A Simultaneously Q-switched and Mode-Locked Fibre Laser

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Introduction

Giant and ultrashort pulse operations of laser devices play an important role in both physics and engineering. The Q-switched operation and mode-locked pulses from fibre lasers have been being of great interests since single-mode fibre lasers were developed. In this paper, we report (1) the first observation of repetitive self-pulsing of a fibre laser, (2) the first demonstration of an all-fibre self-pulsed and mode-locked fibre laser, and (3) a simultaneously Q-switched and mode-locked fibre laser modulated at the Q-switching frequency.

Experimental set-up

The experimental system for this study comprised an end-pumping configuration. Both ends of the fibre were abutted to mirrors to form the laser cavity. For the Q-switching operation, the cavity was expanded to allow an acoustic-optic modulator to be inserted into the cavity. The output mirror had a reflectivity of 50% at the lasing wavelength of 1.5μm. An argon-ion-laser-pumped dye laser operating at 660nm was used as a pump source. The Er^{3+}-doped fibre designed for this study was fabricated using the MCVD method. The host medium for the dopant was GeO_2/SiO_2 glass. The dopant concentration, at 78ppm, was relatively low to allow the laser cavity to be formed from various fibre lengths between 4m to 20m. The refractive index profile of the fibre cross-section is shown in Fig.1. The cutoff wavelength of the fibre was 1.2μm, ensuring a single-mode operation at the lasing wavelength. The laser output was detected using a Ge-detector with a 1GHz bandwidth.

Results

(1) The threshold of the lasing oscillation was measured to be 18mW of absorbed pump power at 660nm. The undamped self-pulses start to occur immediately above the lasing threshold. The frequency of the repetitive pulses varied from 18.5KHz to 37KHz according to the pump level. Also, the peak power of the pulses was an increasing function of the pump power. Both the repetition frequency and pulse peak power are shown in Fig.2 as a function of pump rate. The widths of the pulses were 5μs and 2μs for the lowest and highest pumping rate in the Fig.2, respectively.

(2) Within the envelopes of the pulses described in (1) were self-mode-locked pulses. A single sweep of such a mode-locked pulse train is shown in Fig.3. Using a 1GHz bandwidth oscilloscope, the repetition rate of the passively mode-locked pulses was measured to be 25MHz, as shown in the upper trace of Fig.4. This is consistent with the length of the fibre cavity. A pulse width of 600ps has been measured and is shown in the lower trace of Fig.4, but this measurement width was limited by both the detector and the oscilloscope responses.

(3) Using an acoustic-optic modulator operating at the Q-switching frequency, simultaneous Q-switched and mode-locked operation has been demonstrated. By adjusting the modulation frequency in addition to the on/off ratio of the Q-switcher,

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much stronger and more stable Q-switched pulses were obtained, when compared with those in the case of self pulsing. At a pump level of 60mW absorbed power, a peak power of 500mW for the Q-switched pulses has been achieved, with 8KHz repetition rate and 1.2μs width, while the mode-locked pulses inside the Q-switched pulses were found to have the same characteristics as those obtained in the self-pulsing operation.

Acknowledgments

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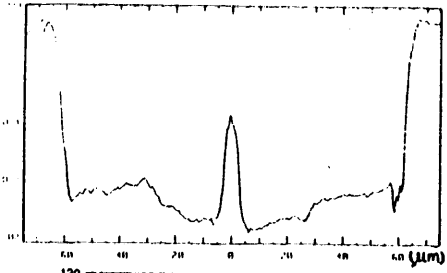

Fig.1 The refractive index profile of the fibre cross-section

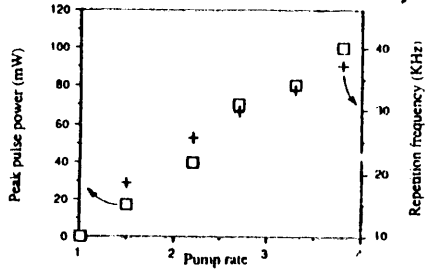

Fig.2 The repetition frequency and peak pulse power as a function of pump rate

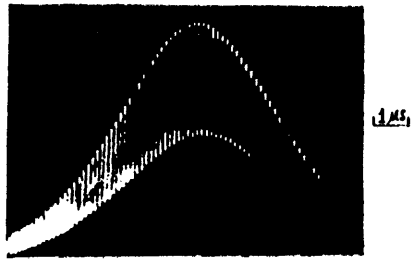

Fig.3 A mode-lock pulse train within the envelope of the self-pulse

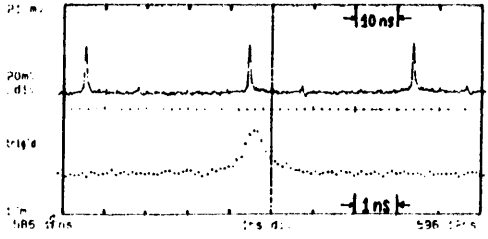

Fig.4 Measurements of the mode-locked pulses showing frequency and pulse width