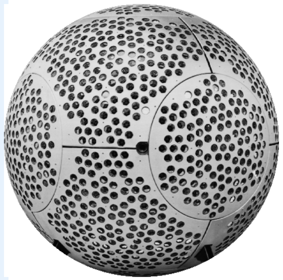
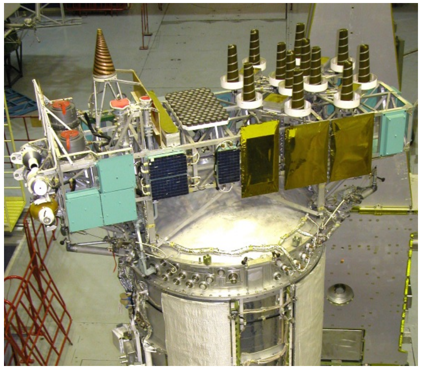
OPEN JOINT-STOCK COMPANY «RESEARCH-AND-PRODUCTION CORPORATION "PRECISION SYSTEMS AND INSTRUMENTS»







New ideas in retroreflector arrays development

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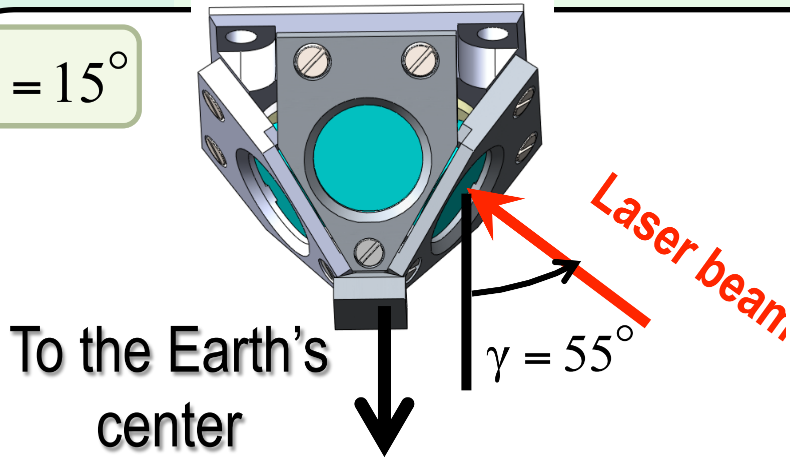
USA, 2014

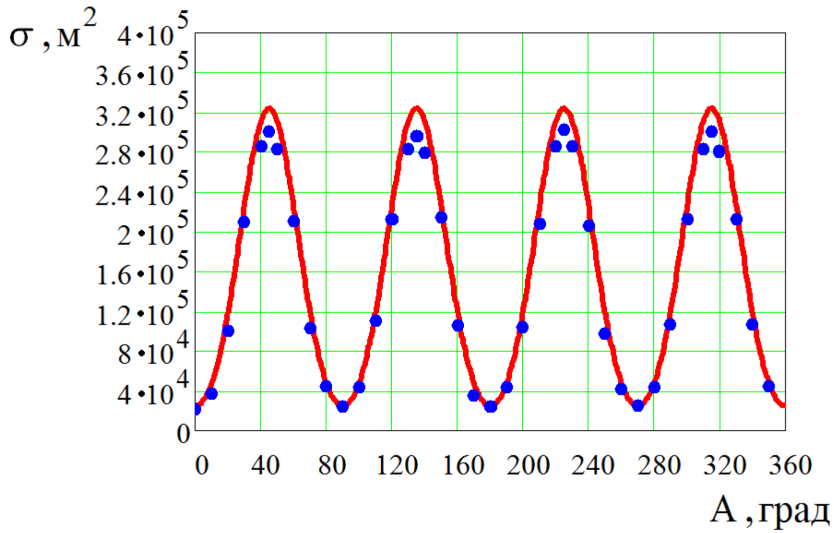
New laser retroreflector array

1. LEO array – “PIRAMIDA”
2. “BLITS-M”
3. Ring retroreflector array for GLONASS
4. Luna’s arrays

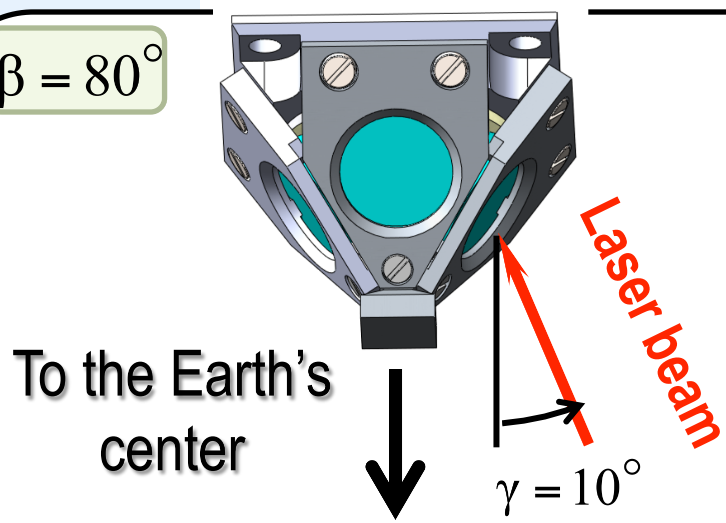
Cross-section of "Piramida"

