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CIRCULAR POLED TRANSDUCER

Filed June 21, 1963

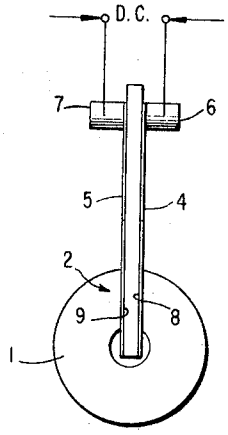


FIG.1

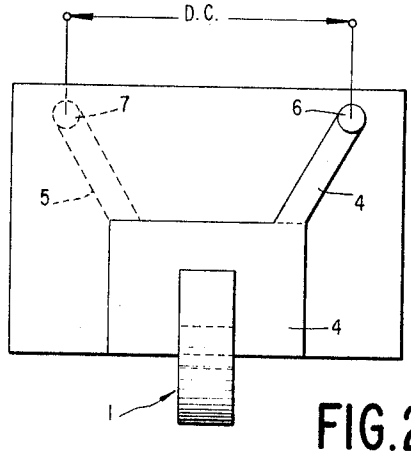


FIG.2

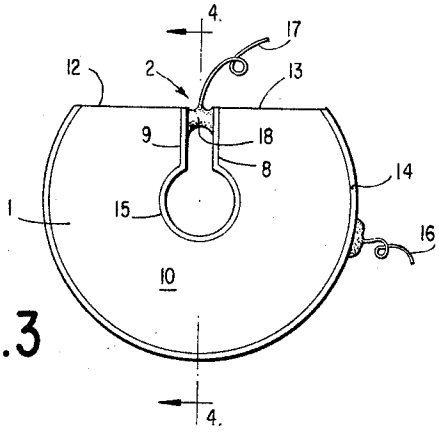


FIG.3

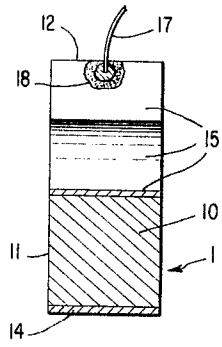


FIG.4

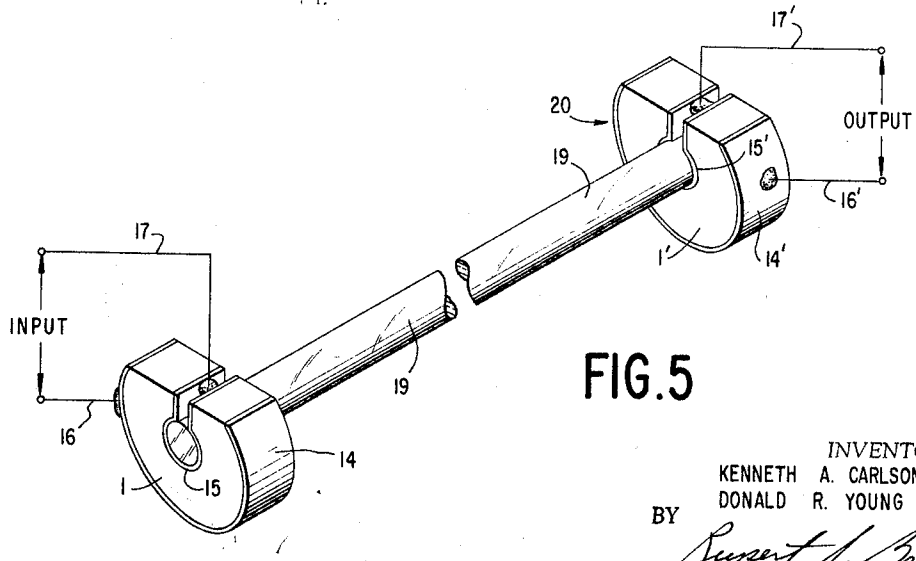


FIG.5

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CIRCULAR POLED TRANSDUCER

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The present invention relates broadly to electromechanical transducers and more particularly to a circular poled transducer and method of circularly polarizing and making the same.

One of the objects of the invention is to provide a minute sized circular poled transducer which is relatively simple in construction, economical to manufacture and adaptable to mass production techniques.

Another object of the invention is to provide a construction of micro-miniature circular poled transducer particularly adaptable for producing fiber delay lines at greatly reduced costs.

Another object of the invention is to provide a novel construction of a toroidal electromechanical device which provides a novel twisting motion.

A further object of the invention is to provide a minute sized twister-type transducer having a relatively high frequency cut-off point and the size of which is inversely related to the frequency response.

Still a further object of the invention is to provide a novel construction of quartz or glass fiber delay line for constructing memory devices and the like.

