

LETTERS TO THE EDITORS

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On the experimental discovery of Mandelstam – Brillouin scattering

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The paper by I L Fabelinskiĭ "The prediction and discovery of Rayleigh line fine structure" [1] is of great interest for the history of physics and especially for the history of such an important question as the discovery of Mandelstam – Brillouin scattering (more familiar to the Western reader as Brillouin scattering). I had an opportunity to read the paper before it was published and I would like to report in this note some additional facts related to the history of this discovery and also to express my opinion about some of the questions discussed.

In 2000, it will be 70 years since Evgeniĭ Fedorovich Gross discovered Mandelstam – Brillouin scattering in quartz crystals and liquids. It was very difficult to detect this phenomenon before the advent of lasers. Prior to E F Gross, such noted researchers as J Cabannes and P Salvier (France), M Vaushe (France), S Rafalovsky (Poland), and C Raman (India) had failed to do it.

Once E F Gross published his results, they were repeated for liquids in the Debye Laboratory at Leipzig University only three years later, and for crystals only in 1938 (C Raman).

An important feature of I L Fabelinskiĭ's paper are the excerpts from letters of E F Gross to G S Landsberg, which were found recently and were written in the period when they were studying the problem of the fine structure of the Rayleigh line [2].

The publication of these letters demonstrates the atmosphere in which the studies aimed at the discovery of the fine structure of the Rayleigh line were developed and it is also important because during the last years of E F Gross's life and especially after his death, statements appeared in the native literature that distorted the real situation (a comment from the editorial board of *Physics – Uspekhi* on the paper by Kastler about Brillouin [2], a note by Bobovich in the *Physical Encyclopedic Dictionary* [3], etc.) and even blamed Gross for his apparently unethical behavior when he published his results on the observation of the fine structure of the Rayleigh line in quartz.

[1] See the previous article in this issue, p. 89.

[2] By courtesy of I L Fabelinskiĭ and permission of L G Landsberg, the complete text of the letters from E F Gross to G S Landsberg was published by the St. Petersburg State University Publishing House [1].

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As one can see from the correspondence (between Mandelstam – Landsberg and Gross), the work proceeded in close contact and everything was done by mutual consent. Initially, they planned to publish simultaneously, but in different notes, the results obtained by G S Landsberg (the broadening of the Rayleigh line) and E F Gross (the fine structure of the Rayleigh line). Then, as follows from the correspondence, E F Gross suggested to L I Mandelstam and G S Landsberg publishing a joint paper based on his experimental results. However, L I Mandelstam and G S Landsberg refused the joint publication because they did not trust the experimental evidence obtained by E F Gross. Finally, E F Gross decided to publish independently his results on the fine structure of the Rayleigh line. He writes to G S Landsberg: "This was promoted, of course, by your repeated amiable advice not to delay the publication of my note."

It was found later that the doubts of Mandelstam and Landsberg were vain, whereas the discovery of the fine structure of the Rayleigh line made by E F Gross proved to be correct and generally acknowledged.

