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OPTICAL BISTABILITY AT 1.54 μm IN A ER^{3+}-DOPED SINGLE-MODE FIBRE LASER

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ABSTRACT

We report the first observation of optical bistability in a rare-earth doped single-mode fibre laser. Hysteresis has been obtained in the lasing characteristic of an Er^{3+}-doped fibre laser operating at 1.54μm using the mechanism of saturable absorption.

SUMMARY

Rare-earth doped single-mode fibre lasers have emerged as a viable alternative source for many applications. To date, several significant advances have been made, including CW [1], pulsed [2,3] and broadly tunable [4] operation of these devices at several different wavelengths in the near infrared region of the spectrum. Semiconductor diode laser pumping of these devices with sub-milliwatt threshold has proved possible and operation of with 30% slope efficiency has been demonstrated [3]. Unlike their bulk glass counterparts, single-mode fibre lasers do not suffer from thermal problems and can therefore be operated at ambient temperature with no auxiliary cooling requirements. Most notably, the small fibre core size (approximately 5 μm) and axial pumping configuration allow CW laser emission to be obtained on 3-level laser transitions which would normally operate only in a pulsed mode.

Tunable CW and Q-switched operation of an Er^{3+}-doped single-mode fibre laser has been obtained at 1.54μm [5] (see Fig. 1), coinciding with the important "third window" for optical fibre communications. Lasing takes place on the 3-level $^4I_{13/2}$-$^4I_{15/2}$ (groundstate) transition when pumped by a Ar^+-ion laser operating at 514.5nm.(Fig. 2)

Due to the high pump light intensity in the core, it is easily possible to saturate the pump absorption band and thus achieve threshold inversion for only a few mW of pump power. Using the configuration shown in Fig. 3, an extremely low lasing threshold of 4mW has been obtained, several orders of magnitude less than would be expected for a conventional 3-level laser.

Optical bistability (the existence of two distinct, stable output states corresponding to a single input state [6]) has potential for a range of all-optical and optoelectronic devices, including for optical memories, switching and amplification. In order to obtain optical bistability, the output of the device must be a nonlinear function of some input parameter and a sufficient degree of feedback should be incorporated. Nonlinear absorption in a saturable absorber has been proposed and demonstrated as one such technique for achieving bistable behavour [7].

Since a fibre laser exhibits saturable absorption, it should also be bistable in a 3-level laser, the intrinsic absorption at the lasing wavelength must be bleached optically before lasing will occur. It has been found that for lasers using short lengths of Er^{3+}-doped fibre (typically <1m, depending on cavity loss) total bleaching of the fibre occurs before threshold and a normal lasing characteristic is therefore obtained. However, if a longer length of fibre is used, it becomes possible to obtain a region at the end of the fibre in which there is residual saturable absorption, giving rise to hysteresis in the output of the laser (Figure 4). Switching thresholds of the devices studied so far have varied from 200mw-1W, again depending on the cavity configuration used. Allowing for launch efficiency, this corresponds to a threshold of <100 mW with 20% output coupling.

Operation of the fibre laser as an optical switch and optical memory has been demonstrated. The operating characteristics of the device will be presented along with measurements of the rise and fall times of the optical bistability.

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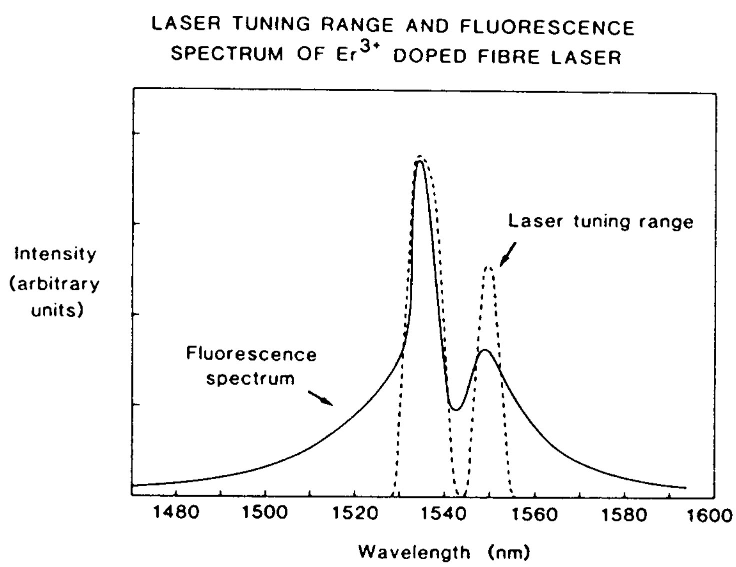

FIG.1. Laser tuning range and fluorescence spectrum of Er^{3+}-doped single-mode fibre laser.

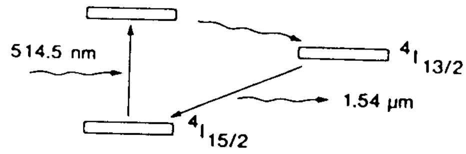

Fig.2. Energy level diagram for Er^{3+}-ions in glass.

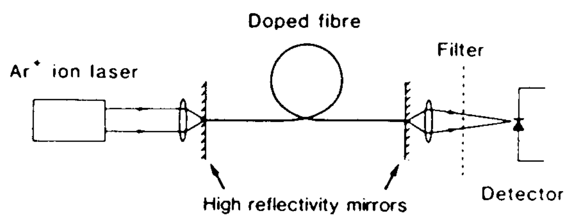

Fig.3. Experimental configuration of Er^{3+}-doped single-mode fibre laser.

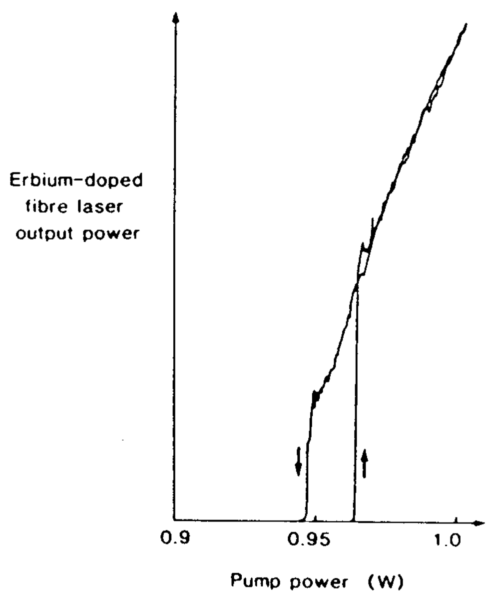

Fig.4. Lasing characteristic of an Er^{3+}-doped single-mode fibre laser showing hysteresis in the output.