Design and Manufacture of Laser Retro-reflector Arrays for LEO and HEO Satellites at SHAO

Zhang Zhongping, Zhang Haifeng, Wu Zhibo,
Chen Wanzhen, Li Pu

Shanghai Astronomical Observatory (SHAO),
Chinese Academy of Sciences (CAS)

Contents:

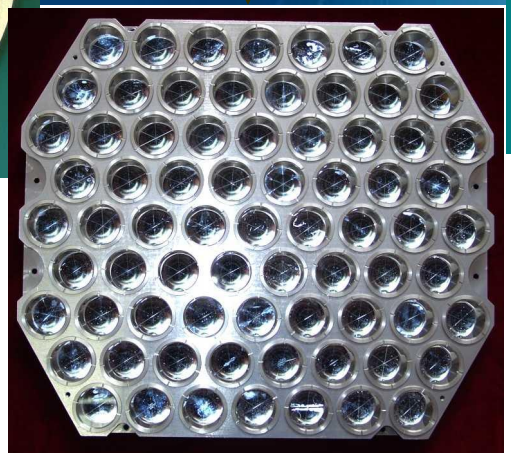
- Introduce
- Retro-reflector Arrays Design for LEO and HEO satellites
- Future development

Introduce

- **Since 1999, SHAO started designing laser retro-reflector arrays (LRAs) for the Chinese space missions.**
- **In 2002, the first set of LRAs made by SHAO successfully onboard Chinese LEO spacecraft (330km).**
- **In 2003, the first set of LRAs by SHAO onboard the Chinese HEO satellite (36,000km).**
- **In 2010, the LRAs for the mission of Chinese first spacecrafts docking was designed, and accurately measurement for the distance of two spacecrafts was successful.**
- **The following shows the products of LRAs at SHAO.**

Shenzhou-4

GEO satellites



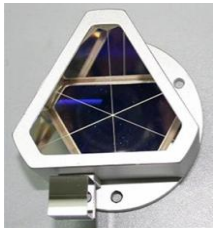
Compass GEO / IGSO

Compass MEO

LRAs of two hemisphere for cylindrical space objects

Shiyan-1

For South Korea



LRAs for spacecraft docking

The list of products of LRAs at SHAO

Type of satellite orbit / LRAs	Satellites	Orbital altitude /km	Size of LRAs / mm	Size of corner cubes / mm	Coating	Weight / kg	Year
LEO (semi-spherical base) for SLR	Shenzhou-4	330	¢200	¢30	none	0.85	2002
	Shiyan-1	790	¢130	¢33	Sliver	0.4	2007
	South Korea	/	¢200, ¢130	¢30, ¢33	Sliver	0.4	2003, 2011
HEO (planar base) for SLR	Compass MEO	21,500	326(w)×280(h)	¢33	none	4.45	2007~2012
	Compass GEO	36,000	490(w)×280(h)	¢30, ¢33	none	4.37, 4.85	2003, 2009~2012
LEO for spacecraft docking	TianGong-1	350	430(L)×422(W)×169(H)	¢33	Sliver	8.6	2011

- Up to now, ~20 sets of LRAs at SHAO designed for Chinese space mission
- The weight: min. one 400g at LEO and the max. one 4.85kg at HEO for SLR

Retro-reflector Arrays Design for LEO and HEO satellites

- **Two types of LRAs are designed for SLR at SHAO:**

  1) semi-spherical base mounted with several corner cubes, equipped onboard LEO satellites for the need of precise orbit determination and calibrations.

  2) planar base covered with lots of corner cubes, for HEO satellites.

