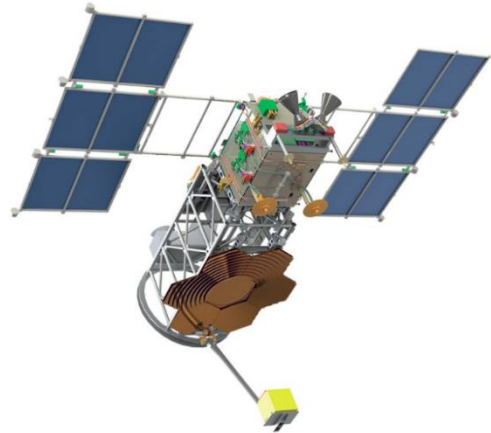




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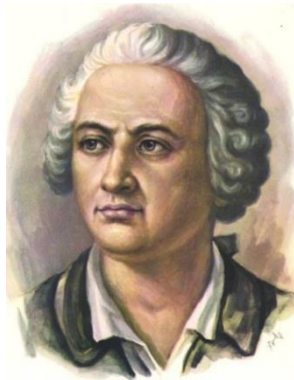
## **Preliminary results of the space laser ranging experiment of spacecraft «Lomonosov»**

**A.S.Akentyev, A.L.Sokolov, M.A.Sadovnikov, V.D.Shargorodskiy,  
V.P.Vasiliev**

**20<sup>th</sup> International Workshop on laser ranging  
Potsdam. 2016**

# Lomonosov

**Mikhail Lomonosov**  
(11.19.1711 – 04.15.1765)



**Lomonosov Moscow State University**



**SC «Lomonosov» was launched  
in 28 April 2016 from the new  
cosmodrome “Vostochniy”**

Scientific equipment is aimed at studying:

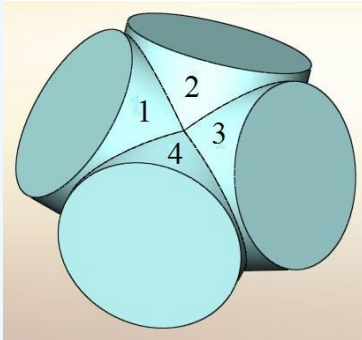
- the cosmic rays of the extremely high energy ( $10^{19} - 10^{20}$  eV).
- the space gamma-bursts.
- the transient luminous phenomena in the upper atmosphere.

## New laser retroreflector arrays

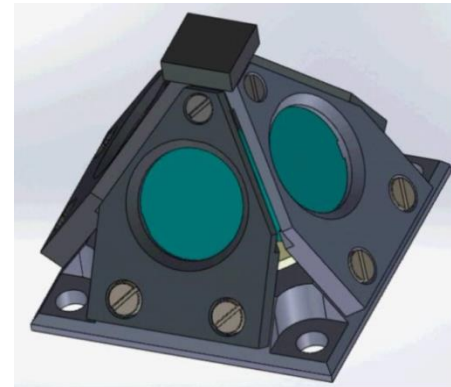
Array	Mass	Size (mm)	Cross section for aberration angle
Array "PYRAMID" for LEO-satellites	60 g	40x40x20	$(1 - 5) \cdot 10^4 \text{ m}^2$
SC "BLITS-M"	17 kg	R = 110	$(0,2 - 0,3) \cdot 10^6 \text{ m}^2$
SC "GLASS"	20,5 kg	R = 110	$(1,0 - 1,1) \cdot 10^6 \text{ m}^2$
Ring retroreflector array for GLONASS	4,0 kg	R = 350	$(1,7 - 1,9) \cdot 10^8 \text{ m}^2$
Array for SC "Luna-GLOB"	0,95 kg	190 x 170 x 45	$(2,3 - 2,5) \cdot 10^8 \text{ m}^2$


## The array “PYRAMID” for LEO-satellites

Location of corner-cube reflectors (CCRs)

