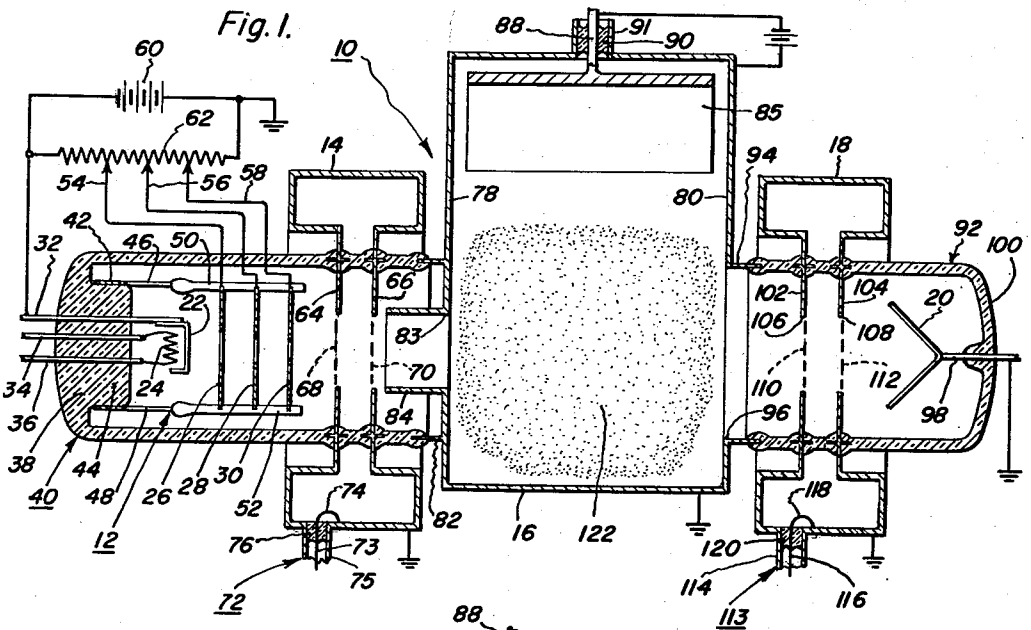
July 30, 1963 J. M. ANDERSON 3,099,768

LOW NOISE ELECTRON BEAM PLASMA AMPLIFIER

Filed March 25, 1959

Fig. 1.



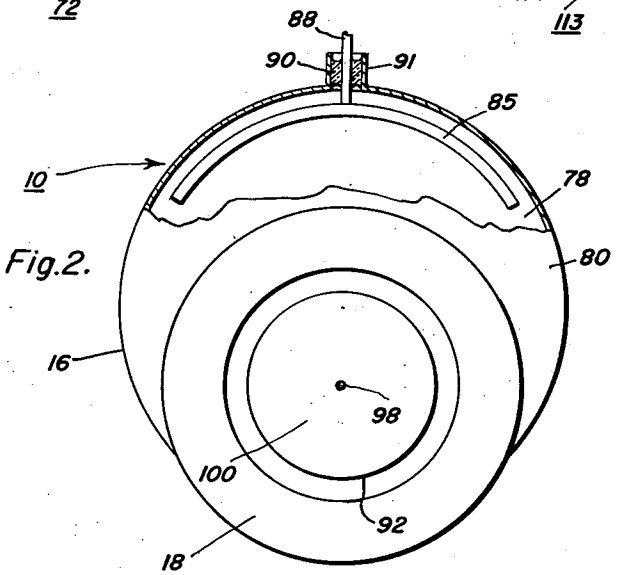


Fig. 2.

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LOW NOISE ELECTRON BEAM PLASMA AMPLIFIER

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This invention relates to an electron discharge apparatus and more particularly to an electronic amplifier device utilizing an electron beam-gaseous discharge plasma interaction, for amplifying electromagnetic wave signals.

In the operation of various electronic apparatus, it is usually necessary to amplify various signals to more tractable magnitudes for allowing various functions to be performed on the signal or for satisfactorily operating various of the circuit devices involved in the apparatus. It is important in increasing the amplitude of a desirable signal to achieve such amplification without introducing noise on the signal as well as to prevent amplification of noise already superimposed on the signal. A wide variety of electronic amplifiers of different types are known for performing such functions and in conventional amplifier circuits, various techniques have been devised for achieving high signal amplification without concomitant noise amplification. In amplifiers exploiting the interaction of an electron beam with the plasma of a gaseous discharge for achieving amplification, however, larger signal-to-noise ratios are desirable.

It is accordingly a principal object of my invention to achieve high amplification and a high signal-to-noise ratio in electromagnetic wave signal amplification utilizing the interaction between an electron beam and a gaseous discharge plasma.

In accordance with my invention and pursuant to the aforementioned object, a density modulated beam of electrons is projected through a gaseous discharge plasma with which it interacts to amplify the modulations on the beam and in accordance with a particular feature of my invention, for minimizing the introduction of noise in the output signal of the amplifier the interacting plasma utilized is that in the negative glow portion of the discharge. Thus, the interacting electrons of the plasma in this region which are of relatively low temperature and low energy, contribute only negligibly to production of noise in the amplification process.