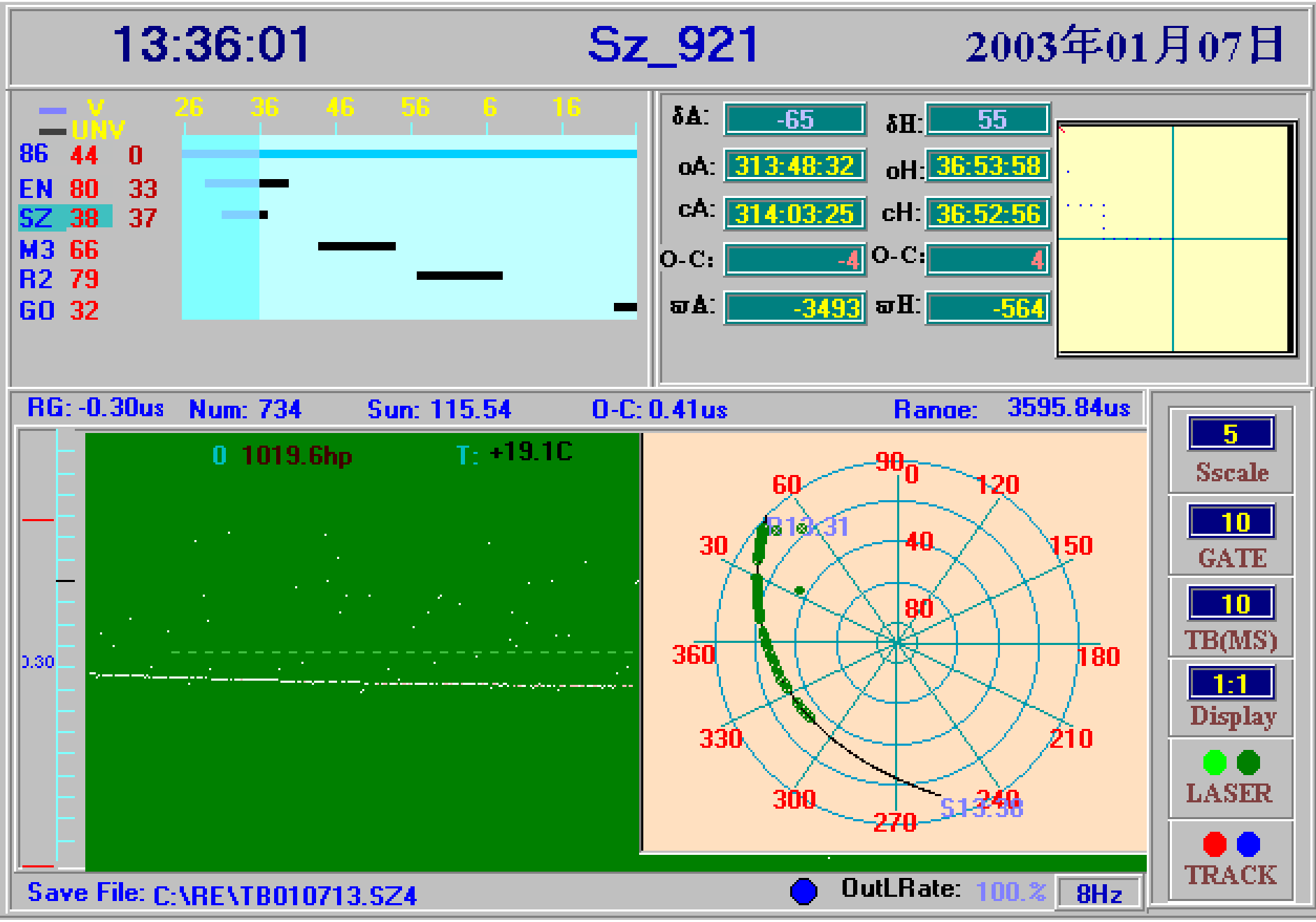
- **The single corner cube with inner circle or triangular incision.**

First LRAs for Shenzhou-4 (330km)

- Type: semi-spherical base
- diameter of single corner-cube: 3.0cm
- diameter of LRAs: 20cm
- Divergence: 12±1″