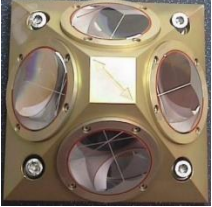


View of the assembly

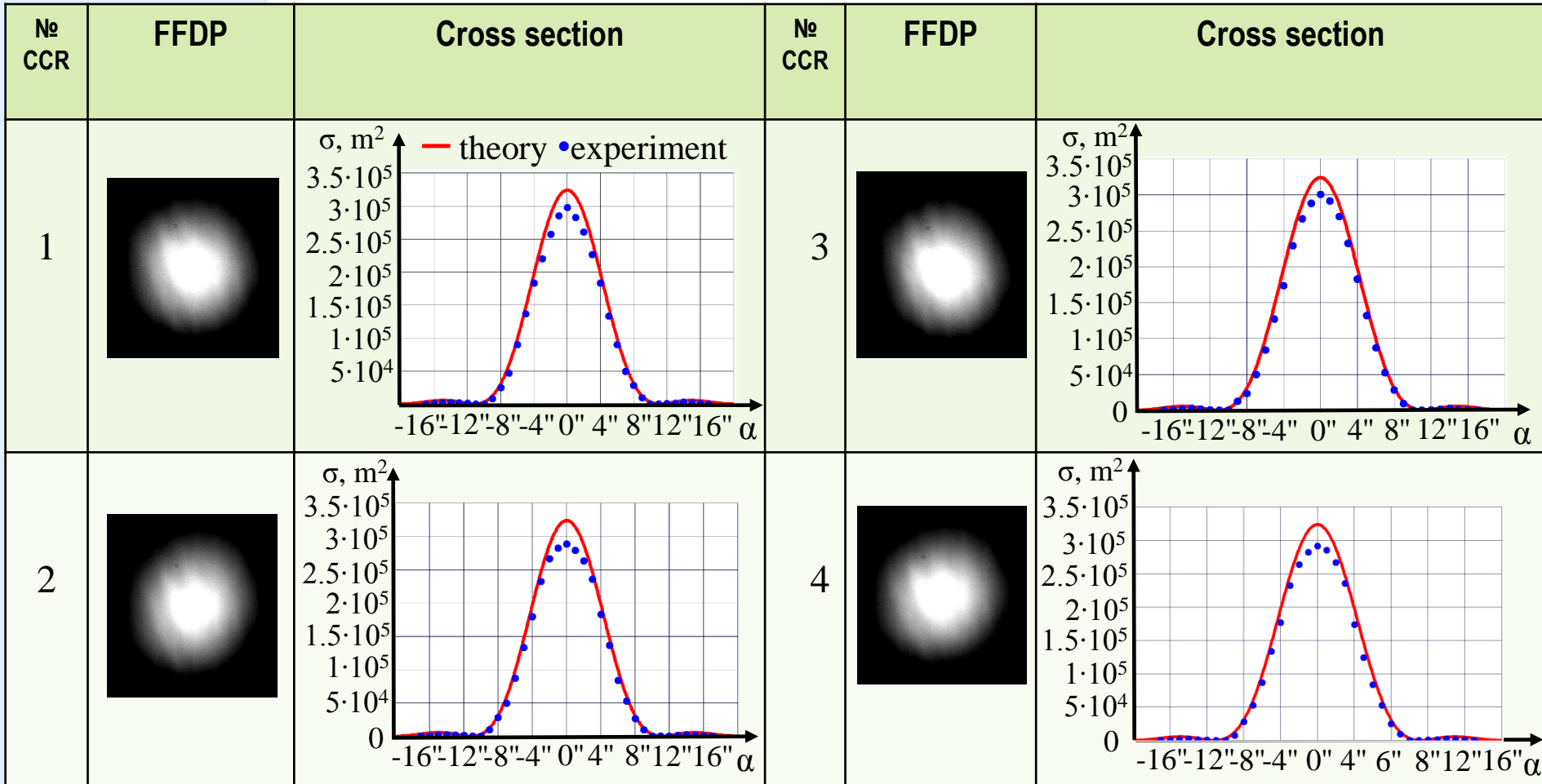


“Pyramid”	Mass	Size	Attitude	Target error	Average cross section
	60 g	40x40x30 mm	< 1000 km	< 0,5 mm	$3 \cdot 10^4 \text{ m}^2$

## Comparison of retroreflector arrays

SC and retroreflector arrays	Number of CCRs	Mass	Size	Target error
<b>Champ</b> 	4	210 g	110x110x48 mm	< 5 mm
<b>CryoSat-2 and other</b> 	7	300 g	Ø114x50 mm	< 6 mm
<b>Pyramid</b> 	4	60 g	40x40x30 mm	< 0.5 mm

