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TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN that I, LLOYD G. CROSS, a citizen of the United States, residing in the City of San Francisco, County of San Francisco, State of California, have invented certain new and useful improvements in a

METHOD AND APPARATUS FOR MAKING A HOLOGRAPHIC PRODUCT

of which the following is a specification.

Abstract of the Disclosure

Method and apparatus for making a hologram from a conventionally exposed motion picture film taken of a subject. The individual frames of the motion picture film are sequentially imaged onto a variable transmittance slit with coherent illumination. Coherent illumination that is not imaged through the motion picture film is also directed onto the variable transmittance slit so that an interference pattern between the imaged and non-imaged illumination is formed. The variable transmittance slit has a clear central portion disposed between two side portions having an illumination transmittance that continuously decreases in a direction horizontally away from the central portion of the slit. As the interference pattern passes through the slit, the illumination is absorbed according to the variation in transmittance. A photosensitive film is placed behind the slit to record the interference pattern. In operation, after each interference pattern is recorded on the photosensitive film, the film is advanced with respect to the slit so that a series of interference patterns are

recorded on the film in a predetermined, overlapping relationship. After the photosensitive film has been exposed, the film is conventionally processed into a hologram. In one embodiment, a hologram is made that reconstructs a color image using incandescent light.

Background of the Invention

Field of the Invention

This invention generally relates to the art of holography and more particularly to the equipment for placing holographic images on film.

Description of the Prior Art

In general, a hologram is a photographic recording of the interference pattern formed by an object beam and a reference beam. The object beam is usually created by reflecting a beam of coherent illumination off of the object being recorded. The reference beam is a beam of coherent illumination coming directly from the same illumination source. The object beam and the reference beam are combined together to generate an interference pattern that is recorded on a photographic transparency, called a hologram. To reconstruct an image of the original object, the hologram is illuminated from behind with a reconstructing beam of illumination having the same characteristics as the reference beam used in making the hologram. A fundamental discussion of holography is given in Scientific American, June 1965, pages 24-35, by Mr. Leith and Mr. Upatnieks.

It is well-known to make a hologram from the successive frames of a motion picture film. The object is photographed with a motion picture camera and the transparency developed from the film is illuminated frame by frame with coherent light to form the object beam. If either the object or the camera is moved during the exposure, then the frames of the film contain data on various aspects of the object. This data can be incorporated into a hologram to produce a three-dimensional image of the original object.

It is also well-known to form a 360° cylindrical hologram with a plurality of interference patterns sequentially recorded thereon.

Heretofore, one of the problems in making holograms has been the requirement to illuminate the object being photographed with a coherent beam of light. This limitation has meant that for all practical purposes holographic subjects have had to be illuminated by a beam of light from a laser. Thus, holography has been heretofore unavailable for natural and artificially lighted subjects, for outdoor photography, cathode-ray tube displays, and for medical diagnosis.

A further problem occuring during the exposure of the film has been the maintenance of interferometric registration between the object being photographed and the film. Even the slightest vibration or relative motion occuring during the exposure period causes the hologram to become distorted.

In addition, in order to view the hologram and to reconstruct the image recorded thereon, the observer needed either an expensive laser or a costly mercury arc light. Consequently, commercially feasible, low cost holograms have been heretofore unavailable.

Another unsolved problem in the prior art has been the lenticulation of the image occuring when a series of interference patterns are recorded on a hologram in partially overlapping relationship using a hard-edged slit. The lenticulation is a variation in photographic density due to the slit structure and appears as a plurality of equidistant, spaced-apart, parallel lines that breaks up the image reconstructed from the hologram. The lines are caused by either a gap between the interference patterns or an overlap of two patterns so that there is not a smooth variation in photographic density between the exposure.

U. S. Patent 3,632,869 entitled, "Partially Overlapping Hologram Motion Picture Record" issued to Bartolini et al. discloses an apparatus for recording holograms that partially overlap each other on a motion picture record. The holograms are overlaped in order to conserve recording material and a uniform exposure density on the film is not attempted.

Summary of the Invention

The present invention is directed to a method and apparatus for making a hologram that consists of a plurality of interference patterns recorded in overlapping relationship to obtain a uniform photographic density. The apparatus includes a slit having a spatially variable transmittance across its horizontal dimension. The slit is placed in front of a photosensitive film that records the interference patterns, and the slit selectively attenuates the illumination falling on the film. The apparatus also includes means for horizontally moving the photosensitive film with respect to the slit so that the interference patterns are recorded on the film in a predetermined, overlapping relationship.

