Overview of the NCST’s New Optical Research Facility

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Abstract - The Naval Center for Space Technology (NCST) at the Naval Research Laboratory (NRL) is building a new capability to support space-related optical research activities. The facility will be located at NRL’s Midway Research Center near Quantico, VA. Phase One, completed in 1999, is a multi-purpose transportable telescope (TRTEL) which has already been used for an air-to-ground optical communications demonstration and for passive satellite tracking operations. The second phase, consisting of a Satellite Laser Ranging (SLR) system built around a 1-meter re-locatable telescope, is scheduled for completion in the summer of 2001. Technical details describing both systems are provided.

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Introduction

The Naval Research Laboratory’s Satellite Laser Ranging station near Quantico, VA is scheduled for completion in Summer 2001. It is the second phase of the NCST’s new optical facility designed to support experiments in direct detection satellite laser ranging, laser communication, atmospheric research, and imaging. The SLR capability is being built around a fast-tracking 1-meter telescope with a shared Tx/Rx aperture and a Coude path. The majority of the electronics sub-system is the hardware which was deployed to the Air Force’s Starfire Optical Range (SOR) from Fall 95 to Spring 97. The laser and the transfer optics have been significantly modified since that time. Although NRL will not maintain continuous operations, all SLR data collected against ILRS satellites will be provided for use by the global scientific community. Additionally, the facility contains a smaller transportable component, the TRTEL, with a 16 inch Meade telescope. Designs are in place to support a Phase Three dedicated Lasercomm trailer when funding permits. The facility is available for joint experiments with interested NRL engineers and scientists as well as those from outside the NRL community.

SLR Ground Station

The layout of the optical facility is shown in Figure 1. The modular configuration was designed to be fully re-locatable, in part or in whole, if required for specific experiments.

One-meter Telescope

The SLR capability was designed around a 1-meter primary mirror Schmidt-Cassegrain telescope. The telescope has an Az/El configuration with a shared transmit and receive aperture and a Coude path. It is an F/89 system with a 12.640 meter focal length. The specifications include a slew rate of 20 deg/s in azimuth and 10 deg/s in elevation with a pointing accuracy of at least 2 arcsec RMS all sky.

SLR Optics

The optics have been designed to incorporate multiple receive legs and a 4-element variable zoom. Figure 2 is an overview of the initial transmit and receive optical design within the SLR trailer. The figure includes two detection legs designed for future use. The transmitted laser beam will be converging at the telescope exit. The primary reason

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2 Honeywell Technology Solutions, Inc., Lanham, MD
3 Research Support Instruments, Inc., Lanham, MD
for this configuration is more uniform illumination of the target. A second driving factor was the ability to implement a variable divergence with minimum optics translation on the transmit leg.

The zoom optics will allow a divergence range of 20 to 800 microradians full angle, resulting in a beam focus range between 1.2 and 50 km. Details of the transmit optics and a block diagram of the modified laser are shown in Figures 3 and 4. Details of the receive optics are shown in Figures 5 and 6.

The laser is a modification of the Continuum YAG laser that was hosted at SOR. The modified laser incorporates an external CW mode-locked master oscillator, which is a diode-pumped Nd:YVO4 [2]. After passing through a Faraday Rotator, the seed pulses pass through a regenerative amplifier cavity and an amplifier chain consisting of 2 Nd:YAG rods (9.5 mm and 12 mm). There are four pulse widths available from the laser system at 8, 30, and 190 ps and 6.5 ns. The laser was previously operated at a 532 nm wavelength, and although it maintains that capability, operations at MRC will initially be limited to 1064 nm. This wavelength will provide a 2x energy increase along with increased atmospheric transmission. However, detector efficiency in the near-IR will be significantly reduced. The pulse train will have 210 ps wide pulses with 600 mJ per pulse at a 10 Hz repetition rate.

**Electronics**

The direct detection system makes a standard SLR round trip time-of-flight measurement as described in Reference 1. At this time, there is no capability to make the epoch time measurements required for lunar ranging. The electronics are identical to those hosted at SOR with the exception of a detector change and the electronics required to support the laser modifications. A 230 micron APD will replace the PMT as the primary ranging detector. Figure 7 shows the electronics diagram with these changes. Also incorporated into the design is a safety interlock system to prevent unintended or hazardous projection of the laser beam.
outside of the dome. For air safety reasons, a Laser Hazard Reduction RADAR system has been integrated to detect passing aircraft. The emitted laser beam will be blocked when an aircraft flies within a hazardous distance from the laser beam. The RADAR will be bore-sighted with the telescope and will completely subtend the laser beam.

