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VLSI micro/nano-photonics: A new frontier in 21st century optics

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This lecture discourses on a newly emerging frontier technology that we call VLSI (Very Large Scale Integrated) micro/nano-photonics. It is a new field of optical micro/nano-scale technology rapidly evolving to complete the unfinished optical information revolution. The lecture discusses the science and engineering of micro/nano-photonics and integration that can lead to VLSI photonic devices of generic and application-specific nature. The micro/nano-photonics technology is aimed to be compact, high-speed and low-powered for broad-based 21st century green and sustainable IT/BT/NT applications. The system consists of arrays of micro/nano-scale optical wires, devices and circuits on chips to perform the functions of sensing, switching, modulating, processing, transporting, routing, and distributing optical signals. The optical components include micro/nano-scale light sources, waveguides, detectors, switches, modulators, sensors, couplers, filters, resonators, photonic crystal devices, plasmonic devices, and quantum structures, made of polymer, silicon, optical and other materials. We discuss scientific and technological issues and challenges for the miniaturization and integration of micro/nano-scale photonic devices for high-density integration and application. New perspectives and visions will be discussed along with the historical perspectives of the electrical technology.

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Laser of ultra-high security, integrated quantum photonics, and on-chip quantum optical computing

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For decades, one of the expeditions of quantum physics has been to build a quantum computer that can process large-scale, challenging computational problems exponentially faster than classical computers. While scientists and engineers are progressing toward this target, almost every part of a quantum computer still needs noteworthy Research and Development (R&D). Current research is focusing on every angle of the quantum computer problem, including:

- innovative ways to generate entangled photon pairs,
- inventive types of gates and their fabrication on chips,
- superior ways to create and control qubits,
- novel designs for storage/memory buffers,
- effective detectors, and
- Creative ways to optimize them in various architectures.

Optimizing the waveguide geometry, integrated quantum optical circuits are constructed to realize single-photon quantum computing. The central elements for such circuits include sources, gates and detectors. However, a major missing function critical for photonic quantum computing on-chip is a buffer, where single photons are stored for a short period of time to facilitate circuit synchronization. As a significant step in the field, an all-optical integrated quantum processor is being developed at the National Institute of Quantum Computing (NIQC). For fault-tolerant quantum computing, the speech will explore the frontier of current quests for quantum processing of ultra-high security, integrating the following enabling techniques including:

- probabilistic Bayesian network,
- quantum filtering,
- Error Correction Code (ECC), and
- Riemannian geometry

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