FEDERAL SPACE AGENCY

FGUP «Science-Research Institute for Precise Instrument Engineering»

About compliance of “GLONASS” S/C retroreflectors system with the requirements of International Laser Ranging Service standard

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IAG RESOLUTION #2

Placing Laser Retro-reflectors on Satellites of the Global Navigation Satellite System

The International Association of Geodesy, …

recommends

(i) that all future GNSS satellites carry precision laser retro-reflector arrays; and

(ii) that a careful pre-launch ground calibration/measurement of the center of mass offset of the array be provided.

i) IUGG - International Union of Geodesy and Geophysics
ii) IAG - International Association of Geodesy

Problems solved by quantum-optical systems (QOS) to increase accuracy of ephemerides, temporal and geodetic support for GLONASS

1. Metrological control of calculation accuracy of GLONASS ephemerides distributed in navigation messages.
2. Calculation and maintenance of communication parameters GGSK (PZ-90.02) with ITRF (ITRF - 1997, 2000, 2005)
3. Determination of geocentric coordinates of ground control complex basing on QOS coordinates calculated from laser ranging data of Lageos (USA) and ETALON (Russia) satellites.
4. Provision of required accuracy of geodynamic parameters by creation of collocation nodes with different types of measurement facilities: VLBI, QOS and one-way systems (OWS)

One-way (request-less) laser measurements

When photo receiver and time interval counter are installed onboard the S/C, its onboard time scale records arrival time (“STOP”) of laser pulses sent from the ground station at “START” times linked to the ground time scale.

In fact, the difference between “STOP” and “START” moments of time will have only components defined by the distance to the S/C and difference between onboard and ground time scales.

Mutual use of two-way and one-way laser measurements on all GNSS S/C

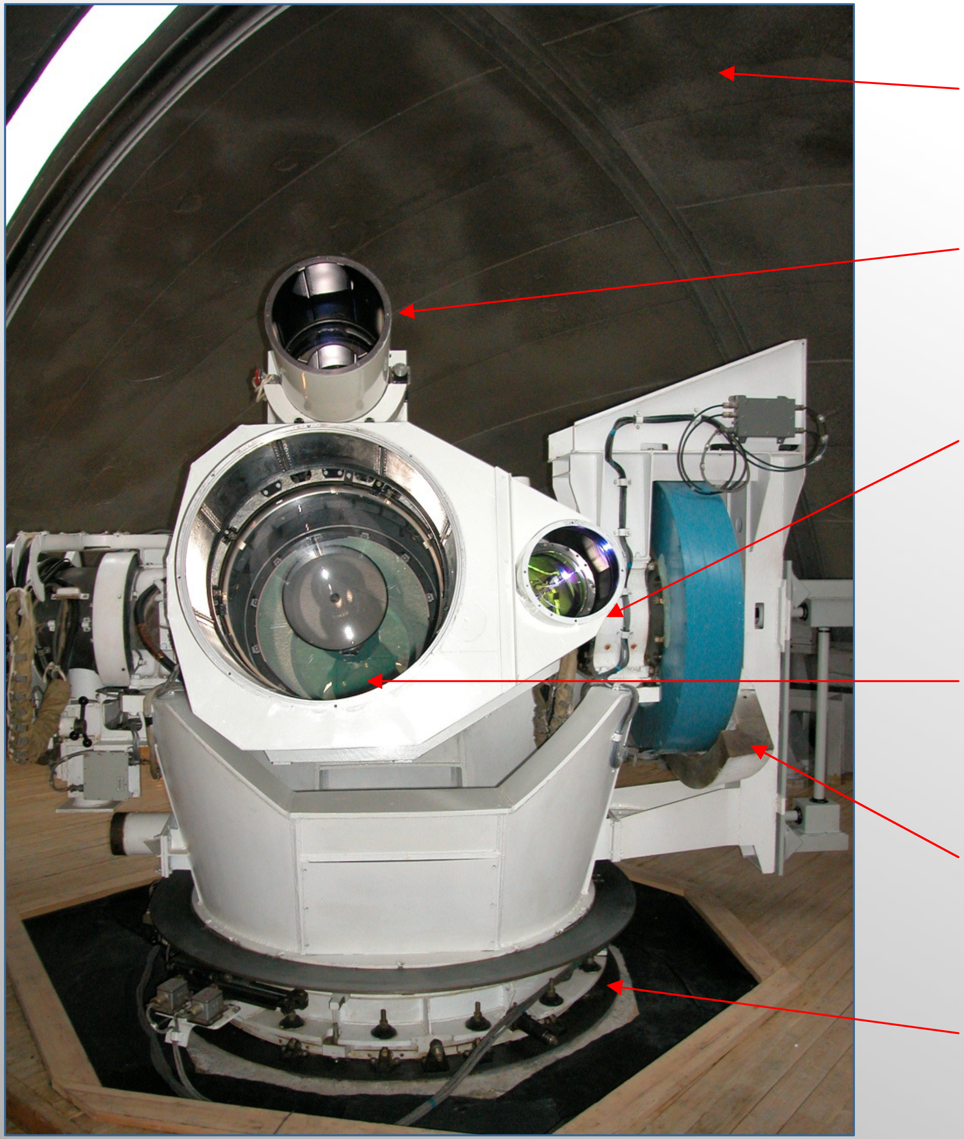
Will allow:

