United States Patent

[11] 3,549,891

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[21]	Appl. No.	**573,416**
[22]	Filed	**Aug. 18, 1966**
[45]	Patented	**Dec. 22, 1970**
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[32]	Priority	**Sept. 20, 1965**
[33]		**Great Britain**
[31]		**No. 39903/65**

[54] **CYCLOTRON RESONANCE PHOTOTUBE HAVING AXIAL MAGNETIC FIELD AND TRANSVERSE ELECTRIC FIELD**
7 Claims, 2 Drawing Figs.

[52] **U.S. Cl.** **250/211,** 250/41.9, 250/207, 313/94, 330/4.7
[51] **Int. Cl.** **H01j 39/14**
[50] **Field of Search** .... 250/207, 24, 41.9(2), 199; 313/94; 330/4—7

[56] **References Cited**

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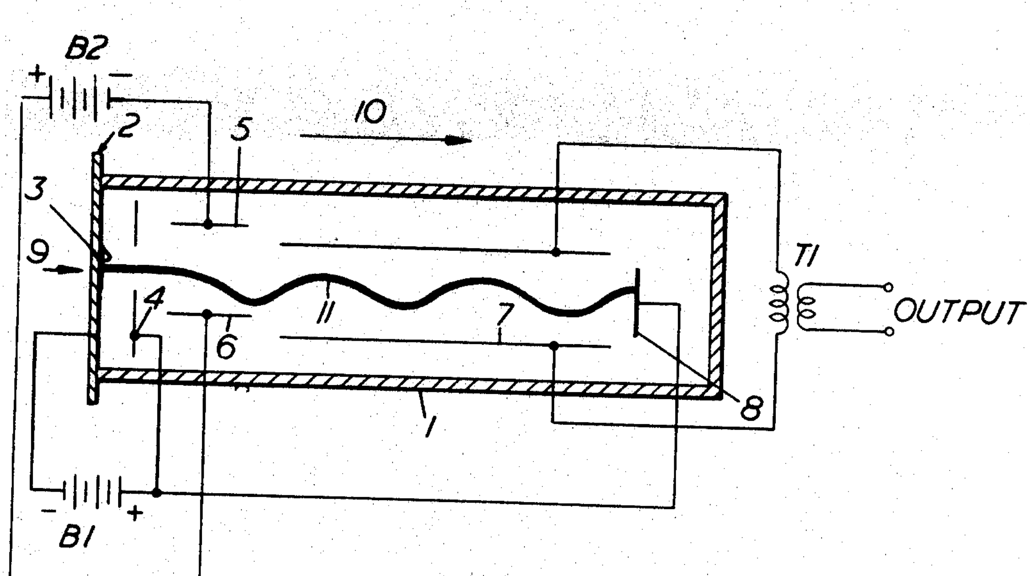
ABSTRACT: A photocathode at one end of a phototube emits an electron beam having a spiral motion at a cyclotron resonance frequency. An axial magnetic field and transverse DC electric field provide the beam with the spiral motion and the rotational energy is extracted by an output coupler. A collector electrode at the other end, having a DC potential applied thereto, collects the electron beam. A quadrupole amplifier between the field electrodes and coupler may provide improved sensitivity.



