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(54) **PROJECTOR WITH TUNABLE RESONANCE FREQUENCY**

WANDLER MIT EINSTELLBARER RESONANZFREQUENZ

PROJECTEUR ACCORDABLE EN FREQUENCES

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Description

[0001] The present invention is concerned with a frequency tunable projector for coupling between electrical signals and corresponding acoustic vibrations, in particular, but not exclusively, with a frequency tunable projector employing bending or radial vibration modes and suitable for use in aquatic environments.

[0002] Projectors form a category of transducers which are operable to be stimulated by electrical signals into mechanical vibration and thereby emit acoustic waves. Moreover, the projectors are also operable to receive acoustic waves and generate corresponding electrical signals in response. The projectors typically employ man-made polarized electrostrictive materials such as lead zirconate titanate (LZT). Such electrostrictive materials are commonly referred to as "piezoelectric materials".

[0003] A known type of transducer capable of coupling between acoustic waves and associated electrical signals comprises a metallic disc bonded to a polarised LZT disc. The metallic disc incorporates first and second major faces which are planar and mutually parallel. Likewise, the LZT disc comprises third and fourth major faces which are also mutually parallel. The LZT disc is bonded by adhesive or by soldering at one of its major faces to one of the major faces of the metallic disc to form a composite concentric structure. Both third and fourth faces of the LZT disc are metallized to provide first and second electrodes respectively. An alternating electrical signal applied between the first and second electrodes generates an alternating electric field across the LZT disc which cyclically changes stress within the disc, thereby causing it and the metallic disc to which it is coupled to vibrate. Conversely, acoustic waves which couple to the metallic and LZT disc result in changes of stress within the LZT disc thereby causing a corresponding alternating electrical signal to be generated at the electrodes.

[0004] The composite structure is supported in operation at its peripheral edge and exhibits modes of resonance whereat its efficiency for coupling between acoustic waves and corresponding electrical signals is enhanced compared with off-resonance operation. Equation 1 provides an expression for the modes of resonance:

$$\nu_n = \frac{1}{2\pi\sqrt{M_n C_n}} \quad \text{Eq.1}$$

where

ν_n = resonant frequency of a mode n;

M_n = collective effective resonant mass of the structure at the mode n; and

C_n = collective effective compliance of the structure at the mode n.

[0005] One useful mode of resonance for the structure corresponds to the discs becoming momentarily concave and convex when flexing; this will be referred to as its bending mode of resonance.

[0006] The known type of transducer described above suffers a problem that its resonances can exhibit relatively high resonance mechanical Q_m factors, for example in excess of 10, which limits a frequency bandwidth over which the transducer performs most efficiently. In practice, bandwidth is inversely proportional to Q_m factor, hence it is not presently possible to obtain enhanced efficiency over a wide frequency range greatly in excess of bandwidths associated with the resonances.

[0007] In a publication "Tunable Sonar Transducer" by Steel et al. Electronic Letters 3, July 1986 Vol.22 No. 14 pp. 758-759, a transducer is described as comprising in sequence a first LZT ceramic disc referred to as a "drive ceramic" and a second LZT ceramic disc referred to as a "control ceramic". The ceramic discs are mutually bonded at their abutting faces using epoxy adhesive. Moreover, the discs are supported by a solid epoxy/iron backing region.

[0008] The first LZT disc functions as a drive element for exciting mechanical vibrations, whereas the second LZT disc functions as a variable stiffness element whose mechanical stiffness can be varied depending upon electrical load connected thereto. By controlling the stiffness of the second disc, the transducer's fundamental resonant frequency can be tuned over a range of 2.6 octaves.

[0009] In the transducer, the first LZT disc is operable to vibrate in a longitudinal or thickness mode, namely the disc momentarily thickens and thins in response to an electrical drive signal applied thereto. This is known as a "longitudinal mode" or "thickness mode" of operation. The first LZT disc is operable to emit acoustic pressure waves into a medium surrounding the transducer.

[0010] The transducer described in the publication would be regarded by one ordinarily skilled in the art as being optimal because the transducer can be tuned to operate at its fundamental resonance over a relatively wide frequency range of 2.6 octaves.

[0011] In contrast with the transducer, the inventor has appreciated that it is feasible to extend the operating bandwidth of a projector whilst also ensuring that it provides enhanced coupling efficiency associated with operating at resonance, the projector incorporating a cavity which is cyclically compressed and rarefied when the projector is vibrating in a bending or radial mode.

[0012] According to a first aspect of the present invention, there is provided a frequency tunable projector for coupling between electrical signals and corresponding acoustic waves in an environment exposed to the projector, the projector incorporating transducing means for coupling between the signals and the corresponding acoustic waves and tuning means for tuning a resonant frequency of the transducing means, the transducing means and the tuning means incorporated into one or more walls of a cavity, the one or more walls at least partially isolating the cavity from the environment, and the one or more walls operable to vibrate in at least one of a bending vibration mode and a radial vibration mode to cyclically compress and expand the cavity.

[0013] The invention provides the advantage that the projector exhibits resonance modes whose resonant frequencies are capable of being swept to match the frequency of electrical signals applied to the projector or generated in the projector, thereby enhancing operating efficiency of the projector.

[0014] At least one of the transducing means and the tuning means are preferably fabricated from active materials such as one or more of lead zirconate titanate, lead titanate, barium titanate or lead metaniobate. Moreover, lead magnesium niobate in combination with lead titanate is also useable, these being in either ceramic or crystalline form. Furthermore, crystalline quartz or a magnetostrictive material such as nickel or a proprietary material Terfenol D can be used.

[0015] For purposes of describing the invention, a cavity is defined as being a fluid filled region at least partially surrounded by associated walls, the fluid being one or more gases (for example including air), a vapour, a liquid, a compressible solid or any mixture of these. Moreover, a bending mode of vibration is defined as a mode of vibration in which a member is excited into vibration as a consequence of cyclical differential stress generated across the member causing it to bend; this bending mode does not include deflection of the member by applying a direct force thereto as in a longitudinal or thickness mode of vibration. Furthermore, a radial mode of vibration is defined as being a vibration mode of a substantially circular-form member, for example a cylinder or a ring, where it cyclically radially expands and contracts.

[0016] A ring is defined as a circular member whose radius and height are in a ratio not exceeding 1.5.

[0017] Conveniently, the transducing means comprises one or more transducing elements and the tuning means incorporates one or more tuning elements, the elements mutually mechanically coupled together and operable to vibrate as a composite structure in a bending vibration mode or a radial vibration mode. This provides the advantage that the tuning means is effective at tuning the transducing means.

[0018] Advantageously, mechanical stiffness of the tuning means is modifiable in response to an electric load or an electrical potential applied to the tuning means. Such modification is beneficial because it enables rapid tuning of the transducing means under electronic control.

[0019] The elements are brittle components whose abrupt edges can become shattered when driven heavily into vibration and whose abrupt edges can become chipped during assembly. It is therefore beneficial to ensure that the elements incorporate peripheral edges which are rounded. Such rounding counteracts problems of chipped and shattered edges.

[0020] Conveniently, the one or more transducing elements comprise a Navy Type I or III LZT ceramic and the one or more transducing elements comprise a Navy Type VI LZT ceramic according to a United States standard MIL-STD-1376. These ceramics provide mechanical and transducing properties which are well adapted for the projector.

[0021] When operable in a bending vibration mode, at least one cavity wall advantageously incorporates a backing plate onto which the elements are mechanically mounted. The backing plate provides a practical support for the elements and is sufficiently compliant to vibrate in a bending mode.

[0022] Conveniently, the backing plate is fabricated from a high-tensile tool steel or a maraging steel, for example Aeromet-100 maraging steel. These steels provide the advantage of being able to withstand pressures associated with operating the projector in aquatic environments to depths of several hundred metres. Alternatively, the backing plate can be fabricated from an aluminium alloy, brass or bronze, or other convenient material.

[0023] For enhancing pressure bearing capability of the projector, the backing plate can be of a non-uniform thickness. Conveniently, the backing plate is circular and thickens to an apex at a central region of the plate in order to equilibrate the distribution of stress through the elements and to counteract stress concentrations which limit permissible drive signal amplitude and depth performance of the projector.

[0024] In order to obtain a greater amplitude of acoustic waves into a medium surrounding the projector, a plurality of the walls can incorporate the transducing means and the tuning means, the walls coupled together through a spacer element, the spacer element and the walls operable to cooperate to enclose the cavity.

[0025] Conveniently, the spacer element is fabricated from a metal. For achieving enhanced robustness and counteracting corrosion, the metal is preferably a stainless steel. Alternatively, the spacer can be fabricated from an insulating

material. Conveniently, the insulating material is a fibre-reinforced polymer.

[0026] Advantageously, the spacer element incorporates a projection for engaging onto one or more backing plates bearing the transducing means and the tuning means, the projection operable to provide an annular edge mount for the backing plates. Incorporation of the projection provides a convenient manner to construct the projector and form its cavity.

[0027] In order to simplify construction of the projector and thereby potentially reduce its manufacturing cost, the elements can be directly mutually bonded and also directly bonded to their associated backing plate, the backing plate functioning as a first electrical connection to the elements and an interface between the elements functioning to provide a second connection common to the elements.

[0028] According to a second aspect of the present invention, there is provided a projector whose walls are substantially in the form of a cylindrical or ring structure comprising the transducing means and the tuning means.

