100 kHz satellite laser ranging demonstration at MLRO

D. Dequal[1*], C. Agnesi[2], L. Calderaro[2], F. Vedovato[2], L. S. Amato[1], M. S. de Cumis[1], G. Vallone[2], P. Villoresi[2], V. Luceri[3], G. Bianco[1]

1) Agenzia Spaziale Italiana
2) Università degli Studi di Padova
3) E-geos S.P.A.

* daniele.dequal@asi.it

The introduction of kHz lasers for satellite laser ranging (SLR) led to an increase of data rate and enabled the spin rate measurement for several satellites [1], showing how an increase of the repetition rate can augment the potential of SLR technique. To further investigate the potential of higher rate regime, we performed a data acquisition campaign with an Ekspla "Atlantic 60" 100 kHz repetition rate laser for SLR at the Matera Laser Ranging Observatory (MLRO). The small pulse width and the low single photon detector jitter led to a single shot precision comparable to that of traditional stations, but with a much higher return rate. The system has consistently tracked several LEO satellites as well as Lageos 1 and 2. The return histograms show in several cases multiple peaks, due to the retroflection from different corner-cubes. This opens up the possibility of attitude determination of retroreflector arrays and a new method for spin rate measurement. Finally, we show how such a high repetition rate laser could be optimized for SLR, allowing the tracking of high MEO satellite.

System specification

100 kHz complete system working in parallel with the traditional 10 Hz system for check. Lower energy per pulse must be compensated with single photon detection.

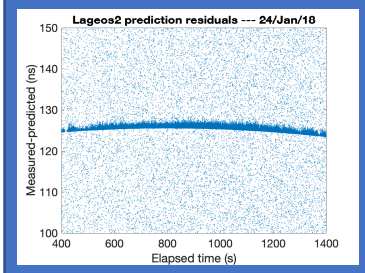
Laser specs	
Repetition rate	Single shot–1 MHz selected: ***100 kHz***
Pulse energy	100 µJ @100 kHz
Pulse duration	9 ps (FWHM)
Wavelengths	1064/***532***/355 nm
M^2	<1.3

Detector spec	
Sensitivity	Single photon
Det. efficiency	50% (@532nm)
Dark count rate	400 Hz
Time jitter	40 ps (FWHM)
Active area	200 µm diam.

Ekspla, Atlantic 60 **MPD, PD-200-CTX**

Raw-data and filtering

The returns are easily distinguished from background when compared to expected time of arrival computed from two line elements, i.e. from *prediction residuals*.

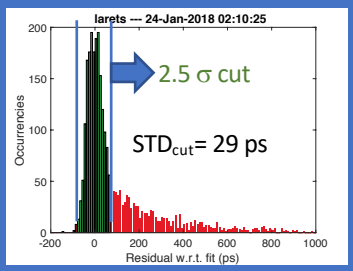


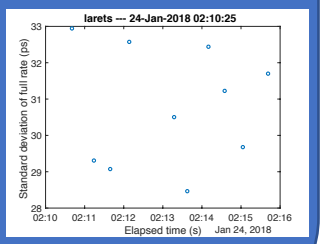
Satellite	MLRO counts	Ekspla counts	Ratio
Ajisai	2556	75578	29,6
Beacon C	3806	247905	65,1
Cryosat	1926	473548	245,9
Jason 3	3530	279561	79,2
Lageos 1	3872	44580	11,5
Saral	598	10367	17,3
Starlette	2291	708924	309,4
Starlette	1038	43943	42,3
Stella	1136	49221	43,3
Stella	1522	108574	71,3

Full rate data precision

According to ILRS procedures:

- Division of orbit in fixed time intervals
- Polynomial fit of prediction residuals
- 2.5 σ cut of the polynomial *fit residuals*
- Repeat polyfit on selected data
- Calculate standard deviation of selected data

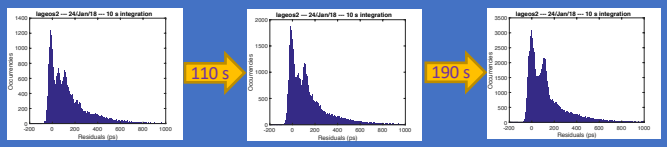




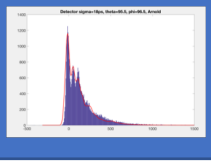
CCR array signature

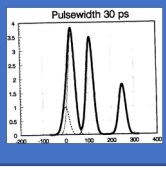
The passage is divided in 10-sec intervals; for each interval we analyze the ***histogram of the fit residuals.***

The presence of multiple corner cube (CCR) planes gives multiple peaks. Their position depends on the time-varying satellite's orientation.



Analysis ongoing to determine the satellite orientation and spin from the peaks position and motion [2].





The first use of 100 kHz laser for SLR operation has shown a potential for precise ranging operation. While the single shot jitter, mainly due to the single photon detector used, is at the level of other kHz stations, the return rate has been much increased. In possible future applications, working at 400 KHz with the same energy per pulse would lead to a factor x4 improvement of data rates. Another factor x4 can be obtained avoiding the coupling with traditional 10 Hz system, leading to a ***possible increase of a factor x16 on the return rates***, allowing high MEO tracking. The unprecedented repetition rate achieved could open up the possibility for improved precision in SLR and the development of new techniques for satellite attitude and spin determination.

References:

[1] D. Kucharski et al. Adv. in Space Research 43 (2009) 1926–1930
[2] P. O. Minott et al., NASA TP 3400 (1993)

Acknowledgments:

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