

## Tutorial

### Silicon photonics for next generation computing systems

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#### Abstract

*The current tendency in high performance computing systems is to increase the parallelism in processing at all levels utilizing multithreads, increasing the number of chips in racks and blades, as well as increasing the number of cores on a chip. The scaling of overall system performance that soon might approach Exaflop/s is, however, out of balance with respect to limited available bandwidth for shuttling ExaBytes of data across the system, between the racks, chips and cores. We will discuss how optics can provide huge power and bandwidth benefits closer and closer to the chip and eventually into the chip itself that would allow to overcome severe constraints of today's mostly copper I/O interconnects. Particular emphasis will be given to silicon photonics integrated circuits designed for low power off-chip and on-chip optical networks.*



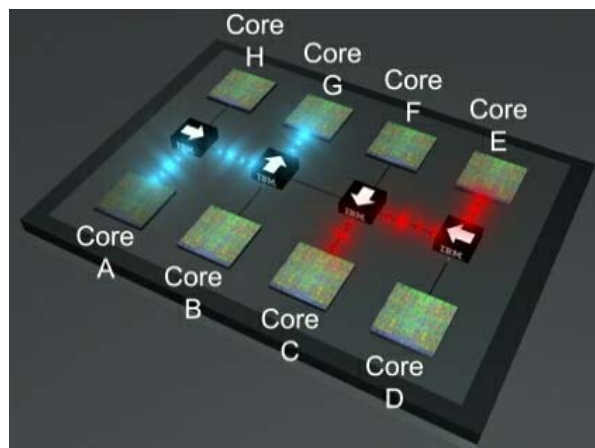
#### Vlasov Yurii

Dr. Yurii Vlasov is a Manager at the IBM TJ Watson Research Center where he is leading a team on silicon integrated nanophotonics for on-chip optical interconnects since joining IBM in 2001. Prior to IBM, he has developed semiconductor photonic crystals at the NEC Research Institute in Princeton, and at the Strasbourg IPCMS Institute, France. He also was, for over a decade, a Research Scientist with the Ioffe Institute of Physics and Technology in St. Petersburg, Russia working on optics of semiconductors. Dr. Vlasov has published over 60 journal papers, filed over a dozen of US patents, and delivered more than 100 invited and plenary talks in the area of nanophotonic structures. He is a Fellow of the OSA and the APS..

### Extended Abstract

Optics is destined to be utilized in data centers since optical communications can meet the large bandwidth demands of high-performance computing systems by bringing the immense advantages of high modulation rates and parallelism of wavelength division multiplexing. As it already happened in long-haul communications decades ago when optical fibers replaced copper cables, the copper cables that connect racks in the datacenters are started now to being replaced by optical fibers. Following the same trend optics can become competitive with copper at shorter and shorter distances eventually leading to optical on-board and may be even on-chip communications. This large datacom market might provide therefore an immense opportunity for optics to grow and prosper in forthcoming years subject to meeting very strict demands of extremely low cost and ultra-low power per a bit of transferred information.

Silicon photonics offers high density integration of individual optical components on a single chip. Strong light confinement enables dramatic scaling of the device area and allows unprecedented control over optical signals. Silicon nanophotonic devices have immense capacity for low-loss, high-bandwidth data processing. Fabrication of silicon photonics system in the complementary metal-oxide-semiconductor (CMOS)-compatible silicon-on-insulator platform also results in further integration of optical and electrical circuitry, thus opening a way for mass production of ultradense optoelectronic integrated circuits. Following the Moore's scaling laws in electronics, dense chip-scale integration of optical components can bring the price and power per a bit of transferred data low enough to enable optical communications in high performance computing systems.



*Artist' concept of on-chip optical network. The silicon broadband optical switch, represented by the black boxes in the figure, performs the key role of directing optical traffic between various distant cores within the on-chip optical network.*

In this tutorial we will review recent concepts, demonstrations and advances in the density and complexity of nanoscale silicon photonics circuits that are developed to enable the integration of complete optical systems on a monolithic semiconductor chip. We will show that depending on the length scale of a particular communication link, whether it is a rack-to-rack, on-board chip-to-chip or on-chip interconnects, the requirements and performance metrics for devices, circuits and complete optical systems are also different. To meet these stringent requirements and utilize fully all the benefits of optics an innovative engineering is necessary at all levels starting from the design of individual devices to the overall architecture of high-performance computing system.