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FREQUENCY DEPENDENCE OF ACOUSTIC SATURATION IN SMOKY QUARTZ

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Abstract.- High frequency ultrasonic measurements were performed in gamma irradiated natural quartz at 1.2 K at frequencies down to 20 MHz as a function of applied power. The two-level systems resonant attenuation shows saturation effects which decrease notably at frequencies below 200 MHz. These results are consistent with a decreasing density of states at frequencies close to $\Delta_0$.

A consequence of the tunneling model of TLS in amorphous and disordered solids is the existence of a gap in the density of states $n(E)$ for energy splittings $E = \sqrt{\Delta^2 + \Delta_0^2}$ smaller than the tunnel splitting $\Delta_0$. Among the observable effects of this prediction would be a departure of the low temperature specific heat from linearity in $T$ and a rapid decrease of the resonant ultrasonic attenuation for frequencies $\omega$ such that $\hbar \omega < \Delta_0 / 1,2/$. For TLS in crystalline matrices one expects $\Delta_0$ to be single valued or, for small amounts of local disorder, narrowly distributed so that the change in these properties would take place in a shorter temperature (frequency) range than for glassy TLS. In this work we report the disappearance of the resonant ultrasonic attenuation of gamma irradiated Brazilian quartz for frequencies below 140 MHz in accordance with the existence of a gap in the density of states.

The intensity dependence of the resonant ultrasonic attenuation of shear waves along the AC-axis of crystals irradiated to $1.5 \times 10^6$ Rads was measured in a non-resonant sample holder bathed by He pumped to 1.2 K. Typical acoustic intensities varied from 20 mW/cm$^2$ to 5 $\mu$W/cm$^2$. An ultrasonic pulse length $\tau_p$ of 1 microsecond was used throughout. The attenuation coefficient was determined from pulse-echoes separated by several hundred microseconds. The output of the video detector was averaged by means of a transient recorder coupled to a multichannel analyzer.

The experimental results show a frequency independent resonant attenuation above 200 MHz followed by a drastic reduction of $\alpha$ for frequencies below about 170 MHz. The magnitude of the attenuation at
140 MHz is barely discernible above the experimental accuracy (5 x 10^{-4} dB/μsec.) and undetectable below this frequency (Fig. 1). We also find a frequency independent critical intensity \( J_c \) of about 35dB below a reference acoustic intensity of 200 mW/cm^2.

Assuming steady state conditions at low frequencies (\( \hbar \omega << 2kT \)) the attenuation coefficient of the unsaturated resonant absorption is given by:

\[
\alpha = \begin{cases} 
\frac{\pi n(E) (\gamma t \Delta_0)}{2 \hbar \nu \nu c kT} & \hbar \omega > \Delta_0 \\
0 & \hbar \omega < \Delta_0 
\end{cases}
\] (1)

For energy splittings greater than \( \Delta_0 \) a constant density of states \( n_0 \) describes well these and previously reported results /3/. For energy splittings in the neighborhood of \( \Delta_0 \), assumed here to be single valued, the decrease observed in the unsaturated absorption \( (J<J_c) \) takes place in a frequency range comparable to the inhomogeneous linewidth \( T_2^{-1} \).

In the inset of Fig. 1, we have plotted the frequency dependence of the maximum resonant attenuation. The width of the transition is about 50 MHz. From this curve we estimate \( \Delta_0 \) and \( T_2 \) to be 130 MHz (0.5 μeV) and 3 nsecs., respectively. Taking for \( n_0 \) the specific heat value \( 6 \times 10^{32} \text{ erg}^{-1} \cdot \text{cm}^{-3} \) we find from Eq. (1) \( \gamma_t \sim 0.14 \text{ eV} \) which is 20 times smaller than that reported for quartz glass /4/ and close to the mean value calculated from \( (\gamma \Delta_0) \) obtained by dielectric loss measurements /2/.

In summary, by studying the frequency dependence of the resonant ultrasonic attenuation due to TLS in smoky quartz we have established the existence of a gap in the density of low energy states as predicted by the tunneling model.

REFERENCES
1.- J.C. Lasjaunias, R. Maynard and M. Vandorpe, J. de Phys. 39,
C6-973 (1978).