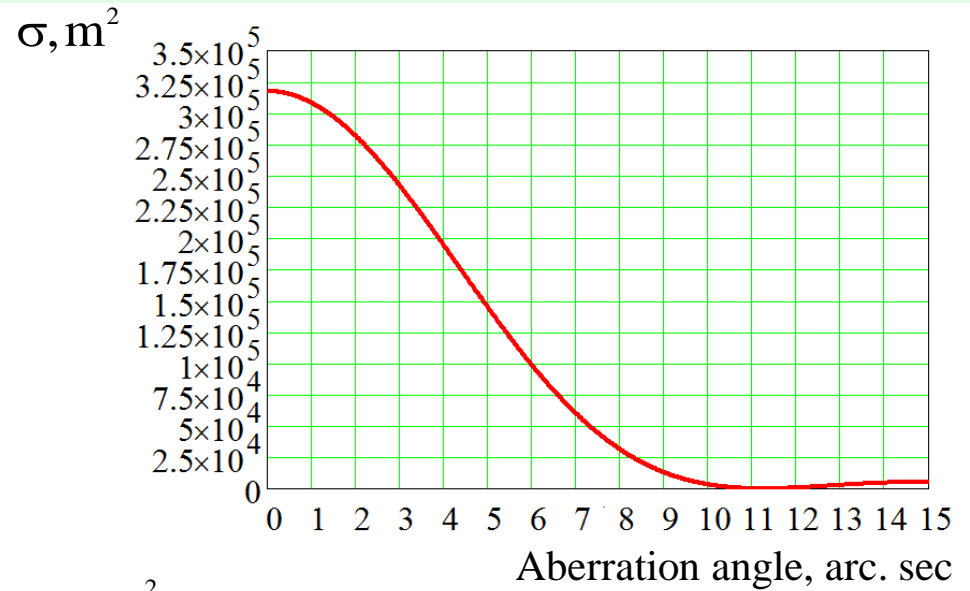
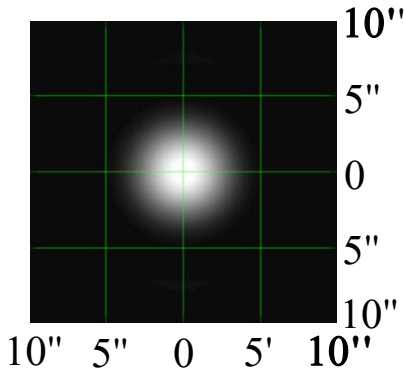
# Cross-section of the corner-cube reflectors



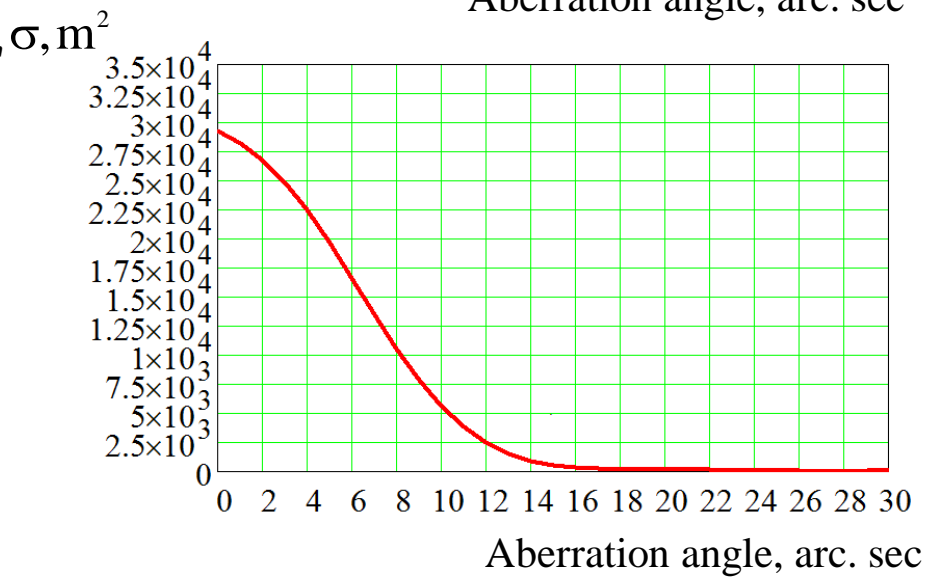
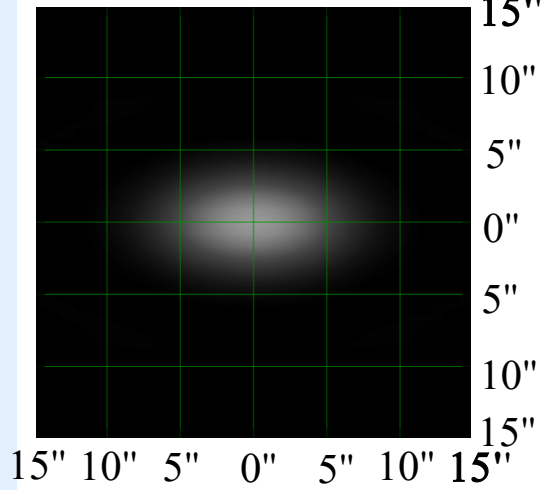
**Aperture size is 12 mm**

