United States Patent

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[73] Assignee **RCA Corporation**

[54] **CATHODE-RAY TUBE WITH SCREEN COMPRISING LASER CRYSTALS**
15 Claims, 3 Drawing Figs.

[52] **U.S. Cl.** **313/92,** 331/94.5
[51] **Int. Cl.** **H01j 29/32,** H01s 3/00
[50] **Field of Search** ..... 313/65 (T), 92 (PH), 92 (PF); 331/94.5; 329/144; 250/199

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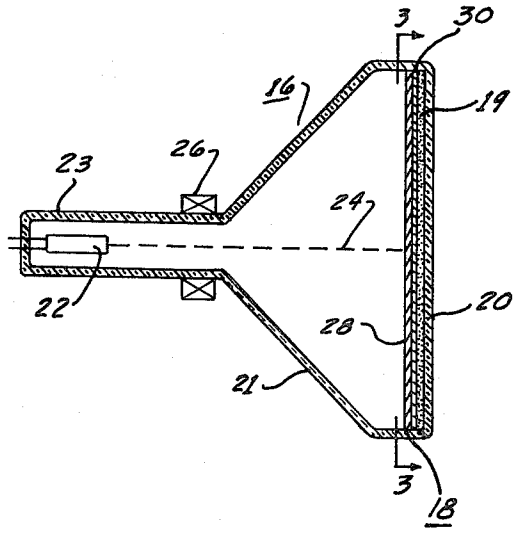
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ABSTRACT: A cathode-ray tube has a screen comprising an array of laser crystals, in which the individual laser crystals emit coherent light in a narrow disclike beam when excited by an electron beam.



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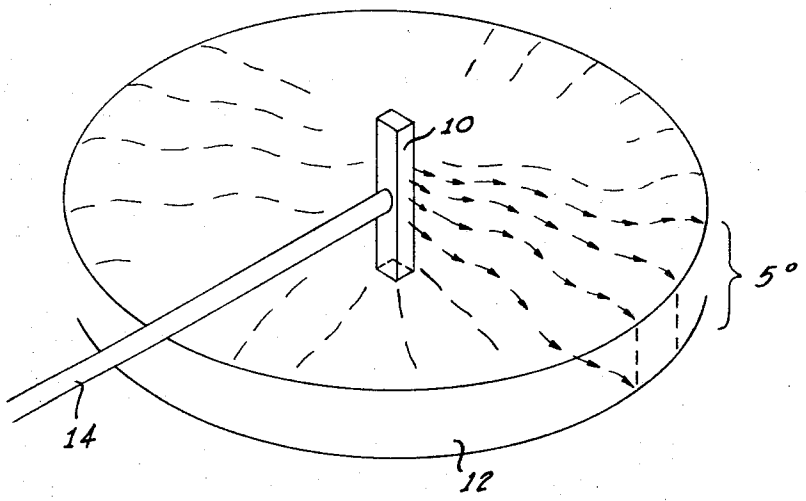


Fig. 1.

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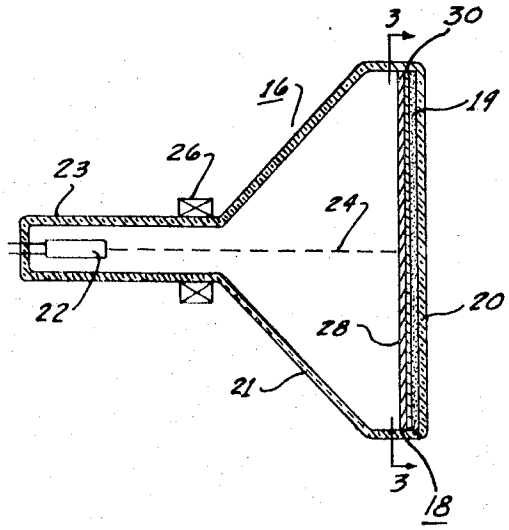


Fig. 2.

