WI2 High-gain rare-earth-doped fiber amplifier at 1.54 μm

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Optical amplifiers are of interest as wideband in-line repeaters for telecommunications and as signal regenerators for a variety of sensor applications. Much current research has concentrated on semiconductor laser amplifiers[1] which are difficult to splice to fiber systems. It is clear that an amplifier consisting of a special optical fiber which is compatible with telecommunication fiber would overcome this problem. This paper describes the first results of an optical fiber amplifier based on an Er^{3+}-doped fiber[2] which has a maximum gain at a wavelength of 1.536 μm. A single-pass gain of 26 dB and a maximum output of 13 dBm at 140 MHz has been demonstrated.

The experimental configuration is shown in Fig. 1. A 3-m length of Er^{3+}-doped fiber (300-ppm Er^{3+}) with a spot size of 3.6 μm and cutoff wavelength of 1150 nm was used as the amplifier fiber. The pump wavelength chosen was 650 nm (Ar^{+}-pumped DCM dye laser) for which the fiber absorption was 5 dB/m.

To prevent the onset of laser action at high amplifier gains, the optical feedback resulting from Fresnel reflections was reduced by index-matching one end of the fiber. In practice, splicing the fiber into a fiber system would be sufficient to largely eliminate etalon effects, since low-reflectivity splices are readily achievable. This attribute contrasts with the case for a semiconductor laser amplifier where reflections are very difficult to eradicate.[1] Note that, although the experimental fiber used here has a small spot size, amplifier fibers compatible with telecommunications fibers can be readily designed.

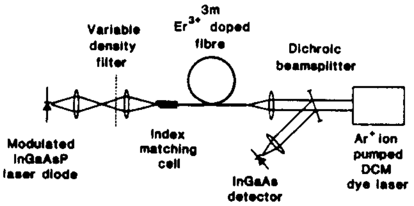
A 140-MHz sinusoidally modulated signal from a InGaAsP DCBH laser was coupled into the fiber up to a maximum power of −7 dBm. The amplified output from the fiber was extracted using a dichroic mirror with reflectivity of 90% at 1.536 μm (Fig. 1). This arrangement was chosen for experimental convenience, whereas in a practical in-line repeater a dichroic four-port coupler would be used to couple the pump into the doped fiber.

Since Er^{3+} is a three-level laser system,[3] an absorption band measured as 15 dB/m exists at the lasing wavelength of 1.536 μm. This absorption is bleached at pump powers of a few milliwatts, and as the pump power is increased further, the fiber exhibits gain. Figure 2 shows the gain characteristic at the chosen 140-MHz modulation rate. It can be seen that a gain of 26 dB is obtained for inputs up to 10 μW (−20 dBm). Thereafter, gain saturation occurs more slowly than for an equivalent semiconductor laser amplifier, and much higher output powers can be achieved (up to 13 dBm in this experiment). These measurements were made at the maximum absorbed pump power of 60 mW obtainable from the dye laser. Even better results are anticipated at higher pump powers, the limit being set by residual reflections from the fiber ends. Note also that the frequency response is expected to be much higher than the 140 MHz used here, which was limited by mounting the laser diode.

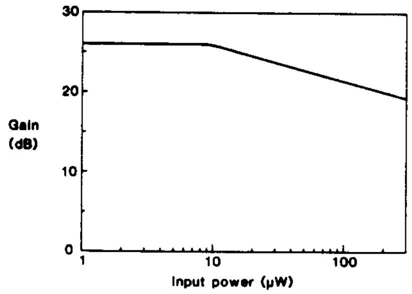
The noise performance of optical amplifiers is normally limited by spontaneous emission, which in an Er^{3+}-doped fiber is expected to be low, owing to the exceptionally long fluorescence decay time of 15 ms.[2,3] This was confirmed by measurements from which an input noise equivalent power of −68 dBm in a 140-MHz bandwidth was calculated. Since this noise is distributed over the full fluorescence spectral width of ~15 nm (Fig. 3), further noise reduction could be achieved by filtering.

Summarizing: preliminary results show that Er^{3+}-doped fiber amplifiers have excellent gain and noise characteristics, which could make them attractive as wideband optical repeaters. **(12 min)**

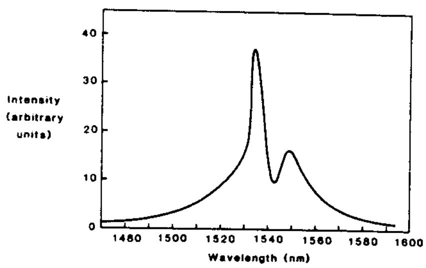
1. M. J. O'Mahony *et al.*, Electron. Lett. **21**, 501 (1986).
2. S. B. Poole *et al.*, IEEE/OSA J. Lightwave Technol. **LT-4**, 870 (1986).
3. R. J. Mears *et al.*, Electron. Lett. **22**, 159 (1986).



WI2 Fig. 1. Experimental configuration of a fiber amplifier.



WI2 Fig. 2. Gain characteristic at 1.54 μm.



WI2 Fig. 3. Fluorescence spectrum for an Er^{3+}-doped fiber.