



# New Russian systems for SLR, angular measurements, and photometry

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## Abstract

A brief description is presented of two novel-type stations providing satellite laser ranging, angular measurements, and photometry (in reflected sunlight), recently developed in the Institute for Precision Instrument Engineering (IPIE). Putting the stations in operation will expand the Russian Laser Tracking Network to 6 stations.

# COMPACT LASER/OPTICAL STATION PARAMETERS

## SLR of spacecraft with retroreflectors

- spacecraft orbit height range: 400 to 40000 km;
- daytime and nighttime measurements for spacecraft with orbit heights 400 to 6000 km;
- NP RMS errors 0,5 to 2 cm (averaging interval 60 s);
- residual (systematic error) 0,5 to 2 cm;
- elevation range 20 to 85 deg.

## Angular measurements

- Visual star magnitude:  $\leq 12^m$
- RMS error for spacecraft angular velocity up to 40 arcsec:  $\leq 2''$

## Photometry

- Visual star magnitude:  $\leq 10^m$
- Brightness determination error:  $\leq 0,2^m$



## DESIGN FEATURES OF THE COMPACT STATION

- The weight of any single unit of the system (in package) does not exceed 50 kg with system total weight less than 300 kg. Thus, no special lifting mechanisms are needed for installation.
- An autonomous housing for the optical unit and mount allows installation on a small base, without erection of a special tower.
- Low power consumption ( $\leq 2,5$  kW) allows supply from single-phase mains or from a portable power generator.
- Low cost in serial production and simple technology provides manufacturing by existing industrial firms.

## COMPACT SLR STATION IN OPERATION



The option for mounting on a fixed position has a weight of 170 kg (optics + mount). No lifting mechanisms are needed for installation. The station has been tested near the 6-meter telescope of Russian Academy of Sciences (in Northern Caucasus) during 2005.

Currently, serial manufacturing is organized of the compact station for the Russian Laser Tracking Network . It is planned to produce 15 stations more until 2010.

## Autonomous cover of the compact SLR station



Right half of the housing is installed

# COMPACT STATION OPERATOR'S WORKPLACE

All electronic equipment is on desktop





# Pointing/tracking system and mount of the compact station

## Mount parameters

- Mount type: Az-EI, with two flanges for equipment mounting
- Digitally controlled high-torque motor drive
- Equipment weight on each mount flange:  $\leq 20$  kg
- The mount is provided with an autonomous housing
- Angular rotation range:
  - Elevation: 5 to 95 deg
  - Azimuth: - 278 to +278 deg
- Maximal angular speed 30 deg/s; maximal angular acceleration 30 deg/s<sup>2</sup>

# Mobile laser/optical station parameters

## SLR of spacecraft with retroreflectors

- spacecraft orbit height range: 400 to 40000 km;
- daytime and nighttime measurements for spacecraft with orbit heights 400 to 6000 km;
- NP RMS errors 0,5 to 2 cm ( averaging interval 10 s);
- residual (systematic error) 0,5 to 2 cm;
- elevation range 20 to 85 deg;

## Angular measurements

- Visual star magnitude:  $\leq 14^m$
- RMS error for spacecraft angular velocity up to 40 arcsec:  $\leq 2''$

## Photometry

- Visual star magnitude:  $\leq 12^m$
- Brightness determination error:  $\leq 0,2^m$



## Operation site with installed equipment (containers and telescope)



The mobile station is placed into 3 containers installed on wheels for transportation. The weight of optics and mount units is 12 tons. Except this unit, the system comprises an equipment container with operator's workplace, as well as a "house" for operator's rest.

The mobile station acceptance tests have been completed on the Russian cosmodrome "Baikonur" in Kazakhstan.



Mobile station under housing



Mobile station during transportation



Mobile station preparation for operation.



Mobile station in operation

# Mobile station operator's workplace





# Versatile pointing/tracking control virtual panel

Телескоп Архыз Дата 2005/11/11 Время 16:39:05 Сдвиг времени 0.000 So\_эв Гринв= 017:02:16 Dt=0 Тград = 0.0 Рмм рт ст = 0.0 Н% = 0.0

0 ОТКЛ 1 ПН 2 АС 3 Поиск 4 КН 5 РУ 6 АСР 7 Зв\_В 8 ФК

**Азимут**

Ось визир **042:15:54**

Программа **042:15:54**

Поправка **000:00:00**

Ошибка **000:00:00**

Пеленг **000:00:00**

СкорПрогр **000:00:17**

СкорФакт **000:00:00**

Солнце **-060:52:29**

Луна **063:45:43**

Привязка **-019:45:56**

**Угол Места**

Ось визир **037:27:05**

Программа **037:27:05**

Поправка **000:00:00**

Ошибка **000:00:00**

Пеленг **000:00:00**

СкорПрогр **000:00:06**

СкорФакт **000:00:00**

Солнце **-001:58:28**

Луна **011:09:40**

Привязка **-002:47:58**

**Поле**

Широкое

Среднее

Узкое

**Дискрет**

1 с

5 с

15 с

1 м

2 м

5 м

7338 18625

**ПЛЮС**

Сброс Влево ← Сброс Вверх ↑

Стоп Вправо → Стоп Вниз ↓

Общ. Стоп

Время Привязки ДОС 00 00 00

Время Измерений 00 00 00

Привязка ДОС

Привод

Включить

Выключить

Иск. Данные Привязка ДОС Измерение Тесты Поправки ДОС Калибровка КалибрСписок Регистратор