# Far Field Diffraction Pattern (FFDP) and cross-section of CCR for «Pyramid»

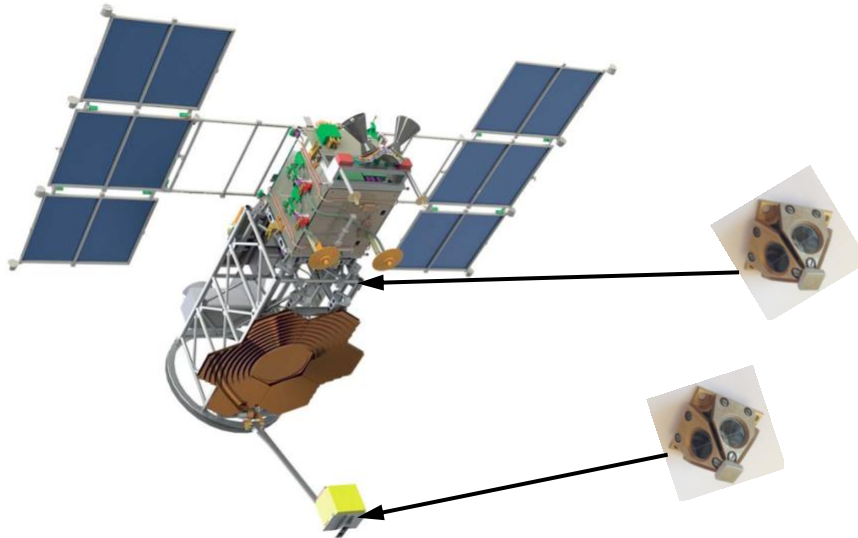
Incident angle = 0°



Incident angle = 30°



## Two retroreflector arrays «Pyramid» for SC «Lomonosov»



Orbit type	sun-synchronous
Orbit altitude	500 km
Inclination	97,6°
Spacecraft mass	620 kg
Exploitation period	3 years

**The purpose of the retroreflectors installation on the SC "Lomonosov":**

**additional emergency monitoring of rod photodetectors opening by recording the time interval between the pulses, reflected from two retroreflector arrays "Pyramid";**

**And also**

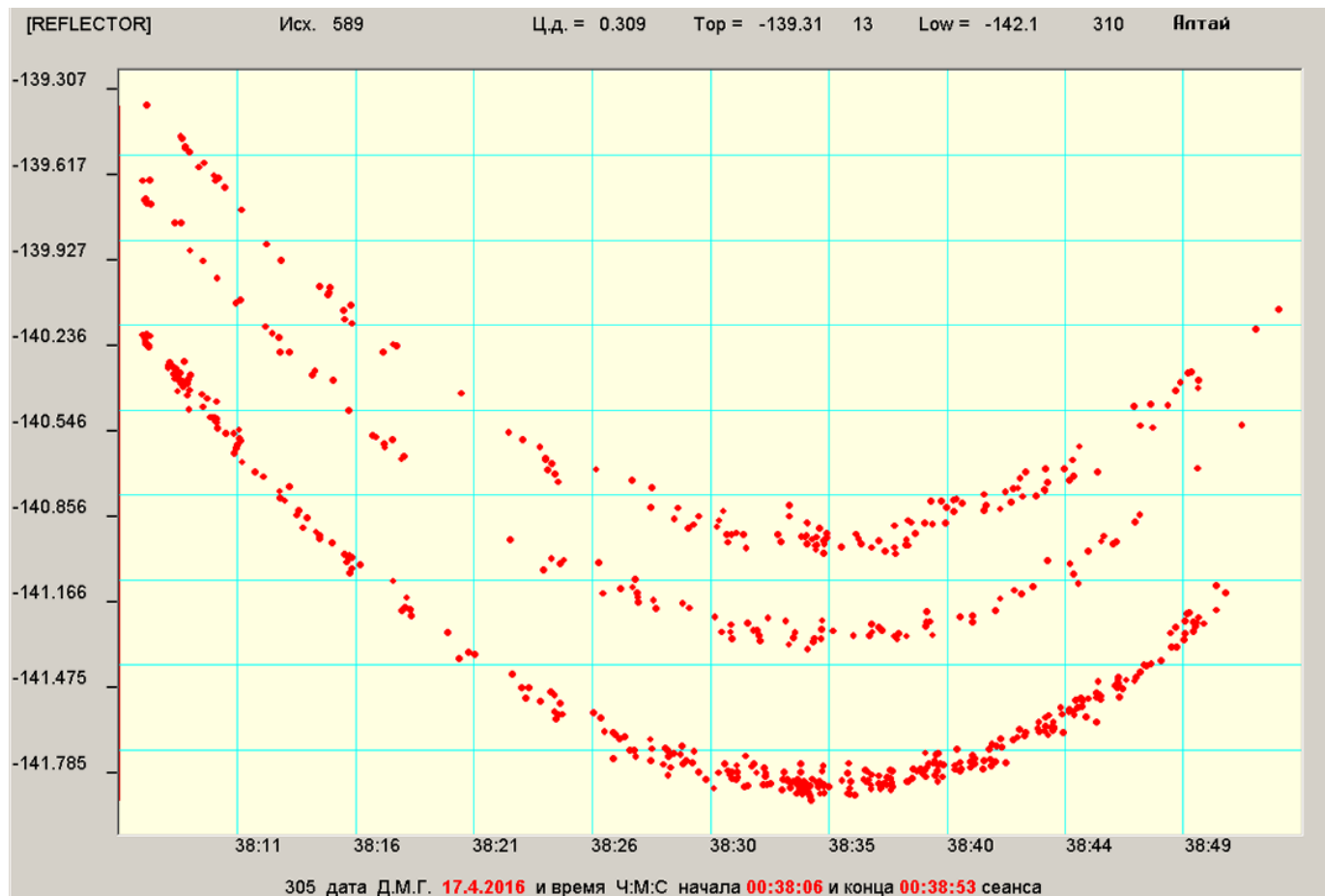
- determining of the spacecraft orientation;**
- construction of the orbit for the radio equipment calibration;**
- evaluation of operating and accuracy characteristics of RA in space.**



