A compact, mobile, robotic, high-precision tracking platform for Astrometry, Photometry, SLR, Transponder, On-orbit testing, and Lasercom

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Abstract

Cybioms' automated tracking systems, capable of sub-mm SLR normal point precision and 1 mm system accuracy on geodetic satellites, have been going through field commissioning. A scaled-down lower-cost modular version of this with a compact telescope (~300 mm) capable of reaching GNSS with sub-arcsecond precision tracking has been completed after extensive laboratory prototype testing. Currently, such a new tracking telescope is going through integration in the lab in support of a US Govt project. This tracking platform will support target imaging, photometry, astrometry, debris tracking, laser transponder, lidar, SLR, and lasercom. Simultaneous multicolor high PRF (MHz) SLR capability with separate transmit and receive telescopes, is planned for SLR in the future. One key consideration is the modularization and packaging of hardware functions to reduce cost, weight, and suitability as a broad platform. To enable a compact SLR platform for precision geodetics and to minimize the need for surveying, there is a built-in provision for precise and repeatable optical placement over a fiducial reference as well as internal system calibration.

<1> Aerospace Laser applications – compact automated platform need

1. Aerospace Laser applications include SLR, lidar, transponder, lasercom, laser beacons, on-orbit testing of satellites, and defense. Ideally, these require a robust modularized platform. For the above applications, TX and RX hardware vary but for a few common subsystems, e.g., telescope, timing, computing, weather, etc.
2. Cybioms has previously developed 50 cm and 100 cm bistatic and monostatic telescopes for aerospace applications. These are large platforms, costly, and deployed permanently. These are neither compact nor easily re-deployable.
3. The traditional SLR systems are based on telescopes of 50 cm or more. By their intrinsic sizes and weights, these are meant to be permanent deployments.

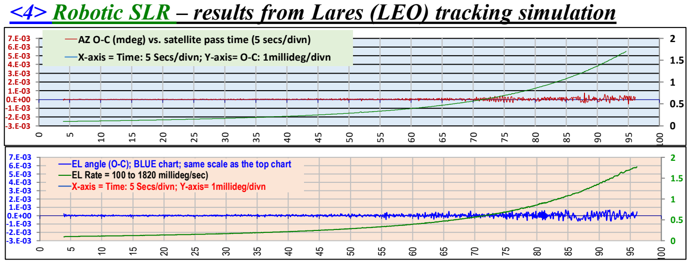
<2> Aerospace Laser applications – projected capability and features

1. Next Generation robotic systems require compact and robust telescopes integrated with computers, electronics, optics, and lasers.
2. Cybioms' existing automated SLR systems are capable of sub-mm normal point precision and ~1 mm system accuracy on geodetic satellites. These have been going through field commissioning. Cybioms has plans for a high PRF (MHz) multi-wavelength ranging system in a bistatic telescope configuration.
3. A scaled-down lower-cost modular version of a compact telescope (~300 mm) to track GNSS and GEO with sub-arcsecond precision tracking has been completed. This architecture also supports "dynamic aperture scaling".
4. The tracking platform will support target imaging applications, photometry, astrometry, debris tracking, laser transponder, lidar, SLR, and lasercom.

<3> Robotic SLR – laser parameters

Parameter	Value	Values with units
Laser Energy per pulse (Joule)	**1.00E-06**	1 microjoule
Laser PRF (Hz)	1.00E+06	1 MHz
Laser Average power @1MHz (W)	1.00E+00	1W
Laser Pulsewidth (s)	1.00E-11	10ps
Laser Wavelength 1- IR (m)	1.06E-06	1064 nm
Laser Wavelength 2 - Green (m)	5.32E-07	532 nm
Laser Peak Power (W)	1.00E+05	0.1 MW
Laser Beam diameter (cm) at the telescope exit aperture	20.00	20 cm
Laser Beam Area (cm2)	314.16	314 cm2
Laser energy density at the telescope exit (J/cm2)	3.18E-09	3 nJ/cm2
Avg laser irradiance over the 20cm dia of the TX telescope <W/cm2>	0.0032	3.2 mW/cm2
Peak laser irradiance over the 20cm dia <W/cm2>	318.310	318 W/cm2
MPE for visible pulsed 532nm at 10ps<J/cm2>	2.00E-07	0.2 µJ/cm2
MPE for IR 1064nm at ~10ps <J/cm2>	2.00E-06	2 µJ/cm2

