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The calibration light source for the Large Array of imaging atmospheric Cherenkov Telescopes (LACT)

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The LACT project will deploy 32 atmospheric Cherenkov telescopes with a diameter of 6 meters at Haizishan, Daocheng County, Sichuan Province, to conduct detailed structural measurements of multiple ultra-high-energy gamma-ray sources discovered by LHAASO. The cameras are installed on the optical focal plane of the telescopes to image the Cherenkov light reaching their surfaces. We will develope a multi-wavelength LED light source, positioned at the center of the reflector disk, for the calibration and monitoring of the camera's gain.

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1. Introduction

The Large Atmospheric Cherenkov Telescope (LACT) will be constructed at the LHAASO site located on Haizi Mountain in Daocheng County, Sichuan Province. So far, LHAASO has discovered more than 40 high-energy gamma-ray sources, but most of these sources exhibit extended characteristics. The angular resolution of each LACT telescope is better than 0.05° above 10 TeV, and it provides superior gamma-proton discrimination at ultra-high energies by utilizing LHAASO's unique muon detector array. This will significantly enhance the detection sensitivity for gamma rays above 10 TeV, and compared with other IACT experiments worldwide, it offers higher angular resolution and sensitivity.

The LACT project will construct 32 atmospheric Cherenkov telescopes with a 6-meter aperture. Each telescope is mainly composed of a support and rotation system, a Davis-Cotton reflector optical system, a silicon photomultiplier (SiPM) camera system, and a calibration system. The camera consists of an octagonal detector array made up of 1,616 SiPM pixels, with a pixel pitch of 25.8 mm and a field of view per pixel of approximately 0.2°. The SiPM camera will be installed on the focal plane located 8,000 mm from the center of the reflector. It will measure the intensity and shape of the Cherenkov light focused onto its surface in an imaging manner, which will then be used for scientific physical analysis. Therefore, the calibration of the photon detection coefficient of the camera is very important.

We will place a multi-wavelength LED calibration light source at the center of the mirror disk to monitor and calibrate the photon detection system of the camera in real time. The calibration light source consists of a structural housing, six LEDs with different wavelengths (light-emitting diodes), a logic control circuit board, and a DC power supply. The light emission frequency of the source can be adjusted between 1 Hz and 1 MHz, and the pulse width can be adjusted between 15 ns and 1000 ns. The uniformity of the light distribution on the telescope's focal plane from the calibration source must be better than 2.5%. Considering the working environment of the telescope at an altitude of 4,410 meters, with low oxygen levels, strong ultraviolet radiation, and variable weather conditions, the structural housing has been designed with features such as sealing, UV resistance, ease of installation, and lightweight to ensure stable and normal operation of the light source. Chapter 2 of this paper introduces the mechanical structure and material selection and processing of the light source housing, while Chapter 3 presents the test results of the LED light emission characteristics.

2. Structure of the light source

Figure 1 illustrates the primary body of the calibration light source constructed from 6061-T6 aluminum alloy. Surface treatments such as anodization, plastic spraying, and red paint coating are applied to enhance its durability and prevent structural damage from accidental impacts. This material is chosen for its high strength, toughness, and corrosion resistance, ensuring the mechanical structure's reliability and safety. In typical atmospheric conditions, a protective oxide film forms on the surface, slowing down corrosion, thereby reducing maintenance and replacement expenses. With a density of approximately 2.7 g/cm^3, significantly lower than steel, 6061-T6 aluminum alloy maintains strength and stiffness while reducing overall weight. The manufacturing process involves

an integrally cast chassis with four side walls formed by bending to ensure effective sealing and cost efficiency. The calibration light source system is situated at the center of the telescope mirror