[0029] Conveniently, the structure is operable to vibrate in a radial vibration mode. A cylindrical or ring structure is a robust geometrical shape capable of vibrating radially and also capable of withstanding elevated pressures associated with operating the projector in aquatic environments to depths of several hundred metres.

[0030] Advantageously, elements of the transducing means comprise a Navy Type I or III IZT ceramic and elements of the tuning means comprise a Navy Type VI LYT ceramic. These LYT ceramics are well adapted for use in the projector according to the second aspect of the invention.

[0031] Conveniently, for purposes of making electrical connections, elements of the transducing means are arranged in abutting pairs, and elements of the tuning means are also arranged in abutting pairs. The electrical connections can be made to the elements at interfaces where elements of each pair mutually abut.

[0032] Advantageously, the elements enclose the cavity within the projector. End caps are conveniently incorporated at ends of the structure to form the cavity within the structure. In order to prevent the elements from electrically shorting, the end caps are preferably fabricated from an insulating material.

[0033] Alternatively, the cylindrical or ring structure can be open at its ends and incorporate a centrally-located element, for example a hollow insulating tube, mounted concentrically therein and separated therefrom by an annular gap. Use of the concentrically-mounted element provides the advantage of increasing transducing sensitivity of the structure, and provides a mount for a plurality of cylindrical or ring transducers configured in a line array.

[0034] Embodiments of the invention will now be described, by way of example only, with reference to the following diagrams in which:

Figure 1 is a plan view of a projector according to a first embodiment of the invention;

Figure 2 is a cross-sectional view through the projector shown in Figure 1;

Figure 3 is a cross-sectional view through a projector according to a second embodiment of the invention;

Figure 4 is a side view illustration of a projector according to a third embodiment of the invention;

Figure 5 is a side view illustration of a projector according to a fourth embodiment of the invention including a hollow concentric tube;

Figure 6 is a plan view illustration of the projector shown in Figure 4;

Figure 7 is an illustration of a projector according to a fifth embodiment of the invention including concentric hollow tubes;

Figure 8 is an illustration of a projector according to a sixth embodiment of the invention including concentric ring elements; and

Figure 9 is a schematic illustration of radial mode vibration of the projector shown in Figure 5.

[0035] Referring now to Figure 1, there is shown a frequency tunable bender projector indicated by 10 comprising a cylindrical spacer 12, a circular backing plate 16 incorporating a peripheral lip edge 14 engageable onto the spacer 12, and an LYT ceramic disc 20. The spacer 12, the plate 16 and the disc 20 are mutually concentrically aligned. The disc 20 is mounted onto an outwardly facing major face of the backing plate 16.

[0036] An internal structure of the projector 10 is illustrated in a cross-section view indicated by 100 in Figure 2. This cross-section view 100 is taken with respect to a line A-B in Figure 1.

[0037] Although not illustrated in Figure 1, the projector 10 incorporates a total of two backing plates 16a, 16b and

four LZT ceramic discs 20a, 20b, 20c, 20d. Moreover, the projector 10 is symmetrical about a plane intersecting the spacer 12 midway therethrough, the plane being parallel to major exposed surfaces of the plates 16 and the discs 20.

[0038] The backing plates 16a, 16b are fabricated from a maraging steel, for example Aeromet 100, although high-tensile tool steel, an aluminium alloy, brass or bronze are alternatively employable to reduce cost.

[0039] Importantly, the backing plates 16a, 16b are of non-uniform thickness, namely they progressively thicken towards their axial centre to form non-exposed apexes 102a, 102b respectively. This progressive thickening enables the projector 10 to function with external pressures applied thereto which would otherwise be capable of causing failure by fracture or depolarisation of the discs 20 if major surfaces of the backing plates 16a, 16b were all mutually parallel.

[0040] The spacer 12 incorporates an annular inwardly orientated projection 104 onto which the lips 14a, 14b of the plates 16a, 16b respectively engage. The projection 104 in co-operation with the plates 16a, 16b forms an fluid-filled cavity 106 in a central region of the projector 10. The cavity 106 can be, for example, filled with air, a vapour, a liquid or a compressible solid.

[0041] The ceramic discs 20b, 20c are adhesively bonded or soldered onto outwardly orientated major faces of the plates 16a, 16b respectively. Likewise, the ceramic discs 20a, 20d are adhesively bonded or soldered to the ceramic discs 20b, 20c respectively. The discs 20 have rounded peripheral edges; this provides a benefit of rendering these parts less prone to damage, for example by chipping during assembly.

[0042] Advantageously, the ceramic discs 20a, 20d are designated to be transducing discs operable to sense acoustic waves and provide corresponding signals, or to generate acoustic vibrations in response to electrical excitation applied thereto. They are fabricated from a Navy Type I LZT ceramic if the projector 10 is to be operated in a pulse driven manner. Alternatively, the discs 20a, 20d can be fabricated from a Navy Type III LZT ceramic if the projector 10 is to be operated in a continuous wave manner. Navy Type I and Navy Type III LZT ceramics are defined in a United States standard MIL-STD-1376 "Piezoelectric Ceramic Material and Measurements Guidelines for Sonar Transducers" Version B, 1995.

[0043] Advantageously, the ceramic discs 20b, 20c are designated to be tuning discs operable to provide an electrically modifiable stiffness. They are fabricated from a relatively softer Navy Type VI ("soft") ceramic according to the standard MIL-STD-1376.

[0044] Table 1 provides an indication of some characteristics of the Navy Type I, II, III and VI ceramics which mutually distinguish them for open circuit and short circuit loading conditions.

Table 1

Compliance	Electrical loading	Navy Type I ceramic	Navy Type II ceramic	Navy Type III ceramic	Navy Type VI ceramic
S_{33}^E (pm ² /N)	short circuit	15.5	18.8	13.5	20.8
S_{33}^D (pm ² /N)	open circuit	7.9	9.4	8.5	9.0
Change		96%	100%	59%	131%

[0045] Data in Table 1 are taken from information provided by a company Morgan Matroc which manufactures LZT ceramic parts.

[0046] The Navy Type VI ceramic is substantially different from the Navy Type I and III ceramics with regard to compliance. The Navy Type II and VI ceramics exhibit a proportionately larger change in elastic constant between open-circuit and short-circuit conditions compared with Navy Type I and III ceramics; this change makes the Navy Type VI ceramic particularly suitable for use in tuning the projector 10.

[0047] Navy Type VI LZT ceramic discs exhibit a mechanical stiffness S_{33} which can be varied in a range from substantially 20.8 pm²/N to 9.0 pm²/N as electrical loading applied to the discs is varied from open circuit to short circuit respectively; this corresponds with a stiffness change of 131%.

[0048] The discs 20a, 20b, 20c, 20d are substantially 5.5 mm thick and 75 mm in diameter. Moreover, the discs 20a, 20b, 20c, 20d are polarised in a direction normal to their major surfaces and metallized on these surfaces to provide two electrical connections for each disc 20. Furthermore, the discs 20b, 20c are connected to respective variable load impedances in the electrical equipment which can be varied in a range of a substantially capacitive loading to a substantially inductive loading. Alternatively, the discs 20b, 20c are connected to a source of drive signal which is operable to modify their effective mechanical stiffness.

[0049] When the projector 10 is operable as a transmitter, the discs 20a, 20d are connected to a source of drive signal included in the electrical equipment for exciting mechanical vibration in the projector 10 for projection therefrom as acoustic waves. Alternatively, when the projector 10 is operable as a hydrophone, the discs 20a, 20d are connected to inputs of amplifiers included in the electrical equipment for generating a received signal from outputs of the amplifiers. The source and the variable load impedances are operable to excite the projector 10 at a specified frequency and

provide variable loads so as to tune resonance of the projector 10 to the specified frequency, thereby ensuring enhanced efficiency for converting the drive signal into mechanical vibration within the projector 10.

[0050] Operation of the projector 10 will now be described with reference to Figures 1 and 2.

[0051] When the projector 10 is being employed as a transmitter, the electrical equipment outputs the drive signal which excites the discs 20a, 20d into vibration. The equipment simultaneously applies an impedance loading, or a subsidiary phase shifted and amplitude shifted drive signal, to the discs 20b, 20c to tune them and their associated backing plates 16a, 16b and discs 20a, 20d so that their composite resonant frequency coincides with a principal signal component in the drive signal. The plates 16a, 16b vibrate in response to the drive signal in a bending mode, thereby cyclically becoming alternately concave and convex. In contrast to prior art described above, the discs 20 do not vibrate in a longitudinal mode. Fluid within the cavity 106, for example air, gas, vapour or compressible solid such as foam, becomes cyclically alternately compressed and rarefied as acoustic waves are coupled primarily from the discs 20a, 20d to a medium surrounding the projector 10; the medium can be salt water in an aquatic environment for example. The discs 20 when assembled into the projector 10 can be coated in a flexible polymer layer such as polyurethane to protect them from the medium.

[0052] When the projector 10 is being employed as a hydrophone for sensing acoustic waves received thereat, the discs 20a, 20d function as sensors to generate an electrical signal for the electrical equipment and the discs 20b, 20c operate to tune the projector 10 to a frequency range of interest. The projector 10 can thereby, for example, be made to operate as a swept frequency hydrophone which is capable of receiving and processing chirped acoustic waves reflected from an obstacle or collision hazard in the vicinity of the hydrophone.

