Optical pulse detection and transmission in particle-detector systems

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Extended Abstract

Aperture-array radio telescopes have proven to be capable of outstanding precision in measuring the atmospheric particle cascades created by high-energy cosmic rays. Recent measurements [1] have revealed cosmic rays above 10^{17} eV to be primarily composed of unexpectedly light particles — protons and helium nuclei — with significant implications for their as-yet undetermined origin. The low-frequency component of the Square Kilometre Array, when complete, will be capable of measuring a larger sample of cosmic rays with unprecedented precision, permitting discrimination between protons and other nuclei — a key distinction between galactic and extragalactic origin models — and providing a window on hadronic physics at energies beyond those that can be probed with terrestrial particle accelerators [2].

Practical use of the Square Kilometre Array for this purpose requires the on-site deployment of an array of particle detectors, which we are developing. The primary role of these detectors is to provide a trigger signal, on a cosmic-ray event, to cause the storage of buffered radio data. Our design makes use of photonic technology in two respects:

- Each detector contains a $\sim 1\text{m}^2$ block of scintillator plastic, which responds to the passage of a high-energy particle by emitting a pulse of light. This pulse is then detected by silicon photomultipliers (SiPMs), each 6×6 mm^2, which convert it to an electrical signal with the required high time resolution (~ 1 ns). Careful design of the optical system is required to guide sufficient photons to the SiPMs while retaining timing information.
- The signal from each detector must be returned to a central processing facility without emitting any radio-frequency interference that may interfere with the operation of the telescope. The likely distance of this link (~ 2 km) also makes the use of conventional co-axial cable difficult. To avoid these problems, we use an analogue fibre-optic link. These links are designed for broad-band signals, such as those from the radio antennas of the Square Kilometre Array. Our application, in which the signal consists of intermittent pulses with ~ 1 ns rise time, requires careful testing to ensure that timing and amplitude information can be preserved.

With these technologies, we expect to meet our design goals with a prototype particle detector, and provide the Square Kilometre Array with an efficient trigger to allow breakthrough cosmic-ray studies.

References

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