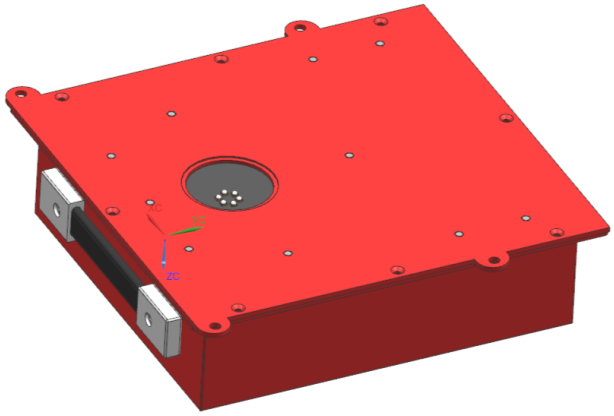

Figure 1: The structure of the LED light source, composed of a box, a logic-control electronic board and six LEDs with different wavelengths.

on a perforated plate (refer to Fig. 2). This plate is equipped with M6 threaded holes positioned at 25 mm intervals. The front panel of the light source enclosure contains four lugs, arranged at 175 mm × 250 mm, which is a multiple of 25 mm, ensuring precise alignment and attachment to the perforated plate. For optimal proximity to the mirror center, the left lug is positioned at the enclosure's left end face. To minimize interference with Cherenkov light and considering the internal dimensions of the LED and power supply components, the enclosure dimensions are fixed at 260 mm × 254 mm. A frosted glass with a diameter of 55 mm is affixed to the enclosure panel to serve as the light exit for the LED.

3. Light distribution test result.Blue: without any glass; Orange:with

Calibrating the camera necessitates a signal mimicking the pulses produced by Cherenkov light in a single SiPM pixel unit during air showers. The light source should allow swift frequency modulation between 1 Hz and 1 MHz, with a pulse duration ranging from 15 to 100 ns. The pulsed LED's surface must exhibit a photon density distribution uniformity surpassing 95%, setting strict criteria for the LED's photon density uniformity. To assess this uniformity, we implemented the subsequent technical methodology.

The SiPM detector and LED were tested under LED operating conditions of 500 Hz frequency, 30 ns pulse width, and 15 V driving voltage, resulting in the photon density distribution data presented in Figure 4.

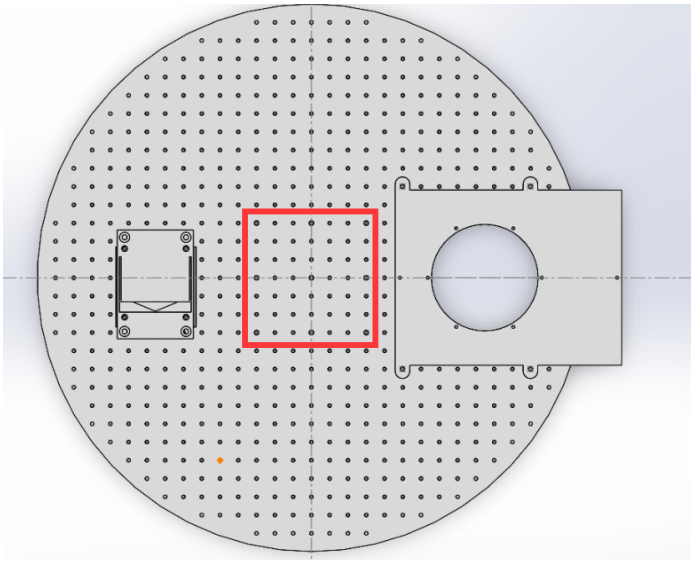

Figure 2: The mounted position of the light source.The LED light source will be mounted at the bottom of the reference plate, which has a hole array the fix light source and a large circular hole to allow the light pass through.