- Number of corner cubes: 9
- Material: Fused quartz
- Without coating
- Weight: 850g
- Laser measurements at domestic stations

designed in 2002

Real time laser measurement



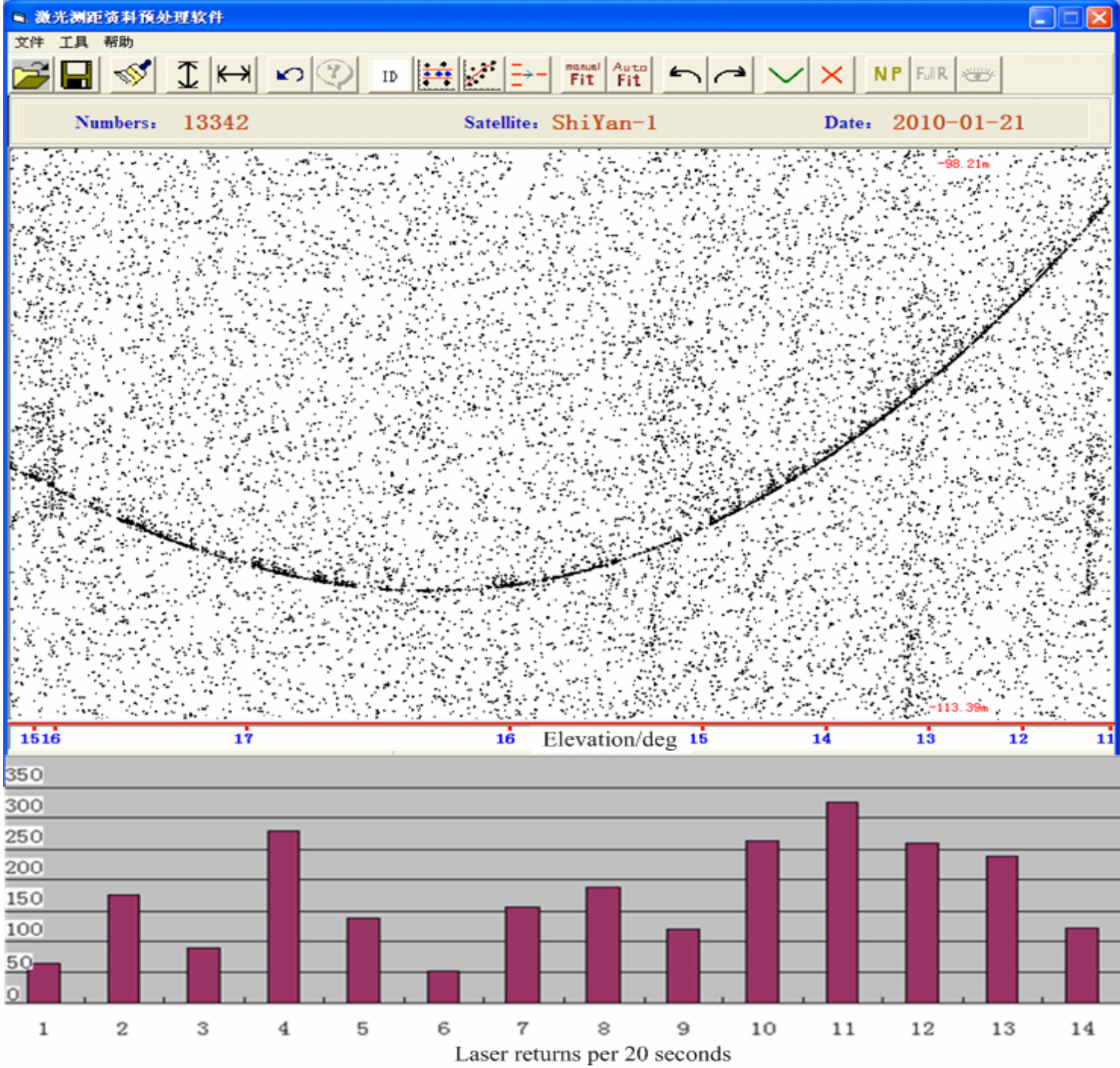
LRAs for ShiYan-1 satellite (790km)

