field intensity. Other types of losses (recombination and elastic losses), according to estimates, are insignificant under these conditions.

In the presence of diffusion losses, the time constant θ' for avalanche development increases in accordance with the relation

$$\frac{1}{\theta'} = \frac{1}{\theta} - \frac{1}{\tau_D} ,$$

where θ is the time constant for avalanche development in the absence of losses and τ_D is the diffusion time ($\tau_D = \Lambda^2/D \sim f^2/D$, where Λ is the diffusion length and D is the diffusion coefficient).

Quantitative allowance for the diffusion losses, made under the assumption that the diffusion of the electrons from the focusing volume is free and that an important role is played in the investigated gases by slow-electron diffusion due to the Ramsauer effect, gives good agreement between the experimental results and the avalanche theory.

[1] R. G. Meyerand and A. F. Haught, Phys. Rev. Lett. 11, 401 (1963).

[2] Ya. B. Zel'dovich and Yu. P. Raizer, JETP 47, 1150 (1964), Soviet Phys. JETP 20, 772 (1965).

NONLINEAR EFFECTS IN A HYPERSONIC WAVE

A. L. Polyakova
Acoustics Institute
Submitted 31 May 1966
ZhETF Pis'ma 4, No. 4, 132-134, 15 August 1966

When a light wave produced by a giant laser pulse is focused inside a quartz single crystal, a hypersonic wave builds up [1]. Estimates show that in such experiments the intensity of the sound wave is quite appreciable, and consequently an important role in its propagation should be played by nonlinear phenomena. Nonlinear phenomena lead to a distortion of the wave form, to the appearance of higher harmonics, and in the case of sufficiently large intensities to the formation of a periodic shock wave.

This nonlinear-distortion process is counteracted by energy dissipation, which leads to a spreading of the steep shock fronts. To characterize the degree of nonlinear distortion in a sound wave we can introduce the dimensionless parameter [2]

$$R = \frac{\epsilon p}{\eta_{eff}\omega} , \tag{1}$$

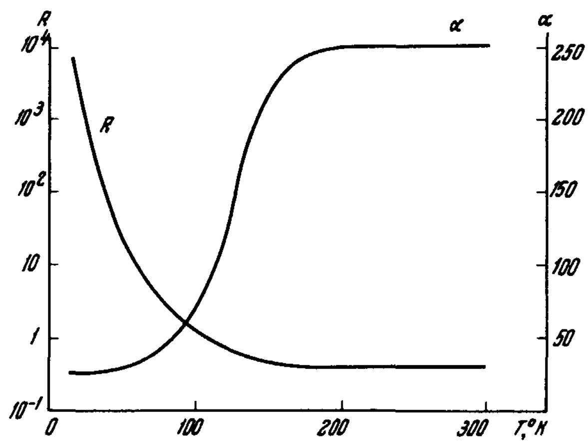
where p and ω are the amplitude of the pressure and the frequency of the sound wave, ϵ a nonlinear parameter of the medium, of the order 4 - 5 for solids, and η_{eff} a certain effective "viscosity" of the medium, which determines the dissipation of the sound energy. If $R \ll 1$, then the dissipation prevails over the nonlinearity and the sound wave behaves essentially like a small-amplitude wave. If $R \gg 1$, then the nonlinearity prevails, and the sound wave is strongly distorted in form and becomes a periodic shock wave. The width of the shock-wave front is in this case $\delta \sim \lambda/R$, where λ is the length of the sound wave. The amplitude of the n-th harmonic is 1/n-th of the amplitude of the first harmonic.

Using known expressions for the absorption coefficient of quartz [3,4] we can write the parameter R in the form

$$R = \frac{\epsilon p(1 + \omega^2\tau^2)}{C T \gamma^2 \omega\tau}, \tag{2}$$

where C is the specific heat per cm^3, γ the Gruneisen constant, τ the relaxation time characterizing the time necessary to establish equilibrium of the phonon gas, and T the temperature. It is easy to see that at a fixed temperature the parameter R has a minimum at a frequency $\omega = 1/\tau$. Inasmuch as both C and τ depend strongly on the temperature, the nonlinear effects are also sensitive to the temperature.

