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Some recent experiments on two-port magnetoelastic delay lines

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The operation of magnetoelastic delay lines using the axially-magnetized <100> YIG rod configuration has been described by several workers (1,2). Recently details of the excitation process have been revised (3,4), but for the present we will only need to use the original (more easily visualized) description. Reference to Figs.1 and 2 will show how the device operates: a YIG rod is placed in a uniform external field, H_o, but because the shape is not ellipsoidal, the demagnetising field in non-uniform and the internal field on the rod axis varies as shown in Fig.2. Figure 1 shows the dispersion curves for photons ($w = ck$, c = velocity of light), phonons ($w = vk$, v = velocity of sound), and spin waves ($w = \gamma H + Dk^2$, γ = gyromagnetic ratio, D = exchange energy constant). The process giving rise to magnetoelastic echoes can be pictured (crudely) as follows. A microwave pulse enters the coaxial cable and loop, and excites a spin wave at T, the crossover point between photons and spin waves. The spin wave travels toward the end face E, but before it reaches E, it is largely converted to a phonon at C, the crossover point between spin waves and + ve circularly polarized phonons. The phonon continues to E, where it is reflected, undergoes the inverse process and gives rise to an echo when it returns to T.

The delay line is strongly dispersive, largely because the point T, and therefore the path length (twice the distance between T and E) varies with frequency. Thus this device is suitable for use in pulse compression radar (5). However, pulse compression radar really requires a two-port device, i.e. separated inputs and outputs, and we will now discuss two ways in which this can be conveniently achieved. The first is simply to bond an acoustic quarter wave plate (usually consisting of a <110> YAG disc) to each end of the rod (6); this reverses the sense of polarization of the acoustic wave, so that it is reflected from E as - ve circularly polarized. Since this is not coupled to the spin system (Fig.1) it can travel through to the far end of the rod E′, undergo a second polarization reversal, and be detected at T′. Similar effects can be observed in <110> YIG rods (7).

The second device I wish to mention utilizes the interaction of spin waves with longitudinal phonons (see Fig.1). Now if the rod is oriented parallel to any acoustic pure mode axis, <100> <110> and <111>, this interaction vanishes (8), but if the rod is cut half way between <100> and <110> the interaction becomes allowed (9). The effective magnetoelastic coupling coefficient is, however, about 5 times smaller than for shear waves in the <100> YIG rod. Consequently, the spin-phonon conversion efficiency in the region of C is reduced and, in general, some of the energy 'hops' across to the transverse phonon branch. Thus one sees two echo patterns. However, at high frequencies the longitudinal phonon should be much the stronger, and a 2-port device becomes possible by evaporating a piezoelectric thin film transducer (e.g. CdS or ZnO) to the endface E.

This, and a closely related mechanism can also account for the excitation of longitudinal microwave phonons by Ni film transducers excited to ferromagnetic resonance (10). Note that, from Fig.1, the longitudinal phonon has 'first option' on the spin wave energy because its dispersion curve crosses the spin wave dispersion curve at a lower k-value than does the transverse phonon dispersion curve.

References

(1) Strauss, W., Proc.I.E.E.E., 53, 1485 (1965)

(2) Schlomann, E., Joseph, R.I. and Kohane, T., Proc.I.E.E.E., 53, 1495 (1965)

(3) Vasile, C.F. and Larosa, R., J.Appl.Phys., 39, 1863 (1968)

(4) Auld, B.A., Collins, J.H. and Webb, D.C., J.Appl.Phys., 39, 1598 (1968)

(5) Collins, J.H. and Zapp, H.R., Proc.I.E.E.E., 56, 273 (1968)

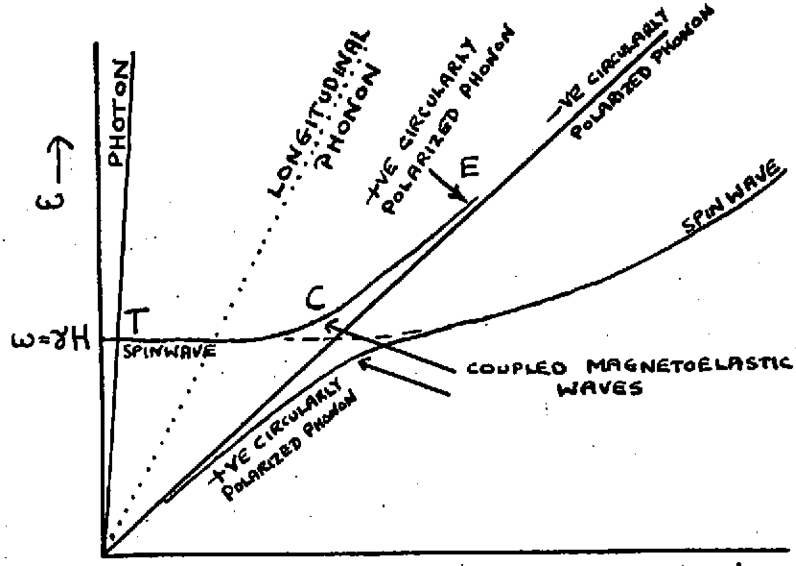
(6) Auld, B.A., et al, App.Phys.Lett., 9, 436 (1966) also Van de Vaart, H. and Smith, H.I., App.Phys.Lett., 9, 439 (1966)

