Generation of ~625nJ Pulses from a Mamyshev Oscillator with a few-mode LMA Yb-doped Fiber

Di Lin[1], **Duanyang Xu**[1], **Jing He**[2], **Yutong Feng**[1], **Zhengqi Ren**[1], **David J. Richardson**[1]

1. *Optoelectronic Research Centre, University of Southampton, SO17 1BJ, UK*
2. *Cambridge Graphene Centre, University of Cambridge, CB3 0FA, UK*

Mamyshev oscillators (MOs) have recently attracted considerable interest due to their outstanding performance allowing, for example, the generation of ~190 nJ pulses of sub-50fs duration from a step-index (SI) polarization-maintaining (PM) 10 µm core diameter single-mode fiber (SMF) [1]. Pulse energies up to 1 µJ have been achieved using large-mode area (LMA) photonic crystal fiber [2]. However, the use of more conventional SI-LMA fiber has not been greatly explored due the presence of higher-order modes (HOMs) that can disrupt stable mode-locking and significantly reduce the maximum pulse energy [3]. Here we overcome this by careful coiling of the gain fiber and using intracavity spatial mode filters to suppress HOMs and demonstrate the generation of ~625 nJ pulses directly from a MO based on SI-LMA fiber with 25 µm core diameter.

A schematic of our experimental setup is illustrated in Fig. 1(a), which comprises two concatenated arms. The first arm consists of a ~2.5-m length of double-clad, 10µm core-diameter, single-mode PM Yb-doped fiber (PM-YDF). It acts as a lower-energy feedback loop for the second power-scaling arm and is forward cladding-pumped by an 8 W, 975 nm laser diode. The second arm consists of a ~2.5-m length of LMA PM-YDF that has a 25/250 µm core/cladding diameter with a numerical aperture (NA) of 0.065/0.46. It was backward cladding-pumped by a 50 W, 975nm laser diode. The V-number of the fiber at ~1µm is ~5.1, which is large enough to support the propagation of up to the LP_{02} mode. The fiber was coiled with a bending diameter of ~ 7cm and two SMFs were employed as intracavity spatial-mode filters and were placed on either side of the 25 µm fiber in order to suppress HOMs. Two blazed gratings coupled to two SMFs were used to form the offset bandpass filters required, each offering Gaussian-shaped spectral transmission profiles - one with a centre wavelength set at 1028nm with a 4 nm full-width at half-maximum (FWHM), and the other at 1048nm with a 2 nm FWHM.

Mode-locking is initialized by seeding with an external ~300 fs pulse source. The MO generates ~5 ps chirped pulses with an average power of 8 W at a repetition rate of 12.8 MHz, corresponding to a single pulse energy of ~625 nJ. Attempts to further power scale always resulted in parasitic lasing around 1030nm and an abrupt loss of mode locking eventually occurs. The spectrum of the output pulse at 625 nJ is measured to be ~116nm (10dB bandwidth) as shown in Fig. 1(b). The output pulses were temporally compressed in an external grating compressor with 600 lines/mm gratings (~60% efficiency). The autocorrelation (AC) traces of the compressed pulses and the calculated transform-limited (TL) pulse (shown in Fig. 1(c)) have a FWHM duration of ~59 fs and~39 fs, respectively. The duration of the dechirped pulse is thus estimated to ~44 fs assuming a deconvolution factor of 1.33 (derived from the TL pulse shape). The slight side lobe in the AC traces is likely due to a combination of nonlinearity and higher-order dispersion induced by the fiber section and the grating compressor. We estimate the main pulse peak to contain ~ 66% of the total energy leading to a compressed pulse peak power estimate of ~ 5.6 MW at the compressor output. The beam quality (M^2) was measured to be ~1.08.

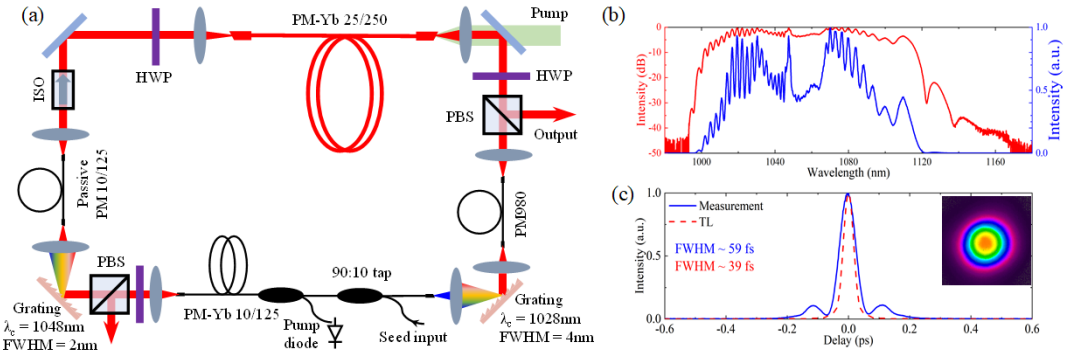

Fig. 1 (a) Schematic of the experimental setup;(b) Measured spectrum in both logarithmic(red) and linear(blue) scale at 625 nJ pulse energy; (c) The intensity AC traces of compressed pulses(blue) and TL pulses(red). Insert in (c) is the measured far-field beam intensity

References

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