LETTERS TO THE EDITOR

P.A. Cerenkov
The Physical Institute of the Academy of Sciences U.S.S.R., Moscow
Received June 15, 1937

Visible Radiation Produced by Electrons Moving in a Medium with Velocities Exceeding that of Light

In a note published in 1934 [1] as well as in the subsequent publications [2] [3] [4] the present author reported his discovery of feeble visible radiation emitted by pure liquids under the action of fast electrons (β-particles of radioactive elements or Compton electrons liberated in liquids in the process of scattering of γ-rays). This radiation was a novel phenomenon, which could not be identified with any of the kinds of luminescence then known as the theory of luminescence failed to account for a number of unusual properties (insensitiveness to the action of quenching agents, anomalous polarization, marked spacial asymmetry, etc.) exhibited by the radiation in question. In 1934 the earliest results obtained in the experiments with γ-rays led S.I. Wawilow [5] to interpret the radiation observed as a result of the retardation of the Compton electrons liberated in liquids by γ-rays. A comprehensive quantitative theory subsequently advanced by I.M. Frank and I.E. Tamm

[6] afforded an exhaustive interpretation of all the peculiarities of the new phenomenon, including its most remarkable characteristic – the asymmetry.

According to their theory, an electron moving in a medium of refractive index n with a velocity exceeding that of light in the same medium ($\beta > 1/n$) is liable to emit light which must be propagated in a direction forming an angle θ with the path of the electron, this angle being determined by the equation:

$$\cos\theta = 1/\beta n, \tag{1}$$

where β is the ratio of the electron velocity to that of light in vacuum.

A successful experimental verification of formula (1) was only performed with water [4] for which, at the moment

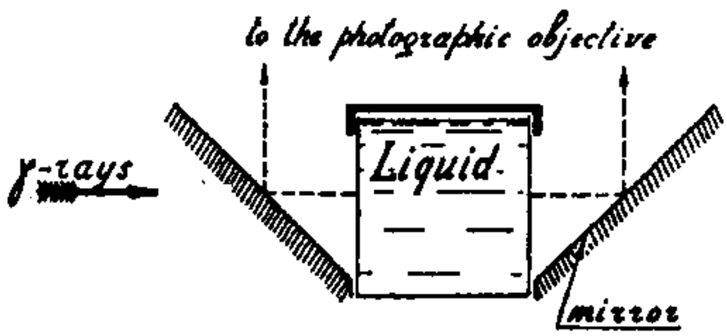

Figure 1: Arrangement of apparatus.

of publication of the above theory, data were already available which had been obtained by visual observations by the method of quenching [7] [8].

We recently performed additional experiments in which the intensity of radiation was recorded photographically, the records being taken simultaneously for all the angles θ lying in a plane passing through the primary electron

beam. The liquid was placed in a cylindrical glass vessel with very thin walls, and the light emitted by the liquid was reflected by a conical mirror in an upward direction to the object glass of a photographic camera as indicated in Fig. 1. An approximately parallel beam of γ-rays, filtered through a 3-mm lead plate, fell on the liquid horizontally. The γ-radiation used was equivalent to that of 794 mg of radium. The considerable thickness of the lead screen, the large aperture of the object glass (f : 1.4) and the long exposure (72 hours) ensured sufficient distinctness of the photographs.

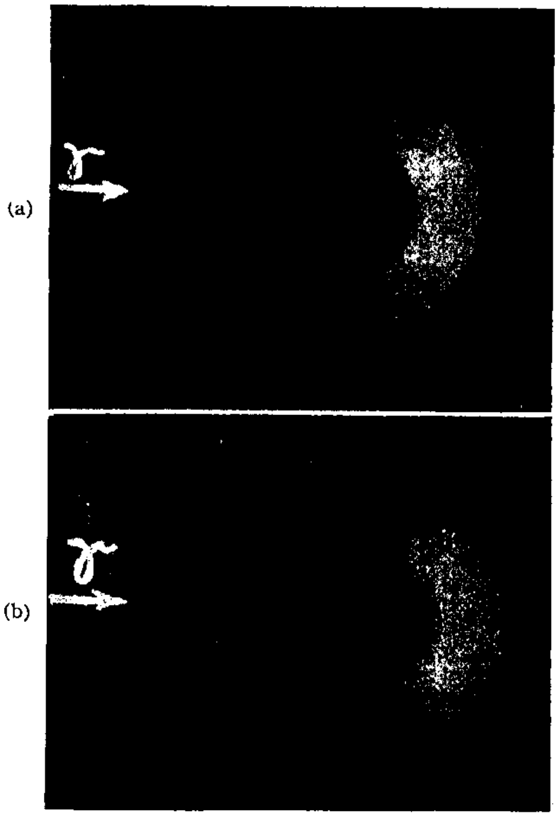

Figure 2: Photographs showing asymmetry of luminescence, (a) water, $n = 1.337$; (b) benzene, $n = 1.513$.

The latter were obtained for ten different liquids. Two of the photographs taken (positive) are represented in Fig. 2. An examination of these photographs leads to the following conclusions:

(1) In all the pure liquids investigated the radiation propagates mainly in the onward direction of the primary beam, the blackening of the negatives being only visible on part of the annular circle.

(2) The area of the blackened sector increases with the refractive index of the liquids (see Fig. 2: (a) $n = 1.337$ for water and (b) $n = 1.513$ for benzene).

(3) Each photograph exhibits two diffuse but clearly visible maxima of blackening, which are symmetrical with respect to the primary beam. Their

angular spacing increases with the refractive index of the liquids, and, to a first approximation, agrees with the values which might be expected according to Eq. (1). The absence of distinct maxima of blackening is undoubtedly associated with the difference in energy of the Compton electrons liberated from the molecules of the liquids by γ-rays, with the non-parallelism of these electrons and with the fact that the energy of each electron, moving in a liquid, gradually changes from the initial energy to zero.

All the results obtained are in good agreement with I.M. Frank and I.E. Tamm's theory of the coherent radiation of electrons moving in a medium [6].

P. A. CERENKOV

The Physical Institute of the Academy of Sciences of U.S.S.R., Moscow,
June 15, 1937.

References

[1] Cerenkov, C.R. Ac. Sci. U.S.S.R. **8,** 451 (1934).

[2] Cerenkov, C.R. Ac. Sci. U.S.S.R. **12** (3), 413 (1936).

[3] Cerenkov. C.R. Ac. Sci. U.S.S.R. **14**, 102 (1937).

[4] Cerenkov, C.R. Ac. Sci. U.S.S.R. **14,** 105 (1937).

[5] Wawilow, C.R. Ac. Sci. U.S.S.R. **8,** 457 (1934).

[6] Frank and Tamm, C.R. Ac. Sd. U.S.S.R. **14,** 109 (1937).

[7] Bull. Ac. Sci. U.S.S.R. No. 7, 919 (1933).

[8] E. Brumberg and S. Wawilow. C.R. Ac. Sci. U.S.S.R. **3,** 405 (1934)