NASA SBIR 2004 Phase I Solicitation

S2.05 Advanced Photon Detectors

Lead Center: GSFC

Participating Center(s): MSFC

The next generation of astrophysics observatories for the infrared, ultraviolet (UV), x-ray, and gamma-ray bands require order-of-magnitude performance advances in detectors, detector arrays, readout electronics, and other supporting and enabling technologies. Although the relative value of the improvements may differ among the four energy regions, many of the parameters where improvements are needed are present in all four bands. In particular, all bands need improvements in spatial and spectral resolutions, in the ability to cover large areas, and in the ability to support the readout of the thousands to millions of resultant spatial resolution elements.

Innovative technologies are sought to enhance the scope, efficiency, and resolution of instrument systems at all energies and wavelengths:

- The next generation of gravitational missions will require greatly improved inertial sensors. Such an inertial sensor must provide a carefully fabricated test mass which has interactions with external forces (i.e., low magnetic susceptibility, high degree of symmetry, low variation in electrostatic surface potential, etc.) below 10–16 of the Earth’s gravity, over time scales from several seconds to several hours. The inertial sensor must also provide a housing for containing the proof mass in a suitable environment (i.e., high vacuum, low magnetic and electrostatic potentials, etc.).

- Advanced charged couple device (CCD) detectors, including improvements in UV quantum efficiency and read noise, to increase the limiting sensitivity in long exposures and improved radiation tolerance. Electron-bombarded CCD detectors, including improvements in efficiency, resolution, and global and local count rate capability. In the x-ray, we seek to extend the response to lower energies in some CCDs, and to higher, perhaps up to 50 keV, in others.

- Significant improvements in wide band gap (such as GaN and AlGaN) materials, individual detectors, and arrays for UV applications.

- Improved microchannel plate detectors, including improvements to the plates themselves (smaller pores, greater lifetimes, alternative fabrication technologies, e.g., silicon), as well as improvements to the associated electronic readout systems (spatial resolution, signal-to-noise capability, dynamic range), and in sealed tube fabrication yield.
Imaging from low-Earth orbit of air fluorescence UV light generated by giant airshowers by ultra-high energy (E > 10^{19} \text{ eV}) cosmic rays require the development of high sensitivity and efficiency detection of 300–400 nm UV photons to measure signals at the few photon (single photo-electron) level. A secondary goal minimizes the sensitivity to photons with a wavelength greater than 400 nm. High electronic gain (~10^6), low noise, fast time response (2 to 10 x 10 mm^2). Focal plane mass must be minimized (2 g/cm^2 goal). Individual pixel readout. The entire focal plane detector can be formed from smaller, individual sub-arrays.

For advanced x-ray calorimetry improvements in several areas are needed, including:

- Superconducting electronics for cryogenic x-ray detectors such as SQUID-based amplifiers and their multiplexers for low impedance cryogenic sensors and superconducting single-electron transistors and their multiplexers for high impedance cryogenic sensors;
- Micromachining techniques that enhance the fabrication, energy resolution, or count rate capability of closely-packed arrays of x-ray calorimeters operating in the energy range from 0.1–10 keV; and
- Surface micromachining techniques for improving integration of x-ray calorimeters with read-out electronics in large scale arrays.

Improvements in readout electronics, including low power ASICs and the associated high density interconnects and component arrays to interface them to detector arrays.

Superconducting tunnel junction devices and transition edge sensors for the UV and x-ray regions. For the UV, these offer a promising path to having "three-dimensional" arrays (spatial plus energy). Improvements in energy resolution, pixel count, count rate capability, and long wavelength rejection are of particular interest. We seek techniques for fabrication of close packed arrays, with any requisite thermal isolation, and sensitive (SQUID or single electron transistor), fast, readout schemes and/or multiplexers.

Arrays of CZT detectors of thickness 5–10 mm to cover the 10–500 keV range, and hybrid detector systems with a Si CCD over a CZT pixelated detector operating in the 2–150 keV range.

For improvements to detector systems for solar and night-time UV and EUV (approx. 20–300nm) observing the following areas are of interest: Large format (4 K x 4 K and larger); high quantum efficiency; small pixel size; large well depth; low read noise; fast readout; low power consumption (including readout); intrinsic energy and/or polarization discrimination (3d or 4d detector); active pixel sensors (back-illumination, UV sensitivity); and high-resolution image intensifiers, UV and EUV sensitive, insensitive to moisture.

Space spectroscopic observations in the UV, visible and IR requiring long observations times would be much more sensitive with high quantum efficiency (QE) and zero read noise. Techniques are sought which improve the QE of photon counters, or eliminate the read noise of solid state detectors.

X-ray and gamma-ray imaging with higher sensitivity, dynamic range, and angular resolution requires innovations in modulation collimators and detection devices. The energy range of interest is from a few kilo-electron Volts to hundreds of milli-electron Volts for observations of solar flares and cosmic sources. Collimators with size scales down to a few microns and thicknesses commensurate with photon absorption over a significant fraction of this energy range are required. Low-background detectors capable of