

The Precision Laser Inclinator long- term sensitivity in thermo-stabilized conditions (first experimental data)

Presented by Mikhail Lyablin

N.Azaryan¹, V.Batusov¹, J. Budagov¹,
V. Glagolev¹ M. Lyablin¹, G. Trubnikov¹, G. Shirkov¹,
J-Ch. Gayde², B. Di Girolamo², D. Mergelkuhl², M. Nessi²

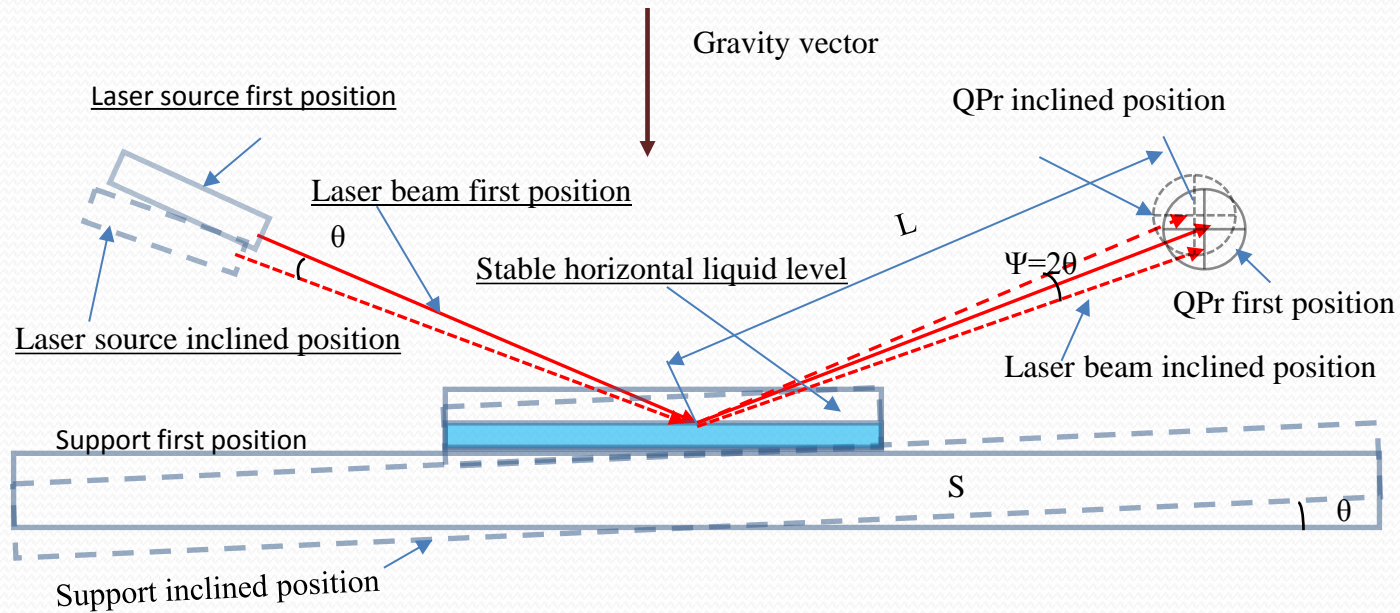
1-Join Institute for Nuclear Research

2- European Organization for Nuclear Research

The introduction

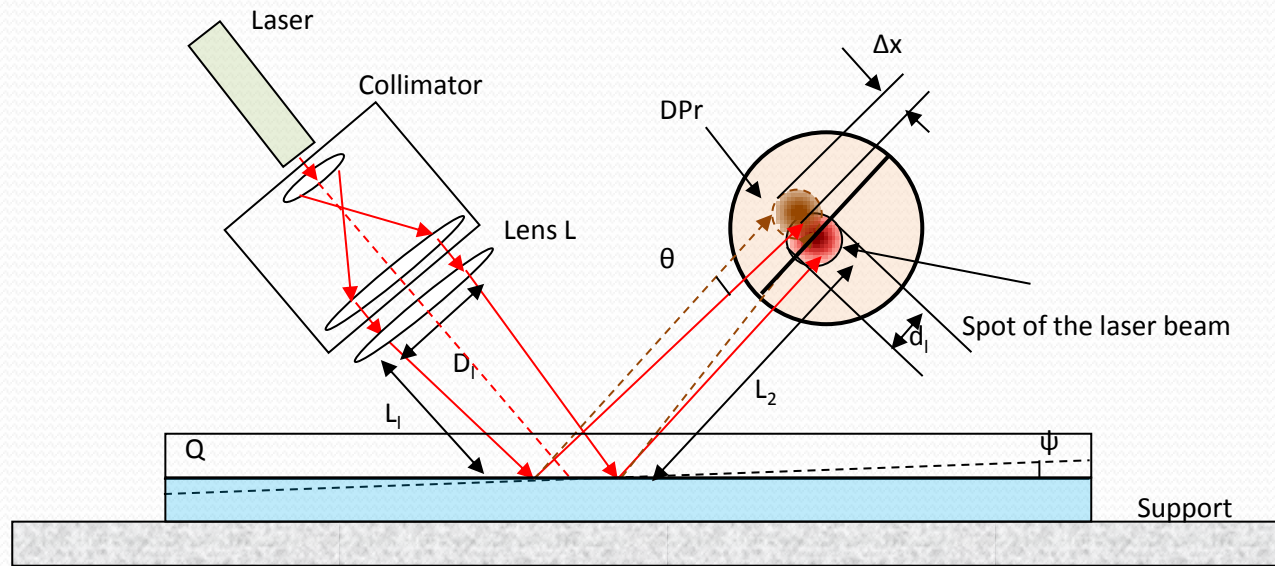
- The principal significance parameter of any energy collider (CLIC, ILC, LHC..) is its luminosity.
- One of the reasons for the decreasing of an average luminosity is the ground angular motion.
- We propose a conceptually new design high precision detector of ground angular oscillations – The Precision Laser Inclinometer.
- We think the Precision Laser Inclinometer measurement data can be used for colliding beam space stabilization of beam focus wandering .

