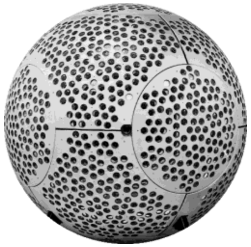
Retroreflector systems used in laser ranging of geodetic and navigation satellites

Ajisai / Japan



ETALON / Russia

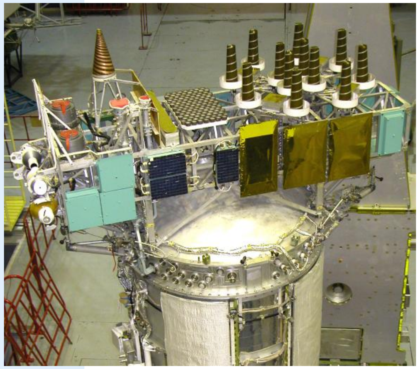
LAGEOS / USA

GFZ-1 / Russia

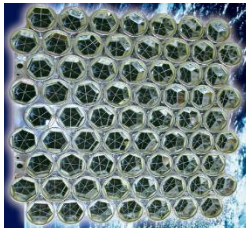
WESTPAC / Russia

LARETS / Russia

METEOR / Russia



GLONASS / Russia



Compas / China

GIOVE / Russia

GPS №35,36 / Russia

Main Laser Retroreflector Systems of “RPC “PSI”

Type of spacecraft	Altitude, km	Launching	Number of spacecrafts	Number of CCR on a spacecraft	Type of reflective coating
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	2000 - 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 № 729 (Russia)	19100	2008	1	112	*TIR*
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	1	autonomous sphere	*Al*
GLONASS-K	19100	2010	1	123	*TIR*
SPECTOR-R(Russia)	до 330 000	2010	1	100	*Ag*

The main trends of laser retroreflector systems (LRS) optimization:

Goals:

- decrease of the correction to the results of measurement;
- increase of cross-section.

1. New interference coatings (generally – gradient) with a view to:

- *optimize FFDP of reflected radiation to compensate speed aberrations;*
- *reduce solar heating influence;*
- *decrease a loss of light in CCR;*

2. Remote control of FFDP

- *Rotation of CCR array;*
- *Variation of the polarization state of laser radiation.*

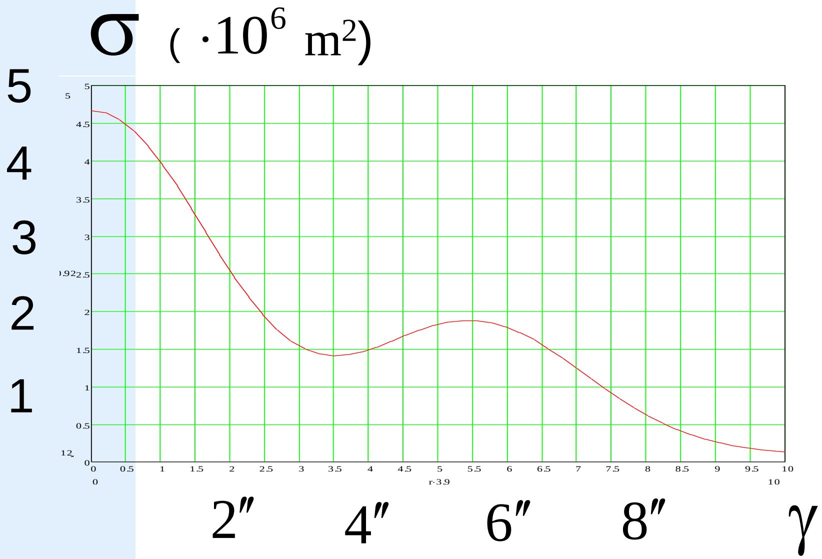
3. Size of CCR and value of CCR dihedral angles.

4. LRS configuration for an accurate correspondence to the center of mass of the satellite.

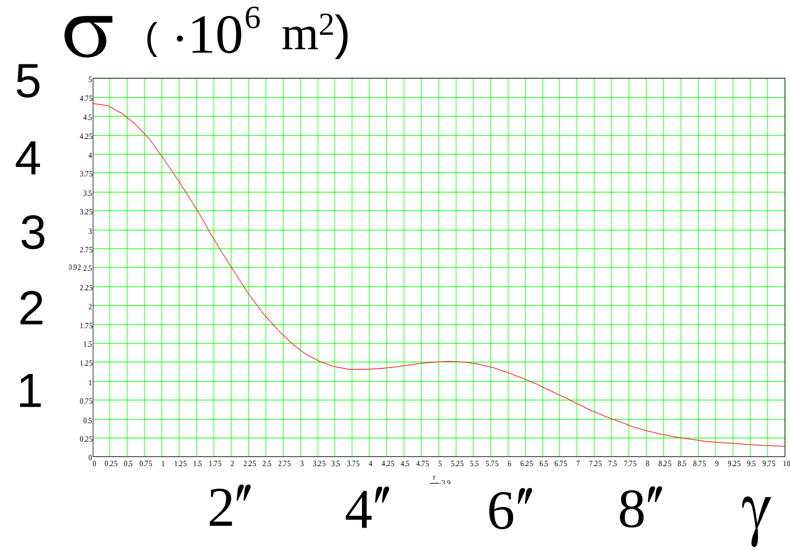
5. Glass spherical satellites of BLITS type – absolute correspondence of measurements to the center of mass of the spacecraft.

