STATE SCIENTIFIC CENTER OF THE RUSSIAN FEDERATION

FEDERAL AGENCY
ON TECHNICAL REGULATING AND METROLOGY

RUSSIAN METROLOGICAL INSTITUTE
OF TECHNICAL PHYSICS AND RADIO ENGINEERING

VNIIFTRI

Laser ranging in Main metrological center of the Russian State service of time, frequency and the Earth rotation parameters determination.

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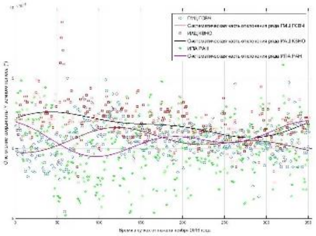
OUTLINE

1. VNIIFTRI – national metrological institute

2. SLR stations in Mendeleevo and Irkutsk
3. Metrological support of SLR measurements in VNIIFTRI



4. VNIIFTRI as EOP analysis center (software and results)
5. SLR time transfer experiment
6. Progress in SLR equipment

VNIIFTRI is national scientific institution of Russian Federation, responsible to manage more then 50 national standards and has as a central subject Main metrological center of T&F and EOP Service of Russia

- Provides for customers include GLONASS T&F information, national timescale UTC(SU) data.

All custumers should be synchronized with few ns uncertanty

- Provide EOP and ERP data. Reliable, precise and fast.

Historical retrospective

Laser ranging measurements FSUE "VNIIFTRI" is held since the 1970

Now we have 2 SLR stations «Mendeleevo-1874» and SLR station «Irkutsk-1891» in the East-Siberian Branch of VNIIFTRI in the city of Irkutsk.

Parameters :
Operating wavelength 0.532 micron;
Frequency 300 Hz;
Pulse duration of 250 ps;
Pulse energy 2.5…2.7 mJ;
Beam divergence 7…12 arcsec;
The diameter of the receiving aperture and TV Guide 25 cm.
SLR stations produced in Russia in 2011

Equipment of SLR-stations “Mendeleevo” and “Irkutsk”

These stations have the similar equipment:

•The laser location system (Russian designed);

•Time and frequency standards (H-masers) and synchronization system;

•Precise gravimeters;

•GPS/GLONASS receivers;

•Local Geodetic Network;

- Communication Network.

The stations provide:

•Metrological support of GNSS GLONASS;

•Support of reference line Mendeleevo – Irkutsk (~ 4200 km) as metrological national standard;

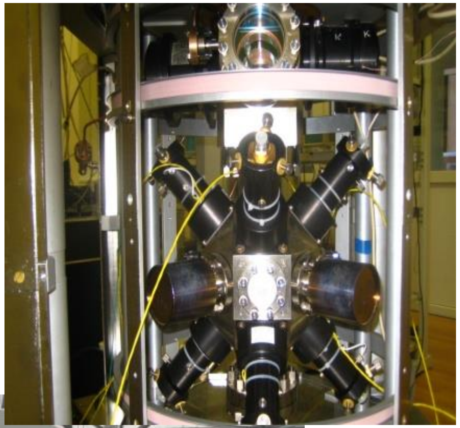
•Earth rotation parameters determination and predictions;

•Time transfer;

•Work on the global SLR Network.

Metrological support

We use our SLR station together with:
Sate time and frequency standard in Mendeleevo UTC(SU);
State standard of length in Mendeleevo;
Secondary time and frequency standard in Irkutsk city.



Additional equipment

Mobile laboratory with mobile TWSTFT station and active H-maser;
Fixed TWSTFT station in Mendeleevo;
Standard of comparison - Leica TDA 5005;
Other accessories.

The base system for time and frequency (ZAO “VREMYA CHE”, Nizhniy Novgorod, Russia)

Composition:

- time and frequency keepers – 4 units;
- one unit for the signals comparisons;
- one unit for the time scale comparisons;
- working place for operator;

New clock ensemble and T&F transfer instruments

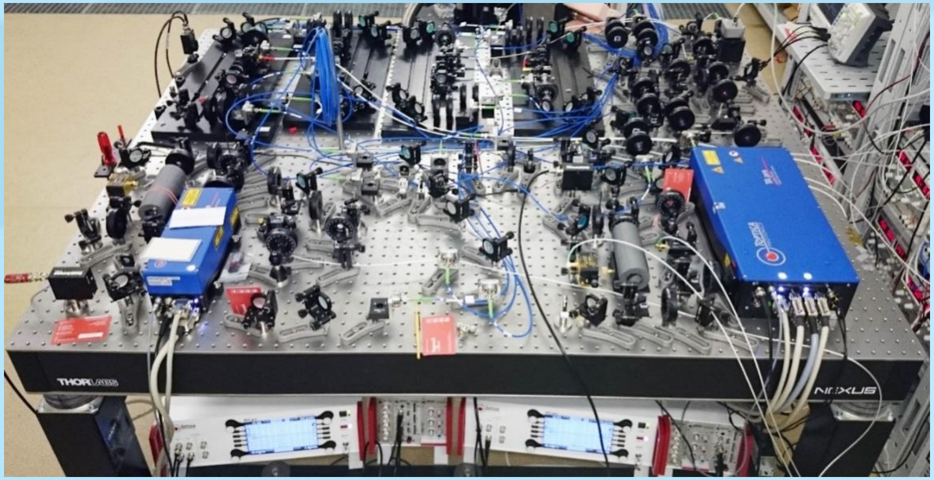
H-masers

- $\sigma_y(\tau) \sim 2.2\text{-}2.9 \times 10^{-16}$ $\tau = 1$ *day*
- $\sigma_y(\tau) \sim 0.8\text{-}1.2 \times 10^{-16}$ $\tau = 10$*days*
- *Frequency drift* $\leq 0.8 \times 10^{-16}$ / *day*