The Precision Laser Inclinometer (basic idea)



- The main idea is to use the effect of horizontality of surface of the liquid.
- Angular displacement of the laser beam reflected from the surface of the liquid is proportional to the inclination of the support with cuvette with liquid

The accuracy of the Precision laser Inclinometer



$$\psi = \frac{1}{2} \theta \quad d_1 = 1.22 \lambda \frac{F}{D_1}$$

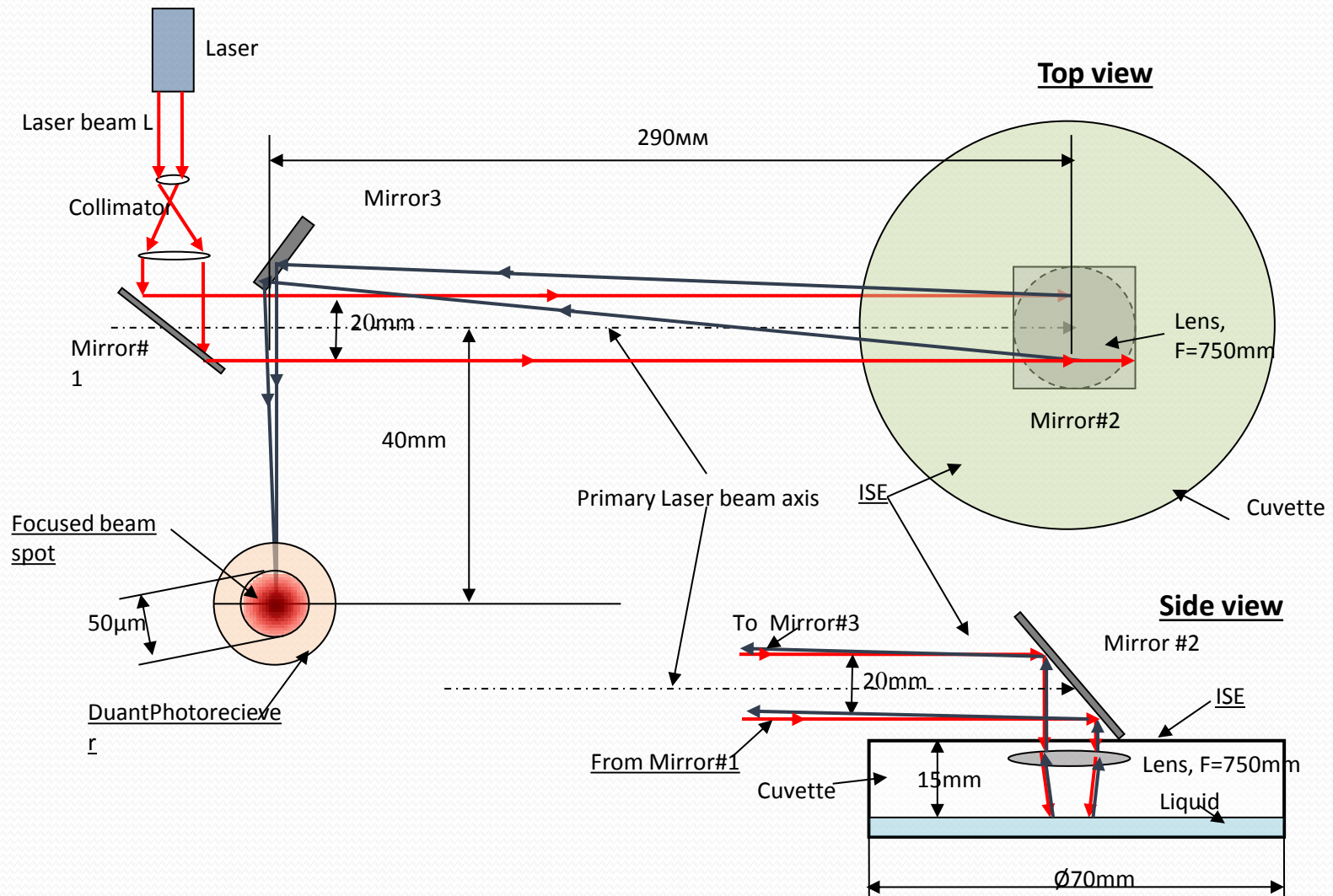
$$L_1 \ll L_2 \quad F = L_1 + L_2$$

$$\psi_n = \frac{\pi}{16} 1.22 \frac{\lambda K_{n.ADC}}{D_1}$$

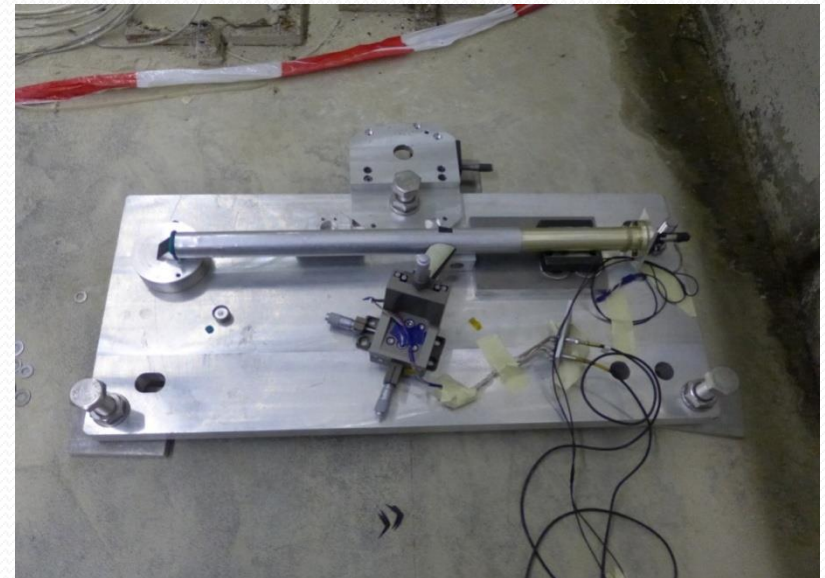
