The ASHRA Detector

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Abstract

We propose a new air fluorescence and Cerenkov detector ASHRA. The ASHRA phase-1 detector consists of 1+1/3 observational stations installed at the distance of 30–40 km in a mountain site. It ensures the large target mass for neutrinos and low-energy threshold for TeV gamma rays. The observational station is composed of 12 wide-angle high-precision telescope, which can cover completely all-sky view. Each telescope has a field-of-view of 50 deg. × 50 deg. and spot size resolution of 1 arcmin. To realize the ASHRA telescope concept, we newly apply the following techniques matured in the other fields: i) Baker-Nunn optics optimized to keep better than 1 arcmin. resolution in 50 deg. field of view, ii) electrostatic lens image intensifier tube (IIT) with the resolution matched with that of the above optics, iii) gated IIT with a fast image shutter, and iv) CMOS image sensor which read triggered images out of the above IIT.

1. Introduction

ASHRA (All-sky Survey High Resolution Air-shower telescope) [1] can take an image of air-shower (AS) through two kinds of yielded lights, Cerenkov and fluorescence, with the 1 arcmin resolution in the entirely all sky coverage of field of view. These advanced features of ASHRA can provide us the systematic exploration into extragalactic VHE particle radiators in the Universe. Detailed designs of the ASHRA detector are discussed in this contribution.

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Fig. 1. ASHRA station arrangement in Hawaii Big Island.

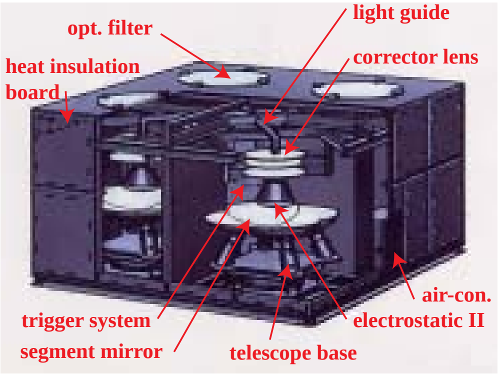

Fig. 2. The ASHRA telescope. It consists of four sub-telescopes viewing the same field.

2. Observational station and telescope

The ASHRA observational station consists of 12 light collection telescopes covering entirely all sky with totally 80 mega pixels in the CMOS sensor arrays. The station site candidates are currently locations near the summits of the three mountains of Mauna Loa, Hualalai, and Mauna Kea on the Hawaii Big Island after taking into account the geometrical distribution for redundant observation ensuring stereo aperture for EHECRs, atmospheric purity, rate of fine weather, low light pollution, accessibility, and so on (Fig. 1.).

In the first step, we are planning to install one full station including 12 telescopes at the site near the Mauna Loa summit and 4 telescopes in another station on the top of Hualalai which is distant from Mauna Loa by 35 km to start up all-sky survey for TeVγs and precise measurement for arrival directions of EHECRs using stereo fluorescence technique (the ASHRA phase-1 project; ASHRA-1). In the second step, enhancing the Hualalai site into one full station and installing one another station at the site on the higher side of Mauna Kea to complete the three full stations, we will proceed to discovery and resolve higher energy phenomena in the Universe with lower flux (the ASHRA phase-2 project; ASHRA-2). We should note that Mauna Loa is the most massive mountain in the world, which is very useful as a detection target for VHEνs.

The telescope consists of four smaller sub-telescopes viewing the same field to ensure the high sensitivity and the cost-performance (Fig. 2.). Each of sub-telescope utilizes optimized Baker-Nunn optics [2] (Fig. 3.). We found concrete optical parameters based on the Baker-Nunn optics, which keeps spot size less than 1 arcmin (0.016°) for incident parallel light rays with the incident angles less

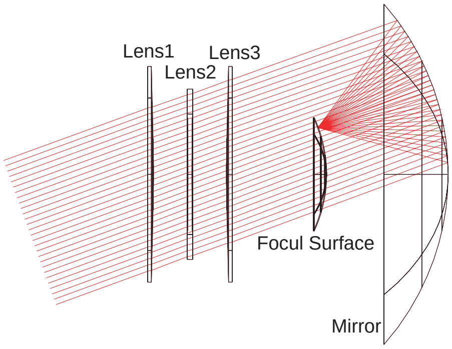

Fig. 3. Schematic view of the telescope based on modified Baker-Nunn optics.

