PROGRESS ON THE MULTIFUNCTIONAL RANGE RECEIVER FOR SGSLR

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Receiver Goals

We describe a multichannel range receiver which simultaneously :

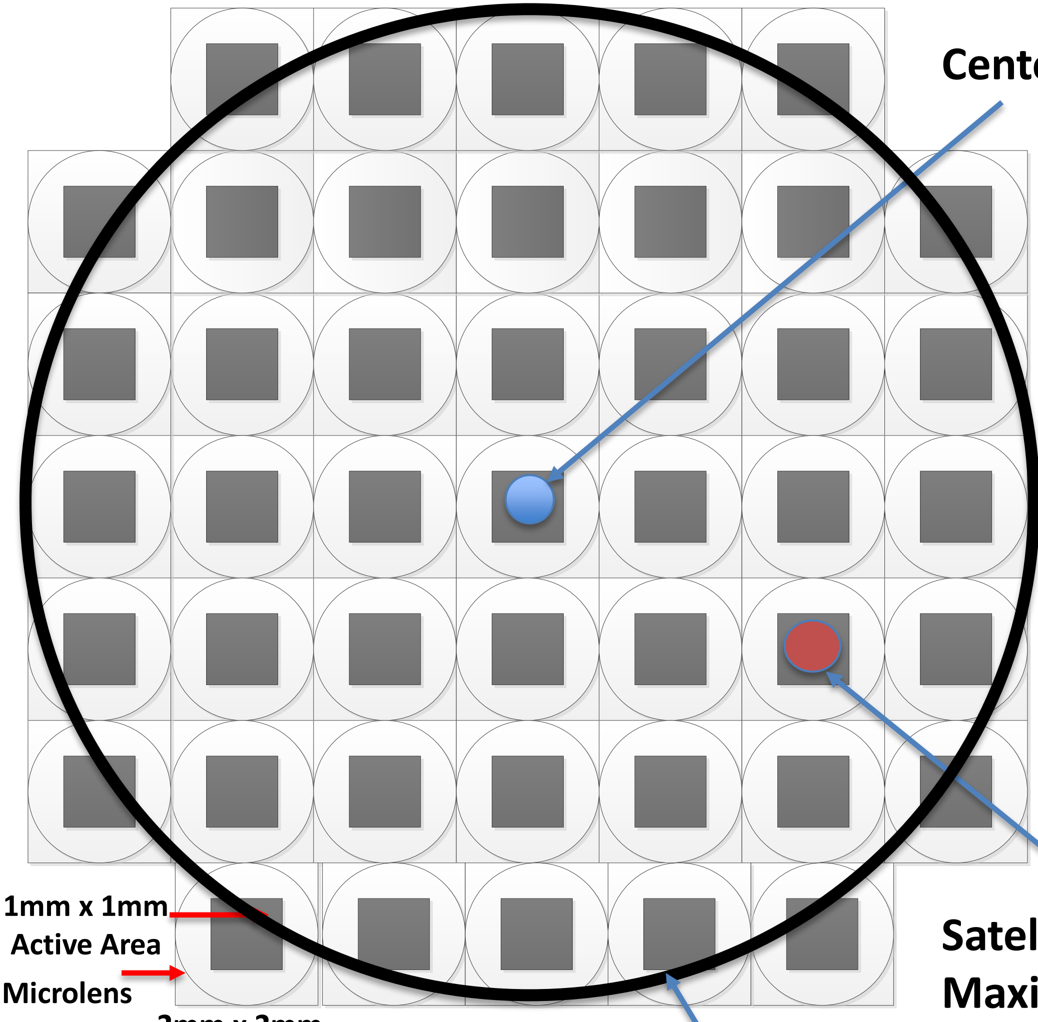
1. Serves as an accurate and self-calibrating Event Timer (ET) for photon start/stop events and other timing signals;

2. Provides a high resolution measurement of the satellite angular position relative to the telescope optical axis which is then used to correct for telescope pointing error;

3. Acts as an Electronic Spatial Filter which eliminates the vast majority of noise counts and therefore greatly reduces potential noise-induced bias in the range measurement for weak links.

4. Can utilize Segmented Anode Microchannel PhotoMultiplier Tubes (MCP/PMTs) or arrays of Silicon PhotoMultiplier (SiPMs) as the detector.