F-Lens focus; d_1 -Diameter of the focus spot; ψ -angular inclination of the support; θ -angular inclination of the laser beam; $K_{n.ADC}$ -relative resolution 24bit ADC
For $\lambda=0.63\mu\text{m}$, $K_{n.ADC}=5.5 \cdot 10^{-7}$ and; $D_1=10\text{mm}$, we obtain

$$\psi_n = 8.5 \cdot 10^{-12} \text{rad}$$

The Scheme of the experimental set up

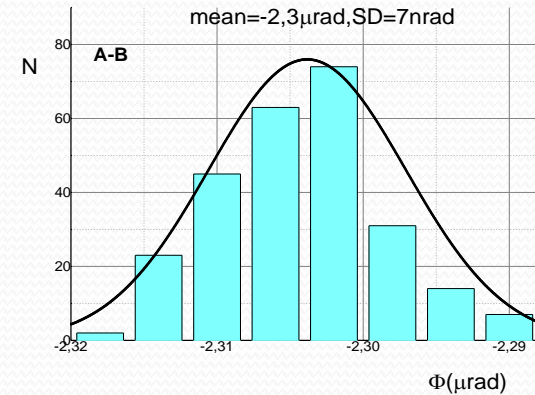
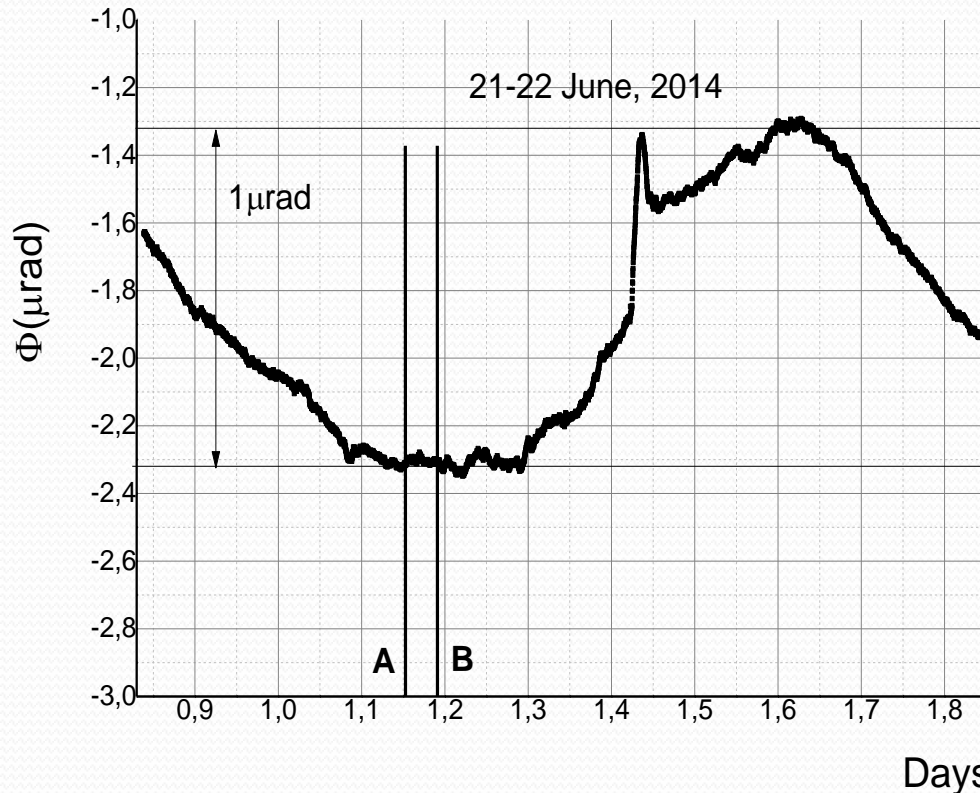


The Precision Laser Inclinator and Transport Tunnel TT₁ (general view)



The **140m** long TT₁ is located at **10m** depth underground and has stable daily temperature of **16.4°C±0.1°C**.