It is an object of the present invention to provide a novel method, apparatus, and holographic product that overcomes the limitations and disadvantages of the prior art.

A further object of the present invention is to completely eliminate the need for illuminating the original object with coherent light from a laser. In the present invention coherent light is only used to expose the photosensitive film while recording the interference patterns. Laser illumination is not used to illuminate the original object and is not used to reconstruct the image.

An additional object of the present invention is to eliminate the rigid registration heretofore required between the object in the original scene and the camera recording its image. In the present invention the object is photographed with a conventional motion picture camera and 360° of relative motion can be accomodated. The registration required to make a hologram is accomplished thereafter using the apparatus of the present invention.

A further object of the present invention is to eliminate any vertical parallax occuring when the hologram is reconstructed. With the present invention an extended, vertical, white light source such as a conventional fluorescent light can be used to reconstruct the image on the hologram. A beam of coherent illumination is not required.

An additional object of the present invention is the elimination of vertical lenticulation from the reconstructed image. The lenticulation is removed by overlapping the interference patterns in a predetermined relationship on the hologram.

A further object of the present invention is to increase the final resolution of the image by overlapping a plurality of interference patterns on a hologram. Additional objects and features of the invention will appear from the following description in which the preferred embodiments have been set forth in detail in conjunction with the accompanying drawings.

Brief Description of the Drawings

Fig. 1 is a diagrammatic isometric view of the apparatus of the present invention with certain parts including a collimating lens removed for clarity;

Fig. 2 is a schematic diagram illustrating certain components of the apparatus of Fig. 1 including a variable transmittance slit and the orientation of the lenses and mirrors proximate to the photosensitive film;

Fig. 3 is a diagrammatic isometric view of a portion of the apparatus of Fig. 1 illustrating the diffusing optics and the imaging optics for the motion picture film;

Fig. 4 is a diagrammatic isometric view of the apparatus for making a variable transmittance slit according to the present invention;

Fig. 5 is a front elevational view in section taken along line 5-5 of Fig. 2 illustrating the variable transmittance slit according to the present invention;

Fig. 6 is a graph of the illumination transmittance of the slit of Fig. 5 illustrating the variation of illumination transmittance with respect to the horizontal dimension of the slit;

Fig. 7 is a schematic diagram illustrating the variable transmittance slit of Fig. 5 and the superpositioning of the interference patterns on the photosensitive film;

Fig. 8 is a graph of the relative amounts of image density of the interference patterns recorded on the photosensitive film with respect to the film surface illustrating the superposition of the interference patterns on the photosensitive film of Fig. 7;

Fig. 9 is a schematic diagram illustrating an alternative optical arrangement wherein a diffusing screen is used in the object beam near the variable transmittance slit and a pinhole and expanding lens for the reference beam are remotely located from the slit; and

Fig. 10 is a table of optical alignments for the apparatus of Figs. 2, 3, and 9 giving the results obtained by the respective lineups.

Description of the Preferred Embodiments

In general, a hologram is made according to the present invention by first photographing the object using a motion picture camera and conventional motion picture film in the usual manner. Coherent illumination of the object is not required, and either natural or artificial light can be used. Thereafter the motion picture film is conventionally processed according to the directions of the film manufacturer. The apparatus illustrated in Fig. 1 makes a holographic product by exposing the frames of motion picture film in sequence onto a photosensitive film mounted on the apparatus. The exposed photosensitive film is subsequently developed according to the directions of the film manufacturer into a hologram.

By way of a general over view of the apparatus, in Fig. 1 reference numeral 16 indicates a major supporting assembly for mounting the various components of the apparatus. Attached to the major supporting assembly 16 is a laser 18 that provides coherent illumination for making the holographic product and a shutter 19 for controlling the duration of the exposure. The illumination from the laser is directed through the shutter 19 into a beam splitter 20 that separates the laser illumination into a reference beam 22 and an object beam 24. The object beam is directed into a diffuser optical assembly 26 where the object beam passes through a frame of the motion picture film. For the purposes of definition,the beam passing out of the motion picture film is thereafter called the image beam 27. The image beam is directed into a slit optical assembly 28 where the image beam is combined with the reference beam 22 to form an interference pattern. The slit assembly includes a variable transmittance slit and photosensitive film (both not shown in Fig. 1) onto which the interference pattern is recorded.

