

June 25, 1968

M. B. FISHER

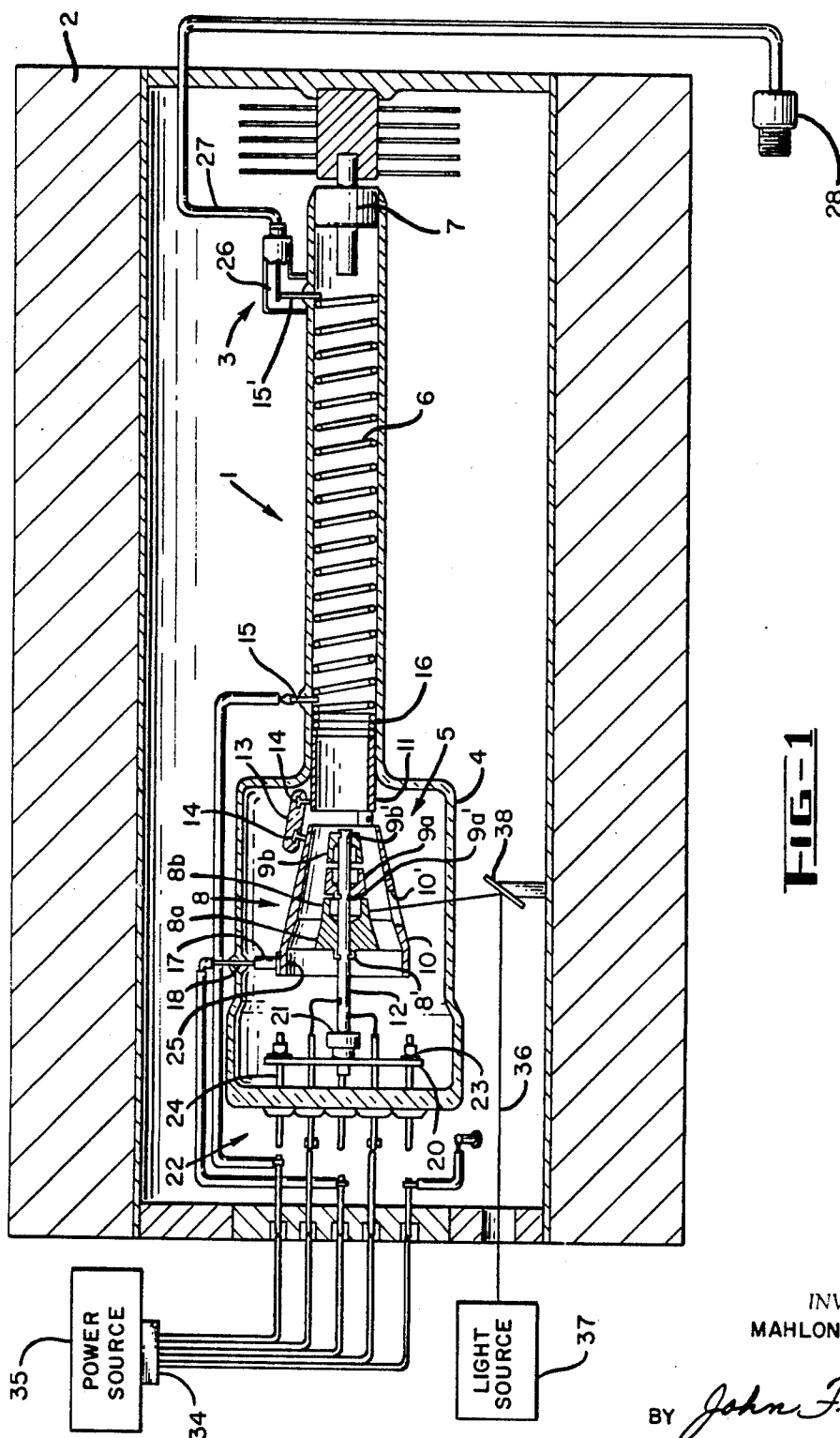
3,390,272

PHOTOMULTIPLIER

444,241

Filed March 31, 1965

2 Sheets-Sheet 1



INVENTOR
MAHLON B. FISHER

BY *John F. Lawler*
ATTORNEY

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2 Sheets-Sheet 2

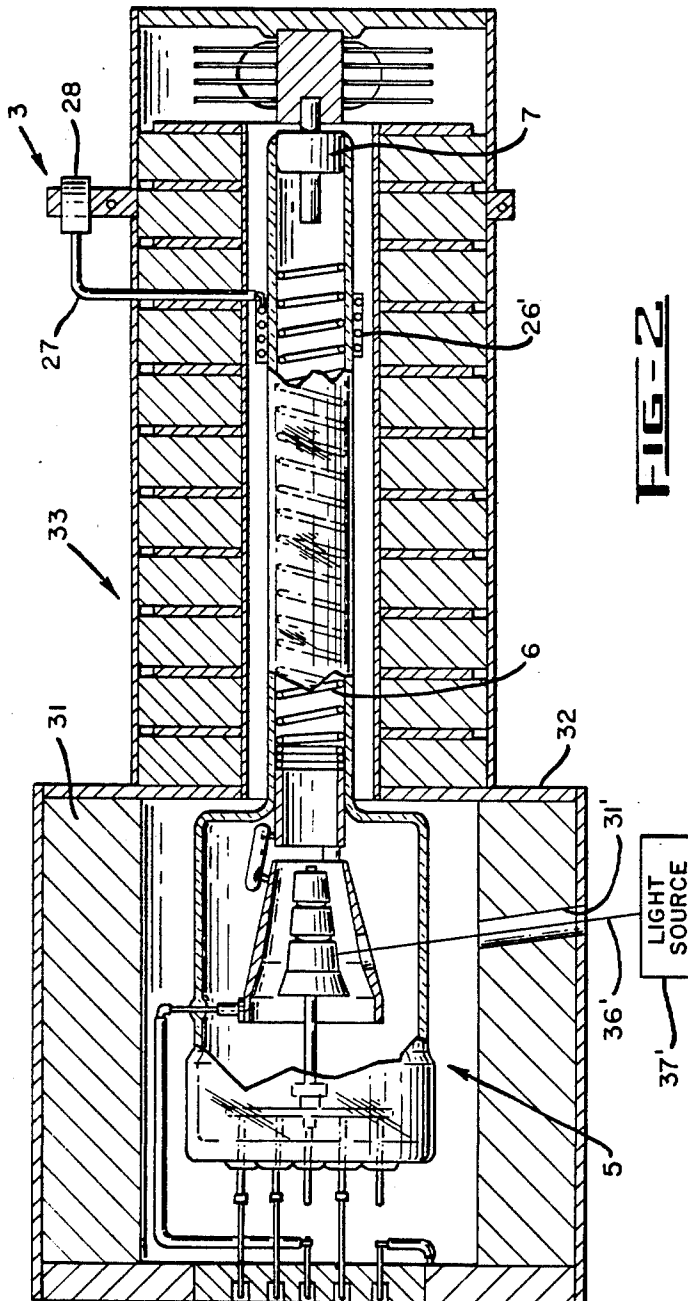


FIG-2

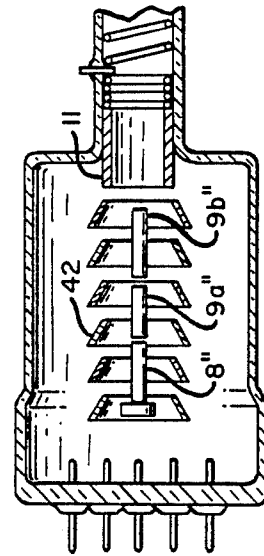


FIG-4

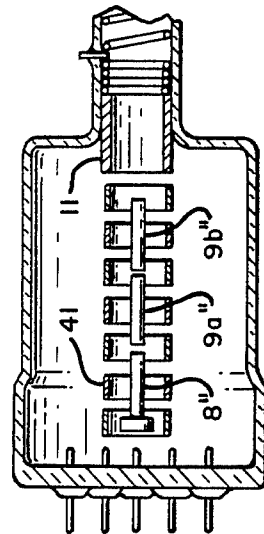


FIG-3

INVENTOR
MAHLON B. FISHER

BY *John F. Lawler*
ATTORNEY

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PHOTOMULTIPLIER

Mahlon B. Fisher, Monte Sereno, Calif., assignor to Sylvania Electric Products Inc., a corporation of Delaware

Filed Mar. 31, 1965, Ser. No. 444,241

17 Claims. (Cl. 250-199)

ABSTRACT OF THE DISCLOSURE

This photomultiplier comprises an electron gun and helical slow wave structure supported in axial alignment and located in an axial magnetic field. The cathode and dynode electrodes of the electron gun comprise axially spaced truncated cones having external electron emissive surfaces. A hollow focus-accelerating electrode is radially spaced from and is supported coaxially around and substantially coextensive with the cathode and dynodes. The focus-accelerating electrode also has a truncated conical shape and has an opening therein through which light is passed to the photosensitive surface of the cathode.