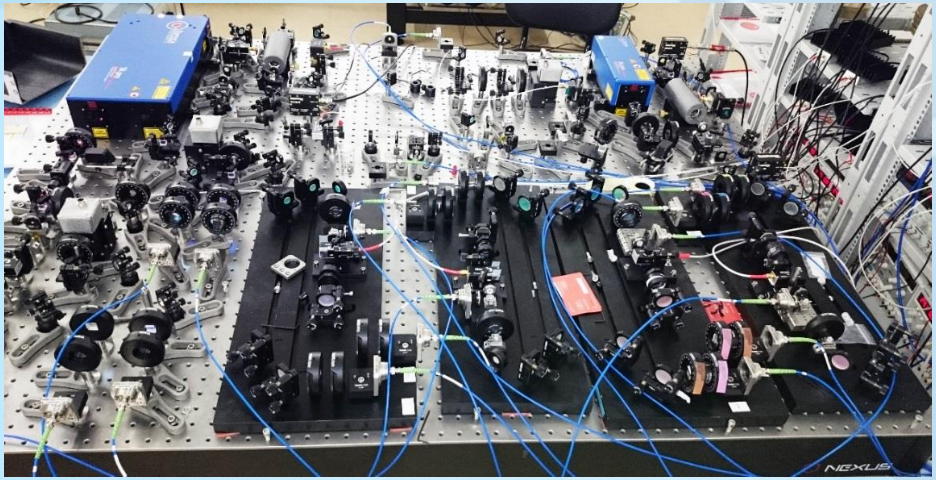
T&F internal measuring system

- $T\ u_A < 20$ ps / *single shot*
- $F\ u_A < 1 \times 10^{-18}$ / *day*

Rb fountain frequency standards



Laser optical system Rb1



Laser optical system Rb2

μ-wave cavity

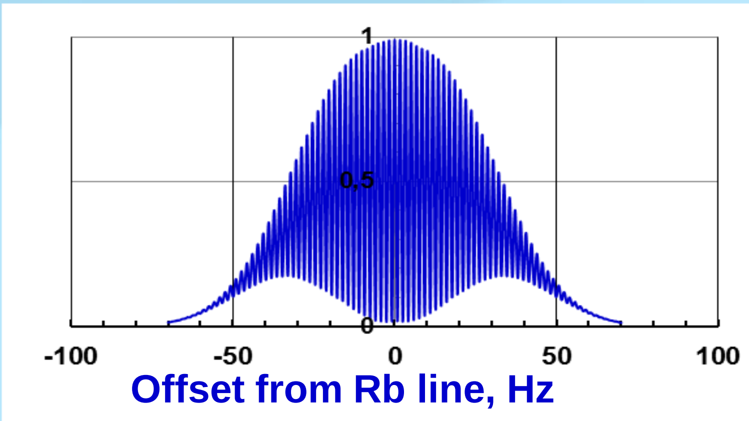
reference source

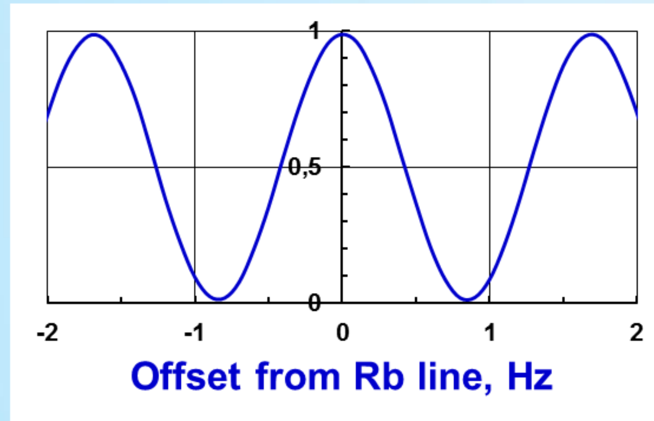
μ-wave probe
signal synthesizer

