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GROUND BASED LASER RANGING FOR SATELLITE LOCATION

by

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ABSTRACT

In this article, we describe a new satellite laser ranging capability which is a joint effort between the Naval Research Laboratory and Air Force Optical Tracking Facility at Malabar, Florida. Initial measurements off LAGEOS indicates that uncorrected radial range rms values of 8mm are readily achievable. Number of photoelectron counts are on the order of 180 which are off by an order of magnitude from predicted values.

I. INTRODUCTION

A new SLR capability designed and implemented by the Naval Research Laboratory is now operational at the Air Force Optical Tracking Facility in Malabar, Florida. The configuration is based on the monostatic design utilized by a number of the NASA systems in the geoscience network. The laser itself is more powerful than those used by the NASA network and electronics are somewhat different. The system was designed for experimental efforts in tracking unenhanced satellites (those satellites without retroreflectors), plumes, and other targets which may or may not have large laser ranging cross sections.

II. CONFIGURATION

A. Tracking & Acquisition:

Tracking and acquisition was done by the optical tracking facility at Malabar, Florida. Malabar's facility provided a bistatic optical acquisition capability when tracking in "terminator" mode. In this mode, a platform is sunlit but the tracking station is in the dark. The initial acquisition is done passively with the 1.22 m aperture telescope. Once trained on the satellite in question, the0.61 m aperture telescope can track the target within 5-10 μR of accuracy. All vectors, offsets, and tracking is done under computer control using a MicroVax III. Video recordings of a laser ranging event is made in addition to a digitized record of tracking vectors and related offsets.

The transmitter/receiver design is monostatic although acquisition is bi-static. Once the 0.61 m telescope is trained on the target, laser ranging commences. A diagram of the overall method is shown in Figure 1.

