A THESIS

ENTITLED

INVESTIGATIONS OF SOME OPTICAL CHARACTERISTICS OF A GAS LASER BEAM

Presented by

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ABSTRACT

A description of the D.C. gas laser used in this work which has been successfully assembled in this laboratory, its alignment and adjustment are given. An experimental study of the propagation, divergence, focusing and collimation of the laser beam are carried out. Correlation between theoretical formulae by previous authors and the experimental results obtained is made. The optical arrangement for collimation has been described and deduced from theoretical findings. Lines of equal amplitude and surfaces of equal phase have been established experimentally.

Multiple-beam fringes are formed by the laser beam on high order surfaces of localization. A silvered air-wedge has been used and fringes are located at long distances from the interferometer on numerous surfaces superceding a conventional [illegible].

Introduction

Laser oscillation is marked by a remarkable narrowing of the spectral and angular distribution of the spontaneous emission of radiation from a particular level of excitation. The specific process of laser oscillation designating the behaviour of a laser above a well defined threshold is distinguished from the general process of stimulated emission.

The notation of stimulated emission was advanced by Einstein in 1917.

Definite proposals of applying the phenomenon of stimulated emission to produce amplification were made independently by Basov, Prokhorov,[1] Townes and Weber.

The use of a gas discharge to obtain a negative absorption coefficient was proposed by Fabrikant[2] in 1959 in a system in which the relaxation of the lower level was to be obtained by inelastic collisions with atoms or molecules in a buffer gas.

Lamb[2] in 1950 mentioned the possibility of obtaining negative temperatures between the $2\,^2S_{1/2}$ and $2\,^2P_{3/2}$ levels of hydrogen.

The first successful [illegible] of stimulated emission was made in (1954) by Gordon, Zeiger and Townes[4] who used the inversion transition of ammonia to obtain continuous maser oscillation at 24 [illegible] c/s.

Schawlow and Townes[5] in (1958) analyzed the Fabry-Perot interferometer as a highly overmoded rectangular resonator and concluded that optical maser action should be possible using the F.P. interferometer.

Maiman[6] in (1960) irradiated a ruby crystal in the form of a rod with plane parallel ends coated with silver, with intense pulses of light from a flash lamp and found above a certain threshold of energy of the incident light, unusually strong amplification of a single wave-length in the red part of the visible spectrum at $\lambda = 6943$ Å.

This observation were very quickly extended by Collins, Nelson, Schawlow, Bond, Garrett and Kaiser[7] in 1960, who demonstrated the coherence and directionality of the stimulated radiation and also observed the characteristic relaxation oscillations in the amplitude of the output radiation.

Javan[8] and Sanders[9] in (19[illegible]) explored the effectiveness of electron excitation and exchange of excitation as a means of producing negative absorption. This work led to Javan's [illegible] in the fall of (1960).

An important advance was the development of the p-n junction laser in (1962) by Hall, Fenner, Kingsley, Soltys, and Carlson,[10] Nathan, Dumke, Burns, Dill and Lasher,[11] and Quist, Rediker, Reyes, Krag, Lax, McWhorter, and Zeiger.[12] By injection high current densities in Ga As P-n diodes, they demonstrated a striking line narrowing accompanied by strong directionality of the recombination radiation.

Faust et al.[13] have obtained maser oscillation by electron excitation of the pure noble gases (neon, argon, krypton and xenon). Very large number of transitions at wavelengths from about 1 to 35 μ were obtained.

The unusually high gain of over 50 dbm on the 3.508 line of Xe has been measured in a He-Xe mixture[14] and in pure Xe.[15] With such high gain, a gas maser can be constructed at 3.508 with size comparable with solid state maser, but having high spectral purity.

In general the basic properties distinguishing the laser light from light obtainable from other sources are :

1- high intensity

2- monochromaticity

3- the relative coherence in time domain, coherence of radiation emanating from different parts of the laser and the resulting collimation

4- narrowing band width

5- the ability **to** atim it in the proper direction.

The coherence of the light obtainable from a gas laser makes it possible to extend the range and precision of measurements based on interferometry, while the high monochromaticity leads to an improvement of the precision of measurements based on a frequency change.

Interferometry with ordinary light sources is possible only when the path difference does not exceed a few centimeters. With a He-Ne laser as a source, the permissible path difference exceeds any convenient laboratory distance. Such a laser used to determine the length of a meter bar by an automatic fringe counting method. In many laboratories He-Ne lasers are used with interferometric measuring equipment to evaluate the quality of optical component such as lenses, prisms, and laser rods.

Townes and his collaborators performed an improved version of the Michelson-Morley experiment whose object is to test the isotropy of space with respect to light propagation. The experiment confirmed with three times the precision of the classical experiments that there is no anisotropy in the velocity of light associated with the motion of the earth.

Also laser methods have been devised to determine electron densities and temperatures of plasmas by measuring either the index of refraction, i.e., a change of optical length, or the spectral line width.

Laser beam was used in spectroscopic analysis. Minute samples can be vaporized by focusing the laser beam on a small spot. After vaporization, the material may be raised to the temperature required by emission spectroscopy by a condenser discharge initiated following the laser pulse.

Lasers have been used as light sources for telephoto pictures, for microscope illuminators, and for high-speed photographic systems. These applications make use of the high brightness and the beam collimation of laser.

The propagation of laser radiation has several distinctive features in comparison with incoherent sources.

Among the main characteristics of laser radiation are the intensity distribution over the laser beam cross section and the divergence of the [illegible] coming directly from the laser or after focusing by a lens. Investigation can be achieved either visually for qualitative studies or on a photographic plate or an electron-optical converter for quantitative investigations. The observed distribution pattern remains the same independent on the position of the screen relative to the laser. It only changes its size which depends nonlinearly on the distance from the centre of radiation i.e. the centre of the cavity resonator for symmetrical reflecting mirrors. The nonlinear variation in size of the field distribution is associated with nonrectilinear propagation of laser radiation.

Among the characteristics of laser radiation associated with its coherence is what appear when a laser beam is focused by a lens or mirror. In ordinary practice with geometrical optics, however placed an object before a converging lens and a screen behind it, we can always choose the distances so that we obtain on the screen either an image of the object or a nearly uniformly [illegible] area. Using laser radiation all planes [illegible] the lens and perpendicular to laser tube axis shows the same field distribution whose scale varies according to a hyperbolic relation in which the parameters of the hyperbola and the position of its asymptotes depend on the properties of the cavity and on the position and focal length of the lens.

THE THEORY OF LASING ACTION IN He-Ne LASER AND DESCRIPTION OF THE MAIN COMPONENTS NEEDED FOR ITS OPERATION

Chapter I