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Nonlinear Optics in Silicon - Applications in Optical Communication Systems

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Silicon photonics is quickly becoming an important and active research area, primarily because of the desire to leverage existing silicon fabrication technology and the potential for integration with conventional silicon electronic components. In this talk, I will discuss nonlinear optical effects in silicon, and ways in which they can be employed in optical telecommunication systems. The nonlinear effect that we have been exploring is two-photon absorption: a process in which two photons are simultaneously absorbed in a silicon photodiode to generate a single electron-hole pair. Unlike many other nonlinear processes, two-photon absorption does not require phase matching, and can occur over a very broad wavelength range with an ultrafast (fs) response time. In silicon, two-photon absorption can be observed at wavelengths from 1100 to 2200 nm, a range that spans the entire spectrum presently used in fiber telecommunications. For years, two-photon absorption was regarded as a deleterious effect in nonlinear optics, because it consumes the optical signal that was meant to produce a nonlinear phase shift. More recently, researchers have found ways to exploit two-photon absorption effects for optical signal processing. For example, if the electrical carriers produced by two-photon absorption are collected by an en external electrical bias circuit, the resulting photocurrent can be directly used in a number of nonlinear processing functions including optical autocorrelation, cross-correlation, quality monitoring, demultiplexing, optical sampling, and clock recovery. In this presentation, I will review the recent applications of two-photon absorption in communication systems, and describe ongoing research being conducted at the University of Maryland. In particular, we have found an explanation for the polarization dependence that is often observed in two-photon absorption, and we have developed a new way to overcome this dependence. As an example of how two-photon absorption can be used in a real communication system, we have demonstrated an 80 Gb/s optical clock recovery system based upon two-photon absorption in a silicon photodiode, and we deployed the system in a 1000 km fiber transmission experiment.