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ERL-6703-GD

DESIGN ASPECTS AND PARAMETRIC CHARACTERISATION
OF A NEUTRAL RARE GAS LASER

by

Kenneth J. Grant

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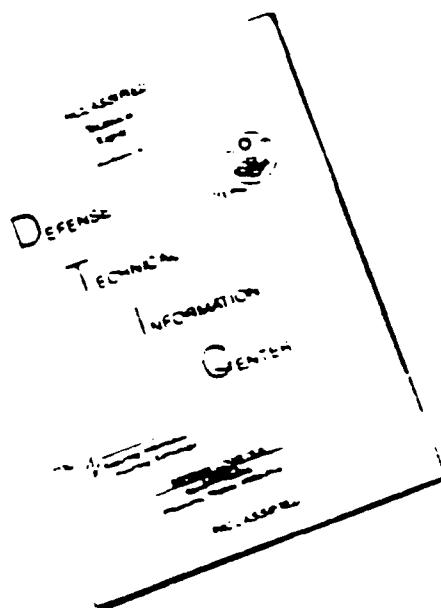
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1 INTRODUCTION

A neutral rare gas laser has been built, and used to produce continuous wave output at several wavelengths in the mid- infra-red region. Some of these lines are of particular interest because of their location in the atmospheric window around 2 μm .

The laser design is described, and results are presented of a parametric study of its operating characteristics. Mixtures of He-Ar, He-Kr and He-Xe were used, with total gas pressures in the range 11 - 35 torr. Excitation of the gas was achieved by a hollow cathode longitudinal discharge, with a maximum current of 110 mA. The output power at each wavelength was monitored as a function of the discharge parameters (total pressure, partial pressure ratio, and current), and the output coupler reflectivity, to determine the optimum working regimes.

2 LASER SYSTEM

The laser cavity is built around two 0.75" diameter, 1.7 m long invar rods, connected by aluminium blocks on which the optical components are mounted. The rear mirror is gold-plated copper, and there is the choice of three output couplers with reflectivities optimised for the

- (i) 1.8 - 2.7 μm ,
- (ii) 3.5 μm , and
- (iii) 2.7 - 4.8 μm regions (Laser Optics, Inc.).

The output couplers are 25 mm ZnSe concave mirrors with a 15 m radius curvature on the inside face. This configuration means that the cavity is a stable resonator. The external surfaces are anti-reflection coated. The Pyrex discharge tube is 1.3 m long, with a nominal internal diameter of 6.6 mm. A water-cooled jacket around the tube removes excess heat.

The gases used in the laser (He, Ar, Kr >99.999%, Xe >99.995% purity) are delivered to the tube via a moisture trap and 7 μm particulate filters. Fine control is maintained over the pressure of the gases by calibrated needle valves. The total pressure is measured by a capacitance pressure gauge (MKS Baratron type 122A). Ballast resistors of 5 k Ω and 7.5 k Ω are in series with the power supply (Industek Pty Ltd) at the cathode and anode ends of the tube, respectively.

3 EXPERIMENTAL LAYOUT

The experimental layout is shown schematically in Figure 1, and a photograph of the apparatus is shown in Figure 2. The laser radiation was dispersed by a 0.25 m focal length monochromator (Oriel 77200), and detected by a power meter (Laser Precision Corp., RKP-360). Correction was made for the spectral response of the monochromator. An XT-compatible computer controlled the current and recorded the power.

4 CONTINUOUS WAVE OUTPUT

Table 1 lists the lines which have been observed to lase in continuous wave mode. The powers are those under optimum conditions, and transitions are given in Racah notation. The atmospheric absorption coefficients were calculated with the Lowtran 6 model.