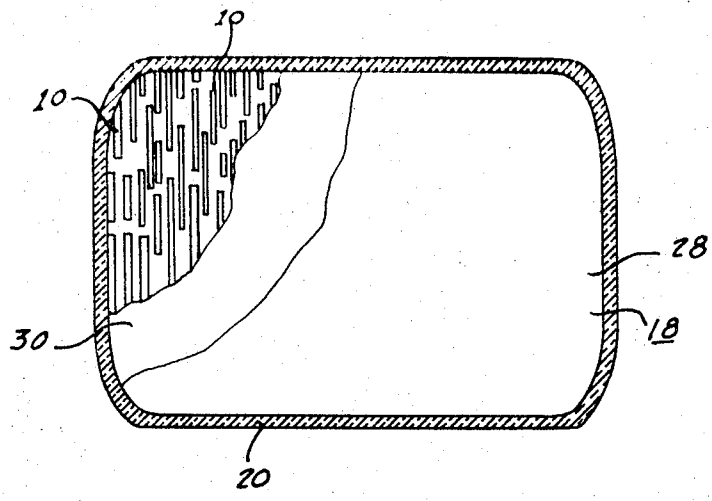


Fig. 3.

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CATHODE-RAY TUBE WITH SCREEN COMPRISING LASER CRYSTALS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates in general to cathode-ray tubes and particularly to cathode-ray tubes having a screen comprising an array of laser crystals.

2. Description of the Prior Art

Most prior art cathode-ray tubes have utilized a screen comprising a thin layer of cathodoluminescent phosphor powder coated onto the interior of a transparent faceplate. When this phosphor layer was scanned by an electron beam, the individual phosphor particles luminesced producing an optical output. In cathode-ray tubes of this type, it has been difficult to produce optical outputs having adequate brilliance because of the limitations inherent in the phosphor materials themselves.

The lack of brightness in prior art cathode-ray tubes has lessened their usefulness for many purposes. It has been difficult, for example, to view these tubes in areas having a large amount of ambient light since the phosphor screen does not provide enough contrast over the background illumination. Low brightness in present cathode-ray tubes has made it difficult, for instance, to develop a portable television receiver suitable for outdoor use because the bright sunlight makes it difficult to view the television screen. Thin window recording tubes such as those used in copying machines require increased brightness and higher contrast to produce satisfactory images on light sensitive recording mediums. Brighter cathode-ray tubes would also be very useful when the image produced on the tube screen is to be projected by a lens system.

SUMMARY OF THE INVENTION

The foregoing problem of achieving increased brightness from a cathode-ray tube is overcome by a novel cathode-ray tube comprising a screen having an array of laser crystals and means to direct a beam of electrons toward the screen. The crystals of certain semiconducting materials such as cadmium sulfide, zinc sulfide, gallium arsenide and zinc oxide will emit a narrow disclike beam of coherent light when excited by an incident electron beam. When these laser crystals are used on the screen of a cathode-ray tube, their relatively narrow angle of light emission directs more of the emitted light toward the viewer and results in a cathode-ray tube having increased brightness.

When a large number of these laser crystals are arrayed on the screen of a cathode-ray tube, they will provide an optical display when scanned by a modulated electron beam. Because the laser crystals emit light in a relatively narrow disc from the point struck by the electron beam, rather than the large solid angle of light emission from phosphor particles, the brightness and contrast of a cathode-ray tube having a laser screen is greatly increased over present cathode-ray tubes. The narrow angle of light emission from the laser crystals also makes this type of screen especially suitable for special purpose cathode-ray tubes such as recording cathode-ray tubes which require high contrast and cathode-ray tubes used in projection systems which require a strongly directional light output.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram showing the narrow disclike beam of light emitted by a single laser crystal;

FIG. 2 is a longitudinal sectional view of a cathode-ray tube having a screen comprising an array of laser crystals; and

FIG. 3 is an enlarged sectional view taken along the line 3–3 of FIG. 2, partially cut away to show the laser crystals.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 shows a vertically-mounted elongated single semiconductor laser crystal 10 of a type which emits a disclike beam 12 of coherent light when struck by an electron beam 14. A description of these crystals and their characteristic pattern of light emission is found in the article "Far-Field Pattern of Electron Semiconductor Lasers" by F. H. Nicoll, published in the PROCEEDINGS OF THE IEEE, Jan. 1967, page 114. Crystals of certain semiconducting materials including zinc oxide, cadmium sulfide, zinc sulfide, and gallium arsenide, will produce a narrow disclike beam of coherent light by stimulated emission when excited by an incident electron beam 14. The beam 12 of monochromatic laser light is emitted from the area on the crystal 10 which is struck by the electron beam 14. This light beam 12 extends in a 360° disc having a narrow vertical angle of approximately 5° to 10°.