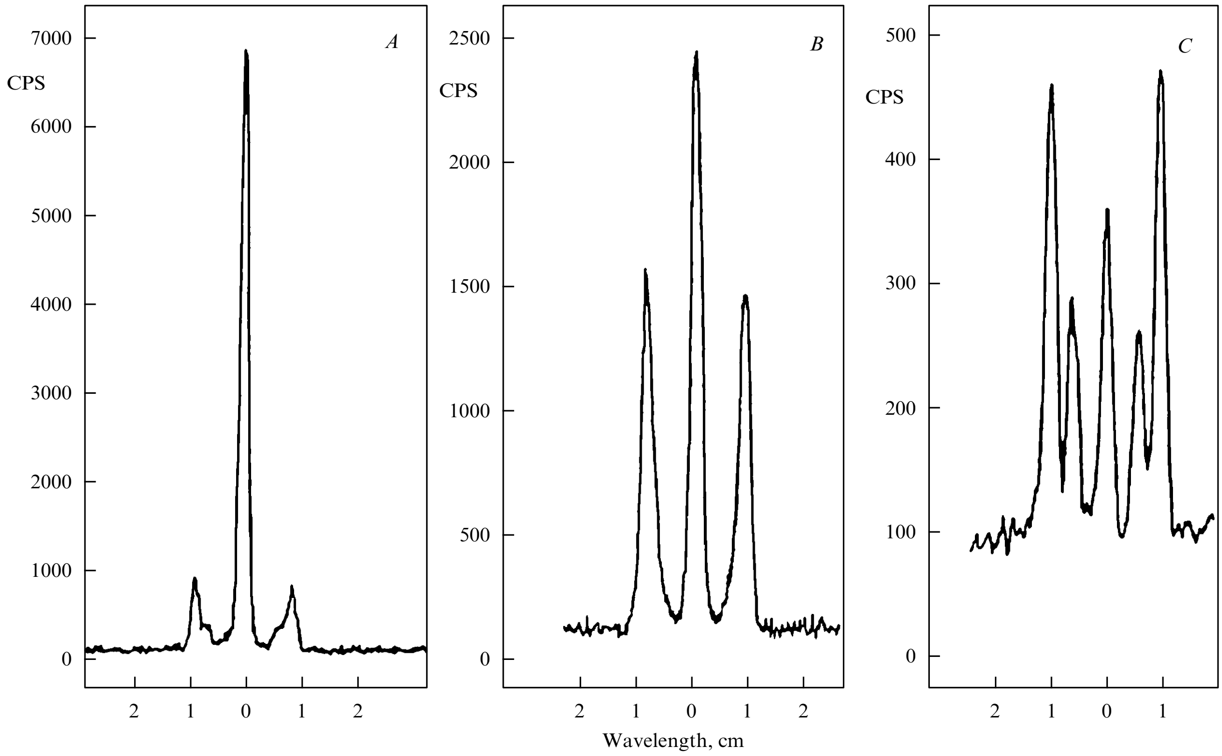
I L Fabelinskiĭ considers the possible reasons for which L I Mandelstam and G S Landsberg could doubt the results of Gross. Among them, he points out the absence of a central component in the spectra obtained by Gross, which was predicted by L I Mandelstam, and the presence of a weak doublet which Gross assigned to overtones of the first two frequencies [3].

Notice here that L I Mandelstam and G S Landsberg associated with E F Gross when he was young (at that time, he was slightly over thirty) and they did not know that they were dealing with an outstanding experimenter. Already within several months after the completion of the study of light scattering by quartz, E F Gross discovered Mandelstam – Brillouin scattering in liquids, and later, when he returned from political exile, he studied Mandelstam – Brillouin scattering in crystals and liquids in detail. In the 1940s, he discovered low 'Gross' frequencies and in the 1950s, he made another spectacular discovery — the spectrum of an exciton in semiconductors.

As follows from the correspondence, E F Gross and G S Landsberg actively exchanged information during this study, and it is natural that E F Gross also sometimes had doubts as to some results obtained by G S Landsberg.

Thus, in a letter of 17 June 1930, E F Gross writes: "I would also like to attract your attention to the fact that your conclusion about the magnitude of the line broadening is not quite correct in my opinion. Because the distance between the orders in your plate is around 0.165 A, it seems to me that the disappearance of the interference pattern indicates that the

[3] These weak lines were observed only in the first experiments of E F Gross and are most likely related to instrumental effects.



line broadening (full width) is no less than this value (the line half-width is no less than the half distance between the orders). The theoretical linewidth (full width), assuming that individual Feinstuctur components are unresolved, is around 0.35 A, i.e. it is greater by a factor of two" [1]. (Underlined by E F Gross. — **B N**). Maybe this remark of E F Gross was the reason that Mandelstam and Landsberg never published their paper whose draft text is presented in the paper of Fabelinskiĭ.

It seems to me, however, that the main discrepancy is explained by another cause. The central component in the experiments of E F Gross was either weak or absent altogether. This made the results of G S Landsberg on the broadening of the Rayleigh line somewhat uncertain. What line was broadened in the experiments of Landsberg in this case? I L Fabelinskiĭ writes: "It seems that the absence of the central line (in the experiments of Gross — **B N**) is a misunderstanding, since nobody has ever observed it later". It is possible that L I Mandelstam and G S Landsberg were of the same opinion. However, E F Gross paid great attention to the problem of the central line. In his paper published in 1938 [4], where he reports for the first time the observation of six components related to longitudinal and transverse acoustic vibrations, Gross wrote: "It is very difficult to solve the problem of the existence of the unshifted component and its intensity because the intensity of light scattered by crystals is very low and spurious light can distort the experimental results. In any case, the intensity of the unshifted component, if it exists, is not higher (and probably less) than that of the shifted components". Therefore, in this paper, which was published eight years after the first paper, E F Gross confirmed that the unshifted component was extremely weak.

