All normal dispersion fiber laser with bandwidth tunable fiber based spectral filter

Ankita Khanolkar[1], Xiaowei Ge[2], Andy Chong [1,3]

1. *Department of Electro-Optics and Photonics, University of Dayton, Dayton, OH 45469, USA*
2. *Department of Electrical and Computer Engineering, Boston University, Boston, MA 02215, USA*
3. *Department of Physics, University of Dayton, Dayton, OH 45469, USA*

khanolkara1@udayton.edu

Abstract: We have demonstrated a stable ytterbium mode-locked fiber laser with an all fiber, bandwidth tunable spectral filter which can generate mode-locked spectrums of different shapes and bandwidth.

OCIS code: (140.3510) Lasers, fiber; (140.4050) Mode-locked lasers

1. Introduction

An intracavity spectral filtering is an effective pulse shaping mechanism for all normal dispersion (ANDi) lasers. It can be realized with the help of free space optical components [1,2] or fiber based spectral filters [3-9]. The latter being attractive because of the all fiber oscillator design. Although the Lyot filter mentioned in Ref. [8] is very simple to implement, the bandwidth of the filter is not easily tunable. It is highly desirable to design a fiber-based filter with an adjustable bandwidth to control spectral bandwidth and central wavelength tunability of a mode-locked fiber oscillator [9]. In this paper, we have numerically and experimentally demonstrated a mode locked ytterbium (Yb) laser using an all fiber, bandwidth tunable spectral filter. Our spectral filter design is based on a single mode fiber (SMF) spliced between two polarization maintaining (PM) fibers and its bandwidth can be easily tuned by changing the polarization state inside the SMF.

2. Numerical and experimental results

The schematic of the fiber based spectral filter is shown in Fig. 1. A short section of SMF (~ 13 cm) is spliced between two PM fibers which in turn are spliced to two in line polarizers at an angle of 45 degree. The PM fiber sections are ~9 cm and ~12 cm each. The polarization state inside the SMF can be changed by tuning the polarization controller (PC1).

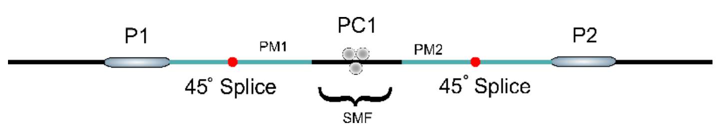

Fig. 1. Schematic of fiber based spectral filter. P: polarizer, PC: polarization controller, PM: polarization maintaining fiber, SMF: single mode fiber

The transmission spectrum of the filter can be easily simulated using Jones calculus. The SMF is treated as a rotating waveplate and the bandwidth (BW) of the transmission spectrum is adjustable by changing the rotation angle of this waveplate. With the promising simulation results, the transmission spectrum of the spectral filter was measured by passing a broadband spectrum through it. Figure 2 shows that the numerical and experimental results match well.

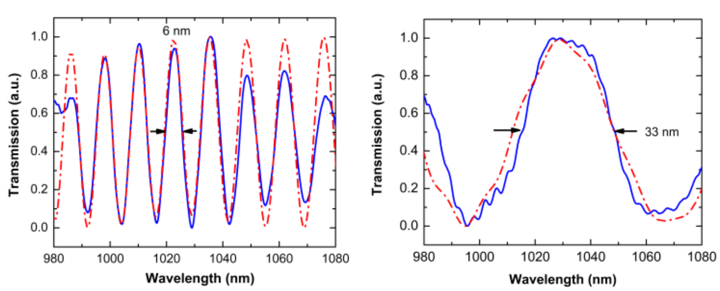

Fig. 2. The theoretical (dashed line) and experimental (solid line) transmission spectra of the filter for the different settings of the PC1.

The same filter was introduced in a Yb laser cavity and the experimental configuration of the oscillator is schematically illustrated in Fig. 3. A WDM couples 976 nm pump into 55 cm of Yb gain fiber followed by ~1 m of SMF. PC2, a

QWP, a HWP, and a PBS serve as an artificial saturable absorber to start the mode-locked operation. The output of the laser is taken directly from the PBS ejection port. An isolator ensures unidirectional operation. A HWP after the isolator adjusts the polarization to maximize the transmission of the spectral filter. A fiber-based coupler is used to monitor the output after the spectral filter.

