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(54) **A device for generating and/or detecting electromagnetic fields.**

(57) The device comprises a source (1) of electrically charged elementary particles, emitting a beam (2) of particles which is split into two partial beams (4, 5) sent onto different paths. A difference in velocity and hence in wavelength is generated between the two partial beams. The two partial beams are recombined into a single beam (14) and their beat is detected as an electrical signal. The velocity difference can be generated by a voltage generator (6b) or by the output voltage of an antenna.

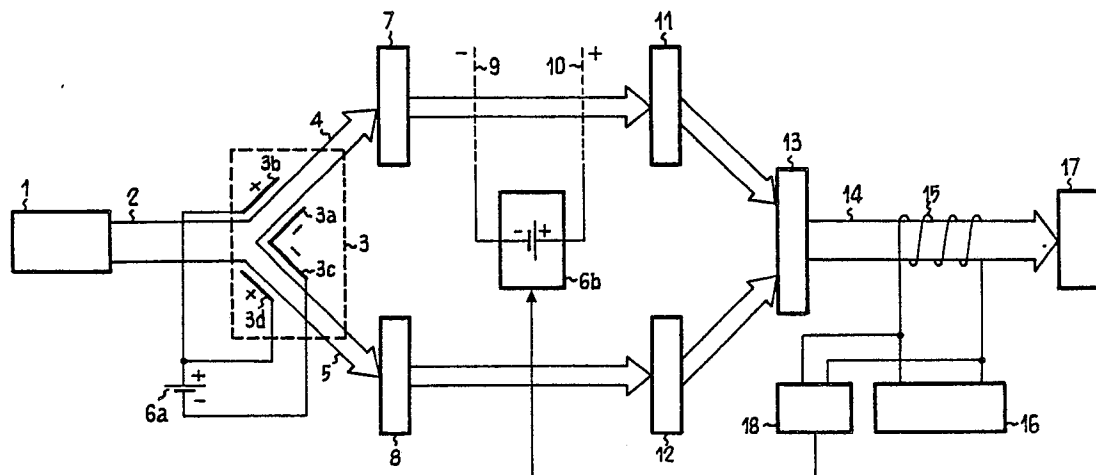


FIG. 1

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A Device for Generating and/or Detecting Electromagnetic Fields

Description

The present invention refers to apparatus based on electron optics techniques and more particularly relates to a device for generating and detecting electromagnetic fields, exploiting the interference between electrically-charged elementary particles.

Preferably, but non exclusively, the invention is used in microwave generators and receivers or in electrical field measurement instruments, always in the microwave frequency range.

It is known that for the generation, reception and amplification of signals with a frequency lying in the microwave range, and more particularly in the upper region of the range, devices exploiting the interactions between electron beams and travelling wave or cavity devices are generally used. The choice of the device is determined by the type of application, more particularly by power, bandwidth, gain ... requirements. All known devices present a number of limitations, more particularly they can operate only in limited frequency bands or require a driving radio-frequency.

The aim of the invention is to provide an extremely sensitive and flexible device, which does not require driving radio-frequencies.

The device according to the invention comprises:

- means for generating a beam of electrically charged elementary particles;
- means for splitting said beam into two partial beams and sending such partial beams along two different paths;
- means for generating a velocity difference between the particles of the two partial beams;
- means for recombining into a single beam the two partial beams, whose particles are moving at a different velocity, so as to cause the two partial beams to beat; and
- means for obtaining, from the recombined beam, an electrical signal at a frequency equal to that of the beat between the two partial beams and sending such an electrical signal to utilising devices.

The beam splitting and recombining means can be a magnetic lens array, or a solid state device, or yet a waveguide manufactured by integrated optics techniques.

Interferometric devices exploiting interference between elementary particles, more particularly ballistic electrons or neutrons, are already known in the literature, however their use for generating and detecting electromagnetic fields has not been suggested.