- Type: semi-spherical base
- diameter of single corner-cube: 3.3cm.
- diameter of LRAs: 13cm
- Divergence: 14±1″
- Number of corner cubes: 9
- Material: Fused quartz
- Silver coating on back surface
- Weight: 400g
- Laser measurements at domestic stations for calibration of GPS measuring orbits.

designed in 2007

Laser Ranging results of ShiYan-1 with 1kHz rate.

Ranging RMS: 7-8mm



LRAs for South Korea

The product is the version of the Shenzhou-4

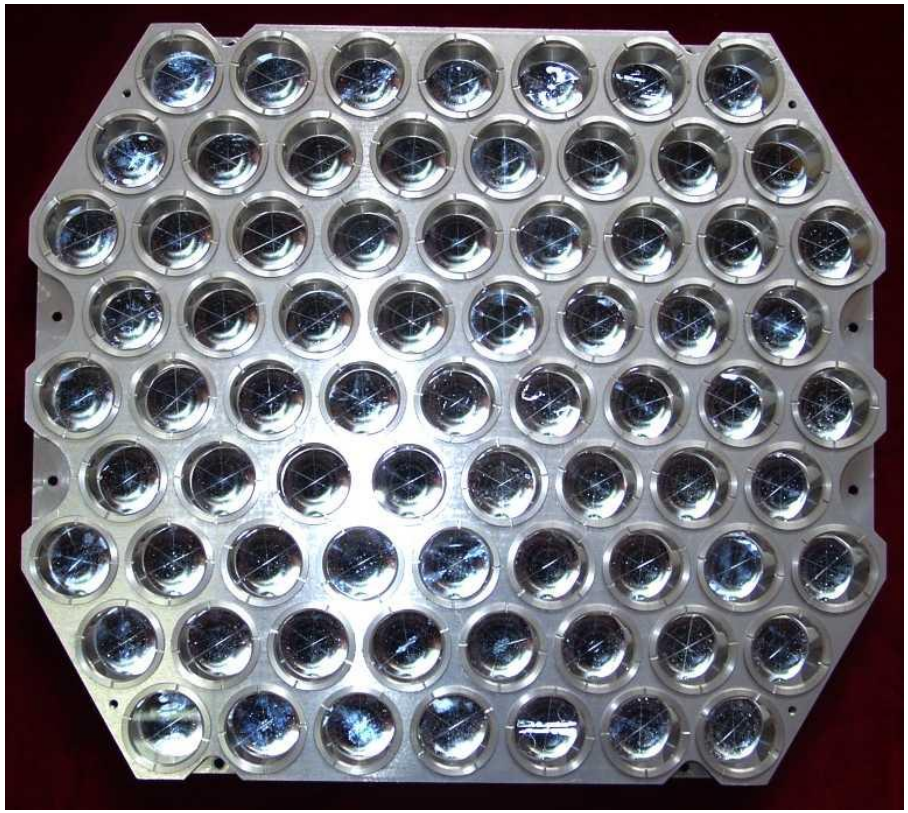
designed in 2003

The product is the version of the ShiYan-3

designed in 2011

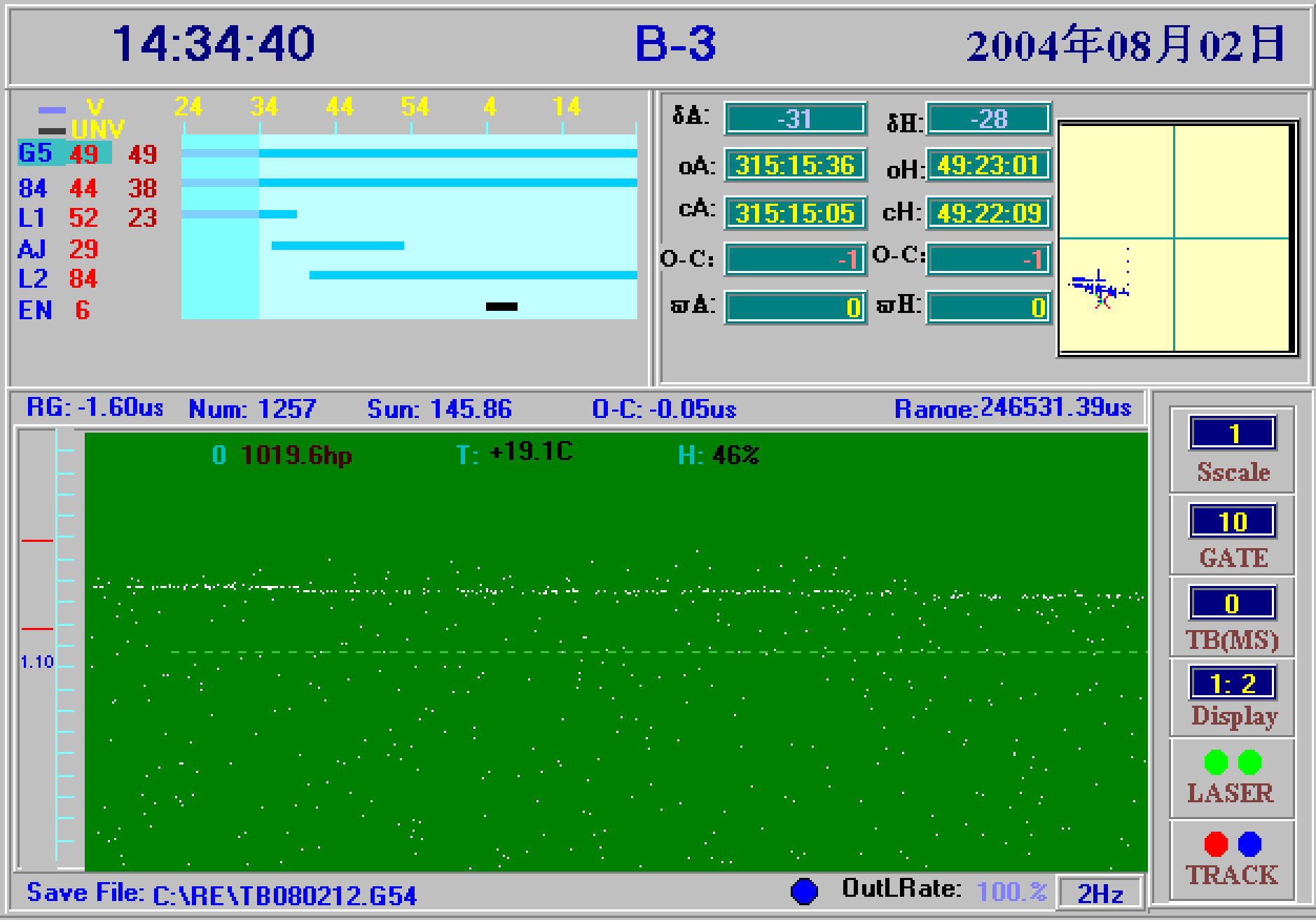
First version of LRAs for HEO satellites

- Size of LRAs (width & height): 41 cm & 36 cm
- Diameter of single corner cubes: 3.0 cm
- Divergence: 6±1″
- Number of corner cubes: 73
- Material: Fused quartz
- Without coating
- Weight: 4.37 kg
- Laser measurements at domestic stations



