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DIODE LASER PUMPED OPERATION OF AN Er^{3+}-DOPED SINGLE-MODE FIBRE LASER

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ABSTRACT

We report the first operation of an Er^{3+}-doped single-mode fibre laser operating around 1.6μm pumped by a CW GaAlAs diode laser. An output power of 130μW was obtained with a lasing threshold of 3mW.

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Rare-earth doped single-mode optical fibres have led to the development of a range of active fibre devices with numerous applications for telecommunications. Low threshold and efficient operation[1] of diode laser pumped Nd^{3+}-doped fibre lasers together with single frequency operation[2] has been reported. In addition, high-power[3], narrow-linewidth[4] Er^{3+}-doped fibre lasers and high-gain fibre amplifiers[5] operating within the important third window for telecommunications (1.55μm) have been demonstrated. As previously noted[3], Er^{3+}-ions in glass have an absorption band around 808nm (Fig.1.) and can therefore be pumped by a GaAlAs diode laser. Dye laser pumping of this laser at 807nm has recently been demonstrated[6]. In this paper, we describe the first diode pumped operation of such a laser and report the extended tuning range obtainable by employing various fibre lengths.

Er^{3+}-doped lasers operate as three-level systems and thus Er^{3+}-doped fibres possess an inherent loss at the lasing wavelength which must be bleached before lasing can occur[7]. With single-mode fibres, however, it is possible to maintain high intensities over long distances and thus saturation of this absorption can be achieved with powers of only a few milliwatts. At wavelengths slightly longer than 1.536μm (the pure three-level transition wavelength), lasing terminates at a partially thermally populated level above the ground state and the laser therefore behaves as a quasi four-level system. Consequently, the inherent loss of the fibre at the lasing wavelength is reduced as the wavelength is increased. By employing a range of fibre lengths, the relative significance of this effect compared to other losses can be adjusted, thus increasing the range of wavelength operation.

The experimental configuration of the Er^{3+}-doped fibre laser is shown in Fig.2. The pump source used in this experiment was a Sony SLD202/V 25mW GaAlAs diode laser with a nominal operating wavelength of 811nm. The laser was cooled in order to temperature tune the wavelength to 808nm and a cylindrical lens used to compensate for astigmatism. The fibre was cleaved by a commercial cleaver and butted to two dielectric mirrors to form the laser cavity. The input mirror had a reflectivity of 99.8% over the lasing range and a transmission of 90% at the pump wavelength of 808nm whilst the output mirror had a transmission of approximately 12% over the lasing range and a reflectivity of 20% at 808nm. The fibre was characterised by a dopant concentration of 300ppm, an NA of 0.27 and a core diameter of 3.1μm, corresponding to a cutoff wavelength of 1100nm.[8]

The lasing characteristic, measured using a Laser Precision RS 5900 calibrated power meter, is shown in Fig.3. A laser threshold of 3mW was achieved, and an output power of 130μW was obtained for an absorbed power of approximately 7mW. This corresponds to a slope efficiency of 3.3%. No attempt was made to optimise the output coupling, and it is anticipated that improvements in performance may be achieved by further fibre and cavity optimisation. It was possible to operate the device at a significantly lower threshold by employing a high-Q cavity, but this limited the output power to less than 30μW.

This particular device lased at a wavelength of 1.62μm, although it has been found that the wavelength of operation is strongly dependent on cavity length for the reasons noted earlier. In order to investigate this effect, the Er^{3+}-doped fibre laser was pumped by a Styryl 9 dye laser operating at 808nm and the output wavelength measured as a function of fibre laser length. The results are shown in Fig.4. It can be seen that operation over a wide wavelength range between 1.55μm and 1.65μm is possible simply by varying the fibre length. For long cavity lengths, the pure three-level transition remains unsaturated and so the lasing wavelength shifts towards the quasi four-level transition around 1.6μm. The lasing wavelength was found to be essentially independent of pump power for powers up to four times above threshold.

