Low-Energy Electron-Beam Pumped Gas-Laser ◇

A. Ulrich, C. Nießl, M. Salvermoser, H. Tomizawa, J. Wieser, and D. E. Murnick [a]
[a] Department of Physics, Rutgers University, Newark, NJ 07102, USA

A low energy electron beam has been used for pumping a laser in dense gas in transverse geometry. Electron beam pumping is routinely used with electron energies ranging from 200keV to 2MeV [1]. Here, the electron energy could be reduced by at least an order of magnitude to about 10keV. This has become possible by the enabling technology of extremely thin ceramic foils used as entrance windows for the electrons, as described in ref. [2] and [3].

Reducing the electron energy reduces the range of the electrons in the laser medium. This in turn increases the pumping power density for a given beam current. The scaling of pumping power density with electron energy E can be determined from the range of the electrons [4] which scales as $E^{7/4}$ in the energy range from 5 to 50keV. Large angle scattering leads to an almost spherically shaped excited volume for an electron beam which enters the gas in a point focus. In the case of a line focus of the electron beam, as normally used for transverse laser pumping, a cylindrically shaped volume is excited. The diameter of the beam pumped volume is given by the range of the electrons. Therefore the volume V scales as $1/E^{7/2}$. Since the beam power P is proportional to E the pumping power density P/V scales as $1/E^{5/2}$.

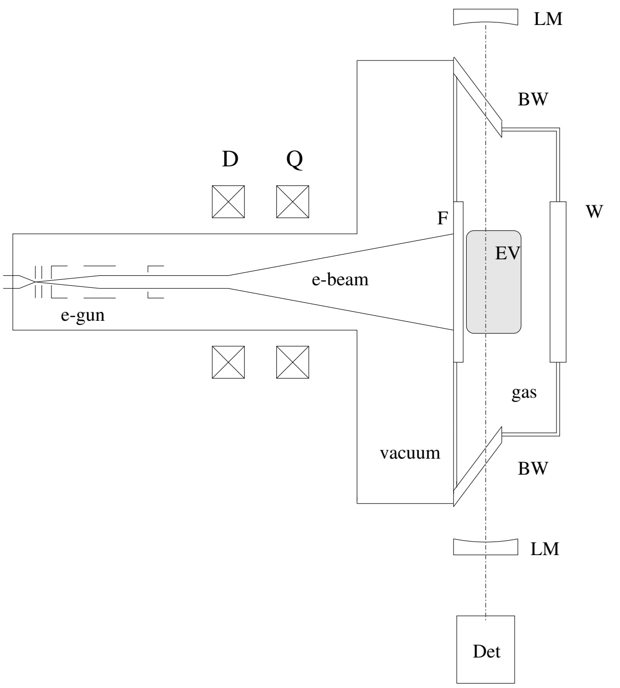

Fig. 1: Schematic drawing of the laser setup. The electron beam is emitted from the electron gun. Steering and shaping to a line focus is performed by the dipole and quadrupole magnets D and Q. The beam enters the laser gas through the entrance foil F. The optical cavity is formed by the laser mirrors LM and Brewster windows BW.

For a first demonstration of laser effect using such very low electron energies for pumping, a pulsed 11keV, 1mA electron beam was focused to an approximately 5mm long line focus and sent through a 40mm long, 0.7mm wide, and 300nm thick SiN_x foil into the laser gas. The energy loss in such a foil is only 15% of the 11W total beam power. The electron beam was produced by a small electron gun (Clinton Electronics, Type 3-659) which is normally used in monochrome TV- tubes. The beam was formed to 40μs long pulses with a repetition rate of 150Hz by applying positive 80V pulses to a slightly negatively biased grid in the electron gun. The beam was tuned using the elctrostatic focusing of the electron gun and magnetic quadrupole and dipole magnets which were mounted outside the evacuated part of the laser setup in which the electron beam was formed. The laser setup is schematically shown in fig. 1.

The $5d[3/2]_1$ - $6p[5/2]_2$ atomic Xe line at 1.73μm in the near infrared was used as the first laser system to be pumped by the low energy electron beam. Argon gas at pressures between 100 and 600mbar was used as the buffer gas to which xenon was added. Laser effect was observed for xenon concentrations between 0.1 and 1% at a total gas pressure of 300mbar. In the first experiments described here a threshold pumping power of 5W and a maximum output power of 6mW at 11W pumping power were observed. Some aspects of the 1.73μm ArXe laser are described in another contribution to this annual report.

The laser cavity was formed by two external mirrors of 50cm radius with curvature held in adjustable mirror mounts on an optical bench at a distance of 40cm. The laser cell was closed by two quartz Brewster windows. The position of the optical axis could be adjusted for optimum overlap with the electron beam pumped volume by adjusting the position of the aligned cavity with respect to the laser cell. For 300mbar argon buffer gas pressure the energy deposition depth [5] of 11keV electrons is 2.3mm. This matches quite well with the diameter of the mode volume of a Gaussian TEM_{00} mode which is 0.7mm at its waist for the cavity parameters described above.

In general, the low energy electron beam pumping has the great advantage for laser schemes which require particle beam pumping of dense gases, such as excimer lasers, that the small pumped volume matches well with stable optical resonators. This allows an alternative mode of operation compared with typical transversely pumped lasers with large volumes and unstable optical cavities.

References

[1] Ch. A. Brau, Excimer Lasers, Chapter 4.3, Editor Ch. K. Rhodes, Topics in Applied Physics, Vol. 30, Second Edition, Springer Verlag, Berlin, Heidelberg, Ney York, Tokyo
[2] J. Wieser, D. E. Murnick, A. Ulrich, H. A. Huggins, A. Liddle, and W. L. Brown, Rev. Sci. Instrum. **68** (1997) 1360
[3] A. Ulrich, H. Shaw, J. Wieser, and D. E. Murnick, Jahresbericht 1996, p. 116
[4] A. Cohn and G. Caledonia, J. Appl. Phys. **41** (1970) 3767
[5] S. Valkealahti, J. Schou, and R. M. Nieminen, J. Appl. Phys. **65** (1989) 2258

◇ Work supported by INTAS Grant 96/351 and NATO Grant 921215