[0053] In a first alternative version of the projector 10 operating as a hydrophone, function of the discs 20 is modified, namely the discs 20b, 20c function as sensors to generate an electrical signal for the electrical equipment and the discs 20a, 20d operate to tune the projector 10 to a frequency range of interest.

[0054] In a second alternative version of the projector 10 operating as a transmitter, instead of connecting the discs 20b, 20c to the variable impedance, the discs 20b, 20c are connected to the electrical equipment but receive a drive signal which is phase shifted and amplitude shifted relative to drive signal applied to discs 20a, 20d; such an alternative arrangement is operable to excite the projector 10 at a specific frequency and tune its resonance to the specific frequency in response to adjustment of phase shift and relative amplitude shift.

[0055] In a third alternative version of the projector 10 operating as a transmitter, function of the discs 20 is modified, namely the discs 20b, 20c are transducing discs and implemented using Navy Type I LZT ceramic and the discs 20a, 20d are tuning discs and implemented using Navy Type VI LZT ceramic.

[0056] In a fourth alternative version of the projector 10, insulating spacers can be included to mutually insulate the ceramic discs 20. The insulating spacers can be fabricated from ceramic alumina which provides substantially insulating properties. Preferably, the insulating spacers are substantially 85 mm in diameter and 1 mm thick with rounded peripheral edges to counteract chipping. The insulating spacers advantageously each have a diameter which is several mm greater than that of the discs 20 to ensure effective electrical isolation, especially when drive signals of several thousand volts amplitude are applied to the discs 20.

[0057] In the projector 10, the discs 20 are polarised in a direction normal to their major faces. If unpolarised electrostrictive material is used for the discs 20, biasing electric fields are required in the direction normal to their major faces for operation. Alternatively, if a magnetostrictive material is used for the discs 20, biasing magnetic fields are applied with field lines normal to their major faces.

[0058] It will be appreciated that variations to the projector 10 and alternative versions thereof described can be made without departing from the scope of the invention. For example, in simplified designs, the backing plates 16a, 16b can be made of uniform thickness to simplify their fabrication, thereby potentially saving cost but degrading their robustness.

[0059] Moreover, the inwardly facing radial projections 104 can be profiled where they engage onto the plates 16a, 16b so as to provide an annular sharp edge form of engagement. Such an arrangement provides the advantage of modifying the effective compliance of the backing plates 16a, 16b thereby allowing them to be tuned on manufacture of the projector 10 by fine trimming the diameter of the annular sharp edge.

[0060] Although in Figure 2 the discs 20 are shown all with similar dimensions, it is understood that they can be made with mutually different dimensions in a modified version of the projector 10.

[0061] Although the projector 10 is illustrated as a symmetrical structure in Figure 2 and incorporates a plurality of backing plates 16, a simplified version of the projector 10 can incorporate a single backing plate as illustrated in Figure 3 in order to reduce cost.

[0062] Referring to Figure 3, there is shown a cross-sectional view through a projector according to a second embodiment of the invention. The projector is indicated by 300 and comprises a cylindrical body indicated by 310, a circular backing plate 320, a first LZT ceramic disc 330, a second LZT ceramic disc 340 and a passivation layer 350. Aeromet-100 maraging steel can, for example, be used for fabricating the backing plate 320. The layer 350 incorporates flexible polyurethane material for protecting the discs 330, 340 and the plate 320 from an environment surrounding the projector

300, for example sea water. The body 310 is fabricated from an electrically-insulating fibre reinforced polymer and includes an inwardly facing step 360 and a rigid end face 370. The discs 330, 340 are fabricated from the Navy Type VI and the Navy Type I or III ceramics respectively.

[0063] The plate 320 is of non-uniform thickness in an identical manner to the plates 16 to form a central apex 380. The plate 320 is engageable onto the step 360 to form a cavity 390. The discs 340, 330 are soldered or bonded to the disc 330 and the plate 320 respectively on a major surface thereof remote from the cavity 390. Electrical connections C_1 , C_2 are made to a first face of the disc 340 and to the backing plate 320 respectively.

[0064] In operation, the disc 330 functions as a control element whose mechanical stiffness is electrically variable depending upon an electrical load connected thereto or an electrical signal applied thereto. Moreover, the disc 340 functions as a drive element when the projector 300 is being used to emit acoustic waves and as a sensor when the projector 300 is being used as a hydrophone. The discs 330, 340 and the plate 320 form a resonant structure whose resonant frequency can be altered electrically to tune the projector 300 to a desired operating frequency.

[0065] The projector 300 has the benefit of incorporating few parts and is therefore capable of being less expensive to manufacture.

[0066] In an alternative version of the projector 300, the discs 330, 340 are fabricated from the Navy Type I or III and the Navy Type VI ceramics respectively. In operation, the disc 340 functions as a tuning element whose mechanical stiffness is electrically variable depending upon an electrical load connected thereto or an electrical signal applied thereto. Moreover, the disc 330 functions as a drive element when the alternative version of the projector 300 is being used to emit acoustic waves and as a sensor when the projector 300 is being used as a hydrophone.

[0067] Although the projector 300 is shown in Figure 3 with its discs 330, 340 of similar dimensions, they can be of mutually different dimensions in a modified version of the projector 300.

[0068] Referring now to Figure 4, there is shown a side view illustration of a projector according to a third embodiment of the invention. The projector is indicated by 400 and incorporates sixteen elongate LZT ceramic elements, for example a tuning element 410 and a transducing element 420, soldered or bonded together to form a cylindrical structure indicated by 415. The tuning element 410 and other tuning elements of the structure 415 marked with "C" are fabricated from a Navy Type VI LZT ceramic. Moreover, the transducing element 420 and other transducing elements of the structure 415 marked with "D" are fabricated from a Navy Type I or III LZT ceramic. The projector 400 also incorporates a first end cap 430 and a second end cap 440 which are fabricated from a metal such as aluminium alloy. Alternatively, the end caps 430, 440 can be fabricated from an insulating material, for example a fibre reinforced polymer. The end caps 430, 440 provide support to the elements at their recessed edges 450, 460 respectively. Moreover, the end caps 430, 440 are also compliant, thereby enabling the structure 415 to vibrate in operation predominantly in a radial mode. In practice, slight bending of the elements will also occur corresponding to a bending mode of vibration. In the structure 415, transducing elements and tuning elements are arranged in abutting pairs circumferentially around the structure 415. The projector 400 includes an internal cavity surrounded by the LZT elements and the end caps 430, 440; this cavity can be filled with one or more gases, for example air, or alternatively filled with a vapour or a compressible solid.

[0069] Although the projector 400 includes sixteen elements, it can be modified to include a different number of elements, for example eight elements, twelve elements or twenty elements, namely all multiples of four elements.

[0070] Although the elements of the projector 400 are shown to have similar dimensions in Figure 4, they can be of mutually different dimensions in a modified version of the projector 400.

[0071] In Figure 5, there is shown an orthogonal view of a projector according to a fourth embodiment of the invention. The projector is indicated by 500 and incorporates sixteen elongate LZT ceramic elements, for example a transducing element 510 and a transducing element 520, soldered or bonded together to form a cylindrical structure indicated by 530. The tuning element 510 and other tuning elements of the structure 530 marked with "C" are fabricated from a Navy Type VI LZT ceramic. Moreover, the transducing element 520 and other transducing elements of the structure 530 marked with "D" are fabricated from a Navy Type I or III LZT ceramic. The projector 500 also incorporates a hollow insulating tube 540 concentrically mounted within the structure 530 and separated therefrom by an air gap, the gap being in the order of 3 to 8 mm wide. The tube 540 is fabricated from a relatively rigid polyurethane material, for example a proprietary polyurethane material sold under a trade mark "Tufset". The air gap serves a similar function to the end caps 430, 440 of the projector 400, namely increasing a mechanical resonant quality factor Q_m of the projector 500 above that obtainable if the projector 500 were devoid of the tube 540 and employed in an aquatic environment with water completely surrounding the elements.

[0072] In alternative versions of the projector 500, the tube 540 is substituted with other types of centrally mounted elements.

[0073] Achieving a relatively high resonant quality factor Q_m in the projector 500 is desirable for increasing its transducing sensitivity. Such an increase is important for efficient operation of the projector 500 in which only half of the elements are employed for transducing purposes, the other half of the elements being used for tuning purposes.

[0074] Referring now to Figure 6, there is shown a plan view illustration of the projector 400. The view is indicated by 600. The elements are polarised in a circumferential direction around the structure 415 such that interfaces where

the elements about function as electrical connection points for the projector 400. As mentioned above, transducing elements occur as abutted pairs in the projector 400. Likewise, tuning elements occur also as abutted pairs therein. Where the tuning elements about in pairs, for example control elements 610a, 610b, there are formed connection points for tuning signals to be applied. Likewise, where the transducing elements about in pairs, for example transducing elements 620a, 620b, there are formed connection points for drive signals to be applied when the projector 400 is functioning as a transmitter, or for connecting to inputs of amplifiers when the projector 400 is functioning as a hydro-
phone.

