DRD2 UK - 2024 Early Stage R&D Scheme
Internal Selection Process Bid Outline

Proposal Title: **Photon Detector Development for the Vacuum Ultraviolet Frontier**

Core proponents:
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Interest gathered via DRD2 proposal:
Task 2.1 UK proponents: Andrzej Szelc (Edinburgh), Jesper Skottfelt (Open University), Joost Vossebeld (Liverpool), John Lipp (STFC Interconnect), Claire Shepherd-Themistocleous (RAL PPD), Patrick Parkinson (Manchester), Tim Echtermeyer (Manchester)
Task 2.1 International proponents: Marcin Kuzniak (Astrocent), Fabrice Retiere (TRIUMF), Peter Fischer (Heidelberg), Alberto Gola (FBK), Paolo Agnes (GSSI), Manuel da Rocha Rolo (Torino), Giuliana Fiorillo (Napoli), Tina Pollmann (Nikhef), Jonathan Asaadi (Arlington), Laura Baudis (Zurich).

Abstract: Internationally-leading fundamental physics searches addressing the STFC's Frontier Physics Science Challenges (A.3, C.1, C.4, C.8) rely on detection of emissions in the vacuum ultraviolet (VUV) wavelength range. While the DUNE near detector and NEXT experiments employ argon and xenon at room temperature, DUNE Far Detectors, DarkSide, LZ and nEXO experiments all employ detectors filled with cryogenic liquid argon (LAr) or xenon (LXe), instrumenting readout areas of 10–100 m^2. The bulk of the light emitted in argon and xenon is in the VUV range: in LAr, the scintillation emission is at 120–140 nm and in LXe at 165–185 nm. The state of the art in large-area silicon sensor array technology is Silicon Photomultipliers (SiPMs) with unsatisfactory performances. At 178 nm, front-illuminated SiPMs have a photon detection efficiency (PDE) in the range of 15% (Hamamatsu, at 178 nm) to 22% (FBK Low Field UV optimised), which drops to 10% for 128 nm.

Efficient single photon sensing using optoelectronic devices is a key theme in the UK's Quantum Strategy, and extending the spectral range is an established goal of quantum imaging research. The VUV spectrum is challenging for detection because the reflectivity is increasing rapidly with decreasing wavelength, making it difficult for VUV photons to penetrate the gain region in avalanche devices. Improving the quantum efficiency (QE) and collected yield of photon detection is a product of design, passivation and coating technology. We aim here to apply strategies proven in astronomical CCD, quantum optics, and digital mammography to achieve an ambitious increase in photon detection efficiency (PDE). The technologies pursued aim to reach

as much as a factor of two improvement in the VUV wavelength range relevant for noble gases, whilst preserving comparable cost per unit area and timing performance.

We propose a programme to develop higher-efficiency single photon sensitive devices, using metasurfaces and novel graphene coatings on silicon and selenium (WP1). We will integrate these into detectors (WP2) and characterize relative quantum efficiency in the VUV and noise (WP3). This leverages capability and infrastructure across a range of UK institutes for the DUNE and DarkSide programmes.

For fabrication, we request access to the National Graphene Institute at the University of Manchester (*17k/yr = 51k*) for the full duration of the project (3 years), and 110k in electronics and sensor production (90k for e2v CMOS and 40k for fabrication runs).
The M&S cost is ~130k and the facility access cost is 51k, for a total of 181k.
In terms of workforce, we envision hiring a postdoc in Manchester (100k/yr for 3 yrs = 300k) to lead the sensors development, liaise with NGI, and supervise the sensor characterization at the Manchester nobel element laboratories (shared among the Manchester PIs). Additional characterizations will be carried out by an Oxford grad student and technician with an ask of 100k total. **The total personnel cost is 400k.**