## SC «Reflector». Ranging session of the Altay station

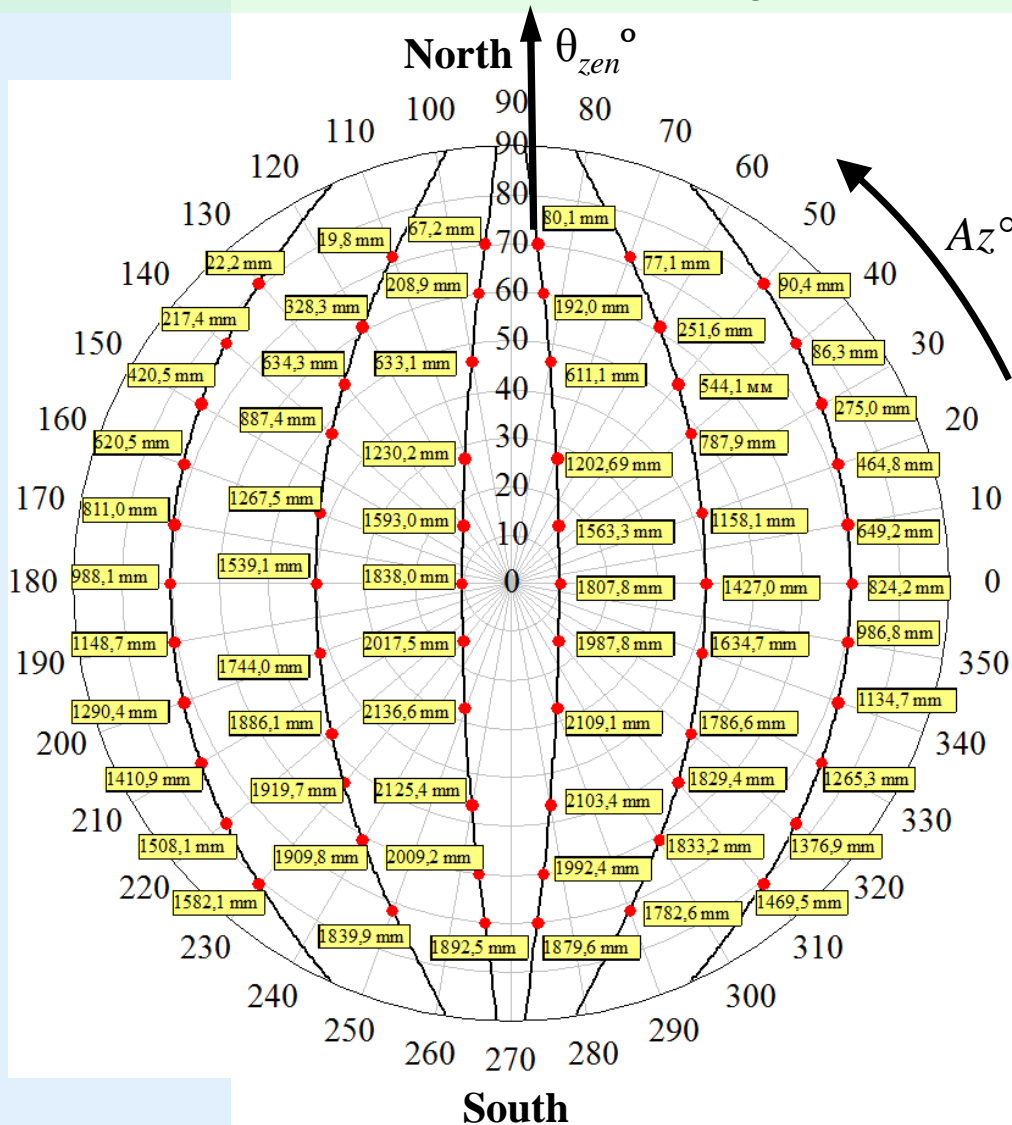


Altitude orbit 1000 km