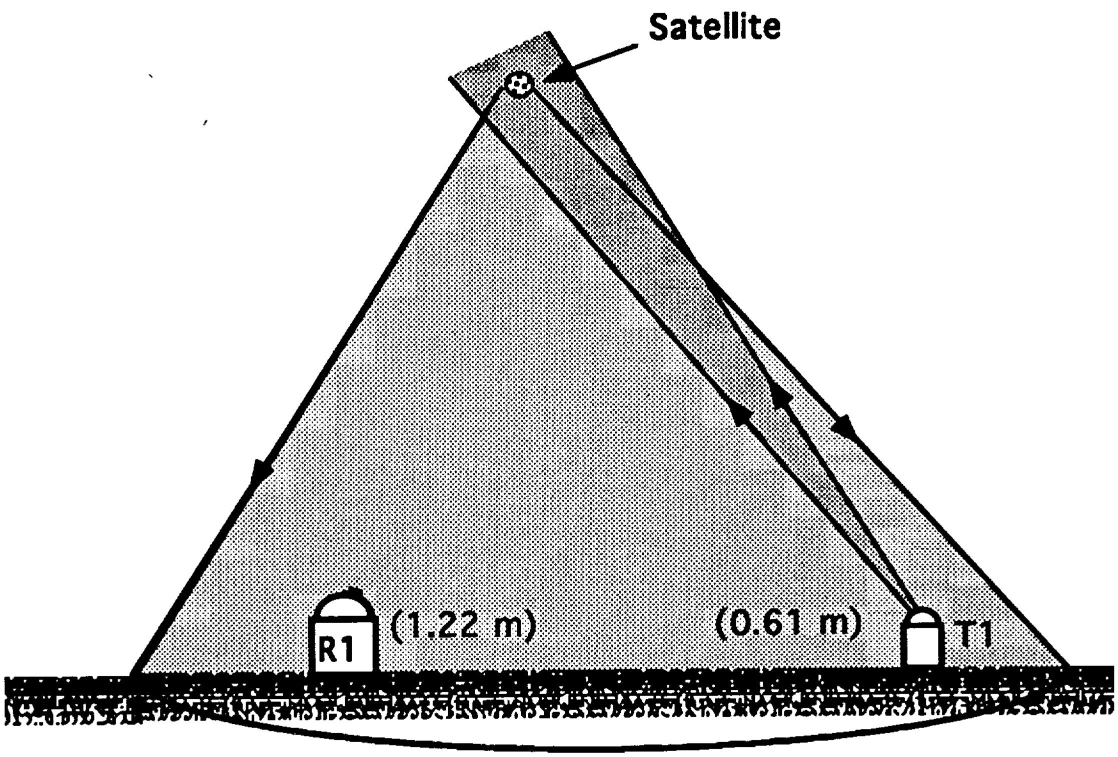

FIGURE 1. NRL/Malabar Satellite Laser Ranging Acquistion Diagram. Initial Acquisition is bistatic when platform is acquired in "Terminator Mode". Once acquired by R1, T1 tracks. The laser ranging T/R is monostatic using T1.

The return signal is collected by the telescope and directed back through the optics where the light is directed to a MCP/PMT using a specially designed annular mirror. The return signal, if strong enough, is split, where part is sent to the time interval counter, and part is sent to a wideband oscilloscope (4Ghz) for waveform capture. An overall system block diagram is shown in Figure 2.

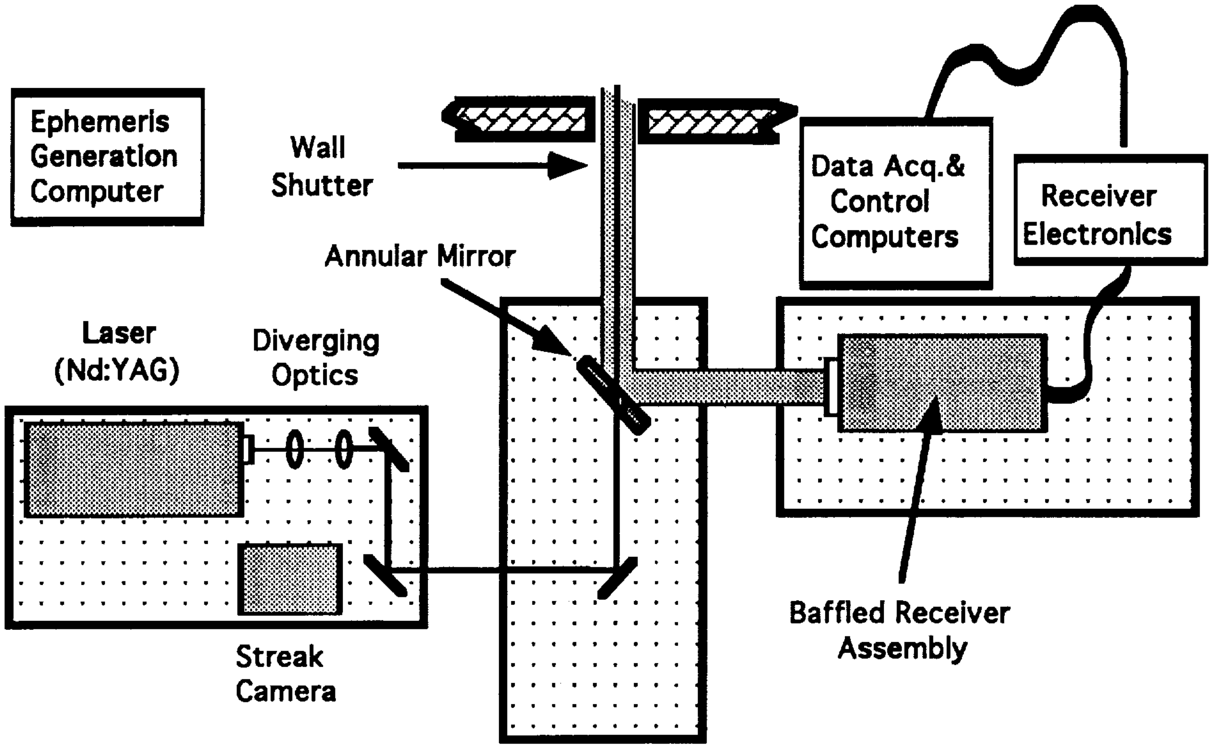

FIGURE 2. NRL/Malabar Satellite Laser Ranging Block Diagram. Configuration shows laser and transmit optics directed through an annular mirror; returned signal is directed via the mirror to the baffled receiver assemby where time differences and waveforms are recorded digitally for off-line analysis.