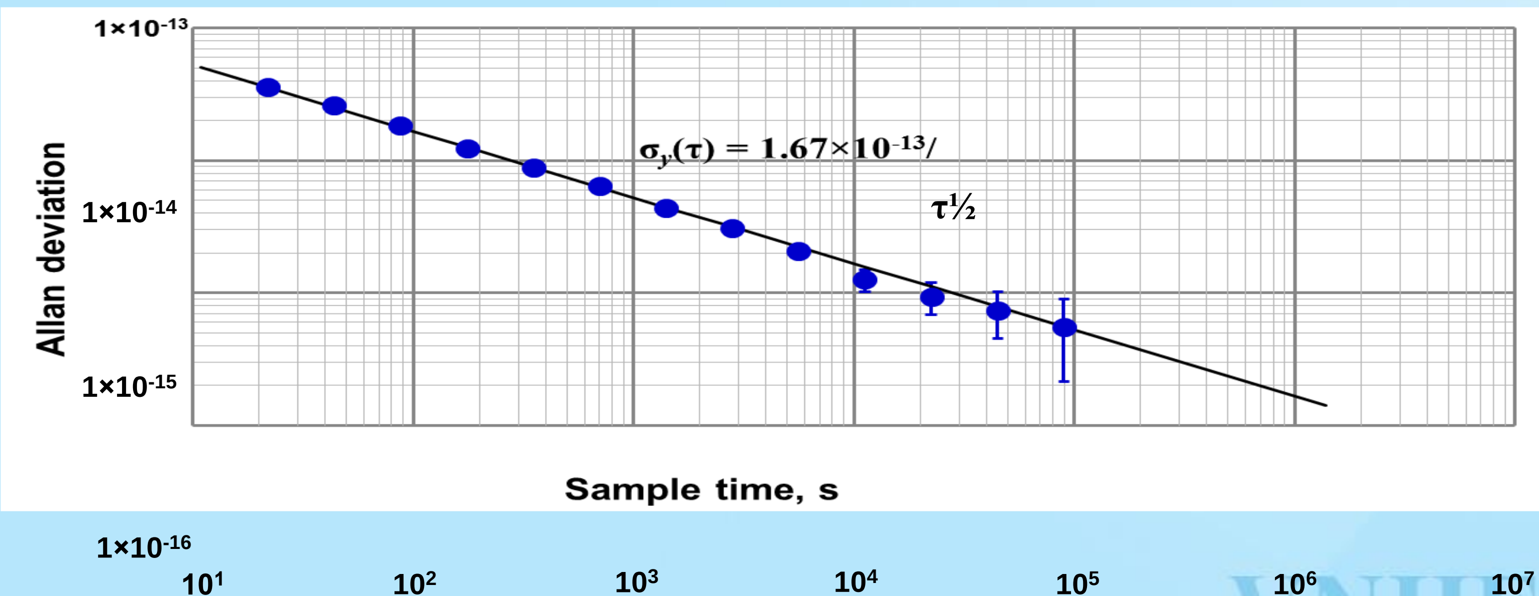
control system

Rb fountain frequency standards

Used as a keepers of time and for reducing difts of H-masers

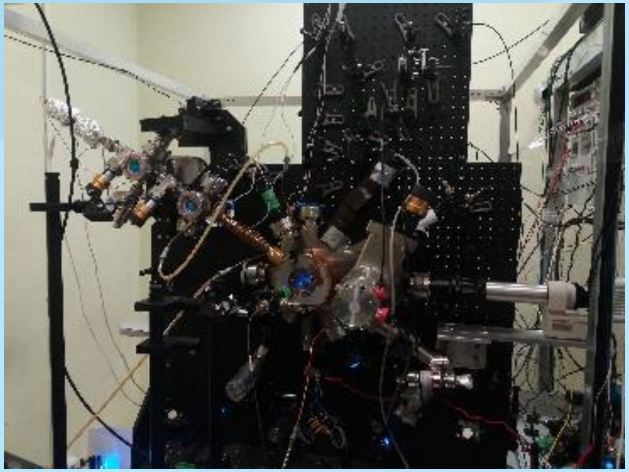




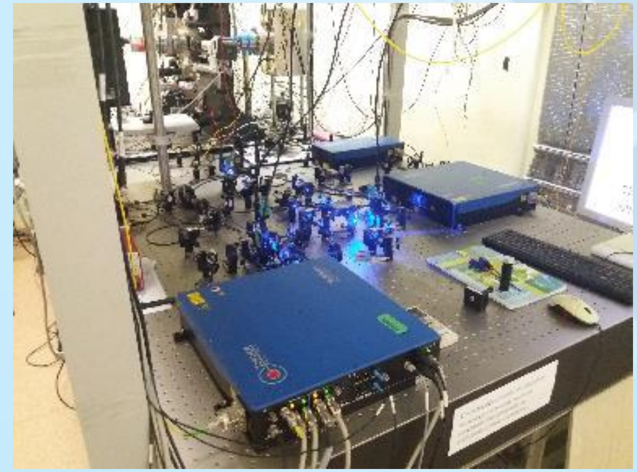


Preliminary frequency stability estimation

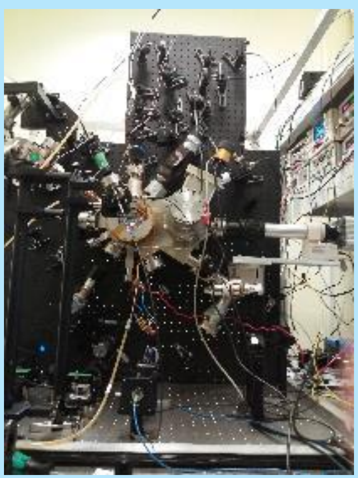
^{87}Sr neutral atoms in an optical lattice frequency standard



