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OPTICAL FIBRE AMPLIFIERS FOR 1.5 MICRON OPERATION

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ABSTRACT

The application of the recently developed erbium-doped optical-fibre amplifier to pre- and post-amplification of optical signals is described. Typical performance is >20dB gain over a 300GHz bandwidth for a 20mW pump.

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With the move towards higher bit-rate communications, optical amplifiers are becoming increasingly attractive because of their large bandwidths (in excess of 100GHz). Semiconductor laser amplifiers and Raman amplifiers have received considerable attention over the past few years[1,2]. At the last OFC we demonstrated a new technique for optical amplification[3] based on an active erbium-doped optical fibre[4]. The fibre amplifier requires a pump power of a few tens of milliwatts, and can be spliced directly into optical fibre systems.

The erbium-doped fibre amplifier has now been extensively characterised. It is the aim of this paper to examine the application of the amplifier to pre- and post-amplification of optical signals.

The three-level laser system of Er^{3+}-ions at 1.5μm can be pumped with a variety of wavelengths including 514nm, 670nm and 808nm. The typical response of the fibre amplifier when pumping on the $^4I_{15/2}$-$^4I_{9/2}$ transition in the region of 670nm is shown in Figure 1. It can be seen that the fibre gain is insensitive to pump wavelength changes over 10nm. Gains of 20dB have been obtained for pump powers of only 20 mW, and at higher pump powers the gain is observed to saturate as the majority of the ion population is excited. The results have been accurately modelled, taking into account the broadening mechanisms and pump variations in the fibre, thereby permitting gain optimisation.

The spectral response of the fibre amplifier is shown in Figure 2. The 3dB bandwidth is in excess of 300GHz, and a gain of 10dB or more is attainable from 1.53μm-1.56μm. The wavelength of maximum gain can be lowered with the addition of B_2O_3 or P_2O_5 to the germanosilicate fibre core. It should be noted that in other respects the doped fibre amplifier resembles a typical telecommunications fibre and is readily spliced with low-loss.

The fibre amplifier has been shown to increase the sensitivity of a simple p.i.n. diode detector by 25dBm. Measurement of the amplified spontaneous emission indicates a maximum sensitivity (10^{-9}BER)for pre-amplified direct detection of -62dBm. Thus the fibre amplifier has considerable potential as a pre-amplifier for optical communications. Although three-level amplifiers are usually considered to be noisy, the high degree of inversion (vis. Figure 1) results in the fibre amplifier closely resembling an ideal four-level amplifier. Furthermore, the exceptionally long spontaneous lifetime (≃13ms) makes the fibre insensitive to fluctuations in the mean signal power.

A typical gain transfer characteristic at a pump power of 40mW is shown in Figure 3. The 3dB roll-off occurs for output powers of approximately +5dBm, and output powers in excess of +10dBm have been achieved. These values are considerably greater than are observed in semiconductor laser amplifiers[5]. The application of the fibre amplifier to front-end boosting of a signal laser diode is very promising, and further results will be presented at the conference.

