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# PATENT SPECIFICATION

DRAWINGS ATTACHED

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## COMPLETE SPECIFICATION

### Improvements in or relating to Optical Masers

We, WESTERN ELECTRIC COMPANY, INCORPORATED, of 195 Broadway, New York City, New York State, United States of America, a Corporation organized and existing under the laws of the State of New York, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to optical masers or lasers.

One of the important properties of optical masers or lasers is that they are theoretically capable of providing a beam of light which is monochromatic. However, in practice it has been difficult to achieve monochromaticity completely.

In particular, it has been difficult to achieve monochromaticity in the past because the optical cavity used typically has been capable of supporting a large number of modes, in which the cavity can and does resonate simultaneously in operation. Since these modes typically correspond to slightly different wavelengths and to different transverse energy distributions or mode pattern the output beam typically comprises light of a number of different wavelengths.

According to the present invention there is provided a helium-neon optical maser arranged to emit visible radiation having a wavelength of substantially 6328 Angstroms.

In an embodiment of the invention a mode pattern selector is included in the optical cavity. The mode pattern selector typically comprises a pair of crossed wires serving as light interrupting elements, and advantageously also includes an iris diaphragm.

The isolation of substantially a single mode pattern for oscillation besides permitting a purer output also effectively increases the efficiency of the system for the isolated mode, thereby increasing the output power available

at the wavelength corresponding to the isolated mode.

In a preferred embodiment of the invention, a gas mixture consisting of 10 parts helium to 1 part neon with a total pressure of about 0.7 millimeters of mercury and having a cross section of 6 millimeters was included within an optical cavity defined by a pair of dielectric layer mirrors designed to have a peak reflectivity at about 6340 Angstrom units. There was also included a mode pattern isolator comprising a pair of crossed wires and an iris diaphragm. The mixture was ionized by a d-c voltage and there resulted maser oscillations at about 6328 Angstrom units, which is in the visible red of the light spectrum.

The invention will now be described with reference to the accompanying drawing in which:

FIG. 1 shows in schematic form a longitudinal section of an optical maser embodying the invention; and

FIG. 2 is a transverse section of the optical maser shown in FIG. 1 showing in more detail the crossed wire mode pattern selector. With reference now more specifically to the drawings:

FIG. 1 shows an optical maser which comprises an elongated quartz tube 11 containing the gaseous active medium. A light beam path through the tube 11 is defined by transparent windows 12 and 13 which are inclined at Brewster's angle to the path of light beam 14. By placing the windows at Brewster's angle, light polarized in the plane of incidence is transmitted without reflection. The tube 11 also includes at opposite ends side sections 15 and 16. Side section 15 contains a thoriated tungsten, thermionic cathode 17 and side section 16 contains a molybdenum cylinder 18 that serves as an anode. A d-c power source (not shown) is connected between cathode 17 and anode 18 for supplying the voltage necessary to maintain a gas discharge along the portion of the envelope extending between the

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two side sections. Beyond opposite ends of the envelope are positioned reflectors 19 and 20 adjacent the windows 12 and 13, respectively. The reflectors 19 and 20 typically are

5 plano-concave spherical dielectric layer mirrors designed to have a reflectivity peaked at the wavelength desired for the output light.

10 Positioned intermediate the window 13 and reflector 20 is the mode pattern selector 21 comprising the two-wire assembly member 22 and the iris diaphragm member 23. The reflectors, the envelope and the mode selector members are all aligned along the light beam path 14 which passes along the axis of the envelope and through the mode selector.

15 FIG. 2 is a front view of the crossed wire assembly member 22. It comprises simply a pair of cylinders 22A and 22B aligned end to end as seen in FIG. 1, each of which includes a separate wire 24, 25 extending diametrically across the cylinder. The two cylinders are separately rotatable whereby the angle of intersection  $\theta$  as seen in a front view can be varied as desired. Moreover, advantageously, the assembly can be moved in the plane normal to the beam path through the cylinders. Moreover, provision may be made for varying the separation along the beam path of the two cylinders for varying the spacing of the two wires therealong. The wires serve as localized discontinuities interrupting the light along the beam path.

20 Additionally, the mode pattern selector advantageously includes the iris diaphragm member 23 which is adapted for varying the size of the iris or opening. This simply can be a member similar to the type used in controlling the size of the lens aperture in a conventional camera. Additionally, it is advantageous to make the position of the iris opening adjustable in the plane normal to the direction of the light path through the iris.