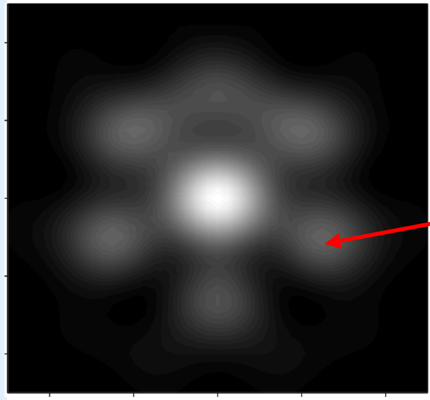
1 : FFDP and cross-section of CCR (TIR). Diameter – 28 mm

CS of one CCR



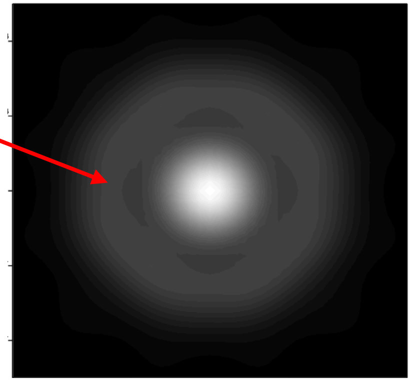
Average CS for the four turned CRR





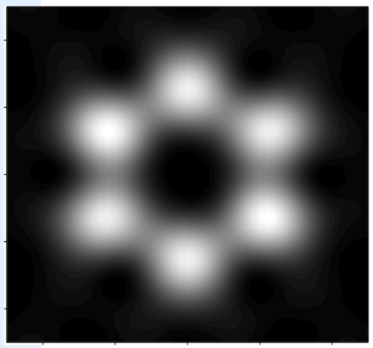
$CS = 1{,}9 \cdot 10^6 m^2$

$CS = 1{,}2 \cdot 10^6 m^2$

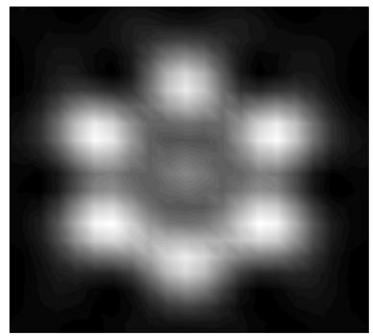


1 : New interference coatings

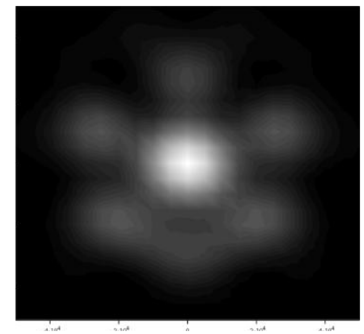
CCR's far field diffraction patterns as a function of the phase shift on reflection



