L.5: Development of ultrafast Mamyshev fiber oscillator

During the last two decades, ultrafast fiber oscillator has evolved from all-anomalous dispersion configuration generating soliton-like pulses to all normal dispersion (ANDi) configuration generating dissipative soliton (DS) pulses in a quest to scale-up the pulse energy directly from the oscillator with ultrashort duration. However, even in ANDi configuration pules energy is limited to 10s of nJ and pulses exhibit significant side-lobes after compression in external grating pair. In recent time, there is a considerable interest in fiber Mamyshev oscillator (MO), which can potentially overcome the challenges involved in ANDi configuration. In its simplest form MO consists of two gain media and two offset band pass filters (BPFs) of appropriate bandwidths, which are spectrally blind to each other. In fiber MO, the gain media and the BPFs are arranged alternately in a linear or ring cavity configuration. Depending on the offset between filters, a strong modulation depth of the saturable absorber can be obtained by strong self-phase modulation (SPM) induced self-amplitude modulation. The major difficulty in fiber MO setup is the self-starting of mode-locking from noise due to the presence of offset filters, which inhibits CW lasing. Hence, an external seed source is usually injected in fiber MO to initiate the mode-locking process. The seed source is then blocked after realizing the stable mode-locked operation in MO and the oscillator continues to operate steadily.

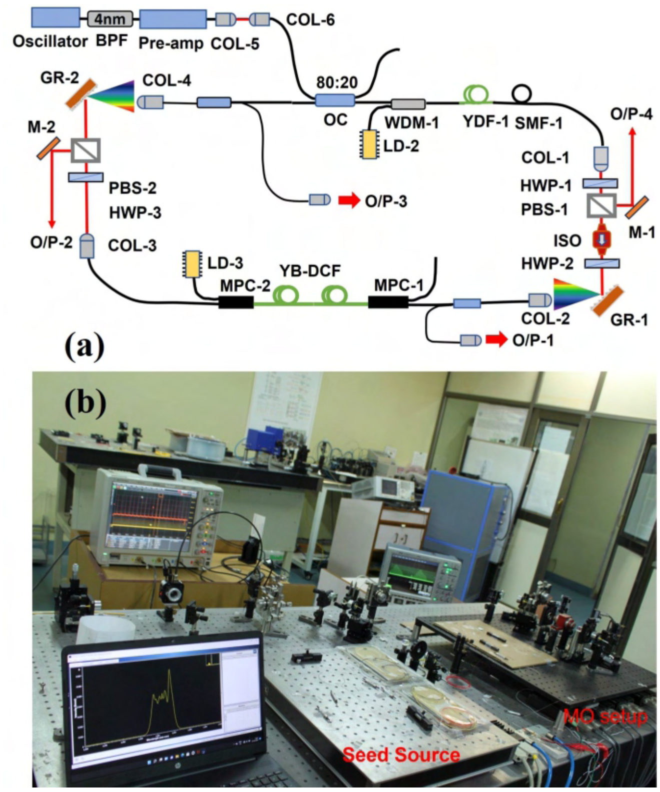

Fig. L.5.1: (a) Schematic and (b) photograph of ultrafast fiber Mamyshev oscillator setup.

Recently, we have constructed ultrafast fiber MO setup driven by conventional mode-locked laser in ANDi configuration as shown schematically in Figure L.5.1(a). The MO consists of two gain media (YDF-1 and Yb-DCF) and two tunable offset band pass filters (BPF1 and BPF2) made using the combination of diffraction gratings (GR1 and GR2) and in-fiber collimators (Col-2 and Col-4), respectively. Both BPF1 and BPF2 have a transmission bandwidth of ~2 nm, and the separation of the peak transmission wavelength of the filters is adjusted to ~5 nm, so that their combination acts like an ideal saturable absorber based on SPM induced strong self-amplitude modulation. Due to the presence of spectrally blind filters, the MO is not self-starting and pulses (5 ps, 40 MHz) from a specially designed seed source in ANDi configuration is injected to MO via an optical coupler (OC) to drive the MO as shown in the schematic. With appropriate pumping levels in the gain fibers in MO, the injected pulses drive the MO in mode-locking state and it remains in the mode-locking state even after blocking of seed pulses from injecting to MO (Fig. L.5.2(b)).

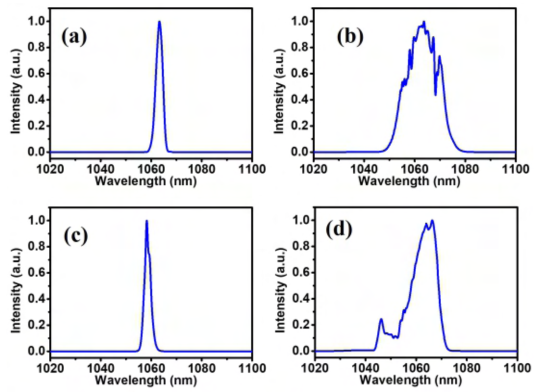

Fig. L.5.2: Recorded spectra at various locations of fiber MO (a) O/P-1, (b) O/P-2, (c) O/P-3, and (d) O/P-4.

The pulses from MO are highly stable (SNR~65 dB) with a repetition rate of 9.6 MHz. To study the spectral shaping dynamics in MO, the pulse spectra are recorded at several locations in the setup and are shown in Figure L.5.2. It can be seen that just after the BPF1 (O/P-1), the spectra is narrow with spectral bandwidth (FWHM) of ~3.2 nm and peak centred at 1063.2 nm. The spectrum broadens considerably to ~16.7 nm (O/P-2, Fig. L.5.2(b)) as it propagates through the fiber due to SPM, while the central wavelength is maintained at ~1063.2 nm. The BPF-2 again reduces the spectral width to ~2.6 nm (O/P-3, Fig. L.5.2(c)), but with peak at ~1058.3 nm clearly indicating the filter offset. The spectrum again broadens to ~11 nm (O/P-4, Fig. L.5.2(d)) as it propagates through the fiber before it is shortened again at BPF1. From O/P-4 around 112 mW of average power is obtained corresponding to pulse energy of ~12 nJ signifying the energy scalability feature of MO. The pulses from the MO are highly chirped with a measured duration of 9.53 ps and was compressed to ~200 fs duration with a clean smooth profile using a grating pair. Further work is in progress to scale-up the pulse energy from the setup.

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