- to obtain high-accuracy direct difference between on-board and ground time scales;
- to calibrate one-way and two-way radio systems included in the GNSS;
- to provide transfer of time signals between remote sites

with accuracies unachievable in radio range..

Altay Optical/Laser Center (AOLC)

AOLC. Telescope overview



Dome fold

Wide-field lens dia. 350 mm, FOV 6.25 sq.deg

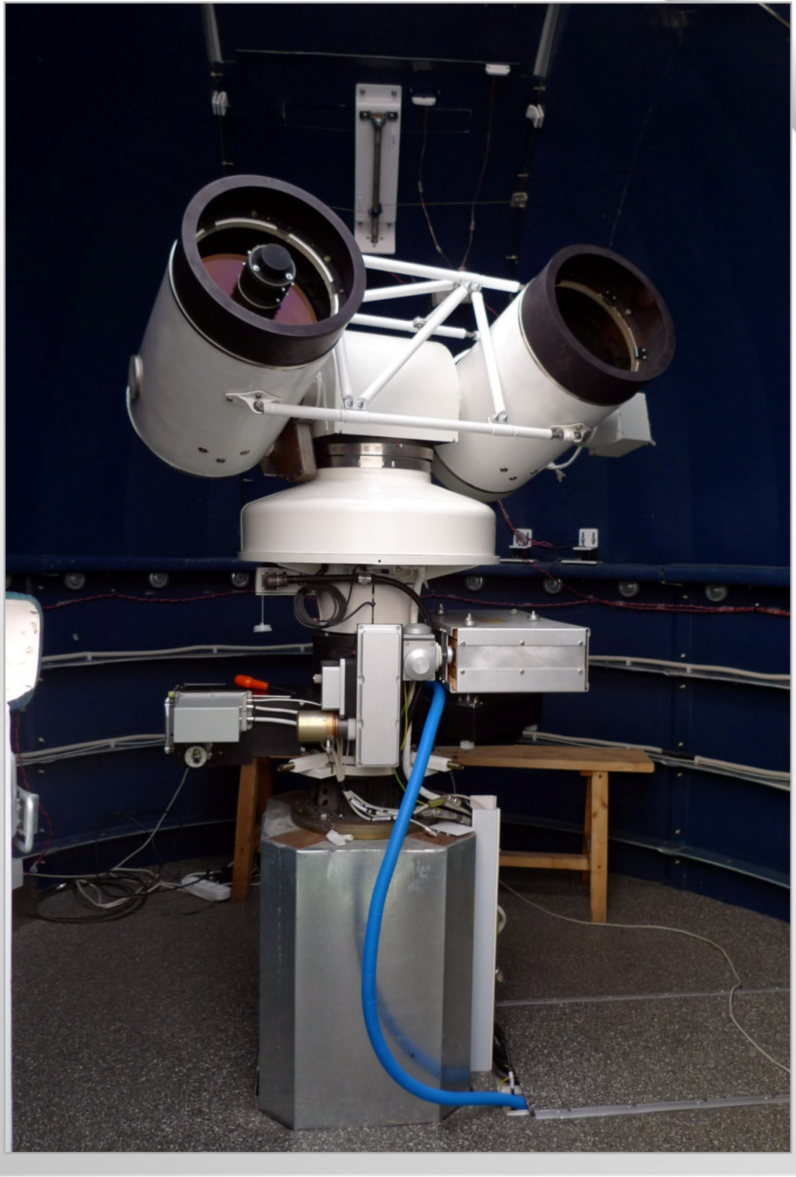
Laser beam collimator dia.200 mm

Main receive lens: dia. 600 mm, FOV 19x14 arc min

Torque motor

Mount

Sazhen-TM laser ranger in stationary dome

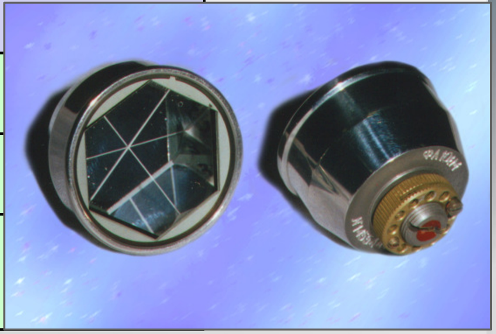


FGUP “IPIE” retroreflector optical systems

S/C type	Orbit altitude, km	Launch year	Number of S/C	Number of RR on S/C	Reflection coating type
Etalon - 1, -2 (Russia)	19 100	1989	2	2142	***Al***
GPS - 35, - 36 (USA)	20 150	1993, 1994	2	32	***Al***
GLONASS (Russia)	19 100	from 2000 to 2006	8	132	***Al***
REFLECTOR (Russia-USA)	1 020	2002	1	32	***Al***
Meteor-3M-1 (Russia)	1 020	2002	1	sphere	***Al***
LARETS (Russia)	690	2003	1	60	***Al***
MOZHAETS (Russia)	690	2003	1	6	***Al***
GLONASS-M (Russia)	19100	from 2003 to present	17	112	***Al***
GLONASS-M # 115(Russia)	19100	2008	1	112	***Total Internal Reflection***
GIOVE-A (ESA) (GALILEO)	23 916	2006	1	76	***Al***
GIOVE-B (ESA) (GALILEO)	23 916	2008	1	67	***Al***
GOCE (ESA)	295	2009	1	7	***Al***
BLITS 2009 (Russia)	832	2009 (planned)	1	autonomous sphere	***Al***
SPEKTR-R (Russia)	до 330 000	2010 (planned)	1	100	***Ag***