Configuration for SiPM Detector



Quasi 7x7 Array (45 pixels)

- Single TOF card can handle all 45 pixels plus additional time events with few psec resolution.
- Can monitor large FOV with adequate angular resolution (FOV/7)
- Central pixel corresponds to center of telescope FOV.
- Each SiPM pixel has a 1mmx1mm active area but the current mechanical packaging limits the spacing between pixels to 2mm.

Laser-Ablated Microlens Array (LAMA)

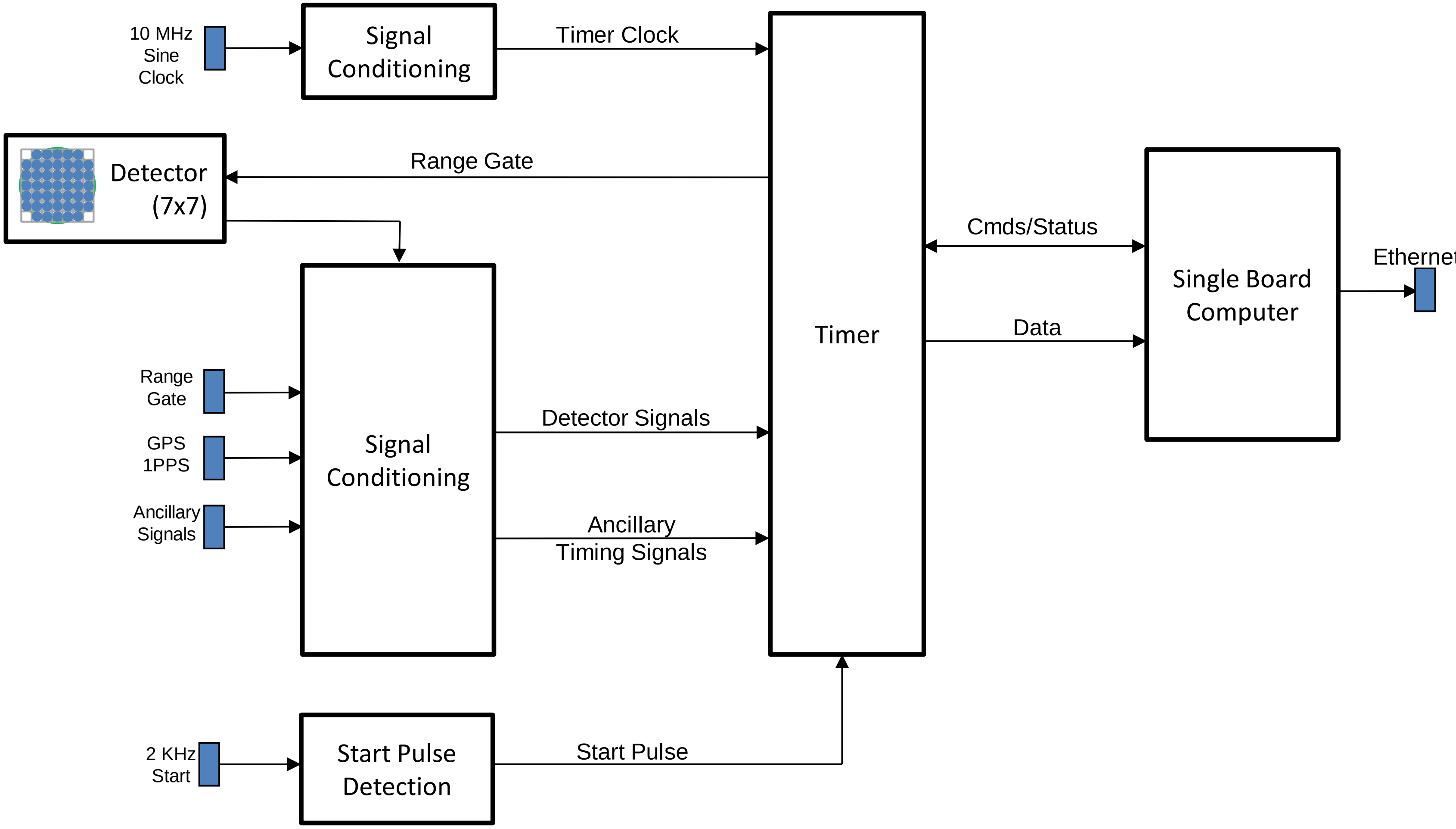
- The LAMA gathers most of the light falling within the 2mm x 2mm area and distributes it within the 1mm x 1mm active area.