The Long term stability (24 hour)

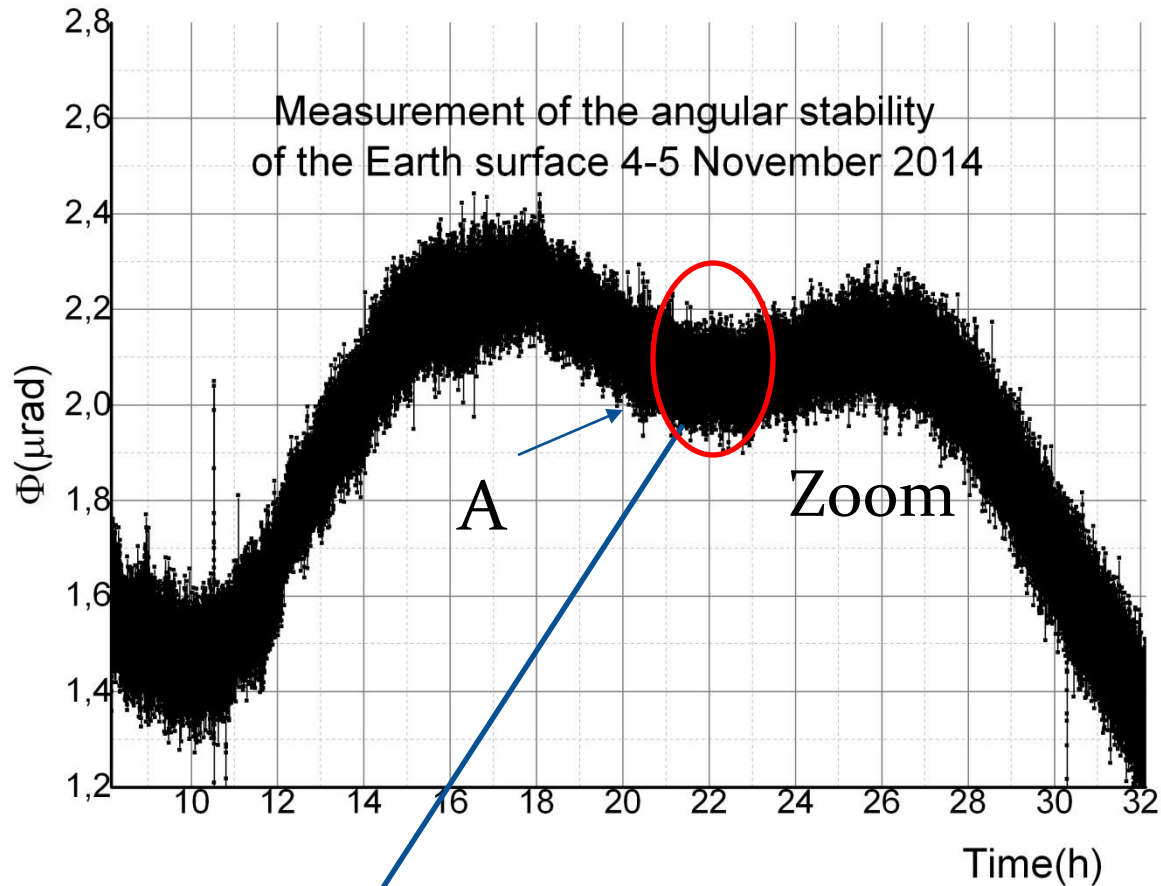


The angular daily data spread reached with the inclinometer is within the **1 μrad** band.

For the single taken short-period (**60 min**) "AB" on the inclinometer angular distribution the sigma is $\sigma_{\text{rms}} = \mathbf{7 \text{ nrad}}$.

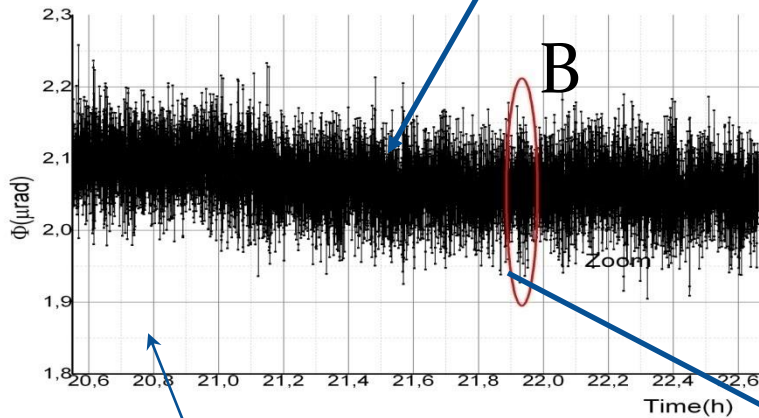
One measurement duration is 50 sec.

