ADVANCES IN ACTIVE FIBRES

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ABSTRACT

Rare-earth-doped fibre lasers and amplifiers have been demonstrated at several wavelengths in the visible and near infrared regions. As potential sources and amplifiers for telecommunications they have wide tunability, high pulse peak-power, high gain and complete compatibility with optical fibres.

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Introduction

The incorporation of rare-earth dopants into the core of single-mode fibres [1,2,3] has led to a new class of both active and passive fibre devices including lasers, in-line optical amplifiers, absorption filters and distributed sensors. Several of these devices have reached a state of development where they are finding uses in telecommunication and fibre sensor applications. There is also considerable interest in the traditional laser area where the fibre laser is seen as a route to compact, all solid-state, tunable sources operating at wavelengths from the visible to the infra-red.

The small core size of the single-mode fibre allows high pump intensities for modest (~mW) pump powers. The pump intensity can be maintained over long lengths and this leads to low lasing thresholds and permits CW diode-laser-pumped operation of three-level lasers [4]. The high pump intensity also allows high-gain (>30dB) operation of erbium fibre amplifiers with excellent saturation properties [5]. In addition, compatibility with existing fibre components is excellent, allowing all-optical fibre circuitry to be assembled with both active and passive components. This is particularly beneficial for the fibre amplifier, where splicing of the active fibre into the link virtually eliminates troublesome Fresnel-reflection feedback which normally limits the gain in optical amplifiers.

Fibre Lasers

A particular attribute of fibre lasers is that the optical-damage threshold of silica is significantly higher than that of the materials used in semiconductor laser fabrication. It is therefore possible to obtain high peak-power pulses from fibre lasers using the techniques of Q-switching and mode-locking. Q-switched pulses at a wavelength of 1.06μm with a peak power in excess of 100W and a duration of 15ns are readily obtained from a diode-pumped Nd^{3+}-doped fibre. Similar performance can be obtained from an Er^{3+}-doped fibre, suggesting prospects as a practical source for OTDR's, non-linear optics and photonic switching.

Although not as advanced as DFB diode lasers, Er^{3+}-doped fibre lasers show potential as very narrow-linewidth sources for coherent communications at 1.55μm. Whereas in the case of a diode laser it is usually necessary to use an external (often fibre) cavity to narrow the linewidth to less than 1MHz, a typical fibre laser is a metre or more long and gives a natural Fabry-Perot linewidth of considerably less than this. The problem is to select one of the many longitudinal modes which are typically spaced at 100MHz. A number of mode-selection schemes used in the traditional laser field are available and will undoubtedly lead to stable, single frequency sources at 1.55μm emitting tens of mW.

A very recent development [6] which shows the potential for combining fibre lasers with intra-cavity non-linear optics in fibres is the production of 4ps mode-locked pulses of several watts peak-power from an Er^{3+} fibre laser with a 2km-long resonator. With the potential for even shorter pulses of higher powers, such lasers could become the preferred method of short-pulse generation.

Erbium-Doped Fibre Amplifiers

Erbium-doped fibre amplifiers are attractive for amplifying optical signals in the third telecommunications window around 1.54μm. They are efficient, near quantum-noise limited, high fibre-to-fibre gain amplifiers which exhibit no polarisation dependence. In addition, they have a spectral bandwidth of around 20nm and show minimal interchannel cross-talk, even when operated in saturation. This last characteristic is particularly attractive for high spectral-density multi-channel networks [7].

As well as extensive characterisation work, current research on erbium fibre amplifiers is aimed at developing practical diode-laser pump sources for the 980nm and 1490nm pump-band wavelengths [8,9] which have emerged as optimal. Diode pumping at 1490nm has been reported [10]. However, although expected to produce higher efficiency and a lower noise figure, diode pumping at 980nm still awaits diode development.

Conclusions

Considerable progress has been made on fibre lasers and amplifiers for the telecommunications area. It is anticipated that applications will be as (i) a high-power pulse source for OTDR and non-linear effects, (ii) a narrow linewidth source for coherent communication at 1.55μm and (iii) a high-gain, pre-, power or in-line amplifier for high bit-rate systems in the third window. In the future, fibre laser sources based on ZBLAN glass show promise for operation at the longer wavelengths required for fluoride-glass transmission.

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