[0075] Referring now to Figure 7, there is shown a projector indicated by 700 according to a fifth embodiment of the invention. The projector 700 includes an outer ceramic tube 710 and also an inner ceramic tube 720. The tubes 710, 720 are both radially polarised. Inner and outer surfaces of the tubes 710, 720 are metallized to provide electrode regions on the tubes 710, 720. Moreover, the inner tube 720 has an outside diameter which matches an inner diameter of the outer tube 710, thereby enabling the inner tube 720 to be bonded by soldering or conductive adhesive, for example using conductive epoxy adhesive, within the outer tube 710 to form a concentric assembly. Electrical connections T_1 , T_2 , T_3 are made to the electrode region on the inside of the inner tube 720, to the electrode regions at an interface between the tubes 710, 720, and to the electrode region on the outside of the tube 710 respectively. The connection T_2 serves as a common connection for the two tubes 710, 720.

[0076] One of the tubes 710, 720 is designated a transducing tube and the other is designated a tuning tube. The transducing tube comprises Type I or Type III LST ceramic whereas the tuning tube comprises Type VI LST ceramic. When the projector 700 is used to emit acoustic waves into a medium surrounding the projector 700, the transducing tube is driven by an alternating electrical signal applied between the connection T_2 and the other connection of the transducing tube, for example the connection T_3 when the tube 710 is the transducing tube; likewise, a phase shifted and amplitude modified version of the electrical signal is applied to the other connection of the transducing tube to tune the projector 700, for example the connection T_1 when the tube 720 is the tuning tube.

[0077] In operation, the projector vibrates in a 1-3 mode, namely its tubes 710, 720 are radially polarised and vibrate in a radial manner. In contrast, the projector 400 vibrates in a 3-3 mode, namely its elements are circumferentially polarised and the structure 415 vibrates in a radial manner.

[0078] In Figure 8, there is shown indicated by 750 a projector according to a sixth embodiment of the invention, the projector 700 similar to the projector 700 except that the tubes 710, 720 are replaced by corresponding concentric rings 760, 770 as illustrated.

[0079] In operation, the projectors 400, 700, 750 vibrate in a radial expansion and contraction mode as illustrated in Figure 9. When drive or tuning signals are applied to the elements of the projector 400, it causes them to widen or thin in a direction of polarisation for each element; when this occurs, the structure 415 experiences cyclical variation of its diameter as illustrated. At a first stage (a), the structure 415 is of nominal diameter. At a second stage (b), in response to a drive signal applied to the structure 415, the structure 415 radially expands. At a third stage (c), the structure 415 contracts to its nominal diameter. At a fourth stage (d), in response to a drive signal applied to the structure 415, the structure 415 radially contracts. At a fifth stage (e), the structure 415 relaxes to its nominal diameter. The stages (a) to (e) are repeated in a cyclical manner when the projector 400 is operational and vibrating. Incorporation of the tuning elements into the projector 400 enables frequency tuning to be undertaken so that the structure's 415 resonant frequency is matched to a drive signal applied thereto, thereby enhancing operating efficiency of the projector 400. The projectors 700, 750 vibrate in a similar cyclical manner to the projector 400.

[0080] It will be appreciated that modification can be made to the projectors 400, 700, 750 without departing from the scope of the invention. For example, a cavity formed within the structure 415 by the end caps 430, 440 and the elements can be filled with one or more gases, for example air, a liquid, a vapour or a compressible solid such as foam

[0081] If it is permissible for the cavities of the projectors 400, 700, 750 to be water filled when operating the projectors 400, 700, 750 in an aquatic environment, the cavities can be vented to the aquatic environment; in the case of the projector 400, this reduces static pressure differential across the structure 415 and thereby enables it to function at greater depths without risk of rupture.

[0082] In order to simplify assembly of the projector 400, the structure 415 can be substituted with a unitary cylindrical ceramic resonator which has been circumferentially polarised. When a cylindrical monolithic piece of ceramic is employed, elements are formed by printing electrodes onto the piece; such printing can be achieved using silk screen printing of conductive metallic inks or by vacuum evaporating metal through a conformal stencil mask onto the piece or by hand painting using a brush. Such a unitary resonator is of one piece of ceramic and has the advantage of being cheaper to manufacture than a barrel stave transducer, for example the structure 415.

[0083] Moreover, the structure 415 can be truncated to be of ring-type form or elongate in the form of an elongate cylinder or tapered cylinder. Additionally, the projector 400 can be coated in a flexible polyurethane layer to protect it from its surrounding environment and to electrically insulate electrical connections made to the elements from disturbance from the environment.

[0084] It will be appreciated that modifications can be made to the projectors 10, 300, 400, 500, 700, 750 without

departing from the scope of the invention. For example, the Navy Type ceramics fabricated from LZT can, if required, be replaced by alternative active materials exhibiting at least one of electrostrictive and magnetostrictive properties. Such alternative active materials can include one or more of lead titanate, barium titanate or lead metaniobate. Moreover, lead magnesium niobate in combination with lead titanate is also useable, the niobate and titanate being in either ceramic or crystalline form. Furthermore, crystalline quartz or a magnetostrictive material such as nickel or a proprietary material Terfenol D can be used.

[0085] Moreover, the structures 415, 530 and the projectors 700, 750 not need have circular cross-section but can be modified to have one or more of the following alternative cross-section forms: elliptical, rectangular or polygonal. A polygonal form is especially appropriate when relatively larger projectors are to be constructed. Likewise, the plates 16, 320 and the discs 20, 330, 340 in the projectors 10, 300 can be of other profiles other than circular as illustrated in Figures 1, 2 or 3, for example also elliptical, rectangular or polygonal.

Claims

1. A frequency tunable projector for coupling between electrical signals and corresponding acoustic waves in an environment exposed to the projector, the projector (10, 300, 400, 500, 700) incorporating :

- transducing means for coupling between the signals and the corresponding acoustic waves
- and piezoelectric tuning means for tuning a resonant frequency of the transducing means

the transducing means comprising one or more transducing elements (20a, 20d, 340, 420, 520, 620, 720, 770) and the tuning means comprising one or more tuning elements (20b, 20c, 330, 410, 510, 610, 710, 760), the elements being mutually mechanically coupled together and being operable to vibrate as a composite structure, wherein the transducing means and the tuning means are incorporated into one or more walls (16a, 16b, 320, 415, 530, 710, 720, 760, 770) of a cavity (106), the one or more walls at least partially isolating the cavity from the environment, **characterised by** the elements vibrating in a bending vibration mode or a radial vibration mode so that the one or more walls are operable to vibrate in at least one of a bending vibration mode and a radial vibration mode to cyclically compress and expand the cavity.

2. A projector according to Claim 1 wherein the transducing means and the tuning means function by exploiting at least one of magnetostrictive or electrostrictive phenomena occurring in one or more of the following materials incorporated into at least one of the means : lead zirconate titanate, lead titanate, barium titanate, lead metaniobate, lead magnesium niobate in combination with lead titanate in either ceramic or crystalline form, nickel and crystalline quartz.

3. A projector according to Claim 1 or 2 wherein mechanical stiffness of the tuning means is modifiable in response to an electric load or an electrical signal applied to the tuning means.

4. A projector according to Claim 3 wherein the elements of the transducing means are mutually electrically isolated from the walls by insulating members, the elements and the insulating members being mutually mechanically coupled so as to vibrate as a composite structure.

5. A projector according to Claim 4 wherein the insulating members are fabricated from an insulating ceramic alumina.

6. A projector according to Claim 4 or 5 wherein the insulating members extend beyond the elements for enhancing mutual electrical isolation of the elements of the transducing means.

7. A projector according to Claim 4, 5 or 6 wherein at least one of the elements and the insulating members incorporate peripheral edges which are rounded to counteract chipping.

8. A projector according to any one of Claims 1 to 7 wherein the at least one cavity wall incorporates a backing plate (16, 320) onto which the elements are mechanically mounted.

9. A projector according to Claim 8 wherein the backing plate (16, 320) is fabricated from a maraging steel, a high-tensile tool steel, an aluminium alloy, brass or bronze.

10. A projector according to Claim 8 or 9 wherein the backing plate (16, 320) is of a non-uniform thickness to enhance

its pressure bearing capability.

11. A projector according to Claim 10 wherein the backing plate (16, 320) is circular and thickens to an apex (102, 380) at a central region of the plate.

12. A projector according to Claim 1,2 or 3 wherein a plurality of the walls incorporate the transducing means and the tuning means, the walls being coupled together through a spacer element (12), wherein the spacer element and the walls cooperate to enclose the cavity.

13. A projector according to Claim 12 wherein the spacer element (12) is fabricated from a metal.

14. A projector according to Claim 13 wherein the metal is stainless steel.

15. A projector according to Claim 12 wherein the spacer element (12) is fabricated from an insulating material or a polymer.

16. A projector according to Claim 15 wherein the insulating material is a fibre reinforced polymer.

17. A projector according to any one of Claims 12 to 16 wherein the spacer element (12) incorporates a projection (104) for engaging onto one or more backing plates bearing the transducing means and the tuning means, the projection thereby providing an annular edge mount for the backing plates.

18. A projector according to Claim 17 wherein the elements (20, 330, 340) are directly mutually bonded and also directly bonded to their associated backing plate, the backing plate functioning as a first electrical connection to the elements.

19. A projector according to Claim 1, 2 or 3 wherein the walls are substantially in the form of a cylindrical or ring structure comprising the transducing means (420, 520, 620, 720, 770) and the tuning means (410, 510, 610, 710, 760).

20. A projector according to Claim 19 wherein the transducing means (720) and the tuning means (710) are implemented as concentrically mounted tubes.