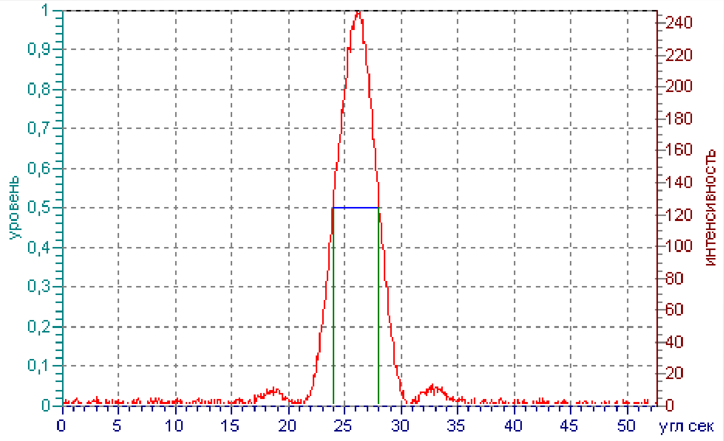
PARAMETERS OF SINGLE REFLECTORS

Parameter	Value, units
Mass in holder	31 g
Dimensions	∅38×32 mm
Equivalent aperture	∅28.2 mm
Prism material	Optical quartz glass
Equivalent cross-section	$\approx 10^{6}$ m^2
Operational wavelength λ	~ 0.2÷2 μm
Light transmission factor (λ = 0.532 μm**)** **with various coating of RR reflective sides** **(field of view 2W at level 0,1)**	
Aluminum	0.57 (± 35°)
Silver	0.82 (± 35°)
Total internal reflection (TIR) with deep polishing of sides	0.92 (± 17°)

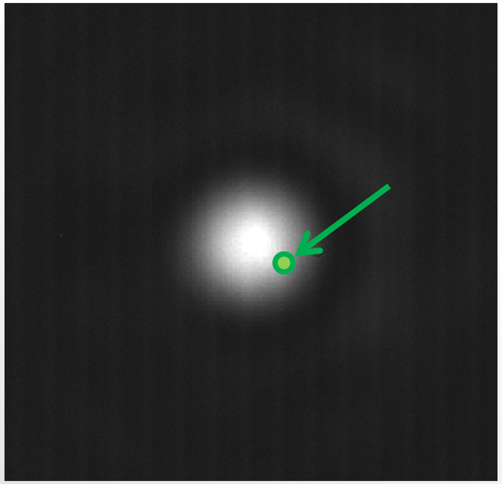


Influence of aberration of light on the efficiency of reception of reflected light