Optical spectroscope chamber



Primary cooling laser system

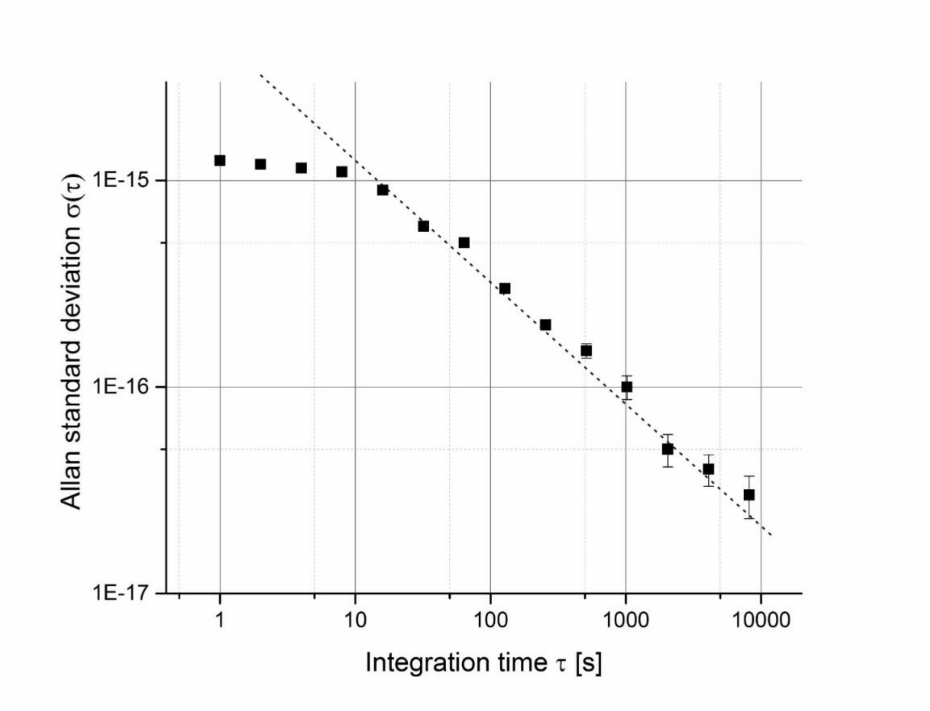


Vertical wall hosts optical lattice system and clock transition laser detection system

Secondary cooling laser system

^{87}Sr neutral atoms in an optical lattice frequency standard

Very preliminary figures



$\sigma_y(\tau)$ plot

frequency difference

between two ^{87}Sr standard

Partial uncertainty budget ^{87}Sr standard	
Physical phenomena	Uncertainty Unit 1×10^{-17}
Black body radiation	2.1
Second order Zeeman shift	3.1
Optical lattice light shift	5.8
Detecting beam light shift	not detected
Cold atom collision	not detected
Total	6.9

VNIIFTRI

New transportable Active H-Maser Clocks

We developed new transportable Active H-Maser Clocks equipped with GNSS receiver and magnetic field measurement system.

- **Time keeping uncertainty 0.2 ns during 12 hours of transportation with typical speed for regional roads.**
- **Temperature coefficient of frequency change**
  $\leq 1.0 \cdot 10^{-15}$ 1/˚C
- **Magnet coefficient of frequency change**

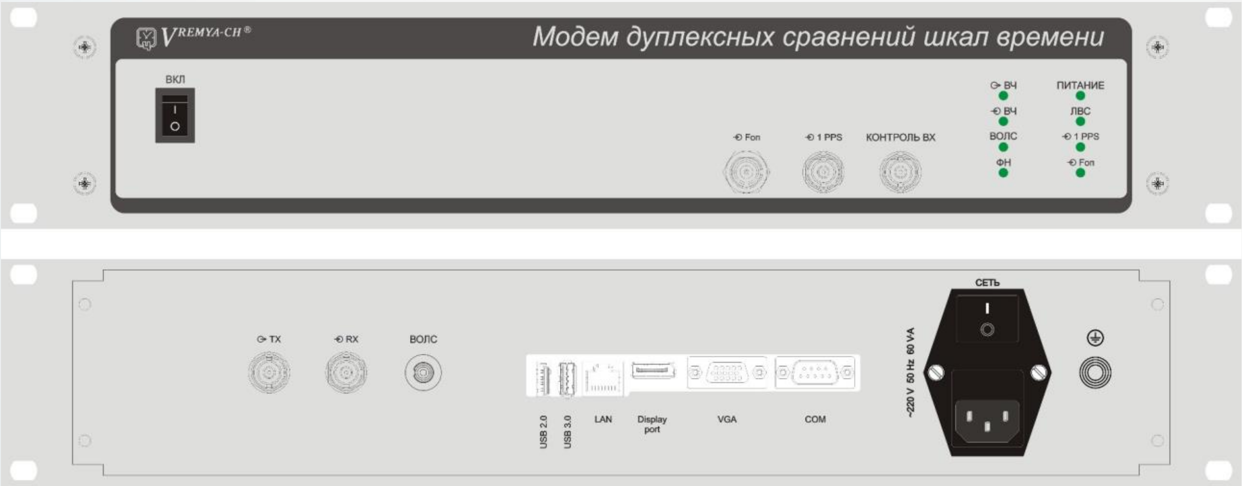
5 MHz ADEV no more than	
1 s	$3.0 \cdot 10^{-13}$
10 s	$3.0 \cdot 10^{-14}$
100 s	$7.0 \cdot 10^{-15}$
1 hour	$4.0 \cdot 10^{-15}$
1 day	$5.0 \cdot 10^{-16}$