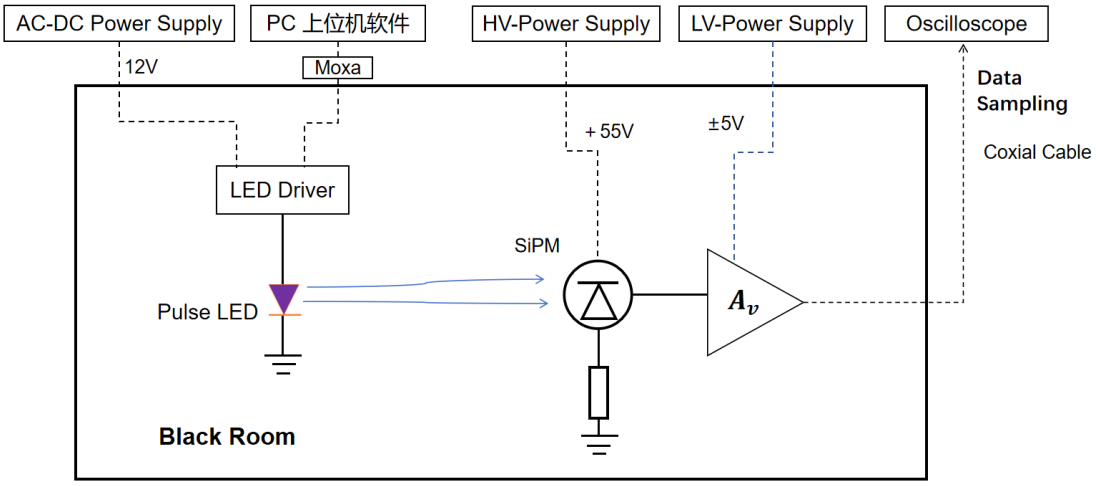

Figure 3: Test platform.

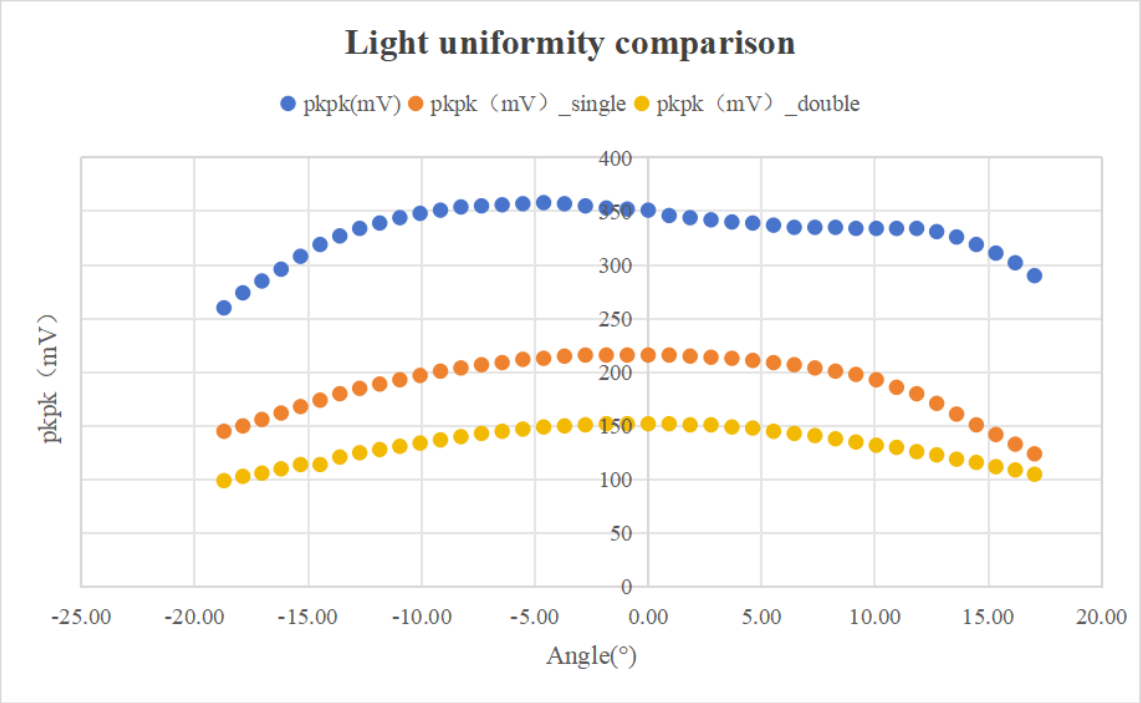

Figure 4: Light distribution test result. Blue: without any glass; Orange: with single-sided frosted glass; Yellow:with double-sided frosted glass.