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3,424,937

ELECTRON IMAGE CORRELATOR TUBE

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Sheet 1 of 2

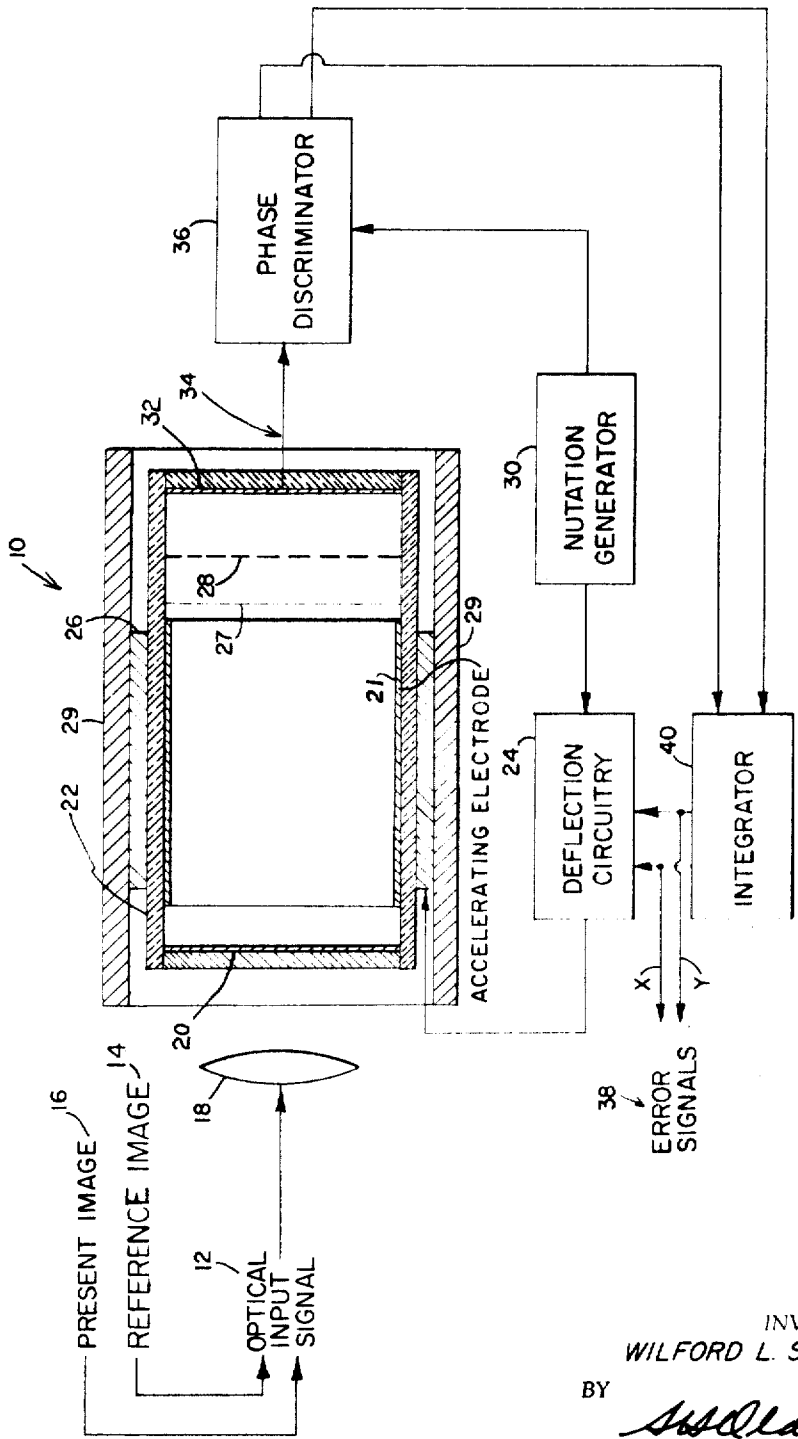


FIG-1

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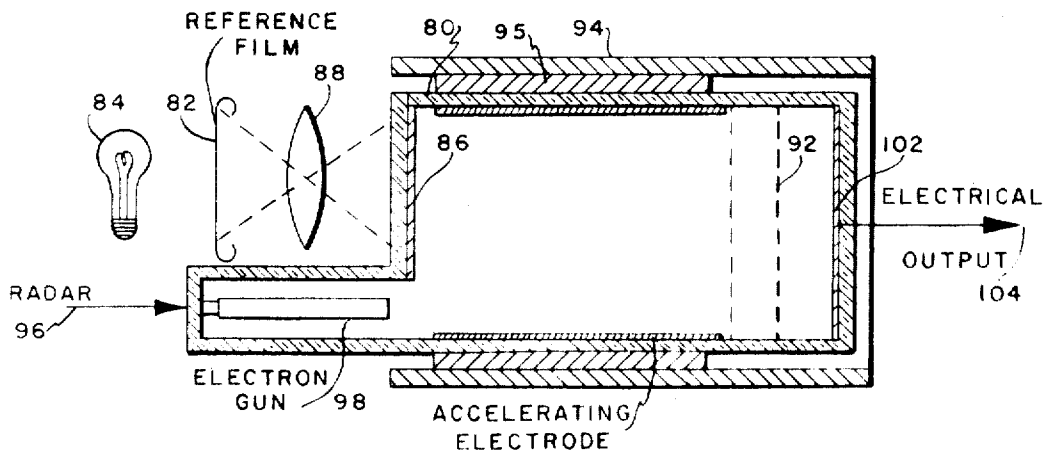
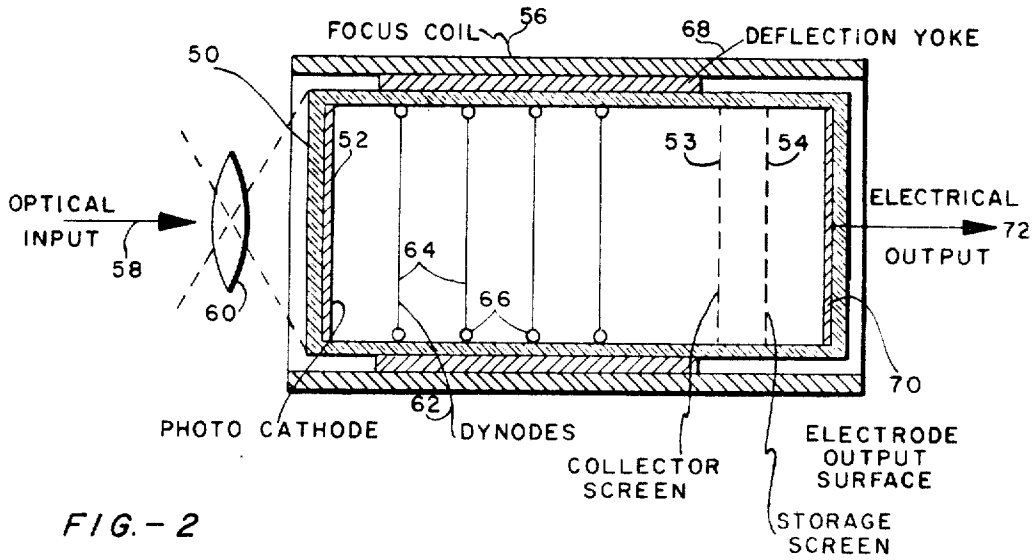
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Sheet 2 of 2



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ELECTRON IMAGE CORRELATOR TUBE

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3 Claims

ABSTRACT OF THE DISCLOSURE

An image matching system having an enclosed electronic tube which, upon appropriate energization, stores a reference electronic image pattern, correlates a second present electronic image pattern with the reference electronic image pattern, and produces an electrical output signal which is a function of the correlation between the patterns. The tube is elongated, hollow, and drawn to a vacuum, and includes either a photocathode or an electron gun to produce electron image information mounted at one end of the tube, and a storage grid or grids located in spaced parallel relationship to the photocathode or gun together with an anode to receive and count electrons to depict correlation information. The tube incorporates an accelerating electrode to uniformly accelerate electrons from the cathode to the grid, dynode amplifiers to enhance the electronic image, particularly for low light levels, and coils wound around the tube to control the scale factor of the images projected electronically therein.