The Short Term Stability of the PLI



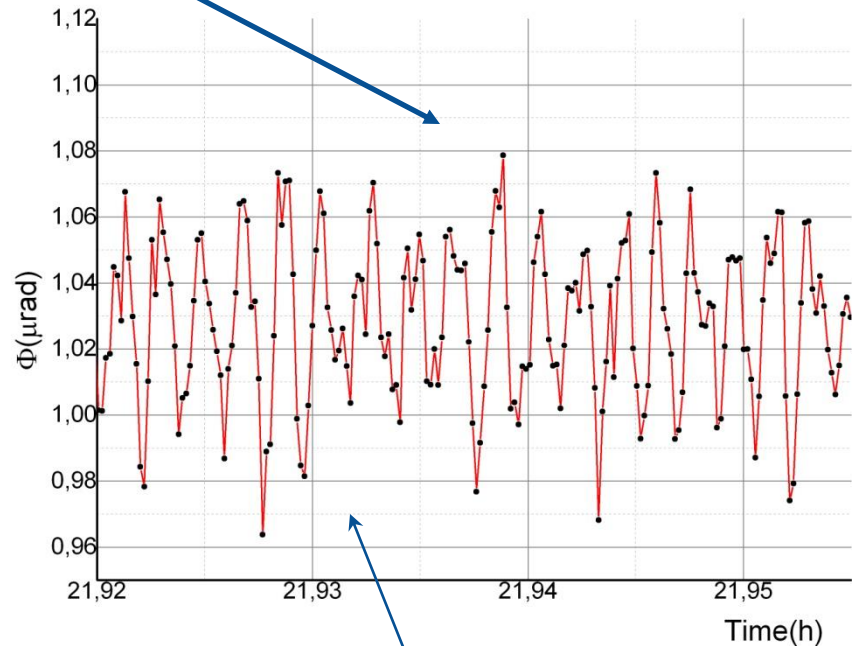
One measurement duration is 0.638sec

The Short Term Stability of the PLI



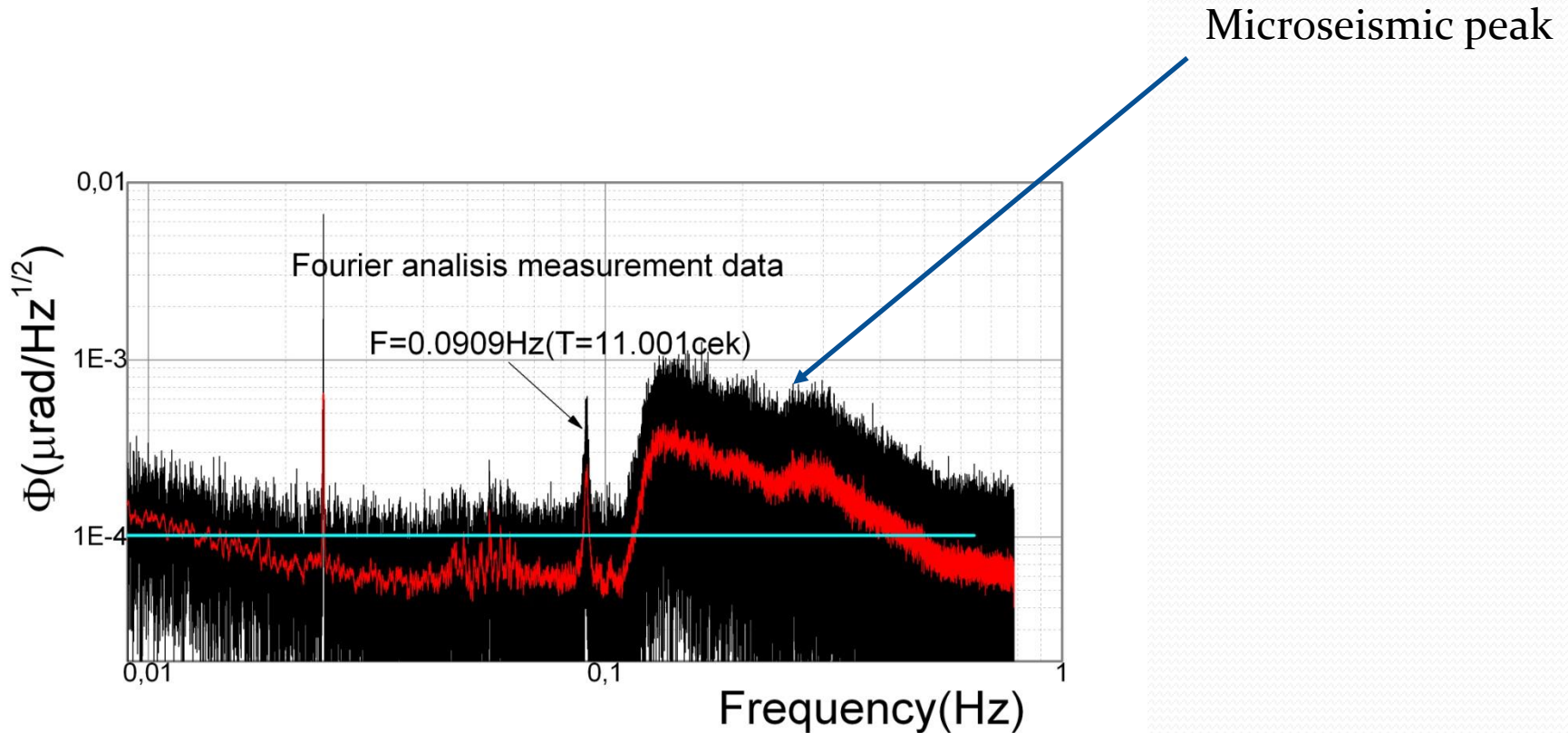
“A”-region in the previous picture