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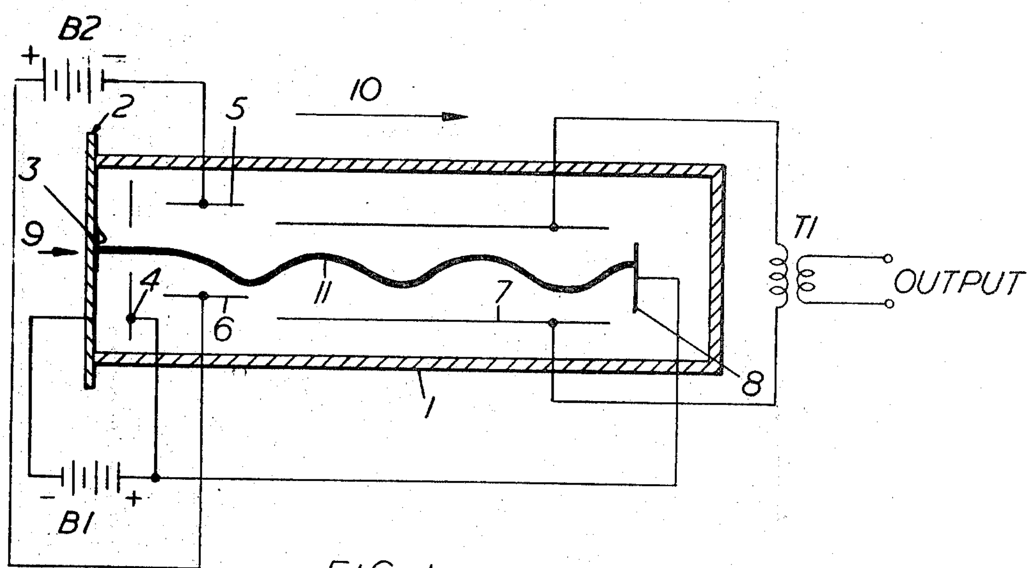

FIG. 1.

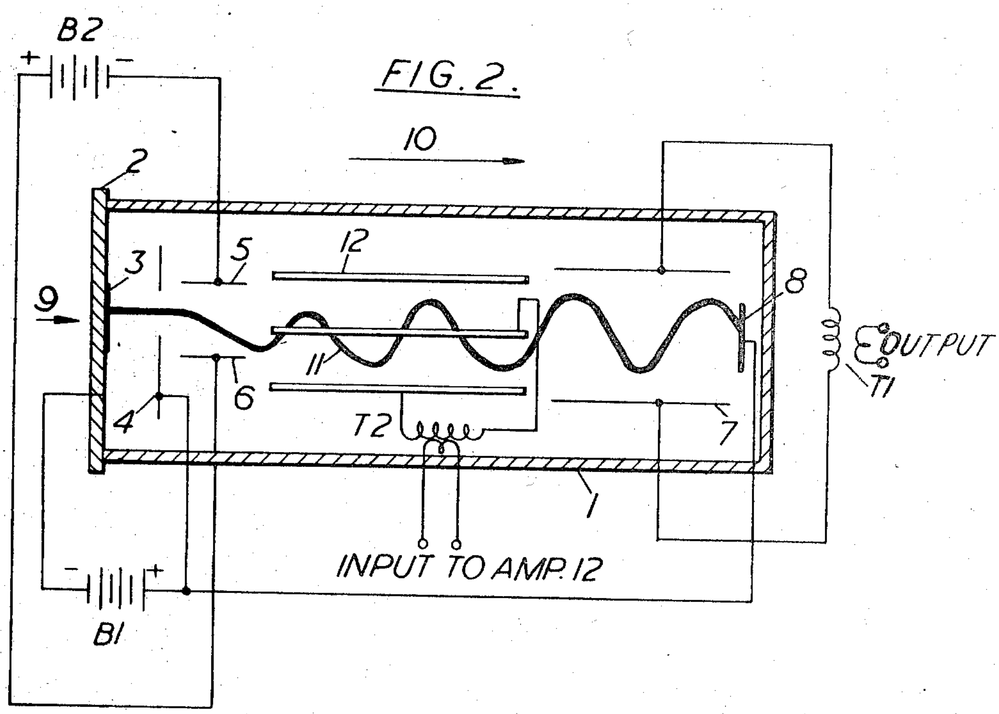

FIG. 2.

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CYCLOTRON RESONANCE PHOTOTUBE HAVING AXIAL MAGNETIC FIELD AND TRANSVERSE ELECTRIC FIELD

CYCLOTRON RESONANCE PHOTOTUBE

The invention relates to a cyclotron resonance phototube.