Distance between retroreflectors: 1 – 2: 0,35 m  
2 – 3: 0,53 m

## Theoretical estimation of a range difference between retroreflector arrays of SC «Lomonosov» for a flight



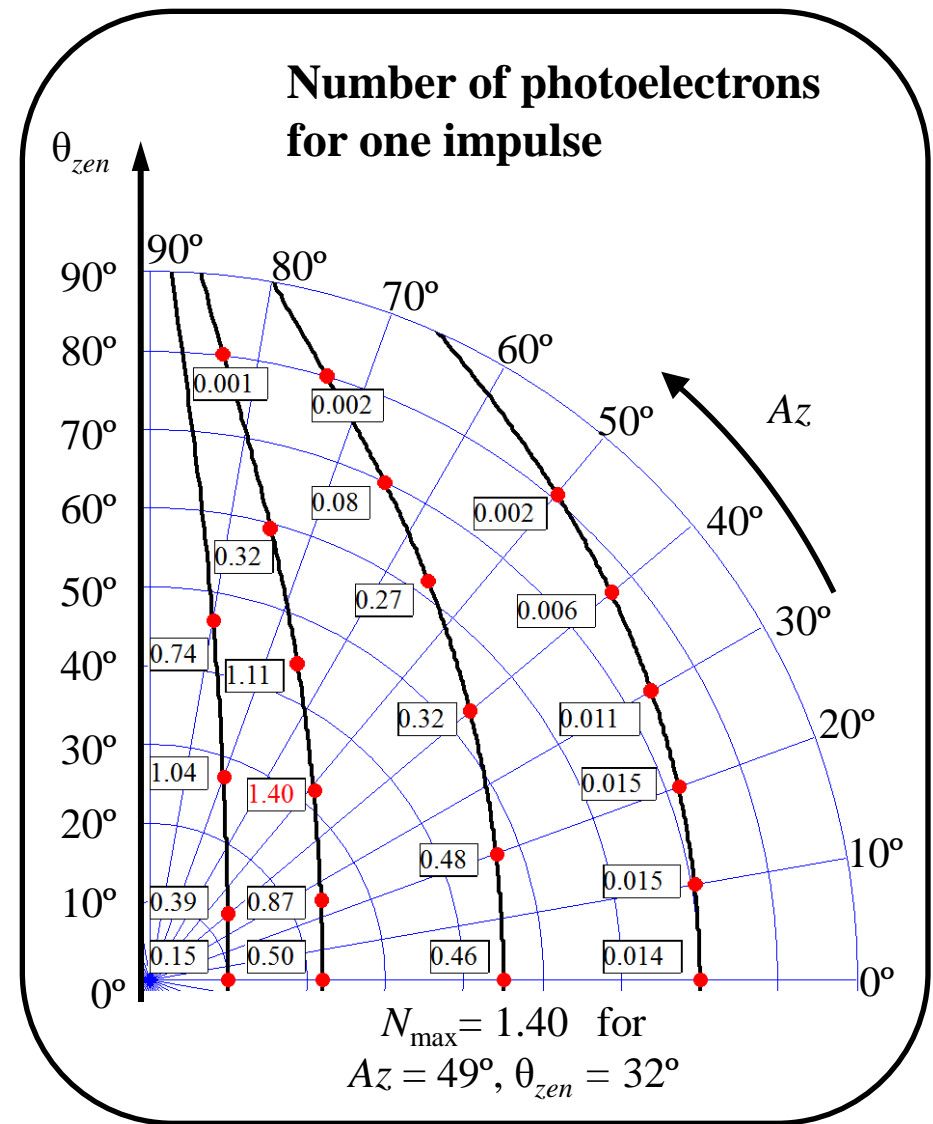
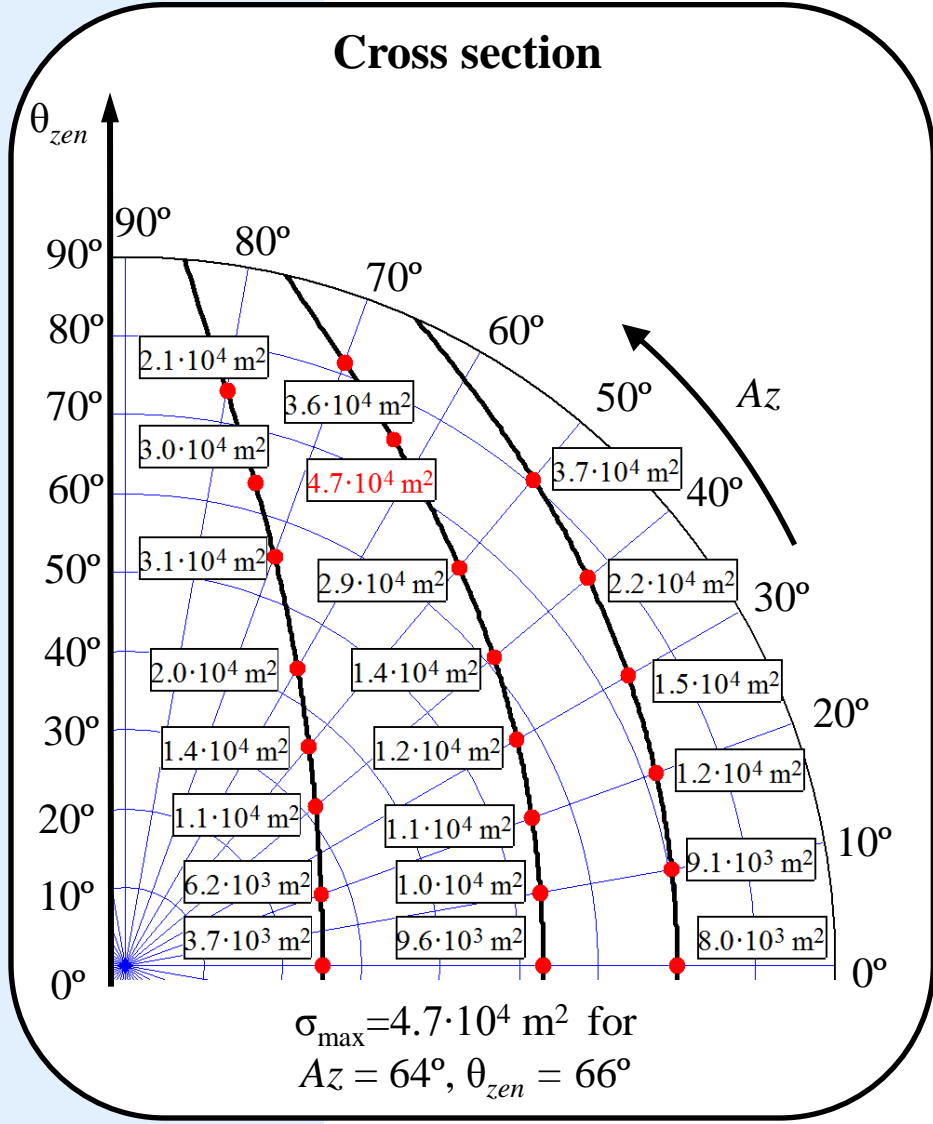
Minimum range difference between  
RA № 1 and RA № 2

