Nanophotonics Integration Technology and Applications: Si-Photonics and Nanoscale Light Emitters

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The current optical technology is costly, bulky, fragile in their alignment, and difficult to integrate with electronic systems, both in terms of the fabrication process and in terms of delivery and retrieval of massive volumes of data that the optical elements can process. The integration of photonic systems requires miniaturization of the optical components, similar to the effort that has led to the extensive miniaturization in electronics. For applications involving 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. By taking advantage of advances in lithographic tools predicted to reach features as fine as 11 nm by 2020, it is possible to arrange deeply subwavelength features in a patterned material composition to act as a metamaterial with space variant polarizability [1]. Our most recent work emphasizes the construction of optical subsystems directly on-chip, with the same lithographic tools as the surrounding electronics. 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 temperature change. 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. As specific examples of our most recent work towards these goals, we discuss nonlinear optical devices [1-3], chip-scale integrated Fourier Transform Spectrometer [4] and programmable phase modulation of free-space modes at GHz rates [5].

Nanoscale light emitters are ultra-compact light sources, which can be densely integrated on-chip with potential applications ranging from high-speed optical computing and sensing to chemical detection and nonlinear optical microscopy. In recent years, nanolaser research [6,7] has shifted in direction from proof-of-concept demonstrations of novel nanoresonator architectures to the development and investigation of nanolasers with high spontaneous emission factors (β). High-β lasers can theoretically achieve ultra-low threshold energy since most of the spontaneous emission (SE) is funneled into the lasing mode [8]. Furthermore, applications centered on high-speed on-chip communication and computing demand research focused on nonlinear dynamical phenomena, direct modulation and array architectures. Therefore, nanolasers also provide excellent miniaturized platforms to explore fundamental physics in the field of nonlinear dynamics [8] as well as the nanoscale optical emitters that are needed for integrated photonic systems.

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