B. Transmitter:

The laser was designed for the effort by Continuum and is a doubled-YAG, Q-switched, mode-locked laser . The cavity design is "active-active" in that a pulse slicer is used rather than a dye to select desired modes. The configuration includes an oscillator stage and two single-pass amplification stages. The laser provides 300 mJ per pulse in a 250 ps pulsewidth. The pulse repetition rate is 10 Hz. The beam divergence is approximately 10 times the diffraction limit.

Initial alignment in the active-active mode has proven to require careful adjustment. For this reason, a streak camera is configured into the testbed. It was found that initial diagnostics are required at start-up but good alignment is maintained thoughout a given ranging session.

Scattered infrared light is focused onto a PIN detector and the output is directed through a constant fraction discriminator (CFD). The signal is then split and sent to a SR 620 time interval counter and to the IRIG board in the HP 9836 Controller, which time-tags the event.

C. Optics:

Adjustable "zoom" optics are installed to vary the divergence of the beam though computer control. The range of variability is designed for an output at the antenna of 10μRad-100μRad.

A special annular mirror was designed such that the transmitted beam passes through a 4.57 cm hole in the 20.32 cm mirror. The return beam is collimated by the telescope to present a ~11.4 cm beam to the flat. The return beam is then directed to the baffled receiver assembly.

D. Receiver:

The return signal is directed through a 1 m focal length lens to a mirror which can be switched in and out of the optical path. When in place, this mirror directs the light toward a Fairchild intensified CCD which enables verification of proper optical alignment of the receive optics. When this mirror is switched out, the beam is focused onto a 500mm pinhole and directed into the gated ITT F4129 PMT/MCP detector. This detector has a quantum efficiency of 16% with a gain of ~10^6 at 532nm. The detector itself is gated to reduce noise using a programmable delay/width generator. The gatewidth can vary from several hundred nanoseconds to 10 μs.

The output from the PMT is amplified, inverted, and passed through a constant fraction discriminator. The output is time-tagged by the SR 620 time interval counter and the difference stored in the computer. A portion of the output is also directed to a Tektronix SCD 5000 4 GHz wideband oscilloscope which digitizes and stores the waveform for later analysis. A block diagram of the electronics is shown in Figure 3.

III. LAGEOS CALIBRATION

The system was calibrated by ranging off LAGEOS for a series of passes. Radial RMS ranges (uncorrected) were estimated to be ~8mm using the system. Detected photoelectron counts were on the order of 50-190. We initially estimated returns on the order of 1100 p.e.'s. It is possible that the divergence convolved with pointing accuracy has a greater error than anticipated. However, scatter loss is most likely to have been the major contributor to the lower returns.

IV. CONCLUSION

The Naval Research Laboratory and the Air Force Optical Tracking Facility have installed a new satellite laser ranging