Other and further objects of the invention reside in the method of circularly polarizing a slotted toroid of ferroelectric material and the method of making an elecromechanical twister type device from such circularly polarized slotted toroids as set forth more fully in the specification hereinafter following by reference to the accompanying drawings, in which:

FIG. 1 is a front elevational view showing the manner in which the toroid of ferroelectric material is connected during the circular polarization process;

FIG. 2 is a side elevational view thereof;

FIG. 3 is a front elevational view of the circular poled transducer of the invention;

FIG. 4 is a cross sectional view taken substantially along line 4—4 of FIG. 3; and

FIG. 5 is a perspective view of a fiber delay line constructed with the circular poled transducers in accordance with the invention.

In constructing the toroidal electromechanical device of the invention, a disc or the like of ferroelectric ceramic material of crystalline structure, such as oxides of lead, zirconium, titanium, lead niobium, potassium niobium, or barium titanate, or combinations thereof, is lapped to geometrical accuracy of flat to a predetermined thickness such as .017 inch, and is then ultrasonically cut into a toroid **1** having a radial slot **2** of desired dimensions, such as approximately .046 inch outside diameter, .012 inch inside diameter, with a slot width of approximately .006 inch. Radial slot **2** is cut into the toroid ultrasonically so that the slot is disposed perpendicular or transverse to the circular axis of the toroid. A strip of insulation material **3**, such as mica or the like, having conducting strips **4** and **5** connected on opposite sides thereof and terminating in terminals **6** and **7**, respectively, is slipped into radial slot **2** such that conducting strips **4** and **5** are disposed in friction contact with, and make electrical contact with, side walls **8** and **9** of slot **2**. The toroid and insulator strip assembly **1**, **3** is then immersed in insulating oil such as transformer oil, held at a predetermined temperature somewhat below the Curie temperature for

the particular ferroelectric material of which the toroid is constructed. The Curie point of barium titanate ceramic is around 120° C. and it has been found that for this material the oil should be held at a temperature of approximately 100° C. While the toroid is thus held at a temperature somewhat below the Curie temperature for the material for which it is constructed a substantially high unidirectional electrical potential, such as 400 volts D.C. is applied across terminals **6** and **7** and thus across the slot side walls **8** and **9** to establish an effective electric field polarization in the material of toroid **1** circumferentially. The D.C. potential is applied across the side walls of the slot for a predetermined period of time, such as a period of approximately one minute causing an asymmetrical shift in ionic positions in the crystalline structure leading to a permanent dipole movement which results in substantially remanent circular polarization of the material of toroid **1**. The toroid is then removed from its immersed position in the oil and the polarizing apparatus consisting of insulator strip **3** and its associated conducting strips **4** and **5** are removed from the toroid slot **2**.

Since the toroid is extremely light in weight the friction contact between conducting strips **4** and **5** and said walls **8** and **9** combined with the surface tension of the oil provides adequate support for the toroid while immersed in the oil bath.

The circularly polarized toroid **1** is then coated with an electrically conductive material, such as copper, which is preferably plated on by means of an electrolysis process. The conductive coating is removed from the front and back faces **10** and **11** of the toroid by a wiping or lapping process, and the outside wall portions **12** and **13** of toroid **1** adjacent the edges of the radial slot are also lapped free of the electrically conductive plate, as shown, leaving a plating of electrically conductive material on the outer peripheral wall of the toroid forming a first electrode as indicated at **14**, and a plating of electrically conductive material on the inside wall of the toroid and the side walls **8** and **9** of the radial slot forming a second electrode **15** insulated or electrically isolated from the first electrode **14** by the toroid of ferroelectric ceramic material. In order for the transducer of the invention to properly operate it is important that the first and second electrodes **14** and **15** form continuous conductive paths around the outside and inside walls of the toroid in order to utilize the full capacitive effect of the toroid. It is to be understood that it is not absolutely necessary for the second electrode **15** to extend into radial slot **2** as described and shown, but from a fabrication standpoint in order to simplify the manufacturing process it is preferred to have second electrode **15** also plated on side walls **8** and **9** of the radial slot.

The circular poled transducer is completed by soldering an electrical conductor **16** to first electrode **14** and an electrical conductor **17** to second conductor **15**. Conductor **16** may be soldered at any point around the periphery of first electrode **14** and conductor **17** may be connected at any point around the periphery of second electrode **15**. However, when the transducer is utilized with a transmitting medium such as a fiber of circular cross section, passing through the center aperture thereof, any protrusion of solder or other material fastening conductor **17** to second conductor **15** at any point in the circular central aperture of the transducer would interfere with the threading of a transmitting fiber therethrough, therefore the most convenient and preferred location for connecting conductor **17** to second electrode **15** is within the radial slot **2** with the solder connection **18** preferably bridging the slot as shown. Electrical conductors **16** and **17** may be connected to electrodes **14** and **15** by any type of hot stage which will operate with such minute components.