There is a periodic process of tilt of the Earth surface with an amplitude of $5 \cdot 10^{-6}$ to -10^{-8} rad in the frequency range of 0.1-1 Hz



B

The Fourier Analysis of the PLI measurement Data.

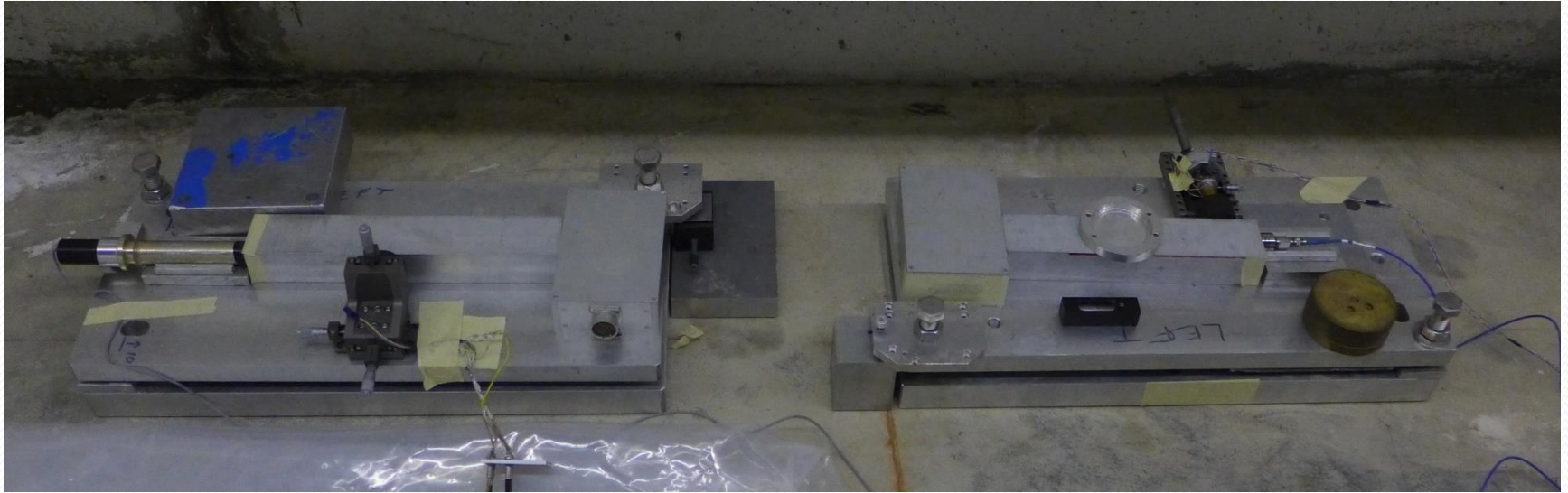


Red line- average data.

