Travelling-Wave Erbium-Doped Fibre Loop Laser

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Abstract: *We describe a new Er^{3+}-doped fibre laser configuration which produces single-longitudinal-mode operation in the 1.5μm region with less than 10kHz linewidth. The fibre laser operates in a travelling-wave mode, preventing spatial holeburning. An added advantage of the configuration is that it allows precise and stable setting of the laser wavelength.*

Introduction: Narrow linewidth single-longitudinal-mode lasers operating in the 1.5μm region are important devices for use in transmitters and local oscillators of future coherent communication systems. In recent years Er^{3+}-doped fibre lasers have been demonstrated to be capable of achieving the linewidth requirements for use in coherent communication systems. Single-longitudinal-mode erbium-doped fibre lasers have been demonstrated using several techniques,[1,2,3,4] including a travelling-wave ring laser. Travelling-wave operation eliminates spatial holeburning in the gain medium and thereby prevents the onset of multimode operation. We describe a new fibre laser configuration which allows for the incorporation of a frequency-selective reflector in a travelling-wave fibre laser, permitting very precise control over the operating wavelength.

Experiment: The laser configuration is shown in Figure 1. Two ports of a four-port coupler were joined in a Sagnac-like arrangement by a length of erbium-doped fibre (Er^{3+} conc. = 800ppm, λ_c = 1525nm, NA = 0.15). An isolator with 45.2dB isolation was included in the loop to ensure unidirectional operation through the loop and hence make the operation different from a Sagnac loop. Pump light was introduced through port A, which was angle polished to prevent reflections. The standard telecommunications coupler had a 50/50 splitting ratio at 1.5μm, while coupling virtually all the pump light into the section of doped fibre. A reflector, either in the form of a dielectric mirror with 70% reflectivity or a Distributed Bragg Reflector (DBR)[5] with 70% reflectivity, bandwidth 0.3nm and centre wavelength 1.552μm, was used on port B to complete the laser cavity. A polarisation controller was used because of the polarisation sensitivity of the DBR. The round-trip laser cavity length of 9.5m corresponded to a passive cavity mode spacing of 21MHz. For convenience the laser was pumped at 980nm from a Ti:sapphire laser.

By virtue of the location of the isolator within the fibre loop, the signal at 1.55μm travels in only one direction through the doped fibre, thus preventing spatial holeburning from occurring. The 3dB coupler directs half of the signal output from the doped fibre to the reflector, and returns half of the reflected signal into the fibre loop to form a resonant cavity. The mechanism for achieving single-longitudinal-mode operation is the same as the travelling-wave ring previously demonstrated[4], but because this laser cavity incorporates a reflector, it combines the travelling-wave operation with the significant advantage of accurate wavelength selection by the DBR.

Using a mirror reflector on port B, single-longitudinal-mode operation was observed at a wavelength of 1.5577μm. Single-frequency operation was verified by using a monochromator with 0.1nm resolution, a scanning Fabry-Perot spectrum analyzer with FSR = 1.3GHz and finesse > 100. In additional proof of single-frequency operation no intermodal beat signal was detectable. However in this mode of operation there is no significant advantage over the travelling-wave ring technique. The advantage lies in the ability to accurately determine the operating wavelength with the use of a frequency selective reflector. When the mirror reflector on port B was replaced with the DBR the lasing wavelength shifted to the wavelength of maximum reflectivity, 1.552μm. Only one mode was evident on a Fabry-Perot spectrum analyzer whose FSR was sufficient to resolve adjacent modes at 21MHz. Again, no intermodal beat was evident. Using the self-heterodyne technique with a 25km delay line the laser linewidth was determined to be about 9.5kHz, as illustrated in Figure 2.

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Discussion: The laser power characteristic was determined taking the output from port A. Threshold occurred for 6mW launched pump power at 980nm. The slope efficiency, illustrated in the characteristic shown in Figure 3, was measured to be 29%. This slope efficiency represents a quantum efficiency of at least 95%, given that the 3dB coupler results in a resonator which is inherently lossy. The choice of a 3dB coupler represents the optimal choice for low threshold operation, while the large output coupling results in high output power. Higher slope efficiency could be achieved through the choice of a different coupler splitting ratio, however this would be at the expense of a higher threshold.

Conclusions: We have demonstrated a novel fibre laser configuration which achieves single-longitudinal-mode operation by operating in a travelling-wave mode. The laser incorporates a frequency-selective reflector which provides the ability to accurately determine the wavelength of operation. A linewidth of less than 10kHz has been measured, with 6mW threshold and 29% slope efficiency.