![Block diagram of the modified SLR laser](image1)

Figure 4: Block diagram of the modified SLR laser

![SLR Detection optics](image2)

Figure 5: SLR Detection optics
Figure 6: Imaging Optics for 1-meter Telescope

Figure 7: SLR Electronics
Transportable System

Collocated with the SLR facility is the smaller, fully contained transportable telescope system (TRTEL) shown in Figure 8. The TRTEL is a Meade LX200 Schmidt-Cassegrain mounted in a precision pointing pedestal. The Meade telescope has an f/2, 16 inch primary mirror, a 5 inch diameter secondary, and an effective system focal length of 406 centimeters. The system works cooperatively with the 1-meter system by collecting meteorological data and measuring atmospheric turbulence. The telescope is also capable of imaging and passive satellite tracking during terminator conditions.

Optical Communications Demonstration

In the fall of 1999, the TRTEL was configured for use as the ground station for an air-to-ground optical communications demonstration [3]. The Meade telescope does not have a coude path. Therefore, an optical system was designed to image the corrector plate of the telescope onto the CCD of the receiver camera or onto the tapered fiber used to couple the light to a Sonet receiver at the base of the TRTEL. A kinematic "flip" mirror was used to provide the manual switch. The imaging optics for the receiver camera consisted of an f/0.7 asphere. The camera used was a model PC23C, 1/3 inch B/W 510 x 492 pixel CCD with minimum required illumination of 0.4 lux. The optics for coupling the light to the receiver circuit consisted of an f/0.7, 50 mm diameter aspheric condensing lens with an f/0.7, 25mm diameter aspheric collimating lens for "down-collimating" the light ray bundle to a few millimeters. The light was then coupled into a tapered fiber with N.A. of 0.22 (500 micron core diameter to 100 micron core) with an 11 mm focal length aspheric fiber coupling lens mounted in a translation stage. The signal was then transmitted to the receiver circuit through 100 micron core multimode fiber. A long wavelength pass filter was used in the optical path to block visible light and to transmit infrared radiation with 75% transmission. The receiver chip was a Sonet SRX-12 designed for a data rate of 622 mbps. The receiver sensitivity was -31.0 dBm for a 10^-10 bit-error-rate.

The field of view (FOV) of the Meade telescope is 0.5 degrees full angle. With the lens and optical path to the camera, the camera FOV was calculated to be 0.3 degrees and measured to be approximately 0.25 degrees or 4.4 milliradians. The FOV of the receiver optics was limited by the acceptance angle of the fiber taper, which was measured as approximately 2 milliradians full angle (0.1 degrees). The transmission through the telescope, receiver system optics, and fiber taper at 1550 nm was measured before the field test to be 1-2%; however, this measurement was made from a short distance with a small diameter (approximately 2 inch) beam with a divergence of 2 milliradians. The actual field test was performed at distances of a few hundred meters to 2.5 kilometers and the divergence of the laser had been increased to 3.2 milliradians. Under these conditions, the transmission through the system was 0.1-0.2 %. This transmission percentage was calculated (conservatively) to be sufficient for a communication link at a range of 2 kilometers and, in fact, during the demonstration, a 622 mbps link was established at a distance of 2.5 kilometers.

Research Opportunities and Conclusion

The design of the optical facility has been ongoing for the past several years. The initial site preparation for the TRTEL was completed in the summer of 2000. The TRTEL will continue to operate at MRC until its next deployment. The groundbreaking and site preparation for the 1-meter telescope and the SLR infrastructure began in January 2001. The shelters to house the laser, optics, and other equipment are due for delivery and installation in February 2001, with the dome installation following in March. With the shelters and dome in place, the laser, optics, and electronics will be installed and integrated. The telescope is due for delivery in June, with the initial operational capability projected for August 2001.

This facility will support research and operational testing in various fields including high precision ephemeris generation. SLR operations will include gathering GFO orbit determination data, which will be provided to the Navy and the global scientific community. Additional planned operations include calibration of the Space Surveillance Network (SSN), Naval Earth Map Observer (NEMO) sensor calibration, and tether dynamics research.

Outside of satellite laser ranging, the facility is designed to support laser communications, imaging and atmospheric turbulence studies. Currently funded optical communications projects include research in both conventional free space communications and links utilizing a modulating retroreflector. Laser communication link quality will be
measured along with atmospheric turbulence data. Both types of data will be correlated to develop new ways of correcting for turbulence to improve free space optical communication.

References


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