This invention relates to an image matching system and more particularly to an image matching system having a single electronic tube which, upon appropriate energization, stores a reference electronic image pattern, correlates a second present electronic image pattern with the reference electronic image pattern, and produces an electrical output signal which is a function of the correlation between the patterns.

Heretofore, the art of image correlation has been set forth in such systems as shown in U.S. Patents Nos. 3,102,260 and 3,054,999 which are generally referred to as "map matching" systems. However, these systems require complex circuits and separate image storage apparatus to effect the comparison and to achieve the correlation function. In other words, the reference image and the present image for comparison are not area-correlated in a single tube with a minimum circuitry. One attempt to provide a correlation in a single tube is disclosed in patent application entitled, "Electronic Image Correlator," filed Oct. 25, 1962, and given Ser. No. 232,961, now Patent No. 3,290,546, also assigned to the Goodyear Aerospace Corporation. However, this correlator tube requires high voltages for operation, and makes no provision to amplify input intensities to facilitate correlation, nor does it provide for changing the size or scale of input information so that only a desired portion of the input may be utilized for correlation.

It is the general object of the present invention to avoid and overcome the foregoing and other difficulties of and objections to prior art practices by providing a simplified, improved, relatively inexpensive image matching system characterized by a minimum of parts, lightness of weight, and relatively small space requirement, but having high operating efficiency, and speed.

Another object of the invention is to provide a single electronic tube which stores and correlates electronic image patterns where the intensity of the electronic image patterns can be amplified in the tube, and where the scale factors of the electronic image patterns can be changed in the tube.

Another object of the invention is to provide a single electronic tube wherein a first reference electrical input signal is stored and correlated with a second present electrical input signal to produce an electrical output signal which is a function of the degree of correlation.

Another object of the invention is to provide a single electronic tube wherein a first electrical input signal is stored on a grid and correlated with a second electrical input signal projected onto the grid by measuring the number of electrons passed through the grid storing the first electrical input signal where the numbers of passed electrons are measured as a current from a receiving anode.

The aforesaid objects of the invention, and other objects which will become apparent as the description proceeds, are achieved by providing an image matching system for electrically correlating optical reference display information with optical present display information comprising an electronic tube having read-in means operative to provide a first electronic image pattern which is equivalent to the optical reference display information, an electronic storage grid means for storing the first electronic image pattern, read-out means to sense the number of electrons that pass through the grid means, means for focusing the first electronic image pattern generated by the read-in means on the storage grid, means to amplify the first electronic image pattern as it is focused and stored on the grid to increase the strength thereof, means to provide a second electronic image pattern which is equivalent to the optical present display information, and means for amplifying, focusing, and moving the second electronic image pattern relative to the first electronic image pattern stored on the grid means in a plane substantially parallel to the plane of the grid means to correlate the electronic image patterns, the degree of correlation received as a current detecting the maximum number of electrons sensed by the read-out means.

For a better understanding of the invention, reference should be had to the accompanying drawings, wherein:

FIGURE 1 is a schematic illustration of one embodiment of the image matching system of the invention;

FIGURE 2 is a schematic illustration of an electronic image correlating tube adapted to be used in the image matching system of FIGURE 1; and

FIGURE 3 is a schematic illustration of a modified electronic image correlating tube adapted to be used in the image matching system of FIGURE 1.

The art of image correlation generally involves providing a reference image of a certain section of the earth's terrain. Then a subsequent image of the same area of the terrain hereinafter called the present image, is matched or correlated with the reference image. In this manner an unmanned aircraft can fly a predetermined flight path governed by previously prepared reference image information.