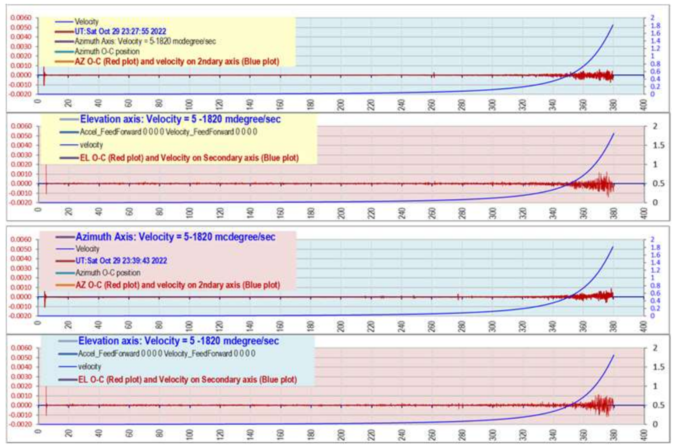
<4> Robotic SLR – results from Lares (LEO) tracking simulation



AZ & EL angles were simulated using the same Lares satellite data file for the velocity range of 100-1820 mdegrees/s. There was a disturbance at the highest EL velocities as the telescope EL axis was not loaded with the payload and was not perfectly balanced. The statistical analysis included the entire range of data

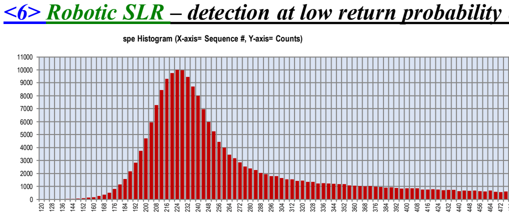
All units below are in degrees; **AZ (O-C): Mean = 3.5E-5; StDev =1.1E-4; EL (O-C): Mean =2.2E-5 deg; StDev = 1.7E-4 deg; X-axis =Time = 5secs/divn; Y-axis =O-C= 1E-3 deg**

<5> Robotic SLR – LEO-GEO tracking (2 -1800 mdeg/sec) simulation



X-axis= Time (in sec); Y-axis= O-C (in deg); Blue background = AZ, pink is EL axis

<6> Robotic SLR – detection at low return probability at the spe level

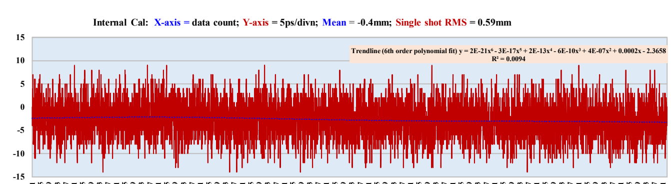


1. With a high QE, low jitter SPAD detector, and an eye-safe picosecond/femtosecond laser, we can meet the sub-mm data "npt" performance targets.
2. In prior work with MLRO at the ASI Matera observatory, Cybioms did achieve extremely good SLR tracking with a 1-arcsec laser beam divergence (BD) on GNSS and 2-arcsecond BD on Lageos, both at the "mpe" level.
3. Tight BD allowed maximizing the link due to the precise tracking capability of Cybioms' telescope servo-control system. Over 90% return data rate with a 1-arcsecond laser beam divergence was achieved for GNSS and 95% return on Lageos @mpe level

<7> Robotic SLR – capability and features

1. Automated monitoring and analysis of all external environmental parameters such as pressure, temperature, humidity, wind, fog, cloud cover, lightning, dust, seeing, and atmospheric transmittance are routinely performed (24 x7).
2. Furthermore, the system's operational parameters and their dependencies on the environmental conditions are also monitored as a function of time.
3. The set of past and present operational data allow the estimation of future performance, assisted by situational awareness.

<8> Robotic SLR – internal calibration range simulation



Electronic simulation of long ranges is not accurate using commercially available delay generators. It is possible to simulate shorter ranges accurately by optical and electronic delay lines. The above data is a short-range measurement of ~50ns delay. **Mean = -0.4mm**; **Singleshot RMS = 0.59 mm**

<9> Conclusions

1. Significant progress has been made towards achieving robotic SLR in a compact geometry. The robotic platform developed in hardware and software for SLR will also support other laser applications.
2. Cybioms is working with laser manufacturers for an optimal multiwavelength laser. We plan to complete a lower-cost robotic SLR system with sub-mm normal points in the near future.