Table 1 Continuous wave output

Gases	Wavelength [μm]	Transition	Power [mW]	Atmospheric absorption coefficient [km^{-1}]
He-Xe	2.026	$5d[3/2]_1 - 6p[3/2]_1$	13.7	0.21
	2.651	$5d[3/2]_1 - 6p[1/2]_0$	1.2	26.4
	3.366	$5d[5/2]_2 - 6p[3/2]_1$	6.4	0.60
	3.434	$7p[5/2]_2 - 7s[3/2]_1$	4.0	0.23
	3.507	$5d[7/2]_3 - 6p[5/2]_2$	30.0	0.19
	3.650	$7p[1/2]_1 - 7s[3/2]_2$	0.5	0.16
He-Kr	2.523	$4d[1/2]_1 - 5p[3/2]_2$	0.8	7.17
	3.066	$6p[1/2]_1 - 6s[3/2]_2$	4.1	2.00
He-Ar	2.061	$3d[3/2]_2 - 4p[3/2]_2$	0.1	0.21
	2.207	$3d[1/2]_1 - 4p[3/2]_2$	0.3	0.16
	2.397	$3d[1/2]_0 - 4p[1/2]_1$	0.3	0.28

5 THE 2 μm ATMOSPHERIC WINDOW

Of the laser lines detected, three were chosen for detailed study because of their location in the 2 μm atmospheric window, viz. the He-Xe 2.026 μm line, and the He-Ar lines at 2.061 and 2.207 μm .

5.1 He-Xe 2.026 μm line

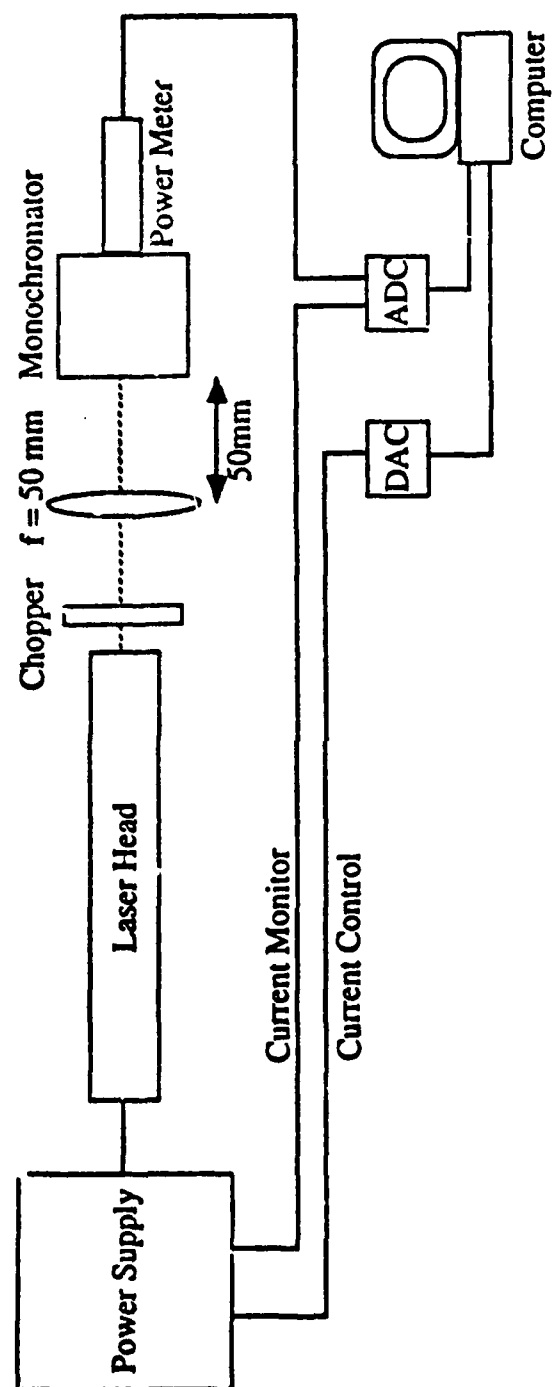
The output power of this line is shown as a function of discharge conditions at a total pressure of 11 torr in Figures 3a and b. Figure 3a shows that, for all He:Xe ratios, the power increases monotonically with current up to the maximum of 110 mA. In Figure 3b, power is plotted versus He:Xe partial pressure ratio for a range of currents. For each current there is an optimum He:Xe ratio. The higher the current, the larger the optimum He:Xe ratio ie, the leaner the mixture is in Xe. The maximum power of 13.7 mW is obtained at 110 mA and He:Xe = 80:1. This line will lase with higher total gas pressures, but with lower power. (11 torr is the lowest pressure that will sustain a stable discharge.)