- **For improving the accuracy of time keeping – is provided possibilities of elevation recording with aim of taking into account relativistic correction.**

New DPN/TWCP TWSTFT Modem

Has developped new digital modem for TW time and frequency transfer. This modem designed for two methods Dual Pseudo Random Noise (DPN) and Carrier Phase (TWCP). Modem may be used as for satellite as an optical fiber links. To enable TW transfer using optical fiber modem contains Tx and Rx optical modules, optical insulator and circulator. Expected metrological characteristics: $Tu_B \sim 100$ps, $Fu_B \sim 5 \times 10^{-15}$/day.

Also we have correlation station for VLBI evaluation and



Calibration and performance monitoring

Calibration and control of metrological characteristics is carried out:

- by means of SLR-system directly during the measurement session;
- using the State special standard of length: periodic - control of the additive component of the error;
- using equipment of The state standard of time and frequency: periodic – control of the multiplicative component of the measurement error of the range and the error of the binding of the measurement time to the national time scale UTC(SU).

The level of the received signal at calibration and control of metrological characteristics is established equal to the signal received from satellites "Lageos" at average values of transparency of the atmosphere in point of supervision.
Periodic monitoring is carried out at least four times a year, in conditions specific to each season.

comparison laser range system with standard of length.

We produce it in several steps:

Comparison standard (Leica TDA 5005) and retroreflector calibrated on national state standard of length;

Transfer comparison standard and retroreflector established at calibrating basis;

Placing retroreflector to reference point of laser range;

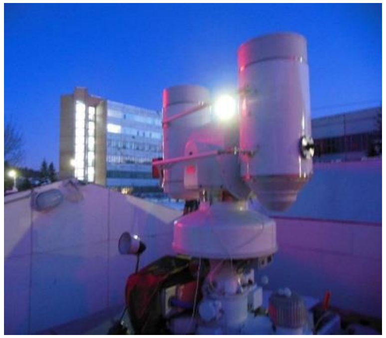
Put the comparison standard on the geodetic point;

Direct the telescope to the geodetic point, and measure the distance by comparison ;

Transfer the reflector on the geodetic point and measure the distance of the laser range

finally distance between reference point of laser range instrumentation and geodetic point, which determine calibrating basis, measured.

As results of measurements, additive constant of SLR-system is determined.



VNIIFTRI as the Russian Main Metrological Center of Time, Frequencies and Earth Rotation Service carried out the rapid EOP processing based on GNSS, VLBI,SLR and LLR observations for many years.

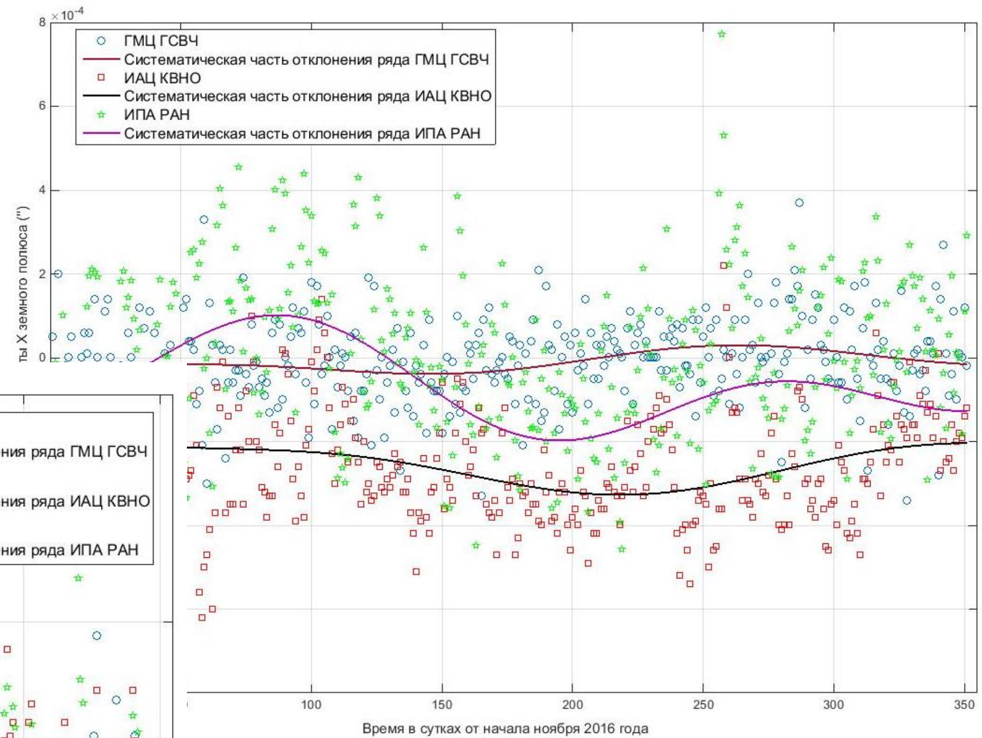
The EOP activities at VNIIFTRI can be grouped in four basic topics:

