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GEOPHYSICS

Recording of Deformation Anomaly of a Tsunamigenous Earthquake Using a Laser Strainmeter

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A deformation anomaly with a size of approximately 59.3 μm caused by a tsunamigenous earthquake on December 26, 2004, was detected using a 52.5-m horizontal laser strainmeter of the unequal arm type set in Primorskii Krai of Russia. It was possible to predict a powerful tsunami wave based on the size of the deformation anomaly, which reached the strainmeter location region from the earthquake epicenter in 19 min 54 s.

In 2000, a laser strainmeter of the uneven arm type with the measuring arm length equal to 52.5 m was set at the Cape Schultz experimental station of the Il'ichev Pacific Institute of Oceanology to study variations in microdeformations of the Earth's crust. At present, this strainmeter is included in the laser interferometer complex, which consists of vertical and horizontal laser strainmeters, a laser nanobarograph, and a laser meter of pressure variations in the hydrosphere [1]. All devices are based on the application of modern laser interference methods using frequency-stabilized lasers as light sources.

The main properties of the setups are as follows: (i) measurement of the main parameters of geospheres at the level of background oscillations; (ii) frequency range 0–1000 Hz; and (iii) virtually unlimited dynamic range. The measuring complex is additionally provided with a meteorological station, GPS-receiver, low-frequency seismoacoustic and hydroacoustic projectors, and hydrophysical and hydroacoustic receivers. The experiments at the complex were aimed to study the regularities of energy exchange between geospheres at the atmosphere–hydrosphere–lithosphere boundary in the acoustic and ultrasonic ranges [2]. The laser interference complex is located at a point with coordinates 42.58° N, 131.13° E.

The field of our research is only slightly related to the physics of earthquakes and their precursors. However, some of our papers are related to this problem [3–5]. Our low interest in earthquake physics explains the late appearance of this article.

A deformation anomaly was found during processing of the records of the 52.5-m laser strainmeter obtained in December 2004 related to the tsunamigenous earthquake of 2004. Figure 1 shows a record of the laser strainmeter containing oscillations and the deformation anomaly caused by the tsunamigenous earthquake at 00:58:53 at a point with coordinates 3.30° N, 95.87° E. According to the record of the strainmeter, the deformation anomaly followed the earthquake. The record of the 52.5-m laser strainmeter shows that the deformation anomaly is ~59.3 μm, which corresponds to a strain of the order of $1.1 \cdot 10^{-6}$, which is significantly greater than the amplitudes of semidiurnal or diurnal tides observed at the location of the laser strainmeter [6]. The strain direction suggests a sharp increase in the length of the strainmeter basis followed by slow relaxation. It is likely that the Earth's crust responded similarly at the earthquake epicenter. Taking into account the attenuation and dispersion relationship

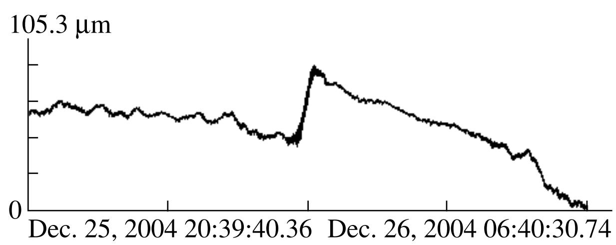

Fig. 1. A record of the 52.5-m laser strainmeter in 2004.

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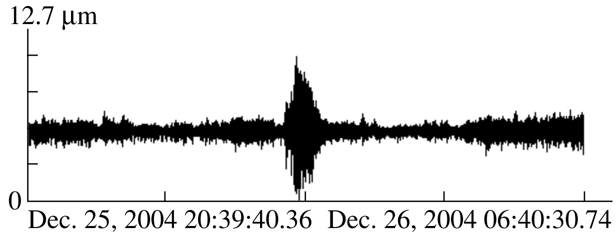

Fig. 2. A filtered record of the 52.5-m laser strainmeter in 2004.

