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Readout of Spectrum of Hole-Burning on piezoelectric resonators

圧電共鳴体のホールバーニングにおけるスペクトルの読出し

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1. Introduction

The hole-burning phenomena have been well studied in the light absorption areas and applied them to the memory systems [1]. The necessity conditions for observation of the hole-burning phenomena are, 1: the absorption frequencies of resonant absorbs are different from each other, 2: the total absorption frequencies spread wide and moderately, 3: large amplitude oscillation introduces some changes, life times of which are long enough to be detected, in the characteristics of absorbers.

These conditions can be well fulfilled by piezoelectric resonators as follows. The ensemble of resonators with different dimensions satisfies the conditions of 1 and 2. The resonant oscillations of piezoelectric powders have been well studied [2]. For the third condition, some possibilities have been proposed [3,4]. Our proposition is that large amplitude oscillations excited introduce plastic deformation into particles [4]. The particles prepared by destruction of large grains have large crystal defects, for example, crystal dislocations, which contribute oscillation damping and apparent elasticity [5].

In this report, we show the read patterns in the spectrum, which were written by pulse sequences, not only by frequency scanning but also excitation of all oscillators composing holes.

2. Experimental

Our samples of the piezoelectric powders Potassium Bromide $KBrO_3$ were prepared through destruction of commercial grade grains with pestle and mortar. We used two standard meshes of 105 and 125 ìm to limit the sample diameters. The experimental measurements were performed on the powder samples introduced into the parallel plates condenser with the surface of 8 x 10 cm^2 and separated at a distance of 1 mm. The samples were kept at room temperature and under the pressure of 0.1 Pa. The figures and the crystallographic angles of samples were at random, and the oscillation modes were not assigned. However, the oscillations characteristics of the piezoelectric powders prepared by the nearly the same processes have been well studied and shown that they resonantly oscillate [2]. In Fig. 1, the measurement block diagram is shown.

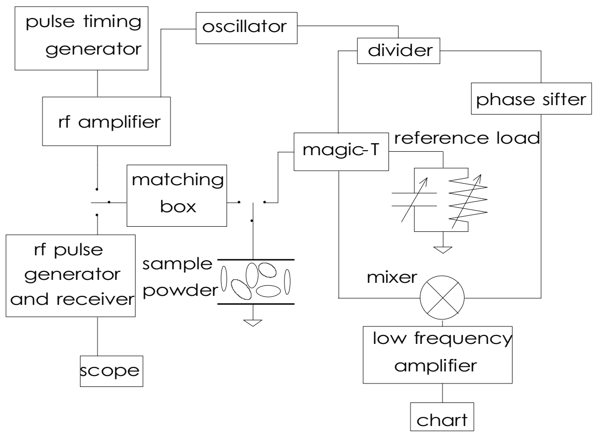

Fig.1. Block diagram for writing and reading hole patterms.

The synthesized oscillator (R&S SMX) and timing generator (Agillent 33250A) produce the pulse sequences. Our applied sequent pulses were described with Δ–τ and N, which means we applied N pulses with pulse width Δ and the intervals of pulse starting times of τ. These pulses were amplified with gated RF amplifier (MATEC 5500 + 515A) and applied to the sample condenser filled with specimen powders through matching box.

2-1. Hole pattern detection by magic-T

The detections of the hole patterns were performed with the magic-T systems, which has been widely used in the magnetic field. Before the holes were written, the output from the magic-T was set null by tuning the reference load composed of variable resistance and condenser connected in parallel. The hole signals could be detected as the output from magic-T as the destruction of the balance. We obtained these signals with scanning frequencies. In Fig. 2, we showed the detected

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results introduced by pulses applied of 2-50, 4, with carrier frequency of 20 MHz.