21. A projector according to Claim 19 wherein the transducing means (770) and the tuning means (760) are implemented as concentrically mounted rings.

22. A projector according to Claim 20 or 21 wherein the tubes or rings are radially polarised.

23. A projector according to claim 19 wherein the elements of the transducing means (420, 520, 620) are arranged in abutting pairs, and elements of the tuning means (410, 510, 610) are also arranged in abutting pairs.

24. A projector according to Claim 23 wherein electrical connections are made to the elements at interfaces where elements of each pair mutually abut.

25. A projector according to Claim 19, 23 or 24 wherein end caps (430, 440) are incorporated at ends of the cylindrical or ring structure to form the cavity within the cylindrical or ring structure.

26. A projector according to Claim 25 wherein the end caps (430, 440) are fabricated from a metal.

27. A projector according to Claim 19, 23 or 24 wherein a centrally-located, element is incorporated concentrically within the cylindrical or ring structure and separated therefrom by a gap providing the cavity.

28. A projector according to Claim 27 wherein the centrally-located element comprises a hollow insulating tube.

Patentansprüche

1. Frequenzabstimmbarer Schallgeber zum Koppeln zwischen elektrischen Signalen und entsprechenden Schall-

wellen in einer dem Schallgeber ausgesetzten Umgebung, wobei der Schallgeber (10, 300, 400, 500, 700) folgendes enthält:

- wandelnde Mittel zum Koppeln zwischen den Signalen und den entsprechenden Schallwellen
- und piezoelektrische Abstimmittel zum Abstimmen einer Resonanzfrequenz der wandelnden Mittel

wobei die wandelnden Mittel ein oder mehrere wandelnde Elemente (20a, 20d, 340, 420, 520, 620, 720, 770) umfassen und die Abstimmittel ein oder mehrere Abstimmtelemente (20b, 20c, 330, 410, 510, 610, 710, 760) umfassen, wobei die Elemente mechanisch gegenseitig zusammengekoppelt sind und dahingehend arbeiten, daß sie als eine Verbundstruktur vibrieren, wobei die wandelnden Mittel und die Abstimmittel in eine oder mehrere Wände (16a, 16b, 320, 415, 530, 710, 720, 760, 770) eines Hohlraums (106) integriert sind, wobei die eine oder die mehreren Wände den Hohlraum zumindest teilweise von der Umgebung isolieren, **gekennzeichnet dadurch, daß** die Elemente in einem Biegeschwingungsmodus oder einem Radialschwingungsmodus vibrieren, so daß die eine oder die mehreren Wände dahingehend arbeiten können, daß sie mindestens in einem Biegeschwingungsmodus oder einem Radialschwingungsmodus vibrieren, um den Hohlraum zyklisch zu komprimieren und auszu-

dehnen.

2. Schallgeber nach Anspruch 1, wobei die wandelnden Mittel und die Abstimmittel dadurch fungieren, daß sie mindestens das magnetostruktive oder elektrostruktive Phänomen ausnutzen, die in einem oder mehreren der folgenden Materialien auftreten, die in mindestens eines der Mittel integriert sind: Blei-Zirconat-Titanat, Blei-Titanat, Barium-Titanat, Blei-Metaniobat, Blei-Magnesium-Niobat in Kombination mit Blei-Titanat entweder in keramischer oder kristalliner Form, Nickel und kristalliner Quarz.

3. Schallgeber nach Anspruch 1 oder 2, wobei mechanische Steifigkeit der Abstimmittel als Reaktion auf eine elektrische Last oder ein elektrisches Signal, angelegt an die Abstimmittel, modifiziert werden kann.

4. Schallgeber nach Anspruch 3, wobei die Elemente der wandelnden Mittel gegenseitig elektrisch von den Wänden durch isolierende Glieder isoliert sind, wobei die Elemente und die isolierenden Glieder gegenseitig mechanisch gekoppelt sind, um als eine Verbundstruktur zu vibrieren.

5. Schallgeber nach Anspruch 4, wobei die isolierenden Glieder aus einem isolierenden keramischen Aluminiumoxid hergestellt sind.

6. Schallgeber nach Anspruch 4 oder 5, wobei sich die isolierenden Glieder über die Elemente hinaus erstrecken zum Verbessern der gegenseitigen elektrischen Isolierung der Elemente der wandelnden Mittel.

7. Schallgeber nach Anspruch 4, 5 oder 6, wobei mindestens eines der Elemente und der isolierenden Elemente periphere Ränder enthält, die abgerundet sind, um einem Abplatzen entgegenzuwirken.

8. Schallgeber nach einem der Ansprüche 1 bis 7, wobei die mindestens eine Hohlraumwand eine Trägerplatte (16, 320) enthält, auf der die Elemente mechanisch befestigt sind.

9. Schallgeber nach Anspruch 8, wobei die Trägerplatte (16, 320) aus einem Maraging-Stahl, einem hochzugfesten Werkzeugstahl, einer Aluminiumlegierung, Messing oder Bronze hergestellt ist.

10. Schallgeber nach Anspruch 8 oder 9, wobei die Trägerplatte (16, 320) eine ungleichförmige Dicke aufweist, um ihre Druckbeaufschlagungsfähigkeit zu verbessern.

11. Schallgeber nach Anspruch 10, wobei die Trägerplatte (16, 320) kreisförmig ist und sich zu einem zentralen Gebiet der Platte hin zu einem Scheitel (102, 380) verdickt.

12. Schallgeber nach Anspruch 1, 2 oder 3, wobei mehrere der Wände die wandelnden Mittel und die Abstimmittel enthalten, wobei die Wände durch ein Abstandshalterelement (12) zusammengekoppelt sind, wobei das Abstandshalterelement und die Wände zusammenwirken, um den Hohlraum zu umschließen.

13. Schallgeber nach Anspruch 12, wobei das Abstandshalterelement (12) aus einem Metall hergestellt ist.

14. Schallgeber nach Anspruch 13, wobei das Metall rostfreier Stahl ist.

15. Schallgeber nach Anspruch 12, wobei das Abstandshalterelement (12) aus einem isolierenden Material oder einem Polymer hergestellt ist.

16. Schallgeber nach Anspruch 15, wobei das isolierende Material ein faserverstärktes Polymer ist.

17. Schallgeber nach einem der Ansprüche 12 bis 16, wobei das Abstandshalterelement (12) einen Vorsprung (104) enthält zur Ineingriffnahme an einer oder mehreren Trägerplatten, die die wandelnden Mittel und die Abstimmittel tragen, wobei der Vorsprung dadurch einen ringförmigen Randfuß für die Trägerplatten bereitstellt.

18. Schallgeber nach Anspruch 17, wobei die Elemente (20, 330, 340) direkt aneinander und auch direkt an ihre assoziierte Trägerplatte gebondet sind, wobei die Trägerplatte als eine erste elektrische Verbindung zu den Elementen fungiert.

19. Schallgeber nach Anspruch 1, 2 oder 3, wobei die Wände im wesentlichen in Form einer Zylinder- oder Ringstruktur vorliegen, die die wandelnden Mittel (420, 520, 620, 720, 770) und die Abstimmittel (410, 510, 610, 710, 760) umfaßt.

20. Schallgeber nach Anspruch 19, wobei die wandelnden Mittel (720) und die Abstimmittel (710) als konzentrisch montierte Röhren implementiert sind.

21. Schallgeber nach Anspruch 19, wobei die wandelnden Mittel (770) und die Abstimmittel (760) als konzentrisch montierte Röhren implementiert sind.

22. Schallgeber nach Anspruch 20 oder 21, wobei die Röhren oder Ringe radial polarisiert sind.

23. Schallgeber nach Anspruch 19, wobei die Elemente der wandelnden Mittel (420, 520, 620) in anstoßenden Paaren angeordnet sind und die Elemente der Abstimmittel (410, 510, 610) ebenfalls in anstoßenden Paaren angeordnet sind.

24. Schallgeber nach Anspruch 23, wobei elektrische Verbindungen zu den Elementen an Schnittstellen hergestellt sind, wo Elemente jedes Paares aneinander anstoßen.

25. Schallgeber nach Anspruch 19, 23 oder 24, wobei Endkappen (430, 440) an Enden der Zylinder- oder Ringstruktur integriert sind, um den Hohlraum innerhalb der Zylinder- oder Ringstruktur auszubilden.

26. Schallgeber nach Anspruch 25, wobei die Endkappen (430, 440) aus einem Metall hergestellt sind.

27. Schallgeber nach Anspruch 19, 23 oder 24, wobei ein mittig angeordnetes Element konzentrisch innerhalb der Zylinder- oder Ringstruktur integriert und durch einen den Hohlraum bereitstellenden Spalt davon getrennt ist.