Луна = 32.17 Солнце = 88.81

Дата	Alfa	Delta	длитель ИД звезд, мин	
2005/11/11	21 44 28.309	+09 53 57.780	30	
TStart = 016:38:00 TFinish = 017:08:00 DT = 000:30:00				
ВыхВтчк 16:38:39				
Число Точек = 61				
Время	Азимут	Скорость АЗ	Угол Места	Скорость УМ
016:38:00	042:34:41	-000:00:17	037:20:51	000:00:06
016:38:30	042:26:05	-000:00:17	037:23:43	000:00:06
016:39:00	042:17:29	-000:00:17	037:26:34	000:00:06
016:39:30	042:08:52	-000:00:17	037:29:24	000:00:06
016:40:00	042:00:14	-000:00:17	037:32:15	000:00:06
016:40:30	041:51:36	-000:00:17	037:35:04	000:00:06

До нач измерений С 150

Вых в точку измерений

Чтение ИД КО из памяти

ЗвздПривязки

Скорость Г М С долиС

АЗИМУТ

УГОЛ МЕСТА

Шаг ms

Сек

траекторная поправка по времени

Right: image of star catalog.

Center: image of calculated catalog star positions in the TV camera field of view (around the telescope pointing direction).

# Versatile angular measurement (astrometric) virtual control panel

**Параметры ТВ-системы**  
 Размер изображения 768\*576 пикселей  
 Количество градаций яркости 256

**Параметры изображения**  
 Уровень Фона = 6  
 Уровень Шума, СК0 = 12  
 Яркость = 110 Контраст = 103  
 Размер Строба в пикселах = 14  
 Интегр Контраст = 3702

**Координаты строба в пикселах**  
 ГНстр = -3.2 ВНстр = -3.3

**ЕСТЬ Захват Объекта**  
**Данные от системы наведения**  
 23.10.2005  
 Время 22:35:20  
 Звездное время 21:44:35

Число звезд в поле 21  
 iNear = 0  
 0.000000 0.000000 0.0 0 0

dX = 0.000000 dY = 0.000000  
 AzStar = 0.000000 ElStar = 0.000000  
 AzObj = 175.636255 ElObj = 78.118506

0.093785 0.966363 11.0 -373.5 56.2  
 0.096535 0.962811 11.0 -324.1 283.4  
 0.096735 0.969343 11.0 -246.6 -100.2  
 0.098572 0.966924 10.0 -214.1 54.2  
 0.099040 0.969603 10.7 -170.3 -100.7  
 0.101249 0.969519 10.4 -100.7 -81.7  
 0.103032 0.969864 10.4 -40.2 -90.9  
 0.103216 0.968321 10.8 -50.7 1.3  
 0.104642 0.967287 8.3 -15.9 71.2  
 0.106715 0.968433 10.4 62.4 16.4  
 0.107776 0.970619 8.4 119.0 -106.0  
 0.108627 0.972008 10.8 160.5 -182.8  
 0.110412 0.972992 10.3 227.4 -230.1  
 0.110489 0.970280 10.6 202.0 -69.5  
 0.112454 0.968227 10.7 243.9 63.6  
 0.112535 0.965920 11.0 223.1 200.3  
 0.112679 0.967025 10.5 238.9 135.9  
 0.113970 0.966612 10.5 276.2 168.1  
 0.114949 0.972917 9.1 370.9 -198.6  
 0.115349 0.969053 7.3 344.9 32.1  
 0.117145 0.965339 10.9 365.5 262.2

N кадра 110  
   
 Убрать Фон

Угол места 078:06:55 078:07:07 dEL 000:00:-12  
 Азимут 175:39:09 175:38:11 dAZ 000:00:59

**Размер Строба**

Показать места звезд   Включить Запись Измерений

Накопление Кадров  
 1  2  4  8  16

Замедление Прокрутки Кадров  
 1  2  4  8  16

Ошибки измерения относительно прогноза  
 dHour угл с dDelta угл с Sum  
 Строб на ближнюю Звезду

Оценки координат изображений звезд X Y  

1	-16.889727	64.191643	-15.948194	71.188865	9
2	-51.582660	-6.165915	-50.669253	1.301038	8
3	62.584868	11.273658	62.389349	16.424091	10
4	205.074018	-73.810675	202.044523	-69.499573	14
5	121.222010	-110.031585	119.021010	-106.045573	11
6	-100.951018	-87.202351	-100.740642	-81.742564	6
7	-40.368937	-95.582900	-40.197159	-90.868619	7
8	-217.568514	46.072859	-214.122989	54.164875	4

 A1 = 0.987997 B1 = 0.010357 C1 = 0.000005  
 A2 = -0.005703 B2 = 1.013385 C2 = 0.000103  
 dXobj = -3.36 dYobj = 3.38

Upper left: TV frame with GLONASS-712 spacecraft in the center

Lower left: star catalog fragment

“+” marks: position of catalog stars in the TV frame

“II” marks: star tracking gates (stars selected for spacecraft angular position measurements)



## Stations of both types have similar laser ranging system with the following parameters:

<b>Operation wavelength</b>	<b>0,532 <math>\mu\text{m}</math></b>
<b>Pulse repetition rate</b>	<b>300 Hz</b>
<b>Laser pulse duration</b>	<b>250 ps</b>
<b>Laser pulse energy</b>	<b>2,5 mJ</b>
<b>Output beam divergence</b>	<b>5 arcsec</b>
<b>Receive telescope diameter</b>	
- compact station	<b>25 sm</b>
- mobile station	<b>60 sm</b>
<b>Timing accuracy (measurement position on time scale)</b>	<b>200 ns</b>

# Laser ranging control virtual panel (daytime observation of LAGEOS)