5.2 He-Ar 2.061 and 2.207 μm lines

Figures 4 and 5 show the output of the 2.061 and 2.207 μm lines, respectively, as functions of the discharge conditions at 35 torr. These lines have significantly different characteristics to the Xe line, and lase over a much narrower range of conditions. This is particularly so in the case of the 2.061 μm line, which only lases between 35 and 70 mA (Fig. 4a). The 2.207 μm line lases between 15 and 55 mA, with the optimum value being dependent on the He:Ar ratio. Figures 4b and 5b show power versus partial pressure ratio. For each line, the optimum value of He:Ar is dependent on the current. Both lines require gas mixtures which are rich in Ar, and will not lase if He:Ar > 6.5:1.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the contributions of the following: Dr Shane Brunker for fruitful discussions regarding this work; Robert Roseiter for writing the data acquisition software; Fred Buttignol and John Wheatley for their assistance with the high voltage system; and Norm Jeffrey and John Bridgman for the construction of various mechanical components.

**Figure 1. Experimental layout.**

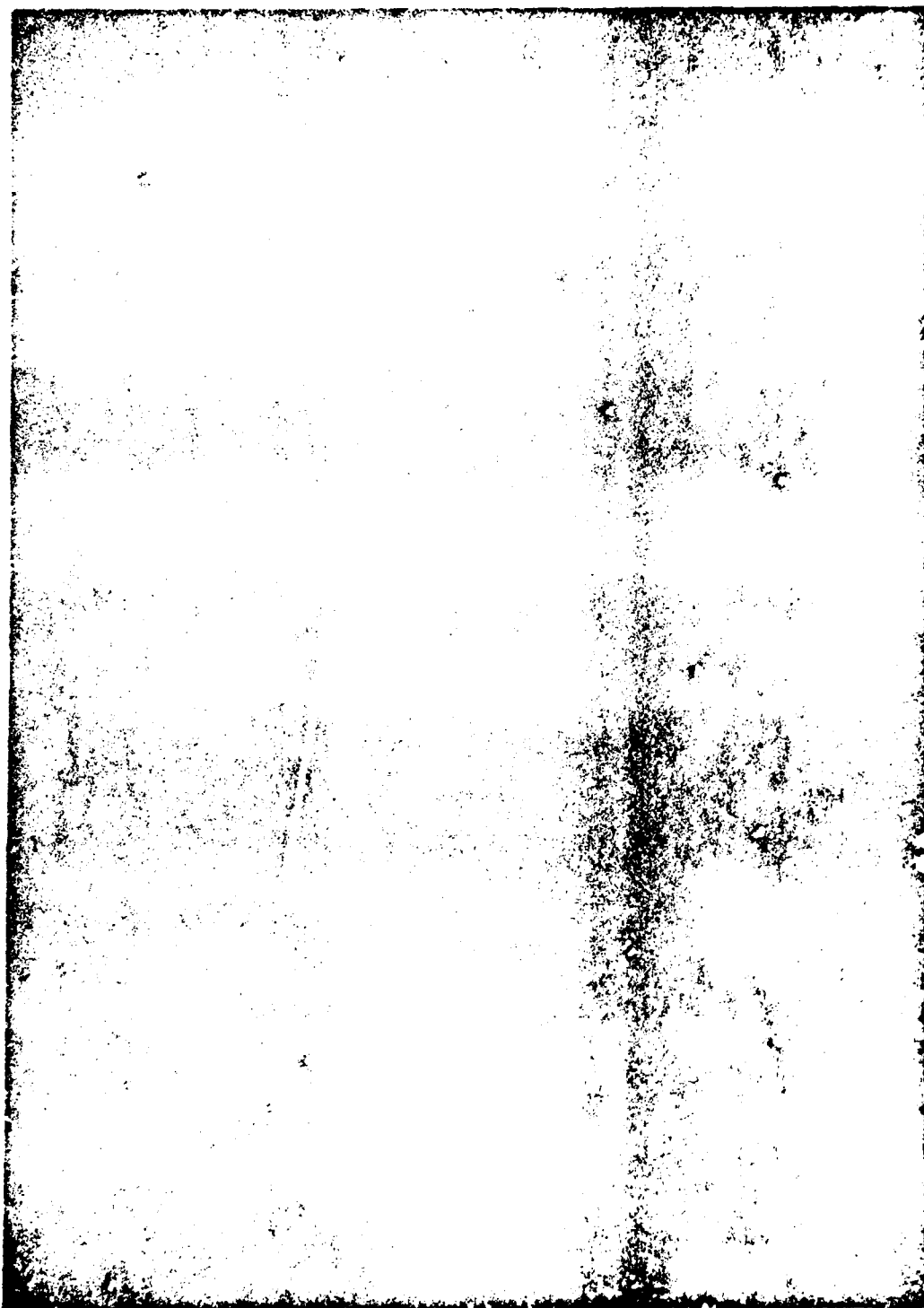
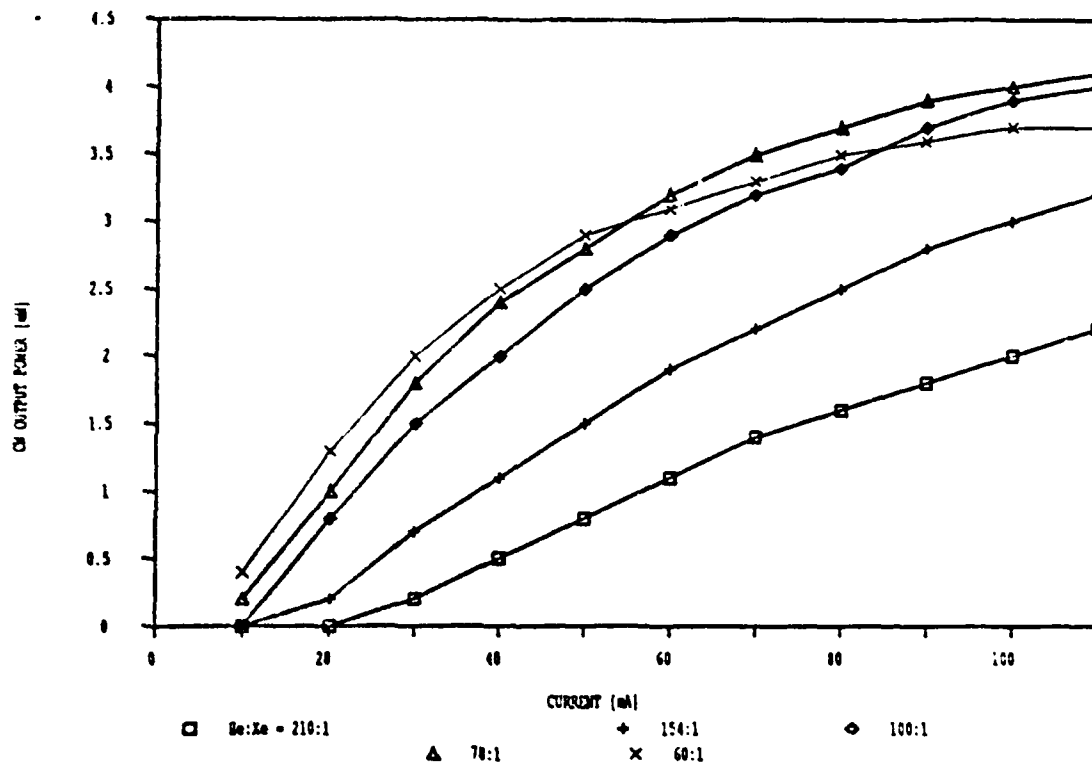
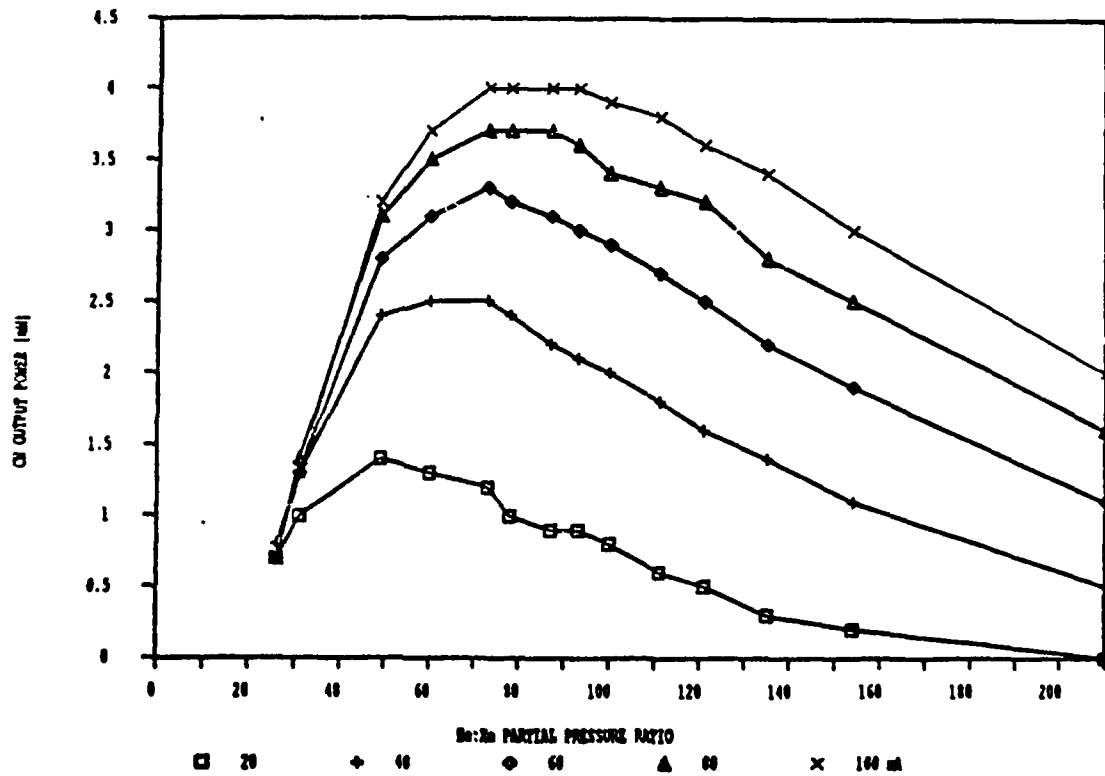
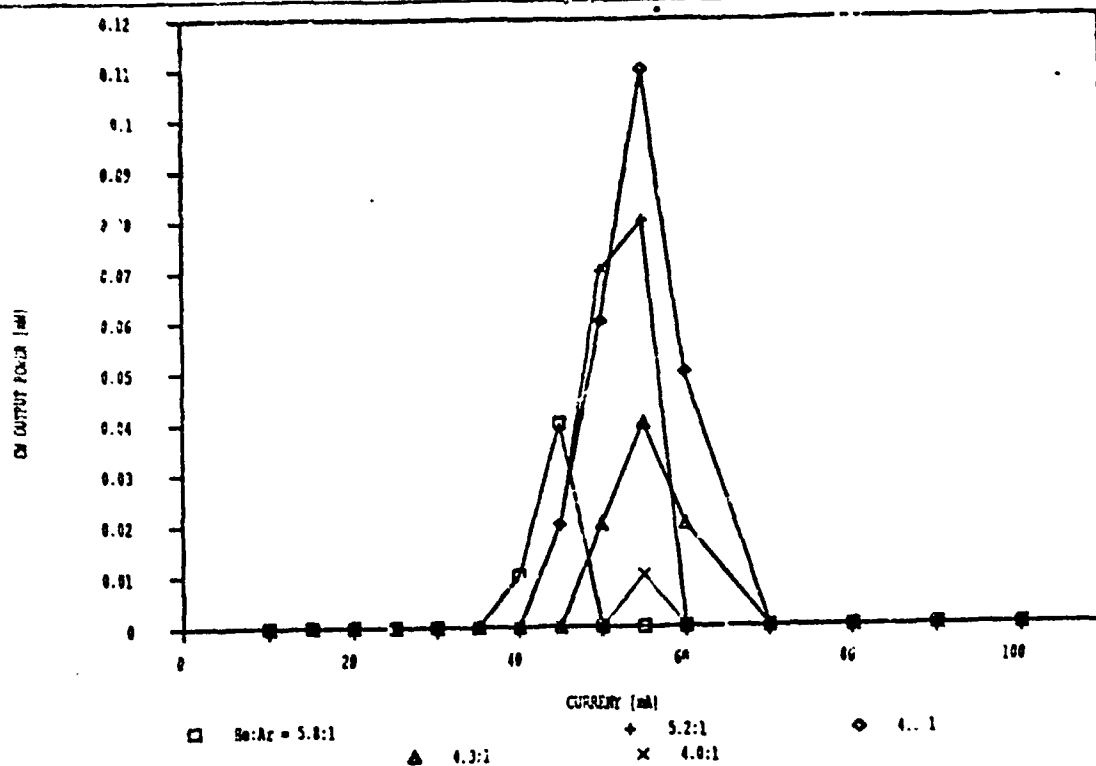
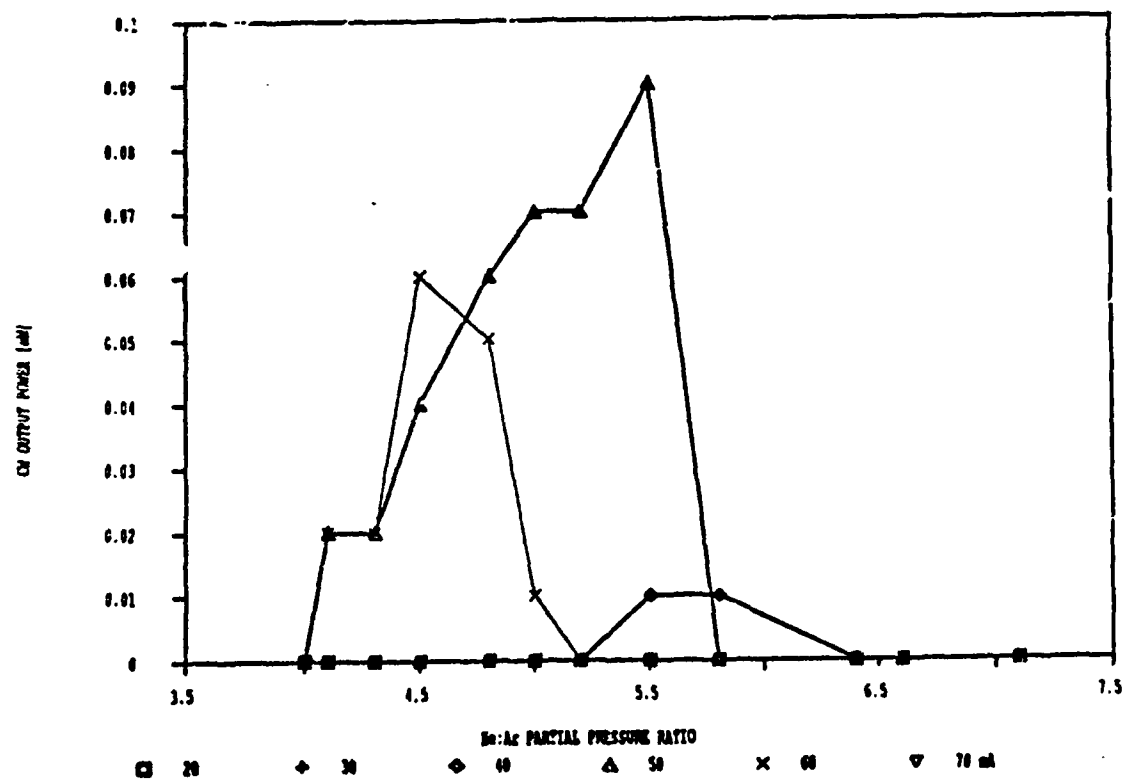


