NEW METHOD OF OBSERVING THE PRESSURE OF LIGHT

Yu. F. Ogrin
Institute of Radio Engineering and Electronics, USSR Academy of Sciences
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The pressure of light was investigated by P. N. Lebedev experimentally in 1900 [1]. His experiments were repeated in the last few years by V. B. Braginskii and co-workers at the Moscow University [2]. They have also proposed an absolute meter for the determination of the energy of a light beam from its pressure.

It should be noted that the pressure measurement is based in both methods on the excitation of free oscillations of a pendulum consisting of a very thin metallic plate suspended in a suitable manner. We propose in this paper a method of determining the pressure of light with the aid of the system shown in Fig. 1. One of the mirrors of a Michelson interferometer is replaced by an element sensitive to the pressure of light. This element consists of a mica plate (50 - 100 μ thick having an opening covered by a nitrocellulose film. A layer (film) of silver 100 - 200 Å thick is deposited on both sides of the film by vacuum sputtering. When the nitrocellulose film is about 1000 Å thick, this element is sensitive to small pressures, for if the interferometer is properly aligned the photoreceiver can register a film deflection of about 10^{-10} cm. The sensitivity of the instrument was verified by using an air stream of properly reduced pressure.

It was established that in order to deflect the film by an amount equal to $\lambda/4$ (λ - wavelength of the light, equal to 0.63 μ), a sufficient pressure is of the order of 10^{-3} dyne. It is easy to verify that a light beam of 1 W power produces an approximate pressure of 6×10^{-4} dyne, i.e., the sensitivity of the described instrument suffices fully to measure the light pressure.

The main problem in such measurements is the elimination of interfering effects. These effects and the methods of their elimination are described in sufficient detail in a Candidate's dissertation by V. N. Rudenko (Moscow University). In the main, the interference is produced by the temperature difference between the surfaces of the plate that receives the momentum of the light. In our case, owing to the small thickness of the films, the temperatures of both sides are practically equal, and this interference should therefore be much smaller. However, in our case there arises a thermal effect connected with the difference between the thermal expansion coefficients of silver and nitrocellulose. If the silver covers only one side of the nitrocellulose film, the deflection produced by the illumination is much larger than that due to the light pressure alone. Sputtering of silver on both sides makes the system symmetrical and the thermal effect is either

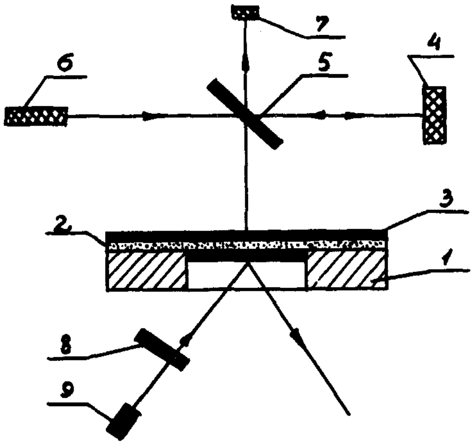

Fig. 1. Experimental setup: 1 - mica, 2 - nitrocellulose film, 3 - silver film, 4- mirror, 5 - semitransparent mirror, 6 - laser, 7 - photoreceiver, 8 - mechanical modulator, 9 - illuminator.

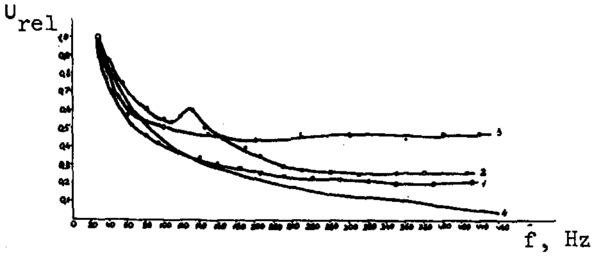

Fig. 2. Frequency curves of light modulation: 1 - illumination from below, 2 - illumination from above, 3 - electromechanical modulation, 4 - frequency characteristic of gas-filled bolometer.

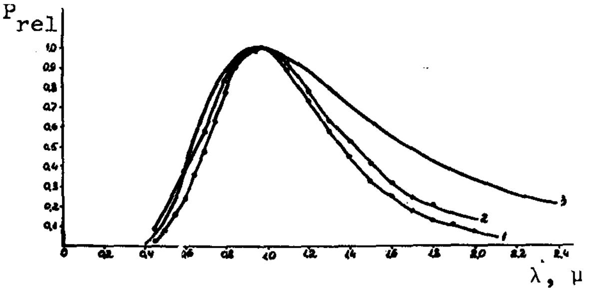

Fig. 3. Spectral curves of tungsten-lamp radiation pressure: 1 - experimental curve, 2 - pressure curve with allowance for wavelength dependence of light reflection coefficient, 3 - theoretical.

nonexistent (in the case of absolute symmetry) or so small that the light pressure can be observed. It should be noted in addition that the nitrocellulose film stretches after coating the mica, so that it becomes possible to work with light modulated at a frequency of several hundred Hertz. All thermal effects are greatly reduced at such frequencies.