T/R Offset vs T/R Half FOV

SGSLR has a Dual Risley Prism (DRP) device which provides a transmitter point-ahead such that, when the telescope is pointed at where the satellite was one light transit time ago, the DRP points the transmit beam to where the satellite will be one light transit time later. This maximizes the satellite illumination and the received signal strength. The T/R angular offset is a maximum when tracking at zenith and a minimum when tracking at the lowest elevation angle (10°). The Max/Min angular offsets are listed for representative satellites in the table below. In the last talk, the SGSLR link analyses suggested that, for all but the lowest elevation angles where the atmosphere severely degrades signal strength, a full transmitter beam divergence of 28″ (4" pixel resolution) for Starlette and LAGEOS and 14″ (2" pixel resolution) for GNSS satellites gives robust return rates. Note that the T/R half FOV is larger than the Max/Min T/R offset in all cases. Thus, even with an inexact T/R offset correction, the satellite image would fall well within the 2 sigma radius of the Gaussian transmit beam, which contains 87% of the total laser energy. If the TRP and diffraction limited telescope are both pointing properly, the satellite returns should always be centered within the array. If the DRP pointing is slightly off, however, the receiver will still center the telescope on the satellite, but the satellite will not be located at the peak of the Gaussian transmit beam with a corresponding reduction in signal return rates.

Satellite	Altitude, km	Max/Min T/R Offset (arcsec)	T/R Half FOV (arcsec)
Starlette	950	10.13 to 5.22	14
LAGEOS	6000	7.78 to 6.70	14
GNSS	20,000	5.33 to 5.18	7
GEO	35,790	4.21 to 4.16	TBD

SGSLR Receiver Block Diagram

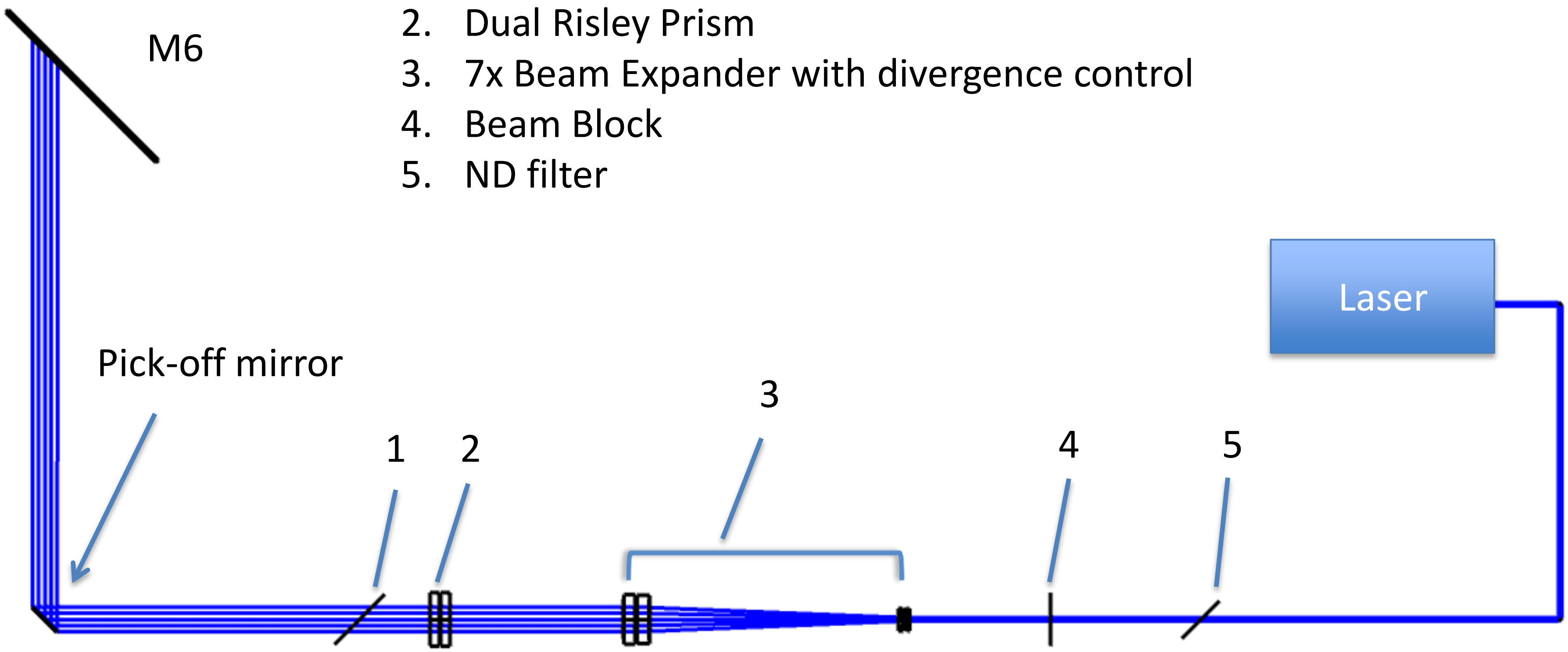


SGSLR Demo Receiver

3U EMI shielded enclosure; 16.73” x 16” x 5.22”

