where $M_0$ is the ground state of the anthracene.

However, according to [2], the magnetic field, by mixing the states $\Pi_1$ and $\Pi_3$, should lead to an increase of the fraction of the short-lived excitons ($\Pi_1$) and consequently, in accord with this scheme, it should lead to an increase of the luminescence intensity, in contradiction to the experiment. The quenching effect of the magnetic field and the small magnitude of the effect can be understood by assuming that the recombination of the electrons and holes ($e_i$ and $h_i$) injected into the crystal results essentially in the production of molecular excitons, which are not affected by the magnetic field:

$$e_i + h_i \rightarrow \frac{1}{4} M_S^* + \frac{3}{4} M_T^* . \qquad (3)$$

On the other hand, for $\Pi$ excitons with charge transport to be produced in accordance with scheme (1) it is necessary to have electrons that are at a higher energy level, the number of which is small under dark injection conditions. Such electrons, however, are produced when generated by light, especially in the process of annihilation of triplet molecular excitons $M_T^*$ [3,4]. The injected electrons $e_i$ may possibly be those in the narrow conduction band (and localized on the anthracene molecules), while the e electrons are those in the broad conduction band [6]. The injected holes $h_i$ are apparently equivalent to h in all cases. Simultaneous occurrence of the processes (1) and (3), under the condition that only a small fraction of the $e_i$ electrons go over into e, makes it possible to explain the observed luminescence quenching.

[1] E. L. Frankevich and E. I. Balabanov, Fiz. Tverd. Tela 8, 855 (1966), Sov. Phys.-Solid State 8, 682 (1966).
[2] E. L. Frankevich, Zh. eksp. teor. fiz. 50, 1226 (1966), Soviet Phys. JETP 23, 814 (1966).
[3] E. L. Frankevich and I. A. Sokolik, ibid. 52, 1189 (1967), transl. in press.
[4] E. L. Frankevich and I. A. Sokolik, Fiz. Tverd. Tela 10, No. 7 (1967), Sov. Phys.-Solid State 10, No. 7, in press.
[5] W. Helfrich and W. G. Schneider, J. Chem. Phys. 44, 2902 (1966).
[6] W. Helfrich and W. G. Schneider, Phys. Rev. Lett. 14, 229 (1965).

## QUARTZ RESONATOR WITH Q CLOSE TO $120 \times 10^6$ AT TEMPERATURE 2°K *

A. G. Smagin and V. I. Nikol'skaya
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We investigated the absorption mechanisms brought about by inelastic processes in quartz crystals by measuring the internal friction in resonators at low and infralow temperatures. The resonators were quartz elements in the form of doubly-convex lenses of AT-cuts, secured in a special manner to a quasineutral plane, and placed in a vacuum bulb. They were excited in a crystal holder with slots, at a fundamental frequency 1000 kHz.

The internal friction of the piezoelectric quartz was measured by a method in which the time of the free damped oscillations was automatically recorded [1]. The Q factor was calculated from the determined time of decrease of the amplitude in free damping of the oscillations; the measure of the internal friction was taken to be the quantity $Q^{-1}$. The instrument makes it possible to measure Q with an error not exceeding several per cent.

The temperature was measured with a platinum resistance thermometer accurate to ±0.01% in the temperature interval 12 - 300°K, and with a germanium thermometer accurate to ±0.1% in the interval 1.5 - 7.0°K.

The investigated quartz sample was sealed in a red-copper container and placed in a liquid-helium cryostat consisting of a doubly-cooled dewar; liquid nitrogen is poured into the outer vessel, the system is cooled to 77°K, and liquid helium is then poured into the inner vessel.

The measurements yielded the temperature dependence of several quartz samples in the interval 2 - 300°K.

The measurement results show that the dissipative-temperature characteristics of the quartz have two clearly pronounced relaxation-process peaks due to energy absorption at 20 and 50°K, and a number of sharply outlined sharp peaks due to the influence of the coupled oscillations in a wide interval of nitrogen temperatures (Figs. 1 and 2).

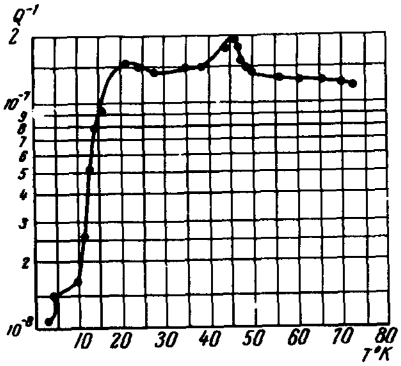


Fig. 1. Internal friction of AT-cut quartz at 1 MHz (No. 7) vs. temperature.

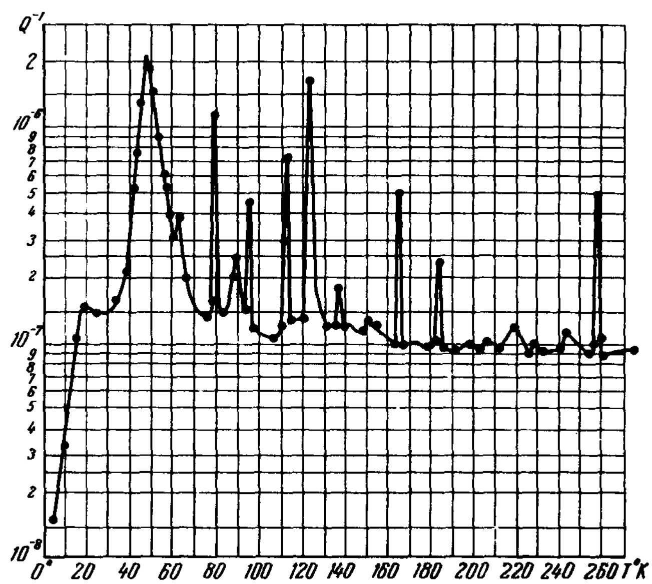


Fig. 2. Internal friction of AT-cut quartz at 1 MHz (No. 30) vs. temperature.