28. Schallgeber nach Anspruch 27, wobei das mittig angeordnete Element eine hohle isolierende Röhre umfaßt.

Revendications

1. Projecteur accordable en fréquence pour assurer le couplage entre des signaux électriques et des ondes acoustiques correspondantes dans un milieu exposé au projecteur, le projecteur (10, 300, 400, 500, 700) incorporant :

- un moyen transducteur pour assurer le couplage entre les signaux et les ondes acoustiques correspondantes, et
- un moyen d'accord piézoélectrique pour accorder une fréquence de résonance du moyen transducteur,

le moyen transducteur comprenant un ou plusieurs éléments transducteurs (20a, 20d, 340, 420, 520, 620, 720, 770) et le moyen d'accord comprenant un ou plusieurs éléments d'accord (20b, 20c, 330, 410, 510, 610, 710, 760), les éléments étant mutuellement couplés mécaniquement et pouvant être mis en oeuvre pour vibrer comme une structure composite, dans lequel le moyen transducteur et le moyen d'accord sont incorporés dans une ou plusieurs parois (16a, 16b, 320, 415, 530, 710, 720, 760, 770) d'une cavité (106), ladite ou lesdites parois isolant au moins partiellement la cavité du milieu, **caractérisé en ce que** les éléments vibrent dans un mode de vibration

de déformation ou un mode de vibration radiale, de sorte que ladite ou lesdites parois peuvent être mises en oeuvre pour vibrer dans au moins un mode parmi un mode de vibration de déformation et un mode de vibration radiale pour assurer la compression et la dilatation cycliques de la cavité.

- 5 **2.** Projecteur selon la revendication 1, dans lequel le moyen transducteur et le moyen d'accord fonctionnent en tirant profit de phénomènes magnétostrictifs ou de phénomènes électrostrictifs, ou des deux, se produisant dans une ou plusieurs des substances suivantes, incorporées dans au moins un des moyens : le titanate de plomb-zirconate, le titanate de plomb, le titanate de baryum, le métaniobate de plomb, le niobate de plomb-magnésium combiné au titanate de plomb sous forme céramique ou cristalline, le nickel et le quartz cristallin.
- 10 **3.** Projecteur selon la revendication 1 ou 2, dans lequel la rigidité mécanique du moyen d'accord est modifiable en réaction à une charge électrique ou à un signal électrique appliqué au moyen d'accord.
- 15 **4.** Projecteur selon la revendication 3, dans lequel les éléments du moyen transducteur sont mutuellement isolés électriquement des parois par des organes isolants, les éléments et les organes isolants étant mutuellement couplés mécaniquement de façon à vibrer comme une structure composite.
- 20 **5.** Projecteur selon la revendication 4, dans lequel les organes isolants sont constitués d'une céramique d'alumine isolante.
- 25 **6.** Projecteur selon la revendication 4 ou 5, dans lequel les organes isolants se prolongent au-delà des éléments pour renforcer l'isolement électrique mutuel des éléments du moyen transducteur.
- 30 **7.** Projecteur selon la revendication 4, 5 ou 6, dans lequel au moins un des éléments et les organes isolants incorporent des bords périphériques qui sont arrondis pour éviter les ébréchures.
- 35 **8.** Projecteur selon l'une quelconque des revendications 1 à 7, dans lequel ladite au moins une paroi de cavité incorpore une plaque de support (16, 320) sur laquelle les éléments sont montés mécaniquement.
- 40 **9.** Projecteur selon la revendication 8, dans lequel la plaque de support (16, 320) est constituée d'acier maraging, d'acier à outils à haute résistance à la traction, d'un alliage d'aluminium, de laiton ou de bronze.
- 45 **10.** Projecteur selon la revendication 8 ou 9, dans lequel la plaque de support (16, 320) présente une épaisseur non uniforme afin de renforcer sa capacité de tenue en pression.
- 50 **11.** Projecteur selon la revendication 10, dans lequel la plaque de support (16, 320) est circulaire et s'épaissit jusqu'à un sommet (102, 380) situé au niveau d'une région centrale de la plaque.
- 55 **12.** Projecteur selon la revendication 1, 2 ou 3, dans lequel une pluralité des parois incorporent le moyen transducteur et le moyen d'accord, les parois étant couplées par un élément d'écartement (12), l'élément d'écartement et les parois coopérant pour fermer la cavité.
- 13.** Projecteur selon la revendication 12, dans lequel l'élément d'écartement (12) est en métal.
- 14.** Projecteur selon la revendication 13, dans lequel le métal est de l'acier inoxydable.
- 15.** Projecteur selon la revendication 12, dans lequel l'élément d'écartement (12) est constitué d'une matière isolante ou d'un polymère.
- 16.** Projecteur selon la revendication 15, dans lequel la matière isolante est un polymère armé de fibres.
- 17.** Projecteur selon l'une quelconque des revendications 12 à 16, dans lequel l'élément d'écartement (12) incorpore une protubérance (104) destinée à s'engager dans une ou plusieurs plaques de support portant le moyen transducteur et le moyen d'accord, la protubérance formant ainsi une monture à bord annulaire pour les plaques de support.
- 18.** Projecteur selon la revendication 17, dans lequel les éléments (20, 330, 340) sont directement fixés mutuellement et également directement fixés sur leur plaque de support associée, la plaque de support servant de première

connexion électrique avec les éléments.

- 5 **19.** Projecteur selon la revendication 1, 2 ou 3, dans lequel les parois prennent essentiellement la forme d'une structure cylindrique ou en anneau comprenant le moyen transducteur (420, 520, 620, 720, 770) et le moyen d'accord (410, 510, 610, 710, 760).
- 10 **20.** Projecteur selon la revendication 19, dans lequel le moyen transducteur (720) et le moyen d'accord (710) sont réalisés sous la forme de tubes montés concentriquement.
- 15 **21.** Projecteur selon la revendication 19, dans lequel le moyen transducteur (770) et le moyen d'accord (760) sont réalisés sous la forme d'anneaux montés concentriquement.
- 20 **22.** Projecteur selon la revendication 20 ou 21, dans lequel les tubes ou les anneaux sont polarisés radialement.
- 25 **23.** Projecteur selon la revendication 19, dans lequel les éléments du moyen transducteur (420, 520, 620) sont disposés par paires en butée, et les éléments du moyen d'accord (410, 510, 610) sont également disposés par paires en butée.
- 30 **24.** Projecteur selon la revendication 23, dans lequel des connexions électriques sont établies avec les éléments au niveau des interfaces, la ou les éléments de chaque paire se trouvent en butée mutuelle.
- 35 **25.** Projecteur selon la revendication 19, 23 ou 24, dans lequel des embouts (430, 440) sont incorporés aux extrémités de la structure cylindrique ou en anneau pour former la cavité dans la structure cylindrique ou en anneau.
- 40 **26.** Projecteur selon la revendication 25, dans lequel les embouts (430, 440) sont en métal.
- 45 **27.** Projecteur selon la revendication 19, 23 ou 24, dans lequel un élément en position centrale est incorporé concentriquement dans la structure cylindrique ou en anneau et en est séparé par un espace formant la cavité.
- 50 **28.** Projecteur selon la revendication 27, dans lequel l'élément en position centrale comprend un tube isolant creux.
- 55