In conclusion, we have demonstrated for the first time operation of a diode laser pumped Er^{3+}-doped fibre laser operating around 1.6μm. Wavelength tuning is possible by varying the length of fibre used, thus changing the degree of saturable absorption present in the cavity. It is anticipated that devices derived from this laser will find many uses as sources and amplifiers for telecommunications.

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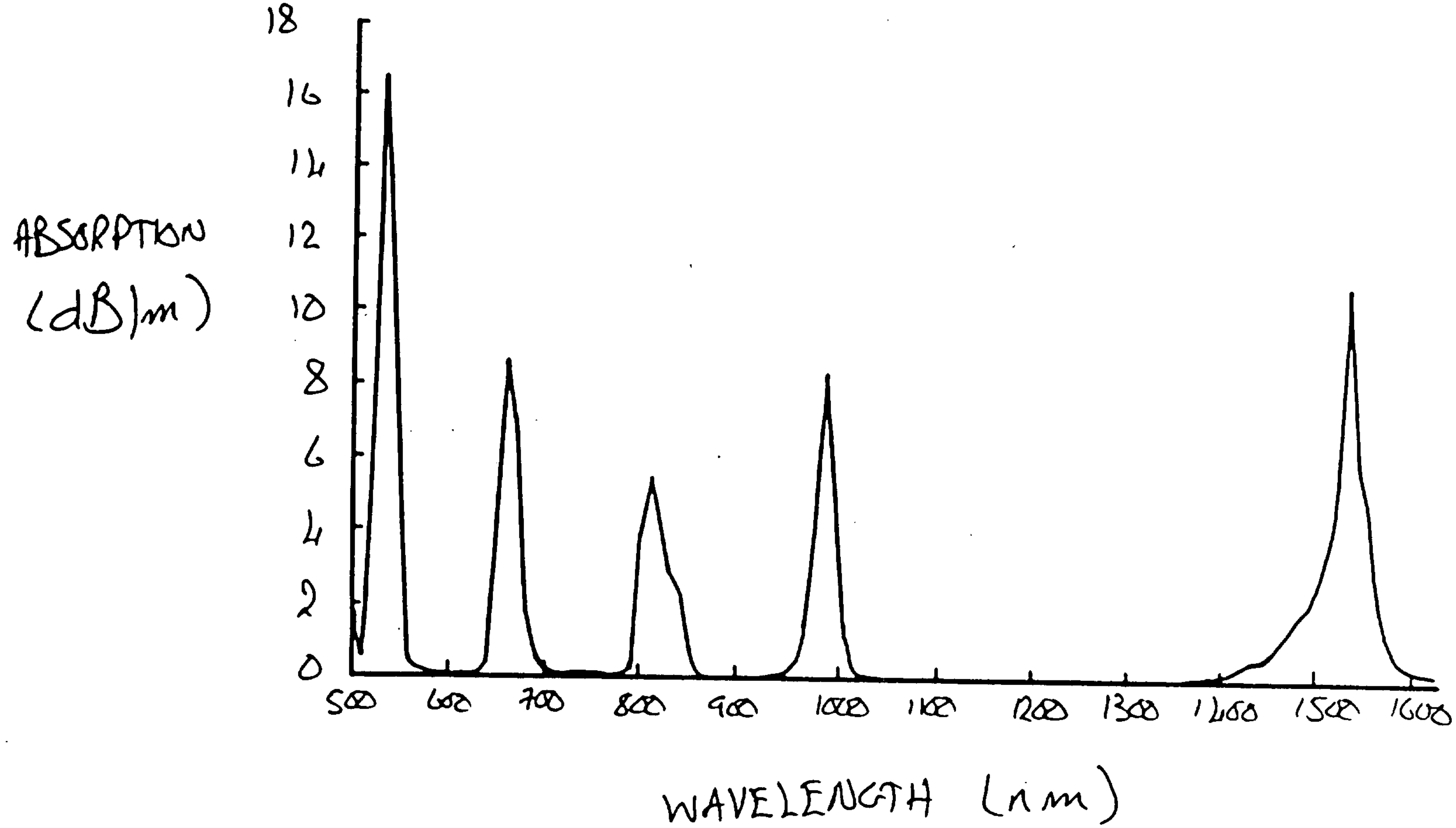
FIGURE CAPTIONS