LRAs of Chinese first version GNSS satellites (GEO) made in 2003

Real time laser measurement

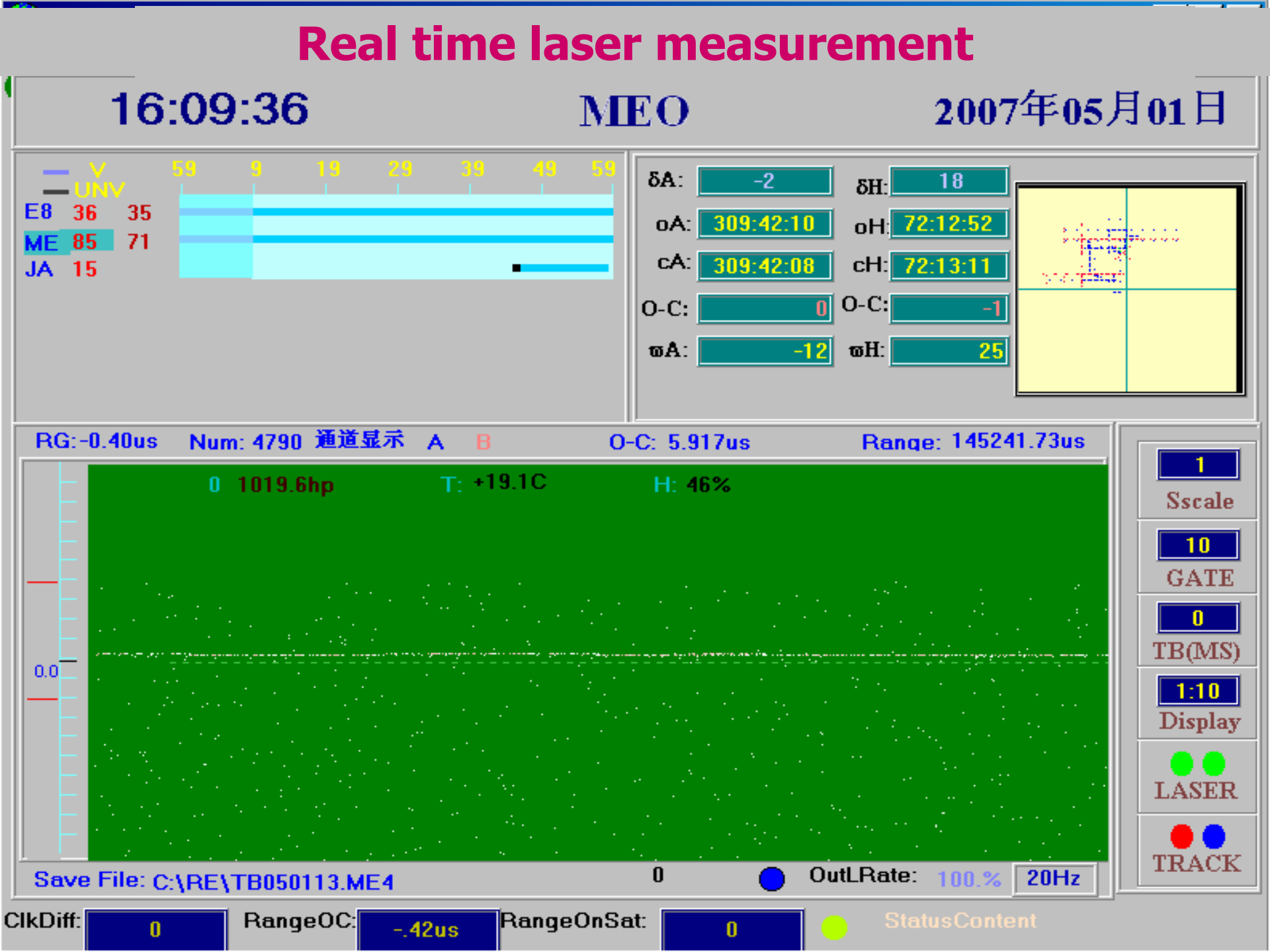


COMPASS-MEO(21,500km)

- Size of LRAs (width & height): 32.6 cm & 28 cm
- Demeter of single corner cubes: 3.3 cm
- Divergence: 7±1″
- Number of corner cubes: 42
- Material: Fused quartz
- Without Coating
- Weight: 2.45 kg
- Laser measurements at global stations

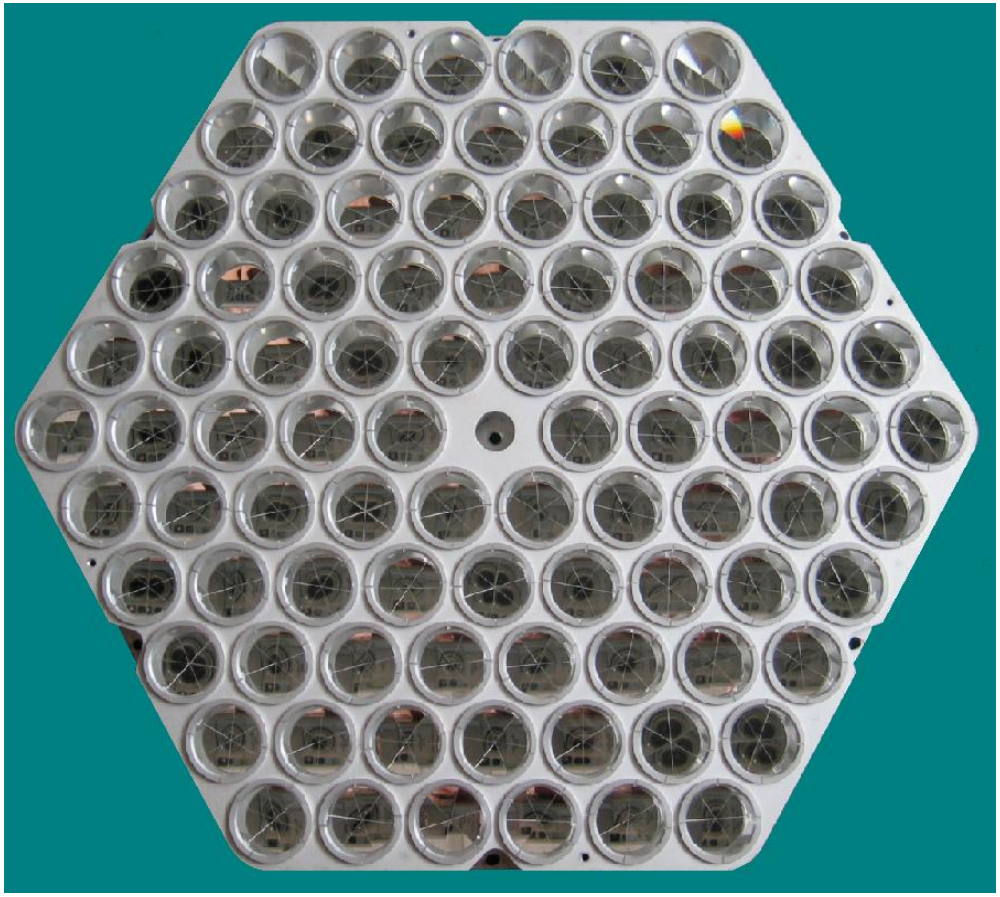
LRAs of Chinese second version GNSS (MEO) made in 2006