The invention will be better understood with

reference to the annexed drawings, which show some embodiments of the device using an electron interferometer, and in which:

- Fig. 1 is a schematic representation of a device according to the invention, used as a generator of electromagnetic fields and made as a vacuum tube;

- Fig. 2 is a representation similar to that of Fig. 1, yet concerning the use as a detector;

- Figs. 3 and 4 show, in perspective and plan views respectively, a possible embodiment of the device as a solid-state device, and

- Figs. 5 and 6 show, in perspective and in cross section respectively, a possible embodiment of the device as an integrated optics device.

As shown in Fig. 1, the device for generating electromagnetic fields according to the invention comprises a conventional electron gun 1 which generates an electron beam 2. For the aims of the invention, the electrons in the beam can have a kinetic energy of the order of 150 eV, corresponding to a wavelength of about 0.1 nm and a frequency of about $7 \cdot 10^4$ THz. Said values are obtained by applying the well known relations which link kinetic energy E , wavelength λ , velocity v , rest mass m_0 and frequency ν of an electron moving in an electrical field with potential V :

$$E = eV = m_0 v^2 / 2 \quad (e = \text{electron charge})$$

$$\lambda = h / m_0 v$$

$$\nu = v / \lambda.$$

Since the kinetic energy considered in this application is much lower than electron rest energy (about 500 keV) the formulae applied are the approximate ones valid for non-relativistic conditions.

A device 3 splitting beam 2 into two partial beams 4, 5 to be forwarded along different trajectories is located along the path of beam 2. Device 3 can comprise two pairs of facing plates 3a, 3b and 3c, 3d, respectively, one plate in each pair being connected to a negative voltage and the other to a positive voltage. The voltage source is schematized by a battery 6a. Negative plates 3a, 3c are joined so as to form a wedge, the axis of beam 2 crossing the vertex of said wedge. Under these conditions substantially half beam 2 is made to pass between plates 3a and 3b, and the other half beam is made to pass between plates 3c, 3d.

The two partial beams 4, 5 are caused to pass through respective deflection systems schematized by lenses 7, 8, more particularly magnetic lenses. At least partial beam 4, outgoing from lens 7, passes through two modulating grids 9, 10, connected to a voltage source 6b which can coincide with voltage source 6a; grids 9, 10 vary the velocity and hence the wavelength of the electrons of par-

tial beam 4. More particularly, a voltage difference of 1 microvolt between the two grids 9, 10 causes a wavelength variation corresponding to a frequency variation of the order of 480 MHz. In the drawing it has been assumed that grids 9, 10 accelerate beam 4. The accelerated beam is then deflected by another lens array 11 and sent to means 13 (e.g. another magnetic lens array), making beam 4 beat with partial beam 5, whose electrons have not undergone any energy variation with respect to the original beam 2. Beam 5 is deflected towards means 13 by lenses 12, analogous to lenses 11.

As an alternative, a second pair of grids, between which a potential difference is established which is different from that applied to grids 9, 10, may be located on the trajectory of beam 5.

Beam 14 resulting from the beating is made to pass through an inductor 15 (e.g. consisting in a resonant cavity or any other broadband microwave receiving system), supplying an electrical signal at the beat frequency to a utilising device 16, and is finally collected by anode 17.

For drawing simplicity the device housing, similar to that of kinescopes, thermoionic tubes and the like, has not been represented.

The high flexibility of the system provided by the invention is easy to deduce from what stated above. In fact, the frequency generated solely depends on the velocity difference among the partial beams and hence on the voltage applied to grids 9, 10 (or on the difference between the voltages applied to the grids placed in the two branches): by voltages whose order of magnitude is comprised between some nanovolts and some ten millivolts, frequencies ranging from some Megahertz to some Terahertz can be generated. It is to be noted that conventional reference voltage generators, possibly associated with high precision and stability resistive dividers, allow voltages of the order of the nanovolts to be generated without any difficulty.

The frequency generated can be stabilized by a conventional frequency control circuit 18 which receives a fraction of the signal extracted by inductor 15 and supplies a voltage signal for adjusting source 6b.

