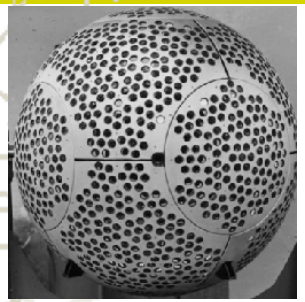
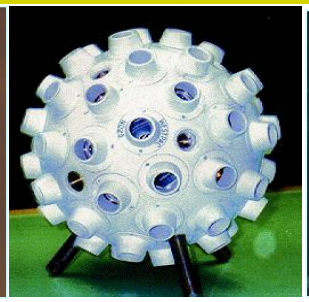
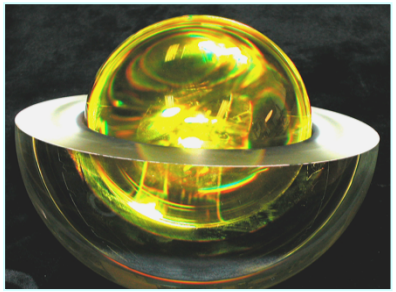
ILRS Technical Workshop
SLR tracking of GNSS constellations
Metsovo, Greece, 2009

What is needed to approach submillimeter accuracy of SLR ?



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Single-electron mode of signal detection

- The return signal intensity fluctuations practically do not affect the ranging accuracy;
- The random error of multiple range measurements is reduced due to the increased number of single measurements;
- The systematic error of ranging caused by the return signal arrival time dependence on the average number of photoelectrons in a single pulse is also reduced.

Determination of random (σ_N) and systematic (Δ_N) errors for multiple range measurements

$$\sigma_N = \frac{c}{2} \cdot \sqrt{\frac{\sigma_t^2 + \sigma_r^2 + \sigma_d^2}{f_{se} \cdot T_N}}$$

$$\Delta_N = \frac{c}{2} \cdot n_{se} \cdot \left[0.28 \cdot \sigma_t + 0.34 \cdot \sigma_r\right]$$

$$f_{se} = n_{se} \cdot F_t = \frac{\eta}{h\nu} \cdot \frac{4P_{av}}{\pi\theta_t^2} \cdot \sigma \cdot \frac{A_r}{4\pi R^4} \cdot \tau_{opt} \cdot \tau_{atm}$$

σ_t – RMS return pulse duration;
σ_r – photoreceiver resolution;
σ_d – jitter of time interval meter;
n_{se} – average number of photoelectrons in return pulse;
F_t – laser transmitter pulse repetition rate;
P_{av} – laser transmitter average output power;
f_{se} – average frequency of signal photoelectrons in the photodetector output.

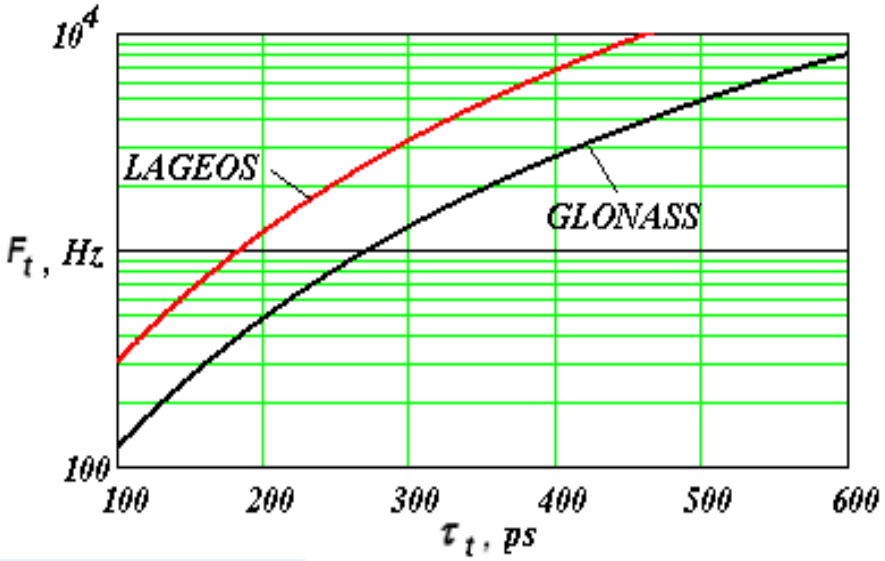
Determination of required laser pulse repetition rate F_t and average frequency of signal photoelectrons in the photodetector output f_{se}

