# Will nanophotonics "save" microelectronics?

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As the world's economy demands ever-higher rates of data transfer, the limitations of electronics for high-speed communication become an increasing problem. Already these limitations have prompted a shift from electronic-based transmission lines to fiber optics, first for long-distance data transmission, and then for shorter-distance transmission within data centers. As data transmission rates continue to rise, efforts have turned toward using optical communication for even shorter distances, between and even within computer chips, with light sources, modulators, guides, and detectors all incorporated on the same chip. A recent post-deadline paper by researchers at IBM and Aurrion stated that "over the past decade, silicon photonics has transformed from a fringe research topic in specialty conferences to being viewed as the key solution to meeting the demands of next generation telecom and datacom systems".

The integration of an optical communication network onto a single chip requires great research effort toward miniaturization of the optical components, similar to the effort that has led to the extensive miniaturization of electronic components. For applications involving communication in a photonics layer between different components on the same chip, the photonic components must be comparable in size to the electronic components, and minimally interfere with each other when densely packed. Such future systems further require the discovery of new technologies that can operate not only at ultrafast rates (<1 ps), but also at extremely low energies, and with low levels of insertion loss. Additionally, future technologies will need to be highly compact, as well as resilient to unwanted electromagnetic interference (EMI) and temperature change. Only devices that possess all of these characteristics will be fit for incorporation into large switching fabric arrays, which are essential in the implementation of data centers and cloud computing applications. Moreover, the device designs should provide scalability with respect to the operating wavelength, and the optical carrier should be allowed to range in a broad spectral range to support the necessary aggregate information bandwidth.

Our most recent work emphasizes the construction of optical subsystems directly on-chip, with the same lithographic tools as the surrounding electronics. This has been made possible by the advances in lithographic tools, which can now create features significantly smaller than the optical wavelength and is predicted to reach 11 nm resolution by 2020. Arranged in a regular pattern, subwavelength features act as a metamaterial whose optical properties are controlled by the density and geometry of the pattern and its constituents. As specific examples of our most recent work towards these goals, we will present nanoscale-engineered second-order nonlinearities in Si and various composite metal-dielectric-semiconductor gain geometries used to create new types of nanolasers for chip-scale integration of optical information systems.

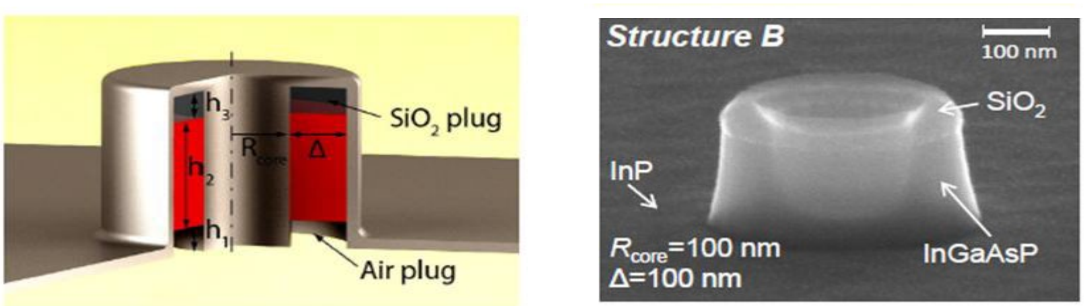


Fig.1. Nano-coaxial resonator: (left) design of nano-coaxial resonator with gain; (right) SEM micrograph of fabricated coaxial nano-laser.