The size of the transducer is inversel related to the frequency response of the device and the dimensions mentioned earlier in the specification are not intended as limiting in any respect but given only by way of example to indicate the minute dimensions with which a transducer of the invention can be manufactured. A measurement of frequency response of a transducer having the mentioned dimensions indicates a resonance at 2.5 megacycles with a frequency cut-off point as high as 6 megacycles.

In operation, potentials applied across electrical conductors **16** and **17** pass a current radially through the high capacitance-low impedance device from first electrode **14** to second electrode **15**, or vice versa, and the resultant electric fields within the ferroelectric ceramic material from the current flow and from the circular or circumferential polarization field impart a twisting or torsional motion to the transducer. The inside periphery of the transducer tends to rotate in one direction while the outside periphery of the transducer tends to rotate in the opposite direction to produce the torsional motion. This is apparently due to the fact that the potential signal applied across conductors **16** and **17** is applied orthogonal to the circular polarization vector of the toroid.

The preferred environment of use of the transducer of the invention is in combination with a fiber transmitting medium to produce a delay line, although its application is not limited to this use. A delay line constructed according to the teachings of the invention and using a pair of transducers as herein described is shown in FIG. 5 wherein a transmitting medium, such as quartz fiber or glass fiber, indicated at **19**, of circular cross section is connected to the inside periphery of second electrode **15** of a transducer constructed according to the teachings of the invention by means of cementing or the like to form a rigid bond between the transmitting medium **19** and second electrode **15**. The opposite end of the fiber transmitting medium **19** is threaded through the central aperture of a similar transducer, as indicated by prime numerals, and cemented to the inner periphery of second electrode **15'** in a manner similar to the first transducer so that the transducers are rigidly connected to the transmitting medium and disposed in spaced relation along the same. When used in this manner the outside peripheries of the transducers are generally clamped so as to prevent movement of the same. However, it is not essential that the outside peripheries be clamped and lack of clamping of the outer surfaces will not preclude operation of the delay line. An input signal impressed across conductors **16** and **17** causes a torsional motion of the inside periphery of the transducer relative to first electrode **14** thereby imparting a twisting motion to the transmitting medium **19**. That is, in operation there is actually a minute rotative motion between electrodes **14** and **15** caused by the ferroelectric toroid **1**. This twisting motion sets up a torsional wave in the transmitting medium and the trosional wave travels along fiber **19** and is received by the transducer indicated by primed numerals connected at a desired point along the fiber. The torsional wave is received by the transducer, indicated at **20**, and the twisting motion is transferred thereto resulting in the generation of electrical energy due to the properties of the circularly polarized ferroelectric material **1'**. This electrical energy appears as an output signal across conductors **16'** and **17'** which are connected to an amplifier and/or a detection device to receive the signal. The first transducer thus converts the electrical energy applied across conductors **16** and **17** into mechanical motion and the second transducer **20** converts the mechanical torsional wave motion back into electrical energy which is delayed in time from the signal applied at **16** and **17** due to the propagation time along the transmitting fiber **19**. By appropriate arrangement of transducers and transmission lines a memory device may be constructed as will become apparent to one skilled in the art.

Transducers in the prior art have been used in some instances with highly accurate and very expensive machined discs in order to provide a transmitting medium to produce a delay line. Transducers constructed according to the teachings of the present invention enable the construction of an accurate and efficient delay line which merely requires the use of an inexpensive transmitting fiber, thus greatly reducing the complexity and costs of delay lines of this general type.

While the invention has been particularly shown and described with reference to a preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention.

We claim:

1. A signal delay apparatus comprising, an elongated solid transmitting fiber, a toroid of ferroelectric ceramic material having a radial slot therein, said toroid connected to one end of said fiber in surrounding relation, a first electrode connected to the inner surface of said toroid and said fiber, a second electrode connected to the outer surface of said toroid, means for passing an electrical signal between said electrodes to establish torsional waves in said fiber, and another toroid of ferroelectric ceramic material having a radial slot and electrodes connected about the inner and outer surfaces thereof engaging the opposite end of said fiber in surrounding relation for receiving said torsional waves and reconverting them to delayed electrical signals.

2. A signal delay apparatus as set forth in claim **1** in which said elongated solid transmitting fiber is constructed of glass.

3. A signal delay apparatus as set forth in claim **1** in which said elongated solid transmitting fiber is constructed of quartz.

4. A transducer comprising a ring of ferroelectric material having a radial slot therein and having substantial permanent circular polarization, a first electrode connected on the outer peripheral surface of said ring and terminating adjacent the slot, a second electrode connected about the inner surface of said ring and the sides of the slot, first conductor means connected to said first electrode and second conductor means connected to said second electrode and bridging the slot for passing and receiving current passed through said ring, and said first and second electrodes connected to apply current to said ring orthogonal to the vector of the circular polarization.

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