While the specification concludes with claims particularly pointing out and distinctly claiming the subject matter which I regard as my invention, the invention may be better understood from the following description taken in connection with the accompanying drawing in which:

FIG. 1 is an elevation view in section illustrating the construction of a practical form of device according to my invention, and

FIG. 2 is an end view, partly in section, of the device shown in FIG. 1.

Referring now more particularly to the drawing for a detailed description of the invention, in the figures, **10** represents generally an amplifier according to my invention including an electron gun designated generally at **12**, an input cavity **14**, an interaction chamber **16** filled with an ionizable gas at low pressure, an output cavity **18**, and an electron collector **20**. These components are sealed together at adjoining surfaces to form a sealed enclosure which contains the ionizable gas at low pressure as hereinbelow more fully described.

The electron gun **12** comprises an electron emissive, coated cathode **22**, a heater **24** for heating the cathode to a temperature of copius thermionic emission and a plurality of three beam forming or accelerating electrodes

26, **28** and **30** of disk shape and being centrally apertured to accommodate the passage of electrons. The cathode **22** is secured to a conductive rod **32** and heater **24** is connected at its ends to conductive rods **34** and **36**. For supporting the cathode **22** and heater **24**, the rods **32**, **34** and **36** are embedded in an end wall **38** of an envelope shown generally at **40**. For supporting electrodes **26**, **28** and **30**, a clamping ring **42** is tightly fitted about an inwardly protruding portion **44** of wall **38** and has a plurality of projecting arms such as **46** and **48** extending along a portion of the envelope. Rigidly secured to the ends of the arms **46** and **48** are corresponding extensions such as shown at **50** and **52**, of glass or other suitable insulating material to which the electrodes **26**, **28** and **30** are secured at spaced locations. More than two such electrode supports may be provided as is desired or necessary. The proper potentials may be applied to the accelerating electrodes through conductive wires **54**, **56** and **58**, leading to respective electrodes **26**, **28** and **30**. Such potentials and the potential of cathode **22** may be derived from a source of direct potential shown as a battery **60** connected across a resistor element **62** and to which the cathode and respective electrodes are connected at different points. The positive most portion of the element **62** is grounded, the cathode is connected to the negative most portion thereof and the accelerating electrodes are connected at points intermediate to the positive most and negative most portions. Suitable heater current may be provided for heater **24** in any conventional manner.

The electrons produced by gun **12** are attracted to collector **20** which is grounded and therefore at a high positive potential with respect to cathode **22** and the electrons in their beam path, first traverse input cavity **14** which is a hollow, annular member with inwardly directed, disk shaped member **64** and **66** extending from a circular opening in the cavity and the disks are apertured at a central region thereof but have respective screen grids **68** and **70** covering such apertures. An input signal may be introduced into the cavity to excite the same by any suitable wave guide and coupling means such as the coaxial wave guide **72** having the inner conductor **73** thereof terminating in coupling loop **74**. The outer conductor **75** of wave guide **72** is directly connected to the conductive wall of cavity **14** but the inner conductor **73** is insulated therefrom along portions remote from its end by suitable insulating material **76**.

In response to excitation of cavity **14** by the introduction of a signal of the proper frequency, the grids **68** and **70** vary in potential with respect to each other in a sinusoidal manner, whereby electrons traversing the grids from gun **12**, are selectively accelerated and retarded to produce bunching as they leave the gap between the grids and drift into the chamber **16**.

The chamber **16** comprises a round enclosure closed by end walls **78** and **80** and envelope **40** is secured to a circular flange **82** eccentrically positioned in wall **78**. An opening **83** concentric with flange **82** is formed in wall **78** and protruding from the wall **78** toward gun **12** is a tubular sleeve **84** serving as a surface for diffusion of charged particles which prevents positive ions present in chamber **16** from entering the region between grids **68** and **70** to confine positive ions within the chamber **16**. It is to be understood that other and different ion traps such as auxiliary grids may be utilized equally well. For producing a gaseous discharge in chamber **16**, as shown in FIG. 2, as well as in FIG. 1, an arcuate, cold cathode **85** is disposed along a portion of the interior of chamber **16** remote from the eccentric opening in the chamber and a direct potential difference is applied across the anode chamber and cathode derived from a source repre-

sented by a battery **86**. The cathode **85** is supported by a conductive rod **88** which is secured to the cathode at one end and sealingly bonded to an insulator **90** which in turn is sealingly bonded to a tubular supporting bracket **91** extending from the chamber **16**.

In alignment with the envelope **40** and on the side of chamber **16** remote therefrom is disposed an envelope **92** which is sealed at one end to a flange **94** extending about an opening **96** in wall **80** and in coaxial alignment with opening **83**. The collector **20** is supported on a conductive rod **98** which extends through an end wall **100** of the envelope **94** and is sealed thereto and for the present purposes, the rod **98** is connected to ground.

