Measurements of variations in the direction of light beam

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(Translated from Russian by Herman Holushko)

Periodical (-20"..0") and “random (-46"..+15") deflections of the light beam relative to the Earth surface were measured on the distance of 1.52 m during 109 days. The systematic non-refractional deflection of light beam down to the center of the Earth with average value of 11".6 was discovered. The atmospheric refraction coefficient *k* was considered to be stable and equal to 0.14±0.05. The absolute optical gravimeter was suggested for the forecast of major earthquakes. It was determined that the Moon phases have impact on long-period deflections with two days lag.

Variations in the directions of the light beam were experimentally detected in 1980. The correlation of 0.52 between the experimental data and the measurements performed using standard relative gravimeters suggest the relationship between the discovered optical effect and the local variations of the gravity potential [1]. At the same time, qualitative experiments were performed in an elevator and on a marine vessel using the mobile version of the measurement device. The light beam has shown relevant reaction (in the direction and the value of deflection) on the acceleration of the vessel and the elevator.

The comparison of the measurements of absolute deflection of light beam in May 2003 (Sevastopol, Crimea, Ukraine) and the measurements taken in the same period using torsion gravity sensors (Uzun-Agatch Seismic Station, Kazakhstan) shows their sufficient identity.

It is well known practice in geodesy when measured vertical directions (angles) are adjusted with the correction related to empirical unitless coefficient of atmospheric refraction *k*. This coefficient is quite stable with minor deviations (up to 30%) from the average value. At present time *k* is considered to be equal to 0.14 [2]. In 19th century it was believed that *k*=0.16 [3]. The author noticed that *k* interpreted as angle measure (in optimal, usual distances of 2-5 km) corresponds to angle correction of 7.5" The phenomenon of “stability” of *k* points to the possibility of systematic deflection of the light beam not related to refraction.

The preliminary research which was started in 1980 revealed the need for creating essentially new equipment and much more demanding methodology of detection and measurement of the absolute deflection (relative to horizontal plane) of the light beam. In 1983 a special mirror was manufactured to enable precise measurements. Also the author decided to carry out measurements during much longer period of time (more than 3 months) and to conduct statistical processing of measurement data.

It is necessary to note that empirically known variations of the atmospheric refraction coefficient, from 0.1 to 0.2 [2], define the limits of average light beam deflection as -5"..-10". However in practice the deflection may vary from +5" to -25".

In April-May 2003 the author made an attempt to perform such experiment but insufficient techniques along with a short observation period didn’t allow obtaining reliable results. The next series of measurements were planned for fall-winter of 2003/2004. The results of the first month of observations (September 23 – October 27, 2003) were published in the article [1].

The device for measuring light beam deflection in vertical plane is called AGON (Absolute Gravimeter Optical of Nikitin). It consists of two main parts: theodolite T2 N109211 (1974) with sighting mark of accuracy 2" and a special mirror in front of it where the reflection of the theodolite and the sighting mark can be seen. The mirror is implemented as a disk with the diameter of 150 mm and thickness of 20 mm. Both sides of the disk are high precision optical mirrors. The parallel misalignment of the mirror sides is not more than 0.2".

The mirror was suspended from the metal beam on the ceiling on a thin counter-twisted thread line of 0.5 m. This allows both sides of the mirror to be turned towards the theodolite. The distance between rotation axes of the theodolite and the mirror is 1.52 m. The sighting mark is made of thin white caprone line 0.015 mm thick which is secured horizontally in the center of the objective. The theodolite is mounted on a wooden geodesic tripod. The orientation of the device “theodolite – mirror” (AGON) is North-South with the accuracy of ±5º.

Visible “up and down” shift of sighting mark relative to the graticule of the telescope determines the real deflection of light beam and represents the subject of measurement.

The process of one full measurement of light beam deflection includes two elementary measurements, “circle left” and “circle right” for both sides (I and II) of the mirror. In other words one full measurement includes four visual matches of the graticule to the mirrored image of sighting mark (thread). After the first two measurements for one side of the mirror (with the rotation of the telescope through zenith “circle left” and “circle right” as shown in *Figure 1*), the mirror gets turned 180˚ and the second two measurements for another side of the mirror take place.