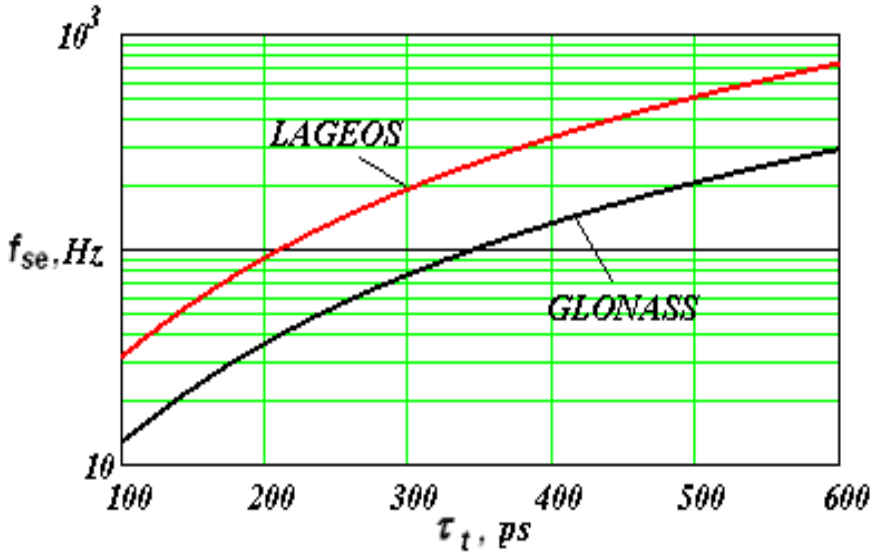
$$F_t = \left[\frac{c}{2}\right]^3 \cdot \frac{1}{T_N} \cdot \frac{0.28 \cdot \sigma_t + 0.68 \cdot \sigma_r}{\Delta_N} \cdot \frac{\sigma_t^2 + \sigma_r^2 + \sigma_d^2}{\sigma_N^2}$$

$$f_{se} = \left(\frac{c}{2}\right)^2 \cdot \frac{1}{T_N} \cdot \frac{\sigma_t^2 + \sigma_r^2 + \sigma_d^2}{\sigma_N^2}$$