The temperature dependence of the parameter R for quartz is shown in the figure (the numerical values were obtained for a pressure amplitude $p = 2 \times 10^8$ dyne/cm^2 and a frequency $f = 2.7 \times 10^{10}$ sec^{-1}; the sound absorption was taken from the experiments of [3,4]; these parameters correspond closely to the experimental conditions in [1]).



The nonlinear effects play essentially different roles at different temperatures. Whereas the nonlinearity in the sound wave, for given values of the frequency and amplitude, is small at room temperature, the nonlinear effect becomes decisive at low temperatures. At $T \sim 25°K$ we have $R \sim \lambda/a$ and consequently, at these and lower temperatures the sound wave is a periodic shock wave with a front width $\delta \sim a$, where a is the lattice constant. The rapid increase of the parameter R with decreasing temperature is connected with the fact that the absorption of sound in the quartz at low temperatures does not depend on the frequency and, consequently, the dissipation does not lead to the smearing of the steep shock fronts.

Absorption of such a wave depends on the amplitude and can greatly exceed the absorption of a small-amplitude wave. If the absorption coefficient of such a wave is defined as $\alpha = (1/p)(dp/dx)$, then for $R \gg 1$ we have $\alpha = (2/\pi)\alpha_0 R$, where α_0 is the absorption coefficient of a small-amplitude wave [2]. The dependence of α on the temperature T is shown in the figure. At high T and for $R < 1$, the value of α coincides with α_0, and at low temperatures and $R \gg 1$ it is equal to $\alpha_1 = \epsilon p\omega/\pi\rho c_s^3$ and does not depend on the temperature. The difference between α_0 and α_1 decreases with increasing sound amplitude.

It should be noted that the large forces that arise in the front of the shock waves can cause local damage to the crystal at low temperatures, such as observed by Krivokhizha at al. [1] In addition, at large values of R a purely longitudinal wave cannot exist and shear stresses arise, which under certain conditions can reach large values. These stresses can also cause crystal damage.

I am grateful to I. L. Fabelinskii, G. A. Askar'yan, and K. A. Naugol'nykh for useful discussions.

[1] S. V. Krivokhizha, D. I. Mash, V. V. Morozov, V. S. Starunov, and I. L. Fabelinskii, JETP Letters 3, 378 (1966), transl. p. 245.

[2] L. K. Zarembo and V. A. Krasil'nikov, UFN 68, 687 (1959), Soviet Phys. Uspekhi 2, 580 (1960).

[3] H. E. Bommel and K. Dransfeld, Phys. Rev. 117, 1245 (1960).

[4] R. Nava, R. Azrt, I. Ciccazello, and K. Dransfeld, ibid. 134A, 581 (1964).

FEATURES OF SCATTERING OF FAST BEAMS OF H, N, AND O ATOMS IN MOLECULAR GASES (N_2, O_2)

Yu. N. Belyaev and V. B. Leonas
Mechanics Research Institute at the Moscow State University
Submitted 2 June 1966
ZhETF Pis'ma 4, No. 4, 134-138, 15 August 1966

Exact knowledge of the surfaces of the potential energy of interaction (or potential curves for spherically symmetrical systems) is essential for a theoretical calculation of both elastic and inelastic processes accompanying atom-molecule collisions. A reliable method of obtaining the corresponding information is to scatter fast beams by gas targets. In particular, scattering of beams of energy ~1 keV at small angles (~10^{-3} rad) yields information on the interaction of colliding particles in the energy region ~1 eV [1].

The experimental setup and the measurement procedure were described in the papers by the authors and Kamnev et al. [1] Measurements of the total scattering cross sections were made with the aid of beams with energies from 0.6 to 4 keV, using three different detector angular apertures (θ_0). The relative error of the measured values of $Q(\theta_0, E)$ lies in the range 1 - 1.5%, and the error of the absolute measurements does not exceed ±8%.

The figure shows a log-log plot of the measured cross sections against the beam energy. The cross sections are given relative to the value for O-N_2, and to obtain the true cross sections the values from the figure must be multiplied by 1.19 for H-N_2 and O-O_2, by 0.91 for H-O_2, by 0.81 for N-N_2, and by 0.76 for N_2-N_2 and N-O_2.

From the initial linear sections of the plotted curves we can determine the parameters K and n of the effective spherically-symmetrical potential $V = K/r^n$ of the investigated systems. These values and the ranges of the closest-approach distance within which they are valid are summarized in the table.