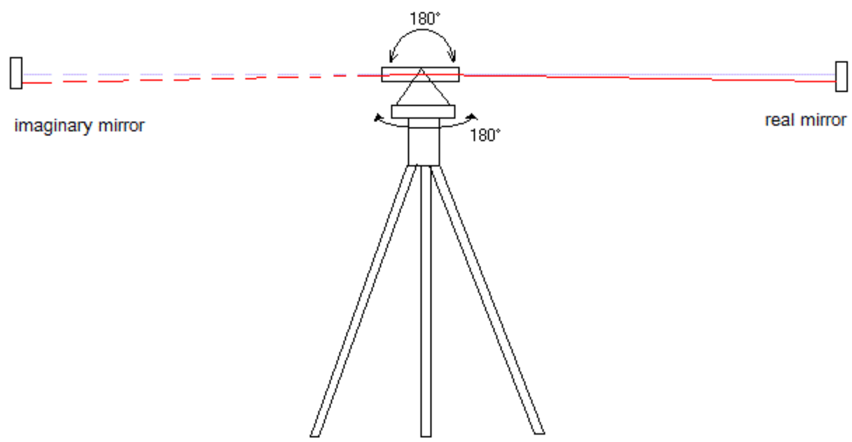

Figure 1
Measurement setup

The contact level of the vertical circle alidade was corrected before each elementary measurement. The value of light beam deflection Ω was calculated after each full measurement as a half-sum of average values for both sides of the mirror.

$$\Omega = (I_{average} + II_{average}) / 2 \qquad (1)$$

The measurements were taken every six hours in Kiev time (GMT +2:00) during 109 consecutive days by the author.

Graduation marks on the theodolite glass limb have value of 10 arc minutes. The value of the smallest graduation is 1" which allows visual assessment with the accuracy of 0".1. In this case, the measurements were rounded to the nearest 1".

The total uncertainty of measurement $M\Omega$ includes the following: the error of sighting (m_s), the error of reading (m_r), the error of horizontal positioning (m_h) and the error related to parallel misalignment of mirror sides (m_p). The T2 is a theodolite which in field conditions has the accuracy of direction measurements of 2". It is generally admitted that in laboratory conditions where sighting mark and verniers are illuminated by electrical light and the operator has sitting position, the accuracy is 2-2.5 times higher and can be considered as 0".8 [2]. The error of horizontal positioning (according to work experience) is about 0".3. The error related to parallel misalignment of mirror sides is 0".2 according to manufacturer certificate. The total uncertainty of measurement $M\Omega$ can be calculated as following:

$$M\Omega = \sqrt{m_s^2 + m_r^2 + m_h^2 + m_p^2} = 1''.2 \qquad (2)$$

On certain natural phenomena such as equinox, winter solstice, perihelion, apogee, perigee, solar eclipse, moon eclipse, etc. the measurements were performed (when possible) twice as more often. The results of intermediate measurements were not counted in the result sheet and were used only for clarifications and further analysis of measurement results. The measurement results are presented in *Figure 2*.

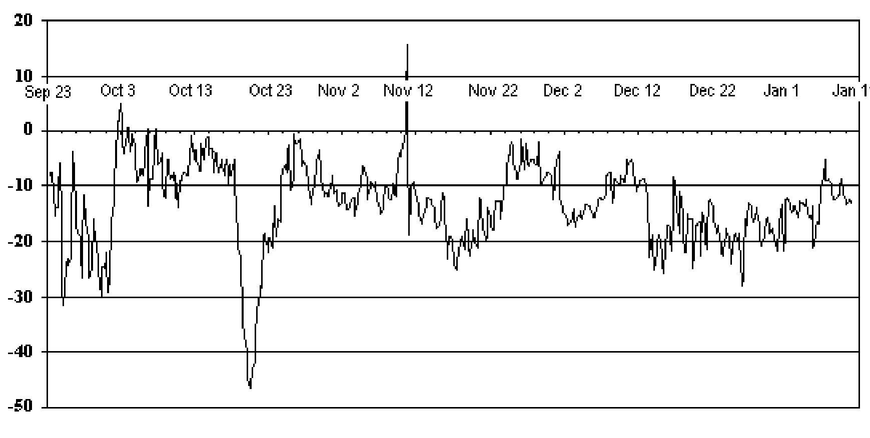

Figure 2

Dependency of the light beam deflection on measurement date (September 23, 2003 – January 9, 2004)

The observation time can be broken into the following periods:

- Period of abnormally high seismic activity from 09/23/03 to 10/02/03;
- Period of (arguable) relaxation of gravity potential from 10/02/03 to 10/03/03;
- Period of extreme (up to - 46") deflection from 10/18/03 to 10/22/03;
- Period of "quiet background" with deflection -5"..-20" from 10/22/03 to 12/13/03;

- Period of sudden changes (15") on 11/10/03;
- Period of abnormal negative deflections from 12/14/03 to 01/09/04

The average deflection for the whole period of 109 days is 13",2 with standard deviation of 7",5.