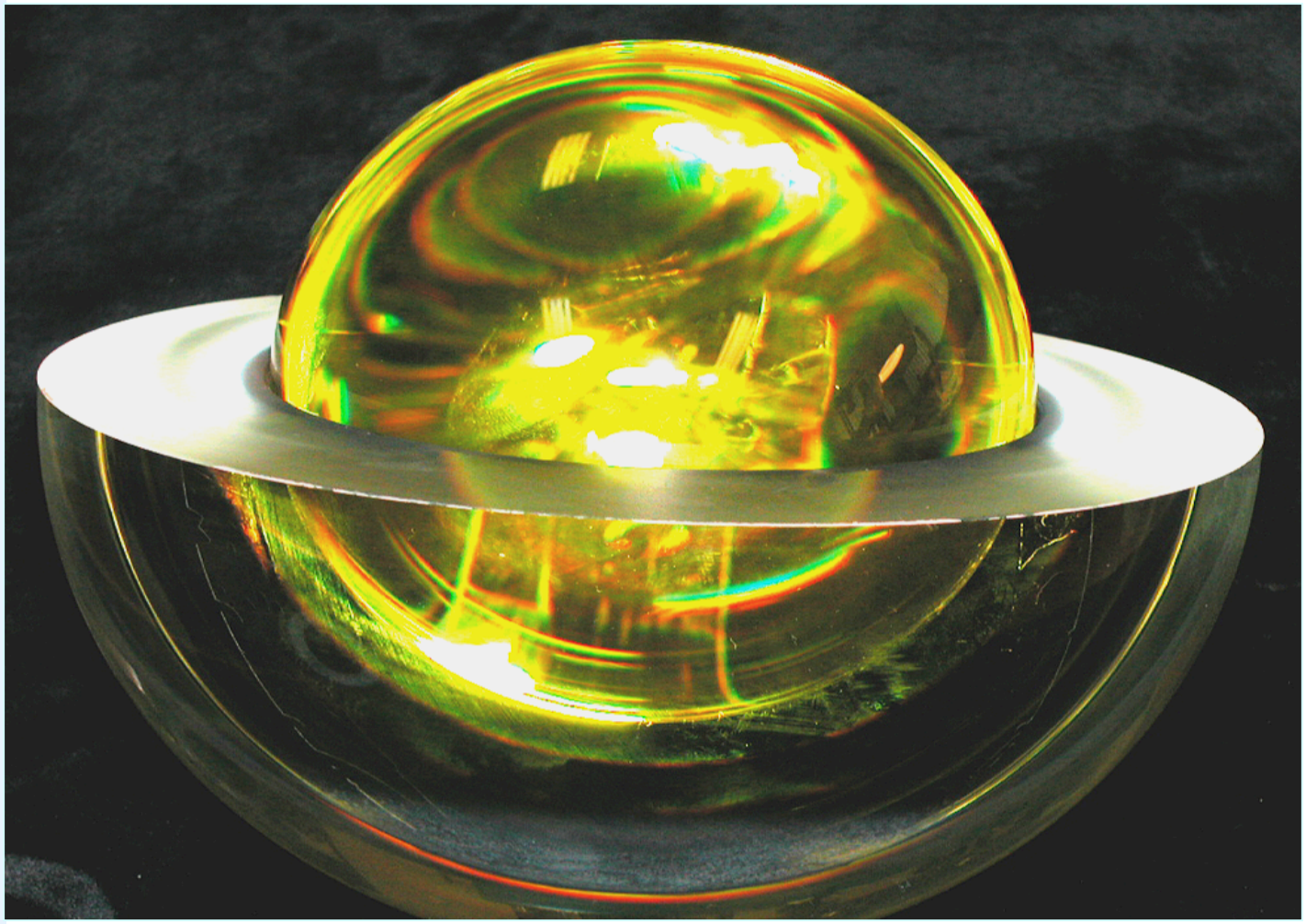
Graphical presentation of the results
(one millimeter random+systematic errors)

$$\tau_t \approx 2.4 \cdot \sigma_t$$





Microsatellite BLITS



Pulse repetition rate and frequency of measurements for some targets

Spacecraft	Accuracy	Laser pulse duration	Frequency of measurements	Pulse repetition rate
	$\Delta_N+\sigma_N$	τ_{tr}	f_{se} *	F_t *
Glonass	1 mm	<150 ps	~200 Hz	~5 kHz
Lageos	1 mm	<150 ps	~75 Hz	~1 kHz
BLITS	1 mm	<20 ps	~300 Hz	~1.5 kHz
BLITS	0.1 mm	<20 ps	~30 kHz	~1.5 MHz

* Dynamic range of signal variations has been taken into account

Summary

- *The obtained expressions allow an unambiguous determination of the F_t and f_{se} parameters for a SLR system operating in a single-electron detection mode with a given observation time T_N and values σ_N and Δ_N, as well as known parameters σ_t, σ_r and σ_d of the SLR system receive channel;*

- *with the LAGEOS return pulse duration of 180ps and the GLONASS return pulse duration of 520 ps (which in both cases corresponds to the transmit laser pulse duration 150 ps), the minimum required Ft values are approximately 1kHz for LAGEOS and 5 kHz for GLONASS (for 1 mm accuracy).*
  Correspondingly, the required minimum fse values will be then ~ 70Hz for LAGEOS and 200 Hz for GLONASS.

- *with the BLITS return pulse duration < 20 ps the required Ft values must be > 1.5 kHz and required fse values must be >300 Hz (for 1 mm accuracy).*
  The required Ft values for 0.1 mm accuracy must be > 1.5 MHz and required fse values must be >30 kHz.

НИИ ПРЕЦИЗИОННОГО ПРИБОРОСТРОЕНИЯ

Thank you! ☺