Directional pattern with Al and TIR

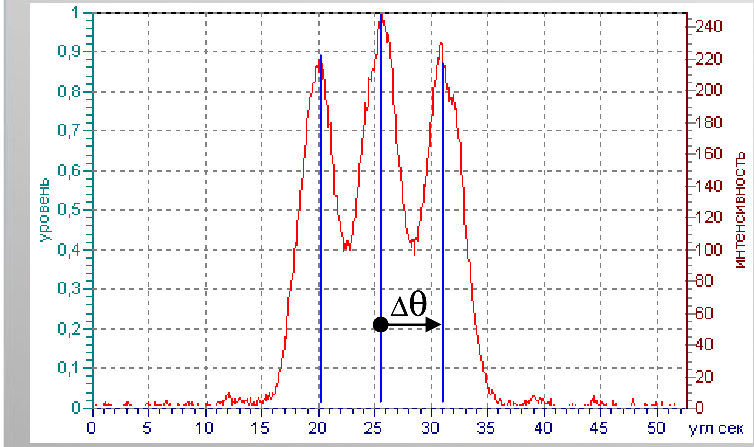


4.0 arc seconds

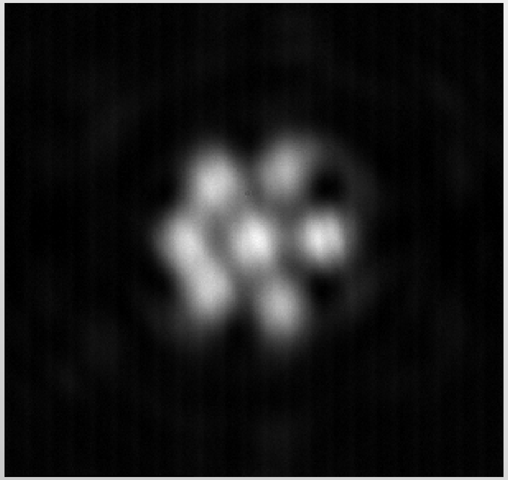


RR with aluminum coating

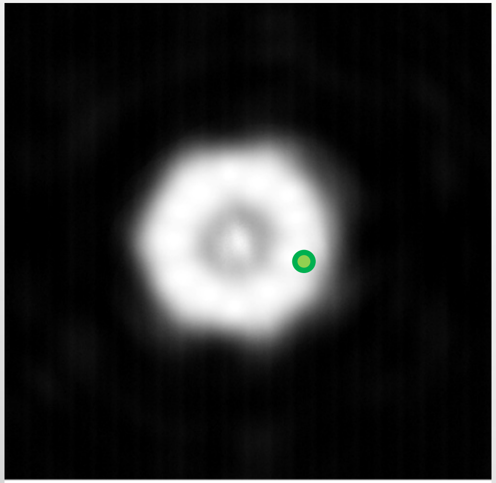
Position of laser ranger in the reflected pattern due to light aberration



$\Delta\theta$ = 5.4 arc seconds – light aberration for S/C GLONASS



RR with total internal reflection



Result of addition of several patterns of RR with TIR

Results of observation by ILRS stations of GLONASS spacecraft No. 102,109 (from 01.07.2008 to 30/06/2009) and 115 (from 04/04/2009 to 30/06/2009)

	station	G 99	G 102	G 109	G 115	K
1	7839 Graz	1650 (413)	980 (433)	1038 (375)	1813 (28)	1,48
2	7105 Greenbelt	91(247)	130 (439)	127 (616)	132 (54)	1,14
3	7110 Monument Peak	112 (200)	124 (337)	145 (431)	215 (132)	1,69
4	7080 MacDonald	78 (39)	61 (137)	68 (91)	155 (39)	2,25
5	7090 Yarragadee	106 (1107)	106 (1407)	110 (1930)	165 (348)	1,54
6	7501 Hartebeesthoek	71 (8)	67 (70)	53 (28)	91 (68)	1,43
7	7810 Zimmerwald	531(1052)	546 (1537)	517 (1636)	613 (489)	1,15
8	8834 Wettzell	95 (162)	85 (174)	93 (237)	153 (101)	1,68
9	7358 Tanegashima	513 (27)	371 (84)	600 (78)	552 (12)	1,12
10	7941 Matera	227(99)	275 (105)	135 (118)	830 (53)	3,91
11	7825 Mount Stromlo	61 (340)	48 (317)	70 (609)	72 (227)	1,21
12	7406 San Juan	18 (890)	19 (1166)	13 (306)	24 (341)	1,44
13	1873 Simeiz	31 (41)	24 (25)	25 (67)	27 (22)	1,01