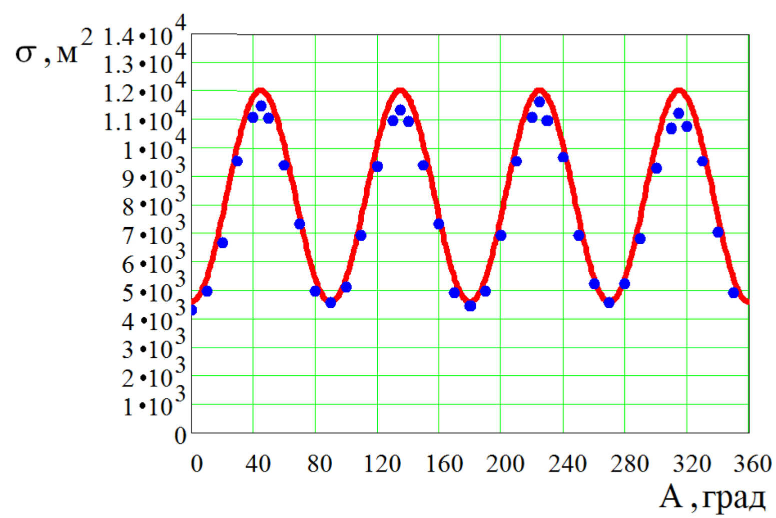
$\beta = 15^\circ$



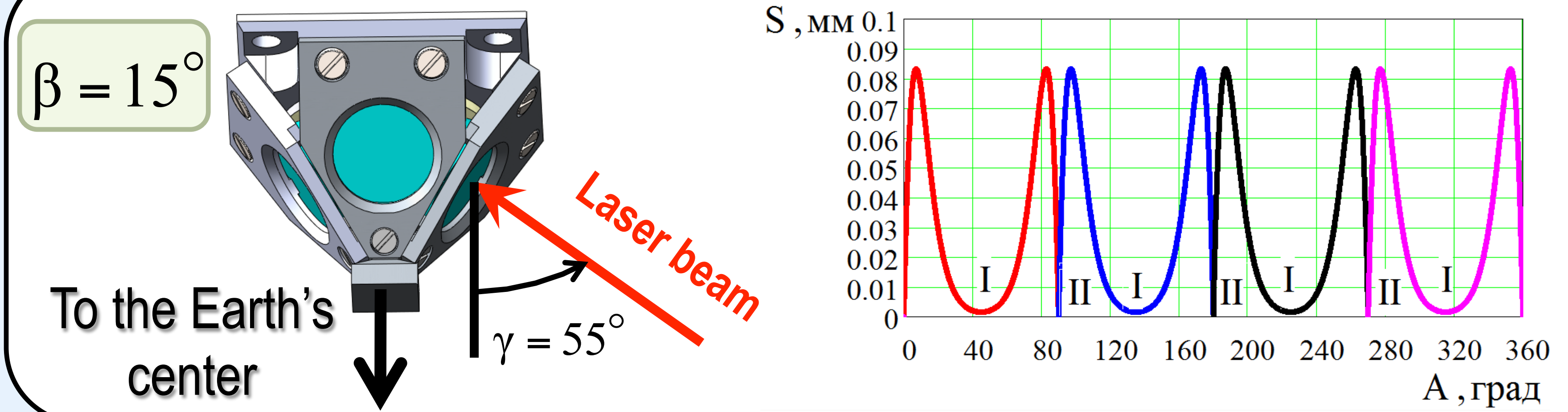


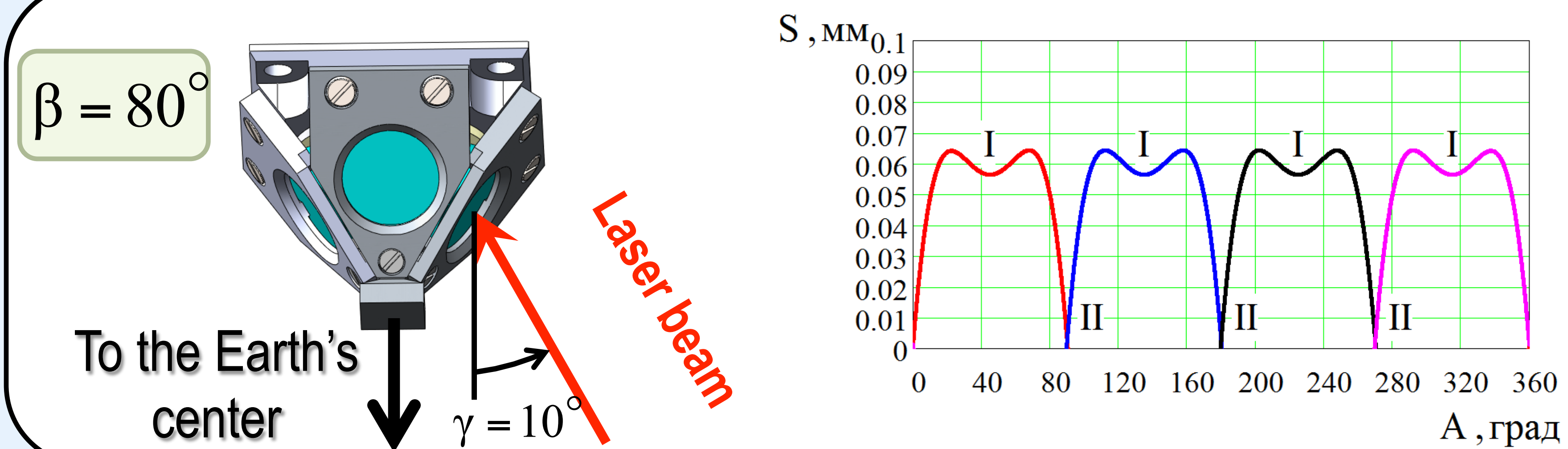
$\beta = 80^\circ$



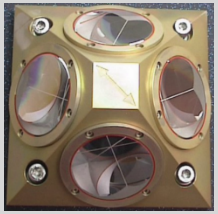
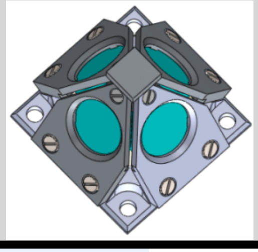