Noise of the Precision Laser Inclonometer in the frequency range

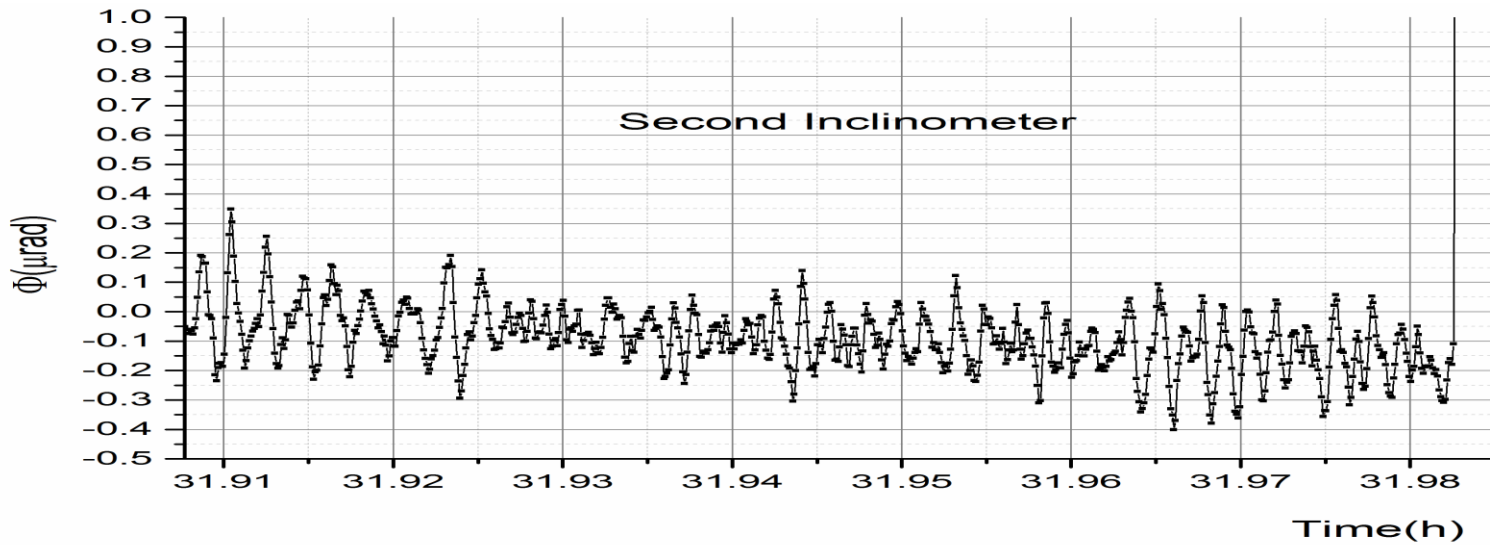
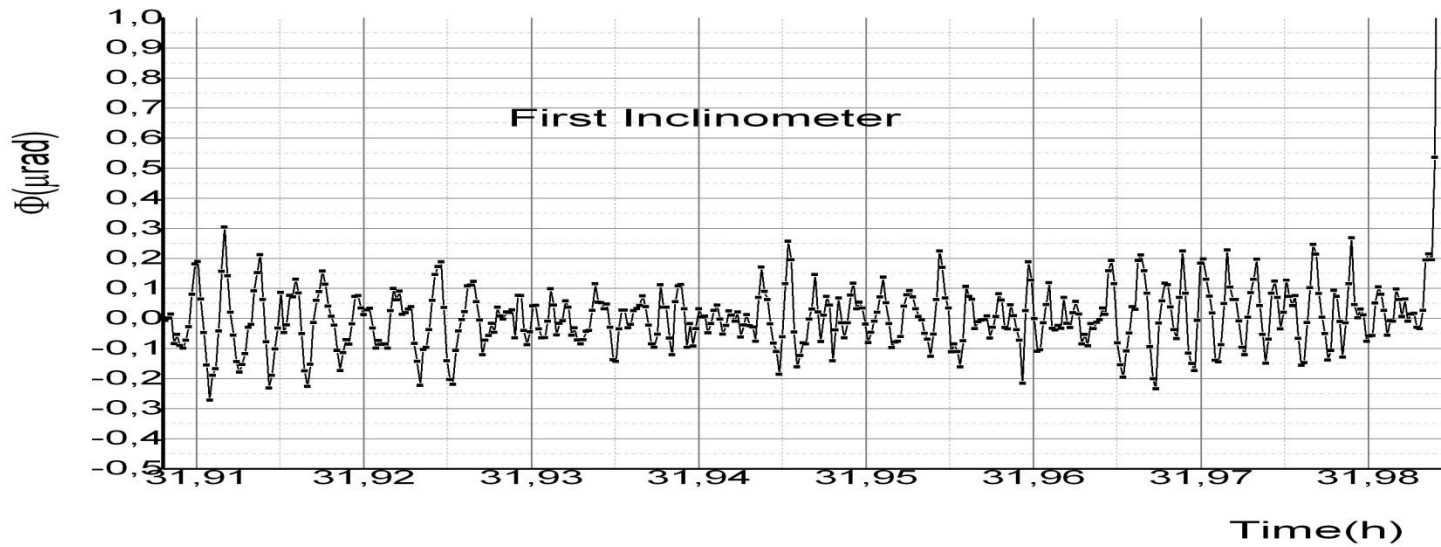
0.01-0.1 Hz is $\sim 10^{-10}$ rad.

The Proof of the reality of an angular oscillations of the Earth's surface at the frequency of the "microseismic peak"



- Two independent (different: lasers, recording ADCs, computers)
- The Inclinometers recorded angular oscillations of the surface in one direction