This invention relates to photomultipliers and more particularly to means for detecting and amplifying microwave modulation of optical wavelength signals.

One method of detecting a modulated light beam is the use of photoelectron emission from a photosensitive cathode illuminated by the modulated light beam. Since the current generated by the photoelectron emission process is very small, it is desirable to amplify the current to a sufficient magnitude to be more readily useful. It is particularly desirable to amplify the photoelectron current such that the shot noise caused by irregularities in the emission of electrons from the cathode exceeds the thermal noise produced by random motion of electrons in the output coupling mechanism caused by thermal action. Conventional photomultiplier tubes such as described in volume NS-11, IEEE Transactions on Nuclear Science, June 1964, are available for multiplying photoelectron current modulated by low frequency signals to such a level. These devices are not suitable, however, for amplifying photoelectron current modulated at microwave frequencies because of the relatively large spread or variation in transit time of electrons such as when traveling from one end of the tube to the other which is characteristic of multipliers. Photomultipliers proposed for amplifying signals generated by optical wavelength radiation modulated at microwave frequencies are described in "Dynamic Crossed Field Electron Multiplier" (DCFEM), by O. L. Gaddy and D. F. Halshauser in "Proceedings of the IRE," volume 50, No. 2, page 207, February 1962; "High Speed Photomultipliers," by R. C. Miller and N. C. Wittwer, Bell Telephone Laboratories, Inc., in IEEE International Convention Record, volume 13, part 5, page 7, 1965; and "LASECONS: Microwave Phototubes With Transmission Photocathodes," by D. J. Blattner et al., in IEEE International Convention Record, volume 11, part 3, page 79, 1963. Particularly, the latter photomultiplier has limited current carrying capability, is fragile and has relatively short life. The other two photomultipliers require relatively large and heavy magnets and have a low equivalent resistance such that many stages of multiplication are required to provide a specified signal level.

An object of this invention is the provision of a photomultiplier capable of operating with large beam currents while having a longer life than has been heretofore achieved.

Another object is the provision of a microwave photomultiplier employing a small lightweight magnetic focusing structure.

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Another object is the provision of a photomultiplier requiring fewer stages than conventional microwave photomultipliers to obtain the same degree of amplification.

Another object is the provision of a microwave photomultiplier having low transit time spread.

Another object is the provision of a microwave photomultiplier having a high current density electron beam-forming multiplier structure capable of operating with a helical slow wave structure.

In accordance with a preferred embodiment of this invention, an optical wavelength signal modulated at microwave frequencies is incident on the photosensitive cathode surface of an electron gun in an axial magnetic field. The electron gun comprises an elongated cathode shaped like a cone axially aligned with and spaced from a plurality of axially spaced similarly shaped dynodes. A hollow focus-accelerating electrode also having the shape of a truncated cone is supported coaxially around and substantially coextensive with and radially spaced from the cathode and dynodes. A photosensitive emission layer on the external cathode surface is located adjacent to an opening in the focus-accelerating electrode through which the modulated light beam is directed toward the cathode. Each electron emitted by the cathode travels in a cycloidal path and generates a plurality of secondary electrons upon impact with the adjacent dynode. The secondary electrons also follow a cycloidal path and successively strike adjacent dynodes to generate successively greater numbers of secondary electrons at each dynode. The beam of secondary electrons from the last dynode traverses an adjacently located helical slow wave structure and terminates at a collector electrode at the opposite end of the slow wave structure. The modulation signal on the electron beam is transferred to a traveling wave on the slow wave structure. The amplified signal is coupled from the traveling wave on the helix by well known coupling techniques.