Figure 2 shows the frequency curves (1, 2) of the modulation of a laser beam with the aid of mechanically modulated light from an incandescent lamp illuminating the sensitive element. Curves 1 and 2 correspond to illumination of the film from below and from above, respectively. The two curves coincide for some elements. These curves are interpreted as follows: when the element is not fully symmetrical (for example, unequal thicknesses of Ag films), the thermal effect is also presence, and then (as has been verified), the films bend in one direction regardless of the illumination direction. Consequently, for any given illumination direction, the thermal effect and the ponderomotive effect (light pressure) have opposite signs. If the thermal effect decreases with increasing ω more rapidly than the ponderomotive effect, then at a certain value of ω the deflection vanishes completely. Actually, a minimum should apprently occur, as is indeed the case. Curve 3 is the mechanical characteristic of the element; a current of frequency ω was passed through the element placed in a magnetic field, and a photoreceiver was used to register the mechanical oscillations of the film. Comparison of curves 1, 2, and 3 shows that when $\omega > 200$ Hz the film oscillations are due to the light pressure. Curve 4 is the frequency characteristic of a bismuth bolometer whose operation is based on the thermal processes. Since the construction of this bolometer is absolutely similar to that of our element, curve 4 apparently describes also the thermal effects occurring in our case. This curve shows that the thermal processes decrease more rapidly with increasing frequency than the mechanical ones.

All the foregoing allows us to assume that when $\omega > 200$ Hz the described element can be used to observe the pressure of electromagnetic radiation.

By way of an example of the new capabilities of the method, Fig. 3 (curve 1) shows the spectral curve of the radiation pressure of a tungsten lamp (T = 3000°K), polotted by the described method using a 3MR-3 monochromator. The figure shows also the same curve as calculated by Planck's formula. We see that the curves differ somewhat. Preliminary investigations have shown that in this region of the spectrum the coefficient of light reflection from silver sputtered on a nitrocellulose film depends on the wavelength. Curve 2 has been obtained from curve 1 with allowance for this dependence. The difference between curves 2 and 3 in the region $\lambda > 1\ \mu$ may be the result of unaccounted-for absorption in the optical system.

We note in conclusion that the use of a radiotechnical method of meauring film oscillations may greatly expand the capabilities of the proposed method.

The author is grateful to E. Saval'skaya for preparation of the films and to E. F. Kushchenko for technical assistance.

[1] P. N. Lebedev, Davlenie sveta (The Pressure of Light), Gosizdat, 1922.
[2] V.B. Braginskii, I. I. Minakova, and P. M. Stepunin, PTE No. 3, 183 (1965).

SHOWER SPECTROMETERS WITH RADIATORS OF THALLIUM HALIDE SALTS

A. A. Varfolomeev, V. I. Glebov, E. I. Denisov, and Yu. B. Korolevich
I. V. Kurchatov Atomic Energy Institute
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The radiators customarily employed in total-absorption Cerenkov spectrometers are made of lead glass, necessitating constructions of relatively large dimensions and weights. There are known attempts to use radiators of other materials [1] for the purpose of reducing the radiator dimensions or to improve their spectral characteristics. We have used in this study one of the densest transparent materials, namely single-crystal KRS-6, which is a mixture of TlCl and TlBr salts (see [2]). This has made it possible to construct spectrometers having the smallest known dimensions, without loss of energy resolution at 100% gamma-quantum and electron registration efficiency.

The spectrometer radiators have the form of a truncated cone with angle $\sim$20% between the axis and the generator (Fig. 1). The radiator height is 14 cm, its volume 0.9 l, and weight 6.5 kg. The critical energy of the radiator material is 9.2 meV, and the radiation unit is 1.02 cm. the radiator material is transparent to light in the 4200 - 20000 Å range.

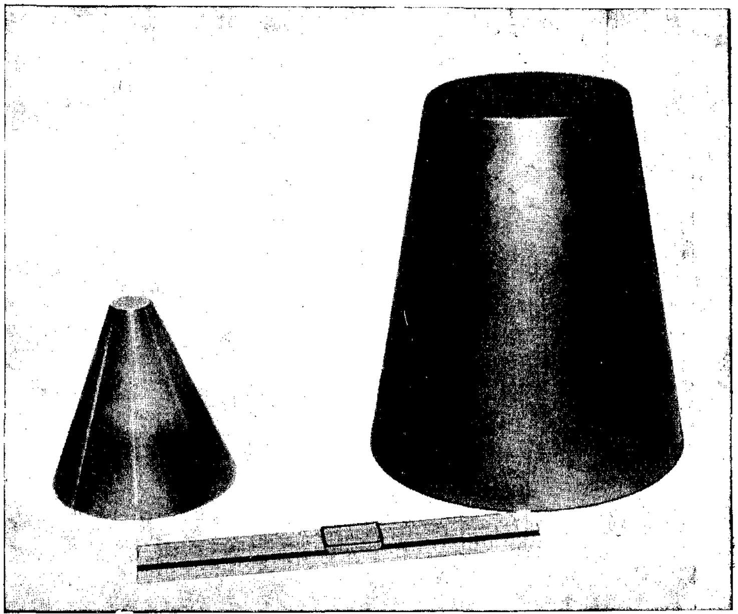

Fig. 1. Radiators 14 rad. un. thick made of KRS-6 and of lead glass.

The total intensity of the Cerenkov light of charged shower particles (at the same primary-particle energy) in KRS-6 is only 20% lower than in lead glass. The better light-gathering conditions in a compact crystal radiator make it possible to obtain a high energy resolution.

The small dimensions of the crystal radiator lead to a decrease of the light signal compared with