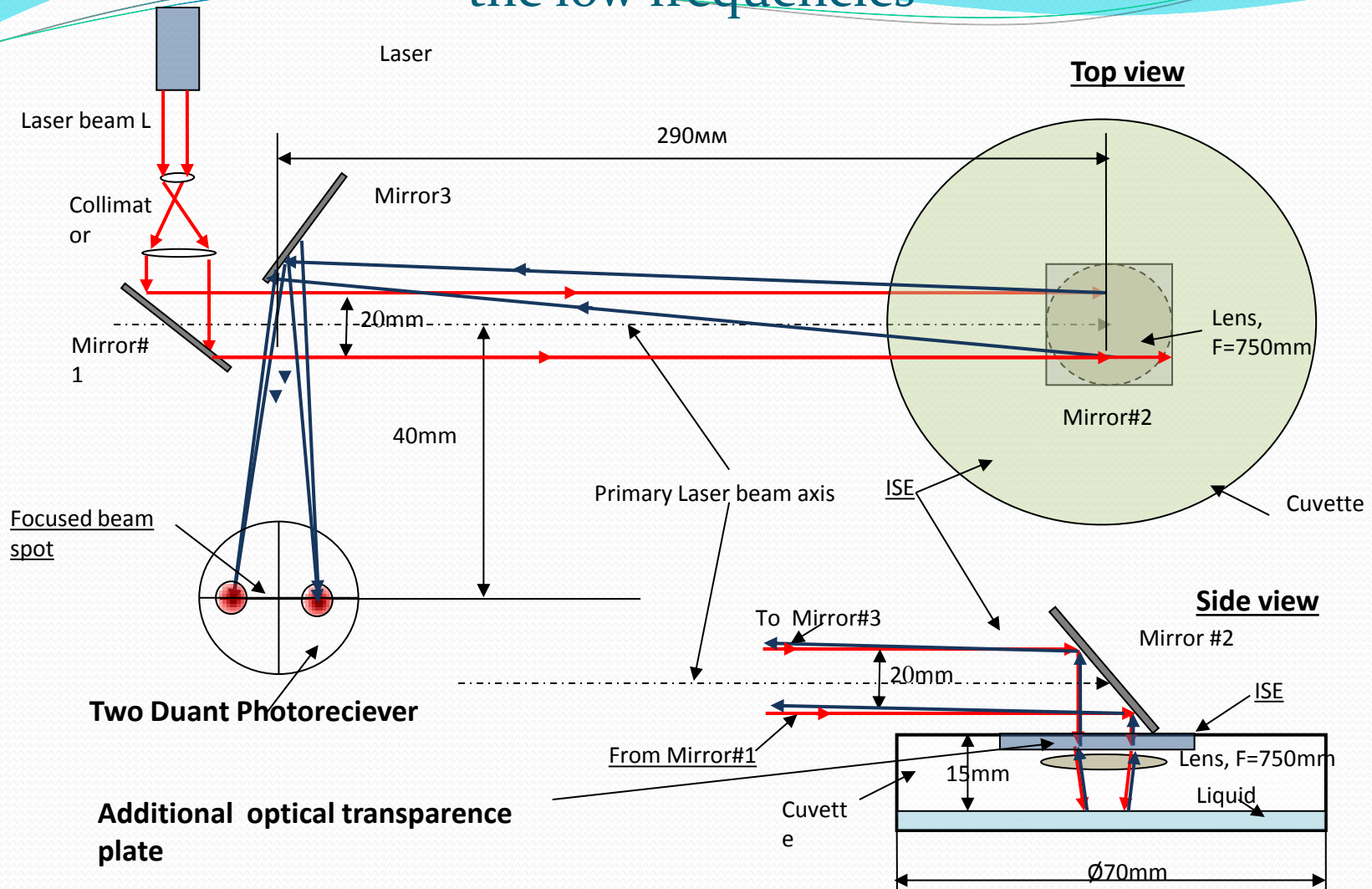
The Comparison of the measurements of two inclinometers



The Sources of the Long term noises of the Precision Laser Inclinometer

- The Noise angular oscillation of a laser beam (non-uniform heating effects of laser active medium).
- The instability of the power density distribution a cross laser beam.
- The Thermal deformation of structural elements of the Inclinometer.

The Laser angular noise compensation for the Inclinometer in the low frequencies



- For the reduction of the effect of noise angular deviation of the laser beam an additional transparent dual flat plate is used. The reflection laser of beam from dual flat plate is used as a way of fixing of the angular variation of the laser beam and was applied in the further processing of data with the inclinometer.

The Development of the Precision Laser Inclinator

- The stabilization of the noises of the laser power and of angular movement of the laser beam in the Precision Laser Inclinator.
- The compact design inclinometer
- The simultaneous measurements of two angular coordinates

Conclusion

- The first experiments with Precision Laser Inclinator . measured values of noise of the Earth Surface angular motion at different frequencies.
- For a period of one day (10^{-5} Hz) the $1 \mu\text{rad}$ variation of an amplitude was registered.
- The value of standard deviation of the Earth angular motion for the one hour period ($3 \cdot 10^{-3}$ Hz) was founded to be 7 nrad
- In the $0.01-0.1$ Hz frequency range the Fourier analysis defined the magnitude of the noise to be $\sim 10^{-10}$ rad.
- The PLI sensitivity limited by the ADC registration noise was defined to be $8.5 \cdot 10^{-12}$ rad.
- The proof data of the reality of the angular variation of the Earth's surface at a frequency of "micro-seismicity peak" were given.
- The amplitude of the oscillation parameters of the microseismic peak was $5 \cdot 10^{-6}-10^{-8}$ rad
- We plan to further improve the precision of the Laser Inclinator to be better than achieved 10^{-6} rad in the frequency interval $10^{-5}-10^{-3}$ Hz