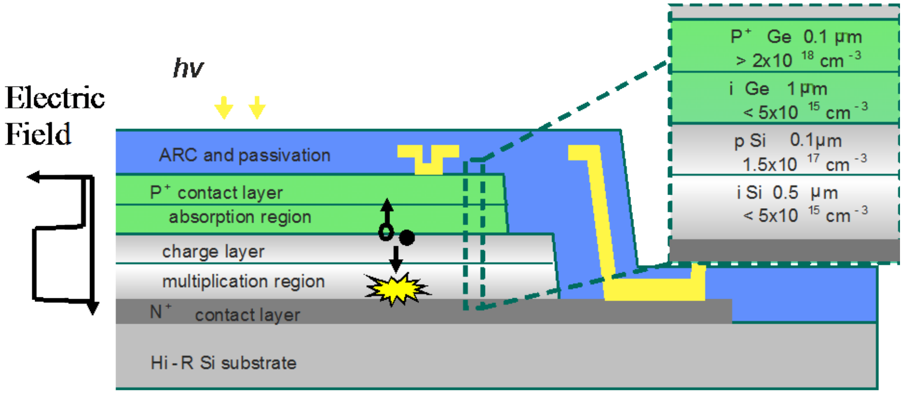
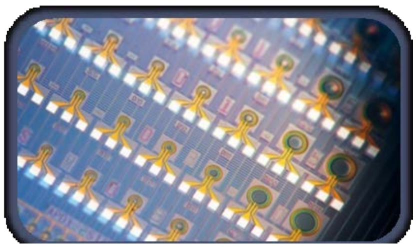
Photonic Devices and Circuits Research





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"Working to upgrade electrical generation and delivery systems."

Our group is primarily interested in the development of photodetectors, which are photonic devices that absorb light and convert the optical information into electrical signals. We work on low-noise avalanche photodiodes in the ultraviolet for biological agent detection and free-space communications. In the near infrared we have invented new types of avalanche photodiodes for high-performance fiber optic receivers. Our most sensitive avalanche photodiodes detect at the single photon level. For these photodiodes we have developed new detection techniques that enable quantum communications, the most secure method of transmitting information. We also have a strong program in the infrared for high-speed, high-power photodiodes. Applications include video distribution in CATV service, replacement of point-to-point microwave links, interconnects for phased-array antennas, and links to antennas for microwave transmission. To date, we have established world-record performance in RF output power and immunity from signal distortion. This work is evolving toward monolithic integrated circuits that are compatible with Si CMOS technology. Most recently, we have established a solar cell program. We work with chemists, who synthesize new materials for organic solar cells. Our studies focus on determination of the physical mechanisms that limit the performance of these new materials.

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Avalanche Diodes

Initial development of III-V compound avalanche photodiodes (APDs) was driven by fiber optic telecommunications, primarily for high-bit-rate, long-haul receivers. Compared to receivers with p-i-n photodiodes, those that utilize APDs achieve 5-10 dB better sensitivity. For these devices, research has focused on reducing the excess noise and developing structures with high gain-bandwidth products to accommodate the ever-increasing bit rates of fiber-optics systems. Recently, imaging applications such as 3-D imaging, sensing, and space-related spectroscopy have stimulated interested in APD arrays and large area devices that operate in the UV and short wavelength infrared range. For these tasks, speed is not critical, but it is essential to attain very low dark current densities and low multiplication noise. Our research strives to solve the challenges related to APDs when they are used for non-telecommunication purposes. For example, silicon carbide APDs are becoming increasingly important in UV detection. They can potentially be used for applications, such as UV astronomy, chemical or biological reagent detection, and flame detection. We have extended this work to single photon detection in the UV and infrared. Our detectors have record performance that enables quantum communication over optical fibers. This involves transmission of single photons with the polarization representing the two possible states of a single bit. Any interception of the transmission will result in high error rates that can be easily detected.

Photodiodes

The photodiode has been serving mankind for many years. It is used to read data off countless optical discs and bar code scanners, sense the onset of twilight for numerous streetlights around the world and detect billion and billions of pulses of light that underpin optical communication. In recent times there has been a rapid build-out of Internet capacity. This has propelled a hike in the performance of photodiodes, which have made major strides in power-handling and detection speeds. In turn, this improved photodiode performance has helped engineers to fully exploit many opportunities in the burgeoning field of photonics. Our group is working to build faster, more responsive photodiodes with greater linearity. These higher performance photodiodes can improve the performance of analogue optical links, which are used for radio over fiber, distributing radio frequency signals and military radar.

Organic and Inorganic Solar Cells

Organic bulk heterojunction (BHJ) materials have been the subject of numerous studies in recent years as they could potentially be used for the fabrication of very thin, flexible, and low-cost solar cells. They are formed by mixing two materials in solution that have donor and acceptor properties. Compared to the bilayer structure, charge transfer at the donor-acceptor interface is facilitated because the length scales of both polymer: fullerene phases are on the order of the exciton diffusion length, the excitons can be quickly dissociated at the donor/acceptor interface. Charge transfer is accomplished by the formation of polaron pairs proximate to the interface, which is an intermediate step from an exciton to free polarons. Current flow occurs when the polaron pairs dissociate into negative and positive polarons, which are transported to their respective electrodes by a hopping mechanism. The promise of BHJ solar cells is mitigated to some extent by the low efficiencies that have been reported. We are working to better understand inherent inefficiencies and improve upon them.

RECENT RESEARCH DEVELOPMENTS

- Demonstrated photodiodes with 1W RF output power, 5X higher than previous state-of-the-art.
- Developed a new single-photon detection technique that enables monolithic integration of the receiver.
- In collaboration with Intel Corp, we developed a Si-based avalanche photodiode that achieved record fiber optic receiver sensitivity at 10 Gb/s data rate. These devices are fabricated in a CMOS fab line and can be integrated with other functional components.

RECENT GRANTS

- ONR – High-Power, Wide-Bandwidth Photodiodes
- DOD/Army – Low-Dark Current Visible Avalanche Photodiodes
- Harris Corporation – Photodetector Technology for High-Power Optoelectronic Transmitters
- Discovery Semiconductors, Inc. – Low-Noise, UV-to-SWIR Broadband Photodiodes for Large-Format Focal Plane Array Sensors

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