25 The arrangement described has been used successfully to produce continuous maser oscillation at 6328 Angstrom units corresponding to the  $3s_2-2p_4$  transition in neon. In this maser, the active medium was a helium-neon mixture with a helium-neon ratio of 10 to 1 and a total pressure of about 0.7 millimeters of mercury. The two reflectors were spaced about 150 centimeters apart and each reflector was a thirteen layer dielectric mirror designed to have a peak reflectivity at about 6340 Angstrom units. The radius of curvature of the spherical surface of each reflector was 100 centimeters. A voltage of about 1700 volts was set up between the cathode and anode and a current of about 30 milliamperes flowed therebetween. The constricted portion of the tube extending between the two side sections had a length of 85

centimeters and an inner diameter of 6 millimeters. The crossed wires each had a diameter of 1 mil. With the exception of the peak reflectivity of the mirrors, considerable variation in the parameters is tolerable.

65 Basically, the mode pattern selector reduces the number of transverse energy distributions that the optical cavity will support efficiently. The only transverse modes supported will be those which have nulls at the places where the light interrupting elements are located in the light path. By reducing the number of such modes that is supported, there is reduced the number of oscillatory modes that are excited with a consequent improvement in the purity of the resulting light and also an increase in the power output associated with the modes that are excited.

70 For increased mode isolation, it is feasible to add still additional light interrupting or absorptive elements in the light path within the optical cavity. In particular, there may be included along the light path an additional partially reflective element as disclosed in our copending application No. 37498/62 (Serial No. 1,015,154).

#### WHAT WE CLAIM IS:—

1. A helium-neon optical maser arranged to emit visible radiation having a wavelength of substantially 6328 Angstroms.

2. A maser according to claim 1, which comprises an optical cavity formed by dielectric mirrors having a peak reflectivity of substantially 6340 Angstroms.

3. A maser according to claim 2, including separate light interrupting elements in the path of the radiated light beam of the maser for reducing the number of resonant modes of the cavity.

4. A maser according to claim 3, in which said elements comprise a pair of crossed wires.

5. A maser in accordance with claim 4, including also means forming an iris diaphragm in the path of the radiated light beam.

6. An optical maser according to any one of the preceding claims, in which the helium-neon ratio is about 10 to 1 at a total pressure of about 0.7 millimeters of mercury.

7. A maser according to any one of the preceding claims, including means for forming a discharge within the helium neon negative temperature medium.

8. An optical maser arranged and adapted to operate substantially as herein described with reference to and as shown in the accompanying drawings.

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Positioned intermediate the window 13 and reflector 20 is the mode pattern selector 21 comprising the two-wire assembly member 22 and the iris diaphragm member 23. The reflectors, the envelope and the mode selector members are all aligned along the light beam path 14 which passes along the axis of the envelope and through the mode selector.

FIG. 2 is a front view of the crossed wire assembly member 22. It comprises simply a pair of cylinders 22A and 22B aligned end to end as seen in FIG. 1, each of which includes a separate wire 24, 25 extending diametrically across the cylinder. The two cylinders are separately rotatable whereby the angle of intersection  $\theta$  as seen in a front view can be varied as desired. Moreover, advantageously, the assembly can be moved in the plane normal to the beam path through the cylinders. Moreover, provision may be made for varying the separation along the beam path of the two cylinders for varying the spacing of the two wires therealong. The wires serve as localized discontinuities interrupting the light along the beam path.

Additionally, the mode pattern selector advantageously includes the iris diaphragm member 23 which is adapted for varying the size of the iris or opening. This simply can be a member similar to the type used in controlling the size of the lens aperture in a conventional camera. Additionally, it is advantageous to make the position of the iris opening adjustable in the plane normal to the direction of the light path through the iris.

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For increased mode isolation, it is feasible to add still additional light interrupting or absorptive elements in the light path within the optical cavity. In particular, there may be included along the light path an additional partially reflective element as disclosed in our copending application No. 37498/62 (Serial No. 1,015,154).

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4. A maser according to claim 3, in which said elements comprise a pair of crossed wires.

5. A maser in accordance with claim 4, including also means forming an iris diaphragm in the path of the radiated light beam.

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