With reference to the drawings, there is shown in FIGURE 1, an image matching system which is indicated generally by numeral 10 and comprises an optical input signal 12 adapted to receive reference image information 14 and present image information 16. The reference image information 14 may be stored radar signals of the earth's terrain, or certain target characteristics. Generally, the invention contemplates that the reference image information will be focused by a lens 18 onto a photo cathode 20 which is positioned on one end of a correlator tube, indicated generally by numeral 22. The optical image projected on the photo cathode 20, which is a light sensitive element, is converted to an electronic image which is accelerated by a voltage on an accelerating electrode 21 between the photo cathode 20 and a storage grid 28. A permanent or electro-magnetic coil or solenoid

29 is used to achieve a focus of the image onto the storage grid 28. The grid 28 is positioned substantially parallel to the photo cathode 20, but spaced therefrom. After the electronic reference image is stored on the grid 28 of the tube 22, the optical present image information 16 is projected through the lines 18 onto the photo cathode 20. The optical present information is active information such as an actual direct visual signal. It is apparent that other known optical input signals, such as film or direct radar displays, could be utilized in place of the reference image information 14 and the present image information 16, respectively. However, the objects of the invention are well suited to a direct visual input signal where the amplification, intensity, and contrast thereof cannot be changed. It should be understood that in this embodiment of the invention, the reference image information 14 is always placed into the tube 22 for storage on the grid 28 first with the present image information 16 subsequently projected thereon.

In order to achieve the correlation between the reference image information 14 and the present information 16, the present image information 16 in an electronic form is projected and focused by the electromagnetic coil or solenoid 29 so that it falls onto the grid 28. At this point, a nutation generator 30 actuates the deflection circuitry 24 to nutate or move the present electronic image relative to the stored reference electronic image by means of a deflection yoke 26. As will be more fully explained later, the reference electronic image stored on the grid 28 effectively space modulates the projected electron stream representing the present electron image from the photo cathode, permitting electrons to pass through the grid 28 at points where the projected electron stream representing the present image information is similar or correlates with the electronic image stored on the grid 28. This means that the maximum number of electrons will pass through the grid 28 only when the electron stream representing the present image substantially coincides or correlates with the reference electronic image. Thus, the number of electrons passing through the grid 28 constitute a current from an output anode 32 positioned at the end of the tube 22 opposite to the photo cathode 20. An output wire, indicated generally by numeral 34, may be used to conduct the current flow from the anode 32 and may be located to represent the overall current received on the anode 32. The output current may be passed to a phase discriminator 36 and thence to an integrator 40 to determine X and Y error signals 38, all in the well known manner.

Thus, to summarize, the tube 22 contains a light sensitive portion or photo emissive cathode 20 which emits electrons proportional to the amount of light projected thereon. The electrons emitted from the cathode 20 are accelerated towards and focused on an electron storage grid 28 by means of proper biasing and a magnetic focusing field produced by a cylindrical permanent magnet or electromagnetic coil or solenoid 29. A collector element 27 may be positioned adjacent to the forward surface of the grid 28 to collect the electrons that are emitted from the grid 28 as a result of secondary emission during storage. The yoke 26 inside the focus coil consists of two orthogonal pairs of coils which provide for electromagnetic deflection of an electron image to achieve registration with the stored reference image on grid 28.

The present electron image information 16 is subsequently projected on the grid 28 by exposing the cathode 20 to the optical present image 16. The present electron image pattern is deflected electromagnetically by means of the deflection yoke 26 to effect a nutating or scanning movement of the electron stream representing the optical present image 16 relative to the stored reference electronic pattern. The particular deflection path of the present image electrons is controlled by an alternating current from the nutation generator 30 through the deflection circuitry 24 fed to the yoke 26. In order to hold the projected present electronic image in the position of best cor-

relation, the X and Y error signals 38, developed in the integrator 40, are directed to the deflection circuitry 24.