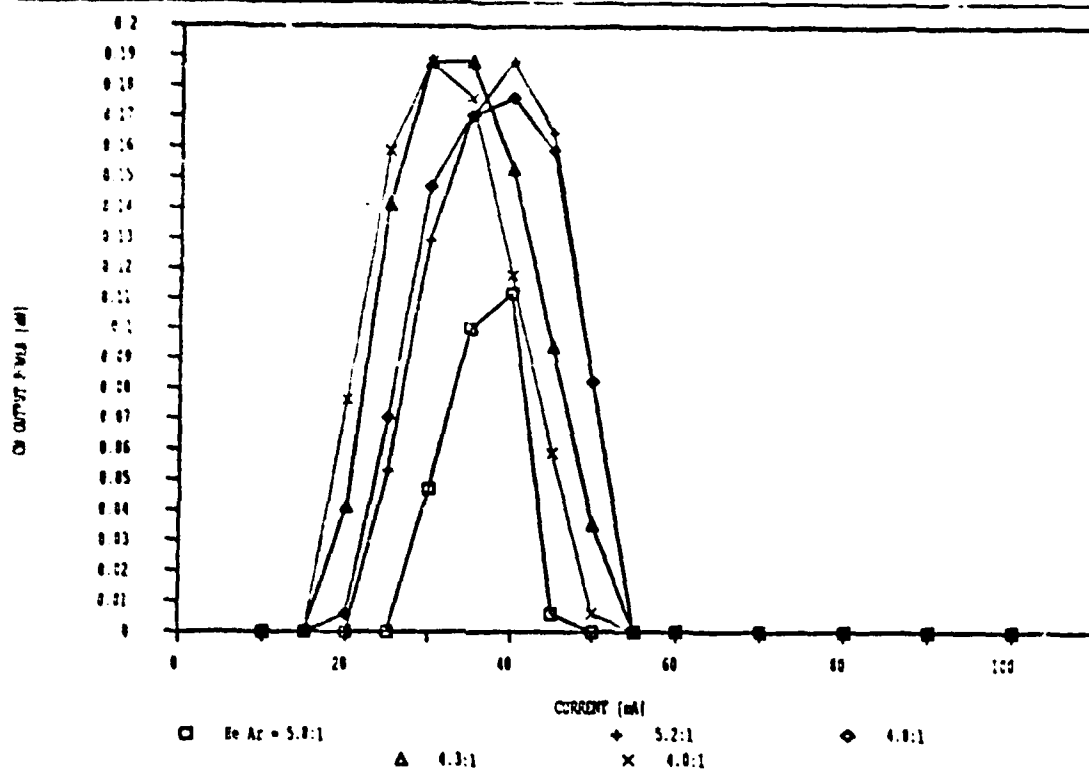
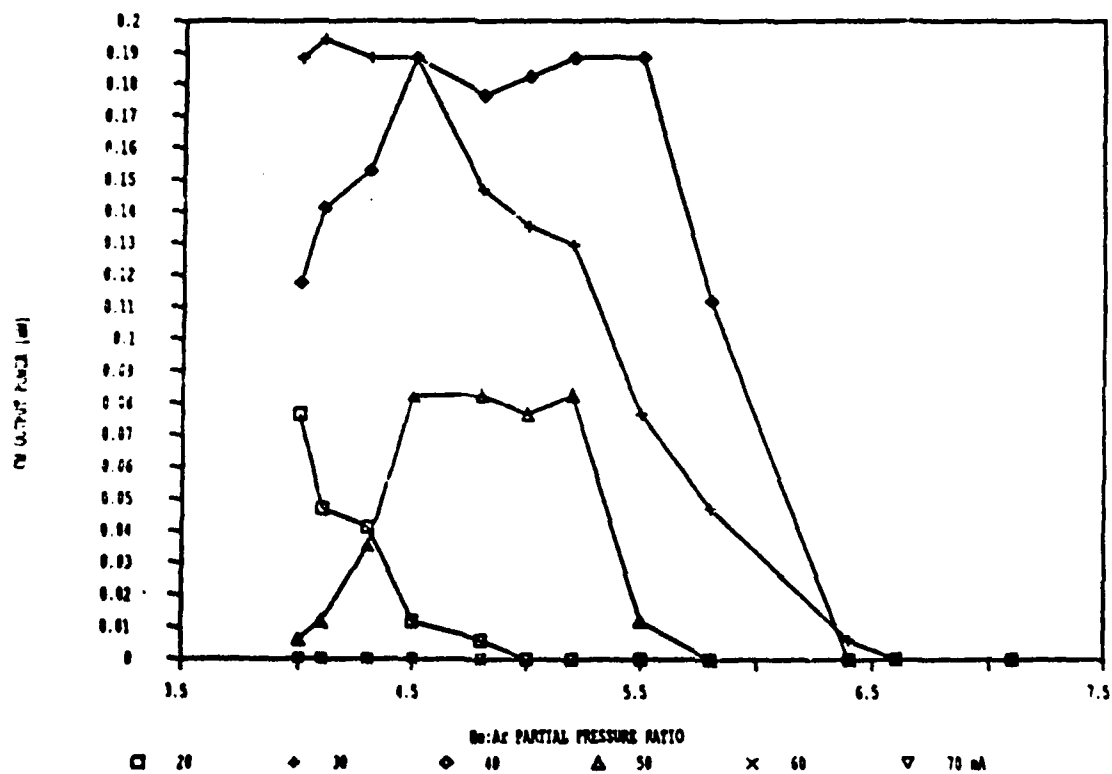
Figure 2 Laser system.

