Pushing the Limit of Photonic Modulation and Detection: From Classical to Quantum Devices

From high capacity, low-power communication to high resolution, low-light imaging, integrated photonics is experiencing a boom similar to that of integrated electronics half a century ago. This talk discusses recent progress in pushing the limit of photonic modulation for ultralow power datalinks in data centers and the limit of photon detection down to single photon level at room temperature. For the first topic, we will focus on a surface-plasma enhanced multiple quantum well modulator based on quantum confined Stark effect. We synergistically utilize the change in both real and imaginary parts of the refractive index in GaAs/AlGaAs quantum wells and selectively couple the light into the surface plasma modes at "off" state, allowing 6-20 dB extinction ratio at 1V voltage swing. This innovation allows an optical bridge operating at an ultralow power consumption <100 fJ/bit and an high data rate >50 Gb/s, representing ~100x energy efficiency improvement compared to state-of-the-art optical links in data centers. For the second topic, we will discuss room-temperature, non-avalanche single photon detectors (SPDs) based on capacitive coupling, which greatly benefits from the CMOS scaling and may inspire new ways of envisioning/optimizing electronic-photonic integration on Si. We will present research on extending the spectral response of Si quanta image sensor (QIS) devices to infrared and ultraviolet regime, utilizing different schemes of such as hot-electron devices, 2D materials, and GeSn nanodots integrated with Si QIS readout methods. We further take a "quantum leap" to present the concept of quantum capacitive photodetectors, minimizing the timing jitter and maximizing the bandwidth of the non-avalanche SPDs. In these quantum capacitive photodetectors, the absorption of a single photon changes the wave function of a single electron trapped in a quantum dot (QD), leading to a charge density redistribution nearby. This redistribution translates into a voltage signal through capacitive coupling between the QD and the measurement probe or a nanoscale MOS gate. Using InAs QD/AlAs barrier as a model system, the simulation shows that the output signal reaches ~4 mV per absorbed photon, promising for high-sensitivity, sub-ps single-photon detection. We will also discuss the fundamental limits and advantages of capacitively coupled photodetectors over avalanche photodetectors in single photon detection and photon counting.

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Theoretical and Applied Physics

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Room E432

Refreshments will be available at 3:30 PM.

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