Some workers ascribe the absorption peak at 20°K to dislocations [2], and others to phonon-phonon interaction [3]; the 50°K peak is ascribed to the presence of alkali $Na^+$ ions [4]. The initial hypothesis was to ascribe the 50°K peak to the singular inelastic behavior of quartz resulting from the vibrations of the oxygen atoms [5].

Our measurements show that the intensity of the 50°K absorption peak changes from sample to sample. If the hypothesis that the oxygen-atom oscillations are responsible for this peak were true, then the intensity of this peak would be constant. This hypothesis contradicts the experimental data, and it can therefore be regarded as proved that the relaxation absorption at 50°K is caused not by this mechanism, but by the presence of alkali-element ions in the structure channels of the crystal.

When the temperature is lowered from 300 to 2°K, the Q of the quartz resonators, which oscillate at a fundamental frequency 1000 kHz, increases by a factor of about 20 and reaches in some cases approximately $120 \times 10^6$. This is the highest value of Q ever reported for an oscillating macroscopic body.

The obtained experimental data serve as a basis for developing a low-temperature quartz generator having, owing to the exceptionally large Q, the highest short-time generated-frequency stability and, owing to the very low temperature, a high long-time stability, practically comparable with that of atomic-molecular standards.


[1] A. G. Smagin, Pretsizionnye kvartsevye rezonatory (Precision Quartz Resonators), Standartgiz, 1964.

[2] H. E. Bommel, W. P. Mason, and A. W. Warner, Phys. Rev. 99, 894 (1955).

[3] W. P. Mason, Acoust. Soc. Amer. 32, 452 (1960).

[4] D. B. Fraser, J. Appl. Phys. 35, 10 (1964).

[5] J. C. King, Phys. Rev. 109, 1552 (1958).


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## DIFFRACTION GENERATION OF PARTICLES BY PROTONS FROM EMULSION NUCLEI IN A PULSED MAGNETIC FIELD


G. B. Zhdanov, M. I. Tret'yakova, and M. M. Chernyavskii

P. N. Lebedev Physics Institute, USSR Academy of Sciences



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A photographic emulsion exposed in a strong (pulsed) magnetic field can serve as an effective means of investigating inelastic diffraction processes on complex nuclei at energies of several dozen GeV, since it not only permits observation of small excitations of the nuclei themselves, but also affords a possibility of investigating quite accurately the emission angles, the momenta, and the nature of all the observed particles. We have observed 107 stars of the 0 + 0 + 3p type, unaccompanied by tracks of recoil nuclei or slow electrons, in Ilford G-5 and K-5 emulsions (600 μ thick exposed in a 180-kOe pulsed field in the CERN proton beams (momenta 24 and 21 GeV/c, total length 1676 m). The experimental conditions made it possible to measure the momenta of all the particles accurate to 10 - 15%, and the effective masses of the $p\pi^+\pi^-$ systems accurate to 5 - 7%.

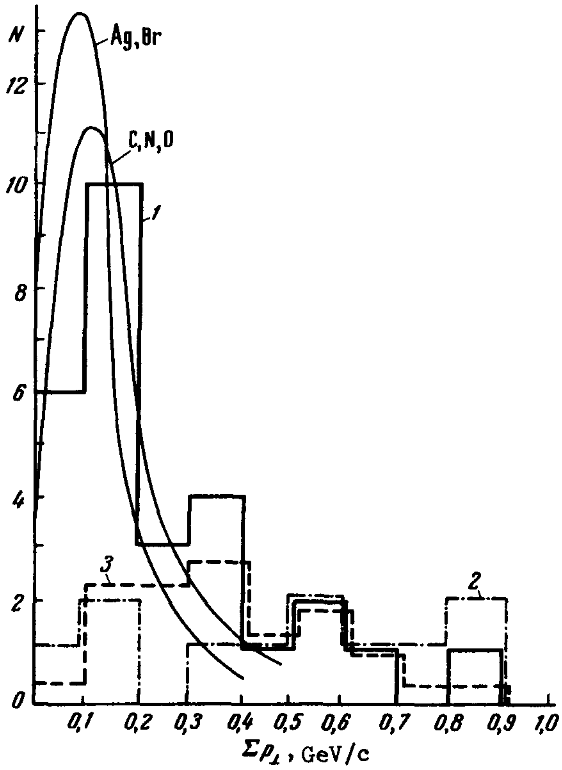


Fig.1

Out of the 107 stars, we selected 28 satisfying the following three necessary conditions of the diffraction process:

1) One of the three relativistic particles is a positive or negative pion.

2) $\delta = \sin\theta_{\pi 1} + \sin\theta_{\pi 2} + (M_N/\mu)\sin\theta_p \leq A^{-1/3} + M_N^2/2\mu p_0$ for A = 14, where $\theta_\pi$ and $\theta_p$ are the pion and proton emission angles, $M_N$ and μ the nucleon and pion masses, and $p_0$ the initial momentum.

3) The total momentum of the secondary charged particles is $\sum_{i=1}^{3} p_i \geq 0.85p_0$ (thereby excluding to a considerable degree the presence of neutral particles).