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ФИЗИКА ЭЛЕМЕНТАРНЫХ ЧАСТИЦ И АТОМНОГО ЯДРА. ЭКСПЕРИМЕНТ

THE PRECISION LASER INCLINOMETER LONG-TERM MEASUREMENT IN THERMOSTABILIZED CONDITIONS (FIRST EXPERIMENTAL DATA)

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The Precision Laser Inclinometer (PLI) was tested at thermostabilized conditions, and the ground angular stability of 1 μrad (observation during 24 h) and 7 nrad (observation during 60 min) was measured.

В работе представлены результаты тестирования высокоточного лазерного инклинометра в термостабильных условиях. Измеренная угловая стабильность земной поверхности при наблюдении в течение 24 ч оказалась равной 1 мкрад, а при наблюдении в течение 60 мин — 7 нрад.

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INTRODUCTION

There are many tasks where the metrology control of the ground angular stability becomes of a principal necessity. In [1, 2], the Precision Laser Inclinometer (PLI) was proposed as a sensitive indicator of the ground motion. The PLI's signal was meant to be used for specialized set-up for laser beam direction stabilization. This paper shows the hardware scheme and the very first encouraging results obtained with a prototype installed in a transfer tunnel at CERN.

The PLI ground motion data, in an experimental environment such as ATLAS, may develop subdetectors relative displacements to be taken into account with the LHC total collision energy rise [4–7]. The ground motion could be considered when stabilization of a space location like the focus area of an accelerator as LHC is interesting for beams forming optics. There are some recent evidences of growing interest to the gravity constant measurement where detectors stability is of vital necessity [3]. In a new large project of CLIC, ILC scale the precision alignment and space stabilization of many accelerator units may need the ground oscillation data.

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THE PRECISION LASER INCLINOMETER

Unlike the previous inclinometer scheme [1] used two platforms to position inclinometer components, the new design tested used only one platform for compactness. It allowed one to decrease significantly the influence of deformation, caused by temperature variations, on the inclinometer data stability.

Note, that for this experiment thermostabilization has been integrated to the inclinometer. This represents a major upgrade of the previous inclinometer design.

Figure 1 shows the principal scheme of an inclinometer used.

The laser beam L from the laser source is sent on optical collimator. After the collimator the ∅2-cm beam is directed with Mirror #1 on the Inclinometer's Sensitive Element (ISE). There, by Mirror #2 the beam is sent into a cuvette with liquid (see side view of Fig. 1); after being reflected from liquid's surface, the beam moves backwards to meet Mirror #3 and further to enter the Duant Photoreceiver (DPr).

To increase the inclinometer's angular resolution[1], the laser irradiation is focused (by the lens with 750 mm of focus distance) into ∅50-μm spot on the DPr surface.

The cuvette inclination angle is registered by the dual photoreceiver. The DPr signal is recorded by the ADC in computer.

The inclinometer scheme used two passive thermostabilizations:

— the perpendicular laser-ray direction with respect to the liquid surface: in this case, the external temperature variations leading to liquid's level change do not disturb the reflected ray direction;

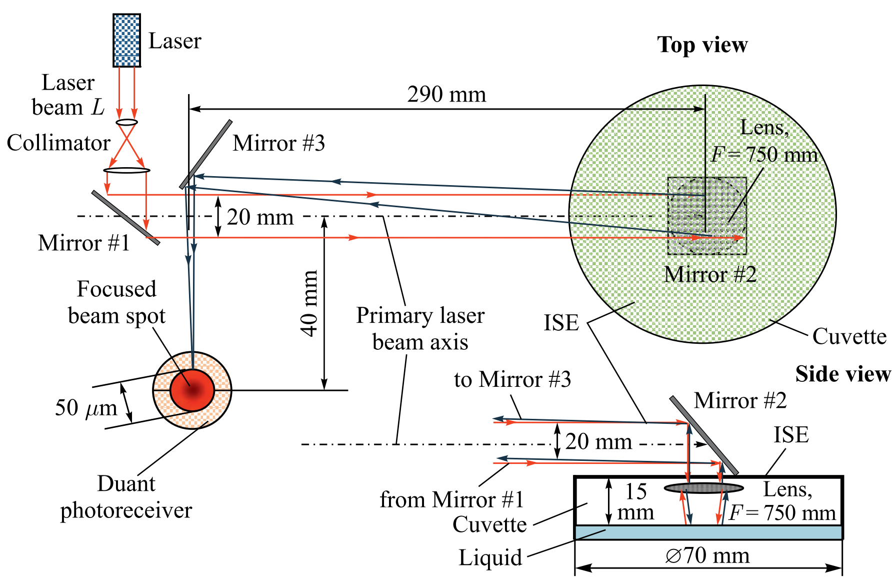

Fig. 1. The principal scheme of the Precision Laser Inclinometer (PLI)

[1]As shown in [8], the registered DPr signal ΔU for laser spot displacement δ is $\Delta U \sim \delta/D$ with D as beam spot diameter on the DPr.