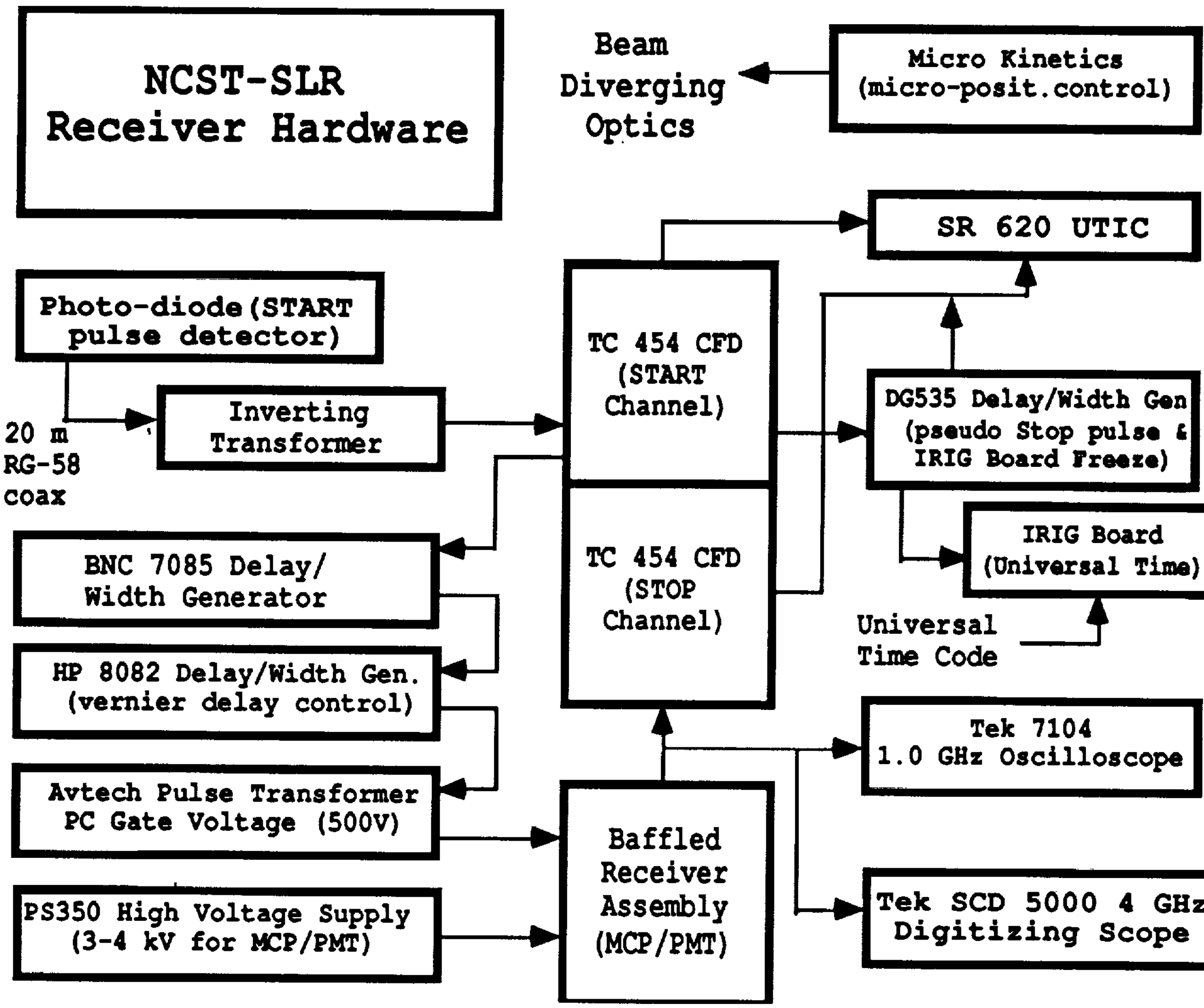

FIGURE 3. NRL Satellite Laser Ranging Receiver Hardware Block Diagram.

capability in Malabar, Florida. The system is based on the NASA monostatic designs used by MOBLAS and other ground sites. The laser itself is a 300 mJ/pulse, 250 ps, 10Hz, Q-switched, mode-locked, active-active design. The detection system includes a gated ITT F4129 PMT/MCP detector and a 4 GHz wideband Tektronix digitizing oscilloscope.

Initial mesurements off LAGEOS indicates that an 8mm uncorrected radial range rms is easily achievable. However, actual p.e. counts are smaller than predicted by an order of magnitude. . This may be due to larger than anticipated divergence and/or to back scatter.

Future efforts will require direct measurement of the divergence in the far-field using the "dithering" technique common to MOBLAS users. Corrections to divergence can be made using the computer-controlled zoom optics in the transmit optical train. Anticipated experiments will include ranging off of platforms which may not have enhanced laser ranging cross sections and ranging off plumes.

V. ACKNOWLEDGMENTS

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