United States Patent [19]

Farah

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[54] **CONTINUOUSLY VARIABLE DELAY LINE**

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[52] **U.S. Cl.** ..... **330/5.5,** 333/30 R

[51] **Int. Cl.** ..... **H03h 7/30,** 333 30 R

[58] **Field of Search** 307/88.3; 330/5.5

[56] **References Cited**

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Piltch et al., "Applied Physics Letters," 15 July 1970, pp. 87–90.

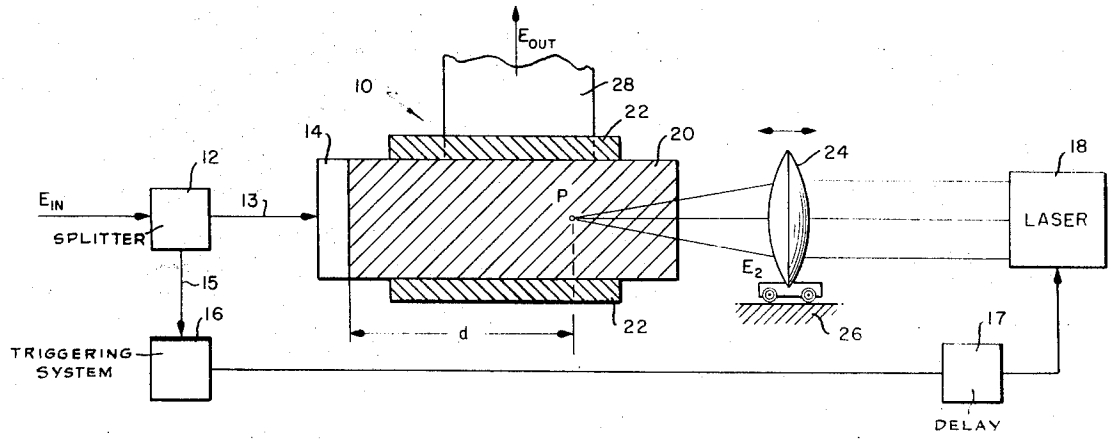
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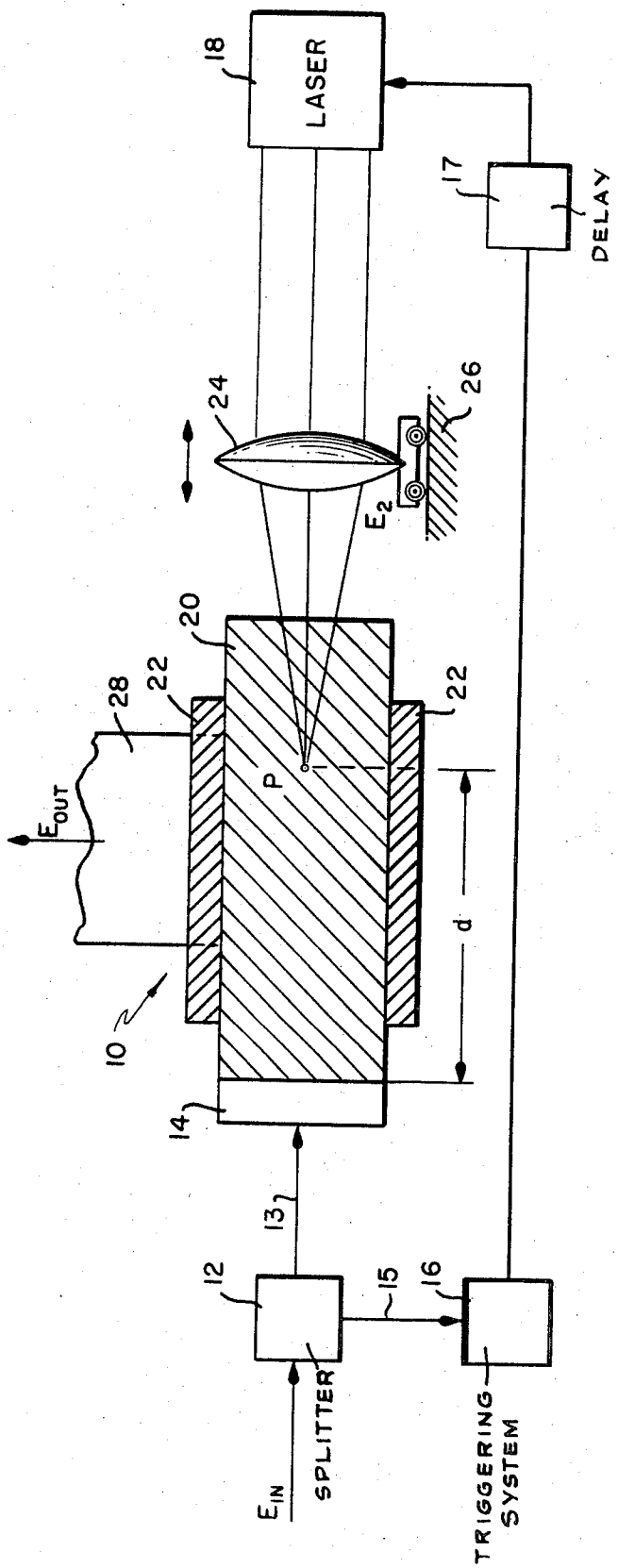
[57] **ABSTRACT**

Microwave information is applied to a $LiNbO_3$ crystal by way of a thin film transducer, and is then convolved with an ultrasonic δ-function. The δ-function is generated by a laser beam and is applied to the crystal at a particular point. The point at which the δ-function is applied to the crystals affects the convolved signal such that the original microwave information may be delayed by a particular amount of time.