The direction of light emission from the crystal is dependent on the material of the crystal and its physical shape. Hexagonal crystals such as zinc oxide and cadmium sulfide have a so-called C axis extending down the center of the hexagonal configuration. Crystals having this C axis will emit light in only a plane perpendicular to the C axis. In other crystals such as gallium arsenide, which do not have a C axis, emission will occur in a plane perpendicular to the longer dimension of the crystal because energy losses within the crystal are lower when the light travels a shorter distance through the crystal.

Whether or not stimulated emission will occur in an individual semiconductor crystal 10 is a function of the crystal thickness, the energy of the incident electron beam, and the temperature of the crystal. The usable thickness of the laser crystals varies with the crystal material ranging from a minimum of approximately 2 microns for gallium arsenide to about 100 microns for cadmium sulfide. As the crystal width increases for any given material, the incident electron beam must be accelerated by increasing voltages to produce lasing. Gallium arsenide and cadmium sulfide crystals have been made to lase under electron bombardment at room temperatures, but at the present time, most of the other laser crystals must be cooled to liquid nitrogen temperatures before lasing will occur. Crystals of cadmium sulfide 2 microns thick have lased at room temperature when pulsed by an electron beam having a beam current of 4 amp/cm^2 and an acceleration voltage of 15 kilovolts.

The semiconductor laser crystals described above are well suited for use in a cathode-ray tube screen. These crystals perform well when pulsed for one-tenth of a microsecond at one-thirtieth of a second intervals. This pulse rate is similar to that commonly used for picture elements on the screen of a cathode-ray tube. Laser crystals of this type exhibit rise and decay times of the order of 1 microsecond or less which is faster than most phosphors, giving them an additional advantage for use in a cathode-ray tube screen.

FIGS. 2 and 3 show a cathode-ray tube 16 which has a target structure 18 including a screen 19 which comprises an array of semiconductor laser crystals similar to the one shown in FIG. 1 arranged on one side of a transparent faceplate 20. The cathode-ray tube 16 is enclosed by an outer glass envelope 21 which is connected to the faceplate 20. An electron gun 22 located in a narrow neck portion 23 of the tube 16 generates an electron beam 24 which is accelerated toward the screen 19. A deflection yoke 26 controls the electron beam 24 causing it to scan the screen 19 in raster fashion. The electron beam 24 modulated by an input signal strikes the individual laser crystals 10 as it scans the screen 19 causing them to emit light responsive to the input signal and to produce an optical display.

A relatively large number of laser crystals 10 are arranged on the inner surface of the glass faceplate 20 to form the screen 19 as shown in FIG. 3. If hexagonal crystals such as zinc oxide or cadmium sulfide are used, the crystals are preferably placed on the screen 19 so that their C axes are parallel. If crystals are used which do not have a C axis, such as gallium arsenide, they are preferably arranged on the screen 19 so that their long axes are parallel. When the crystals 10 are arranged

in this way, they will emit parallel beams of light when struck by the scanning electron beam **24**. Each line of the raster scanned by the electron beam will then emit light in the same narrow vertical angle as the individual crystals **10**. If desired, a relatively small misalignment can be introduced to provide a wider angle of vertical light emission.

The C axes or long axes of the crystals can be aligned, for instance, by mixing the crystals in a viscous binder material and then stretching a relatively thin sheet of this mixture in a manner analogous to that used to align the axis of the elongated molecules in polaroid materials. Stretching a sheet of the mixture of binder material and crystals will cause the long axes of the crystals to align themselves and since the C axes of hexagonal crystals is usually parallel to their long sides, this technique can also be used to align the C axes of the hexagonal crystals. The mixture of crystals and binder material can then be coated onto the inside of the faceplate of a cathode-ray tube.

As is shown in FIG. **1**, each laser crystal emits light in a 360° disc. In order to further increase brightness, the target structure **18** also includes a thin electron-permeable layer of aluminum **28** as best seen in FIG. **2** disposed adjacent to the interior side of the array of laser crystals as shown in FIG. **3**. If the aluminum layer **28** is placed in contact with the screen **19**, the aluminum will absorb some of the light from the crystals **10**, and hence, cause light losses in the crystals, which might prevent the crystals from lasing. To minimize this light loss, the target structure **18** preferably further includes a thin electron-permeable layer **30** of a transparent material such as magnesium fluoride or silicon dioxide which has a lower index of refraction than that of the laser crystals. This layer of transparent material **30** is placed between the aluminum layer **28** and the laser crystal screen **19** with the aluminum layer **28** being coated on the layer **30**. At room temperature, magnesium fluoride and silicon dioxide have indices of refraction of 1.34 and 1.46 respectively while the laser crystals described above have indices of refraction of 2 or more. The aluminum layer is about 1000A in thickness and the layer of material having a low index of refraction is about 300A in thickness. As in prior art phosphor screens, the aluminum layer **28** causes the light emitted rearwardly by the laser crystals to be reflected through the transparent faceplate **20**.