The nutation generator 30 and integrator 40 are known components and can be provided by the average man skilled in the art. It is noted that typical circuits suitable for this purpose are shown and described at pp. 257 and 467 of the textbook "Electronic Tube Circuits" by Samuel Seely, Ph. D., published in 1950 by McGraw Hill Book Company, Inc.

The circuits of the phase discriminator 36 can be readily provided by the skilled electronics engineer. Typical circuits for this purpose being shown and described at p. 521 of the textbook "Wave Forms" (volume 19, MIT Radiation Lab Series) by Louis Ridenour, published in 1949, by McGraw Hill Book Company, Inc.

An electronic tube 50, shown in FIGURE 2, is similar to the tube 22 of FIGURE 1, and performs the function of correlating two information displays in the form of light patterns or images. The tube consists of a photo-emissive cathode 52 which emits electrons proportional to the amount of light falling thereupon. The electrons emitted from the cathode 52 are projected and accelerated towards and focused upon a storage grid 54 by means of proper biasing in a magnetic focusing field produced by a cylindrical permanent or electromagnet coil 56. An optical input 58 is focused via lens 60 onto the photo emissive cathode 52. In case the input image is not of sufficient brightness or amplitude, a plurality of dynode amplifiers, indicated generally by numeral 62, may be positioned along the tube between the photo emissive cathode 52 and a collector grid element 53, in parallel relation to each other and to the cathode 52, the element 53, and the grid 54. Each dynode amplifier consist of a very thin membrane 64 stretched as a diaphragm across an annular ring 66, which ring 66 is normally welded in place within the tube 50. These dynodes 62 may be more properly called transmission secondary emission multipliers as they emit more electrons than they receive. The membrane 64 may comprise a thin film of aluminum oxide which acts as a substrate for an aluminum chloride or potassium chloride coating which provides the secondary emission characteristics. Dynodes of this type are made by the Westinghouse Electric Corporation, and are described on p. 141, book XVI, on Electronics and Electron Physics by Academy Press, 1962.

A second optical image is subsequently passed through the lens 60 to provide an electronic stream representing present image information which is accelerated by the electrical field between the cathode 52 and the grid 54 and focused on the storage grid 54 by the permanent magnet or electromagnet 56. However, this electron stream representing the present image is deflected electromagnetically by means of a deflection yoke 68 placed around the tube 50 between the cathode 52 and the grid 54. Current in the yoke 68 controls the deflection path of the electrons for nutation or other similar movement as heretofore described and shown in FIGURE 1.

The number of electrons that flow through the storage grid 54 is dependent upon the charge pattern of the reference image stored on the grid and the degree of correlation of those electrons representing the present image. A maximum flow of electrons indicates the maximum degree of correlation between the two images. These electrons strike an electrode output surface 70 which provides an electrical output signal 72 representing the degree of correlation.

An electronic tube 80 shown in FIGURE 3 functions substantially the same as those embodiments described above except that a reference film 82 has a light source 84 therebehind to project the image of the film onto a photo cathode surface 86 through a focusing lens 88. This image may then be intensified by controlling the intensity of the light 84, and focused onto a storage grid 92 by means of an electromagnetic coil 94, as more fully described above. In this embodiment the present informa-

tion may be provided by a radar signal 96 stored on the storage grid 92 in a raster produced by an electron gun 98. The image from the reference film 82 may subsequently be focused onto the storage grid 92 with nutation and displacement thereof by a deflection yoke 95 to effect the correlation. An electrical output electrode surface 102 collects the electrons impinging thereon to provide an electrical output signal 104 representing the correlation between the reference image and the stored present image, again as more fully described above. It is seen with this embodiment of the invention that the introduction of the reference image and the present image is more easily accomplished than with the sequential introduction of the information through the same input photo cathode illustrated with reference to FIGURES 1 and 2.

