II-5. Phonon Generation at 70 kMcps

J. B. Thaxter and P. E. Tannenwald

Lincoln Laboratory, Massachusetts Institute of Technology, Lexington, Mass.

Phonons have been generated and detected at 70 kMcps using piezoelectric surface excitation in single-crystal quartz. Echoes are observed from multiple reflections of acoustic waves in a quartz rod excited by a microwave pulse. The temperature dependence of the relative attenuation of several acoustic modes has been measured from 4.2° to 25°K. Previously, experiments using the surface excitation of acoustic waves in solids have been carried out up to 24 kMcps.[1]

The requirements for generation and detection of the phonon echoes are threefold: an intense alternating electric field must be established over the surface of the sample for the excitation of a strong acoustic wave; severe dimensional tolerances are imposed on the quartz rod to preserve the spatial coherence of the acoustic wave; and a sensitive receiver is required

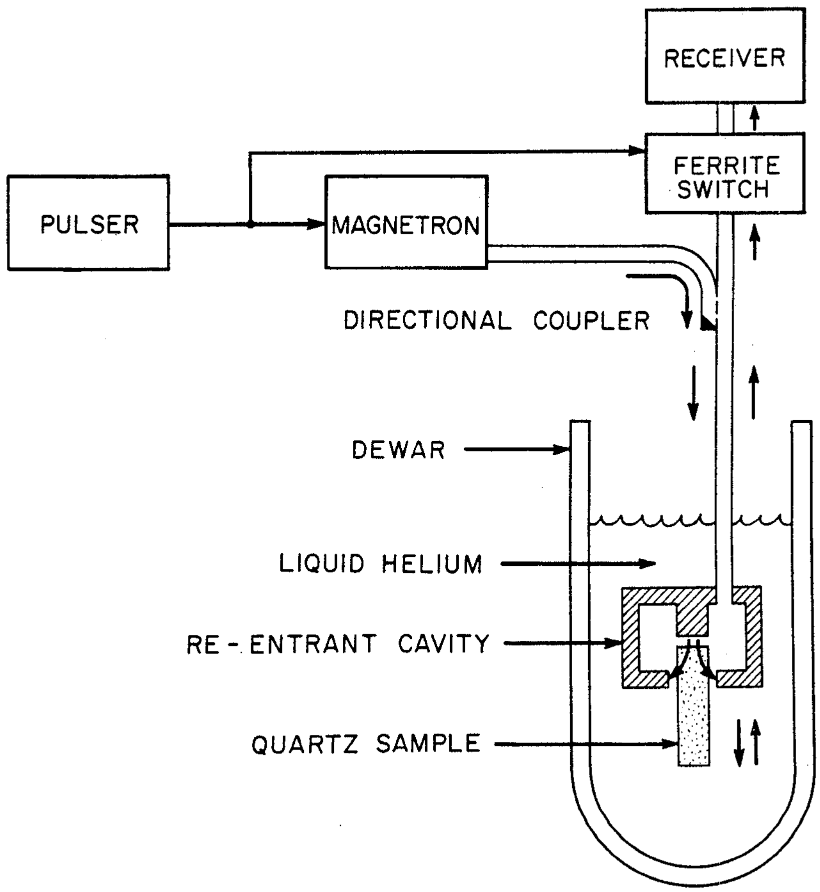

Fig. 1. Microwave system for observation of phonon echoes at 70 kMcps.

to detect the reconverted phonon echoes which are approximately 80 db below the excitation pulse.

The intense electric field is produced by placing the surface of the quartz in the high electric field region of a re-entrant microwave cavity that is excited by a BL221 magnetron, which is capable of delivering to the cavity 400 watts of peak power for 0.2 μsec (see Fig. 1). Altering the geometry of the post in the re-entrant cavity, shown in Fig. 2, to shape the electric field over the surface of the sample gives considerable improvement in the amplitude of the phonon echo at low incident power levels. Unfortunately, the post shapes that enhance phonon echoes also reduce the breakdown level of the cavity, and present results indicate no increase in maximum echo strength, which is obtained just below dielectric breakdown in the cavity.

The sound wavelength in the quartz of approximately 1000 Å imposes severe dimensional tolerances on the sample in order to preserve the phase conditions in the reflected acoustic wave. These tolerances are very close to the best available commercially, and for the 1/4-inch-long by .040-inch-diameter rods used are as follows: end surfaces parallel to 2'' arc; ends flat to 0.1 λ Na light; crystal axis within 10'' of rod axis.

The superheterodyne receiver employed has a sensitivity of -80 dbm with a signal bandwidth of 10 Mcps, and is protected by a ferrite switch that provides 40 db of isolation during the magnetron pulse and 2 db insertion loss during the period of time the echoes are observed. In a typical display of the received echo signal, as shown in Fig. 3, the first large pulse is leakage of the magnetron past the switch. The non-exponential decay rate of the echoes is attributed to interference of the acoustic waves due to nonuniform excitation of the surface and marginal tolerances on the sample.