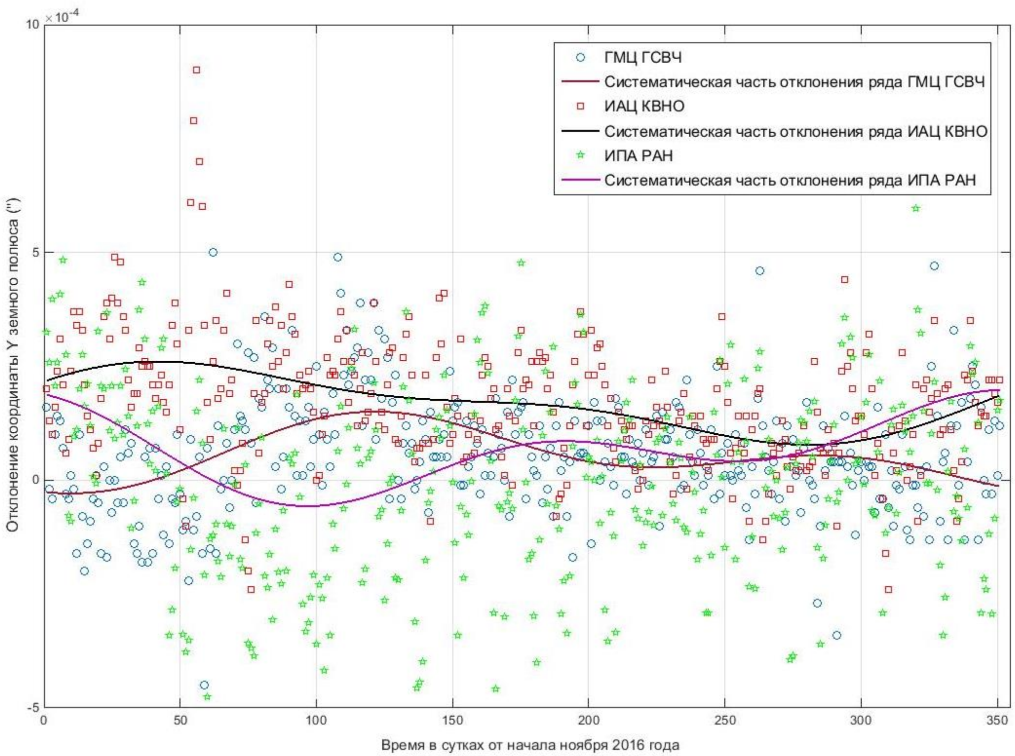
- processing GNSS, SLR , LLR and VLBI observation data for EOP evaluation;
- combination of EOP series for evaluation of reference EOP values (on the eop raws level and observation level);
- combination of GLONASS/GPS satellites orbit/clock;
- providing GNSS and SLR observations at five metrological sites acting under the auspices of Federal Agency on Technical Regulating of Metrology(ROSSTANDART).

