Optical SETI Detector Design

Search for Extraterrestrial Intelligence

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Abstract

In the last decade OSETI, the Optical Search for Extraterrestrial Intelligence, has come to be seen as an attractive means of looking for signals from other intelligent life forms. The High Energy Astrophysics group is developing a new experiment for Optical SETI that we hope will exceed the performance of previous and current projects. Our approach will be to use a large Fresnel lens and small PMTs which will improve the overall signal-to-noise ratio. To obtain signals and differentiate between potential messages and other light pulses, we are building a detector that operates with timing precision of a few nanoseconds. The threshold for this device will need to be tuned so as to cut out background noise and light flashes associated with Cherenkov radiation due to high energy cosmic rays in the atmosphere. Additionally, experiments are underway to determine the suitability of an off the shelf Fresnel lens for the project.

Introduction

Current levels of technology suggest that laser communication is a viable alternative to radio communication over stellar distances. We believe it is not unlikely that other intelligent life in the universe may be near our own level of technological development and therefore could be attempting to communicate through a pulsed laser signal. Searching in the optical range of frequencies has the advantage that we can observe all frequencies at once. Searching in the radio frequencies requires tuning to specific frequencies.

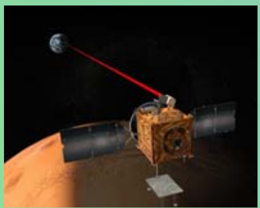

Figure 1: A NASA artist's concept of pulsed-laser stellar communication from the Mars orbiter to Earth.

The design concept for our OSETI telescopes is a simple one involving a large Fresnel lens focused on an array of photomultiplier tubes (PMTs). Each telescope will be paired with a second through a coincidence circuit – these pairs are known as modules and are both positioned to observe the same part of the sky. Using pairs allows us to determine if a flash is a random fluctuation of the ambient light or an actual signal.

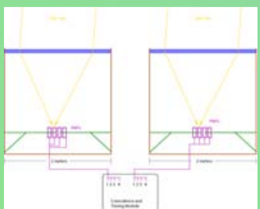

Figure 2: Concept design for a detector module. Light is focused by the Fresnel lenses onto the array of PMTs. The circuit checks for coincident flashes of light.

There is only one source of natural light that could be mistaken for an extraterrestrial signal – Cherenkov radiation. For each observatory there will be 2 or more modules arranged at least two kilometers apart. This arrangement will ensure that coincident light flashes between modules are not due to cosmic rays.

Lens Test

The first step in creating our optical detector system is the development of a prototype telescope using a single commercially available Fresnel lens with a collection area of just over 1.5 square meters. Determining the optical performance characteristics of the lens, primarily the off-axis response, is of utmost importance for determining acceptance of the instrument and ensuring optimal light collection. The primary concern is the characteristic "spot size" of the focal plane images of a distant light source.

Figure 3: Students on the roof of A.W. Smith testing for spot size.

During preliminary testing of the lens on the roof of A.W. Smith, images were taken of the focal plane over a small range of angles. I conducted an analysis of these images using astronomy imaging software. Using this set of measurements to characterize the distortion of the spot as a function of off-axis angle we can conclude that the lens is performing as hoped. These encouraging results suggest that this type of relatively inexpensive Fresnel lens will be usable for scaling up to a larger, more sensitive system.

Lens Results

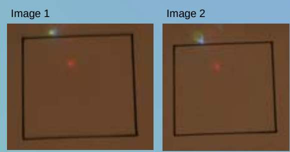

Figure 4: Focal plane images of a point source 2 kilometers away. The black box is 10 cm square. Image 1 is taken at zero degrees off-axis, image 2 at 12.5 degrees. There is already a noticeable coma.

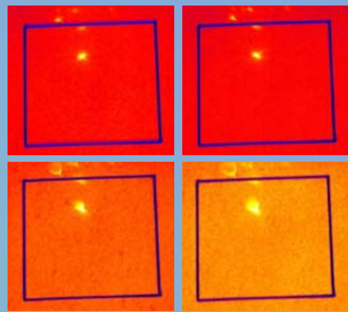

Figure 5: False color images of the focal plane as used to measure half-width and visual size. Images progress from top left to bottom right and from 0 to 12.5 degrees off-axis.

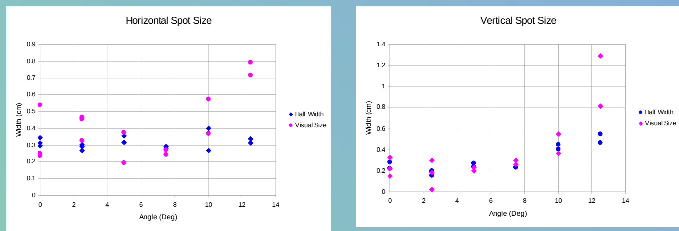

Figure 6: Measurements of the Half-Width and Visual size of the spot size for a range of angles. Half-Width data was taken from half way between the background level and the brightest point within the spot. Visual Size was a measurement of how large the spot appears overall to the naked eye. The horizontal half-width trend is around a constant value of 0.3cm, while the vertical half-width increases with increasing angle. This is in keeping with expectation as the vertical was the direction of change for the off-axis angles.

Coincidence Circuit

The coincidence circuit plays an important role in the overall detector. The circuit will allow us to distinguish possible signals from random night sky background fluctuations. It will compare the signals observed by corresponding PMTs within a telescope pair and use a threshold to determine if a flash was seen. If both telescopes within a module see a flash of light in corresponding PMTs within a range of a few nanoseconds the circuit will emit a pulse and time stamp to be recorded. This data can then be compared to the other modules to determine if the light was from OSETI or Cherenkov radiation.

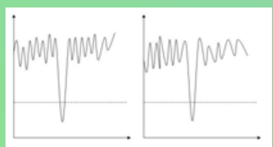

Figure 7: A mock up of the light levels over time measured by 2 corresponding PMTs. The dashed line represents the threshold level, to be determined by simulation, below which light will be considered a 'flash' which is then compared to the same time frame in the second PMT to look for another 'flash'. When the flashes match up it will be considered a 'signal'.

Future Work

The High Energy Astrophysics group at Case Western Reserve University is working toward a fully functional prototype model of a single optical telescope by September of 2009. To this end there are currently several components under development, including the following:

- ❖ A "home" built optical hut to house each telescope, PMT camera system and the electronic components, with a roll-away roof to protect the equipment during foul weather.
- ❖ A custom-designed threshold and dual coincidence logic circuit that will identify and time tag simultaneous light flashes.
- ❖ An end-to-end detector simulation program that will optimize the telescope configuration based on precision measurements.

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