EMCCD detector development for space applications: from the Nancy Grace Roman Space Telescope to future mission opportunities

Supervision team:

Dr David Hall, Dr Jesper Skottfelt and Prof. Andrew Holland

External supervisors:

Doug Jordan and David Barry, Te2v

Lead contact:

David Hall (david.hall@open.ac.uk)

Description:

The Charge-Coupled Device (CCD) has been the detector of choice for space telescopes for visible and X-ray astronomy for several decades, with key successes on the Hubble Space Telescope, XMM-Newton and Gaia to name but a few. However, to push forwards with new discoveries and to better understand the universe we need to observe ever fainter signals.

The Centre for Electronic Imaging (CEI) at the Open University (OU) has been involved in Electron-Multiplying (EM) CCD development since 2004. The EMCCD was developed for low-light-level imaging with applications such as night vision. It was later developed further for use in bio imaging and life sciences, observing faint fluorescence from biological samples. The technology works in much the same way as the standard CCD, but includes an additional register in the silicon that allows the application of higher voltages (approximately 5 times higher than those used as standard in a CCD) to employ impact ionisation, multiplying the signal before it leaves the device and therefore before any additional noise is added. In this way, an EMCCD can be operated with much higher frame rates and with sub-electron noise. Despite the new applications that the EMCCD has found on the ground, it is yet to be employed in a large space mission.

Te2v is a global leader in specialised components and subsystems for innovative solutions in medical, science, aerospace, defence and industrial applications. Based in Chelmsford, UK, Te2v has been trusted to design and deliver CCD and CMOS imaging sensors and sub-systems for over 150 space missions by the world's largest space agencies, including ESA, NASA and JAXA. Te2v has collaborated with the Centre for Electronic Imaging for 16 years, sponsoring PhD students and research fellows, promoting knowledge exchange between its staff and those of the CEI, and providing in-kind support by way of staff time, training and detector samples and worth several hundred thousand pounds per year.

Working with NASA JPL and Te2v, the Centre for Electronic Imaging at the Open University further developed EMCCD technology for use in the Coronagraph in NASA's Nancy Grace Roman Space Telescope (RST, formerly known as WFIRST). Using the photon-counting capabilities, the instrument aims to *directly image* exoplanets rather than observe their

presence by other means. Teledyne e2v produced 2 test devices containing a selection of design variants, designed by a previous CEI PhD student (who now works at NASA JPL on the mission), ultimately leading to this UK technology being selected for the mission and to be provided by ESA. Six devices built in the space programme for the Nancy Grace Roman Space Telescope will be provided to the CEI by ESA for analysis.

In addition, over the next two years, Te2v will carry out full Reliability Analysis, LAT and Uncertainty Analysis specific to the Coronagraph on the Roman Space Telescope using their production camera systems at their Chelmsford site. Whilst this will lead to their acceptance for the Roman Space Telescope, for future applications much further analysis may be required; the risk-averse and time-pressured nature of space mission development left some of the most interesting design changes yet to be fully explored.

This industry-sponsored PhD studentship aims to explore the performance of the device, initially feeding into the Nancy Grace Roman Space Telescope device optimisation programmes, before taking a wider view of other applications for the new “radiation hard” EMCCD.

By working on an industrial placement at Te2v within the relevant teams during the test phase, during the PhD studentship you will gain first-hand knowledge of the device performance against the parameters crucial to the space mission. However, for future space applications there may be many questions left unanswered. By continuing from these initial Te2v tests in the OU laboratories, you will be able to push the testing beyond that capable to be implemented at Te2v by using bespoke research camera systems and by accessing the extensive expertise within the CEI. This opens the potential to develop a new, fully optimised detector to dramatically expand the use of this exciting UK technology and provide a step-change for both space and ground-based applications.

This industry-sponsored PhD studentship will be hosted by the Centre for Electronic Imaging (CEI) at the Open University. Previous STFC-funded CASE studentships with the CEI and Te2v have had great and proven success and provided exceptional scientific return, with major impacts on ESA’s Euclid VIS, JUICE JANUS, Athena WFI and SMILE SXI, alongside new device development programmes at Te2v. All have moved directly into employment following completion in academia, industry or with the space agencies (ESA and NASA).

References:

1. Bush, Nathan L. (2018). The Impact of Radiation Damage on Electron Multiplying CCD Technology for the WFIRST Coronagraph. PhD thesis The Open University.
2. Bush, N.; Hall, D.; Holland, A.; Burgon, R.; Jordan, D.; Morrisey, P.; Demers, R.; Harding, L. K.; Nemati, B.; Effinger, R. and Bottom, M. (2018). Development of in-situ trap characterisation techniques for EMCCDs. Journal of Instrumentation, 13(2), article no. C02025.

Qualifications required: 2.1 Masters in Physics or related subject.