Target error



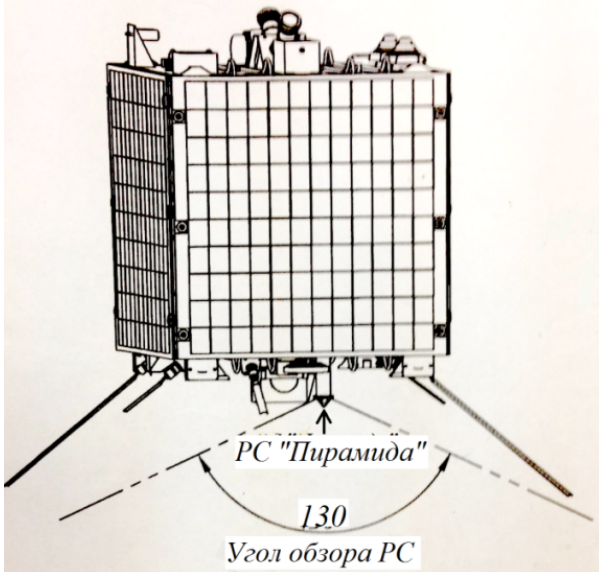


Retroreflector arrays comparison

Retroreflector array	Number of CCR	Mass	Size	Target error
Champ 	4	210 g	110x110x48 mm	± 5 mm
CryoSat-2 	7	300 g	∅114x50 mm	± 6 mm
Piramida 	4	30 g	40x40x30 mm	> ± 1 mm

Conclusions

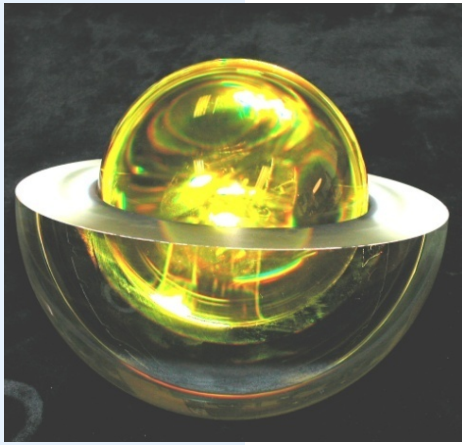
- Construction of the compact retroreflector system allows to reduce the measurement error of the range to a satellite up to 1 mm;
- RCS is in the following limits: from $3{,}2\cdot10^{5}$ m^2 up to $4\cdot10^{4}$ m^2 at the elevation angle of 20° and from $1{,}2\cdot10^{4}$ $м^2$ up to $5\cdot10^{3}$ $м^2$ in the zenith area at the elevation angle 80°
- Piramida will be set to student's spacecraft **«Baumanets-2»:**



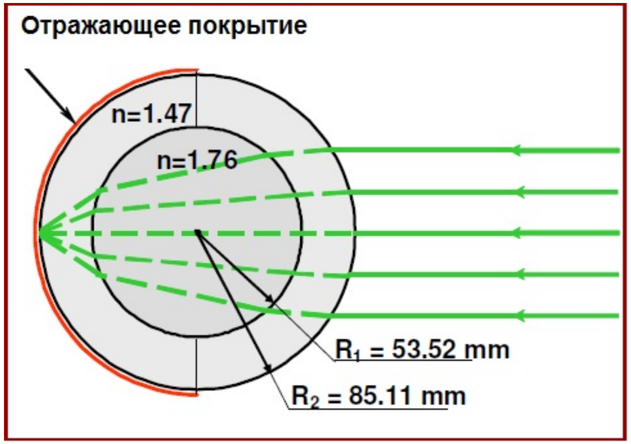
Spherical glass satellite «BLITS»

SC «Meteor-M» with spherical glass nanosatellite «BLITS» on board was launched on September 21, 2009. ILRS announced its support to the «BLITS» orbit. Basic parameters:

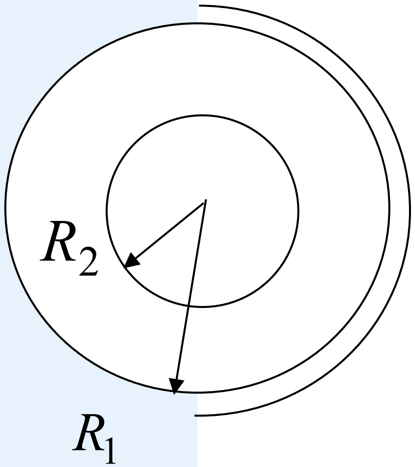
- diameter………………………………………………..170 mm
- mass………………………………………...……..7.5 kg
- orbital altitude…………………………………….. 835 km
- CS………………………………………….......100000 m^2
- target error………………………………….< 100 micrometers



Spherical satellite «BLITS» in details



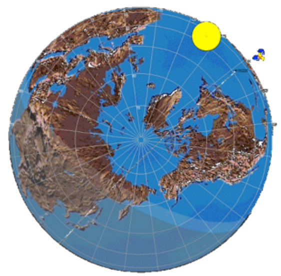
Construction of SC «BLITS-M»

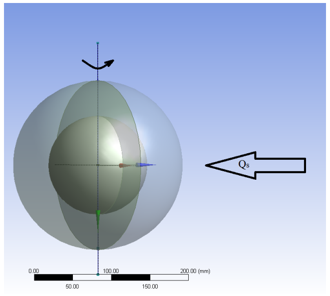


Interference reflective coating

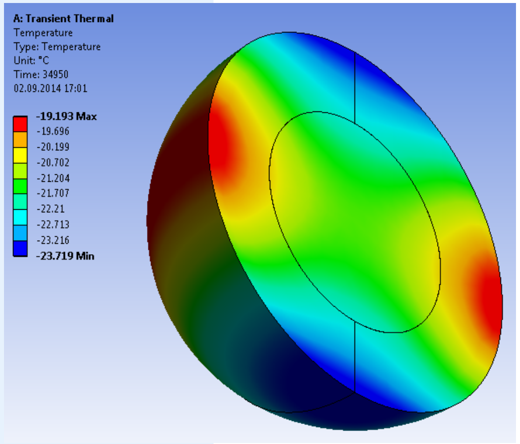
Inner sphere radius R_2	64 mm
Inner sphere material	TF105
Outer radius R_1	110,4 mm
Outer lenses material	K108
Mass	17 kg
Ballistic coefficient	440 kg/m2
Altitude	2000 km
CS	$(2 \div 3) \cdot 10^6$ m^2