The major supporting assembly 16 includes a concrete slab 38 that provides the main foundation for the apparatus. The concrete slab is insulated against vibration and shock by a plurality of rubber cushions 40 that support the concrete slab above the ground 42. The major supporting assembly 16 further includes a primary frame assembly 44 that provides a rigid, stable chassis for maintaining the registration between the diffuser optical assembly 26 and the slit optical assembly 28. The primary frame assembly also supports a reference beam diverging assembly 46 that receives the reference beam 22 from the beam splitter 20 and expands the reference beam prior to its incidence on the photosensitive film (not shown in Fig. 1). The primary frame assembly 44 also rigidly supports a secondary platform 48 that in turn rigidly supports the diffuser optical assembly 26 and the laser 18.

The laser 18 is a conventional HeNe laser producing coherent illumination having a wavelength of 6328-Angstroms. The laser is mounted on the underside of the secondary platform 48 and directs a beam of illumination horizontally rearward through to the shutter 19 to a first transfer mirror 50. The shutter is an electrically controlled, mechanical shutter located on the underside of the secondary platform. The shutter interrupts the beam of illumination from the laser and thereby controls the exposure of the photosensitive film. The first transfer mirror is adjustably mounted on an optical bench 52 that is rigidly attached to the secondary platform 48. The first transfer mirror and all other transfer mirrors hereafter described are front-surfaced silver mirrors of optical quality that redirect the beams of light incident thereon without distortion. The first transfer mirror 50 directs the laser illumination upwardly into a second transfer mirror 54 similarly attached to the optical bench 52. The second transfer mirror directs the laser illumination horizontally forward into the beam splitter 20 that is also mounted on the optical bench 52. The beam splitter 20 is a conventional optical beam splitter that divides the laser illumination into a reference beam 22 and an object beam 24. The object beam 24 is directed from the beam splitter 20 into the diffuser optical assembly 26 hereinafter described. The reference beam 22 leaving the beam splitter is directed onto a third transfer mirror 60 that is supported on the optical bench 52. The third transfer mirror reflects the reference beam 22 onto the reference beam diverging assembly 46 hereinafter described.

The slit optical assembly 28 and the reference beam diverging assembly 46 are schematically illustrated in Fig. 2. The reference beam 22 coming from the third transfer mirror 60 on the optical bench 52 is incident on the reference beam diverging assembly 46. As shown in Fig. 1, the reference beam diverging assembly includes a fourth transfer mirror 66 that reflects the reference beam into a first converging lens 68. The first converging lens focuses the narrow reference beam and passes the beam through a pinhole 70. The pinhole eliminates spacial frequency noise. After passing through the pinhole 70 the reference beam is incident on a variable transmittance slit 72 hereinafter described.

Referring to Figs. 1 and 3, the object beam 24 coming from the beam splitter 20 is directed vertically upward into the diffuser optical assembly 26 that is rigidly attached to the optical bench 52 on the secondary platform 48. Within the diffuser optical assembly the object beam is incident on a fifth transfer mirror 78 that reflects the object beam into a negative lens 80. The negative lens expands the narrow laser beam sufficiently to illuminate a frame of a motion picture film 82. An imaging diffuse screen 148 is positioned between the negative lens 80 and the film 82 in order to provide even and uniform illumination of the film. The illumination passing through the frame of the motion picture film, called the image beam 27, is thereafter incident on an imaging lens 84. The imaging lens focuses the beam on to the slit optical assembly 28 hereinafter described. Located within the imaging lens is a horizontal slit aperture 85 for limiting the vertical divergence of the image beam. The width of the aperture is small enough to prevent spectural smearing and loss of resolution and yet large enough to provide sufficient light for the exposure of the film.

The motion picture film 82 is a conventional black and white or color transparency motion picture film. The film was conventionally exposed to the object in non-coherent light and was processed in accordance with the instructions of the film manufacturer. The motion picture film is transported through the object beam 24 by a plurality of sprockets 86 and a first stepping motor 88 attached thereto. The first stepping motor causes the film to advance frame by frame in sequence in front of the object beam. For each exposure of the photosensitive film, as hereinafter described, one frame of the motion picture film is used.