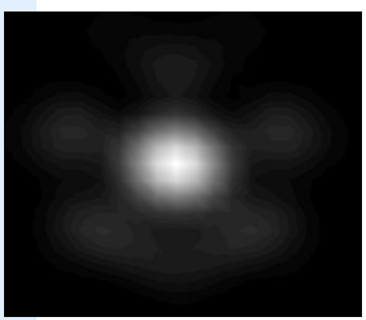
$\delta = 0$



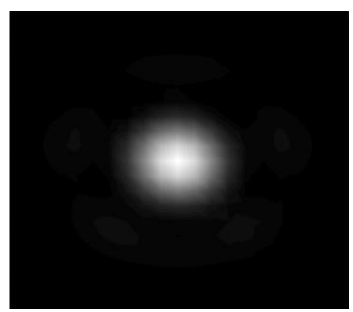
$\delta = 20$



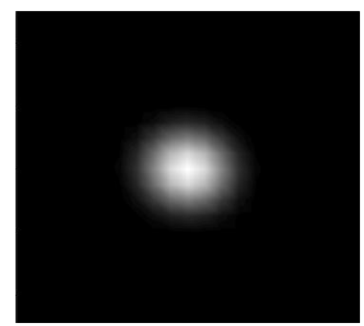
$\delta = 45$



$\delta = 60$



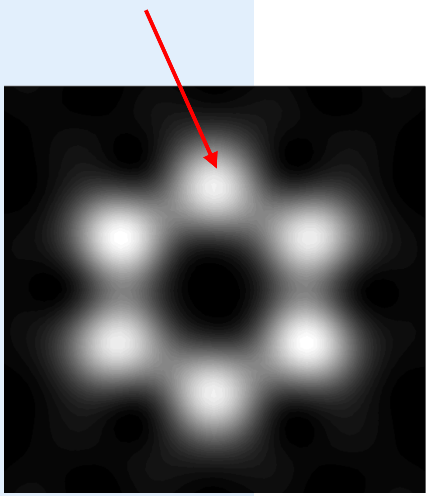
$\delta = 90$



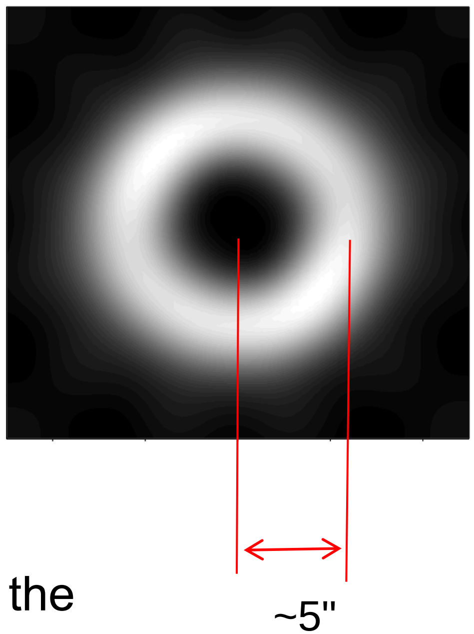
$\delta = 120$

1 : FFDP of CCR with dielectric interference coatings of faces (the phase shift = 0)

$CS = 2{,}4 \cdot 10^6$ м^2

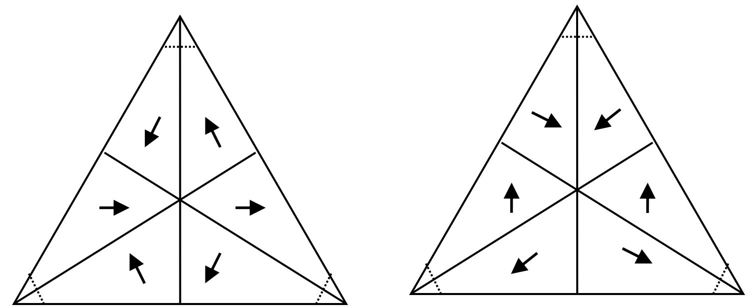


Averaged
$CS = 1{,}9 \cdot 10^6$ м^2

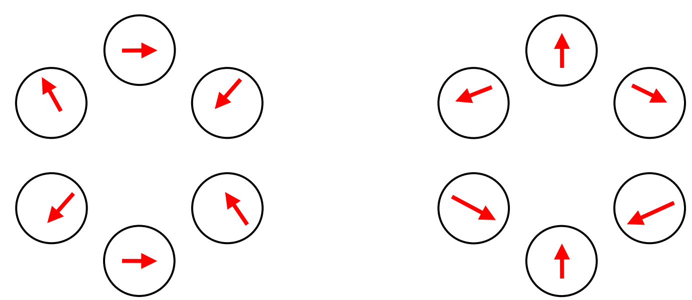


Speed aberration for the GLONASS system is 5.3 "

Polarization structure
in the near field:

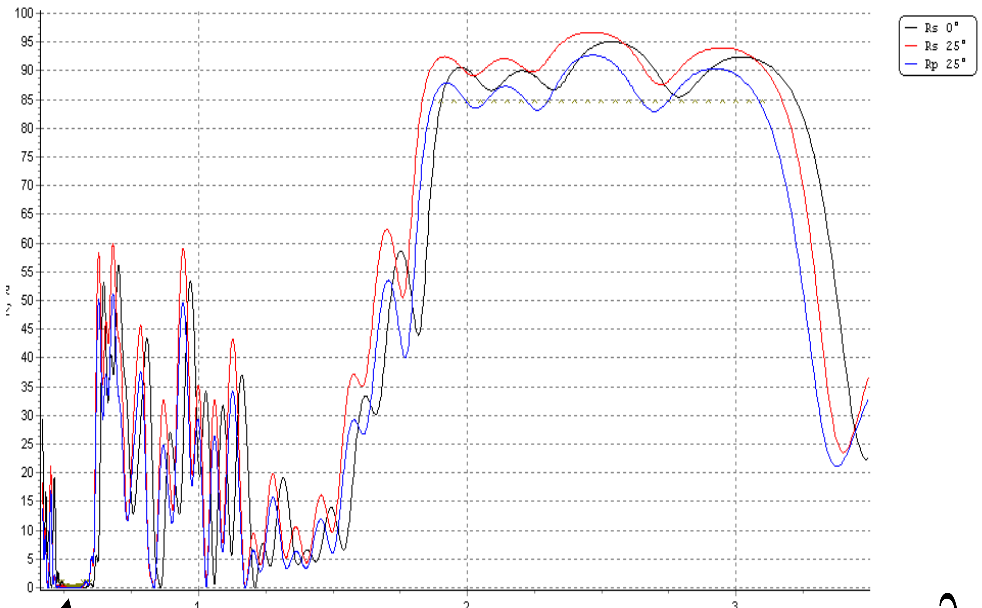


and far-field:



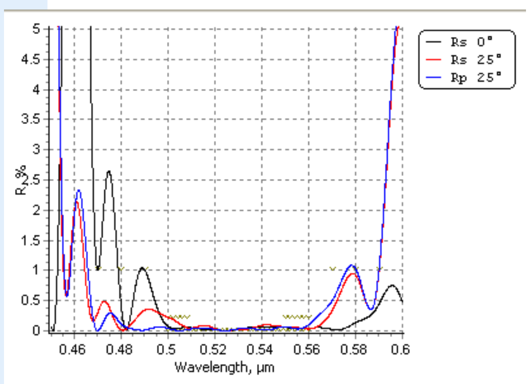
1 : Reduce solar heating influence

ρ

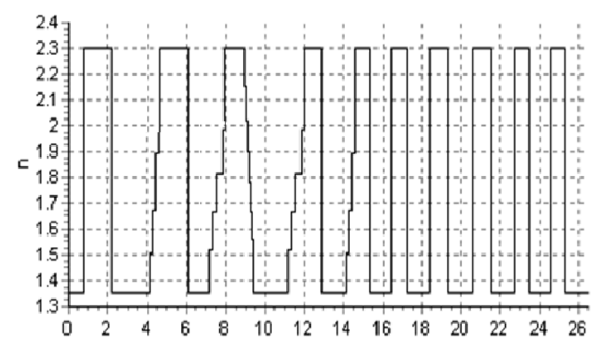


1 2 3 λ

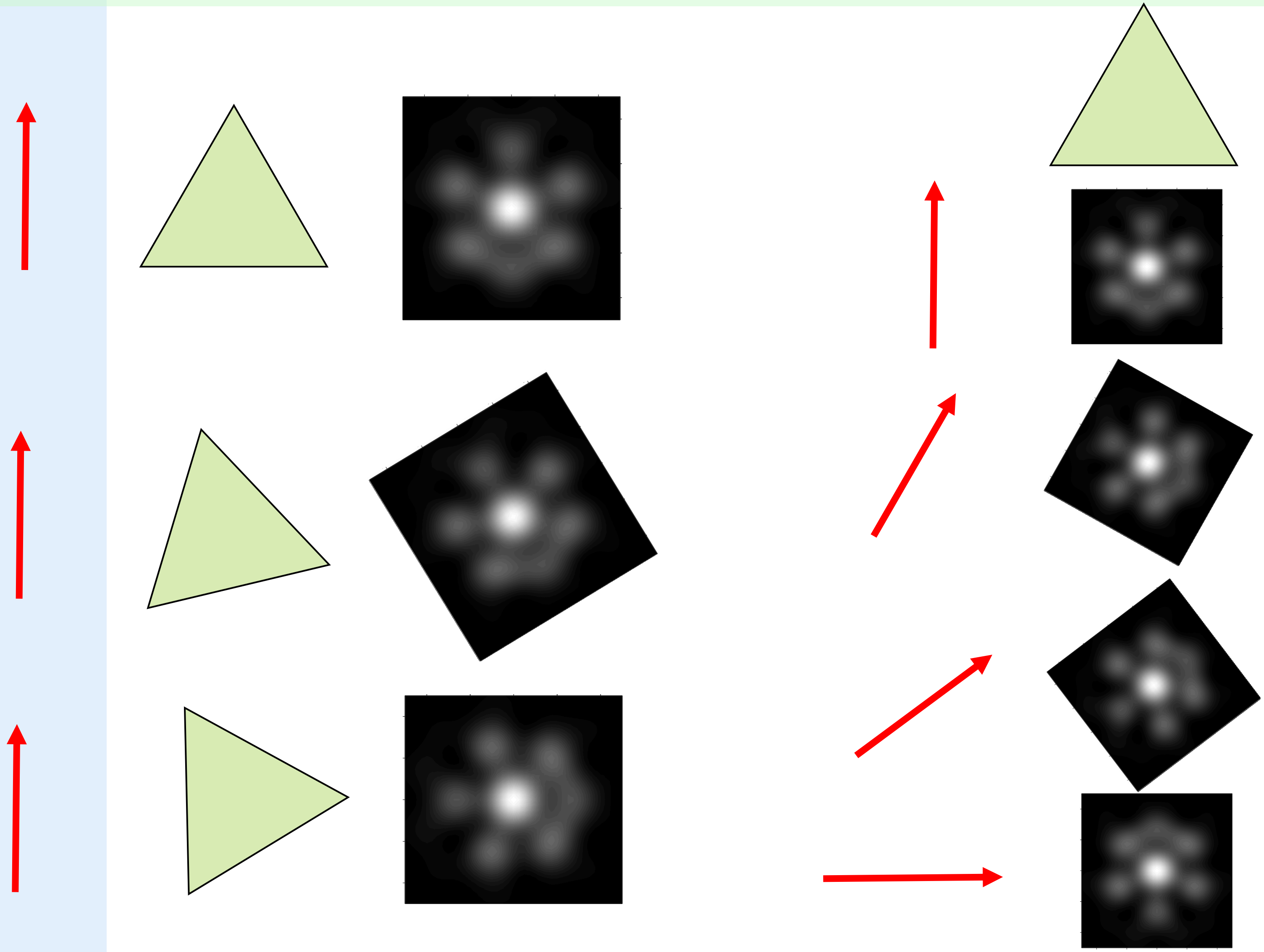
ρ



λ



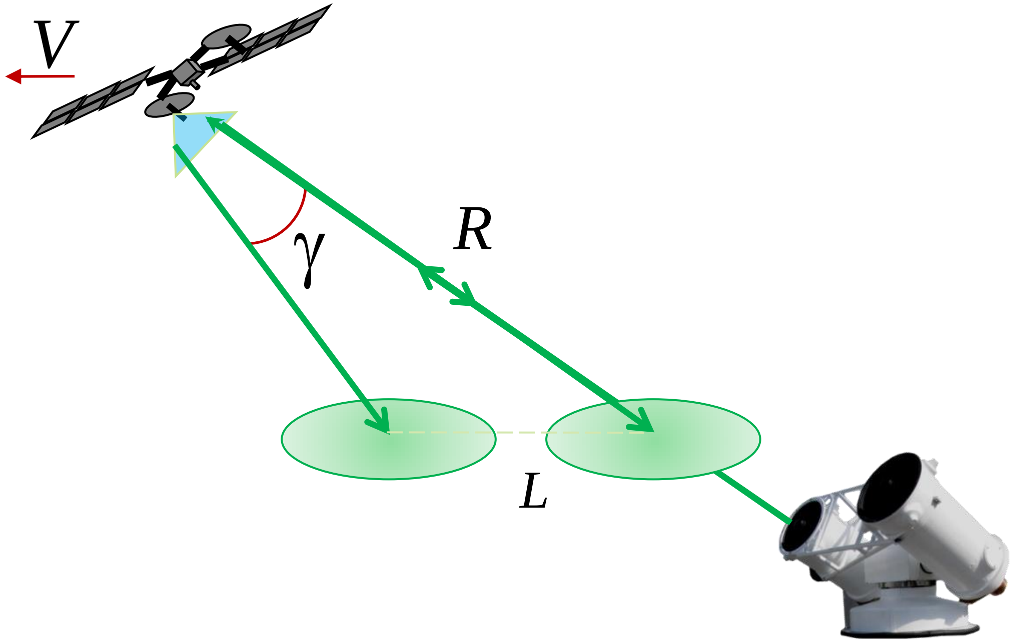
2 : Remote control of FFDP

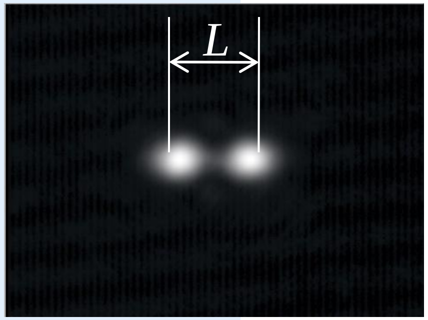