Output cavity **18** is also mounted on envelope **92** and comprises a hollow, annular member with a pair of inwardly directed disks **102** and **104** extending from a circular opening in the cavity and the disks are centrally apertured at **106** and **108** with respective screen grids **110** and **112** covering such apertures. Bunches of electrons in the beam between cathode **22** and collector **20** traverse the gap between grids **110** and **112** and excite the cavity **18**. For removing energy from the cavity **18**, a coaxial wave guide **113** is provided with its outer conductor **114** connected to the conductive wall of cavity **18** and its inner conductor **116** terminating in a loop **118** within the cavity and connected at its end to an interior wall of the cavity. Along portions of the inner conductor removed from its end, it is maintained in nonconductive relationship with the cavity by an insulator **120** sealingly bonded to both the inner conductor and an opening in the cavity.

In constructing the amplifier **10**, it is evacuated and filled with an ionizable gas such as helium at a low pressure of the order of .1 mm. of mercury. Other gases may be utilized and such pressure may be varied over a range, it being necessary, however, to maintain the pressure sufficiently low that the mean free path within the gas is greater than the distance across the anode chamber between grids **68** and **70** and grids **110** and **112**, since it is this region that contains any appreciable number of positive ions and it is necessary for proper operation of the amplifier for a predominance of the electrons from gun **12** to pass through the anode chamber **16**.

In the operation of the amplifier **10**, appropriate potentials are applied to cathode **84**, anode chamber **16**, cathode **22**, electrodes **26**, **28** and **30**, collector **20** and heater **24** to produce both ionization of the gas within the anode as shown at **122** and an electron beam between cathode **22** and collector **20**. In accordance with a feature of my invention, the ionizing potential, the anode dimensions and gas pressure within the anode produce a gaseuos discharge within the anode in a condition of negative glow in the electron beam path in anode chamber **16**. In such a discharge the "ultimate" electrons, which are those that are produced by electron-atom collisions, may possess low values of mean energy of the order of .2 electron volts or less. This corresponds to a temperature of approximately 770° K.

An input signal is introduced into cavity **14** through coaxial wave guide **72** and the excitation of the cavity produces varying potential at grids **68** and **70** to produce bunching of the electrons in the beam from gun **12**. As the bunches of electrons drift into the anode chamber **16**, an interaction the exact nature of which is presently not known in all details, occurs between the negative glow portion of the ionized gas and beam bunches to greatly accentuate the bunching or in other words to increase the bunch density and in effect to amplify the effect of the input signal on the beam. Due to the relatively low energy of the electrons in the negative glow region, introduction of noise on the beam is maintained at a minimum.

The accentuated bunches of the beam continue in their path through the grids **110** and **112** associated with cavity **18** and excite the cavity to permit removal of energy therefrom through coaxial wave guide **113** and such bunches are finally collected at collector **20**.

An amplifier such as herein described is most effective at input frequencies of the order of the plasma frequency of electrons in the ionized plasma. The plasma frequency is the frequency of oscillation that would result if a group of electrons were separated from the positive ions in a predetermined volume of space and then allowed to return. In accordance with my invention, densities of low temperature and low energy electrons in a negative glow region of a discharge are obtainable to achieve effective amplification of signals at frequencies from 1,000 megacycles per second to 100,000 megacycles per second which correspond to electron densities of 10^{10} to 10^{14} electrons per cubic centimeter, respectively.

While the present invention has been described by reference to particular embodiments thereof, it will be understood that numerous modifications may be made by those skilled in the art without actually departing from the invention, I, therefore, aim in the appended claims to cover all such equivalent variations as come within the true spirit and scope of the foregoing disclosure.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. An apparatus comprising a chamber filled with an ionizable gas at low pressure, means ionizing a region of said gas extending entirely through said chamber into a condition of negative glow, means establishing a density modulated electron beam through said region, said beam interacting with the said ionized gas in said region of negative glow to accentuate said modulation and amplify the effects of said signal on said beam and means for extracting said signal from said beam subsequent to said interaction.

2. An apparatus compirsing a chamber filled with an ionizable gas at low pressure, means ionizing a region of said gas extending entirely through said chamber into a condition of negative glow, means including an electron gun and electron collector on different sides of said chamber producing an electron beam through said region, an input resonant cavity having bunching grids between said gun and said chamber and interposed in the path of said beam, means for exciting said cavity by an input signal to density modulate the electrons in said beam, an output resonant cavity having bunching grids interposed in the path of said beam on the side of said chamber remote from said first cavity, and means coupling an energy propagating wave guide to each of said resonant cavities.

3. An apparatus comprising a chamber filled with an ionizable gas and means for projecting an electron beam along a predetermined path through said chamber, the mean free path in said gas being greater than the length of path therethrough followed by said beam, means for density modulating the electrons prior to their entrance into said chamber to produce bunching thereof, means for ionizing the region of said gas along a predetermined path to a condition of negative glow discharge, the electrons in said bunches interacting with said ionized gas in said region to accentuate the bunching of said electrons and means excited by the beam of accentuatedly bunched electrons for removing an amplified signal from said beam.

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