This invention and these and other of its objects will be more fully understood from the following description of a preferred embodiment thereof, reference being had to the accompanying drawings in which:

FIGURE 1 is a longitudinal cross sectional view of a traveling wave photoelectron multiplier embodying this invention and employing a solenoid focusing structure;

FIGURE 2 is a modified form of the embodiment of FIGURE 1 wherein the photoelectron multiplier employs a permanent magnet focusing structure; and

FIGURES 3 and 4 are modified forms of the electron beam forming multiplier structure shown in FIGURES 1 and 2.

Referring to FIGURE 1, the photoelectron multiplier comprises a phototube 1, a solenoid 2 and output coupling means 3. Phototube 1 is an electron tube comprising an evacuated vacuum envelope 4 enclosing an electron gun or beam-forming multiplying structure 5, a slow wave structure 6 and a collector electrode 7.

Electron gun 5 comprises a cathode 8, axially aligned dynodes 9a and 9b, a coaxial hollow focus-accelerating electrode 10 in the shape of a truncated cone and a ring electrode 11. Electrode 10 performs the dual function of electrostatically focusing electrons and accelerating their movement through the gun structure. Cathode 8 is symmetrical about its longitudinal axis and comprises truncated-cone sections 8a and 8b. The dynodes are also truncated-cone electrodes symmetrical about their longitudinal axes. The cathode and dynodes have a central opening extending the length of each electrode for receiving a support or mounting rod 12 made of electrically nonconductive material such as aluminum oxide. Cathode 8 and dynodes 9a and 9b are axially spaced from each other on and rigidly secured to rod 12 such as by brazing. Alternatively, the cathode and dynodes may be secured

to support rod 12 by swedging tabs 8' and 9' into mounting recesses in the support rod. The slope of the conical surfaces and the axial spacing of cathode section 8b and the dynodes are such that a plane through the longitudinal axes of the dynodes and section 8b of the cathode cuts their outer surfaces in a straight line.

Dynodes 9a and 9b are preferably made of beryllium copper. The dynodes are preferably fired in an oxidizing atmosphere under a partial vacuum to form a secondary emission coating of beryllium oxide on the outer surface thereof. Cathode 8 is preferably a non-magnetic metal. The outer surface of conical cathode section 8b is coated with a photosensitive electron emitting material. When an S1 photosensitive surface such as described in "Methods of Experimental Physics," number 6, part B, page 389, by A. H. Sommer and W. E. Spicer, Academic Press, 1959, is employed, the cathode is made of solid silver. The photosensitive surface is preferably formed by oxidizing the silver under a partial vacuum and then subjecting the cathode to a cesium atmosphere until maximum cathode emission is obtained.

The wall of the focus-accelerating electrode 10 has an opening 10' thereon adjacent conical cathode section 8b. Electrode 10 and ring electrode 11 are physically connected such as by glass beads 13 embedded in mounting pins 14 which are welded to the electrodes. Ring electrode 11 is electrically connected to slow wave structure 6 and lead pin 15 such as by a choke helix 16. Electrode 10 is secured in the vacuum envelope by tabs 17 which are welded to the electrode and pins 18.

Alignment rod 12 is secured to a metal mounting plate 20 by a nut 21. Mounting plate 20 is secured to a header 22 by tabs 23, which are welded to the mount plate and header pins 24. Rod 12 has several holes (not shown) extending axially therethrough. These holes contain wires for electrically connecting the cathode and dynodes to separate header pins 24. The header assembly comprises plate 20, rod 12, cathode 8 and dynodes 9. When header 22 is sealed to vacuum envelope 4, the header assembly is positioned such that electrode 10 is coaxial with and substantially coextensive with the cathode and dynodes. The overall axial length of electrode 10 is slightly greater than the overall length of the cathode and dynodes.

Slow wave structure 6 is an efficient circuit for coupling energy from the electron beam since it has a high equivalent resistance. The slow wave structure is preferably a helix of the type employed in conventional traveling wave tube amplifiers. One end of helix 6 is welded to pin 15 adjacent the end of the vacuum envelope containing electron gun 5. The other end of the helix is welded to output pin 15' adjacent collector electrode 7.

Output coupling means 3 comprises a cavity 26 surrounding pin 15'. The inner conductor of a coaxial transmission line 27 is connected to pin 15'. The other end of the coaxial transmission line is connected to connector 28.

