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Triple-Frequency Operation of an Er-Doped Twincore Fiber Loop Laser

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Abstract— **Simultaneous laser operation of three single-frequency modes from an inhomogeneously broadened Er-doped twincore fiber loop laser is reported. Equal output power of 390 μW separation 0.5 nm and linewidth < 10 kHz was measured for each mode in a travelling wave cavity comprising a single gain medium. In addition upto eight wavelength operation has been observed, demonstrating that twincore EDFA's can provide channel equalization in an eight-channel multiamplifier optical network.**

I. Introduction

The realization of stable, equal output power, multiple wavelength Er-doped fiber lasers at 1.5 μm is highly attractive for use in future wavelength division multiplexing (WDM) optical communication systems. However the predominantly homogeneous gain in Er-doped fibers has meant that such devices are difficult to construct as the gain is clamped by the cavity loss at only one lasing wavelength [1]. In the past to achieve stable operation, designs have either incorporated a separate gain medium for each lasing wavelength [2], [3] or alternatively the cavity losses have been carefully adjusted at each wavelength to make the effective gains equal [4], [5]. The former requires many optical components whilst the latter is inherently unstable. In this paper we present a new configuration which uses a single piece of Er-doped twincore fiber to provide an inhomogeneous gain medium through macroscopic (mm) spatial holeburning. The benefits of this approach have already been confirmed by the demonstration of twincore channel equalizers [6], [7]. Previously such inhomogeneity has only been introduced by cooling the fiber to liquid nitrogen temperatures [8]

II. Theory

Twincore fibers have been studied in detail and their characteristics are well documented [9]. It is well known that two identical cores in close proximity will periodically couple light with a characteristic beatlength which is wavelength dependent. By doping both the cores with Er, a gain medium with a degree of large scale (mm) spatial inhomogeneity is made. The bandwidth and strength of the inhomogeneity is controlled by the twincore parameters and its length. By constructing a laser which incorporates a length of Er-doped twincore fiber, multiwavelength laser operation is possible as the available gain at each lasing wavelength is partially decoupled from the others. In addition by making the cavity unidirectional [10], single-frequency operation of each lasing line is ensured.

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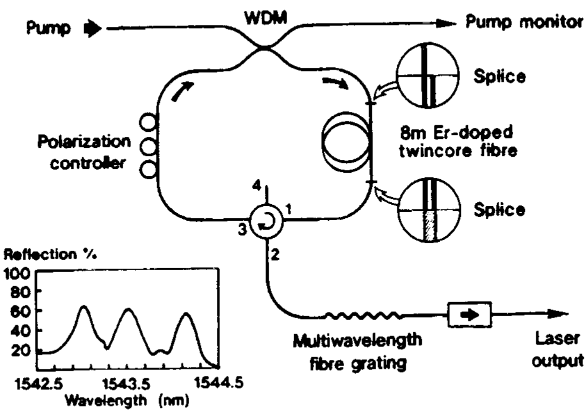

Fig. 1. Schematic of the twincore fiber loop laser.

III. Experiment and Results

The new laser design is shown in Fig. 1 and is a unidirectional travelling wave loop configuration consisting of a 8 m section of Er-doped twincore fiber, a WDM coupler, a circulator, a polarization controller and a multiwavelength fiber grating. The twincore fiber was spliced to one core only at the input whilst at the output light was taken from both cores and only the even mode selected to ensure wavelength independent transmission. The twincore fiber was fabricated with two identical cores of a GeO_2–Al_2O_3–SiO_2 composition which were both doped with 220 ppm of Er. The cores had a radius of 1.5 μm, NA 0.27 and were separated by 4.5 μm that yielded a beatlength of 1.25 mm. The multiwavelength fiber grating had peak reflectivities and bandwidths of 50% and 0.2nm centered at 1543, 1543.5, and 1544.1 nm. It was written into a boron-germania doped silica fiber by a novel phase mask technique [11]. The twincore fiber was pumped by 70 mW from a laser diode at 980 nm and the output was taken after the gratings with feedback suppressed by an optical isolator. The total round-trip loss in the cavity has been measured to be 13 dB, which includes an input splice loss into the twincore of only 1 dB.

Fig. 2 shows the laser output spectra from the laser and one may clearly observe three lasing wavelengths of equal power (390 μW) and resolution limited bandwidth (0.1 nm). To confirm single-frequency operation a HP external cavity singlemode semiconductor laser was tuned to each of the

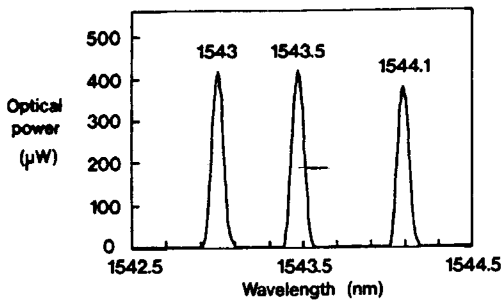

Fig. 2. Laser output spectrum.

