CLM - P 446

CLM - P 446

UKAEA RESEARCH GROUP

Preprint

PLANE-POLARIZED CO_2 LASER BEAM FROM AN UNSTABLE CONFOCAL RESONATOR

K KURIKI
N J PEACOCK

CULHAM LABORATORY
Abingdon Oxfordshire

1976

CLM-P 446

PLANE-POLARIZED CO_2 LASER BEAM FROM AN UNSTABLE CONFOCAL RESONATOR

K. Kuriki* and N. J. Peacock

Euratom/UKAEA Fusion Association,

Culham Laboratory, Abingdon, Oxon, UK.

ABSTRACT

A plane-polarized output has been obtained from a double-discharge TEA CO_2 laser with an unstable confocal resonator, by adding KCl polarizers. The fractional power in the plane-polarized component is 95%. The output energy is unaffected by the presence of the polarizers.

* On leave from Institute of Space and Aeronautical Science, University of Tokyo, Japan.

November 1975

EXPERIMENTAL ARRANGEMENT AND RESULTS

A plane-polarized CO_2 laser beam was obtained from a double-discharge TEA CO_2 laser (1,2,3) with an unstable resonator, by adding polarizers in the cavity. As shown in Fig. 1, the resonator is composed of a concave mirror of radius of curvature $R_1 = 3.95$m, diameter $D_1 = 55$mm, and a convex mirror at the output end with radius of curvature $R_2 = 1.45$m, diameter $D_2 = 17$mm. The polarizers are two, single rectangular KCl plate 100mm x 50mm x 5mm mounted at the Brewster angle of 55^o, each placed between the discharge region and the cavity mirrors as shown in Fig. 1.

The lasing discharge takes place normal to the plane of the diagram in Fig. 1, and is between a flat anode and a flat cathode which has a series of longitudinal grooves cut in it. An auxiliary corona discharge is initiated at the cathode surface by means of trigger wires sealed in glass tubes, which are placed in the cathode grooves. The main capacitor, of capacitance 0.2 µF, is normally charged to 60 kV. The working gas is a CO_2-N_2-He mixture of 1:1:6 at a pressure of one atmosphere.

An uncoated germanium plate has been used as the polarization analyzer. The germanium plate is placed in front of the detector and is set at the Brewster angle of 76^o with respect to an axis parallel to the corresponding axes of the KCl polarisers in the resonator. The beam power was measured by a photon drag detector with a 4mm x 4mm sensing area. In order to sample the same part of the laser beam with and without the germanium analyzer, an aperture limiter of 4mm diameter is placed in front of the analyzer, as shown in Fig. 2. When the germanium analyzer is used, the photon drag detector is moved from position 1 to 2 in Fig. 2. The detector signal, as illustrated in Fig. 2, shows a main pulse of 45 nsec half-width followed by a long tail lasting for about 1µsec. The response of the photon drag detector was measured to be linear over the range of powers measured. The amplitude of the detected pulse is therefore proportional to the input beam power.

The laser output power S_1 is composed of two components: one polarized in the plane of incidence $J_{\parallel}$ and the other polarized at right angles to this plane, $J_{\perp}$

$$S_1 = J_{\parallel} + J_{\perp} . \qquad \text{... (1)}$$

Ignoring the absorption and multiple reflections in the germanium plate, the power transmitted through the analyzer S_2 is given by

$$S_2 = T_{\parallel}^{\,2} J_{\parallel} + T_{\perp}^{\,2} J_{\perp} \qquad \text{... (2)}$$

where $T_{\parallel} = 1.00$ and $T_{\perp} = 0.22$ are the transmission coefficients at one surface for the parallel and perpendicular components, respectively. Combining these equations, the fractional power in the parallel component is

$$J_{\parallel} / (J_{\parallel} + J_{\perp}) = 1.05(S_2/S_1) - 0.05. \qquad \text{... (3)}$$

In practice, S_1 and S_2 were obtained from the average of six shots, in each case. The results were reproducible to within an accuracy of 7%. It was found that $S_2/S_1 = 0.95$ and using Eq. (3) $J_{\parallel} / (J_{\parallel} + J_{\perp}) = 0.95$. The error due to the multiple reflections can be ignored as long as the parallel component is highly dominant as is required in wave- plasma interaction experiments [(4)].

The output energy was measured by a disk calorimeter, the CO_2 laser being pulsed repetitively [(5)], at six shots per minute. This calorimeter has been calibrated using a CW, CO_2 laser of known output power and its sensitivity has been double-checked against a second calorimeter of the double-cone type. The output energy of a single shot using these two calibration methods is 14.5 ± 1.5 Joule and is unaffected by the presence of the KCl polarizers.