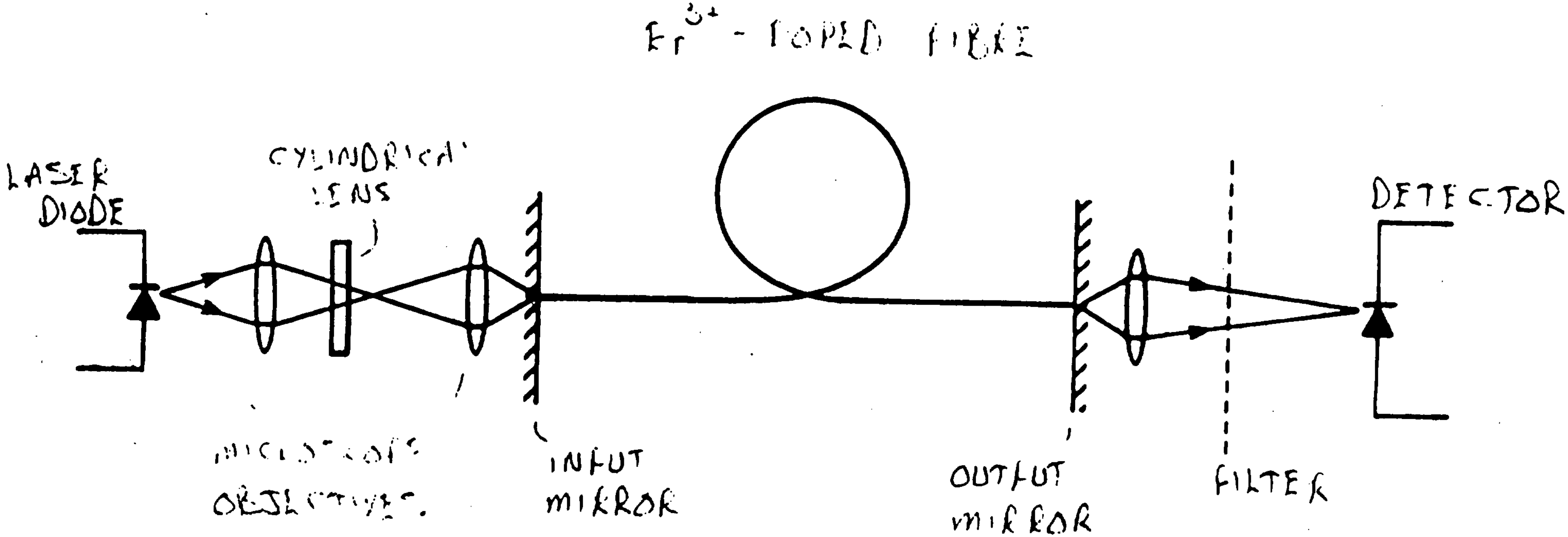
Fig.1 Absorption characteristic of Er^{3+}-doped fibre used in this experiment.

Fig.2 Experimental configuration of Er^{3+}-doped single-mode fibre laser.

Fig.3 Lasing characteristic of diode laser pumped Er^{3+}-doped single-mode fibre laser.