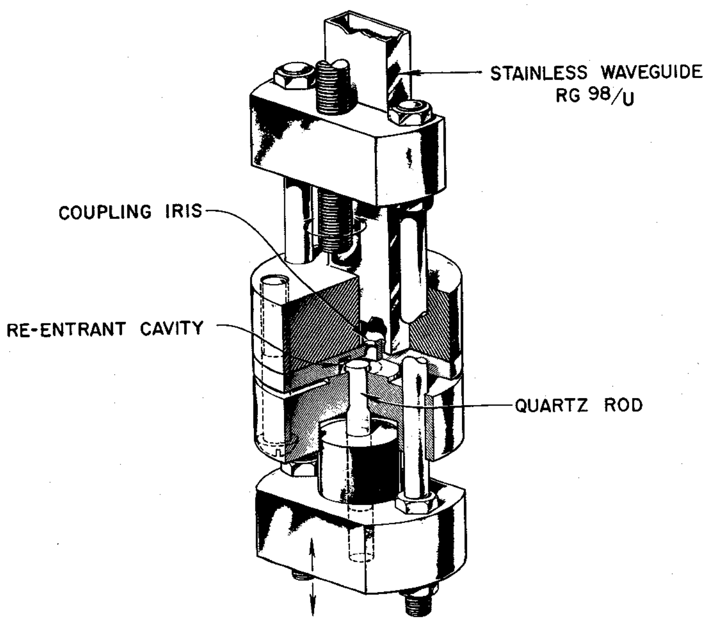

Fig. 2. Microwave re-entrant cavity and quartz rod initially used for observation of echoes. Over-all height is 1 inch.

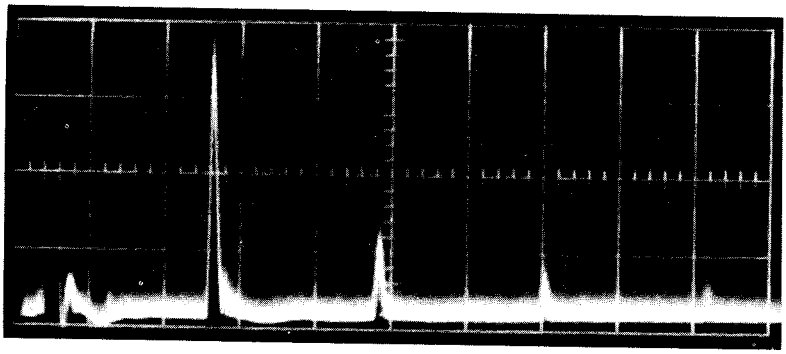

Fig. 3. Longitudinal phonon echoes excited in 1/4-inch, x-cut quartz rod placed in a microwave cavity. Horizontal scale is 1 μsec per division.

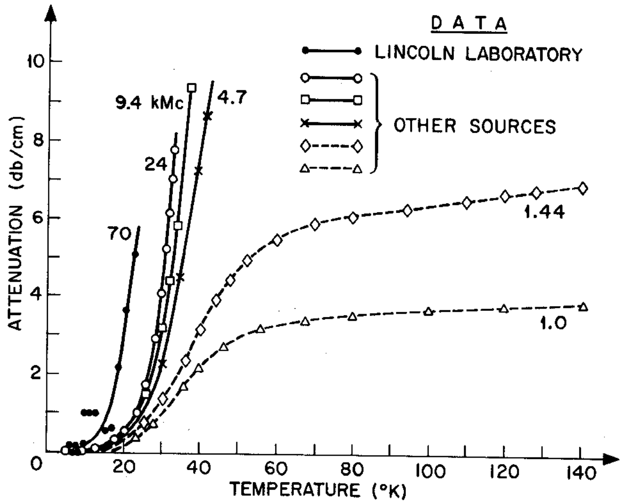

Fig. 4. Temperature dependence of attenuation of longitudinal phonon echoes in x-cut quartz at 70 kMcps. The other curves, shown for comparison, are taken from the literature. (See, e.g., Ref. 1.) All curves normalized to 0 db/cm attenuation at 4.2°K.

Figure 4 shows results of initial measurements of the phonon attenuation at 70 kMcps, in addition to previous results by other observers at lower microwave frequencies. The observed behavior as a function of temperature and frequency is in agreement with that expected on the basis of phonon-phonon scattering theory.

REFERENCE

1. E. H., Jacobsen, *Quantum Electronics* (New York: Columbia University Press, 1960) p. 468. This book also gives other pertinent literature references.