DISCUSSIONS

The large fractional power in the component with parallel polarization can be expected from the following consideration. The transmission coefficient of a KCl plate set at the Brewster angle is 0.76 for the component polarized normal to the plane of incidence. In the round-trip passage the light effectively travels four times through KCl plates. The transmission for the four KCl plates is 0.34 or, expressed as a gain, - 4.7dB. From the output energy measurement, 19% population inversion is estimated to exist in the CO_2 molecules in the lasing volume, and from the pulse shape measurement, 28% of the total liberated energy is found in the main pulse. Using these results and the stimulated emission cross section for the laser transition [6], 10.7 ± 1.1 dB is obtained as the gain due to the stimulated emission. The fractional output coupling of the cavity is 0.86 [7]. Hence, the reflection coefficient of the resonator is 0.14 or - 8.5 dB gain. Thus, for the component polarized normal to the plane of incidence, the net gain is -2.5 ± 1.1 dB and although the error is large, no amplification of this component is concluded. Since the component with parallel polarization is unaffected by the polarizers the net gain is 2.2 ± 1.1 dB and laser amplification can occur. In order to improve the degree of polarization it is recommended that a pair of stacks of KCl plates be placed at the end of the cavity.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the assistance of Mr. P. G. Dawson in the construction of the CO_2 laser. Helpful suggestions by Messrs. B. A. Ward and M. J. Forrest are also acknowledged.

REFERENCES

1. Dumanchin, R., Michon, M., Farcy, J. C., Boudinet, G., and Rocca-Serra, J., IEEE J. Quantum Electron., QE-8, pp 163-165, (1972).

2. Pan, Y. L., Bernhardt, A. F., and Simpson, J. R., Rev. Sci. Instrum., 43 pp 662-666, (1972).

3. Girard, G., Huguet M., and Michon, M., IEEE J. Quantum Electron., QE-9, pp 426-428, (1973).

4. Kuriki, K., Forrest, M. J., Morgan, P. D., and Peacock, N. J., Proc. 3rd Topical Conference on Pulsed High Beta Plasmas, UKAEA Culham Laboratory, (1975).