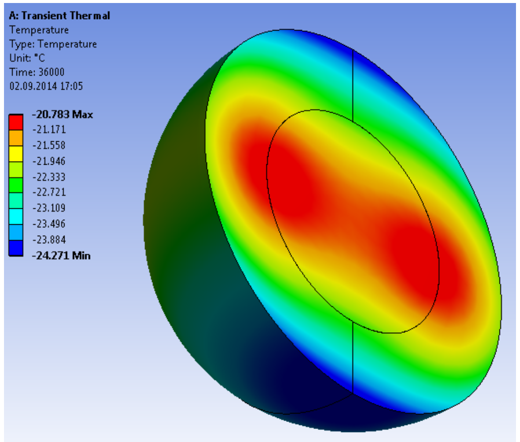
Orbital plane is parallel to the direction to the Sun

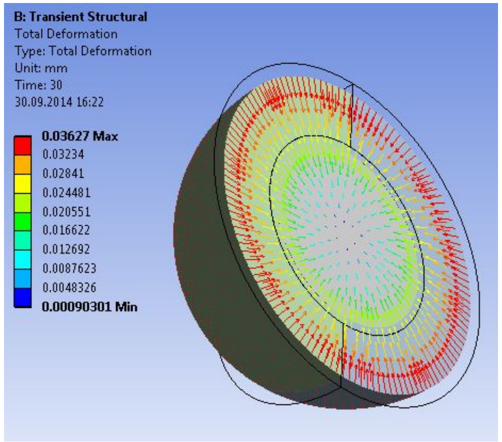




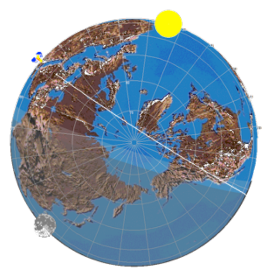
Temperature distribution depending on SC size and thermal deformation for orbit №1.
a – before entering the Earth's shadow, b – before leaving it.

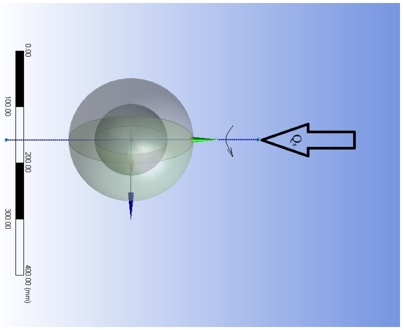




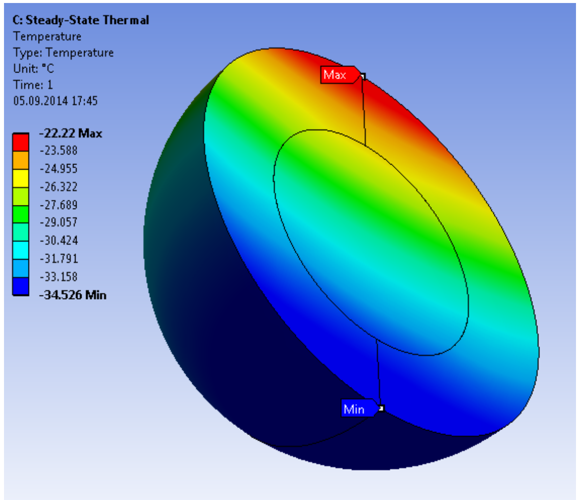


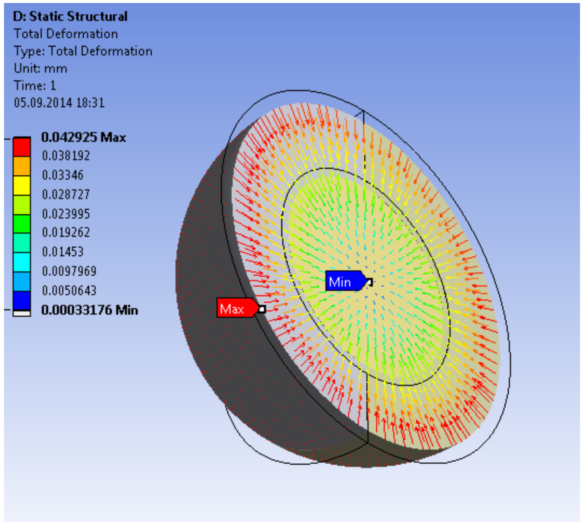
Orbital plane is perpendicular to the direction to the Sun





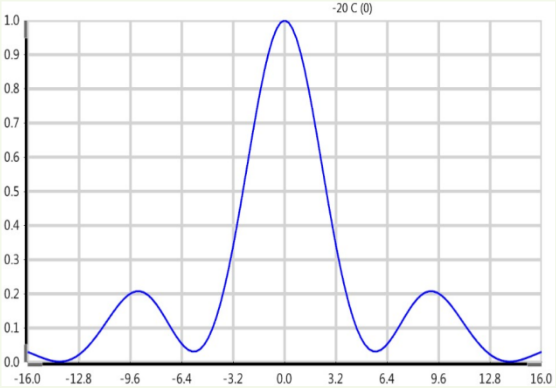
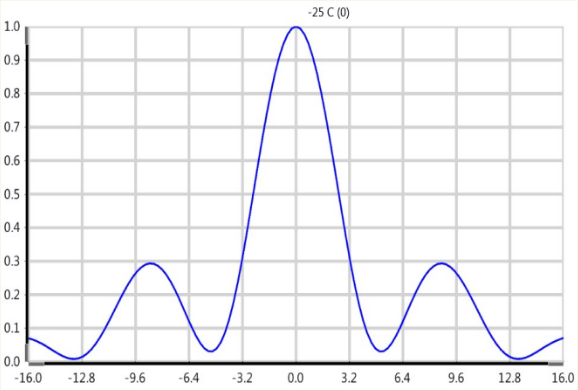
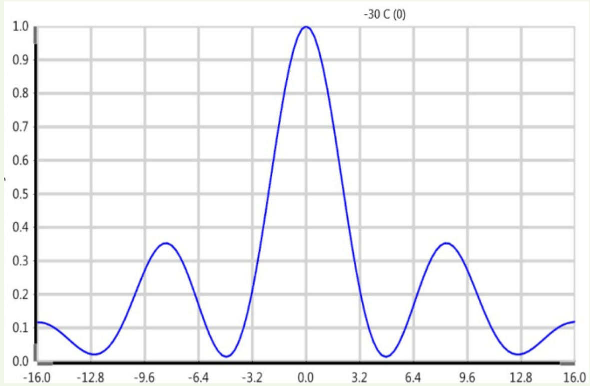
Temperature distribution depending on SC size and thermal deformation for orbit №2