Real time laser measurement



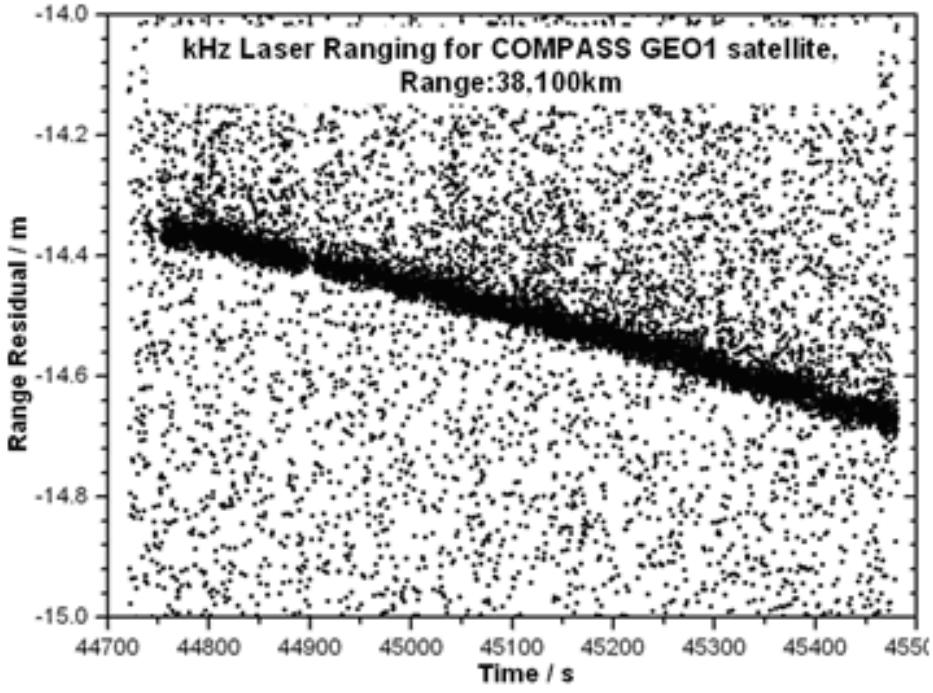
COMPASS-GEO/IGSO(36,000km)

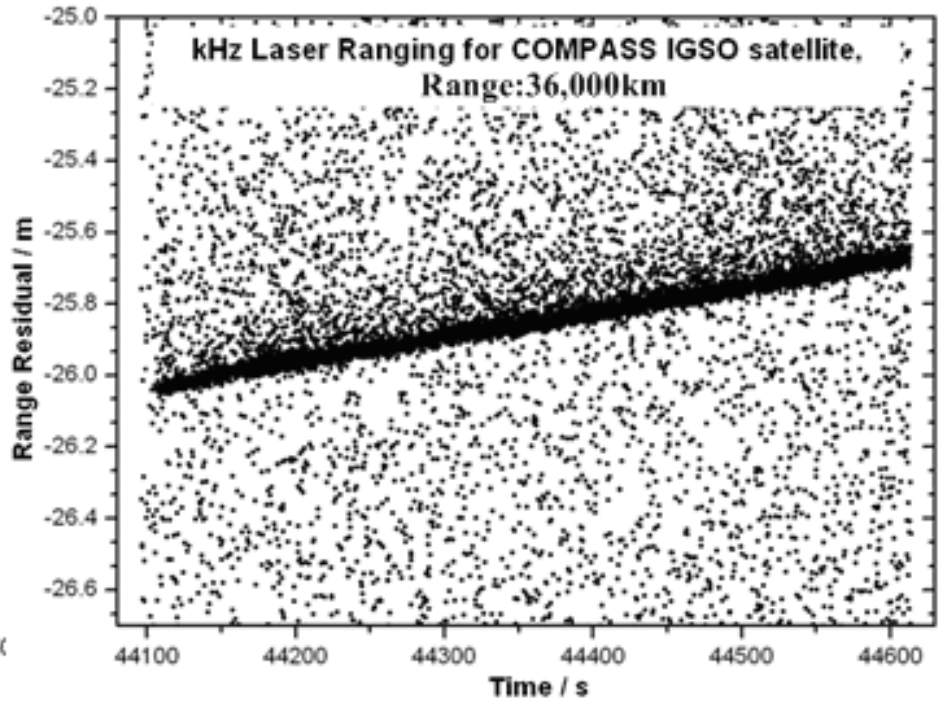
- Size of LRAs (width & height): 49 cm & 43 cm
- Demeter of single corner cubes: 3.3 cm
- Divergence 6±1″
- Number of corner cubes: 90
- Material: Fused quartz
- Without Coating
- Weight: 4.85 kg
- Laser measurements at global stations



