Environmentally Stable Harmonic Modelocked All-Fibre Oscillator

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Nonlinear polarisation evolution (NPE) is the most commonly used saturable absorber mechanism for fibre-based mode-locked oscillators. It provides deep modulation (50% or more), usually leads to self-starting operation, is easy to implement, and can have an all-fibre design [1]. Their inherent downside is the requirement for non-polarisation maintaining (non-PM) fibres, which makes the laser susceptible to the environmental perturbations, particularly temperature fluctuations and vibrations. This sensitivity is greatly amplified during higher-order harmonic mode-locking. We are not aware of any truly environmentally stable mechanism for passive harmonic mode-locking, which is particularly interesting as a seed source for burst-mode lasers for material processing in the ablation-cooled regime. Fundamental mode-locking is an alternative but this approach is not scalable and even at several hundred MHz, all-fibre operation based on NPE becomes increasingly difficult to self-start, typically requires specialty components, and have limited environmental stability.

Here, we present a completely fibre-integrated cavity, based on Yb-doped fibres as the gain medium. The cavity comprises only PM fibre, except for the Yb-fibre, which we coil and isolate by immersing in a heat-conductive polymer that is commonly used in double-clad fibre lasers. The setup is shown in Figure 1 (a). We have deliberately chosen the gain fibre as the only non-PM section to benefit from its isolation. The tightly coiled (to a diameter of 15 cm) gain fibre acts as a mild heat source, which is regulated by the surrounding polymer, automatically achieving passive temperature stabilization without a special effort. The polarisation can be manipulated through two fibre-based polarisation controllers at the ends of the gain fibre. The Yb-doped fibre is double-clad pumped through a PM-signal pump combiner by a wavelength-stabilized multimode pump diode at 976 nm wavelength. A fibre-integrated polarising beam splitter acts as polarisation discriminator and output coupler.

We readily obtain self-starting passive harmonic mode-locking with excellent environmental stability and short-term stability – the supermode suppression is at least 56 dB, as shown in the inset of Figure 1 (b). In the radio-frequency spectrum, the maxima at the fundamental repetition rate and lower harmonics can be efficiently suppressed, which is an important measure of the stability [2]. The intra-cavity power is estimated to be 500 mW. The output power is 250 mW, corresponding to 1 nJ pulse energy. Currently, we obtain operation at the fourth harmonic repetition rate, which corresponds to 254 MHz for this cavity. The harmonic frequency is limited only by the average power handling of the components and should be readily scalable to higher values with sufficient average power. The spectral width of the output signal is 22 nm, as shown in Figure 1 (c). The output pulse has a duration of 5.3 ps in the autocorrelation trace and can be compressed to 180 fs autocorrelation duration, and the estimated pulse width is 120 fs, assuming a Gaussian pulse shape. These parameters render the oscillator an attractive choice as a seed source in ablation-cooled material processing experiments. Further scaling of the repetition rate appears to be possible, while 250 MHz is already high enough to avoid dispersion imbalance problems in fibre-integrated repetition rate multipliers for scaling to the multi-GHz range [3].

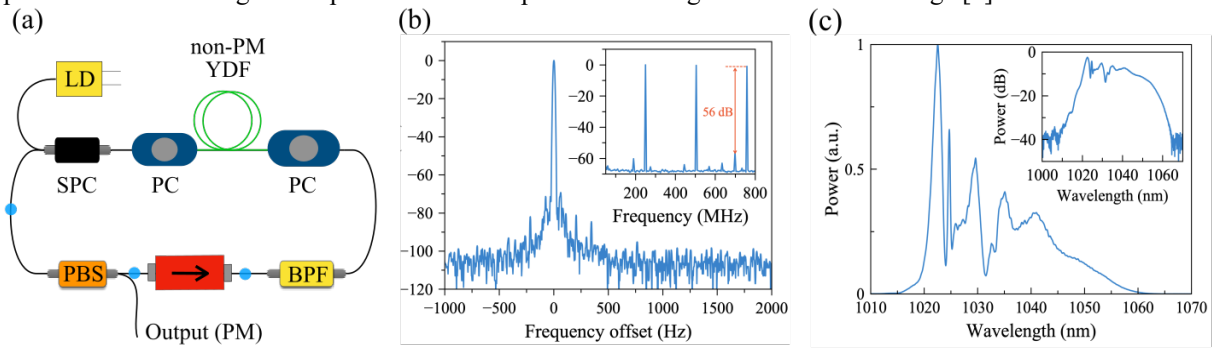

Fig. 1 Layout of the all-fibre, mostly-PM laser oscillator (a), and suppression of the supermodes in the readiofrequency spectrum (b). The output spectrum at the fourth harmonic repetition rate is shown in (c). BPF: spectral band-pass filter, LD: multi-mode pump laser diode, PBS: polarising beam splitter, PC: polarisation controller, PM: polarisation maintaining, SPC: signal-pump combiner, YDF: Ytterbium-doped fiber.

References

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