Readout and Energy Response of Thin Heterostructured III-V Compound Semiconductor Scintillators Crystals with Monolithic Photodetectors

Scintillation based detection has been an indispensable technological approach to particle sensing, and contemporary applications place increasing demands on the properties of scintillator materials. Heterostructured III-V compound semiconductor crystals utilizing quantum dots as luminescent centers have been shown to exhibit a disruptive combination of properties. Experiments involving charged particles with energies approaching 5 MeV have verified the potential of these materials in terms of optical pulse rise and decay times approaching 0.5 ns, and photon yield yields as high as 6e4 photons/MeV at 25% conversion efficiency limited mostly by thermal quenching of the quantum dots and photodetector quantum efficiency at the emission wavelength of ~1100 nm. While luminescent properties may be tailored through careful engineering of the scintillation mediums, optimizing photon collection efficiency and photoelectron readout presents an additional set of technological concerns.

While minority carrier dynamics and conversion efficiencies of these scintillator crystals allow for low power signal readout strategies at frequencies up to a few GHz, requirements such as low noise, moderate gain, and high bandwidth are of particular concern. Monolithic integration of a photodetector provides an efficient method for transducing the scintillation response, as light readily passes from the scintillation medium into a photodetector whose physical dimensions are such that capacitance and noise are not significant detractors to device performance. Operational and charge sensitive amplifier - based readout circuit architectures derived from off-the-shelf parts may be utilized and experiments with such devices exposed to a quasi-monoenergetic ion source produce a range of unique detector energy response functions. These response functions, quantified as histograms of collected charge vs incoming particle energy, were subsequently shown through computational studies to be due to stochastic processes limiting photon collection efficiency.

In this talk I will be presenting our work on designing readout circuits to meet the demands of these novel detectors, along with recent advancements on understanding the response of such devices upon exposure to alpha particles. Avenues of investigation to further current understanding will also be discussed.