$Az = 90^\circ \dots 130^\circ, \theta_{zen} = 60^\circ \dots 80^\circ$

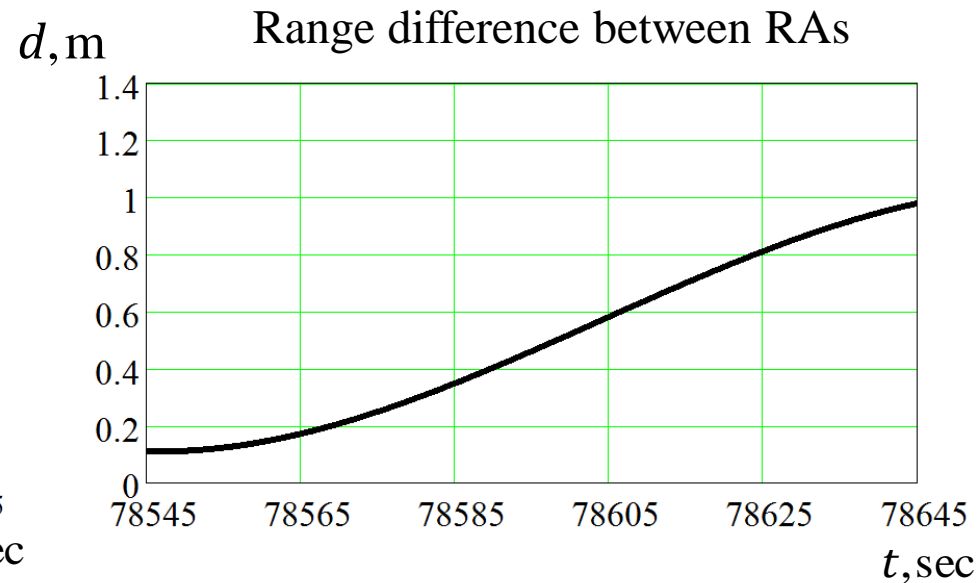
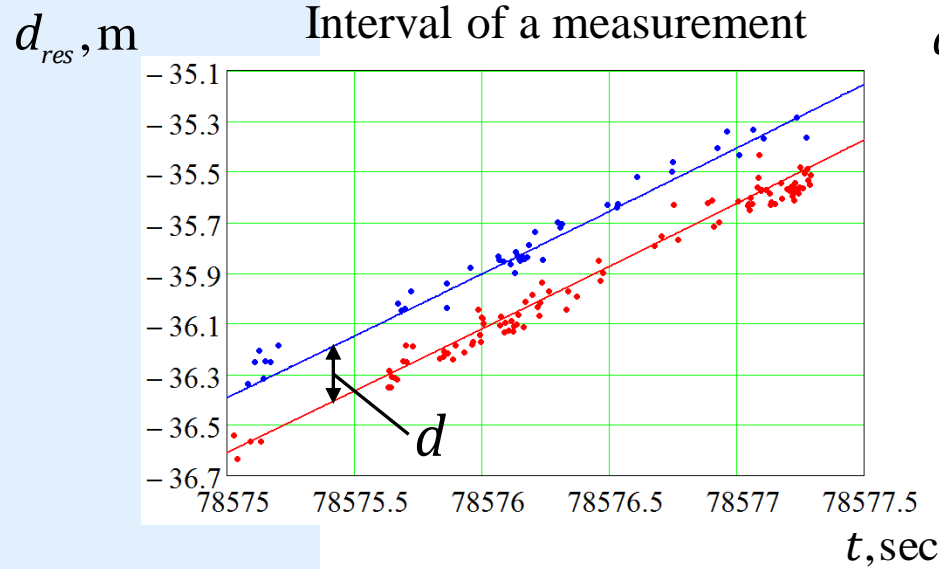
Maximum range difference between  
RA № 1 and RA № 2

$Az = 230^\circ \dots 310^\circ, \theta_{zen} = 10^\circ \dots 50^\circ$

# Theoretical estimation of cross section and number of photoelectrons for RA «Pyramid» in SC «Lomonosov»



## Two track of reflected signals of SC «Lomonosov»



$t$  – time of measurement (UTC) from the beginning of the day

$$d_{res} = d_{pred} - d_m;$$

$d_{res}$  – range residuals;

$d_{pred}$  – prediction range;

$d_m$  – measurement range;

$d$  – range difference between RAs.

## Sessions of SC «Lomonosov» laser ranging

Station	Date of measurement	Flight of SC at the firmament	Range difference between RAs
Altay	07.06.16		
Mendeleevo 2	07.20.16		

## Summary

1. The results of laser ranging SC «Lomonosov» demonstrate reliability, availability and sufficiency of cross-section of the little, high-accuracy array «Pyramid» for mounting at LEO SC.
2. The results of laser ranging SC «Lomonosov» have demonstrated two tracks of signal from first and second array. Thus the additional monitoring of the deployment of the SC “Lomonosov” rod was carried out.
3. Arrays «Pyramid» can to be recommended for monitoring of deployment of LEO SC parts and for determination of SC orientation in the space.
4. Laser stations have ability to determine a distance about 20 cm between retroreflectors in single-photon mode.



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**Thank you for your attention!**