Solenoid 2 provides a uniform unidirectional axial magnetic field over the length of the phototube. When a lightweight structure is required, the photomultiplier employing the permanent magnet structure illustrated in FIGURE 2 may be employed to provide this magnetic field. This alternate structure comprises a cylindrical magnet 31, a magnetic pole piece 32 and a periodic permanent magnet structure 33. Cylindrical magnet 31 has a transverse opening 31' in its wall aligned with opening 10' in electrode 10 and cathode section 8b. Magnet 31 is coaxial with and substantially coextensive with electron gun 5 for providing a uniform axial magnetic field over the combined length of cathode 8 and dynodes 9. Pole piece 32 prevents the periodically varying magnetic field of magnet structure 33 at helix 6 from adversely affecting the unidirectional axial magnetic field at the cathode and dynodes. Output coupling means 3 preferably comprises a coupling helix 26'.

The dynodes, electrodes and helix of the phototube are electrically connected through a connector 34, see FIG-

URE 1, to a source 35 of DC potential. Cathode 8 is maintained at a reference potential. Dynode 9a is maintained at a positive potential with respect to the cathode. Each dynode is maintained at a somewhat higher potential than that of the adjacent dynode in the direction of the cathode. Focus-accelerating electrode 10 is maintained at a much higher positive potential than either the dynodes or the cathode. The electric potential on ring electrode 11 and helix 6 is maintained at the synchronous velocity of a traveling wave associated with the helix. Collector electrode 7 is preferably maintained at a somewhat more positive potential than the helix. In certain applications, helix 6 and focus-accelerating electrode 10 may be operated at the same potential by electrically connecting pins 15 and 18, respectively. The cone angles of cathode 8, dynodes 9a and 9b and focus-accelerating electrode 10 and the electrode potentials are adjusted to provide between both the axially aligned cathode and dynodes and the coaxial conical electrode 10 an electric field having axial and radial components.

In operation, an amplitude-modulated light beam 36 from light source 37 is reflected by optical mirror 38 through aperture 10' of electrode 10 to illuminate a spot on the photosensitive surface of conical cathode section 8b. Modulation of light beam 36 is detected by the photosensitive cathode which generates an electron beam whose electron density varies at the modulation rate of the light beam. Primary electrons are emitted perpendicular to the surface of cathode 8. These electrons are simultaneously accelerated radially toward focus-accelerating electrode 10 and axially toward the dynodes by the electric field between these electrodes. The axial magnetic field imparts to the electrons a circular motion about the axis of the cathode. Thus, the space charge waves of the electron beam comprise both transverse and longitudinal wave components. The primary electrons move in a cycloidal or spiral path about the axis of the tube and strike the outer surface of dynode 9a. The transit time spread of the electron beam is reduced through acceleration of electrons by the high voltage focus-accelerating electrode 10 while concurrently maintaining the secondary emissive dynode 9a at a relatively low voltage. Electrons striking dynode 9a cause a greater number of secondary electrons to be emitted by the dynode. The secondary electrons from dynode 9a also follow a cycloidal path about the axis of the tube, strike dynode 9b, and similarly cause an even greater number of secondary electrons to be emitted from that electrode. More electrons are emitted by each dynode than strike it. Thus, the density of the electron beam emitted by cathode 8 is increased or multiplied by operation of dynodes 9. Although only two dynodes are illustrated here, more may be employed as required for a higher multiplication factor. Electrons emitted from dynode 9b describe a helical path about the axis of the tube within and adjacent helix 6 and are collected by electrode 7.

Modulation of the electron beam is in the form of space charge waves. These space charge waves comprise both transverse and longitudinal modulation components as a result of the helical trajectories of the electrons in the gun region. The slow wave structure supports a traveling electromagnetic wave having a fixed phase velocity synchronized with the slow space charge waves and energy is interchanged between the synchronized longitudinal and traveling waves. The modulation signal is extracted from the traveling wave by cavity coupler 26 and provided at connector 28 for connection to external equipment.