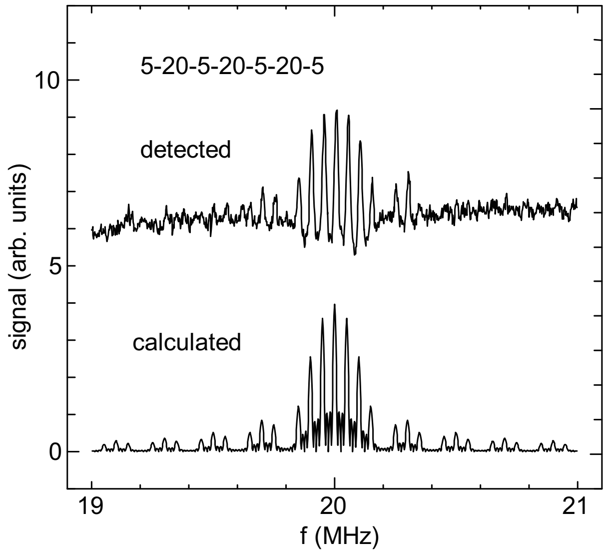

Fig. 2. Detected spectrum patterns by magic-T.

We described these hole patterns with the absolute value of the Fourier components of applied sequent pulses. When we describe the each pulse has rectangular shape and neglect the oscillation decay, the expected hole patterns Q_N are described as

$$Q_N = \left| \left(\int_0^{\Delta} + \int_{\tau}^{\tau+\Delta} + .. + \int_{(N-1)\tau}^{(N-1)\tau+\Delta} \right) e^{i2\pi(f-f_0)t} dt \right|.$$

And, for the patterns shown in Fig. 2 with N=4,

$$Q_4 = \left| \frac{\sin[2\pi(f-f_0)\Delta/2]}{2\pi(f-f_0)\Delta/2} \left\{ \cos\left[2\pi(f-f_0)\frac{3\tau}{2}\right] + \cos\left[2\pi(f-f_0)\frac{\tau}{2}\right] \right\} \right|.$$

We plotted this expression as calculated, and found the good coincidence of peak positions and shapes.

2-2. Hole pattern described with one short pulse

For second detection of the spectrum, we applied one short pulse to excite oscillations with wide frequency components. When there are some periodic patterns in frequency space of absorption or excitation, some coherent outputs might be detected. Our case is expressed as

$$G(t) \propto \left| \int e^{-i2\pi f t} df \cdot Q_4(f) \cdot \frac{\sin[2\pi(f-f_0)\Delta_2/2]}{2\pi(f-f_0)\Delta_2/2} \right|$$

$$\to \left| \int e^{-i2\pi f t} df \sum_n \delta\left(f - (f_0 + \frac{n}{\tau}) \right) \right| = \sum_m \delta(t - m\tau).$$

Here, the Q_4 terms express the written hole patterns. The next sine term with pulse width Δ_2 means applied readout pulse. In the expression after the arrow, we neglected the precise hole patterns and approximate them with Dirac's delta functions at frequencies of $f_0 + n/\tau$ with integer n. With this simplicity, we obtained the expression of the last term, with that we expect to detect the pattern of peaks at $m\tau$ with integer m by application of one read pulse.

We showed the experimental results in Fig. 3 by the read pulse with pulse width Δ_2 of 3μs. These results were obtained on the specimen applied pulses 1-20, 8 with carrier frequency of 18 MHz. We can recognize the coherent pulses at every 20 μs, which corresponds with the interval of applied pulse sequence.

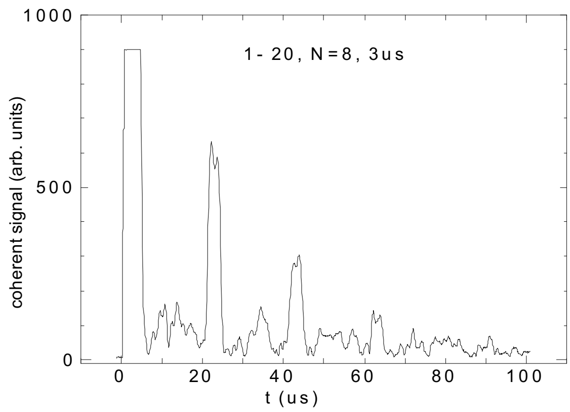

Fig. 3. Detected echo sequence by single RF pulse.

3. Conclutions

We detected hole-burning phenomena in piezoelectric resonator applying subsequent pulses with magic-T method. The observed hole patterns were well described with the Fourier components of applied pulse patterns. And we detected coherent pulses, which were produced by all oscillations composing holes.

4. References

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