In order to provide a proper scale between the reference image and the present image as correlated on the grid, referring to FIGURES 1 and 2, the coil or solenoid 29 of FIGURE 1 and 56 of FIGURE 2 may be wound not only to provide focus capability, but also to control the size of the projected present image. In other words, these may be called electromagnetic lenses which may, by properly controlling the current supplied thereto, appropriately enlarge or reduce the size of the stream representing present electronic image information projected onto the stored reference image on the grid. This is an extremely important criteria as many times it will be impossible to position the storage tube in exactly the same position that the reference image was initially produced. Thus, the present image will be either larger or smaller than the reference image even though it is of the same area. Therefore, correlation without the scale reduction or enlargement would be essentially impossible because of the scale factor.

Thus, the normal sequence of correlation will first involve being sure that the scale between the reference and the present images are substantially the same, and then proceeding with the nutation of the present image to determine the maximum electron passage through the grid 54 impinging upon the electrode output surface.

Another important feature of this invention is that the tube may be operated with very little power and very little voltage requirements. In general, it is contemplated that voltage need only be applied between the photo cathode input and the storage grid and only sufficient to insure proper electron acceleration therebetween. The electrode output surface or anode is generally contemplated to be any conductive coated surface which may be divided if desired, for example, into quadrants, to read the current produced in each section to provide the capability of obtaining scale factor information by comparing the image displacements in the sectors. It has been found that the voltage between the grid and the take off anode is very small, generally in the range of only a few volts. This is because no focusing or control of the electrons passing through the grid is required as all force exerted on the electrons passing through the grid is exerted before they arrive at the grid.

The invention contemplates that the storage grid will generally be made of a fine mesh copper or nickel wire between about a 300 line mesh to about a 3,000 line mesh with the higher mesh resulting in better resolution, but a loss of intensity. This copper mesh will generally be coated with a dielectric similar to silicone monoxide or magnesium fluoride so as to provide enhanced secondary emission and insulation properties of the grid.

Thus, the power requirements to operate the tubes are small as compared to the power requirements for operation of the image correlation tube of the above-identified patent application assigned to Goodyear Aerospace Corporation, where voltages in the neighborhood of 10 kilovolts are required between the grid and the take-off anode to provide for a visible display on an output phosphor screen.

In accordance with the patent statutes, only the best known embodiments of the invention have been illustrated and described in detail, but it is to be understood that the invention is not limited thereto or thereby as the inventive scope is defined in the appended claims.

What is claimed is:

1. An apparatus for electrically correlating a reference and a present optical display information comprising
 - an electronic tube having read-in means and operative to provide an electron pattern which is equivalent to the optical display information,
 - an electron storage grid means for storing an electron pattern,
 - read-out means to collect the electrons that pass through the grid means,
 - a tubular shaped accelerating electrode between the read-in means and the storage grid to accelerate electrons from the read-in means towards the storage grid,
 - means for focusing the electron pattern generated by the read-in means and accelerated by the electrode on the storage grid means,
 - means to place a reference optical display information on the read-in means to generate a first electronic image pattern which is focused on the storage grid by the focusing means and stored by the storage grid,
 - means to place a present optical display information onto the read-in means which, as a second electronic image pattern, is projected and focused by the focusing means on the storage grid,
 - means to move the projected and second focused electronic image pattern relative to the storage grid to correlate the electron patterns, the degree of correlation being a function of the number of electrons passed through the storage grid and collected by the read-out means, and wherein the means for focusing the electronic image patterns on the storage grid means can change the scale factor of the focused patterns to insure that the electron image pattern representing the present optical display information is of the same scale as the electron image pattern stored in the storage grid means representing the reference optical display information.

2. An apparatus according to claim 1 where a low potential is applied between the read-in means and the accelerating electrode to accelerate electrons toward the storage grid means, and wherein a low potential is applied between the storage grid means and the read-out means.

3. An apparatus according to claim 1 where a plurality of dynode amplifiers are placed in equally spaced parallel relation between the read-in means and the storage grid means to amplify the electron images focused by the focusing means onto the storage grid means, and which amplifiers comprise a continuous thin membrane coated with a substance having secondary emission characteristics.

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