Figure 3(a) Power of He-Xe 2.026 μm line versus current.Figure 3(b) Power of He-Xe 2.026 μm line versus He:Xe ratio.

Figure 4(a) Power of He-Ar 2.061 μ m line versus current.Figure 4(b) Power of He-Ar 2.061 μ m line versus He:Ar ratio.

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Figure 5(a) Power of He-Ar 2.207 μm line versus current.Figure 5(b) Power of He-Ar 2.207 μm line versus He:Ar ratio.

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1a. AR Number AR-008-148	1b. Establishment Number ERL-0703-GD	2. Document Date MAY 1993	3. Task Number DST 92/439
4. Title DESIGN ASPECTS AND PARAMETRIC CHARACTERISATION OF A NEUTRAL RARE GAS LASER		5. Security Classification ☐ S ☒ U ☐ R ☐ U Document Title Abstract S (Secret) C (Conf) R (Rest) U (Unclass) * For UNCLASSIFIED docs with a secondary distribution LIMITATION, use (L)	6. No. of Pages 16 7. No. of Refs.
8. Author(s) Kenneth J. Grant		9. Downgrading/ Delimiting Instructions N/A	
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14. DEFTEST Descriptors Gas lasers Design Wavelengths Laser outputs		15. DISCAT Subject Codes 1709	
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17. Imprint Electronics Research Laboratory PO Box 1500 SALISBURY SA 5108		
18. Document Series and Number ERL-0703-GD	19. Cost Code	20. Type of Report and Period Covered ERL General Document
21. Computer Program Used		
22. Establishment File Reference(s)		
23.T1 Additional information (if required)		