The graph which illustrates the dependency of the light beam deflection on measurement date reveals the correspondence to certain gravimetric events such as revolution of the Moon, eclipses, earthquakes, etc.

Using this graph and with the help of Karim Khaidarov, it was determined that certain peculiarities in the light beam deflection precede major earthquakes. It was possible to foresee the earthquake in Japan (19:50:07 UTC on Thursday, September 25, 2003, the magnitude of 8.0) with preliminary forecast 3 days and final forecast 1 day before the earthquake. The forecast was presented to seismologists in Kazakhstan (to Karim Khaidarov).

The period of "quiet background" from 10/22/03 to 12/13/03 (about 52 days) with no abnormal deflection was chosen for statistical processing of the results. The average deflection of the light beam in this period was determined as -11".6 with standard deviation of 5".2 and instrumental error of 0".24. The physical reason for the systematic light beam deflection is unknown. It is possible to suggest that there is some relation to escape velocity (the deflection angle corresponding to the escape velocity would be -7".7).

The smoothed curve of the light beam deflection dependency compared with the curve of the second Moon harmonic shows systematic phase shift of 48-50 hours, which characterizes the time lag between the Moon phase influence and its visible position. In other words the light deflection curve matches the second Moon harmonic shifted 2 days forward (*Figure 3*). The correlation with the second harmonic is 0.62. The correlation with all three harmonics (1st, 2nd and 4rd) is 0.81.

The time lag well corresponds to the fact of ocean tides time lag, also known as "age of a tide" which is a delay between a major tide and astronomical syzygy expressed in terms of fraction of a day. This delay is usually explained by the water viscosity, the shape of the water area, and the relief of the sea bottom in bays. The physical nature of the influence of Moon phases on tides and on light deflection is unknown.

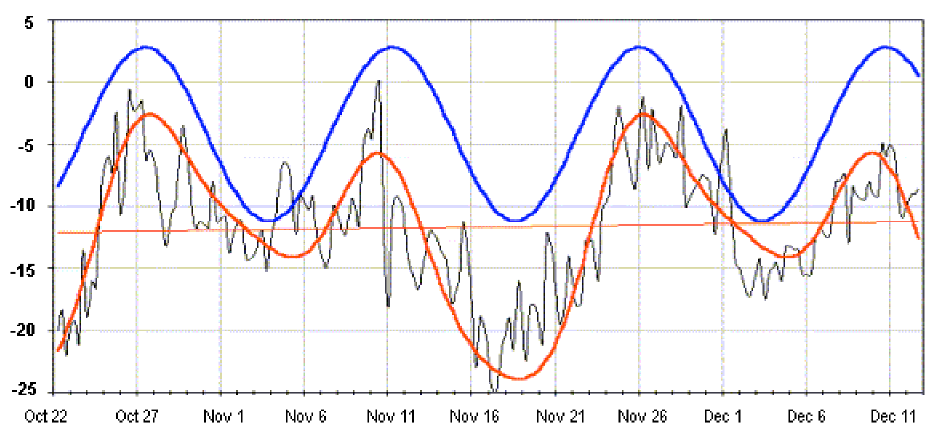

Figure 3
Smoothed deflection of the light beam shifted 2 days forward and the second Moon harmonic
(October 22 – December 13, 2003) [plotted by Karim Khaidarov]

The main factor which creates measurement distortions is some flicker noise with a period from few minutes to few hours and the range of 10". Besides that, the measurement process is not automated. Unfortunately, it is not possible to carry on continuous observation of the variations of light deflection which could be quite informative.

It is also worth saying that the real non-refractional light beam deflection with the range of tens of angular seconds does not exclude accurate scientific and technical measurements (for instance in astronomy or geodesy). The real-life techniques of relative measurements comprise empirical minimization or elimination of periodically appearing "errors".

Summary

The measurements performed using AGON show systematic, periodical and random deflections of light beam from horizontal plane with the range reaching more than 60" during 109 days of observations.

It was determined that systematic deflection amounts to 11",6 downwards in the periods of "quiet background".

The light beam deflection was traditionally considered (in geodesy and astronomy) to be caused by atmospheric refraction only. This research shows that the deflection related to the variations of gravity potential makes up the major part of the overall deflection.

It was discovered that the Moon phases have influence on physical processes occurring on Earth with two days delay relative to visible location of the Moon. In the periods of "quiet background", the correlation between smoothed line of light beam deflection and the second Moon harmonic shifted two days forward is 0.62.

It is shown that AGON can be used for the forecast of major earthquakes (M>6).

Specialists in geodesy, gravimetry, astronomy, geophysics and theoretical physics might be interested in the results of this work.

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