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A Fast Variable Intensity LED Flasher for the Calibration of Cherenkov Experiments

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Our universe offers a natural and unique laboratory to test particle acceleration theories and pave the way towards understanding the violent processes happening in the universe. Gamma ray astronomy has always been at the forefront of unravelling these mysteries. Ground-based imaging telescopes rely on detecting faint, fleeting flashes of Cherenkov light produced when gamma rays interact with Earth's atmosphere. However, the route to such precise measurement demands in-depth calibration—ensuring the encapsulation of spatial and temporal information of every incoming gamma ray particle. Instrumental uncertainties could obscure critical astrophysical signals without a reliable and stable calibration source.

Fast, bright and stable are the three essential features of an ideal calibration system. It should mimic the time profile of Cherenkov light, allowing telescopes to benchmark their detectors with precision. It must cover a broad dynamic range—from single-photon sensitivity to high-intensity flashes—while remaining resistant to environmental variations like temperature drift. Furthermore, a tunable brightness and pulse width extends its usage in different cherenkov light detection environments - from Imaging type telescopes to water cherenkov-based telescopes.

The development and usage of such a system are not new, but the quest is to develop a simple, inexpensive, reliable logic that ensures high-quality calibration results. We have developed a fast, variable-intensity LED flasher system for the Cherenkov Telescope Array(CTA) Small Sized Telescope Camera(SSTCAM). At its core, this system consists of a two-board design: a flasher daughterboard equipped with a high-speed Texas Instruments LMG1025 LED driver and a Maxim DS1023 programmable timing element, and a control board that manages pulse generation, communication, and power. This architecture allows us to generate nanosecond pulses with full-width-at-half-maximum (FWHM) as low as 2 ns, closely resembling the Cherenkov light pulses observed in air showers. The brightness is finely adjustable over four orders of magnitude, making it suitable for both absolute and relative calibration of photodetectors.

The Flasher calibration system has been subjected to extensive laboratory characterization tests, which confirmed its reliability and precision. Lab tests using Silicon Photomultipliers (SiPMs) and Multi-Anode Photomultipliers (MAPMs) demonstrated minimal pulse distortion and excellent stability over prolonged operation. The trigger frequency-dependent intensity variations are limited to just 2%, ensuring consistent performance. A careful analysis of temperature dependence revealed a linear drift of 0.06 V per 10℃, which can be corrected in real time. Beam uniformity tests showed a variation of less than 10% across the focal plane and less than 5 % post beam-modelling-based corrections.

The potential applications of this system extend far beyond gamma-ray astronomy. Any field requiring precise, high-speed optical calibration—such as neutrino observatories, fluorescence spectroscopy, or biomedical imaging—could benefit from this cost-effective, robust alternative to expensive laser-based systems. By providing a reliable and tunable source of fast optical pulses, this LED flasher paves the way for improved calibration standards across multiple scientific and industrial domains.

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