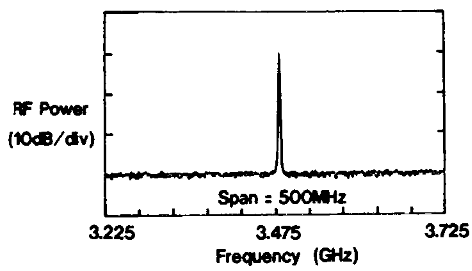

Fig. 3. RF spectrum of beat frequency between one of the lasing modes and an external single mode laser indicating single frequency operation.

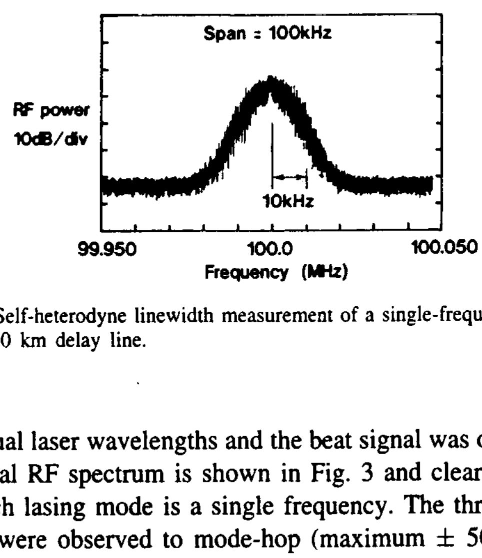

Fig. 4. Self-heterodyne linewidth measurement of a single-frequency mode using a 50 km delay line.

individual laser wavelengths and the beat signal was observed. A typical RF spectrum is shown in Fig. 3 and clearly shows that each lasing mode is a single frequency. The three lasing modes were observed to mode-hop (maximum ± 500 MHz) about their central frequencies and this is to be expected in such a long laser cavity (20 m) without any stabilization. This hopping could potentially be reduced by protecting the laser from environmental perturbations, shortening the cavity length and introducing a length of unpumped Er-doped fiber to provide a tracking filter around the lasing mode as previously reported [12]. To accurately measure the average linewidth of the lasing modes a delayed self heterodyne technique was employed using 50 km of fiber and a linewidth of 10 kHz was measured, this result is shown in Fig. 4.

For a comparison, the twincore fiber was replaced with a single core Er-doped fiber of similar parameters. It was possible to obtain lasing at two wavelengths simultaneously by adjusting the cavity loss, however the laser was very unstable and clearly preferred to lase at just one wavelength. Simultaneous lasing at three wavelengths was not achievable.

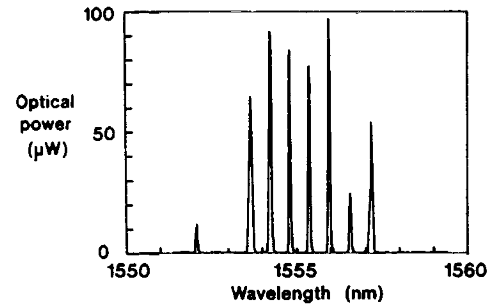

Fig. 5. Eight-channel operation of the Er-doped twincore fiber ring laser.

By splicing into and out of one core of the twincore fiber it was possible to combine the inherent filtering and inhomogeneity of the twincore to obtain laser operation at eight wavelengths as shown in Fig. 5. Although the lasing wavelengths were less stable than when using gratings to select the lasing wavelengths, it clearly demonstrates that the principle of operation expands to many more channels. Since the operation of a ring laser is analogous to that of a long multiamplifier link, the potential of twincore amplifiers [6], [7] for equalization in multichannel WDM networks is confirmed.

IV. Summary

Stable simultaneous lasing of three wavelengths (separation 0.5 nm) at 1.5 μm has been achieved using an inhomogeneously broadened Er-doped twincore fiber in a unidirectional ring laser. The wavelengths were precisely selected by a fiber grating and single-frequency operation of each ensured by the unidirectional configuration. An output power of 390 μW and linewidth less than 10 kHz was observed for each line. In addition, eight wavelength operation has been demonstrated in a similar configuration. These results confirm the potential of twincore amplifiers for automatic channel equalization in WDM multiamplifier links.

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