— application of lens which focuses the ray on the duant photoreceiver: in this case, the ray transversal displacements between laser source and the lens do not change the lens's focus position.

THE EXPERIMENTAL LOCATION

The experiment for determination of the inclinometer long-term stability was installed in CERN's Transfer Tunnel #1 (TT1) (Fig. 2).

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

Fig. 2. The Transfer Tunnel general view in the experiment location area

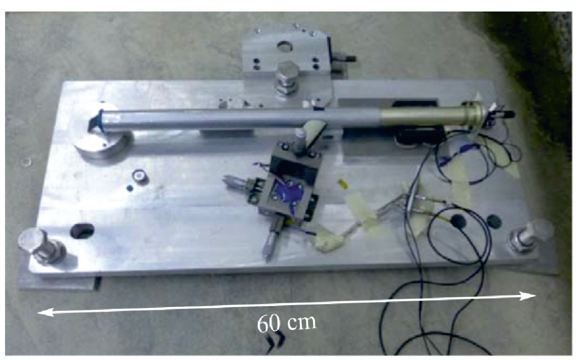

Fig. 3. Precision laser inclinometer location in the Transfer Tunnel #1

The inclinometer was positioned in the middle of the tunnel. The measurements of the tunnel *floor angular oscillations* have been made in the vertical plane containing the tunnel longitudinal axis, corresponding to the direction East–West preliminary.

Figure 3 shows the location and general view of the inclinometer.

THE EXPERIMENTAL RESULTS

Measurements of the angular oscillations of the TT1 floor have been performed during a period of a few days long.

Figure 4 demonstrates the day-long measurements record for the period of 21–22 June, 2014.

The day-long inclinometer data spread is small and limited by the 1 μrad wide interval.

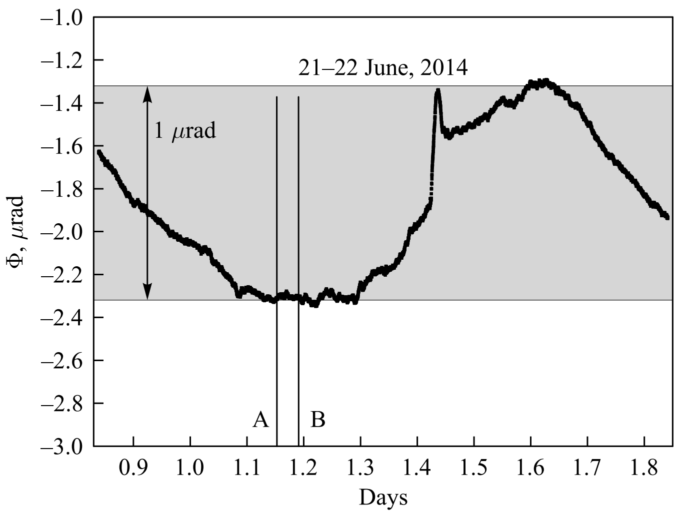

Fig. 4. The record of the day-long angular oscillations of the TT1 floor

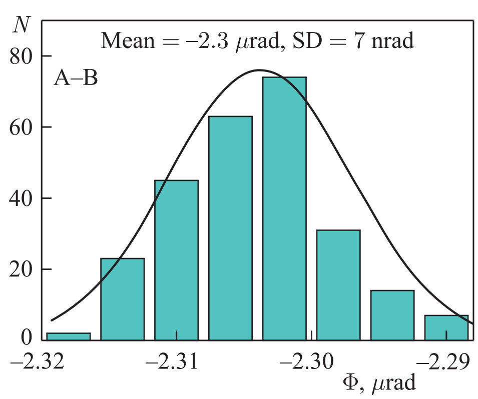

Fig. 5. The distribution of the TT1 floor angular inclinations measured for the A–B period of Fig. 4

Figure 5 shows the distribution of the inclinometer angular measurements for 60 min long A–B interval of Fig. 4. For this case the $\sigma_{\rm rms}$ is found to be 7 nrad.

CONCLUSION

The Precision Laser Inclinometer (PLI) first measurements have been made in thermostabilized conditions and the achieved results are:

— the angular daily data spread reached with the inclinometer is within the 1-μrad band;

— for the single-taken short period (60 min) A–B in Fig. 5, the inclinometer angular spread is $\sigma_{\rm rms} = 7$ nrad.

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