Discrete echo in lithium niobate

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(Submitted July 6, 1976)
Pis'ma Zh. Eksp. Teor. Fiz. **24**, No. 2, 64–66 (20 July 1976)

Discrete echo signals, produced only when the interval between the exciting microwave pulses was equal to or was a multiple of the time of passage of the hypersound through the sample, were observed in monodomain $LiNbO_3$ crystals at a frequency 9.4 Hz.

PACS numbers: 78.20.Hp

Investigations of $LiNbO_3$ crystals by echo-pulse methods,[1–3] a characteristic feature is the existence of an echo signal at any interval between the exciting pulses, provided it does not exceed the relaxation time of the system. The present study has demonstrated experimentally the possibility of observing the echo only at strictly fixed discrete values of the interval in $LiNbO_3$ crystals exposed to coherent light pulses. A mondomain sample of $LiNbO_3$ with iron

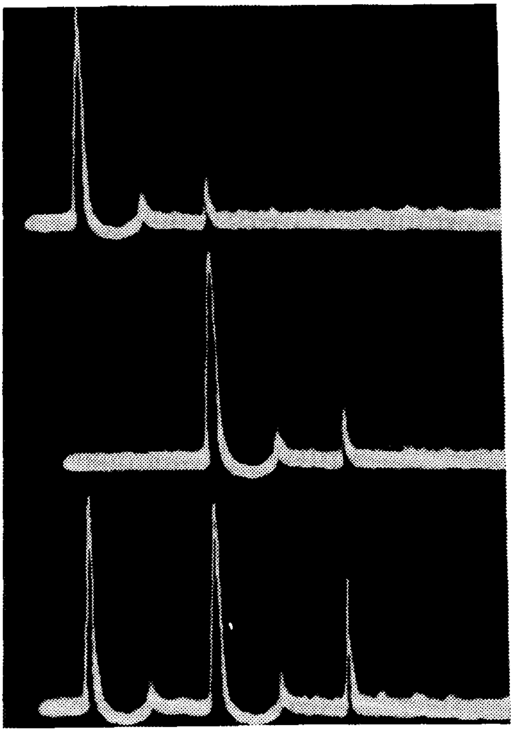

FIG. 1. Upper oscillograms: the first and second microwave pulses are applied to the sample separately; lower oscillogram: result of two-pulse action on the sample with an interval $2\tau_0$ between the microwave pulses. The echo signal is observed at a time $4\tau_0$ after the first microwave pulse.

impurity, the finished surfaces of which were perpendicular to the X axis, was exposed to short (20 nsec) intense (50 MW/cm^2) pulses of coherent light ($\lambda = 0.53\ \mu$) and placed in the measurement cell of the polarization-echo installation [4] and investigated at a temperature 4.2 °K and frequency 9.4 Hz. It should be noted that in our construction of the microwave cell, the electric component of the microwave pulse, with duration 40 nsec, acted on both finished surfaces of the crystal simultaneously. This has led to the appearance of a damped sequence of hypersonic pulses, multiply reflected from the ends of the crystal and separated from one another by the time τ_0 necessary for the passage of the hypersound through the sample. The echo signals were produced only in the case when the second exciting microwave pulse was shifted relative to the first by a time equal to τ_0 or a multiple of this time. When the foregoing time relations were maintained on the ends of the crystal, the sequences of the hypersound pulses from both microwave pulses coincided. The oscillogram shows the case when the delay of the second pulse is equal to $2\tau_0$. The echo is produced at an instant of time equal to double the delay time, i.e., after $4\tau_0$.

The echo signal is not a result of addition of the amplitudes of the hypersonic pulses of two time-shifted sequences. This is confirmed by the fact that the agreement of the analogous pulses for $t=4\tau_0$ (on the oscillogram $3\tau_0$) leads only to a small increase of the amplitude of the resultant signal, whereas the signal at $t=4\tau_0$ exceeds the summary signal.

Changing the delay in either direction by a time larger than the pulse-overlap time led to complete vanishing of the echo, which reappeared at a new interval that was a multiple of τ_0. The experiments have shown that the intensity of the discrete echo signals decreased after heat treatment of the sample, and also after prolonged storage, as is the case when optical holograms are recorded in $LiNbO_3$.

Prior to the irradiation, it was possible to observe in these crystals, only weak signals of the ordinary polarization echo, the intensity of which decreased with smooth increase of the interval. Deterioration of the polish of the end faces led to a complete vanishing of the discrete signals and did not influence the character of the polarization echo. This obviously indicates that discrete echo is of phonon origin.

It is known that information on the initial conditions of the microwave excitation is carried by the elastic wave generated in the surface layer of the crystal. This wave becomes gradually dephased as it propagates through the sample. The surface excitation of the second hypersonic pulse at the instant when the first elastic wave is near the finished surface of the crystal leads to inversion of the elastic wave and to restoration of the initial phase relations after a time equal to the interval between the exciting pulses.

Exposure of the crystal to light pulses leads to ionization of the donor impurities and to capture of electrons by the traps.[5] This manifests itself most strongly for the near-surface regions, where the concentration of the traps is usually larger than in the volume of the crystal. It is obvious that these trapped electrons take part subsequently in the formation of the echo signals.

It appears that if effective recombination of the electrons in the traps can be ensured by some other method, then it will be possible to observe a discrete echo without applying light pulses to the crystals.

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