The screen **19** comprises a relatively large number of laser crystals **10** which may vary slightly in size. Preferably, relatively small crystals are used so that the electron beam **24** will strike several crystals for each picture point in the screen **19**. As is shown in FIG. **3**, the semiconductor crystals may be arranged in random fashion, but their long axes or C axes are preferably approximately parallel. As the electron beam **24** scans across the screen, it excites some of the laser crystals; and causes them to emit a characteristic thin disclike beam of light. This light beam will be emitted from the area of the crystal which is struck by the electron beam and will be emitted perpendicularly to the C axis, or to the long side of the crystal if it has no C axis. Since the C axes or long axes of the laser crystals are approximately aligned, the emitted light beams will be approximately parallel so that the electron beam will trace a line of light having a relatively narrow vertical angle of emission approximately equal to that of the individual laser crystals as it scans across the screen. When a modulated electron beam traces a raster pattern on the screen **19**, a video image is produced.

It may be desirable to mix several different types of laser crystals to form the screen **19**. Since the laser crystals emit light by stimulated emission, the resulting light beam is monochromatic with the color of emitted light being dependent on the material of the laser crystal. By using a mixture of crystals made of different materials, the screen can be made to emit white light or several different kinds of crystals can be arranged to produce light of several different colors. Alloy crystals which emit a color other than those emitted by crystals of a single material can be produced by combining two or more of the aforementioned materials and allowing this mixture to crystallize. The resulting alloy crystal will lase at a wavelength of light between the wavelengths at which its constituent materials would lase. The use of alloy laser crystals allows the screen to emit light at a desired frequency or any combination of frequencies if several different types of alloy crystals are used.

I claim:

1. A cathode-ray tube comprising:

a. an envelope including a transparent faceplate,

b. a target structure positioned within said envelope adjacent to said faceplate

c. means within said envelope for directing an electron stream toward said target structure, and

d. said target structure including a screen comprising an array of laser crystals, each one of said crystals being of substantially uniform composition and said crystals being mounted on said screen so as to emit light directly through said faceplate from the area of impingement thereon of said electron stream.

2. A cathode-ray tube as described in claim **1** wherein said laser crystals are hexagonal crystals of a material chosen from the group consisting of zinc oxide, zinc sulfide and cadmium sulfide.

3. A cathode-ray tube as described in claim **2** wherein said hexagonal laser crystals are arranged on said screen with their C axes parallel.

4. A cathode-ray tube as described in claim **1** wherein said laser crystals consist of gallium arsenide.

5. A cathode-ray tube as described in claim **4** wherein said laser crystals are arranged on said screen with their long axes parallel.

6. A cathode-ray tube as described in claim **1** wherein said laser crystals are less than 100 microns in thickness.

7. A cathode-ray tube as described in claim **1** wherein said array therefor of laser crystals comprises a mixture of laser crystals composed of different materials, said crystals being chosen to emit light at different respective frequencies.

8. A cathode-ray tube as described in claim **1**, wherein said laser crystals are adapted to emit light at a relatively narrow angle.

9. A cathode-ray tube as described in claim **1** wherein each one of said laser crystals is adapted to emit light in a broad angle in at least one plane.

10. A cathode-ray tube as described in claim **9** wherein said broad angle is substantially 360°.

11. A cathode-ray tube as described in claim **9** wherein said crystals are elongated and said plane is substantially perpendicular to the respective major axes of said crystals.

12. A cathode-ray tube as described in claim **11** wherein said crystal has a hexagonal crystallographic structure and said major axes are the respective C axes of said crystals.

13. A cathode-ray tube as described in claim **9**, wherein said screen is adapted to emit light at an angle of substantially 180° and comprises means for causing substantially all of said emitted light to pass through said faceplate.

14. A cathode-ray tube as described in claim **13** wherein said means includes:

a first thin layer of a reflecting material adjacent to said crystals.

15. A cathode-ray tube as described in claim **1** wherein said target structure further includes:

a second thin layer of a material having an index of refraction lower than the index of refraction of said laser crystals between said screen and said first thin layer.