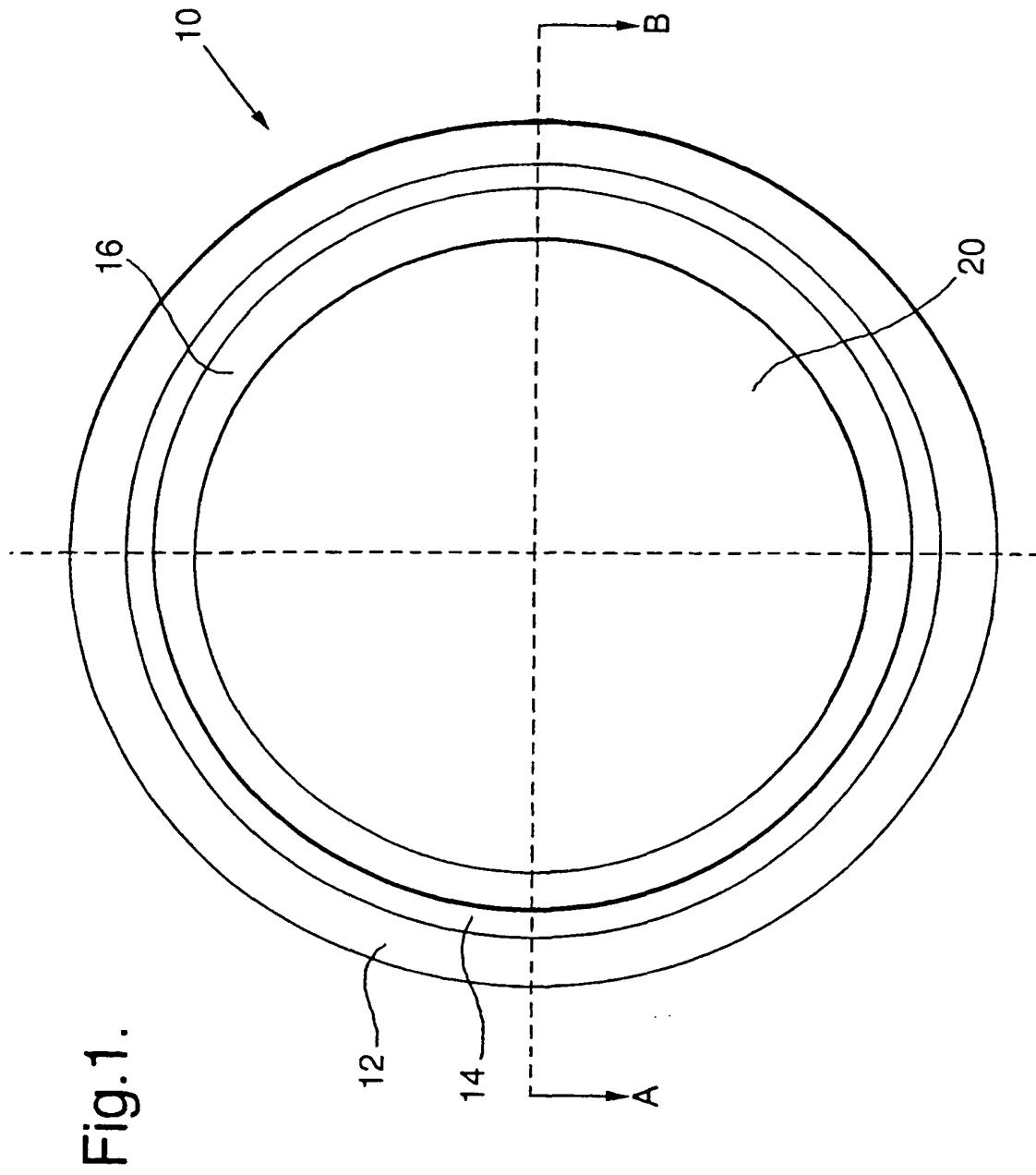
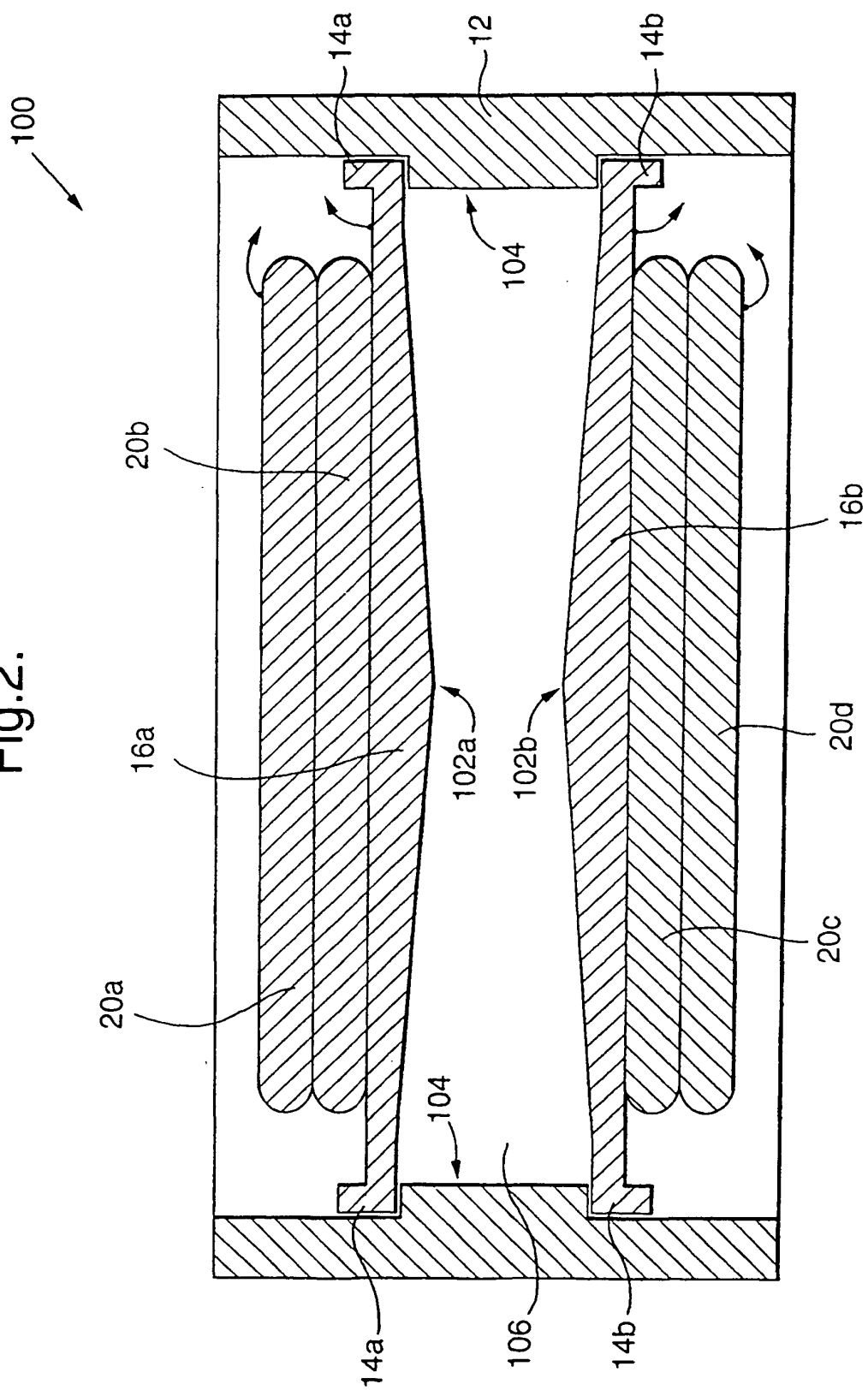


Fig.2.



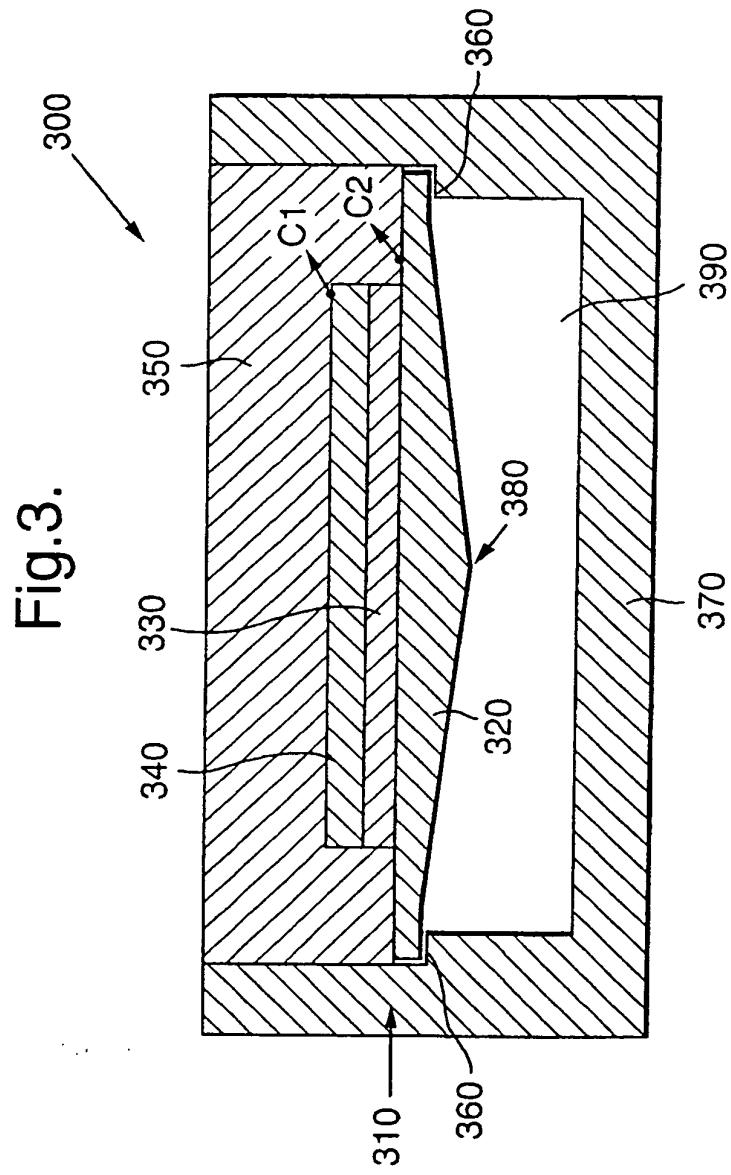
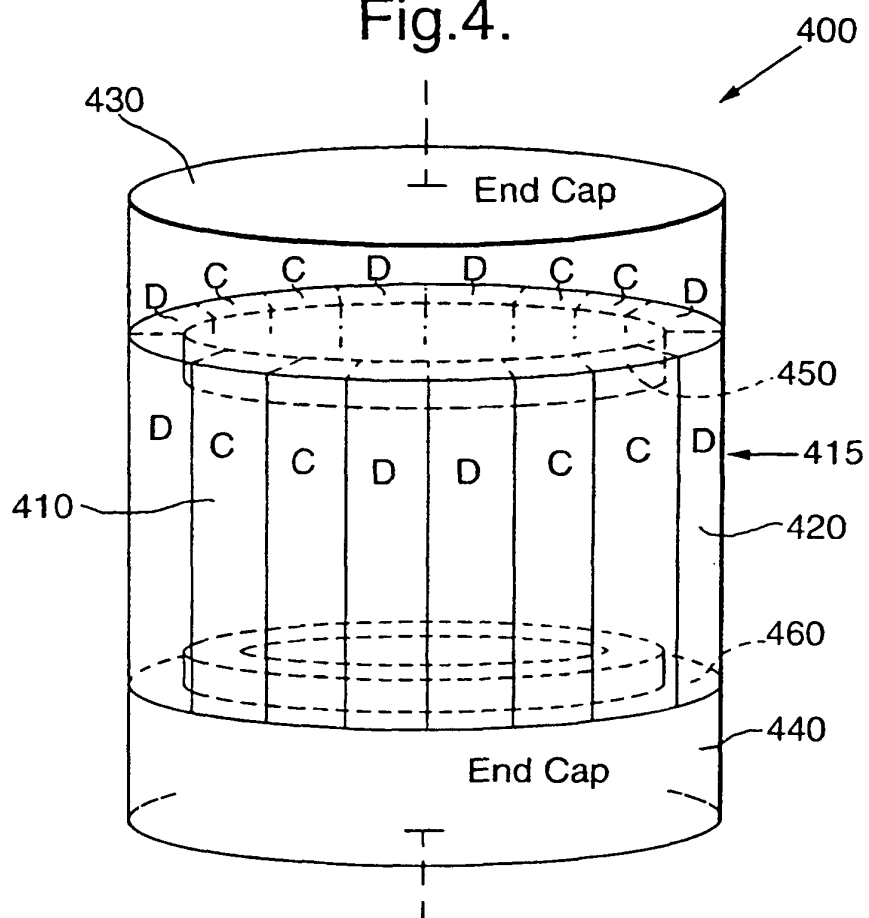
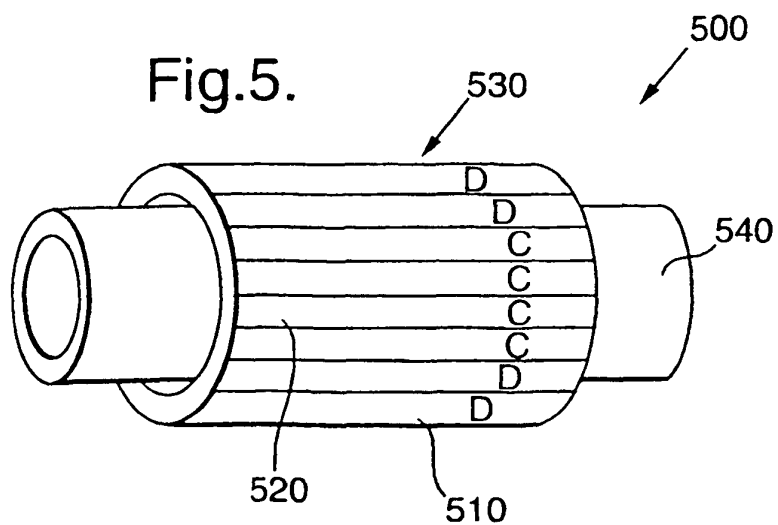


