Polychromatic optical gain tracking model with MKID-based pyramid wavefront sensor

Aurelie Magniez[*†1], Lisa Bardou[1], Charlotte Bond[2], Tim Morris[1], and Kieran O'brien[1]

[1]Durham University – United Kingdom
[2]UK Astronomy Technology Centre – United Kingdom

Abstract

The Pyramid Wavefront Sensor (PWFS) (Ragazzoni, 1996) is widely recognised as providing the best closed-loop performance for high contrast single conjugate adaptive optics (AO) systems, with many current and future AO systems selecting the PWFS as their primary natural guide star wavefront sensor. However, it is limited by its non-linear behaviour. Existing CCD/CMOS detector technology is well suited to PWFS operation, providing near-zero read noise detectors with frame rates of 1 - 3 kHz at either visible or near-infrared wavelengths. However, there is little scope for significant improvement in these detector technologies to further enhance PWFS AO performance and address non-linearities. Here we propose the use of a microwave kinetic inductance detector (MKID) (Day et al., 2003) array as an alternative PWFS detector technology and describe the benefits this can bring to future AO system performance.

An MKID array is a superconducting detector with unique properties compared to CCD/CMOS detectors that provide a measure of the position, arrival time and energy of each photon incident on the array. Sorting the photons into wavebands allows us to measure the wavefront at multiple wavelengths simultaneously, providing additional information to overcome the limitations of the PWFS. In addition, photon counting becomes possible and new methods of reconstruction using temporal information can be explored. The manufacturing of MKID is flexible, allowing the user to enforce some of its different properties such as speed, energy measurement accuracy or the shape of the array according to the requirements.

One of the current topics regarding PWFS limits is optical gain. Accurate tracking of these would improve PWFS performance and increase the contrast. In this presentation, we will demonstrate the advantage of using the wavelength sensitivity of the detector in optical gain (OG) tracking. Using an MKID-based PWFS simulation developed at Durham, we investigate the influence of wavelength, photon noise, modulation radius and Fried parameter (r0) on these gains. We show how wavelength information can be used to track the optical gain in real time and derive preferred device characteristics.

Keywords: Pyramid wavefront sensor, optical gain, polychromatic wavefront sensing, microwave kinetic inductance detector

[*]Speaker
[†]Corresponding author: aurelie.magniez@durham.ac.uk