The power output P_0 of a multiplier is

$$P_0 = \frac{1}{2} i^2 R_{eq} \quad (1)$$

where i is the modulation component of the photocurrent and R_{eq} is the equivalent resistance of the multiplier. The equivalent resistance of the DCFEM and Miller-Wittwer photomultiplier is about 50 ohms as opposed to an equivalent resistance of about 1000 times that value for a

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photomultiplier incorporating this invention. Thus, a very large photocurrent or multiplication is required to obtain a specified signal level from the DCFEM and Miller-Wittwer photomultipliers. In contrast, the same output may be obtained with a multiplier incorporating this invention with a much smaller photocurrent or multiplication because of the very high equivalent resistance of the output circuit. For example, a multiplier having a 50 ohm equivalent resistance has an output power of

$$P_{0_1} = \frac{1}{2} i_k^2 (M_1^2 R_{eq_1}) \quad (2)$$

where M is multiplication. A multiplier incorporating this invention has an output power of

$$P_{0_2} = \frac{1}{2} i_k^2 (M_2^2 R_{eq_2}) \quad (3)$$

Equating Equations 2 and 3, it is seen that a photomultiplier incorporating this invention requires only 7% of the multiplication of the multiplier having a 50 ohm equivalent resistance to provide the same output power. Thus, the photomultiplier incorporating this invention has a longer life since current at and heating of the last dynode are substantially less. If additional cooling of cathode 8 and dynodes 9 is required or desired, alignment rod 12 may be made of a heat conductive electrically non-conductive material such as beryllium oxide. Special precautions must be taken, however, in metallizing and firing this material.

Referring to the modified forms of electron gun 5 in FIGURES 3 and 4, cathode 8" and dynodes 9" may be elongated cylindrical electrodes. The focus-accelerating electrode may comprise a plurality of concentric ring electrodes 41 (FIGURE 3) or truncated-cone electrodes 42 (FIGURE 4) which are axially spaced apart and supported coaxially of and substantially coextensive with the cathode and dynodes. The DC electric potential applied to electrodes 41 or 42 are adjusted to provide substantially the same electric field between both the cathode and dynodes and the focus-accelerating electrode as in the embodiment of FIGURES 1 and 2.

By way of example, a traveling wave photomultiplier similar to the embodiment of FIGURE 1 was built and tested and had the following parameters and operation:

Number of dynodes	3
Cone angles (included angle):	
Cathode section 8b	4°24'
Dynodes 9	4°24'
Electrode 10	10°48'
Axial length:	
Cathode section 8b	0.250
Dynodes 9 (each)	0.118
Electrode 10	1.0
Inner diameter, minimum:	
Electrode 10	0.352
Outer diameter, minimum:	
Cathode section 8b	0.160
Helix:	
Barrel	fluted
TPI	10.0
Wire diameter	0.015
Inner diameter	0.350
Length	8.0
Voltages:	
Cathode 8	0
Dynode 9a	300
Dynode 9b	600
Dynode 9c	900
Electrode 10	3500
Electrode 11	3500
Helix 6	3500
Collector 7	3560
Magnetic field	1000
Modulation index	20

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Cathode	S1
Light beam diameter	inch-- 0.020
Modulated cathode photocurrent	
amperes, average	0.2 × 10 ⁻⁶
5 Current from last dynode	do-- 40 × 10 ⁻⁶
Equivalent resistance	ohms-- 3 × 10 ⁻⁴
Power output	d.b.m-- -35
Bandwidth	G c.p.s.-- 1-3
Signal to noise ratio	db-- 45

Although this invention is described in relation to a preferred embodiment thereof, variations and modifications will be apparent to those skilled in the art. For example, light beam 36 may comprise both a local oscillator light signal and a modulated light beam in order to provide heterodyne operation and an intermediate frequency signal from the cathode. Also, the structural rigidity of the tube may be increased by inserting into mounting rod 12 a reinforcing rod 44 which is secured to collector electrode 7 and extends axially down the length of helix 6. The scope and breadth of this invention, is therefore to be determined from the following claims rather than from the above detailed description of a preferred embodiment thereof.

What is claimed is:

1. A photoelectron gun comprising:

first electrode means comprising an elongated enclosure open at least at one end and having an axis, a plurality of other elongated electrodes supported coaxially within said first electrode means and being axially spaced from each other, one of said other electrodes adjacent one end of said first electrode means having an external photosensitive electron emissive surface, the other of said other electrodes being dynode electrodes having external electron emissive surfaces, said first electrode means having an aperture for passing a beam of light therethrough to the photosensitive surface of said one of said other electrodes, means for selectively electrically energizing said electrodes, and means for generating a unidirectional axial magnetic field.

