Nuclear Instruments and Methods in Physics Research A 595 (2008) 8–11

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

The discovery of the Cherenkov radiation

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ARTICLE INFO

Available online 5 July 2008

Keywords:
Cherenkov radiation
Discovery

ABSTRACT

The exciting story of the discovery of the Cherenkov radiation by the graduate student Cherenkov is recalled.

1. Cherenkov starts his scientific activity

The author of the future discovery Pavel Alekseyevich Cherenkov, born on 28 July, 1904 in the village Novaya Chigla near Voronezh, graduated from the Voronezh State University in 1928. In 1930 he began his post-graduate studies at the Physics-Mathematical Institute of the USSR Academy of Sciences (since 1934, Physical Institute) in Saint-Petersburg. From 1932 on, he worked under the supervision of the academician Sergej Ivanovich Vavilov (Fig. 1). His Ph.D. work was dedicated to "Luminescence of uranyl salts solutions under the action of γ-rays". Cherenkov (Fig. 1) investigated the phenomenon of the luminescence induced by radium γ-rays and compared it with the known emission of luminophor light under the action of visible light. The scientific work was performed in the building of the Academy of Science placed on the embankment of the river Neva (Fig. 2); the measurements decisive for the discovery of the new radiation were carried out in the basement of this building. In those days, Vavilov was working both in Moscow and in Saint-Petersburg. However, he always found some time to discuss with Cherenkov about the progress of the studies: at least twice per week.

2. The experimental technique

For the luminescence studies, all measurements were carried out using in parallel two excitation sources, namely both X-ray from radioactive sources and visible light.

The intensity of the light to be detected was pretty low, thus requiring a very precise photometry method, to make possible quantitative measurements: the optical wedge method. The feeble light was transmitted through an optical system including a wedge element. The wedge was displaced to determine the position corresponding to the threshold for light detection; assuming a constant response of the light detector, the wedge position provides information on the light intensity. The light detector was a human eye adapted to darkness, the eye of the graduate student Cherenkov. To be able to detect feeble light, the post-graduate student was sitting in the room, in absolute darkness, for more than 1 h, before starting the measurements.

Initially the luminescent liquid was contained in a glass vessel. The radiation coming from the vessel walls was generating an undesirable background. Different vessels of various materials were tried, and, among them were the thinnest mica sheets available. Handling mica was similar to jeweller manipulation. The final choice was a platinum vessel: the walls themselves did not radiate and besides, the vessel could be cleaned rather easily.

The scheme of the experimental setup is shown in Fig. 3. The vessel *A* with the luminophor material and the radioactive source are placed in a wooden support *B*, to preserve the stability of the setup. The average thickness of the vessel walls was such as to guarantee the absorption of the α- and β-radiation, while transparency to γ-rays is preserved. Block *B* has two slots R_1 and N_2, where 103.6 mg of radium, protected in a lead ampule, can be placed. The Nicol prism *N* can be used for polarisation measurements, performed with the ampule placed in slot N_2. The optical system includes the collimator L_1, the prism *P*, the telescope formed by two lenses L_2 and L_3 and the optical wedge *K*. Various optical filters can be placed in the frame *E*. The diaphragm *D* defines the field of view.

The setup is simple. Nevertheless, Cherenkov prepared the measurement with a high degree of accuracy and care, paying attention also to the smallest detail, without entrusting anybody in any aspect of the preparation. This care was a precise aspect of his character and at the same time, has been essential for the reliability of the results. In fact, the method selected has a strong subjective character: the accuracy of the result depends not only on the eye capability, but also on many other factors (tiredness, lack of sleep and even the mood). Taking strict account of all this is, of course, complex. The recurring experiments performed with

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0168-9002/$ - see front matter
doi:10.1016/j.nima.2008.07.006

Fig. 1. Vavilov (left); Cherenkov, 1931 (right).

Fig. 2. The building which hosted the USSR Academy of Science in Saint-Petersburg.