LRAs of GEO/IGSO made in 2008-2011

Measuring results of COMPASS GEO and IGSO satellites at Shanghai SLR station by kHz system





GEO,
ranging precision: ~1.1cm

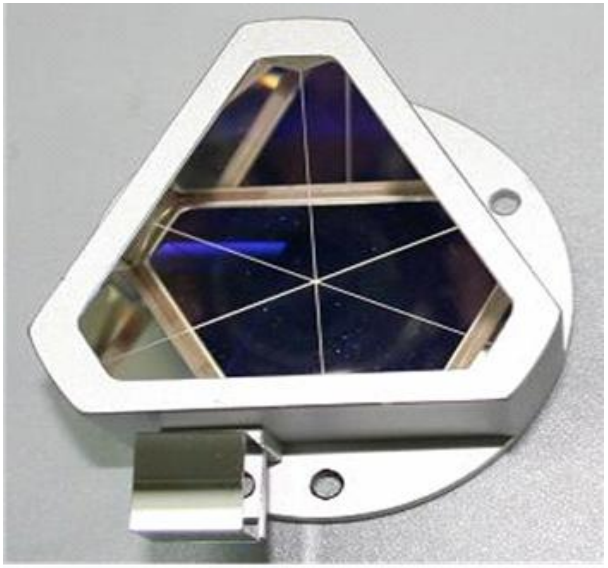
IGSO,
range precision: ~1.4cm

LRAs for spacecraft docking (Shenhou-8/-9 and Tiangong-1)

two kinds of reflectors, one for the far distance and another one for near distance

(A) The far field laser retro-reflector

- Number of corner cubes: 86
- Divergence:<10”
- Weight: 8.6kg
- Size:430mm×422mm×169mm



(B) The near field laser retro-reflector

- One large single of corner cube
- Divergence: 20±1”
- Weight: 190g
- Φ78×38mm

The position of LRAs on Tiangong-1 spacecraft from CCTV

The docking between Tiangong-1 and Shenzhou-8 spacecrafts

Other of LRAs for LEO satellites

- Two hemisphere type of LRAs symmetrically installed on the two side of spacecraft
- The single corner cube with triangular incision
- Diameter of LRAs: 15cm
- Diameter of single corner cubes: 3.34 cm
- Divergence: 14±1″
- Number of corner cubes per hemisphere: 16
- Weight: 970g(two hemisphere)

Design for:

Light weight, large effective reflective area, the big incoming angle scale of laser beam.