Transmit Optics

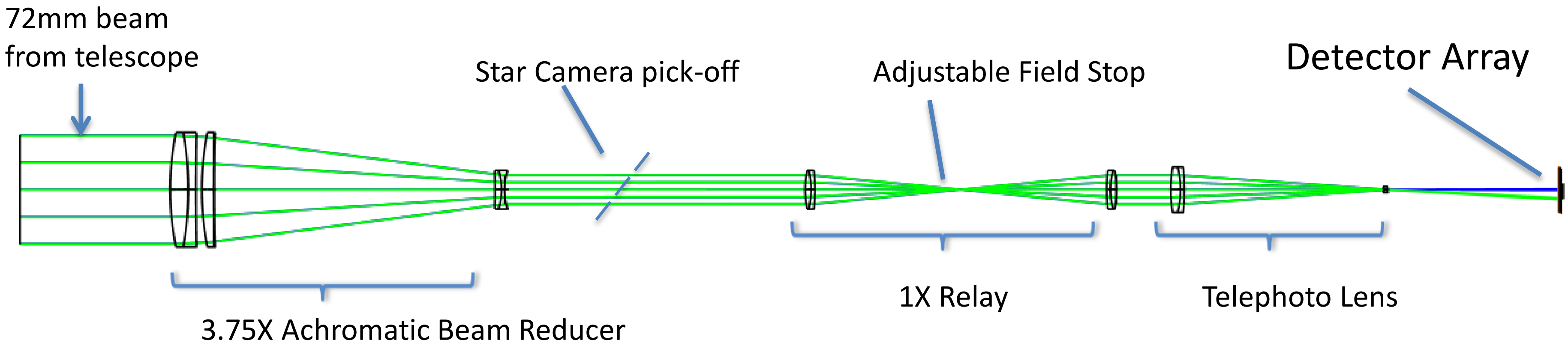
1. Etalon
2. Dual Risley Prism
3. 7x Beam Expander with divergence control
4. Beam Block
5. ND filter

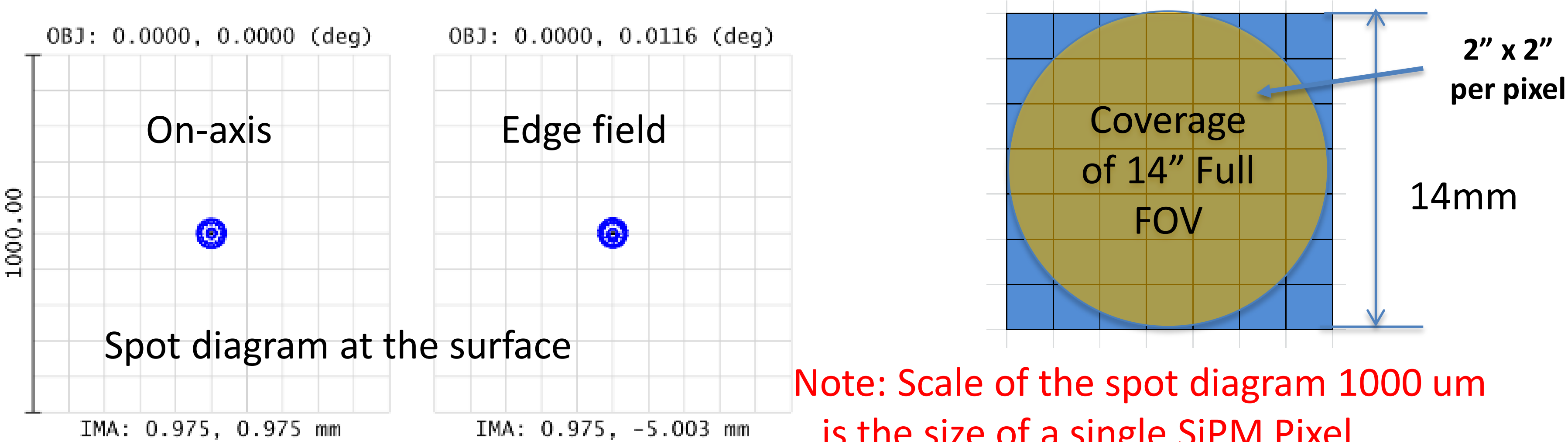


Transmit path uses an insertion mirror, and a portion of the telescope outgoing aperture.