Referring to Figs. 2 and 3, the image beam 27 from the diffuser optical assembly 26 is directed through a collimating lens 92 and a vertically oriented cylindrical lens 94. The collimating lens 92 has a long focal length to collimate the image beam 27 and prevent distortion of the image. The vertically oriented cylindrical lens 94 refracts the horizontal component of the illumination onto the variable transmittance slit 72 without changing the vertical component of the illumination. The use of the vertical cylindrical lens allows the hologram to be viewable in white light. It should be noted that in Fig. 1 the collimating lens 92 was omitted for clarity. It should be understood that the collimating lens 92 is positioned between the vertical cylindrical lens 92 and the imaging lens 84, proximate to the vertical cylindrical lens.

Referring to Fig. 2, the image beam 27 and the reference beam 22 are combined together to form an interference pattern that passes through the variable transmittance slit 72. The variable transmittance slit, hereinafter described, is supported by a light shield 100 that forms a light barrier for the photosensitive film 102. For the purposes of definition the term "photosensitive film" refers to the film onto which the interference pattern is photographically recorded. The term "hologram" refers to this film after processing when the film is converted into a holographic transparency. The photosensitive film is retained in place against vertical motion by a film holder 110. It should be noted that the slit 72 is slightly concave in order to narrow the gap between the slit and film thereby providing an accurate transfer of the variable transmittance of the slit onto the film. Although the variable transmittance slit 72 is not shown in Fig. 1, the slit is located directly behind the vertically oriented cylindrical lens 94 and in front of the film holder 110.

The photosensitive film is stored in two film magazines 104 and is horizontally advanced past the slit 72 by two sprockets 106. The sprockets are driven by a second stepping motor 108 that advances the film a predetermined distance between each exposure. Each interference pattern recorded on the film is thereby overlapped upon the preceding pattern as hereinafter described.

In Fig. 5 the variable transmittance slit 72 is illustrated as it appears to the image beam 27. Fig. 6 is a graph of the illumination transmittance of the slit illustrating the variation thereof with respect to the horizontal dimension of the slit. It should be noted that the slit 72 has no vertical transmittance variation. The variable transmittance slit is characterized by a central portion 116 that is optically clear and non-attenuating. The variable transmittance slit is characterized by a central portion 116 that is optically clear and non-attenuating. There are also two end or side portions 118 that are totally attenuating and pass no illumination. Located between the central portion 116 and each end portion 118 is an intermediate portion 120 that is a transition zone between the non-attenuating portion and the totally attenuating portion. Fig. 6 illustrates that the variation in transmittance from the central portion to the end portions is smooth and without abrupt changes.

To quantitatively describe the illumination transmittance along the horizontal dimension of the slit 72, a dimension "S" is used. S is defined as the slit width and is also the incremental distance that the photosensitive film 102 is advanced by the second stepping motor 108 as hereinafter described. The central portion 116 of the slit is approximately S wide and is centrally located in the middle of the slit. The end portions

118 of the slit are each approximately 1/2 S wide in order to provide an attaching surface for the light shield 100. The intermediate portions 120 are each approximately S wide and smoothly vary between 100% transmittance and 0% transmittance. Thus, the overall width of the slit is approximately 4S, and the illumination transmitting portion is approximately 3S wide. It should be noted that although the slit 72 is physically curved as illustrated in Fig. 2, the distribution of illumination transmittance illustrated in Fig. 6 is a projection onto a flat, vertical plane. In other words, the distribution illustrated in Fig. 6 represents the actual attenuation of the interference pattern as it is recorded on the photosensitive film.

Referring to Fig. 4, the variable transmittance slit is constructed using a slit exposing apparatus 130. The slit exposing apparatus includes an upper horizontal plane 132 having a narrow, central longitudinal slit transmitting light therethrough. The remainder of the upper plane is black and does not pass any light. The slit exposing apparatus further includes an intermediate plane 134 that has a narrow, central, longitudinal black stripe directly underlying the clear slit in the upper plane. The remainder of the intermediate plane is clear and not light attenuating. The slit exposing apparatus also includes a lower plane 136 onto which a sheet of conventional black and white negative film is located. When the slit exposing apparatus is illuminated by a light 138, the illumination therefrom passes through the clear slit in the upper plane 132 and is scattered outward. The black stripe on the intermediate plane 134 blocks the bright image of the slit from falling directly on the negative film located on the lower plane 136. The illumination falling on the negative film is reversed from the distribution of illumination illustrated in Fig. 6. After being exposed to the light 138, the negative film is conventionally processed into a positive film and the slit illustrated in Fig. 5 is formed.

