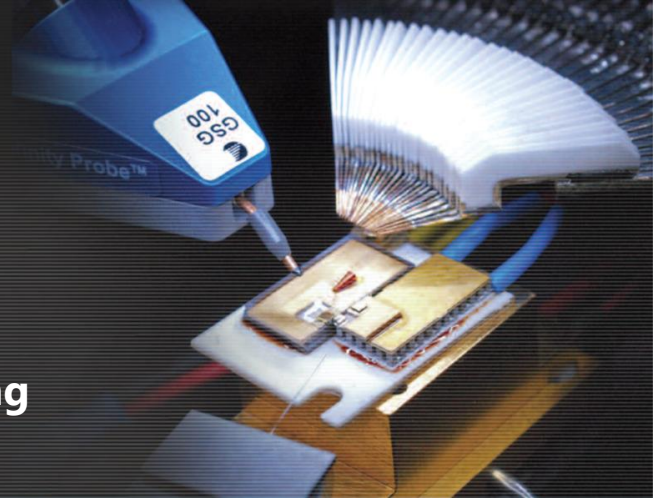
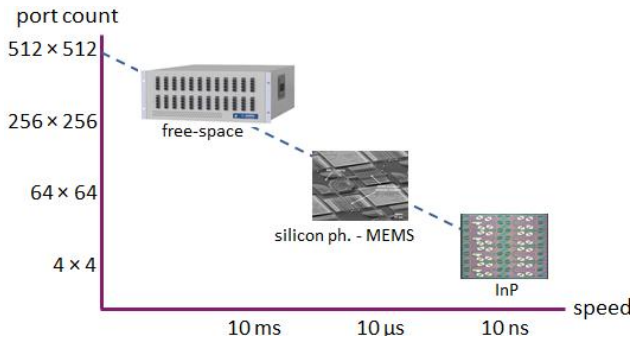


Photonic Integrated Circuits for Datacenter Switching

Optical switches find application in numerous diverse fields, including digital communications, fiber optic sensing, optical metrology, LIDAR systems, atom interferometers, laser interferometry, optopyro-electronics and system redundancy when reliability is critical (e.g. satellite payloads). Each application field comes with different requirements and entails its own challenges. This application note focuses on the application of optical switches in digital communications, more specifically in optical datacenter networks (DCNs), which represent a promising field for their large-scale deployment.

Optical switching is gaining traction as a path for gracefully scaling datacenter networks, due to its inherently broad bandwidth, energy efficiency and transparency to bitrate and protocol[1]. A multitude of switching schemes have been proposed leveraging the most prominent optical switching technologies, such as space-switching (e.g. using micro-electro-mechanical systems – MEMS or semiconductor optical amplifiers – SOAs), wavelength-switching (through combination of tunable lasers with arrayed-waveguide-grating routers – AWGRs), or combination thereof (e.g. using wavelength-selective switches – WSSs). Currently there is no standardization or regulatory framework for optical DCNs since commercial use of the technology is still in its infancy, focusing mostly on pre-commercial demonstrators and pilot deployments of early products[2]. As a result, the network designer is free to innovate and develop a DCN architecture tailored to the needs of the particular system, using the switching approach of choice.



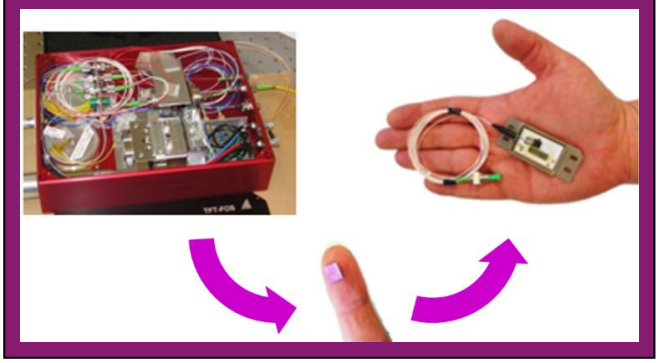
Schematic overview of speed vs. port count for typical optical switch technologies.

[1] ITRS 2.0, 2015

Photonic Integrated Circuits (PICs)

Also known as optical chips, PICs can contain tens to hundreds of optical components. While electronic ICs consist of transistors, capacitors and resistors, a PIC consists of, for example, lasers, modulators, photodetectors and filters, all integrated on a single substrate. These PICs are nowadays extensively used commercially, mainly in datacom and telecom.