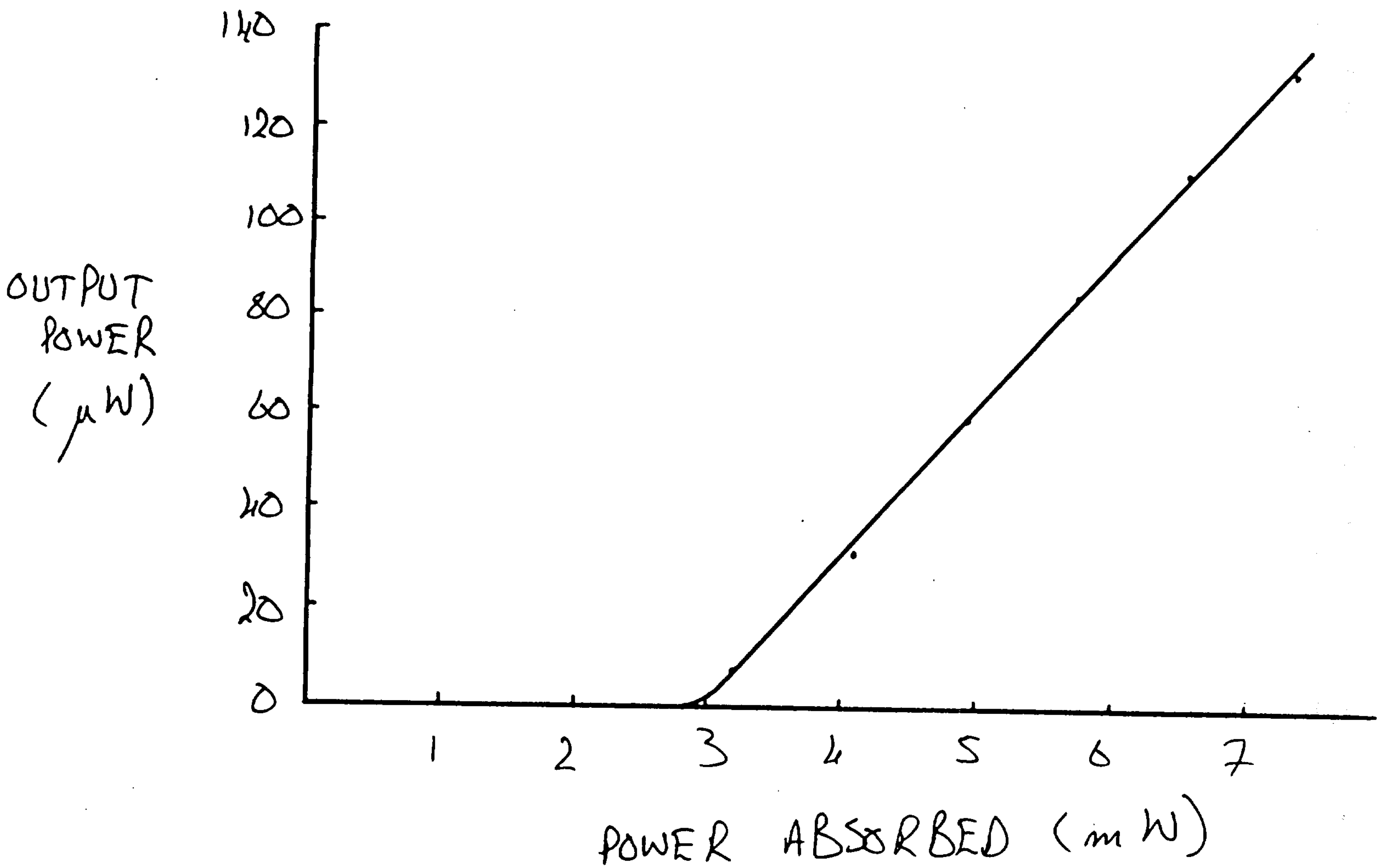
Fig.4 Dependence of fibre laser output wavelength on cavity length.