Receiver Channel

1. with Fixed Telephoto (Full FOV in object space: 14")

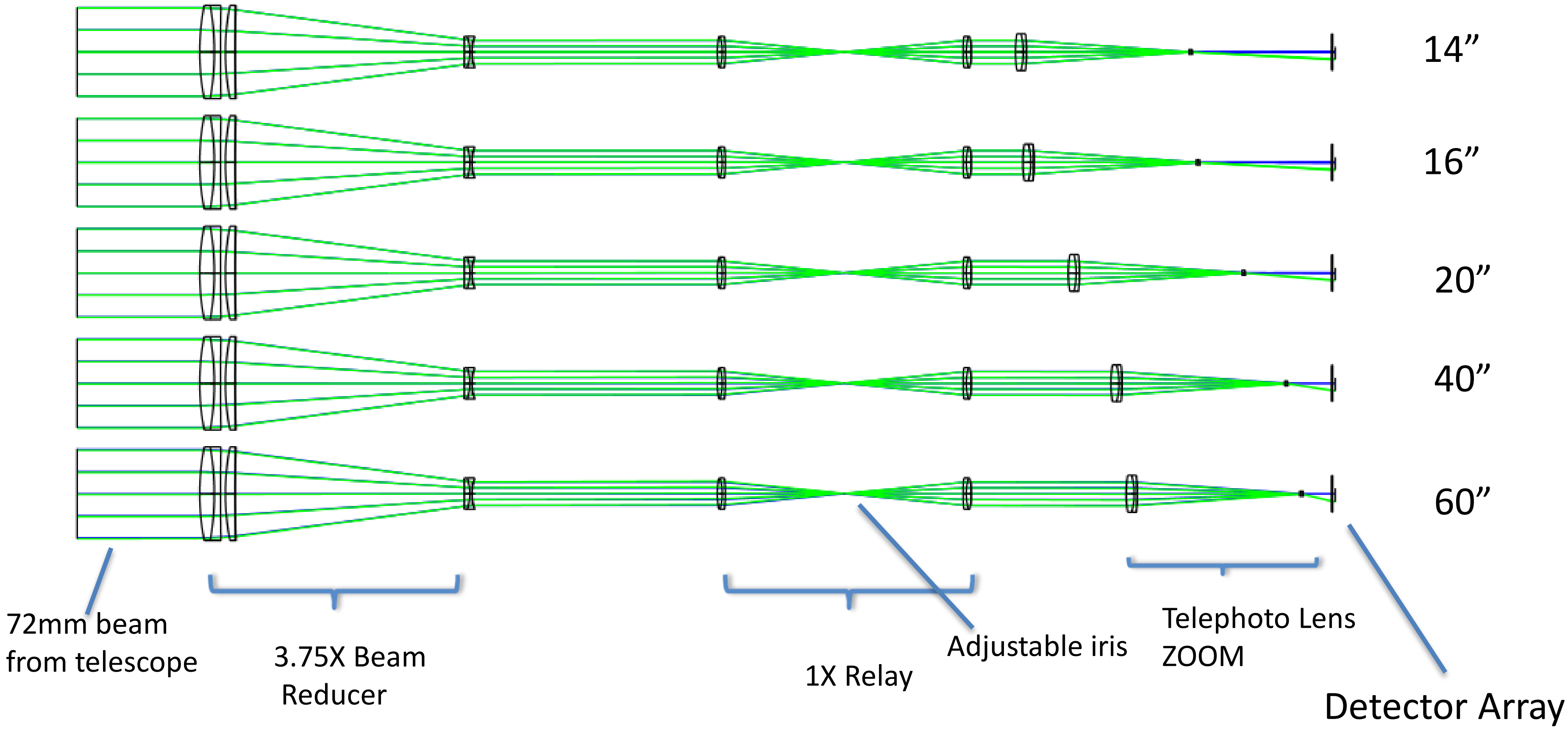




Note: Scale of the spot diagram 1000 um
is the size of a single SiPM Pixel

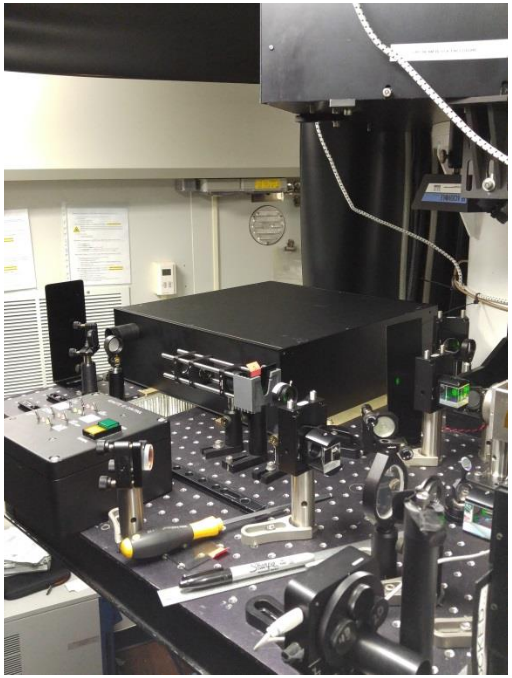
Variable Receiver FOV

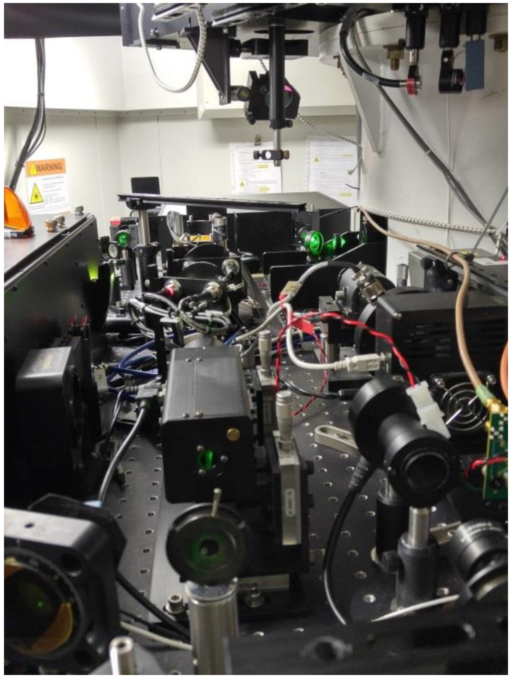
2. with Zoom Telephoto (Full FOV in object space: 14”~60”)



BFL (from last lens of Telephoto to the detector array): 23.50mm~113.88mm

SGSLR Demo Receiver At NGSLR





Summary

- The proposed system provides an accurate measure of the magnitude and direction of the angular error between the satellite and the telescope optical axis while simultaneously serving as a Multichannel Event Timer , providing 45 channels of multistop ranging data having deadtimes less than 2 nsec and event timing precisions of a few picoseconds.

- Maximum utility during satellite acquisition and tracking is obtained by matching the transmitter and receiver FOVs, where the transmitter divergence is controlled by a programmable beam expander and the receiver FOV is controlled by an adjustable iris and a programmable telephoto lens. This ensures that some fraction of the outgoing laser light impinges on the satellite providing some rate of return which increases as the pointing bias is driven to zero, where the peak of the Gaussian beam profile falls on the satellite.

- The design can accommodate segmented anode MicroChannel Plate PhotoMultipliers Tubes (MCP/PMTs) as well as Silicon PhotoMultipliers (SiPMs). Based on inhouse experiments, the SiPMs appear to perform comparably to MCP/PMTs with regard to detection efficiencies and pulsewidths but are significantly less expensive and have relatively short delivery times and long operational lifetimes. Unlike MCP/PMT's, however, current SiPM packaging requires the use of a laser-ablated microlens array which captures most of the light incident on the 2mm x 2mm square and directs it to the 1mm x 1mm active area of the pixel. The multistop and low deadtime characteristics of a given pixel is due to the fact that the active area contains hundreds to thousands of individual single stop SiAPDs, all connected to a common anode, and the receiver optical train is designed to fill the 1mm x 1mm active area.

- During most operating conditions, we expect the satellite signal to fall into one, two, or four pixels out of 45. By ignoring the noise counts in the other pixels , one can eliminate between 91 and 98% of the noise counts in near real time. Thus, the Sigma SGSLR receiver acts as a highly effective Electronic Spatial Filter.

- Field tests of the ranging/timing precision are currently being conducted at NGSLR.