3 : CCR with the controlled DAO (dihedral angle offsets)

Optimization of FFDP:

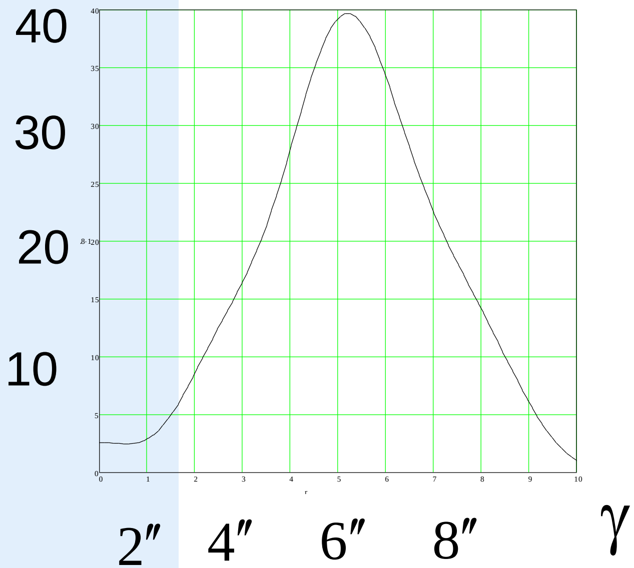
- for low-orbit three-axis attitude spacecrafts;
- for HEO spacecrafts with a ring-shape LR-array;
- for geostationary satellites.