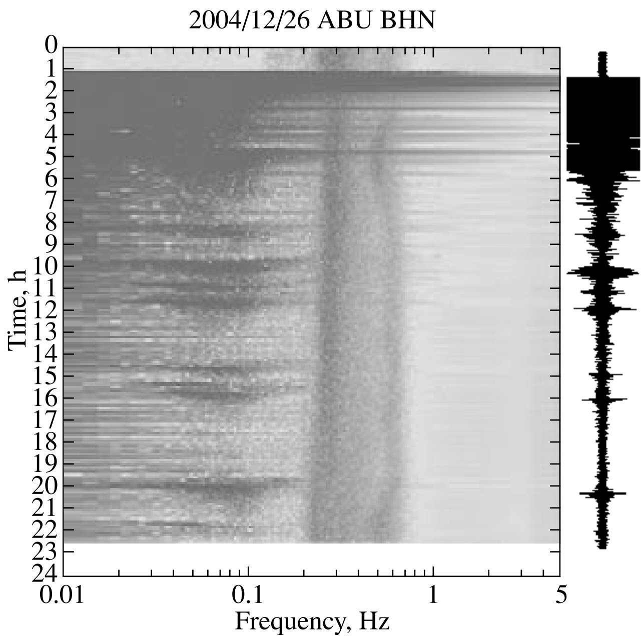

Fig. 3. A record of a broadband seismograph in 2004.

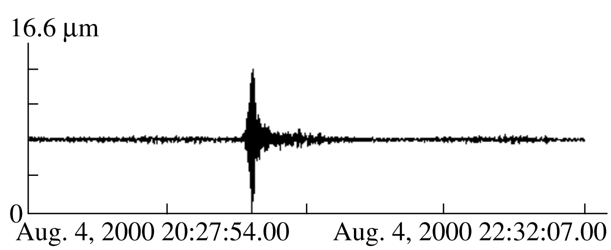

Fig. 4. A filtered record of the 52.5-m laser strainmeter in 2000.

between the velocity of waves and their periods, it is possible to state that the anomaly was significantly greater and the rate of its increase was higher at the epicenter. The oscillations and anomaly caused by the tsunamigenous earthquake propagated from the earthquake site to the strainmeter location in 19 min 54 s. Judging from the record of the laser strainmeter, one could predict the tsunami with 100% confidence if it was known that the earthquake occurred under the water column of the sea or ocean. The coordinates of the earthquake could be determined from the records of seismic stations, while the amplitude of the tsunami wave could be estimated from the elastic energy of the anomaly, size of the rupture, and depth of the sea above the rupture. The size of the rupture could be estimated from the periods of the leading waves that reached the location of the laser strainmeter. Based on spectral processing of the record of the tsunamigenous earthquake, the period of the first wave that reached the location of the laser strainmeter was equal to 42.7 s.

Figure 2 shows a band-filtered record of the laser strainmeter containing the signal of the tsunamigenous earthquake with boundary frequencies 1–0.01 Hz. Figure 3 shows a record of a broadband seismograph containing the same earthquake signal [7]. Almost all seismic stations in Japan are equipped with such seismographs. Figure 4 presents a filtered record of the laser strainmeter with the same filter containing the signal of the Sakhalin earthquake unrelated to the tsunami. Figures 2 and 4 simulate the records of a broadband seismograph, which can record the oscillations with frequencies from 1 to 0.01 Hz. A comparison of all graphs allows us to state that it is practically impossible to distinguish a tsunamigenous earthquake from its counterpart unrelated to a tsunami even using broadband seismographs.

Taking into account the results mentioned above and the fact that the tsunami wave reached the closest coast 2 h after the earthquake, we can affirm that records of even one strainmeter would have been sufficient to predict the appearance of the tsunami wave and save people if the corresponding tsunami warning service had been organized.

The exact coordinates of any event can be determined from the data of a three-coordinate strainmeter. Installation of a number of such strainmeters spatially separated over the surface of the Earth would make it possible to solve the problem of direction finding and identification of different catastrophic events and their precursors.

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