In the diagram of Fig. 2, relative to the use of the device as a detector, grids 9, 10 are connected to an antenna 19 whose output voltage generates the velocity variation of partial beam 4 with respect to beam 5. In this embodiment generator 6b connected to the grids and control circuit 18 are obviously lacking; the other elements of the device remain identical and have been denoted by the same references as in Fig. 1. In this case the beat frequency will provide an indication of the antenna output voltage. The flexibility characteristics disclosed for the generator are obviously present also in the detector.

In an interferometer according to Figures 3 and 4 deflecting plates 3 and magnetic lenses 7, 8, 11, 12, 13 are replaced by a single silica crystal 20, in which three slabs or ears 21, 22, 23 parallel to one another are cut out. Beam 24 generated by gun 1 is made to arrive at Bragg angle θ on the first ear 21 and is split into two beams 25, 26 which are collected and refracted by the second ear 22 so as to arrive at a same point on the third ear 23. Grids 27, 28, connected to a voltage generator or to an antenna, not shown and similar to generator 6b or antenna 19 of Figs. 1 and 2, are placed between the second and the third ears 22, 23.

Two beams 35, 36, phase-shifted by 180° with respect to each other, are present at the output from the third ear of the interferometer. The two beams outgoing from the crystal are then made to pass into respective detectors (not shown), analogous to detector 15 of Fig. 1, and lastly are collected by respective anodes (not shown) similar to anode 17.

Is the device used as a generator, one of the detectors can be connected to utilising devices 16, while the other can be connected to a frequency control device similar to device 18 of Fig. 1.

Thanks to the use of a single crystal for manufacturing the device, the atoms of ear 23 are aligned with those of ear 21, and this allows the electron beam coherence to be maintained along the whole trajectory. A single crystal shaped like that shown in the Figure and used as a neutron interferometer has been described by D.M. Greenberger in the paper entitled "The neutron interferometer", Reviews of Modern Physics, Vol. 55, No.4, October 1983.

Lastly, in the embodiment of Figs. 5, 6, interferometer 30 consists of a substrate 31 of a first semiconductor (e. g. AlGaAs) on which a strip 32 of a second semiconductor (e.g. GaAs) is formed. In the central portion the strip forms two equal-length branches 32a, 32b. One branch is traversed by two metallizations 33, 34 acting as modulating grids 9, 10 or 27, 28 in the preceding Figures. The device can be manufactured by the techniques generally used in integrated circuit manufacturing.

It is clear that what described has been given only by way of non-limiting example, and variations and modifications are possible without going out of the scope of the present invention.

Claims

1. A device for generating and detecting electromagnetic fields, characterized in that it comprises:

- means (1) for generating a beam (2) of electrically charged elementary particles;

- means (3) for splitting said beam (2) into two partial beams (4, 5) and sending such partial beams (4, 5) along two different paths;
- means (9, 10; 27, 28; 33, 34) for generating a velocity difference among the particles of the two partial beams (4, 5);
- means (13) for recombining into a single beam (14) the two partial beams (4, 5) whose particles move at different velocities, so as to cause the two partial beams to beat; and
- means (15) for obtaining from the recombined beam (14) an electrical signal at the same frequency as the beat between the two partial beams and sending such an electrical signal to utilising devices (16).

2. A device as claimed in claim 1, characterized in that said means (9,10) generating a velocity difference between the two partial beams (4,5) are connected to a voltage source (6b).

3. A device as claimed in claim 2, characterized in that said voltage source (6b) is apt to generate a voltage whose value ranges from some nanovolts to some ten millivolts.

4. A device as claimed in any of claims 1 to 3, characterized in that a control device (18) varying the voltage emitted from said source (6b) so as to maintain the frequency of said electrical signal constant is inserted between said means (13) generating said electrical signal and said voltage source (6b).

5. A device as claimed in claim 1, characterized in that said means (9, 10; 27, 28; 33, 34) generating a velocity difference between the two partial beams (4, 5) are connected to an antenna.

6. A device as claimed in any of claims 1 to 5, characterized in that said means (9, 10; 27, 28; 33, 34) generating a velocity difference between the two partial beams (4, 5) comprise a pair of electrodes placed on the trajectory of one of the partial beams.