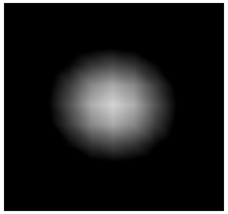




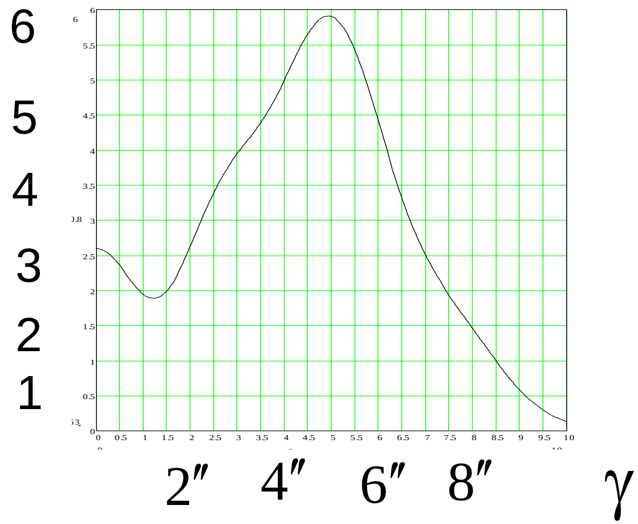
3 : CCR with DAO + coatings.
Diameter 50 mm. Dihedral angle 2,4”

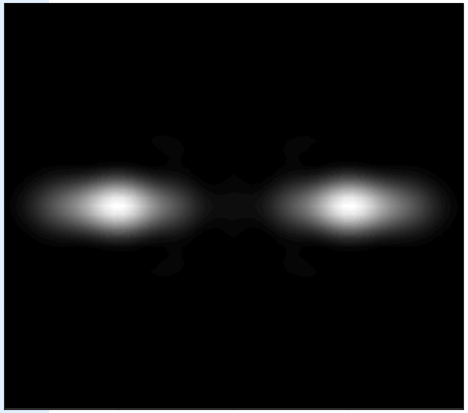
CS ($\cdot 10^6$ м2)



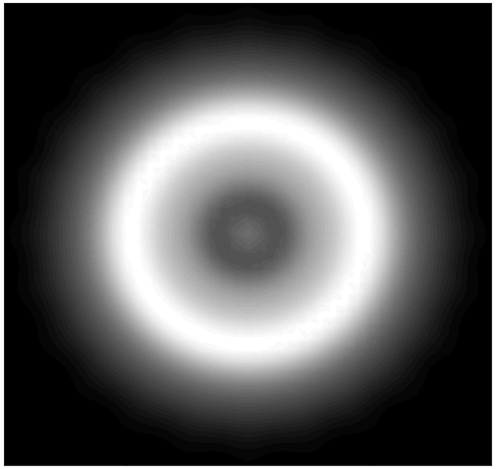


Averaged CS ($\cdot 10^6$ м^2)

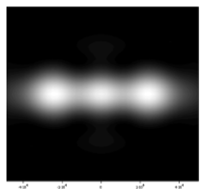
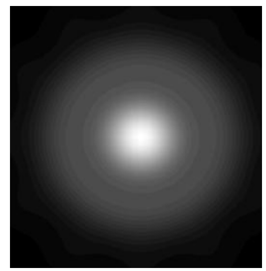
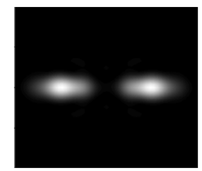
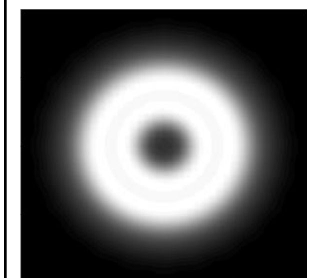
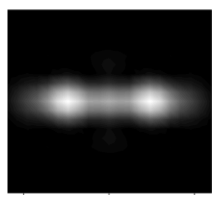
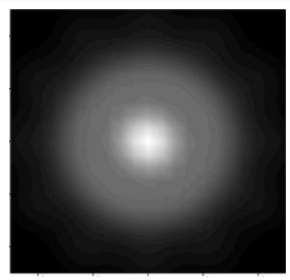
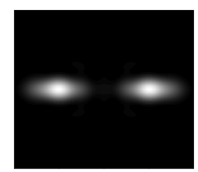
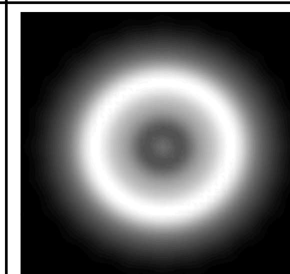
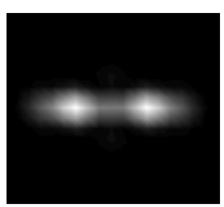
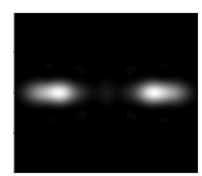
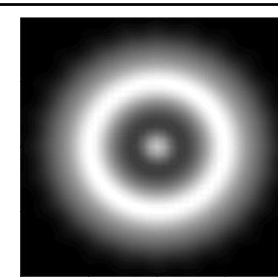




