated transmitter system with integrated functions of non-mechanical beam steering and dynamic OAWG

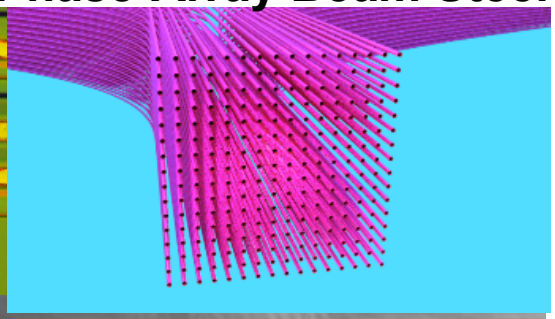
Proietti, R., Liu, L., Scott, R. P., Guan, B., Qin, C., Su, T., Giannone F, & Yoo, S. J. B. (2015). 3D elastic optical networking in the temporal, spectral, and spatial domains. *IEEE Communications Magazine*, *53*(2), 79-87.

2D/3D Heterogeneous Photonic Integrated Circuits at UCD

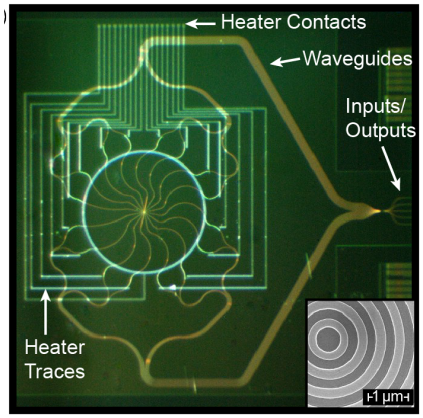
Hybrid InP/Si SOAs



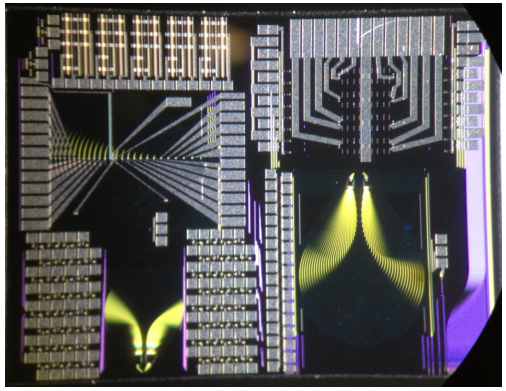
Phase-Array Beam Steering

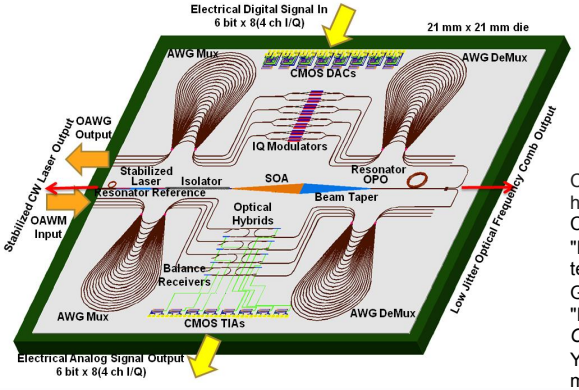


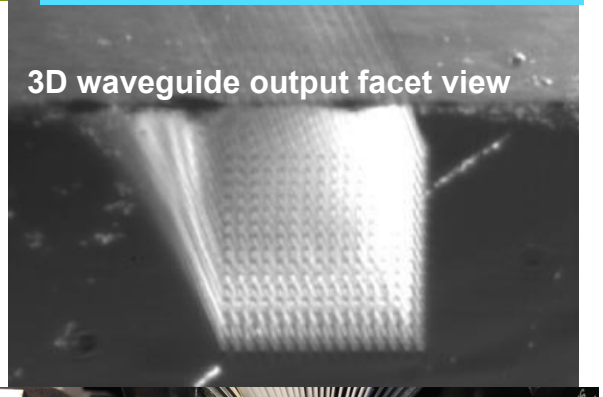
SDM-OAM

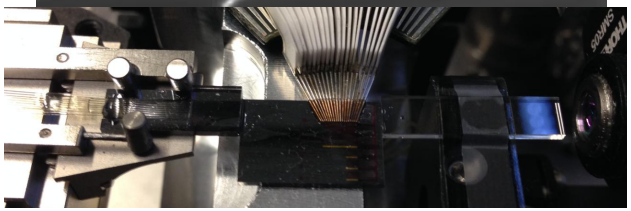


Si-Ge OAWG/OAWM

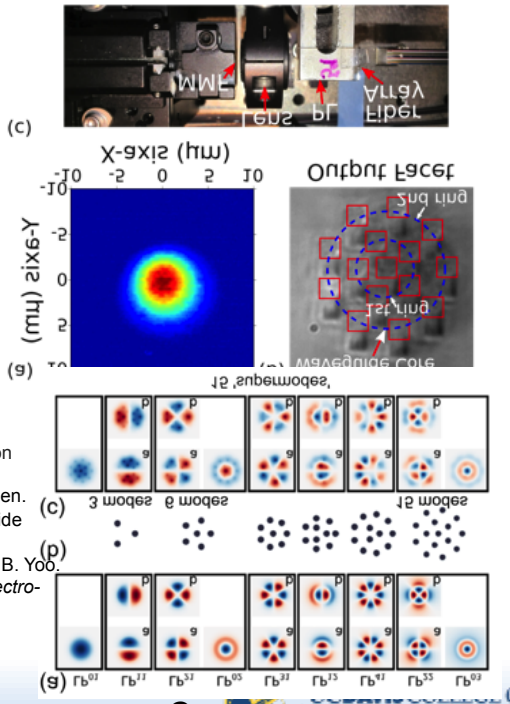








Photonic Lanterns



Cheung, S., Kawakita, Y., Shang, K., & Yoo, S. J. B. (2015). Highly efficient chip-scale III-V/silicon hybrid optical amplifiers. *Optics express*, *23*(17), 22431-22443.

Chen, Haoshuo, Nicolas K. Fontaine, Roland Ryf, Binbin Guan, SJ Ben Yoo, and Ton AMJ Koonen. "Design constraints of photonic-lantern spatial multiplexer based on laser-inscribed 3-D waveguide technology." *Journal of Lightwave Technology* 33, no. 6 (2015): 1147-1154.

Guan, Binbin, Chuan Qin, Ryan P. Scott, Burcu Ercan, Nicolas K. Fontaine, Tiehui Su, and S. J. B. Yoo. "Hybrid 3D photonic integrated circuit for optical phased array beam steering." In *Lasers and Electro-Optics (CLEO), 2015 Conference on*, pp. 1-2. IEEE, 2015.

Yoo, SJ Ben, Binbin Guan, and Ryan P. Scott. "Heterogeneous 2D/3D photonic integrated microsystems." *Microsystems & Nanoengineering* 2 (2016): 16030.