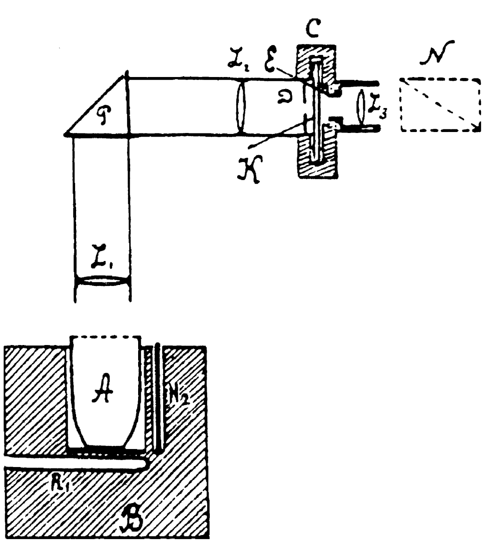

Fig. 3. Scheme of the experimental setup (drawing by Cherenkov).

more modern equipments during the ten years after the discovery showed that there is not a single mistake in the results obtained by Cherenkov.

3. The discovery

While performing his studies of luminescence, Cherenkov accidentally observed a strange phenomenon: a very weak emission of blue light induced by γ-radiation in pure sulphuric acid. The weak light was suspected to be strongly extinguished luminescence. Therefore, investigations of light emission by water and solutions used in the measurements were performed to check the purity of the experimental materials: solutions were repeatedly filtered and water multi-distillation was applied. The luminosity of the light source was checked and quenchers of luminescence were used. The possible influence of self-suggestion while measuring was eliminated having the optical result wedge moved by an assistant. The weak blue light emission still remained.

The luminescence radiation background of the pure solvent was definitely negligible and could be disregarded. Nevertheless, at each measurement, the possible need of a correction to take the effect into account was verified. Also the stability of the correction value was monitored.

Only the whole set of the data, obtained in all the measurements performed in the context of the postgraduate work, allowed to ascertain that the light emission of the solvent and of all the other pure liquids was constant and universal [1,2]. In fact, in spite of significant changes in concentrations, temperature, and viscosity of the liquid, the intensity of the light was found to be always approximately the same and it was distinguishable from the luminescence. Moreover, the unknown light turned out to be polarised. It was also established that the light emission was not induced directly by the γ-rays rather it was emitted by the fast recoiling electrons produced in Compton scattering: there was no light emission irradiating the solvent with X-rays with energy lower than 30 KeV. Shortly later, Cherenkov discovered also the spatial asymmetry of the radiation.

4. A new phenomenon is identified

In 1935 the Ph.D. work about luminescence was completed: the identity of the properties of the luminescence emission excited by radioactive source and by visible light was established. At the same time, the discovery by Cherenkov of the properties of constancy, universality and polarisation of the blue light emitted when high energy electrons travel through liquids indicated the existence of a phenomenon previously unknown. It was Vavilov, Cherenkov's supervisor, who proposed that the detected radiation is a distinct phenomenon. His contribution in establishing the discovery of a new radiation is determinant. He forwarded Cherenkov's results to Frank. In 1937 Frank together with Tamm formulated a theoretical explanation of the radiation based on classical electrodynamics [3]. The observed spatial asymmetry of the radiation was the key point to clarify the genuine nature of a new phenomenon and to build a theory describing it. The radiation was interpreted as produced by electrons moving in a medium with a constant velocity greater than the phase velocity of the light in the medium itself.

Before Frank and Tamm published their theoretical description of the observed glow, the prediction of light radiation by a fast charged particle moving at constant velocity exceeding the velocity of the light had already been formulated by Heaviside in 1889 [4] and by Sommerfeld in 1904 [5]. Electrons and other elementary charged particles had not yet been discovered and the theoretical prediction of these scientists were forgotten on some remote bookshelf.

The formulation of the theory started additional experimental activity to allow quantitative comparison between theory predictions and results. The radiation light spectrum was measured [6] and it was verified that the light is emitted only along a narrow cone. The cone axis coincides with the direction of the charged particle trajectory. The apical angle θ defines the direction of the radiation emission. It is defined by the expression $\cos\theta = c/(vn)$,