Referring to Fig. 1, the motion picture film 82 can be either 8mm, 16mm, or 35mm, and is obtained in the conventional manner. The object or scene desired to be recorded on the hologram is photographed using a conventional motion picture camera and either color negative film or black and white film. The object or scene is not illuminated with laser illumination and either incandescent or natural lighting may be used. For best results it has been found to either rotate the object with respect to the camera or to move the camera with respect to the scene so that different aspects of the object or scene are recorded on the film. After exposure the motion picture film is processed in the conventional manner according to the directions of the manufacturer and a transparency film describing the object is obtained. It should be noted that the motion picture film thus obtained can be used in a conventional motion picture projector without modification.

Referring to Figs. 1-6 inclusive, the motion picture film 82 is first loaded into the diffuser optical assembly 26. The first frame of the film is positioned between the sprockets 86 such that the object beam 24 from the beam splitter 20 will pass therethrough and illuminate the entire frame. Next, the laser 18 is turned on and the various transfer mirrors and lenses of the system are adjusted so that the image beam 27 and the reference beam 22 combine to form an interference pattern that is on the variable transmittance slit 72. The photography room in which the apparatus is housed is thereafter darkened and the photosensitive film 102 is threaded on the two sprockets 106 between the two film magazines 104. When the photosensitive film is in place, the film rests in front of the film holder 110 and directly behind the variable transmittance slit 72. The variable transmittance slit is slightly concave in order to narrow the gap between the slit and the film.

The first exposure of the photosensitive film 102 is made by imaging the first frame of the motion picture film 82 onto the variable transmittance slit 72. The process begins by opening the shutter 19. The laser 18 produces coherent illumination that is now incident on the beam splitter 20. The beam splitter separates the illumination into the object beam 24 and the reference beam 22. The object beam is directed into the diffuser optical assembly 26 where the beam is expanded by the negative lens 80, passed through the frame of the motion picture film, and focused on the slit with the imaging lens 84. The vertical divergence of the image beam 27 is limited by the horizontal slit apperture 85. The collimating lens 92 collimates the beam and the vertically orientated cylindrical lens 94 refracts the horizontal component of the light into the slit.

The reference beam 22 from the beam splitter 20 is directed into the reference beam diverging assembly 46. The diverging assembly expands the reference beam and directs it onto the slit. The reference beam 22 selectively interferes with the image beam 72 creating an interference pattern that passes through the slit and is recorded on the photosensitive film.

After the interference pattern is exposed to the photosensitive film 102, the shutter 19 is closed and the motion picture film 82 is advanced by one frame through the diffuser optical assembly 26 using the first stepping motor 88. Simultaneously with the advancement of the motion picture film, the photosensitive film 102 is advanced a predetermined increment S past the variable transmittance slit 72 using the second stepping motor 108 and the sprockets 106. Thereafter, the second frame of the motion picture film 82 is imaged onto the variable transmittance slit as hereinbefore described, and the reference beam 22 interferes with the image beam 27 to create a second interference pattern that is recorded on the photosensitive film. The above process is repeated over and over until each frame of the motion picture film is imaged onto the slit and an interference pattern corresponding thereto is recorded on the photosensitive film. The above process is repeated over and over until each frame of the motion picture film is imaged onto the slit and an interference pattern corresponding thereto is recorded on the photosensitive film.

The photosensitive film 102 is advanced increment by increment in synchronization with the motion picture film 82 so that the interference patterns are recorded on the photosensitive film in overlapping, sequential relationship. The second stepping motor 108 advances the photosensitive film 102 by an incremental distance S. The distance S is related to the transmittance of illumination through the slit 72 as illustrated in Figs. 5 and 6 and as described hereinbefore. Referring to Figs. 7 and 8, the individual interference patterns are placed on the surface of the photosensitive film so that each portion of the film is exposed to at least three different interference patterns. Fig. 8 illustrates the densities of the die or emulsion images on the film recording the interference patterns with respect to the length of the film. It should be noted that the individual interference patterns are spaced on the film so that a substantially uniform, overall image density is achieved. It should further be noted that each image is approximately 3S long because the clear central portion 116 of the slit is S wide and the intermediate portions 120 of the slit are each S wide.

