Nanostructured Surfaces for Integrated Optoelectronics, Plasmonics, and Quantum Optics

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Abstract (288 Words)

All-optical integrated circuits, which consist of photonic transistors and logic circuits complete with on-chip light sources and detectors, have long been a major goal for scientists and engineers because they may allow ultra-fast computing with ultra-low power consumption. The actual realization of this dream has been very difficult, however, because photons rarely interact with each other and, even with the aid of nonlinear optical materials, interact very weakly. The goal of the proposed research is to leverage recent advances in photonics, plasmonics, optoelectronics, and quantum optics and develop new material and technology platforms for solid-state all-optical information processing. Specifically, we will combine recently developed material and technology platforms – two-dimensional plasmonic crystals and metasurfaces made of single-crystalline silver, silicon-vacancy centers in nanostructured diamond, and two-dimensional transition metal dichalcogenides – and realize integrated all-optical devices and logic circuits that work all the way down to the single-photon level. Examples of these devices include single-photon transistors, chiral photon routers, electrically tunable plasmon switches and modulators, and on-chip light sources and detectors. Importantly, because the foundational structures are two-dimensional and can be defined using top-down methods, there is a clear path forward to combine these devices on a single chip and construct integrated circuits. The proposed research will lay the scientific and technological foundation for solid-state devices for integrated all-optical computing, and as such, has the potential to revolutionize many research areas and applications that are important to the DoD mission, including data communication and computing, signal processing, energy conversion, and even sensing, and imaging. The proposed research, which stands firmly at the cross section between nanoscience, materials science, and quantum science, should provide an ideal educational ground for the next generation of scientists and engineers for the defense and national security workforce.