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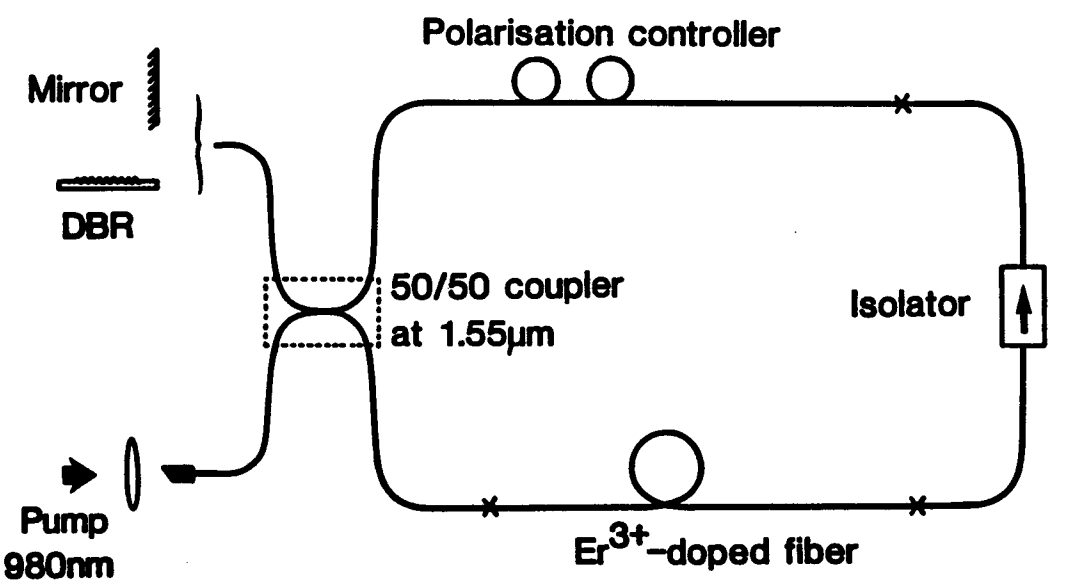

Figure 1. Schematic of travelling-wave Er^{3+}-doped fibre loop laser.

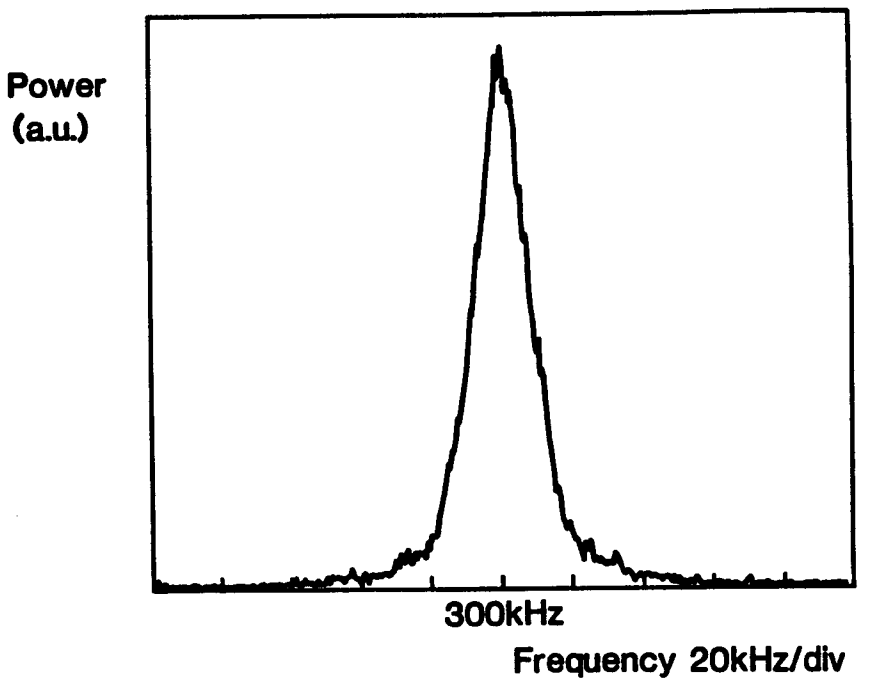

Figure 2. Laser linewidth determined by the self-heterodyne technique with 25km delay line.

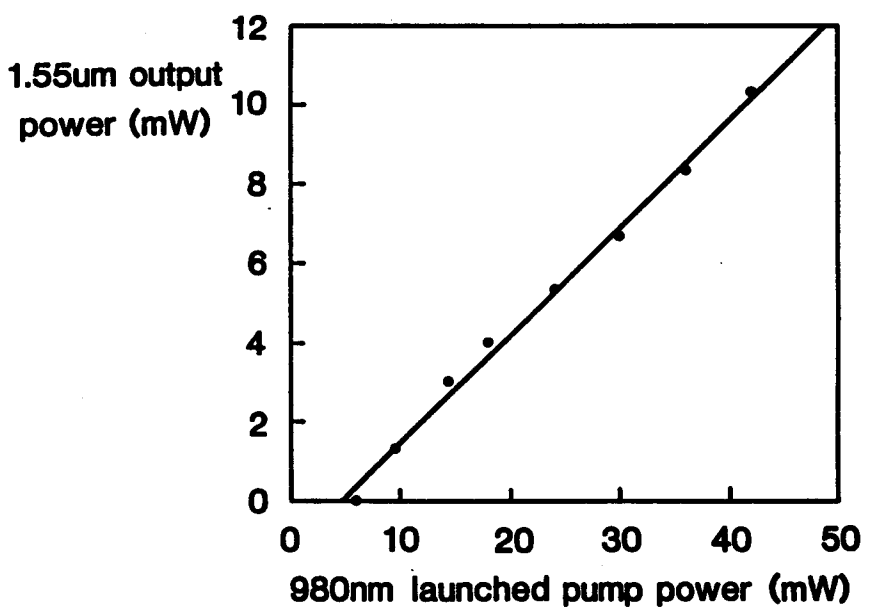

Figure 3. Power characteristic of travelling-wave fibre loop laser.