After all of the frames of the motion picture film have been exposed to the photosensitive film 102, the film is removed from the apparatus. The film is thereafter conventionally processed in accordance with the instructions of the film manufacturer and a hologram is obtained. The resulting hologram is a photographic transparency having a plurality of die images or emulsion images that substantially overlap each other. Fig. 8 illustrates the overlapping relationship of the die images on the film and the relative density of the images.

The hologram can be viewed using a conventional incandescent white light located behind the hologram at an angle equal to the angel of the reference beam. The white light is positioned with respect to the hologram in the same orientation that the pinhole 70 was positioned with respect to the photosensitive film 102. Coherent illumniation is not required for the reconstruction of the hologram because the vertical cylindrical lens 94 is used.

In Figs. 2 and 3 and 9 and 10, four alternative lens and imaging embodiments are disclosed. In each embodiment described herein the basic apparatus for exposing the film, including the support assembly 16, the laser 18, the beam splitter 20, the fifth transfer mirror 78, and the imaging lens 84, is the same as hereinbefore described. In Optical Lineup number I the negative lens 80 broadens the narrow object beam 24 from the fifth transfer mirror 78 so that the beam completely fills a frame of the motion picture film 82. Thereafter, the beam is imaged onto a diffuse screen 146 located in front of the variable transmittance slit 72. The diffuse screen 146 provides uniform illumination of the variable transmittance slit 72. In the Lineup number I the lenses 92,94 of Fig. 2 are removed. The hologram produced from Optical Lineup I is viewable in monochromatic light.

In Optical Lineup number II illustrated in Fig. 9 the negative lens 80 is again used to broaden the narrow object beam 24 from the fifth transfer mirror 78. In addition, an imaging diffuse screen 148 is located between the negative lens 80 and the frame of the motion picture film 82, and the diffuse screen 146 located in front of the slit is retained. The imaging diffuse screen 148 provides more even illumination of the frame of the motion picture film. The hologram produced from Optical Lineup II is viewable in monochromatic light.

Optical Lineup number, III the negative lens 80 is used alone in the diffuser optical assembly 26. The diffuse screen 146 in front of the slit is replaced by the collimating lens 92 and the vertically orientated cylindrical lens 94 hereinbefore described. The vertical lens 94 refracts the horizontal component of the light into the variable transmittance slit 72 without changing the vertical component. The vertical lens produces a white light viewable hologram. The collimating lens 92 prevents distortion of the image on the slit by preventing the image beam from diverging, Optical Lineup number IV, illustrated in Figs. 2 and 3, includes the imaging diffuse screen 184 located in the diffuser optical assembly 26 and the horizontal slit aperture 85. The slit aperture limits the vertical divergence of the image beam. In addition, the collimating lens 92 and the vertically oriented cylindrical lens 94 are located in front of the slit. Optical Lineup IV produces a white light viewable hologram that has better resolution than Optical Lineup III.

Referring to Fig. 2, the reference beam diverging assembly 46 is located at 45° with respect to the image beam 27 and is spatially positioned vertically above the vertical lens 94. When the pinhole 70 in the reference beam diverging assembly is located in this position, the resulting hologram is reconstructable with illumination originating behind the hologram at an angle equal to the angle of the reference beam. If a cylindrical hologram is constructed, then the reconstructing light source can be located in the center of the hologram and the hologram can be rotated thereabout.

Referring to Fig. 9, the reference beam diverging assembly 96 is illustrated at an alternative position proximate to the third transfer mirror 60 on the secondary platform 48. In this configuration the pinhole 70 is located at a point equivalent to infinity. When the pinhole 70 is located proximate to the third transfer mirror, the hologram can be reconstructed from a flat plane, and the source of the reconstructing illumination can be remotely located from the hologram.

An alternative embodiment of the film advancing means is illustrated in Fig. 1. The photosensitive film (not shown in Fig. 1) advanced by attaching the film to the film holder 110 and moving the film holder with respect to the variable transmittance slit (not shown in Fig. 1) The film holder in turn is rigidly attached to a rotatable platform 158. The rotatable platform is pivoted for rotation on the primary frame assembly 44. The rotatable platform is turned by a third stepping motor 160 such that the photosensitive film is advnaced passed the slit for a distance S for each exposure as hereinbefore described. In this embodiment of the film advancing means the light shield 100, the collimating lens 92, the vertical cylindrical lens 94, and the reference beam diverging assembly 46 are stationary. The film holder 110 rotates about the vertical axis of the vertically oriented cylindrical lens 94. The pinhole 70 of the reference beam diverging assembly 46 is located on this axis of rotation so that the resulting cylindrical hologram can be reconstructed by a light at its center of rotation. The manner of exposing the interference patterns on to the film and the process of sequencing the movie film 82 through the diffuser optical assembly 26 is the same as hereinbefore described.