Temperature effect on the SC «BLITS-M» diffraction pattern (FFDP)

CS at the FFDP axis is equal to $(2 \div 3) \cdot 10^6$ m^2

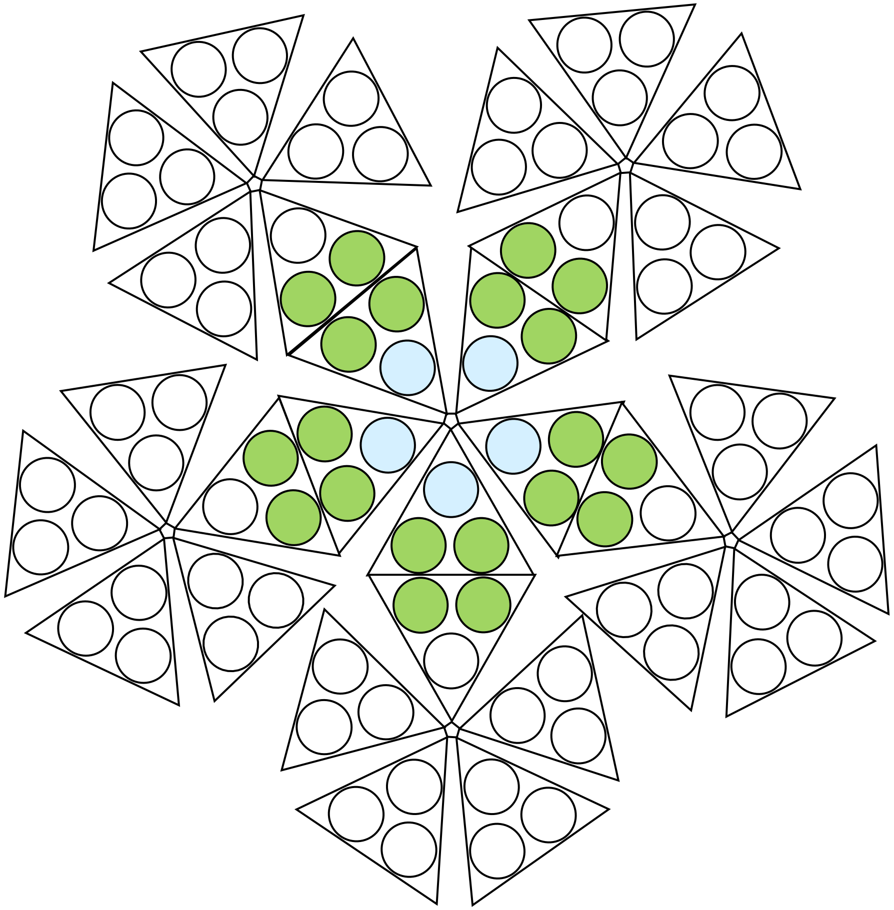
$T = -20^{\circ} C$	$T = -25^{\circ} C$	$T = -30^{\circ} C$
		

Concept of the SC «BLITS-S» construction

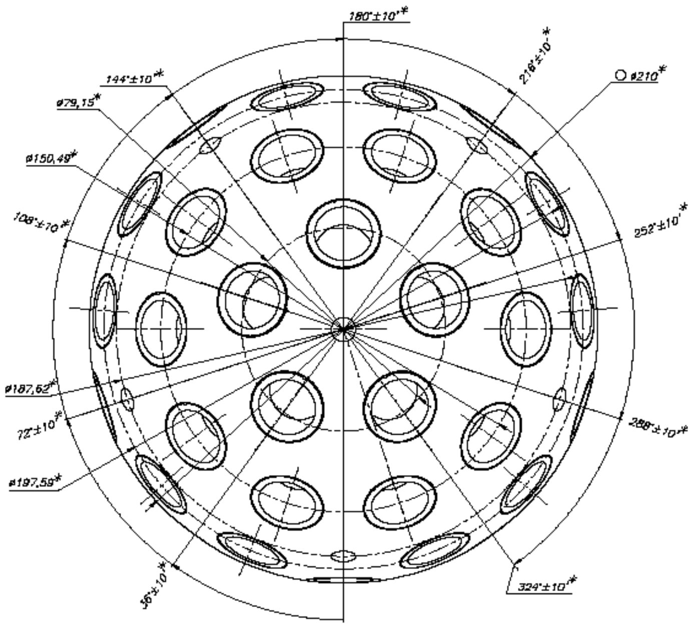
Requirement	Solution	Implementation
Zero signature	Always reflects just one CCR	60 CCR. Maximum angle of incidence – 14^{o}, aperture – 24 mm and blend altitude – 20 mm.
Increasing of CS	CCR size and faces coverage optimization	CCR with a phase-correcting coating of lateral faces for the FFDP formation without a central lobe.
Absence of the “dead” zones where none of the CCR reflects	Selecting both optimal angle between neighboring CCRs and maximum angle of incidence	Angular distance between any neighboring CCRs is approximately equal to the double angle of incidence.
Minimal variation of a systematic correction	Reduction of the sphere’s diameter. Reduction of the maximum angle of incidence to CCR at the expense of blends	Sphere’s diameter by the entering faces of CCR is equal to 168 mm and the carrier sphere’s diameter – 210 mm.
Increasing of ballistic coefficient (BC)	Increase of the carrier sphere’s diameter and its material density	For a heavy flint (TF5) the mass is equal to 18 kg, And BC is equal to 550 kg/m^2.