14	1893 Katziveli	34 (212)	24 (348)	28 (358)	24 (43)	0,84
15	7840 Herstmonceux	240(138)	230 (202)	236 (200)	155 (20)	0,66
K (average for 15 stations)						1.503
K (weighted average for the same stations)						1.435

K - ratio of average number of responses per NP for G 115 to average number of responses per NP for the remaining three S/C (G99, G102, G109).

CONCLUSIONS:

While for previous GLONASS S/C, the size of the equivalent cross-section was accepted to be 70…80 million sq. meters based on D. Arnold calculations, for G-115 the size of the equivalent cross-section, based on the information above, is greater than 100 million sq. meters. This corresponds to ILRS standard for high-orbit navigation S/C.

ILRS Retroreflector Standards for navigation satellites

- Retroreflector payloads for GNSS satellites in the neighborhood 20,000 km altitude should have a minimum “effective cross-section” of 100 million sq. meters (5 times that of GPS-35 and -36)
- Retroreflector payloads for GNSS satellites in higher or lower orbits should have a minimum “effective cross-section” scaled to compensate for R**4 increase or decrease in signal strength
- The parameters necessary for the precise definition of the vector between the effective reflection plane, the radiometric antenna phase center and the center of mass of the spacecraft should be specified and maintained with the accuracy of 0.1 10^{-9} of range.