EOP from satellite laser ranging (SLR) Lageos 1,2

$$STD\ x_p \le 0{,}00008''$$

$$STD\ y_p \le 0{,}00010''$$

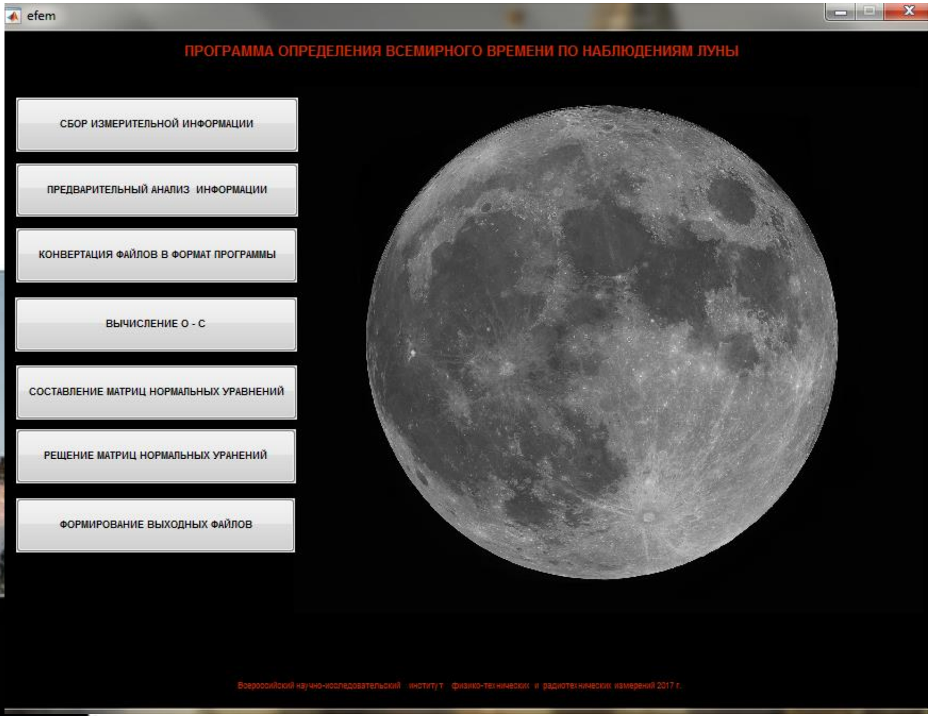




The neural net algorithm was used for prediction of the orbits of satellites. As result VNIIFTRI SLR EOP achieved high accuracy and small latency (only one day).

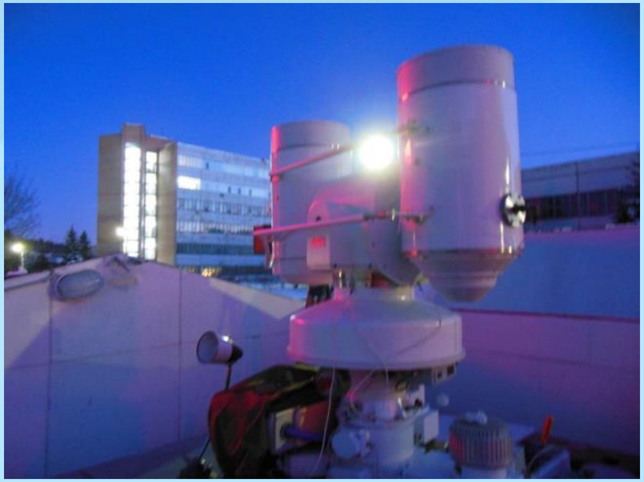
UT1–UTC from Lunar Laser Ranging (LLR)

STD UT1–UTC ≤60 μs



The modern program of UT1 evaluation based on Lunar Laser Ranging measurements were created in the MATLAB environment. Now only ILRS LLR data are processed, but it’s ready for processing the Altay LLR station measurements too.

Time and frequency transfer techniques based on different technologies



Mendeleevo-1874

Irkutsk-1891

Despite VNIIFTRI doesn't participate in Jason-2 Time Transfer by Laser Link (T2L2) campaign we started domestic analogous experiments using GLONASS # 747.

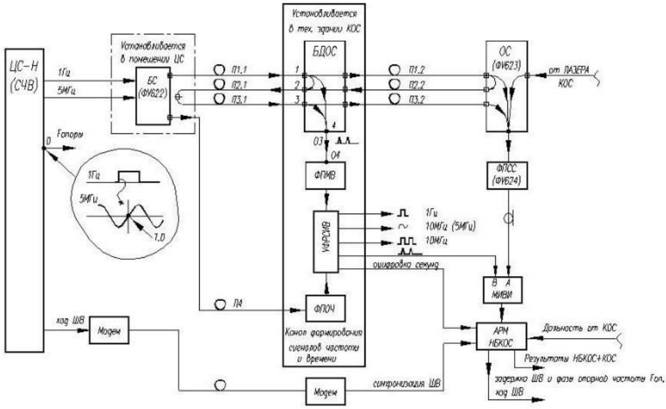
Three laboratories are involved in this activity: VNIIFTRI (*Mendeleevo-1874*), VNIIFTRI ES branch (*Irkutsk-1891*), and GLONASS master station.