2. The photoelectron gun according to claim 1 wherein said other electrodes are truncated cones.

3. A photomultiplier comprising:

first electrode means comprising an elongated enclosure open at least at one end and having an axis, a plurality of other elongated electrodes supported coaxially within said first electrode means and axially spaced from each other, one of said other electrodes adjacent one end of said first electrode means having an external photosensitive electron emissive surface, the remainder of said other electrodes comprising dynode electrodes having electron emissive surfaces, said first electrode means having an aperture for passing a beam of light therethrough to the photosensitive surface of said one of said other electrodes, a collector electrode axially aligned with and spaced from said other electrodes opposite from said one of said other electrodes, means for selectively electrically energizing said electrodes, and means for establishing an axial magnetic field at said electrodes.

4. A photomultiplier comprising:

first electrode means comprising an elongated enclosure open at least at one end and having an axis, a plurality of other elongated electrodes supported coaxially within said first electrode means and axially spaced from each other, one of said other electrodes adjacent one end of said first electrode means having an external photosensitive electron emissive surface,

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the other of said other electrodes comprising dynode electrodes having electron emissive surfaces, said first electrode means having a wall with an aperture for passing a beam of light therethrough to the photosensitive surface of said one of said other electrodes,

a collector electrode axially aligned with and spaced from said other electrodes opposite from said one of said other electrodes,

a slow wave structure axially aligned with and located between said other electrodes and said collector electrode,

means for selectively electrically energizing said electrodes and said slow wave structure, and

means for establishing an axial magnetic field at said electrodes and through said slow wave structure.

5. The photomultiplier according to claim 4 wherein said slow wave structure is a helix.

6. A photomultiplier for amplifying a signal associated with a beam of electrons generated in response to a modulated light beam, said photomultiplier comprising:

first electrode means comprising an elongated open enclosure having an axis,

a plurality of other elongated electrodes supported coaxially within said first electrode means and axially spaced from each other,

one of said other electrodes adjacent one end of said first electrode means having an external photosensitive electron emissive surface,

the other of said other electrodes comprising dynode electrodes having electron emissive surfaces,

said first electrode means having a wall with an aperture for passing the modulated light beam therethrough to the photosensitive surface of said one of said other electrodes for generating a modulated beam of electrons,

a collector electrode axially aligned with and spaced from said other electrodes opposite from said one of said other electrodes,

a slow wave structure axially aligned with and located between said other electrodes and said collector electrode,

means for selectively electrically energizing said electrodes and said slow wave structure for simultaneously accelerating the electrons radially toward said first electrode means and axially toward said collector electrode,

means for establishing an axial magnetic field at said electrodes and said slow wave structure whereby the electrons move in a spiral path about the axis and strike the one of said dynodes adjacent said one of said other electrodes producing secondary emission of a larger number of electrons moving in a spiral path and striking successive dynodes for generating more secondary electrons, the electrons from said dynode opposite said one of said other electrodes traversing said slow wave structure for coupling energy to a traveling wave thereon, and

means for coupling a signal from said slow wave structure.

7. A photoelectron gun comprising:

an elongated cathode electrode symmetrical about its axis, said cathode having an elongated external photosensitive electron-emissive surface,

an elongated dynode electrode axially spaced from said cathode, said dynode having an axis coincident with the axis of said cathode and being symmetrical about its axis, and

focus-accelerating electrode means having a hollow elongated section symmetrical about its axis and having an opening therein adjacent said photosensitive surface of said cathode, said accelerating electrode being spaced from, coaxial with and substantially coextensive with said cathode and said dynode.

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8. The photoelectron gun according to claim 7 wherein said cathode is cylindrical.

9. The photoelectron gun according to claim 7 wherein said cathode is a truncated cone.

10. The photoelectron gun according to claim 7 wherein said dynode is cylindrical.

11. The photoelectron gun according to claim 7 wherein said dynode is a truncated cone.

12. The photoelectron gun according to claim 7 wherein said focus-accelerating electrode means comprises a truncated cone.

13. A photoelectron gun comprising:

a truncated cone cathode electrode having an elongated external photosensitive electron-emissive surface,

a truncated cone dynode electrode having an external electron emissive surface and being axially spaced from said cathode and having an axis coincident with the axis of said cathode, and

focus-accelerating electrode means comprising:

a hollow truncated cone section spaced from, coaxial with and substantially coextensive with said cathode and dynode, the wall of said cone section forming an opening therein adjacent said photosensitive surface of said cathode, and

a cylindrical ring axially spaced from said cone section and having an axis coincident with the axis of said dynode.