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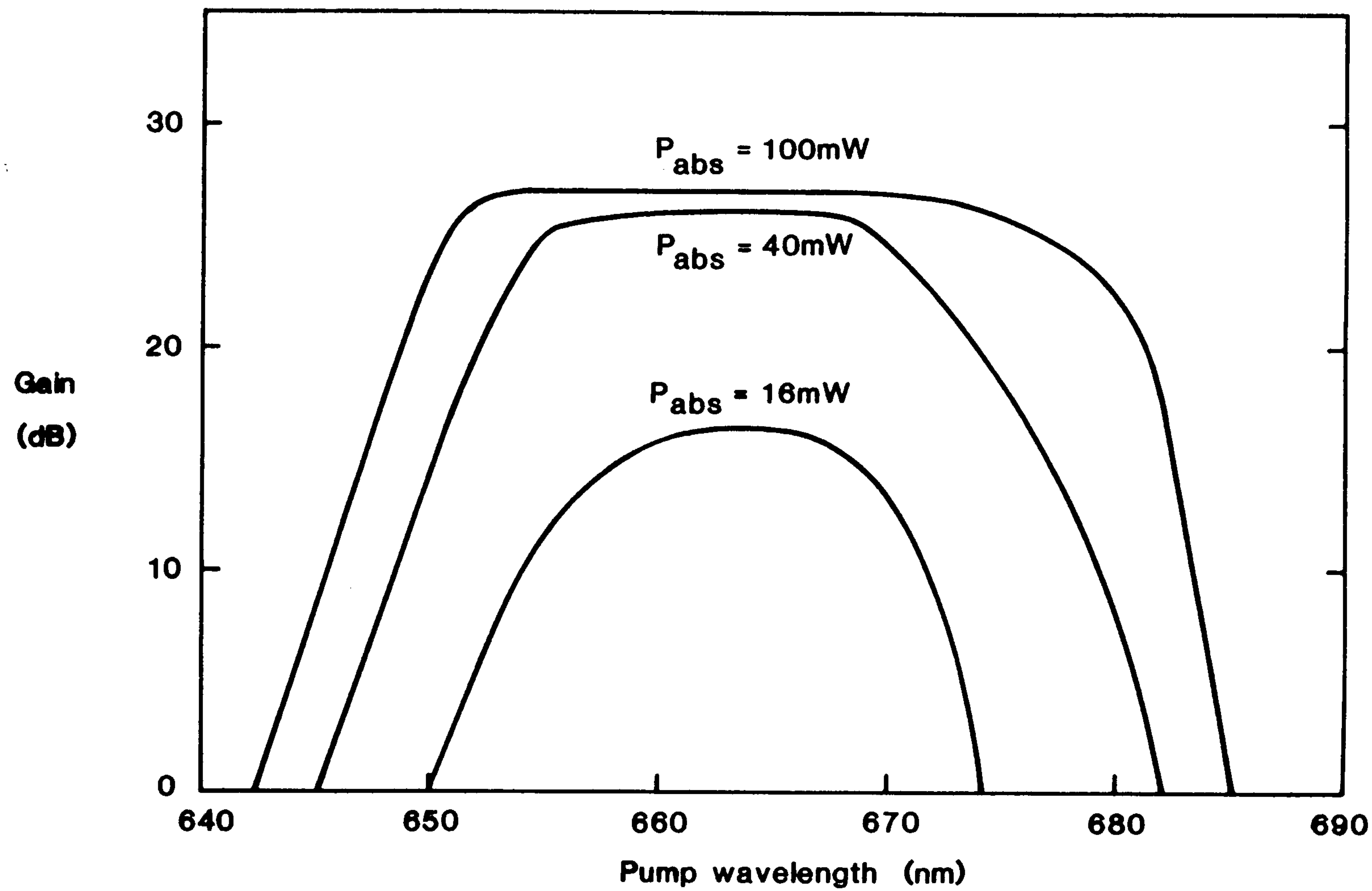
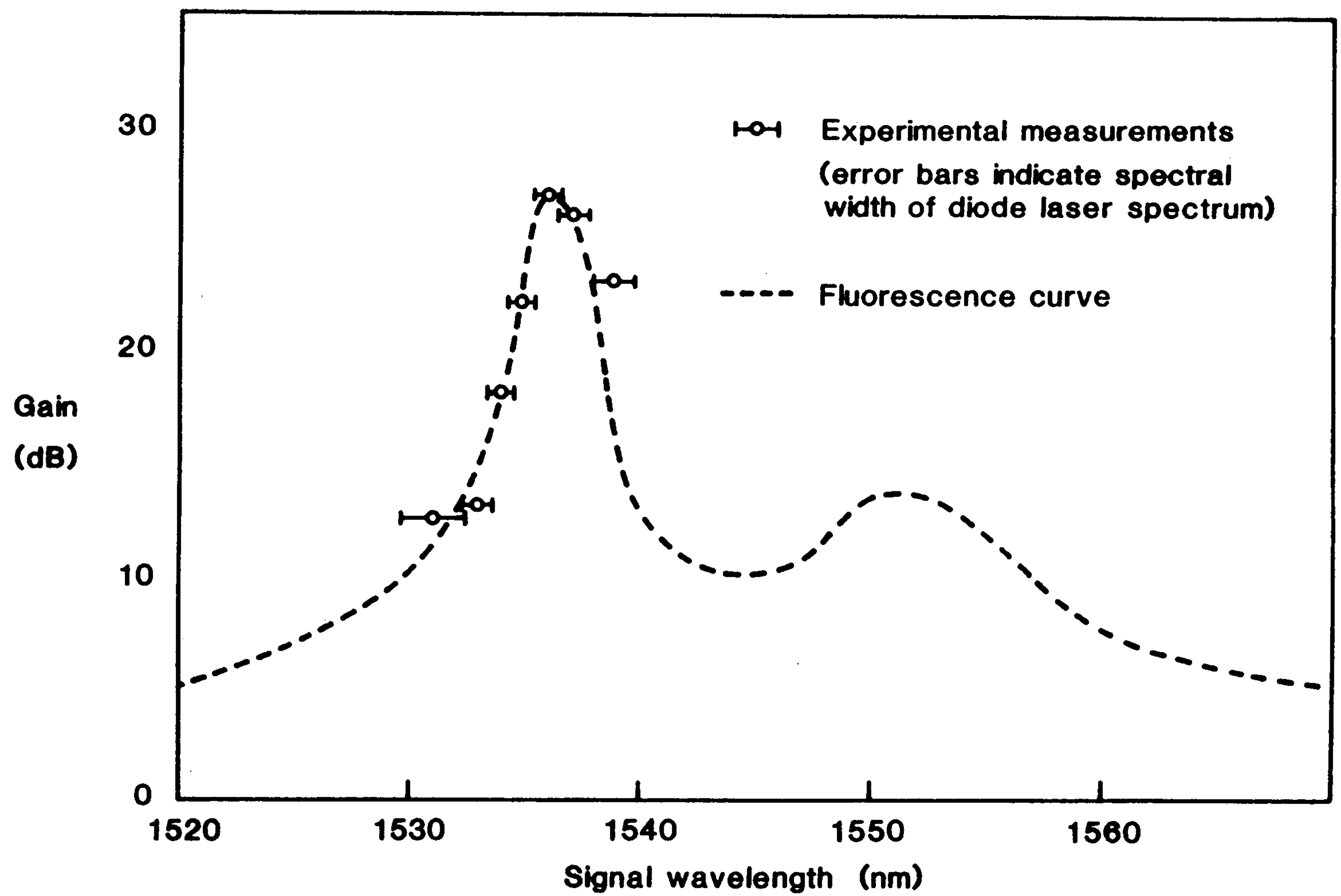
FIGURE CAPTIONS

Figure 1 Amplifier gain versus pump power and wavelength.