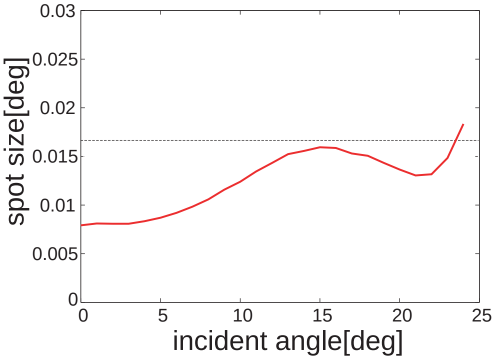

Fig. 4. The rms distribution of spot size as a function of incident angle.

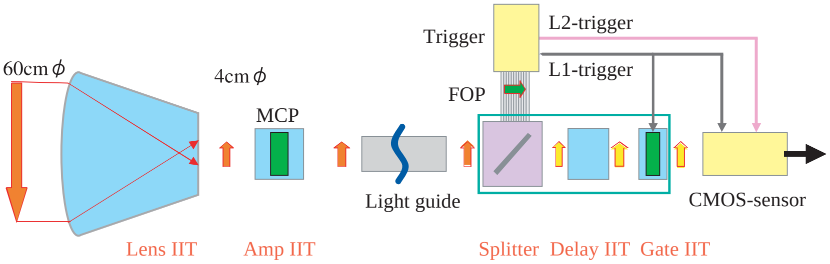

Fig. 5. Photoelectric image pipeline.

than 25° [3] (Fig. 4.). The optical system consists of three corrector normal lenses made of acrylic resin, spherical reflector, focal sphere image intensifier (FIIT) of which sizes are designed to be roughly ϕ1.0 m, ϕ1.8 m, and ϕ0.6 m, respectively. The light images which are gathered and made independently in the four sub-telescope systems are transfered into the following photoelectric image pipeline device together through a light guide. Now the prototype of this optical system with nearly same dimensions as design ones is under fabrication.

3. Photoelectric image pipeline

As shown in Fig. 5., the photoelectric image pipeline consists of FIIT, light guide, self-triggered IIT (STIIT), trigger image sensor, and high resolution CMOS image sensor. Using multiple-stage IIT pipeline and light splitter allows us image transportation to the CMOS image sensor with enough gain without sacrificing the fine image resolution. It also allows us self-triggering for short time phenomena like atmospheric Cerenkov signal. Since the examined resolution at the focal surface is much better than the required one, four light guides after sub-telescopes, which can be connected into one STIIT, significantly contributes to high cost-performance of this system.

FIIT is an electrostatic lens IIT which minifies the image size from 60 cm to ∼4 cm. After the sufficient intensity amplification with the FIIT and a proximity focused IIT (Amp IIT), incoming light is split into two ways: one way is for triggering and the other way is for fine imaging. Following the light splitter, a proximity focused IIT is equipped to make delay for the trigger decision time using the scintillation light on phosphor P-46, of which 10%-decay-time is 200 ns (Delay IIT). The gated IIT after the Delay IIT makes a role of “high speed shutter” by controlling the voltage supplied between the photocathode and the micro channel plate (MCP) using the gate signal from the trigger device [4].

4. Trigger and Fine Imaging Sensor

We have utilized solid-state imagers as the ASHRA trigger and fine imaging sensors to meet the requirements on the image resolution for ASHRA. Especially for fine imaging devices, a CMOS sensor has been adopted in terms of i) easiness of development with low cost and ii) 2-dimensional shuttering. The details of trigger and imaging sensors are described in accompanying paper [5].

5. Summary

The design of ASHRA uses the combination of Baker-Nunn optics, photoelectric image pipeline, and trigger and CMOS image sensors, which successfully reduces the pixel cost dramatically comparing to the traditional air-fluorescence, air-Cerenkov, and water-Cerenkov detectors. As a result, ASHRA provides the advanced features of all-sky survey, 1 arcmin resolution, and simultaneous detection of air Cerenkov and fluorescence lights. This will open a new field, “Observational Particle Astrophysics” by continuously observing TeV gamma-rays, VHE-neutrinos, Knee-CR, and UHECR [6].

References

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