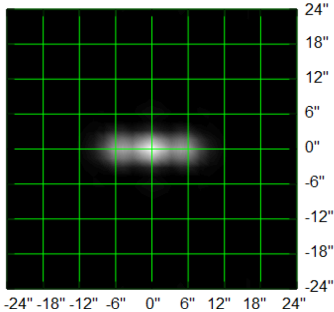
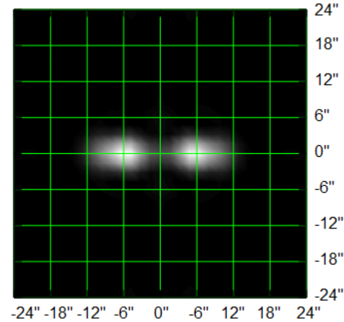
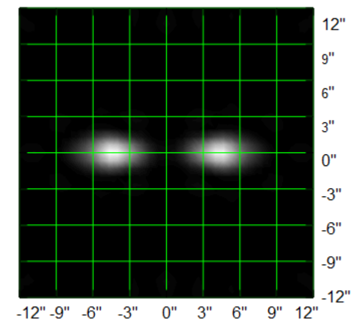
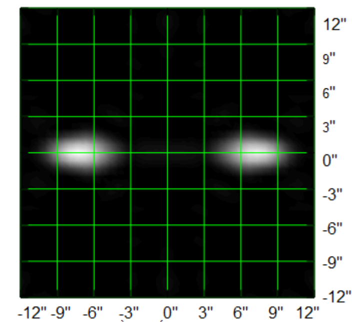
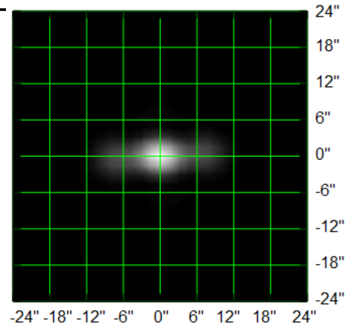
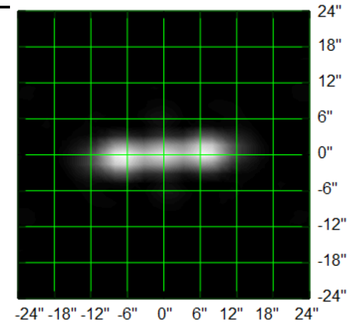
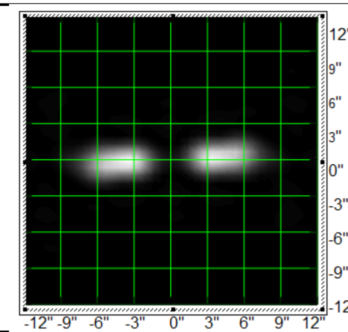
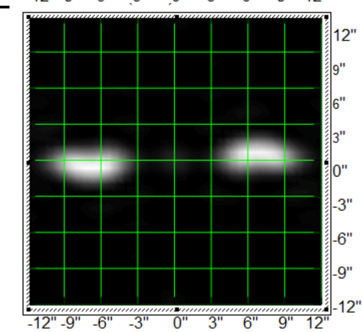
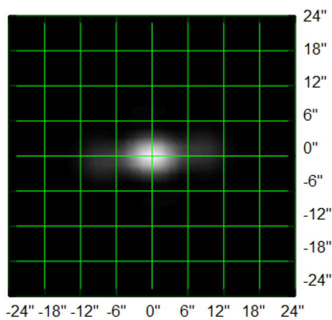
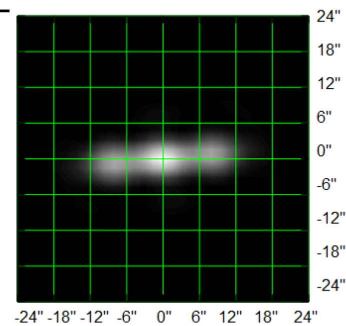
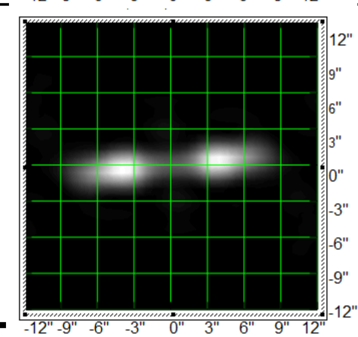
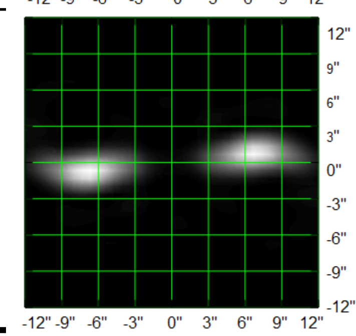
Range of 24 CCR