PIC technology has now become accessible to users without a cleanroom, through so-called multi-project wafer runs and open foundries. Indium phosphide based technology is commercially available through SMART Photonics and Heinrich Hertz Institute. Access is coordinated by the JePPIX platform: http://www.jeppix.eu/.



One of the key challenges in optical DCNs is the combination of scalability with fast reconfigurability. At the optical switch device layer, this translates to a need for high port-count switches with fast reconfiguration time. This is arguably the main limitation of current technologies, which exhibit a tradeoff of speed vs. size: High port-count optical switches, like MEMS, typically offer millisecond reconfiguration times, whereas

[2] http://www.polatis.com/series-7000-384x384-port-software-controlled-optical-circuit-switch-sdn-enabled.asp

nanosecond-speed optical switches like PLZT (lead zirconate titanate) strive to exceed the dimensions of an 8×8 matrix, thus inhibiting network scalability. Innovative network design can partially mitigate these handicaps (e.g. by means of hybrid networks); however to make optical switching in DCNs mainstream, network designers are urgently seeking a technology for low-cost, fast and scalable optical switches.

The opportunity for photonic integration

At the device level, optical switches used in DCNs rely mainly on the following architectures:

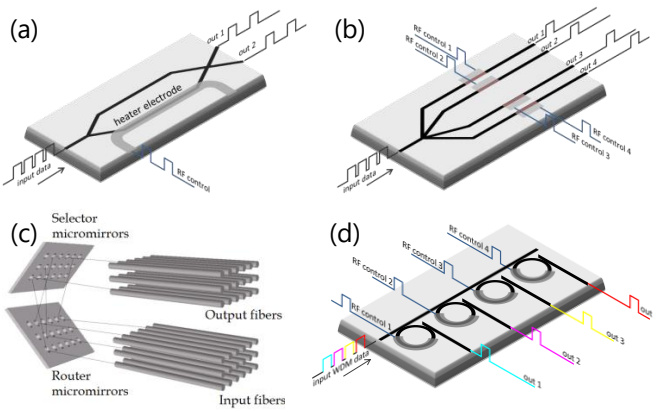
(i) interferometric switches, usually in 1×2 or 2×2 configurations. Scaling of their dimensions can be achieved by cascading several stages of switches, e.g. in a Clos network topology;

(ii) on/off switches configured in broadcast-and-select topologies;

(iii) free-space optical switches.

These device architectures can be used in conjunction with wavelength-selective components like AWGs, gratings or prisms to yield wavelength-selective switch (WSS) devices. Another scheme frequently used in optical DCNs is wavelength switching, combining fast tunable lasers with AWGs – in essence, the ensemble of tunable lasers and AWGs forms a distributed switch. Finally, resonant devices like ring resonators can be used as very energy-efficient switches, which can potentially fit in certain DCN architectures.

Photonic integration (see inset) can be used to implement all the above types of optical switch devices, with the exception of free-space switches – although photonic integration can still benefit from technologies typically used in free-space switches (e.g. combination of silicon photonics with MEMS). With mature laser diode technology, tunable lasers capable of changing their wavelength within a few nanoseconds can be fabricated. Combination of tunable lasers with on-off switches can be achieved on the InP fabrication platform, enabling tight integration of the transceivers with the switch. Silicon photonics offer a low-cost technology for large scale interferometric, on/off or resonant switches. Very precise, compact and low-loss optical filters can be implemented in various platforms like silicon nitride or glass. These PICs are typically packaged and fiber-coupled for environmental stability and ease of operation.



Optical switch device architectures: (a) interferometric switch; (b) on/off switches in a broadcast-and-select topology; (c) free-space switch; (d) resonant, ring-resonator switch.

Packaging of the PIC with electronics and with fiber coupling, at low cost and large volume, though, is still a challenge. In this framework, commercial solutions, e.g., as offered by Technobis IPPS and Linkra/Cordon, have recently become available.

Discuss your application with us

If you are interested to know more about the use of PIC technology for optical datacenter networks, please contact Hercules Avramopoulos, coordinator of the PICs4All Application Support Center (ASC) at the National Technical University of Athens, Greece. We are currently leading collaborative projects for datacenter networks, (NEPHELE, 3PEAT), funded by the European Commission, with a focus on technology development, prototype fabrication and integration with the DCN architecture. We are set up to help you do a feasibility study for the use of PICs for datacenter network applications.

The PICs4All consortium[3] is funded under the Horizon 2020 framework and brings together expertise to support end-users, like academia, research institutes and industry, with PIC technology. The ASCs can help you connect to the eco-system of designers, foundries, packaging and test services.

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[3] http://pics4all.jeppix.eu/