The delay time is a function of the laser position and as a result may be made to vary. Also, since the principles of convolution are employed, the delayed microwave information will also be amplified.

2 Claims, 1 Drawing Figure




18
LASER
17
DELAY
24
26
E_2
20
22
28
22
E_{OUT}
P
d
10
14
13
12
15
16
E_{IN}
SPLITTER
TRIGGERING SYSTEM

CONTINUOUSLY VARIABLE DELAY LINE

BACKGROUND OF THE INVENTION

Time delay systems for microwave frequencies have many drawbacks. The most serious disadvantage is the fact that most of the present devices are incapable of being adjusted from one delay time to another. In the past the only versatility available in the selection of particular delay lines was the substitution of one entire delay system for a different delay system.

It has been found advantageous to provide a microwave delay system which can be continuously varied to provide easily selectable and precise delay times.

OBJECTS OF THE INVENTION

It is therefore an object of the present invention to provide a continuously variable delay system.

Another object of the invention is to provide a variable delay system capable of being used at microwave frequencies.

Another object of the invention is to provide amplification of the delayed microwave signal.

Other objects, advantages and novel features of the invention will become readily apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawing wherein:

THE DRAWING

The FIGURE depicts the system capable of producing a variable time delay at microwave frequencies.

SUMMARY OF THE INVENTION

A microwave signal is applied to an ultrasonic transducer which is attached to a $LiNbO_3$ crystal. The microwave energy is therefore transformed into an acoustic waveform and is propagated through the crystal. A trigger is provided to pulse a high powered picosecond laser into the opposite end of the crystal to provide an ultrasonic δ-function. The laser beam is controllably positioned a distance d from the ultrasonic transducer by a movable lens such that a convolution between the δ-function and the microwave signal takes place. The resultant convolved signal is a signal proportional to the original microwave input but is time delayed an amount proportional to the distance *d*.

DETAILED DESCRIPTION

Referring to the FIGURE, microwave energy E_{1N} enters the system **10** and is applied to signal splitter **12.** The signal splitter **12** divides the energy into two parts **13** and **15.** The microwave energy denoted as **13** is made to impinge upon ultrasonic transducer **14** and the energy denoted as **15** is directed to a laser triggering system **16** which controls the operation of laser **18.**

The ultrasonic transducer is affixed to ferroelectric crystal **20.** The combination is disposed in microwave cavity **22** which is attached to output waveguide **28.**

The purpose of the system shown in the FIGURE is to provide a signal E_{OUT} in waveguide **28** which is delayed in time from energy E_{IN}. The delay is accomplished by acoustical convolution and the amount of delay is a direct function of the distance *d*. That is to say, E_{IN} is acoustically convolved with a burst of white noise E_2 to produce E_{OUT}. The energy E_2 from laser **18** is focussed at point P by lens **24,** or a distance *d* from the transducer/crystal interface.

When microwave energy E_{IN} is applied to transducer **14,** an acoustic wave is propagated through the crystal **20** from left to right as shown in the FIGURE. This acoustical energy passes energy burst E_2 from the opposite direction to give a third signal E_{OUT} (a result of a nonlinear interaction) such that:

$$E(t)_{OUT} = \int E_{IN}(\tau)\, E_2(2t-\tau)\, d\tau;$$

which is the convolution of $E_1(t)$ with $E_2(t)$. The laser **18** produces the δ function for the convolution process, and the amount of delay is expressed as:

$$\text{Delay} = \Delta T + \tau$$

where ΔT is the time delay **17** between trigger **16** and laser **18** and

$$\Delta = d/V;$$

where V is the velocity of sound. The only restriction is that the delay **17** in the laser triggering circuit be equal to or smaller than the time required for the sonic signal from E_{IN} to reach point P.

Examining the individual components of the system, signal splitter **12** can be a directional coupler.

Typically the transducer **14** is a thin film deposit of zinc oxide sputtered on a thin gold electrode laid on the $LiNbO_3$ crystal **20.**

The $LiNbO_3$ is a YZ-cut $LiNbO_3$ delay rod as described by M. Luukkala and G. S. Kino in Applied Physics Letters, Volume 18, Number 9, May 1, 1971 entitled "Convolution and Time Inversion Using Parametric Interactions of Acoustic Surface Waves."

The microwave cavity **22** and its associated waveguide **28** are well known in the art as is double convex lens **24.**

The laser **18** is a pulsed high powered picosecond laser such as a Q-switched ruby laser.

Finally, the electronic delay **17** may be constructed of flip-flops or the like.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed and desired to be secured by letters patent of the United States is:

1. A continuously variable microwave delay line comprising:

means for splitting a microwave signal into a first and a second part;

means for triggering a high powered ruby laser by the use of said first part;

transducer means for transforming said second part into acoustical energy being physically attached to crystal means for propagating said acoustical energy;

movable optical focusing means for focusing the energy from said ruby laser into said crystal means at a distance *d* from said transducer means to propagate a second burst or acoustical energy

such that an acoustical convolution results in said crystal to produce a signal which is delayed from said second part.

2. The device is claimed in claim **1** wherein said crystal means is a $LiNbO_3$ crystal.

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