The invention provides a cyclotron resonance phototube having an axial magnetic field comprising in axial order between a photocathode situated at one end of said phototube and a collector electrode situated at the opposite end of said phototube, an anode electrode, means for establishing a transverse DC electric field and an electron output coupler, said anode electrode being electrically coupled to said photocathode such that a potential difference exists between same, and to said collector electrode thereby maintaining it at the same potential.

According to one feature of the invention a quadrupole amplifier is interposed between the electron output coupler and said means for establishing the transverse DC electric field.

The foregoing and other features according to the invention will be understood from the following description with reference to the accompanying drawings in which:

FIG. 1 shows a cross sectioned side view of a cyclotron resonance phototube.

FIG. 2 shows a cross sectioned side view of a cyclotron resonance phototube with a quadrupole amplifier.

Referring to FIG. 1, a cross sectioned side view of a cyclotron resonance phototube is shown and comprises a cylindrical outer case 1 closed at one end, the open end of the outer case 1 being provided with a plate 2 which contains the semitransparent photocathode 3. Supported within the outer case 1 by means not shown are the anode 4, "twister" electrodes 5 and 6, output electron coupler 7 and the collector 8. A magnetic field 10 is provided parallel to the axis of the phototube.

The photocathode 3 is connected to the anode 4 by an electrical power source B1, for example, a 6 to 10 volts battery, thereby providing a potential drop between the anode 4 and the photocathode 3 to accelerate the electron beam 11 emitted from the photocathode 3. The anode 4 which is connected to the positive terminal of the power source B1 is also connected to the collector 8 thereby maintaining it at the same potential. A static transverse electric field is established between the "twister" electrodes 5 and 6 by way of an electrical power source B2, for example, a 6 to 100 volts battery. The output electron coupler 7, for example, a known type electron coupler which will couple out rotational energy of the electron beam, is situated between the "twister" electrodes 5 and 6 and the collector 8 and is connected to the primary winding of a transformer T1. A coupler of this type is described in an article by C. L. Cuccia in the RCA Review, Vol. 10, Page 270 dated Jun. 1949. The secondary winding of this transformer provides the output for the phototube. The "twister" electrodes 5 and 6 are offset relative to the axis of the electron coupler 7 in order to ensure that the electron beam 11 on leaving the "twister" electrodes 5 and 6 enters the electron coupler 7 on its central axis.

When a pair of coherent light beams, or a single modulated light beam 9 falls on the photocathode 3, the electrons which are emitted form a modulated beam of electrons 11 which is accelerated parallel to the static magnetic field 10, as previously stated, by a potential drop of a few volts between the anode 4 and the cathode 3. The modulation causes density bunching of the electrons. After receiving an initial velocity between the photocathode 3 and the anode 4, the electron beam 11 passes through the static intense transverse electric field established by the "twister" electrodes 5 and 6, this passage being timed by proportioning the electrodes, and electric and magnetic fields to last one-half cycle of the cyclotron resonance frequency. In this passage, the electron beam 11 interacts with the combined transverse electric field and axial magnetic field 10 thereby causing the electron beam 11 to tend to spiral, the electrons receive a maximum of transverse energy and any longitudinal bunching of the electrons within the electron beam 11 is converted into a fast cyclotron wave. The electrons emerge in a synchronous phase relationship and rotate at the cyclotron frequency. By making the electric field established between the "twister" electrodes 5 and 6 sufficiently high, the effect of transverse noise components may be negated.

This cyclotron wave enters the output electron coupler 7 and all of the R.F. cyclotron energy is extracted and coupled to the output via the transformer T1. To clearly visualize the operation of the output electron coupler 7, the electron energies must be identified. The electron receives energy from the accelerating beam potential which causes it to proceed axially to the collector. This energy will determine the transit time. It receives rotational energy from the transverse field established by the "twister" electrodes 5 and 6 and it is this rotational energy which induces the alternating current output to be established and passed to the output system via the transformer T1.