Although the best mode contemplated for carrying out the present invention has been herein shown and described, it will be apparent the modification and variation may be made without departing from what is regarded to be the subject matter of the invention.

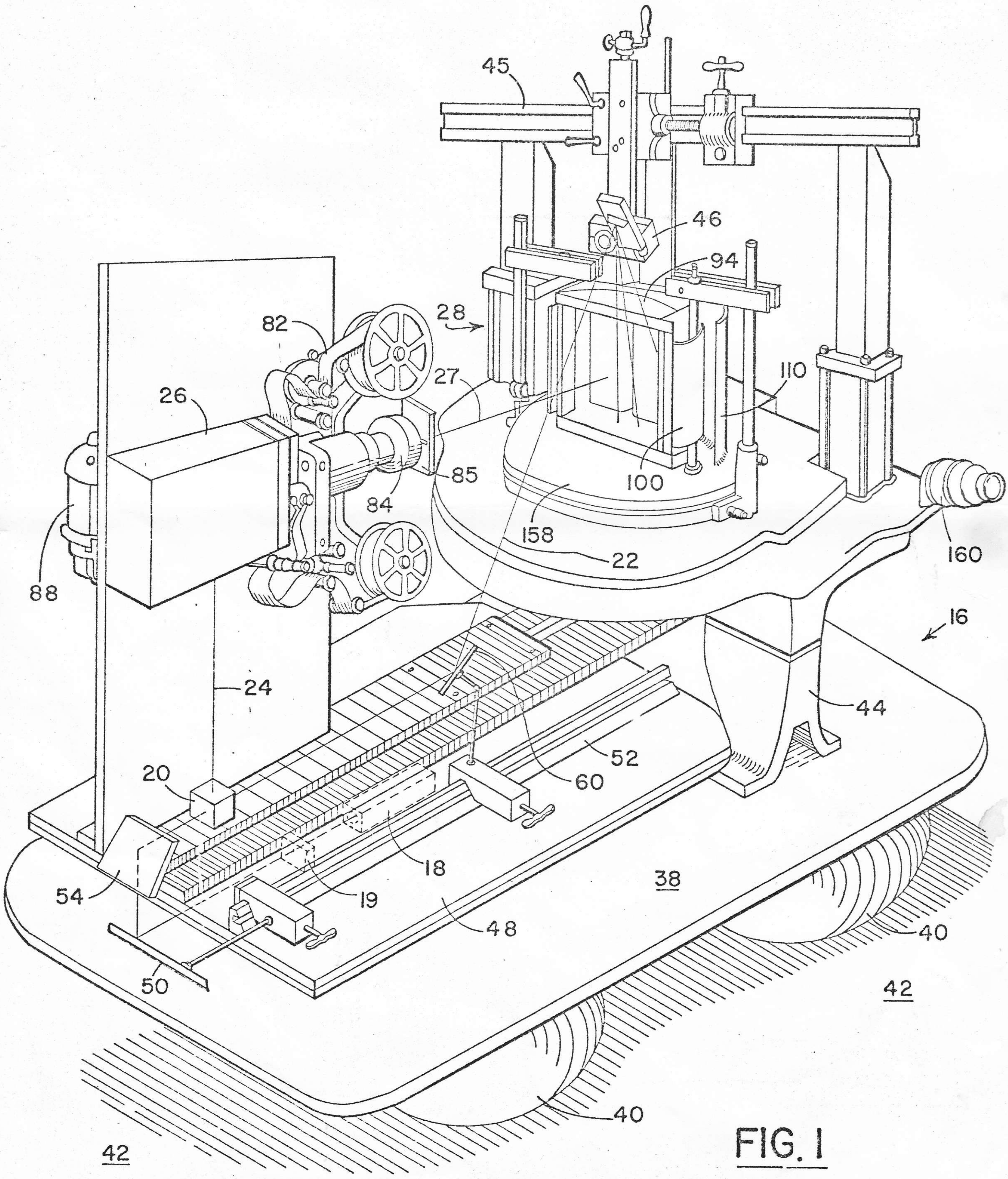

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FIG. 1