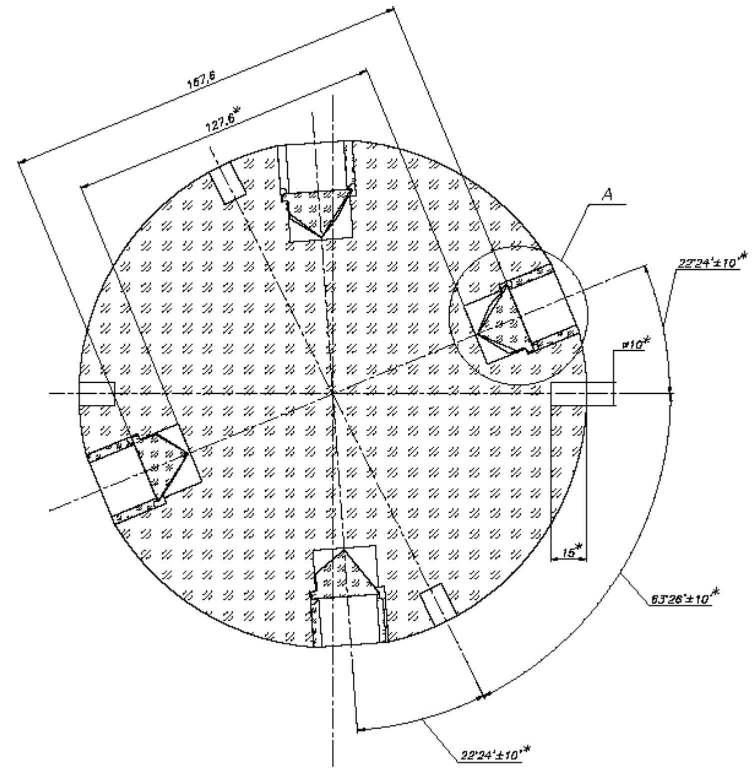
CCRs arrangement on SC «WESTPAC»

This is an icosahedron. 3 CCR x 20 faces = 60 CCR.



Construction of SC «BLITS-S»





Comparison of SC «BLITS», «BLITS -M» and «BLITS-S»

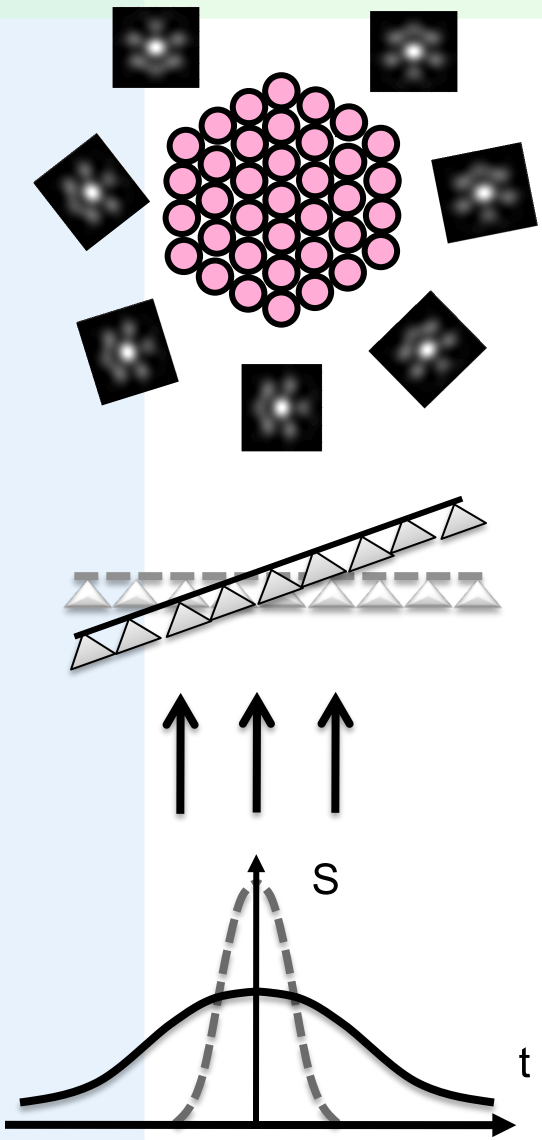
Characteristic	«BLITS»	«BLITS-M»	«BLITS-S»
Diameter	170, 3 mm	220,8 mm	210 mm
Mass	7,46 kg	17 kg	18 kg
Ballistic coefficient	327 kg/m^2	435 kg/m^2	550 kg/m^2
Target error	0,1 – 0,3 mm	0,1 – 0,3 mm	0,6 – 1 mm
Signature	«zero»	«zero»	Minor extension of a signal
RP type	Central lobe with a ring-shaped minor-lobe	Central lobe with a ring-shaped minor lobe	Six minor lobes
RCS for 7 – 8 ang. sec.	$(0{,}1 \div 0{,}2) \cdot 10^6$ м^2	$(0{,}5 \div 0{,}8) \cdot 10^6$ м^2	$(1{,}0 \div 1{,}4) \cdot 10^6$ м^2
Signal type at the angular velocity of 10 turns/minute	Clusters with the interval of 3 seconds	Clusters with the interval of 3 seconds	Sawtooth signal with the period of 0.5 seconds