14. A traveling wave photoelectron multiplier for amplifying a signal on a beam of electrons generated in response to a modulated light beam, said multiplier comprising:

an evacuated electrically non-conductive enclosure containing:

an elongated cathode electrode that is symmetrical about its axis located at one end of said enclosure, said cathode having an elongated photosensitive electron-emissive surface,

an elongated dynode electrode axially spaced from said cathode, said dynode having an axis coincident with the axis of said cathode and being symmetrical about its axis,

focus-accelerating electrode means having a hollow elongated section symmetrical about its axis and having an opening therein adjacent said photosensitive surface of said cathode, said accelerating electrode being spaced from, coaxial with and substantially coextensive with said cathode and said dynode,

a collector electrode located at the opposite end of said enclosure from said cathode and having an axis coincident with the axis of said cathode, and

a slow wave structure located between and axially aligned with said focus-accelerating electrode means and said collector electrode, said structure being symmetrical about an axis coincident with the axis of said cathode,

means for focusing a modulated light beam through the opening in said focus-accelerating electrode means onto said photosensitive cathode surface for producing electrons therefrom,

means for applying DC potentials to said electrodes and said slow wave structure for establishing an axial and radial electric field between said cathode, dynode and said focus-accelerating electrode means for accelerating electrons radially from said cathode and axially toward said collector and for focusing the electrons,

means for establishing a substantially axial magnetic field over the length of said multiplier for causing the electrons to spiral about the axis and strike said dynode to cause emission of secondary electrons therefrom, and for causing the secondary electrons to traverse said slow wave structure to couple energy

to a traveling wave on said structure, said electrons being collected by said collector electrode, and means for coupling a signal from said slow wave structure.

15. A traveling wave photoelectron multiplier for amplifying a signal on a beam of electrons generated in response to a modulated light beam, said multiplier comprising:

an evacuated electrically non-conducting enclosure containing:

a truncated cone cathode electrode having an elongated photosensitive electron-emissive surface, said cathode being located at one end of said enclosure,

a truncated cone dynode electrode axially spaced from said cathode and having an axis coincident with the axis of said cathode,

focus-accelerating electrode means comprising:

a hollow truncated cone section spaced from, coaxial with and substantially coextensive with said cathode and dynode, the wall of said cone section having an opening therein adjacent said photosensitive surface of said cathode, and

a cylindrical ring axially spaced from said cone section and having an axis coincident with the axis of said dynode,

a collector electrode located at the opposite end of said enclosure from said cathode and having an axis coincident with the axis of said cathode, and

a helix slow wave structure located between and axially aligned with said cylindrical ring and said collector electrode, said helix being symmetrical about an axis coincident with the axis of said cathode,

means for focusing a modulated light beam through the opening in said focus-accelerating electrode means onto said photosensitive cathode surface for producing electrons comprising an electron beam having an associated space charge wave varying at a rate proportional to the modulation of the light beam,

means for applying DC potentials to said electrodes and helix for establishing axial and radial electric fields between said cathode, dynode and said focus-

accelerating electrode means for accelerating electrons radially from said cathode and axially toward said collector and for focusing the electrons,

means for establishing a substantially axial magnetic field over the length of said multiplier for causing the electrons to spiral about the axis and strike said dynode to cause emission of secondary electrons therefrom and for causing the secondary electrons to traverse said helix to couple energy to a traveling wave thereon, said electrons being collected by said collector electrode,

means for varying the DC potential applied to said helix for synchronizing the velocity of the space charge wave of the electron beam with the fixed phase velocity of the traveling wave on said helix, and

means for coupling a signal from said helix.

16. A photomultiplier comprising:

first tube-like electrode means having an axis,

a plurality of other tube-like electrodes supported coaxially within said first electrode means and axially spaced from each other,

one of said other electrodes adjacent one end of the first electrode means having an external photosensitive electron emissive surface,

said first electrode means having an aperture therein for passing a beam of light therethrough to the photosensitive surface of said one of the said one of the other electrodes, and

means for selectively electrically energizing said electrodes.

17. The photomultiplier according to claim 16 in combination with a microwave slow wave circuit at the other end of the first electrode means and aligned with the axis thereof.

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HERMAN KARL SAALBACH, *Primary Examiner*.
S. CHATMON, JR., *Assistant Examiner*.