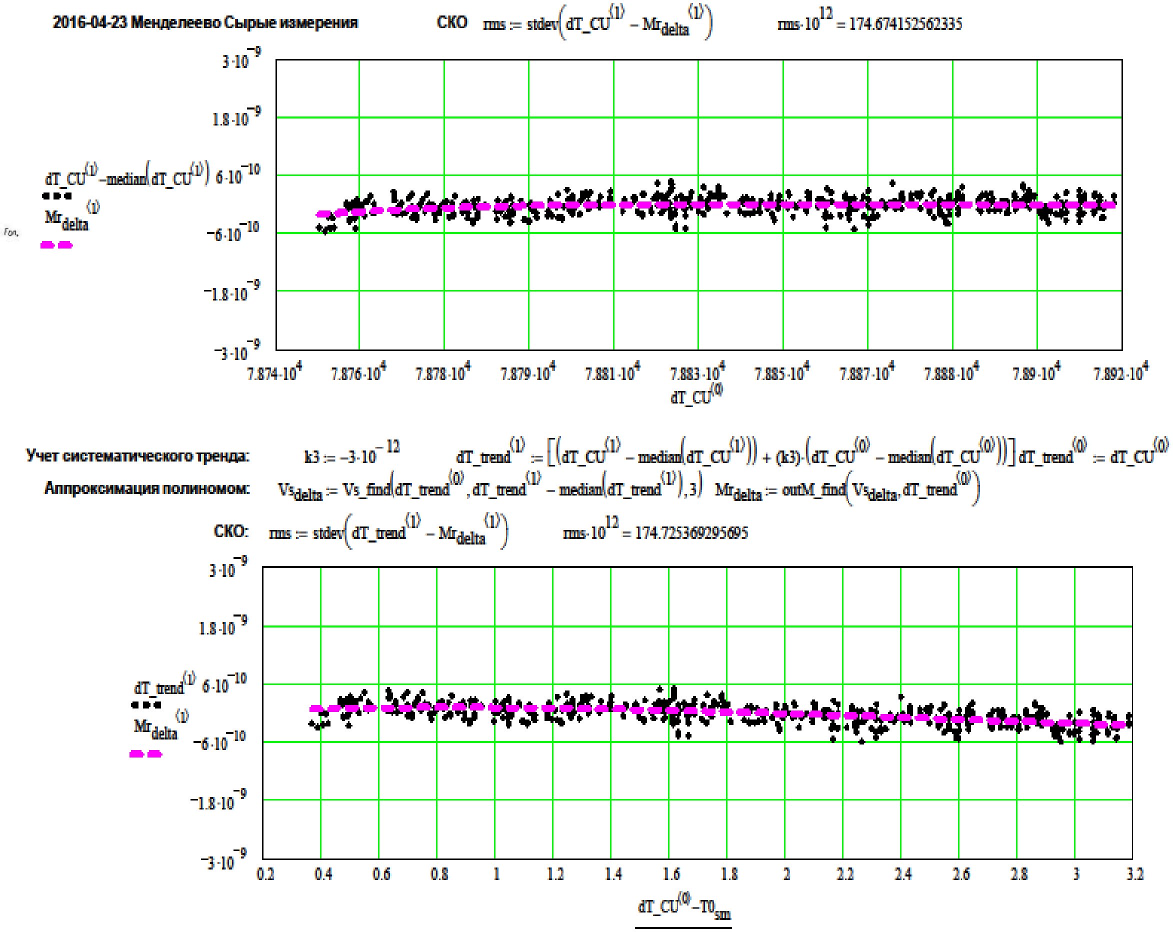
Using laser ranging instruments for the first time in history GNSS time scale has been transferred from one remote laboratory to the other one.

Till now the main source of uncertainty is line link between on land local time scale and laser station itself.

VNIIFTRI

Time transfer





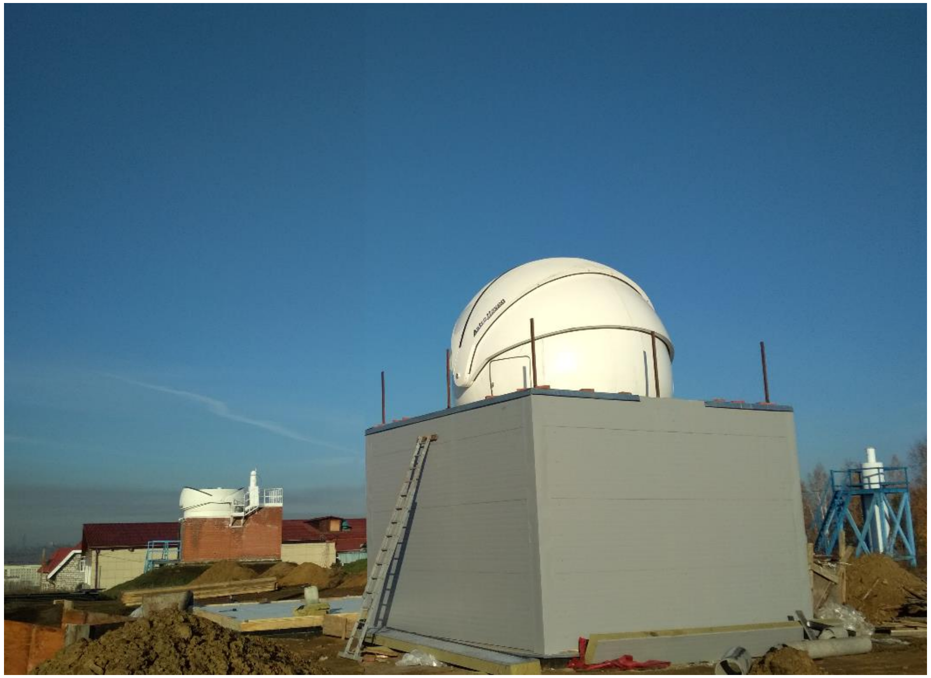
VNIIFTRI has an modern equipment for one-way time calibration using the SLR equipment

The difference between ground clock and GLONASS PRN 747 satellite clock determined with the help of this device are showed on the right side of this slide.

The total uncertainty is about 0,9 ns

New generation of SLR stations

2 new generation stations are coming next year and will be established in Mendeleevo and Irkutsk. Preliminary tests confirmed declared characteristics in few mm.



SUMMARY

1. VNIIFTRI has successful experience to measure laser range for EOP 50 years

2. Carefully calibration of laser station ensures reliable and precise measurements.

3. We can possibility to use national standards for calibration SLR.

4. New neural net algorithm of evaluation SLR/LLR were designed.

5. Time transfer experiments through GLONASS satellites will be continued.

Thank you for your attention !