Recently, it has been found by the methods of scattering of laser light and thermal neutrons that the intensity of the central component in many crystals strongly depends on the quality of crystals and changes many times upon variation in the concentration of defects [5 – 7]. In perfect crystals, as in the experiments of Gross, the central component can be extremely weak, being substantially weaker than the Mandelstam – Brillouin components.

I think that the same situation, i.e. the dependence of the intensity of the central component on the concentration of defects in a sample, persists for quartz crystals as well. The figure shows the spectrum of Mandelstam – Brillouin scattering for three quartz crystals of disparate origin and different optical quality [4].

One can see from these spectra that the intensity of the central component can change many times from sample to sample. Its intensity for sample *A* is many times higher than the intensity of the Mandelstam – Brillouin components. For sample *B*, the intensity of the central component is approximately 1.5 times higher than that of the Mandelstam – Brillouin components, whereas the intensity of the central component for sample *C* of the highest quality is almost 1.5 times lower than that of the Mandelstam – Brillouin components. Because all the experiments were performed at room temperature, such a substantial change in the intensity of the central component cannot be related to fluctuations of the entropy and temperature and is, undoubtedly, determined by the concentration of defects in the quartz crystals.

The collaborators of E F Gross tell that he paid extremely great attention to the choice of samples for studying the fine structure of the Rayleigh line. Among the crystals he selected for this purpose, were samples from a collection of Academician A E Fersman and many quartz stamps of dignitaries, which he purchased in commission shops. It was processed

[4] Spectra courtesy of Yu F Markov (A F Ioffe Physicotechnical Institute, St. Petersburg). He obtained these spectra in 1987 for all the crystals under the same conditions with a triple Dilor-Z24 Raman spectrometer during excitation by an argon laser.

parts of these stamps that were mainly used as samples in the experiments on Mandelstam – Brillouin scattering. It is obvious to me that E F Gross studied samples of type *C* or of even higher quality, for which "the intensity of the unshifted component, if it exists, is not higher than that of the shifted components". At the same time, it is likely that G S Landsberg used samples of type *A* in his experiments. If this was the case, then, of course, it would have been difficult for E F Gross and G S Landsberg to come to an understanding about their results and a mutual distrust could arise between them.

Therefore, the low intensity of the central component in the experiments of E F Gross is neither an error nor a misunderstanding. This is an experimental fact that was found for the first time by E F Gross and was later confirmed for a number of crystals.

Jokingly, we can say that the metropolitan nobles in St. Petersburg possessed stamps made of high-quality quartz, which determined, to some degree, the success of the experiments of E F Gross on the discovery of the fine structure of the Rayleigh line.

Without question, both L I Mandelstam and G S Landsberg, despite their initial doubts, highly appreciated the results on the fine structure of the Rayleigh line obtained by E F Gross in crystals and liquids. In 1936, the Higher Certifying Commission (VAK) considered, by the promotion of Academicians D S Rozhdestvenskiĭ and S I Vavilov, the question of the conferment of the degree of Doctorate of Physicomathematical Sciences on E F Gross without defending a doctoral thesis. G S Landsberg, who was appointed a referee of E F Gross's doctoral thesis by the VAK, pointed out, as follows from the VAK archives, that "merits of E F Gross are significant and he is worthy of the conferment of the scientific degree of Doctorate of Physicomathematical Sciences without defending a thesis" [8]. L I Mandelstam, who was present at the final meeting of the VAK on this topic, said (a citation from the short-hand record [8]): "It seems to me that there are no obstacles (The case at hand was the conferment of the degree of the Doctorate of Physicomathematical Sciences on E F Gross. — **B N**). His name is associated with a subject that will remain in the world scientific literature. There is almost no work that would not refer to Gross in connection with molecular scattering in liquids. Gross discovered the phenomenon of the frequency change and observed the frequency doublet first in quartz and then in water. I do not mention his other works, which are also very interesting and are genuine scientific works. However, Gross made himself a name by this work alone".

L Brillouin also highly appreciated the results of E F Gross. In his letter of 5 February 1935, he wrote: "Dear colleague, in the near future I shall give several lectures on the structure of the Rayleigh emission based on my theory (1921) and your experiments. I would like to have a cliche and photographs for demonstration. Could you send me imprints on paper or glass of the results of your experiments and the experiments of Khvostikov? I would be very happy if you send me these materials, which I intend to demonstrate at one of the meetings of the French Physical Society. I would also appreciate receiving the reprints of your papers, although I have read them already in different journals" [9].

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