A Single Photon Counting and Photon Number Resolving Detector for NASA Missions

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Single photon counting large-format detectors will be a key technology for the future NASA Astrophysics missions such as the LUVIOR and HabEx mission concepts. The High Definition Imager instrument on LUVOIR has baselined a multi-gigapixel CMOS focal plane [1]. At the focal plane, tiling a 1 square degree field with ~10 micron-class pixels would lead to a 4.5 m x 4.5 m focal place, which is clearly prohibitive. With smaller pixels, the optics could be significantly more compact, and spectroscopy would be naturally accommodated with the photon counting performance. A next-decade mission to image exoplanet systems and perform spectroscopy of their atmospheres, such as that of HabEx, will require detectors with (i) ~10^{-10} contrast; (ii) optical and near-IR detection capabilities; (iii) a R>70 IFU able to measure the spectrum of a 30 mag exoplanet; and (iv) a 1" radius FOV [2]. The detectors necessary to meet these requirements would detect single photons, have high radiation hardness, low power draw, and high dynamic range. These requirements are not met by current optical-wavelength detectors, but are well matched to photon counting detectors.

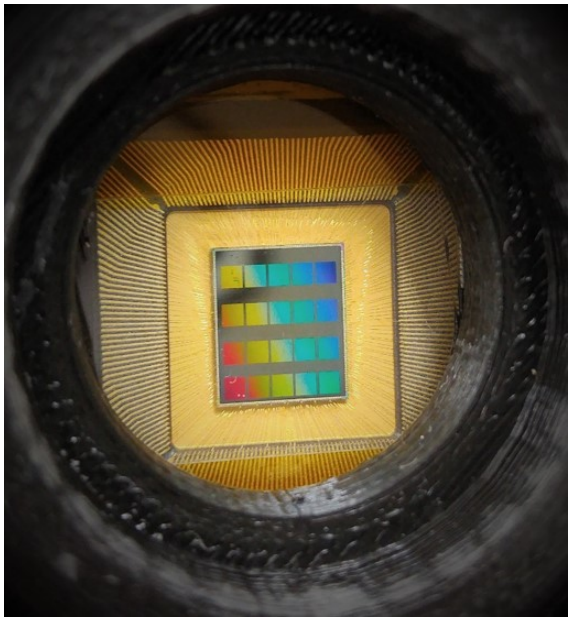

Fig. 1. Twenty 1-Mpix (300 – 1,000 nm) QIS detectors (colored squares) packaged on a chip carrier integrated in the QISPF camera system.

The NASA Cosmic Origins program office has selected this project to fund under the Strategic Astrophysics Technology program. The goal of the project is to mature a critical technology required to enable single photon counting large-format Complementary Metal-Oxide-Semiconductor (CMOS) detectors from Technology Readiness Level (TRL) 3 to 5. A new set of cryogenic-compatible electronics are in development to operate the devices for extensive laboratory characterization. After characterization, one device will be irradiated to replicate damage from high-energy radiation in space while another device will perform a telescope demonstration of the detector technology. In the final part of the project, the detector technology will be re-designed in collaboration with Dartmouth College for future NASA applications.