5. Jennings, D. A. and West, E. D., Rev. Sci. Instrum., 41, pp 565-567, (1970).

6. Gilbert, J., Lachambre, J. L., Rheault, F., and Fortin, R., Canadian Journal of Physics, 50, pp 2523-2535, (1972).

7. Freiberg, R. J., Chenausky, P. P., and Buczeck, C. J., IEEE J. Quantum Electron., QE-8, pp 882-892, (1972).

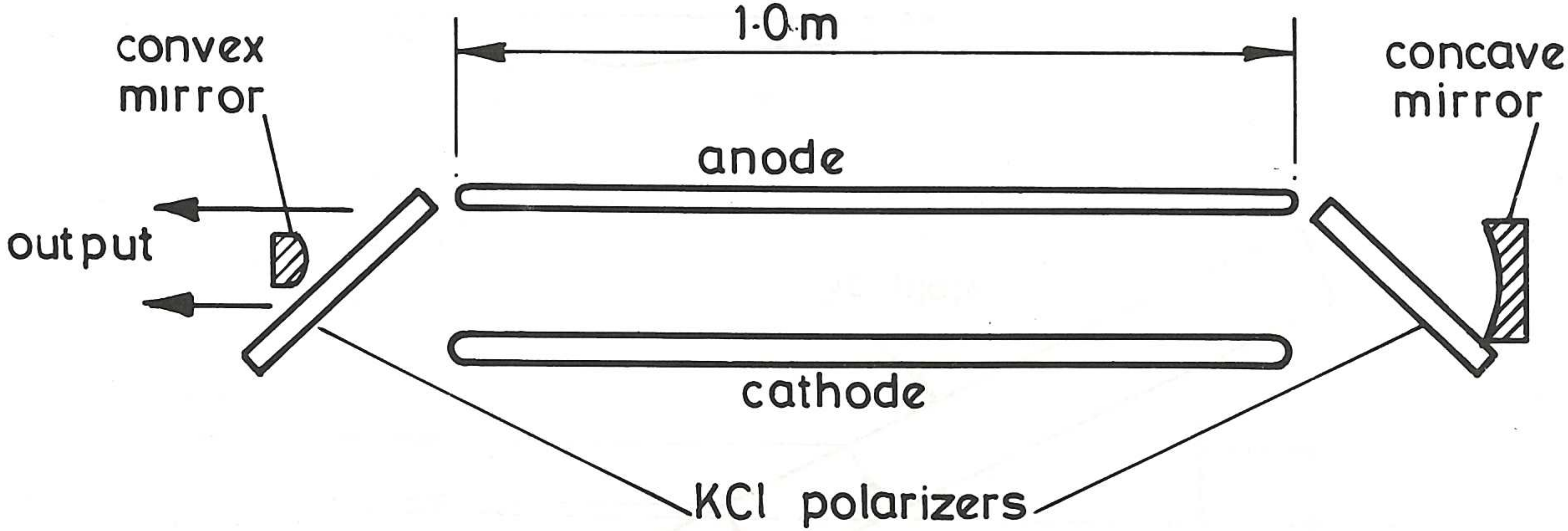

Fig.1 TEA CO_2 laser cavity

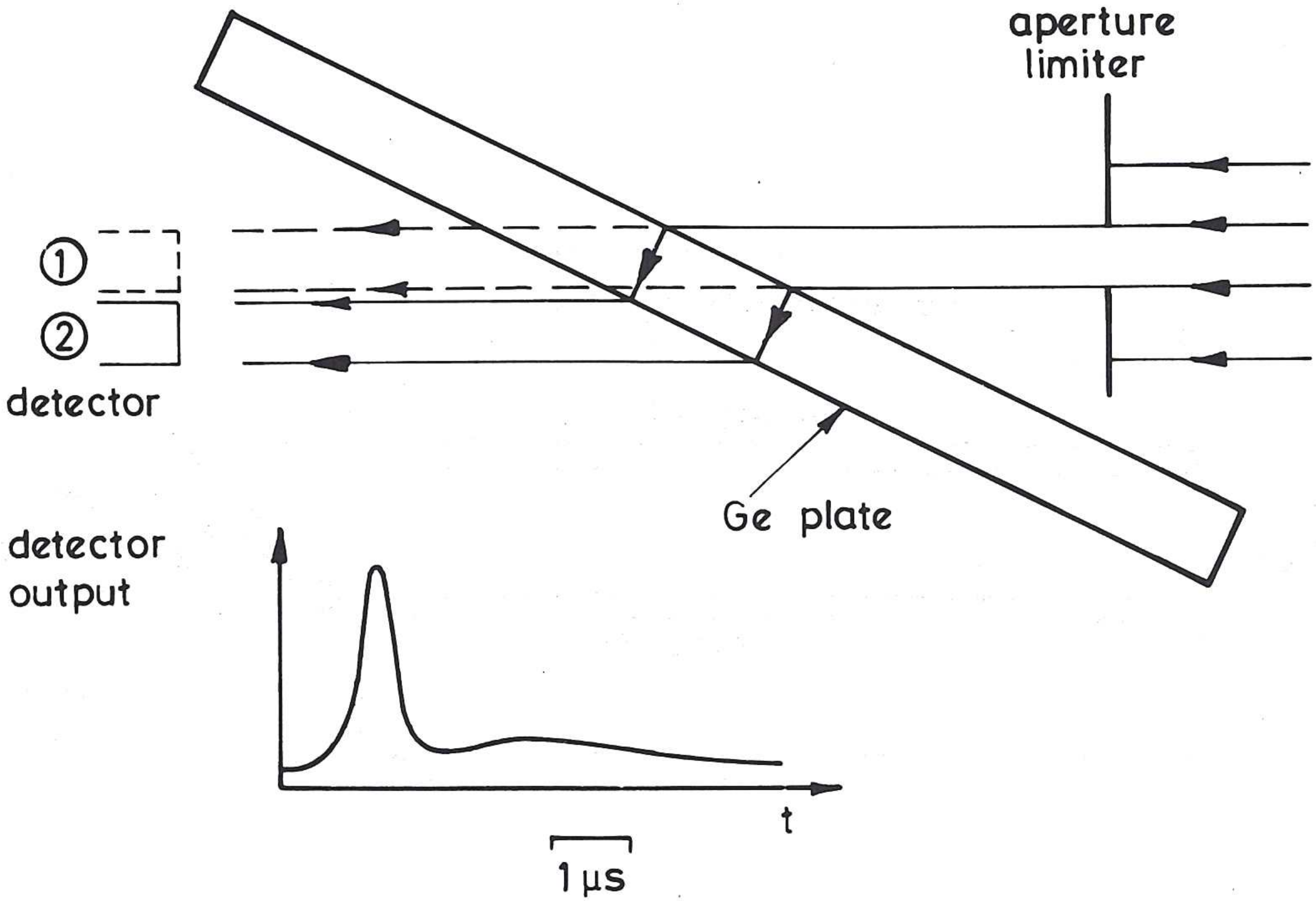

Fig.2 Polarisation analyzer, detector, and detected pulse shape