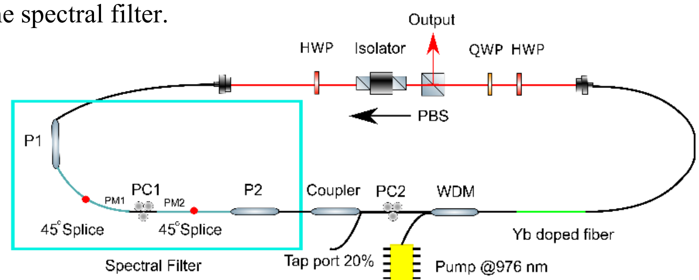

Fig. 3. Experimental set up. PBS: polarizing beam splitter, QWP: quarter wave plate, HWP: half wave plate, WDM: wavelength division multiplexer, PC: polarization controller

Experimental results are shown in Fig. 4. Figure 4(a) shows the spectrum at the 20% coupler port when a broadband amplified spontaneous emission (ASE) is coupled into the spectral filter which in turn depicts the shape of the spectral filter. Figure 4(b) illustrates the spectral filter output at the 20% coupler port when the laser is mode locked. The mode-locked output is obtained at the PBS ejection port and it is shown in Fig. 4(c). Therefore, it is possible to generate completely different shaped mode-locked spectra as output by simply adjusting PC1. Moreover, the bandwidth of the spectrum as well as central wavelength can be tuned.

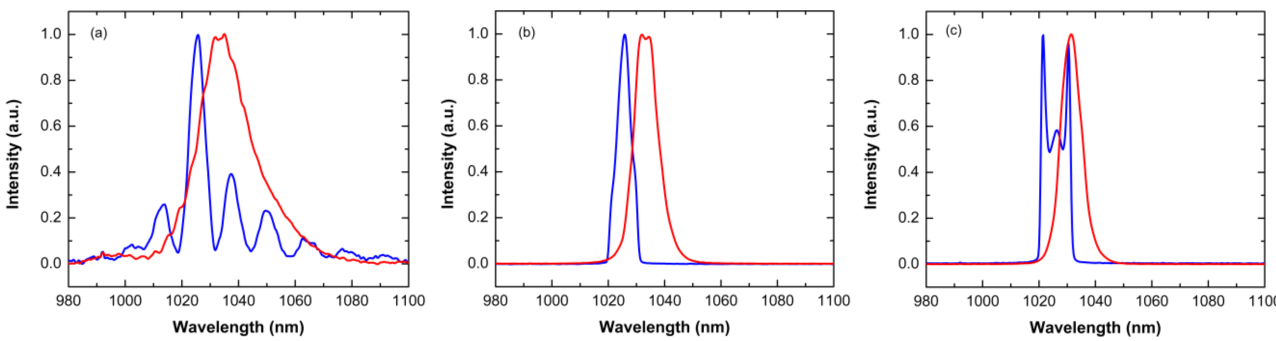

Fig. 4. Experimental spectra for the two different settings of the PC1 (shown by blue and red curve) at the (a) 20% coupler port with the ASE as input (b) 20% coupler port when the laser is mode-locked (c) PBS ejection port

3. Conclusion

We have numerically and experimentally investigated a fiber based spectral filter, the bandwidth of which is easily tunable without changing the length of the fibers. This spectral filter was successfully implemented inside the laser cavity which generated stable mode-locked pulses and their spectral bandwidths can be changed by adjusting the bandwidth and shape of the filter. Further experimental investigation of this laser cavity is currently underway.

4.Acknowledgement

This work was supported by National Science Foundation (Grant No. ECCS 1710914).

5. References

[1] A. Chong, J. Buckley, W. Renninger, and F. Wise, "All-normal-dispersion femtosecond fiber laser," Opt. Express **14**, 10095-10100 (2006).
[2] W. H. Renninger, A. Chong, and F. W. Wise. "Dissipative solitons in normal-dispersion fiber lasers." Physical Review A 77.2 (2008).
[3] O. Prochnow, A. Ruehl, M. Schultz, D. Wandt, and Dietmar Kracht, "All-fiber similariton laser at 1 μm without dispersion compensation," Opt. Express **15**, 6889-6893 (2007).
[4] C. K. Nielsen and S. R. Keiding, "All-fiber mode-locked fiber laser," Opt. Lett. **32**, 1474-1476 (2007).
[5] K. Kieu, and F. W. Wise. "All-fiber normal-dispersion femtosecond laser." Opt. Express **16**, 11453-11458 (2008).
[6] M. Schultz, H. Karow, O. Prochnow, D. Wandt, U. Morgner, and D. Kracht, "All-fiber ytterbium femtosecond laser without dispersion compensation," Opt. Express **16**, 19562-19567 (2008).
[7] Fekete, J., A. Cserteg, and R. Szipőcs. "All-fiber, all-normal dispersion ytterbium ring oscillator." Laser Phys. Lett. **6**.1 (2008).
[8] K. Özgören and F. Ö. Ilday, "All-fiber all-normal dispersion laser with a fiber-based Lyot filter," Opt. Lett. **35**, 1296-1298 (2010).
[9] Y. S. Fedotov, S. M. Kobtsev, R. N. Arif, A. G. Rozhin, C. Mou, and S. K. Turitsyn, "Spectrum-, pulsewidth-, and wavelength-switchable all-fiber mode-locked Yb laser with fiber based birefringent filter," Opt. Express **20**, 17797-17805 (2012).