cw Ion Lasers Pumped by Electron Beams

J. J. Rocca, J. D. Meyer, Zeng-qi Yu, and G. J. Collins

Department of Electrical Engineering, Colorado State University, Fort Collins, CO 80523, USA

PACS: 42.55

We have obtained cw laser radiation from singly ionized Hg, I, Cd, Se, and As by exciting He metal-vapor mixtures with a dc electron beam. The beam is generated by glow discharge electron guns located apart from the active medium. This is the first time that cw ion laser action has been obtained using electron beam excitation.

The conventional manner of exciting cw ion lasers is to use electron collisions in the positive column region of a discharge. A positive column has roughly a Maxwellian electron distribution with a mean electron energy of 3–8 eV, depending on the electrical and geometrical characteristics of the discharge. Hence, only those electrons in the tail of the Maxwell-Boltzman energy distribution are energetic enough to provide direct excitation of ion laser upper levels. In conventional discharges when the metal vapor is added to a rare gas buffer, the electron temperature of the positive column decreases dramatically. Hollow cathode lasers have an electron beam component in the electron distribution, but it is small and inefficiently produced. The beam component accounts for only 10^{-1} of the total discharge current. Even with this small beam component many new laser transitions have been obtained. Both dc hollow cathode and positive column discharges provide too low a density of energetic electrons which are required for excitation of VUV laser transitions.

We report a new type of active medium for cw ion lasers where the plasma is created by an electron beam with an energy between 1 and 10 keV. Electron beam created plasmas with a non-Maxwellian electron energy distribution, having a high density of energetic electrons, provide an attractive approach to increasing the power and efficiency of cw ion lasers as well as extending their spectral operating range to the VUV.

The longitudinal electron beam geometry used to obtain laser oscillation in five ion species is shown in Fig. 1. The electron beam is generated by a glow discharge and is injected into the magnetically confined plasma region. That is, the beam generation and active laser regions are separated from each other. In the case of metal vapors this allows for an independent optimization of the metal vapor pressure in the laser active medium and of the glow discharge created electron beam parameters. A solenoid surrounds the plasma tube providing an axial magnetic field that helps collimate the electron beam. The electron gun has the unique feature of providing a clear optical path. This permits one to match the electron beam created plasma volume with the corresponding volume of the optical resonator. The electron guns produce a well collimated electron beam, with current up to 1 amp and a beam energy between 1 and 10 keV. The electron gun operates at pressures between 0.1 and 3 Torr in helium, without differential pumping. As an example, the output power characteristic of the 6149.9 Å Hg II is shown in Fig. 2.

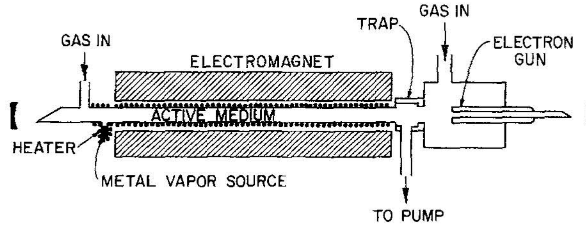

Fig. 1. Schematic diagram of electron beam excited laser apparatus

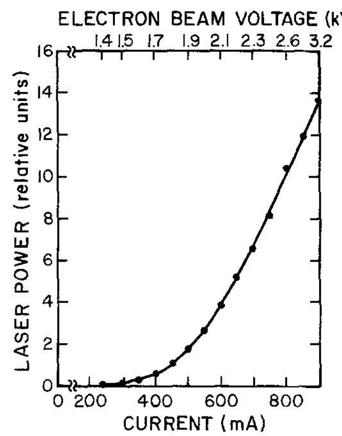

Fig. 2. (a) Laser output power as a function of the electron beam discharge voltage and current. Magnetic field optimized for each current. Temperature of the Hg reservoir 130 °C. Helium flow is 400 SCCM and the average helium pressure in the plasma tube is 2 Torr. (b) Laser output power as a function of helium flow, at a current of 700 mA. Temperature of Hg reservoir 130 °C. Magnetic field strength 3.7 kG

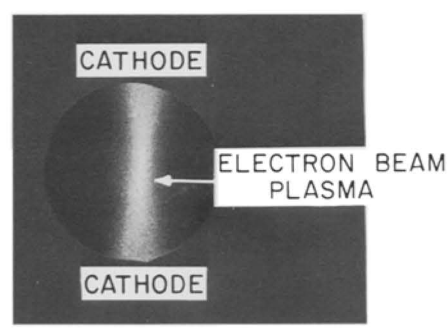

Fig. 3. End view of trapped transverse electron beam discharge

A transverse glow discharge electron beam, shown in Fig. 3, has also been developed along with the longitudinal scheme described above. In Fig. 3 the electron beam is partially trapped between two opposite cathodes. Preliminary results in this transverse scheme will also be presented.

Population inversion density in the electron beam created plasma has been calculated by solving a rate equation model. The electron energy distribution used was determined by solving the Boltzman transport equation for electrons in the He-metal vapor mixtures. Modeling results will be presented for the particular case of the He-Hg^+ laser, and compared to experimental results.