CW LASER OSCILLATIONS IN Cd II IN AN ELECTRON BEAM CREATED PLASMA

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A cw Cd II laser has been demonstrated using electron beam excitation. Cw laser oscillation has been obtained on six transitions of Cd II in a He–Cd plasma. Output power as a function of electron beam discharge parameters has been investigated.

The green laser lines of Cd II fail to oscillate cw in a positive column discharge. Cw laser oscillation on the 5337 Å ($4f\,^2F^o_{5/2} \rightarrow 5d\,^2D_{3/2}$) and 5378 Å ($4f\,^2F^o_{7/2} \rightarrow 5d\,^2D_{5/2}$) transitions of singly ionized cadmium was first obtained by Schuebel [1] in a slotted hollow cathode discharge. Recently, we proposed the use of a dc electron beam to excite cw ion lasers [2]. Here we report cw laser oscillation on these green transitions as well as on the 4416, 6355, 6360 and 8067 Å lines of Cd II, obtained using a dc electron beam discharge as the laser active medium.

The electron beam created plasma presents a non-maxwellian electron energy distribution that has high density of energetic electrons, hence, this plasma is a new and attractive active medium for ion lasers. As a specific example, consider the He–Cd laser. In positive column He–Cd discharges, the electron temperature decreases very rapidly with increasing cadmium pressure [3]. As a result, the metal vapor concentration and the electron temperature cannot be independently optimized. In the electron beam excitation scheme, the Cd concentration in the plasma tube and the parameters of the electron beam discharge can be more independently varied.

The experimental setup used to obtain cw laser oscillation on Cd II transitions is shown in fig. 1. We have used a dc electron beam of energy between 1 and 5 keV to excite a He–Cd gas mixture. The electron beam is generated by a glow discharge electron gun [4] that provides an optical path throughout the axis. This permits us to match the electron beam created plasma volume with the corresponding volume of the optical resonator. Electron beam discharge currents up to 1 A are generated by the glow discharge electron gun. This electron gun operates in helium at pressures between 0.1 and 3 Torr without differential pumping. The electron gun is mounted in a micropositioner that permits one to accurately and easily align it with respect to the axis of the plasma tube. The stainless steel plasma tube is 1.1 cm in diameter and 100 cm long. The electron gun chamber and the plasma tube are separated by a water-cooled metal vapor trap that is connected to the vacuum pump (see fig. 1). At the opposite end of the plasma tube there is a cadmium source reservoir. The plasma tube is surrounded by

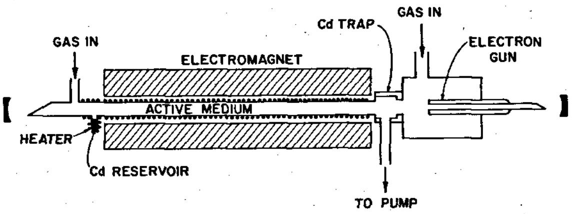

Fig. 1. Schematic diagram of the electron beam Cd ion laser.

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an oven that provides a temperature higher than the one corresponding to the independently heated Cd reservoir. In this way we avoid condensation of Cd on the walls of the plasma tube. A good distribution of the Cd vapor in the plasma region is achieved by flowing He at 200 and 400 standard cc per minute. The axis of the plasma tube is coincident with the axis of a solenoid capable of producing a magnetic field of up to 4.2 kG. The axial magnetic field helps to efficiently deposit the electron beam energy in the plasma, reducing collisions of energetic beam electrons with the walls.

The metal vapor trap used in the first laser experiments had a circular opening of 0.6 cm in diameter connecting the electron gun chamber and the plasma tube. This trap was stopping part of the electron beam from reaching the active medium in the plasma tube. In this first experiment we obtained laser action on the 5337, 5378 and 8067 Å transitions of Cd II. All three laser lines had a current threshold between 60 and 70 mA, corresponding to a discharge voltage of 1.3 kV. Fig. 2 shows the laser power output as a function of the average helium pressure in the plasma tube at a cadmium reservoir temperature of 300°C and an electron beam discharge current of 700 mA. Fig. 3 shows the laser output power as a function of electron beam discharge current and voltage for a magnetic field of 3.9 kG, a Cd reservoir temperature of 300°C, and an average helium pressure in the plasma tube of 1.15 Torr. Under this condition the laser output power of the green lines continues to rise up to the maximum current, but the output laser power of the 8067 Å line saturates and decreases as the electron beam current is increased. This saturation is less evident at weaker magnetic field strengths.

