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ON OPTICAL LOCATION OF THE MOON*

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One of the possible areas of application of optical quantum generators is location (^{1}). The present work describes preliminary results of the location of the Moon with the aid of a ruby optical quantum generator.

Description of the apparatus. Figure 1 shows a schematic diagram of the apparatus. For the transmission and reception of light pulses, one and the same telescope with mirror diameter $D = 2.6$ m (^{2}) was used. The receiving-transmitting equipment is installed at the Coudé focus (focal length $F = 104$ m) and, consequently, remains immobile during rotations of the telescope. The ruby optical quantum generator used in the equipment was developed by V. S. Zuev and P. M. Kryukov and has the following parameters: wavelength $\lambda = 6943$ Å, energy per pulse $W_{\text{per}} = 50 \div 70$ J, pulse duration $\tau_{\text{g}} = 2$ msec, beam diameter $d = 11$ mm, beam divergence $\alpha = 3'$. Lens L_1, with focal length $f = 32$ cm, is a matching lens. It is not difficult to show that the divergence of the beam at the telescope output is equal to
$\alpha_{\text{per}} = \alpha \dfrac{f}{F} \leqslant 0.5''$. This corresponds to a spot diameter on the Moon (without taking into account blurring of the beam in the atmosphere) $d_{\text{l}} \leqslant 0.7$ km.

Taking into account the scattering of light during its double passage through the atmosphere, as well as the possible mismatch of the apertures of the apparatus in the receiving and transmitting modes, the angular field of view of the receiving apparatus was chosen equal to $\alpha_{\text{pr}} = 8''$, which corresponds to a spot diameter on the Moon $d_{\text{l}} = 14$ km. The diameter of the receiving diaphragm in the focal plane of the telescope, corresponding to $\alpha_{\text{pr}} = 8''$, is equal to $d_{\text{d}} = 4$ mm.

A photomultiplier was used as the detector of the reflected signal. To reduce the dark current of the PMT, it was cooled with dry ice ($-76°$). At this temperature the parameters of the PMT are as follows: quantum yield $k_{\text{PMT}} = 0.04 \div 0.05$; dark current $n_{\text{PMT}} = 50$ photoelectrons per second.

To reduce the harmful background, an interference filter for the wavelength $\lambda = 6943$ Å was installed in front of the photocathode, with absorption coefficient at this wavelength $k_{\phi} = 0.5$ and with a passband $\Delta\lambda = 20$ Å. Mirror 3, which

Fig. 1. Schematic of the installation for optical location of the Moon.

Figure 1: Fig. 1. Schematic of the installation for optical location of the Moon.

can occupy two corresponding positions, serves to switch the apparatus from the transmitting mode to the receiving mode.

The signal from the output of the photomultiplier, after shaping and amplification, was recorded by an oscilloscope with a triggered sweep of duration 6 msec. A special device started the oscilloscope sweep with a delay corresponding to the calculated time of propagation of the signal to the Moon and back.

Preliminary estimate of the signal-to-background ratio. The energy of the light pulse reflected by the Moon can be esti—

to estimate on the basis of the relation

$$W_{\text{refl}} = W_{\text{trans}} \frac{S_T}{\pi R^2} \rho k_{\text{trans}} k_{\text{rec}} k_{\text{atm}}^2, \tag{1}$$

where W_{refl} is the energy of the reflected signal per unit area on the Earth; W_{trans} is the energy of the primary signal; S_T is the area of the receiving installation; $R = 384\,000$ km is the distance to the Moon; $\rho = 0.1$ is the albedo of the Moon; k_{trans} and k_{rec} are the coefficients of signal loss in the transmitting and receiving installations; k_{atm} is the coefficient of losses in the atmosphere. For mean zenith angles usually $k_{\text{atm}} = 0.8$. Relation (1) is valid under the assumptions that the light spot is completely accommodated on the lunar disk and that reflection of light by the lunar surface occurs in accordance with Lambert' s law.

For our installation $S_T = 6.76$ m^2, $k_{\text{trans}} = 0.75$, $k_{\text{rec}} = 0.35$ (it is assumed that on each reflecting or refracting surface the signal loss amounts to 5%). Then, from relation (1), we have:

$$W_{\text{refl}} = 2.2 \cdot 10^{-19} W_{\text{trans}}.$$

If one takes $W_{\text{trans}} = 50$ J, which for the wavelength of the quantum generator $\lambda = 6943$ Å corresponds to a number of photons $N_{\text{trans}} = 1.8 \cdot 10^{20}$, then the reflected signal will contain $N_{\text{refl}} = 40$ photons, or, when converted to the number of photoelectrons at the output of the FEU, $n_{\text{refl}} = 1.6 \div 2.0$ photoelectrons.

Fig. 1. Schematic of the installation for optical location of the Moon. *T* —telescope; *OKG*—optical quantum generator; L_1—matching lens; 3—folding

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mirror; D—diaphragm; IF—interference filter; FEU—photomultiplier; OK—dry-ice container

Thus, reliable registration of the signal is possible only by means of statistical accumulation, all the more so because background is registered together with the useful signal. There are several sources of background: the dark current of the FEU, the ashen light of the Moon, the light of the crescent, light scattered in the atmosphere and in the telescope, and the glow of the night sky. A comparative estimate showed that the principal sources of background are scattered light, crescent light $n_{\text{cres}} = (4 \div 40) \cdot 10^{+2}\ \text{s}^{-1}$, and ashen light $n_{\text{ash}} = 5 \cdot 10^2\ \text{s}^{-1}$ (in numbers of photoelectrons at the output of the FEU). The other sources of background may be neglected.

The total background, referred to a time interval $\tau_g = 2$ msec, equal to the pulse duration, is

$$n_\phi = 2 \div 10.$$

Hence the expected signal-to-background ratio is

$$\frac{n_{\text{refl}}}{n_\phi} = 0.16 \div 1.0.$$

Measurement results. The measurement session was carried out on 13 IX 1963 from $4^{\text{h}}00^{\text{m}}$ to $5^{\text{h}}32^{\text{m}}$. As the object of location, the crater Albategnius on the unilluminated part of the Moon was selected.

The start of the oscilloscope sweep was calculated so that the beginning of the reflected pulse would coincide with the middle of the sweep. In this case

the first half of the sweep (3 msec) could be used for measuring the background, and the second for measuring the background and the signal. In addition, for a more accurate determination of the background, a few seconds after the registration of each reflected pulse the background was measured over an interval of 10 sec duration.

Altogether 30 pulses were made during the session. Thus, the signal accumulation time was $30\tau_g = 60$ msec. Averaged over this accumulation time, the number of photoelectrons per pulse ($\tau_g = 2$ msec) in the sweep interval corresponding to the reflected signal is $n_{\phi+c} = 6.2$. The corresponding background value, determined from 10-second intervals, is $n_\phi = 4.67 \pm 0.38$ (root-mean-square error). The background value determined from the first half of the sweep (3 msec) agrees with this value to within the indicated root-mean-square error.

The excess of $n_{\phi+c}$ over n_ϕ, equal to the signal value $n_c = n_{\phi+c} - n_\phi = 1.53$, is four times greater than the root-mean-square error in the measurement of the background and therefore cannot be attributed to its fluctuation.

Thus, the measurements carried out made it possible to reliably register the signal reflected from the Moon.

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CITED LITERATURE

[1] L. D. Smullin, G. Fiocco, Proc. IRE, **50**, 1703 (1962).
[2] B. K. Ioannisiani, Optical-Mechanical Industry, No. 4 (1958).

Note: Figure translations are in progress. See original paper for figures.

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