(7) Lewis, M.F. and Scotter, D.G., J.Appl.Phys., 40, 1187 (1969)

(8) LeCraw, R.C. and Comstock, R.L., in 'Physical Acoustics', 3B, Edited W.P.Mason (Academic Press)

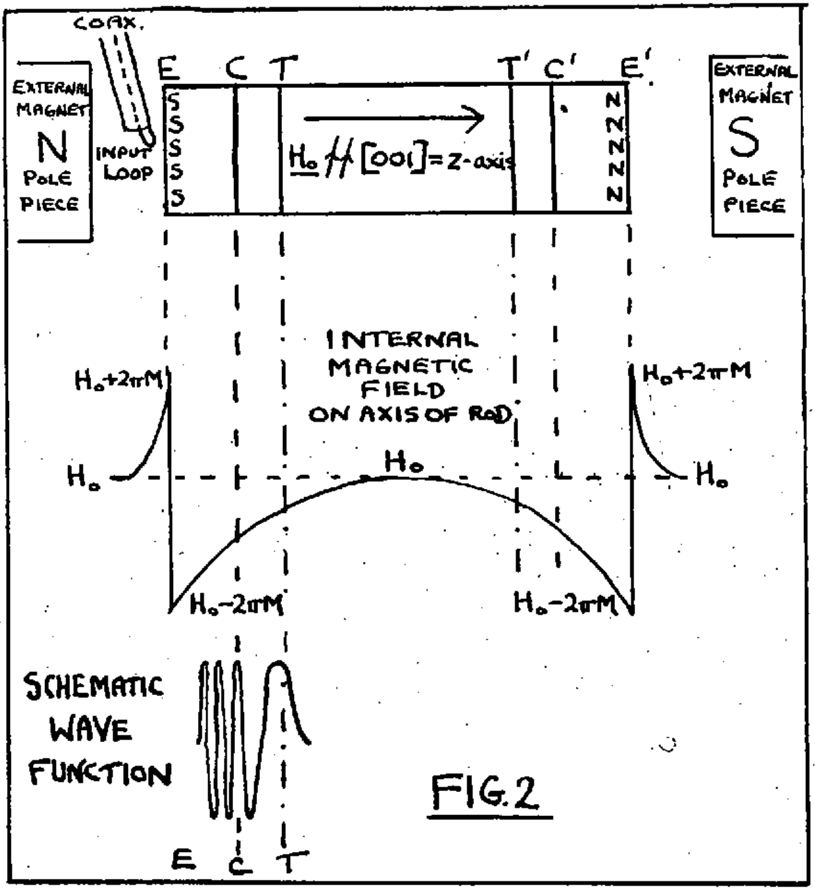
(9) Lewis, M.F., to be published in J.Appl.Phys.

(10) Lewis, M.F., Phillips, T.G. and Rosenberg, H.M., Phys.Lett., 1, 198 (1962).



PHOTON
LONGITUDINAL PHONON
+VE CIRCULARLY POLARIZED PHONON
E
−VE CIRCULARLY POLARIZED PHONON
SPIN WAVE
ω →
C
T
ω=γH
SPINWAVE
COUPLED MAGNETOELASTIC WAVES
+VE CIRCULARLY POLARIZED PHONON
→ k

FIG. 1



COAX.
EXTERNAL MAGNET
N
POLE PIECE
INPUT LOOP
E C T
T′ C′ E′
S S S S S
N N N N N
H_o // [001] = z-axis
EXTERNAL MAGNET
S
POLE PIECE
INTERNAL MAGNETIC FIELD ON AXIS OF ROD
$H_o + 2\pi M$
$H_o + 2\pi M$
H_o
H_o
H_o
$H_o - 2\pi M$
$H_o - 2\pi M$
SCHEMATIC WAVE FUNCTION
E C T

FIG. 2