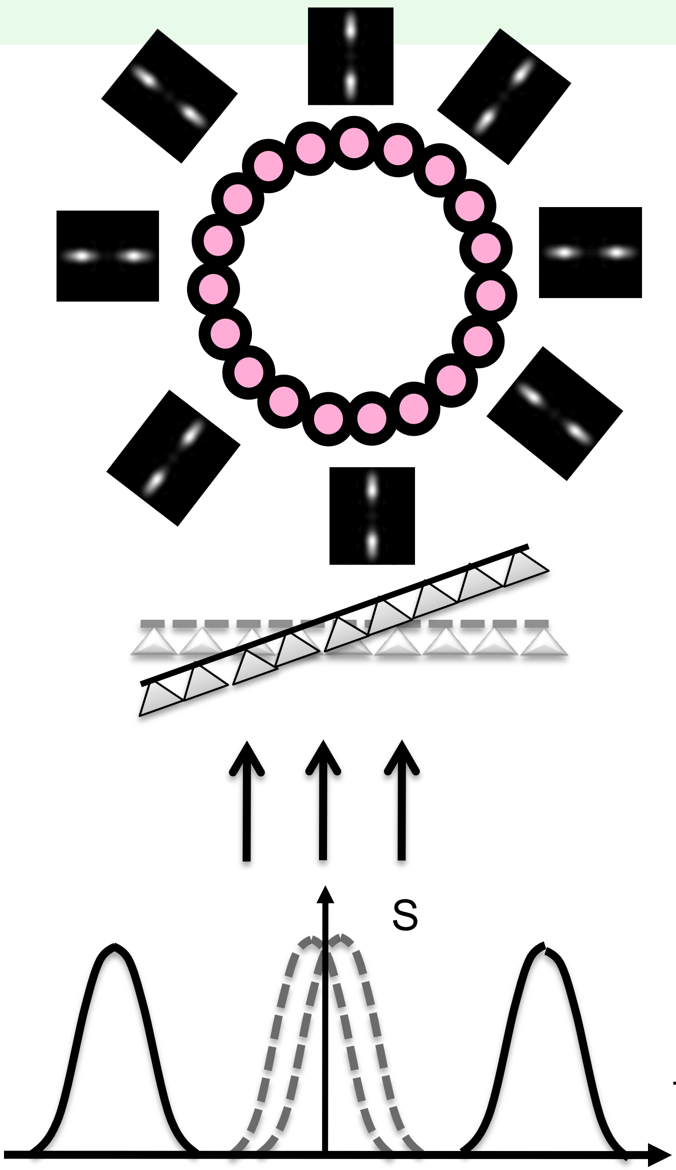
The ring retroreflector array for GLONASS

Basic ideas:

1. Increased aperture CCRs: 42 – 48 mm
2. DAO: 2” – 3” (single DA)
3. Interference dielectric coatings for reducing of solar heating influence
4. Orientations of two-spot FFDP along the radius of RRA

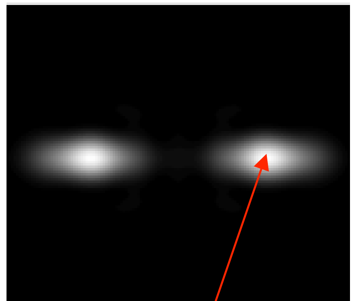
Optimization of LR-array configuration



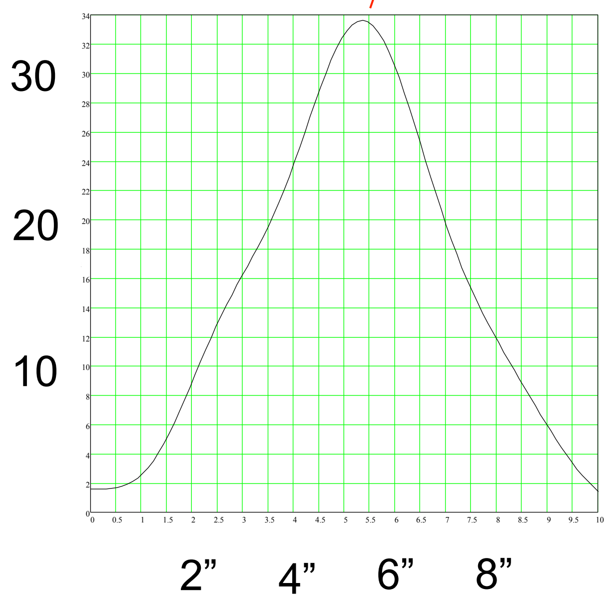


CCRs with DAO + coatings.
Diameter 48 mm. Dihedral angle 2,4”

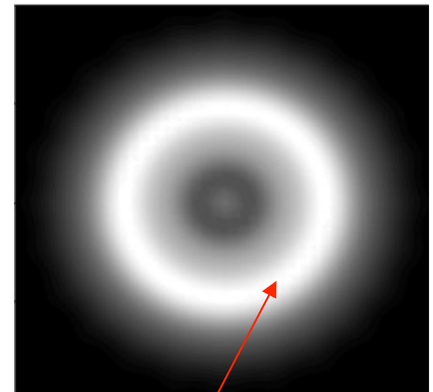
1 CCRs



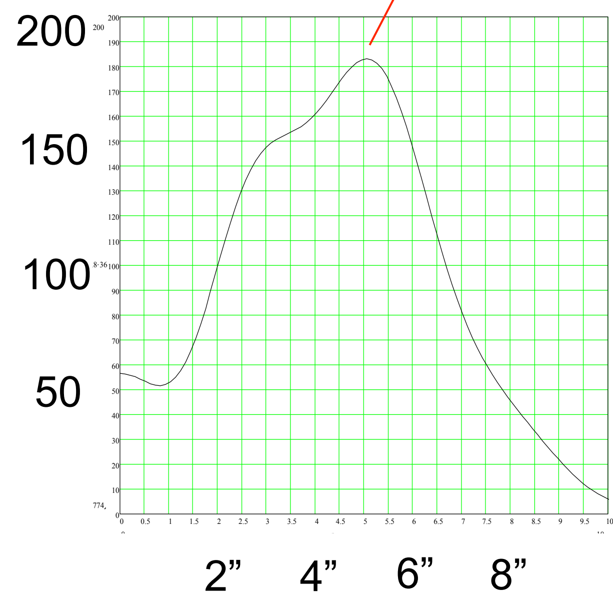
CS ($\cdot 10^6$ м²)