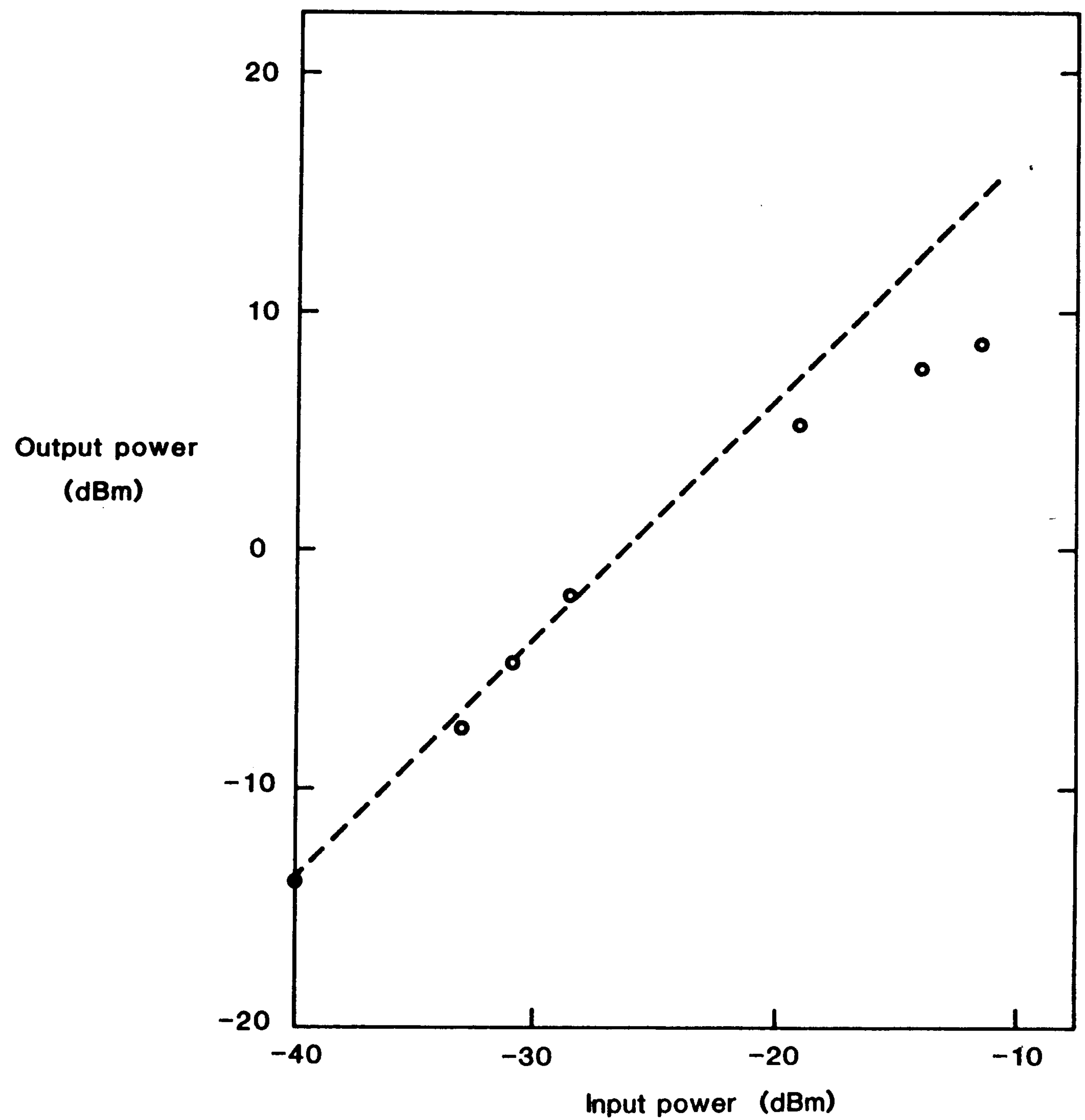
Figure 2 Gain spectrum and spontaneous emission.

Figure 3 Power transfer characteristic.


Gain
(dB)
30
20
10
0
640
650
660
670
680
690
Pump wavelength (nm)
P abs = 100mW
P abs = 40mW
P abs = 16mW



Experimental measurements
(error bars indicate spectral width of diode laser spectrum)
Fluorescence curve
Gain
(dB)
30
20
10
0
1520
1530
1540
1550
1560
Signal wavelength (nm)



Output power
(dBm)
20
10
0
−10
−20
−40
−30
−20
−10
Input power (dBm)