Although the system shown in the drawing according to FIG. 1 indicates conventional vacuum tube electrodes, the output electron coupler 7 may be replaced by its waveguide analogue. Also, because of the simplicity of the structure, it is possible to use an opaque photocathode 3 and illuminate it from the output end of the phototube.

The bandwidth of the phototube is limited mainly by the bandwidth of the output electron coupler 7, which might be a few percent, and the operating frequency would usually be chosen to be in the immediate vicinity of the cyclotron resonance frequency.

Referring to FIG. 2, a cross sectioned side view of a cyclotron resonance phototube with a quadrupole amplifier is shown. The construction of this phototube is exactly the same as the phototube according to FIG. 1 except for the quadrupole amplifier 12, represented by longitudinal conductors at the corners of a square shaped channel. The conductors are situated between the "twister" electrodes 5 and 6 and the output electron coupler.

The phototube operates in exactly the same way as the phototube according to FIG. 1 except the sensitivity of the unit is increased due to the quadrupole amplifier 12.

The quadrupole amplifier 12 is a tube in which quadrupole fields act parametrically upon the fast cyclotron wave of an electron beam to produce an increased transverse motion and amplification. The quadrupole amplifier 12 is excited by way of the input transformer T2 at twice the cyclotron frequency, and the fast cyclotron waves entering it are amplified by the parametric amplification effect which does not depend upon the magnitude of the current. The amplified waves pass into the output electron coupler 7 where the R.F. cyclotron energy is extracted from the electron beam 11 and coupled to the output as previously described. An amplifier of this type used in conjunction with a fast cyclotron wave is described in an article by R. Adler, G. Urbek and G. Wade, in the Proceedings of the I.R.E., Vol. 47, Page 1713, dated Oct. 1959.

Considerations with regard to the bandwidth of the phototube and its operating frequency are the same as outlined for the phototube according to FIG. 1.

Although the system shown in the drawing according to FIG. 2 indicates conventional vacuum tube components, the output electron coupler 7 and the quadrupole amplifier 12 may be replaced by their wave guide analogs.

The advantages of these units are: provides efficient narrow band mixing or demodulation of light beams; wide range of operating frequencies; low voltage requirements; compact, rugged structure.

It is to be understood that the foregoing examples of specific examples of this invention is made by way of example only and is not to be considered as a limitation on its scope.

I claim:

1. A cyclotron resonance phototube comprising an axial magnetic field disposed along said phototube, said phototube including in axial order between a photocathode situated at

one end thereof, said photocathode emitting an electron beam in response to a light beam impinging thereon, and a collector electrode situated at the opposite end of said phototube for collecting said beam; an anode electrode for accelerating said electron beam; parallel plate electrode means disposed about said electron beam for applying a transverse DC electric field to said electron beam; said transverse electric field and axial magnetic field providing said electron beam with a spiral motion, and an electron output coupler coupling out rotational energy of said beam; direct current supply means connected to said parallel plate electrode means and means establishing a potential difference between said collector electrode and photocathode; whereby said electron beam spiral motion has a predetermined cyclotron resonance frequency.

2. A cyclotron resonance phototube as claimed in claim **1** in which a quadrupole amplifier is interposed between the electron output coupler and said means for applying a transverse DC electric field.

3. A cyclotron resonance phototube as claimed in claim **1** in which said means for applying a transverse DC electric field include a pair of electrodes having said DC electric field therebetween transverse to the direction of the axial magnetic field to provide said spiral motion to said electron beam.

4. A cyclotron resonance phototube as claimed in claim **3** in which the center line of said pair of electrodes is displaced relative to the common center line of the remaining axially spaced components but maintained parallel with same.

5. A cyclotron resonance phototube as claimed in claim **3** in which said electron output coupler includes transformer means to facilitate the extraction of the output from the phototube.

6. The device of claim **3** wherein the electrodes and electric and magnetic fields are proportioned to time the passage of the electron beam through said pair of electrodes to last one half cycle of the cyclotron resonance frequency.

7. The device of claim **3** wherein said anode and collector electrodes are at the same potential.