ABSORPTION
(dB/m)
18
16
14
12
10
8
6
4
2
0
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
WAVELENGTH (nm)

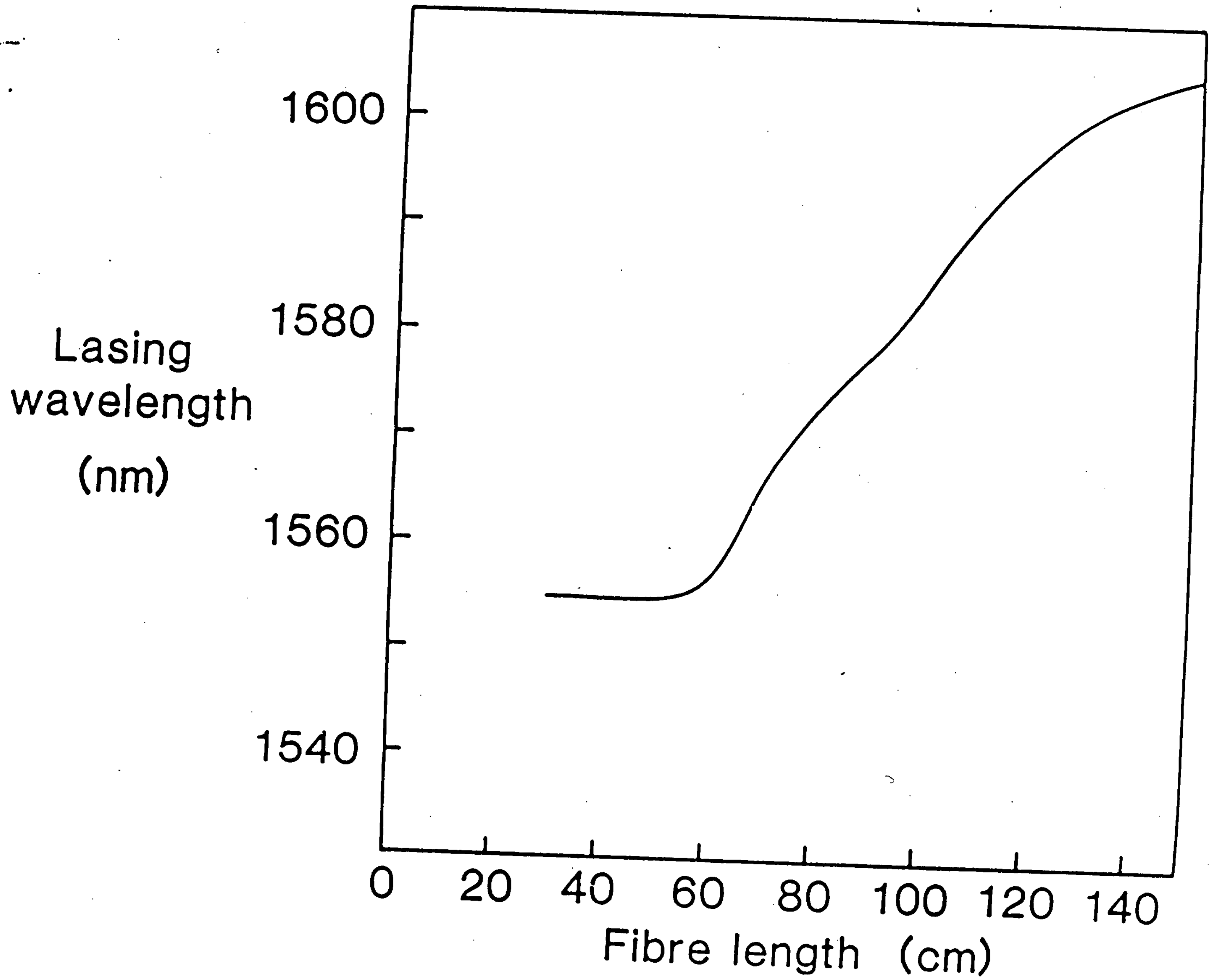


LASER DIODE
CYLINDRICAL LENS
INPUT MIRROR
OUTPUT MIRROR
FILTER
DETECTOR

(a)



OUTPUT POWER (μW)
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
POWER ABSORBED (mW)



Lasing
wavelength
(nm)
1600
1580
1560
1540
0
20
40
60
80
100
120
140
Fibre length (cm)