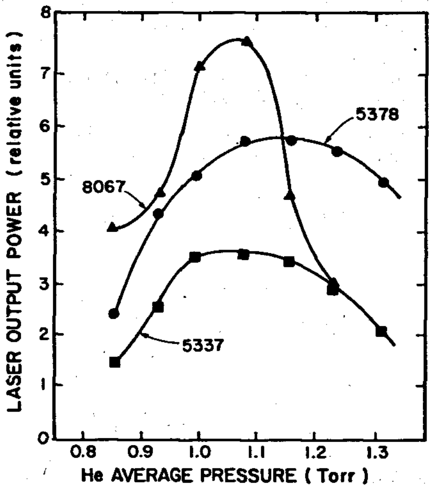

Fig. 2. Laser output power as a function of the average helium pressure in the plasma tube at a current of 700 mA and a Cd reservoir temperature of 300°C. Magnetic field 3.9 kG. Wavelengths are given in A and the intensity of the 5337 A line is 2× its actual value.

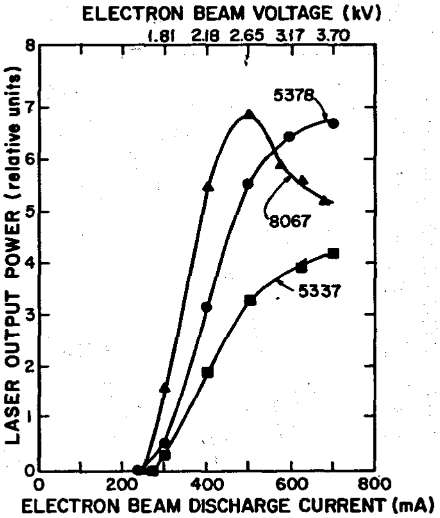

Fig. 3. Laser output power as a function of electron beam discharge current and voltage. Cd reservoir temperature 300°C. Magnetic field 3.9 kG. Average helium pressure in the plasma tube 1.15 Torr. Wavelengths are given in A and the relative intensity of the 5337 A line is 2× ist actual value.

In later experiments we redesigned the metal vapor trap allowing a better deposition of the electron beam into the He–Cd mixture. Enlarging the opening of the metal vapor trap to 1.0 cm in diameter, laser action was obtained on three additional transitions of Cd II: 4416, 6360 and 6355 Å. Also, the optimum magnetic field value for optimum laser output dropped significantly. The laser output power of the red lines as a function of discharge current and voltage is shown in fig. 4 for an optimum magnetic field of 1.25 kG.

The most intense laser lines were the green lines. Using an unoptimized optical resonator with an output coupler reflectivity of 95.5% at 5350 Å a maximum laser power of 80 mW was obtained for the combination of the 5378 and 5337 Å transitions. The output power of the other laser transitions was not optimized or measured.

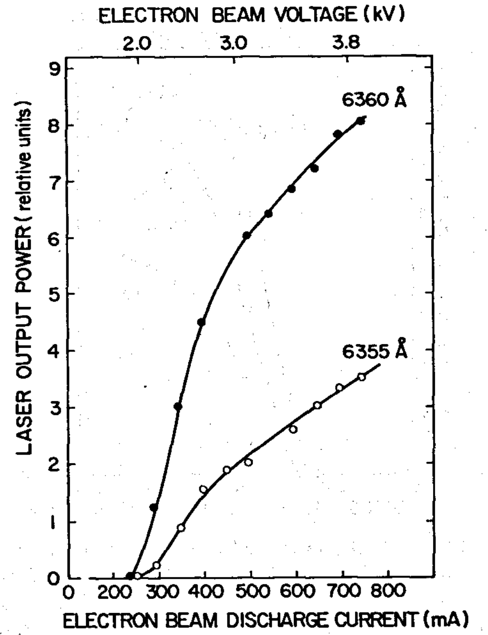

Fig. 4. Laser output power of the 6355 Å and 6360 Å as a function of electron beam discharge current and voltage. Cd reservoir temperature 315°C, magnetic field 1.25 kG. Average helium pressure in the plasma tube 2.5 Torr.

In hollow cathode discharges, the dominant excitation mechanism for the transitions at 5378 and 5337 Å is suggested to be radiative cascade to the upper laser levels via the 6360 and 6355 Å transitions respectively [1]. These two red transitions are laser lines that are populated by charge transfer collisions between He ions and ground state Cd atoms. To examine the possibility of direct electron impact excitation of the green Cd II transitions from the Cd I ground state, we replaced He as a buffer gas. First, laser radiation in a pure He–Cd mixture was established. Then, we observed the laser output power decreased as a function of increasing percentage of Ne until it has been completely quenched with only a 1 : 3 Ne to He ratio. This suggests that the charge transfer process involving He^+ and ground state Cd followed by radiative cascade makes the dominant contribution to the population of the $4f\,^2F$ Cd II laser levels.

In summary we have obtained cw laser radiation for the first time in singly ionized cadmium using electron beam excitation of a He–Cd gas mixture. A cw laser output power of 80 mW was obtained for the combination of the green Cd II laser transitions. The use of a dc electron beam presents a new method of exciting ion lasers.

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