7. A device, as claimed in any of claims 1 to 5, characterized in that said means (9,10; 27,28; 33,34) generating a velocity difference between the two partial beams (4,5) comprise two pairs of electrodes placed each on the trajectory of a respective partial beam and connected to different voltages.

8. A device as claimed in any preceding claim, characterized in that the means splitting and recombining the particle beam are made from a single silica crystal (20).

9. A device as claimed in any of claims 1 to 7 characterized in that the particle beam splitting and recombining means consist of a wave-guide manufactured by integrated-optics techniques.

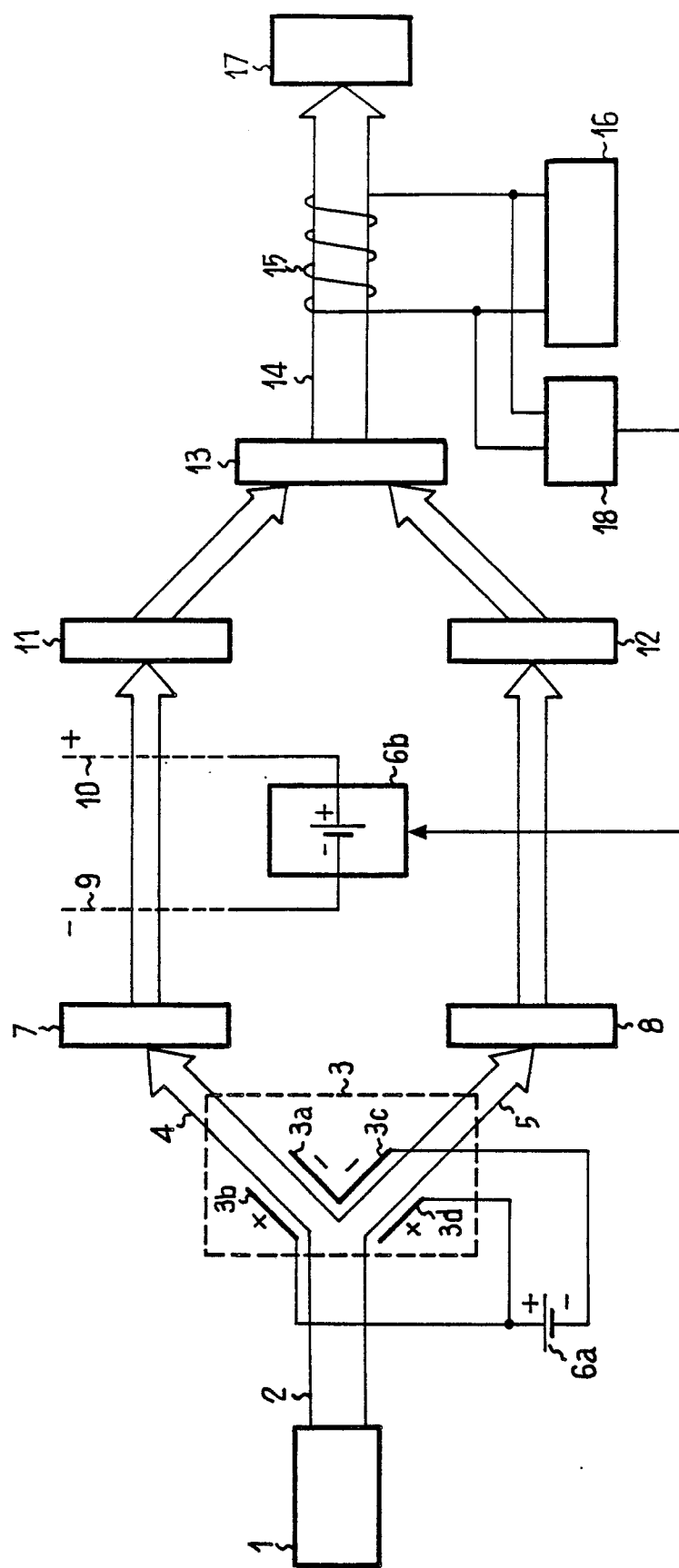


FIG. 1

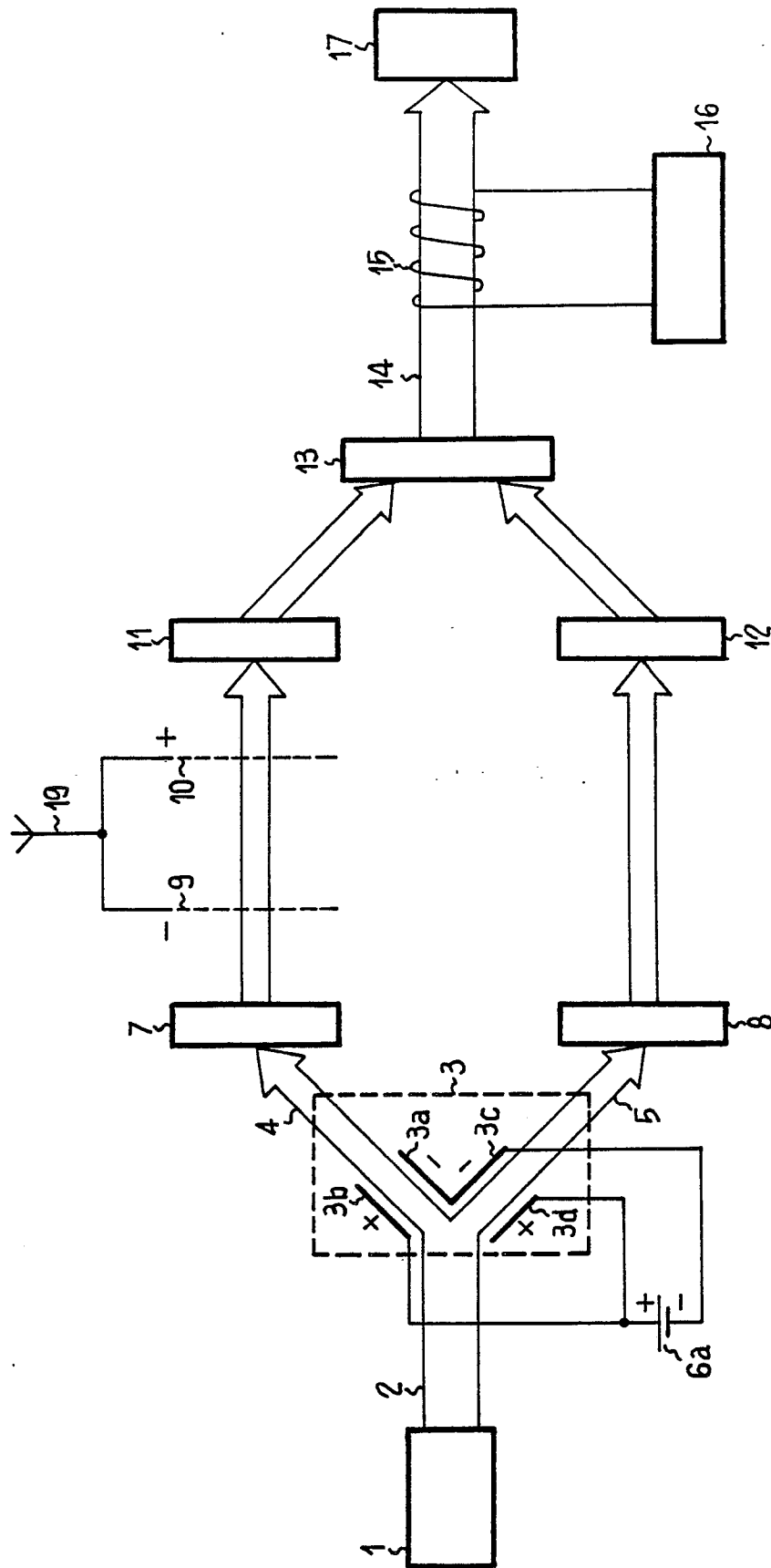


FIG. 2

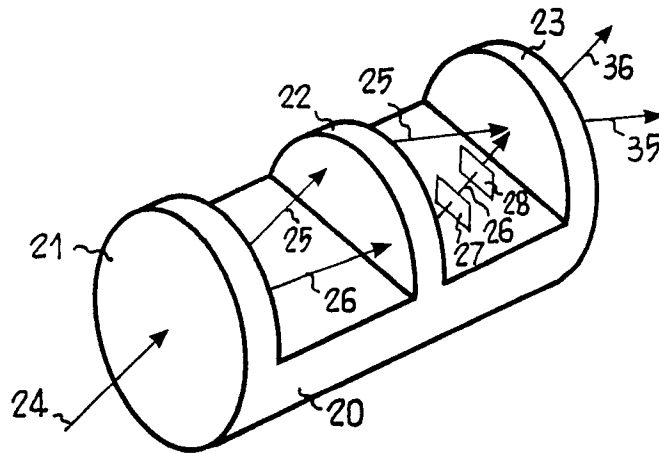


FIG. 3

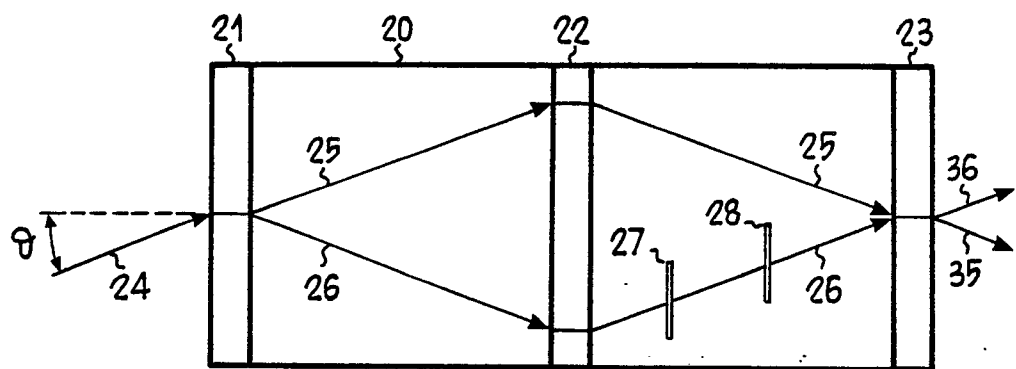


FIG. 4

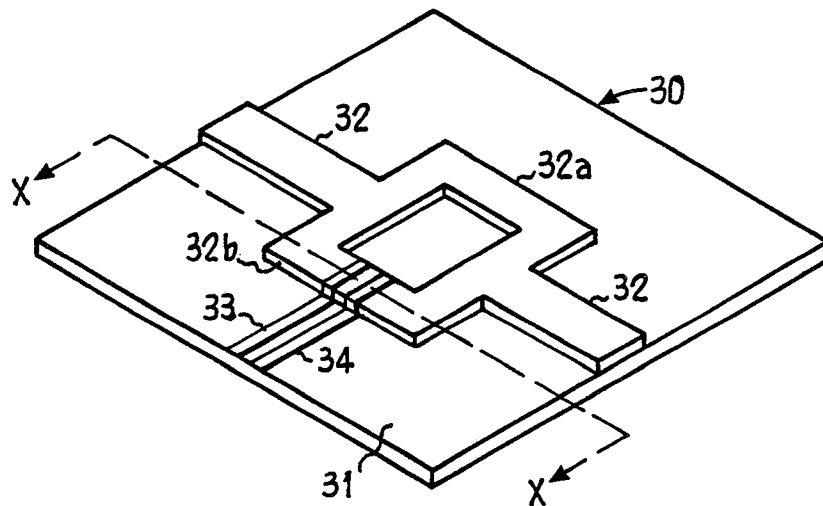


FIG. 5

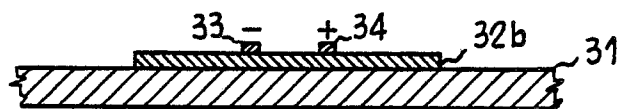


FIG. 6