Fig.4.



C= tuning element
D= transducing element

Fig.5.



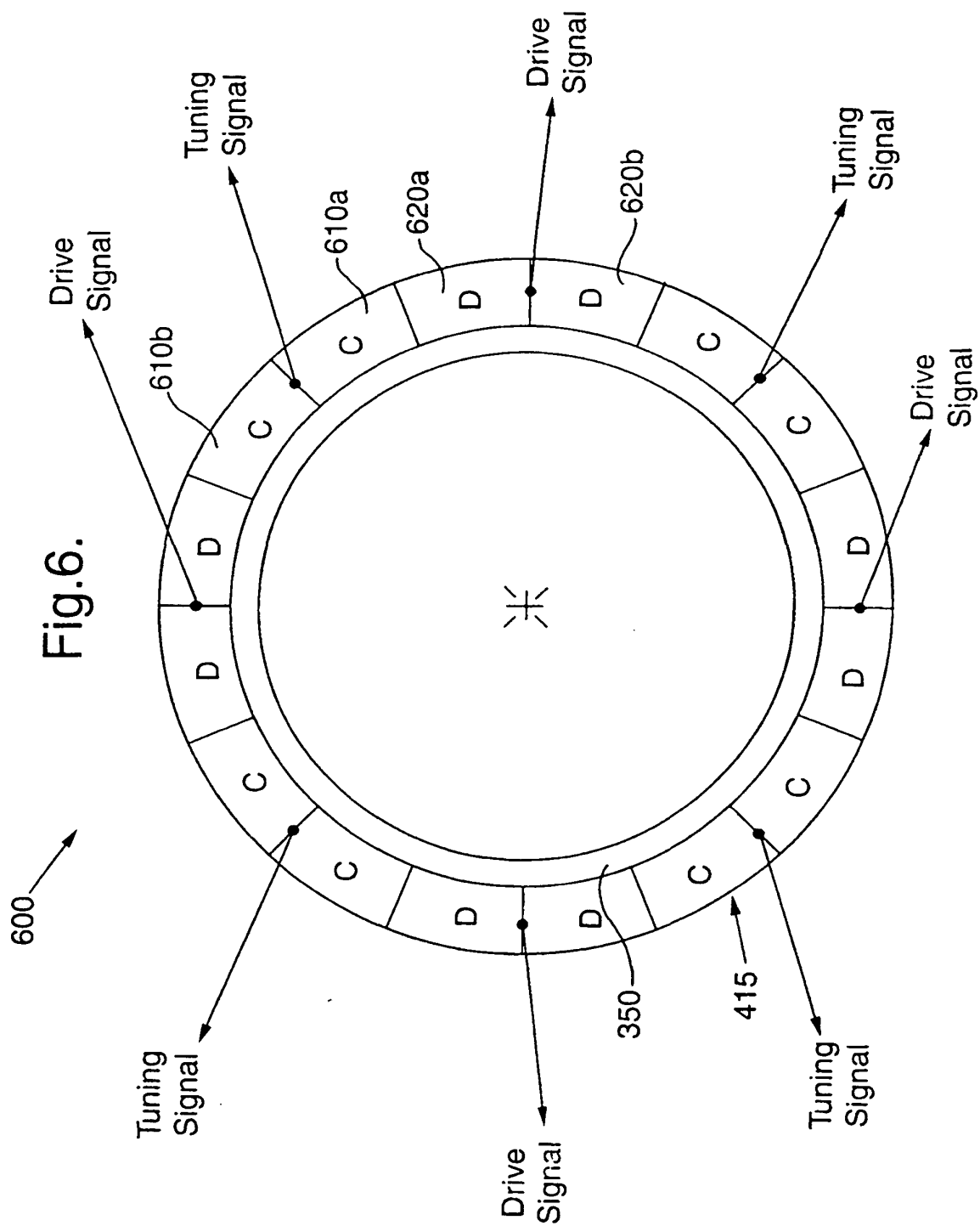


Fig.7.

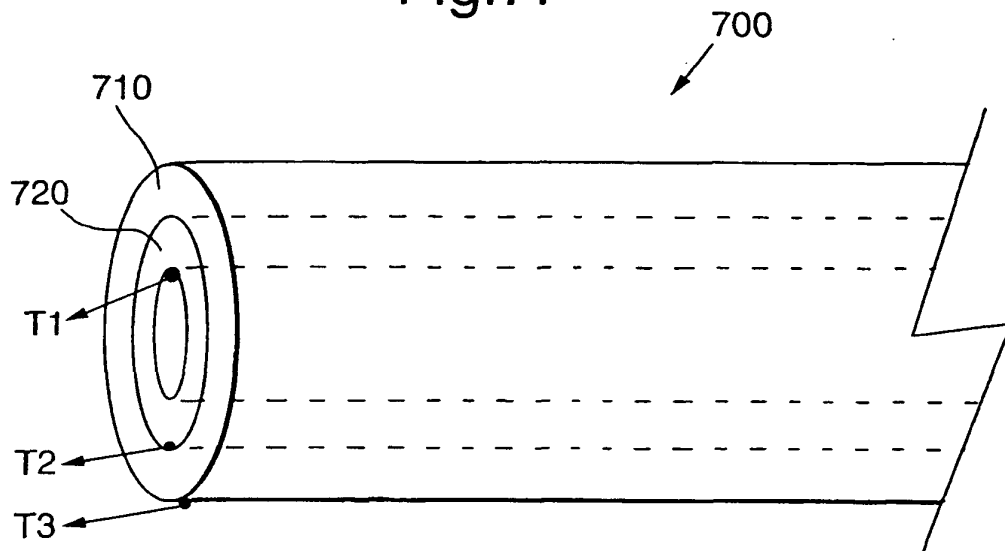


Fig.8.

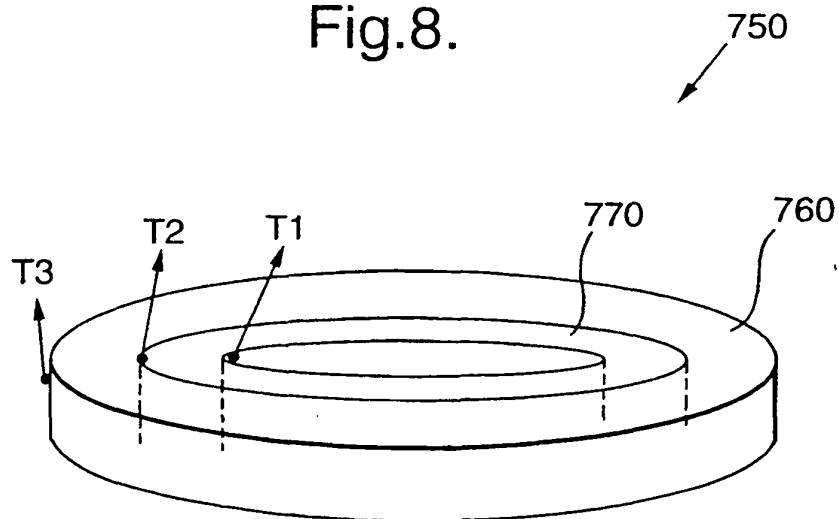


Fig.9.

