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New approach to mode locking of high-energy-pulse fibre lasers

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Abstract: A new mode locking fibre laser configuration is proposed that delivers record-high energy (150 nJ) of short linearly polarised pulses (~ 200 ns) without external amplification. It is further shown that such performance may be achieved by elongation of the laser cavity with a standard PM-fibre.

1. Introduction

Cavity elongation is among the ways of boosting the energy of short pulses directly in a laser master oscillator [1]. It leads to reduction in the pulse repetition rate, thus concentrating more energy per pulse. There are several modifications of this method, which result in high-energy pulses but either with random polarisation [2] or relatively long and with low repetition rate (cavity Q-switching in lasers [3–5]). This work demonstrates that elongation of a fibre laser cavity may be used to achieve comparatively high energy (150 nJ) of relatively short (~ 200 ns) pulses in a desired polarisation following at a high repetition rate (~230 kHz) generated directly in a master oscillator. Considerable extension of the cavity of a fibre laser (~0.9 km) with a standard polarisation-maintaining (PM) optical fibre entails a number of effects (special mode locking regime, harmonic mode locking, environmental stability, etc.) discussed in this work.

2. Experiment

The layout of the studied Yb-doped laser cavity is schematically shown in Fig. 1. The studied laser included a long cavity extended with PM fibre (~0.9-km-long Fujikura, PANDA fibre SM98-PS-U25D), 2-nm wide spectral filter centred at 1.06 μm, and an optical isolator that allowed operation without cavity end mirrors.

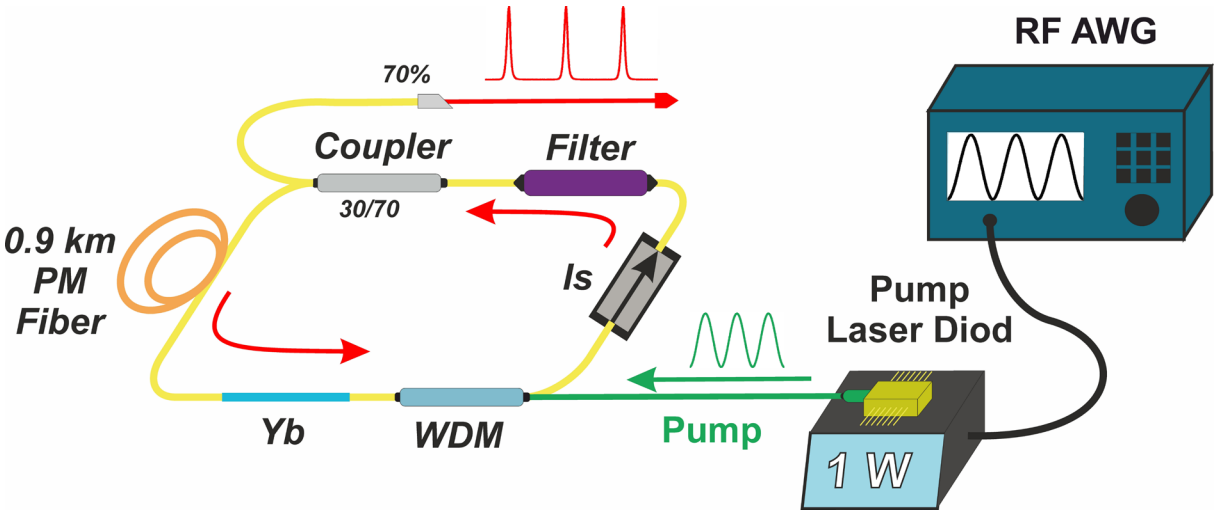

Fig. 1. Experimental set-up: RF AWG - Radio-Frequency Arbitrary Waveform Generator, WDM - Wavelength Division Multiplexer, Is - Fiber-optic isolator.

3. Results

It was established that the shortest duration of the generated pulses (shorter approximately by a factor of 21 than the pumping pulses) is reached under almost synchronous pumping. The term 'almost' is used because in this pumping mode the pumping pulse repetition rate very slightly (by 0.01%) differs from the fundamental pulse repetition frequency (this could be called 'quasi-synchronous' pumping). As it is shown in Fig. 2, a small detuning of the pumping pulse repetition rate with respect to the generated pulse frequency ensures the minimal pulse duration and at the same time their highest energy and stability.

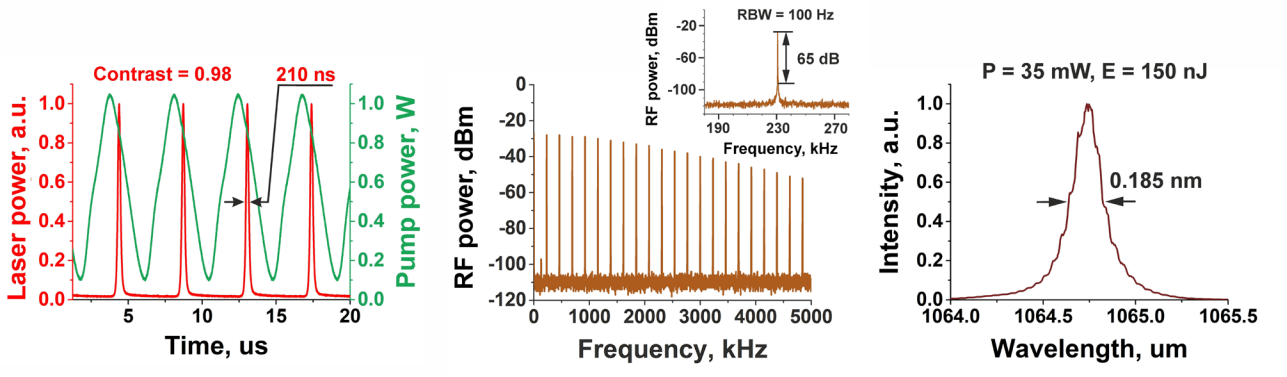

Fig. 2. Parameters of pulses generated in the long fibre laser under conditions of quasi-synchronous pumping. Note that the instantaneous pump power was always above the lasing threshold [6]. Left to right: the time traces of pump power (green) and laser power (red), RF spectrum of laser pulse train, and optical spectrum of laser pulses.

We also present the results of harmonic mode locking experiments and numerical modelling of the laser generation regimes. Generally, the numerical modelling predicts well the measured experimental results.

4. Conclusion

The newly proposed method of quasi-synchronous pumping of a long fibre laser resulted in generation of relatively short linearly polarised (~ 200 ns) pulses carrying 150 nJ without any external amplification. This approach to synchronous pumping opens up new possibilities in fibre laser generation.

5. Acknowledgements and References

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