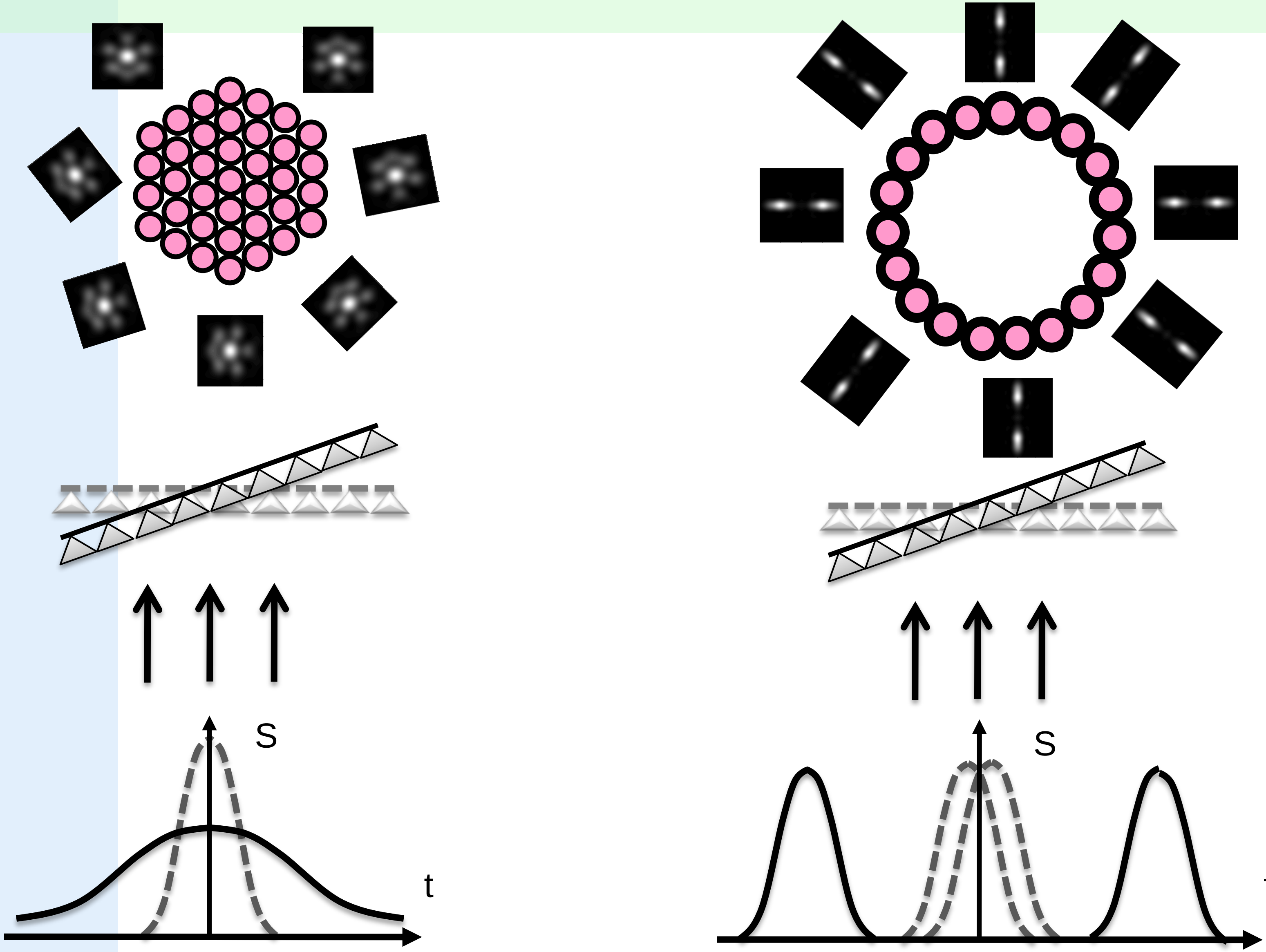
3 : CCR with different DAO.
Diameters: 28 mm and 50 mm

DAO	Equivalent diameter - 28 mm		Equivalent diameter - 50 mm	
	One CCR	Range of CCR	One CCR	Range of CCR
2,2″				
2,4″				
2,6″				

3 : Influence of incident angle on two-spots CCRs

Incident angle	28 mm. DAO – 2”	28 mm. DAO – 3”	56 mm. DAO – 2”	56 mm. DAO– 3”
0				
12				
18				

4 : Optimization of LR array configuration



5 : Spherical glass nanosatellite «BLITS-M»

Expected target parameters of the nanosatellite «BLITS-M»	
goal error	no more than 0.1 mm
CS	$0.3 \cdot 10^6$ - $1 \cdot 10^6$ m^2
time of service under the condition of a flight	at least 10 years
orbital altitude (will be chosen)	1500 km – 3000 km
diameter	no more than 250 mm
mass	at least 20 kg

Thank you for your attention!