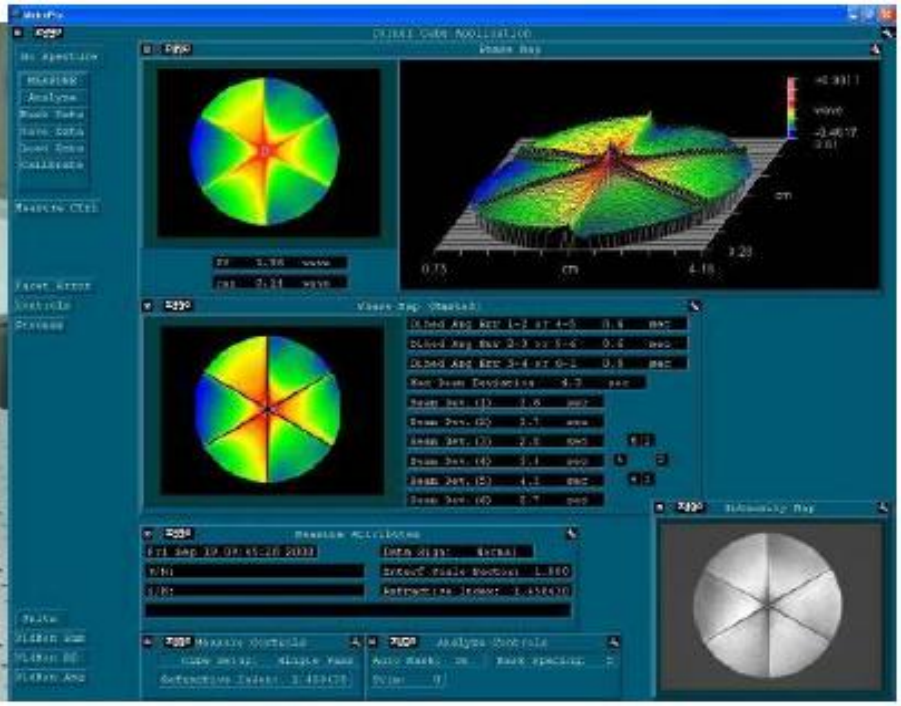
The optical performances test of LRAs

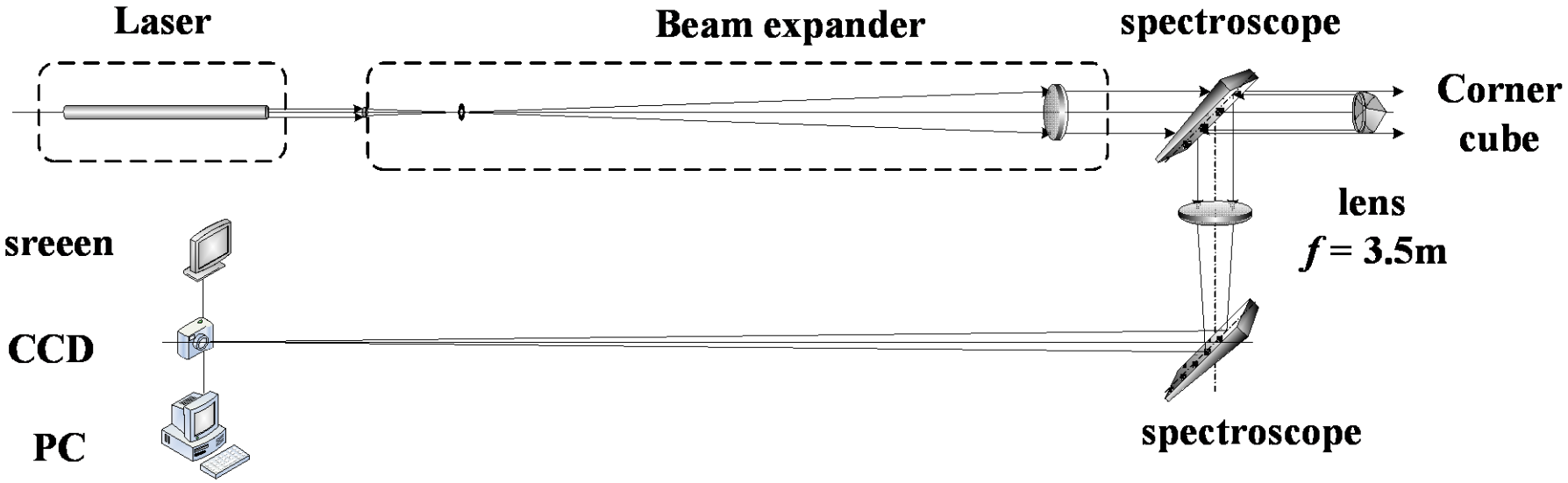
- **Establishment of procedure of optical performances test to insure the ability of reflection**

  dihedral offset, optical reflectivity (532nm)

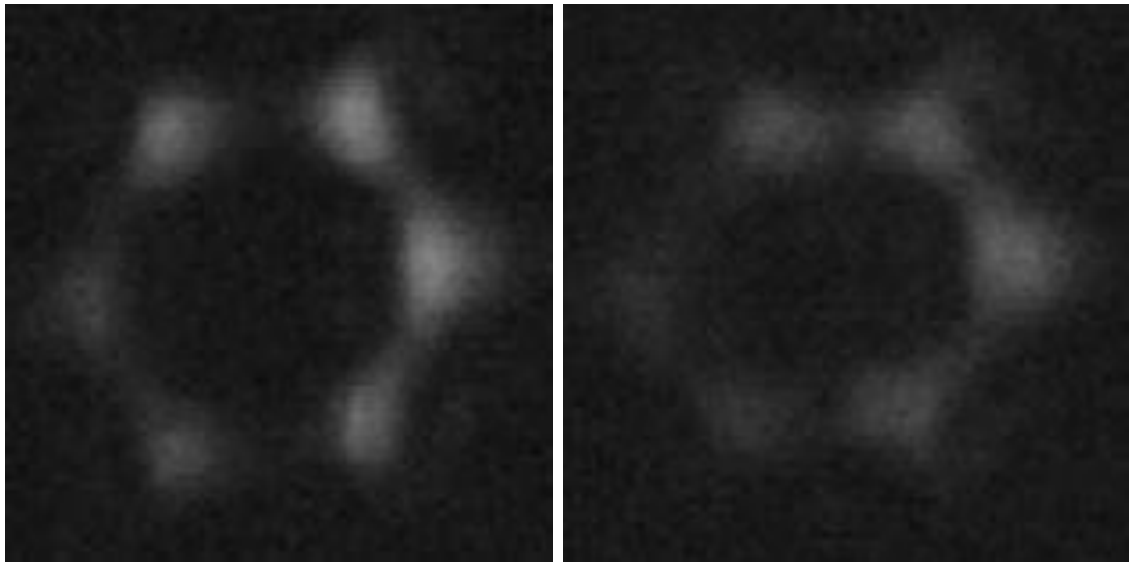
  Diffraction Pattern

ZYGO interferometer





Test of Diffraction Pattern of a corner cube in laboratory



Diffraction Pattern of a single corner cube

Performances test of LRAs under the simulated space conditions

heated vacuum and vibration test

Acceleration test

dynamic impact test

High and low temperature test

Future development

- Improving the LRAs design (light weight, compact, high reflective ablity) for Chinese future LEO and HEO satellites
- LRAs design for Space VLBI satellites (farthest distance 60,000km for SHAO) (seeing the poster)
- Studying on the design of lunar LRAs.

Thanks you for attention.