36 CCRs

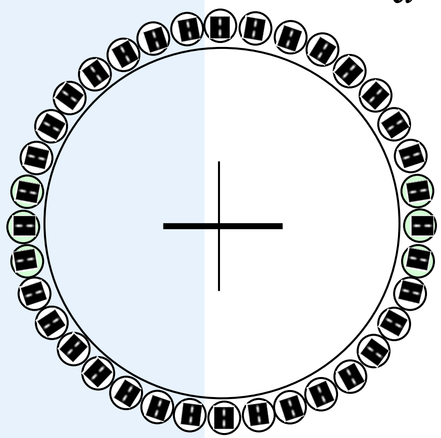


CS ($\cdot 10^6$ м²)

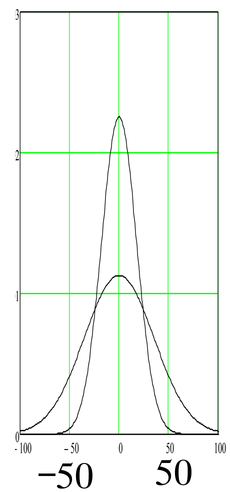


Ring two-spot CCR array for GLONASS

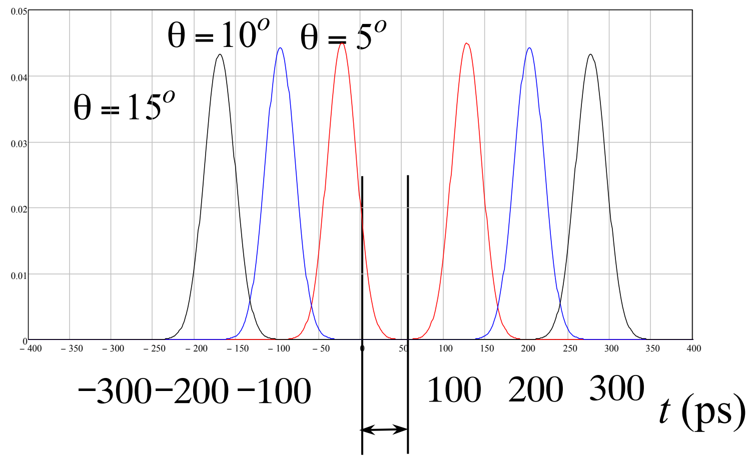
$R = 265$ mm
$d = 48$ mm



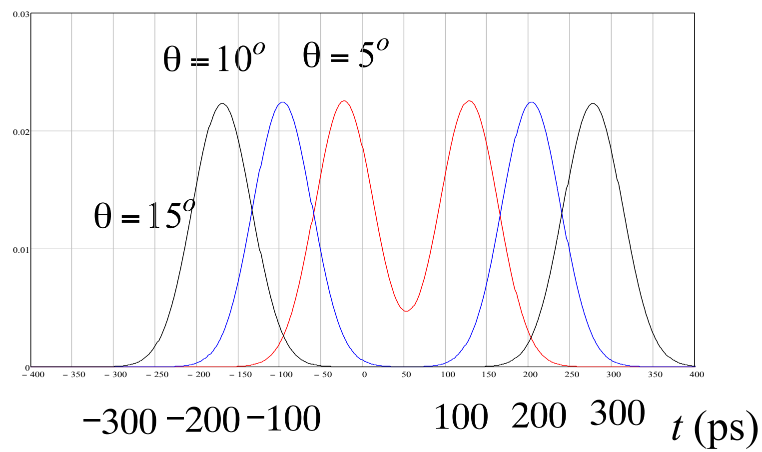
Incident pulse



$2\tau = 50$ ps



$2\tau = 100$ ps



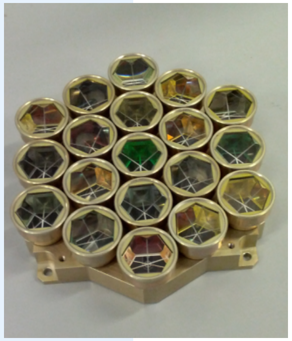
Standard deviation

	$\theta = 5^o$	$\theta = 10^o$	$\theta = 15^o$
50 ps	8 mm	8 mm	8 mm
100 ps	16 mm	16 mm	16 mm

Variants of Luna's arrays

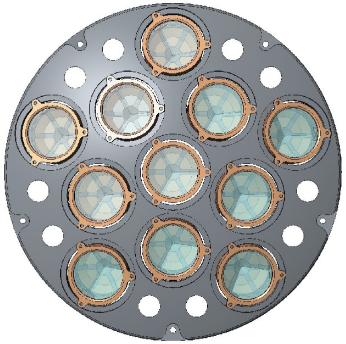
Base characteristics:

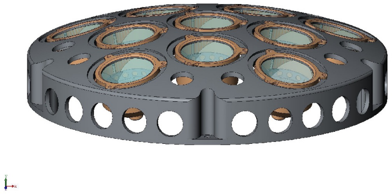
1. Standard CCRs: 28 mm; DAO: 0.
2. Interference dielectric coatings.
3. Compact array of 19 CCR.
4. Size = 160 mm. Mass < 1 kg.



$CS = (2,3 - 2,5) \cdot 10^8 m^2$

1. CCRs: 42 - 48 mm; DAO: 0.
2. Interference dielectric coatings.
3. **Non-planar** array of 11 - 13 CCR.
4. Size = 310 mm. Mass < 2 kg.





$CS = (1,3 - 1,5) \cdot 10^8 m^2$

Conclusions

Thus, new technical and technological solutions provide

- For LEO spacecrafts – a significant increase of laser ranging accuracy (< 1 mm) and decrease of mass (50 g)
- For MEO spacecrafts – new super accuracy “BLITS”
- For navigation satellites - a significant increase of the retroreflector array cross-section and get a higher laser ranging accuracy
- For Luna’s station – compact and enough easy arrays with sufficient accuracy