High Energy Ultrafast Fiber Lasers and Applications
(Invited Paper)

Jian Liu, Huan Huang, Lihmei Yang
PolarOnyx, Inc., 2526 Qume Drive, Suites 17 & 18, San Jose, CA 95131
jianliu@polaronyx.com

ABSTRACT: High energy fs fiber laser development using polarization shaping is present to mitigate pulse narrowing effect. fs fiber laser applications in micro and nano material processing shows promising potential with its unique features of compactness and low cost.

OCIS codes: 140,3510; 140,3500; 140,4050.

1. Introduction
Ultrafast fiber lasers have been evolved into a new era for replacing solid-state ultrafast lasers and exploring new unprecedented applications. Close to kW and mJ level operation for fiber amplifiers have been demonstrated. However, those demonstrations involved many solid state components such as solid state seed oscillator and free space grating stretcher and practically are hard to be robust systems. This paper presents our R&D effort in developing high energy fs fiber lasers with minimum free space components (only the grating compressor) and applications in material processing.

2. High Energy Ultrafast Fiber Lasers with Polarization Shaping
By managing the polarization shaped spectrum in the fiber laser amplifier system (Figure 1), we are able to mitigate the gain narrowing and nonlinear effects in the high energy short pulse fiber amplifier.

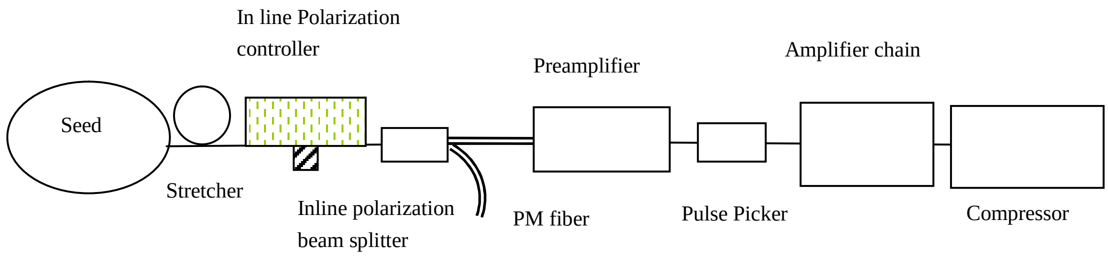


Figure 1 A polarization shaping CPA fiber laser system design

The polarization in a single mode non-polarization maintaining fiber is evolving along the fiber and is wavelength dependent. In the fiber CPA (Chirped Pulse Amplification) laser system, it is even more severe than in other systems. At high peak power operation, the polarization will be completely modified in the fiber stretcher and amplifiers. If not designed properly, the randomly polarized light passes through multistage of amplification chain, including a pulse picker, besides the nonlinearity and dispersion, the polarization related effects, including polarization mode dispersion (PMD) and polarization instability (PI) will affect the pulse shaping process and the compressibility.

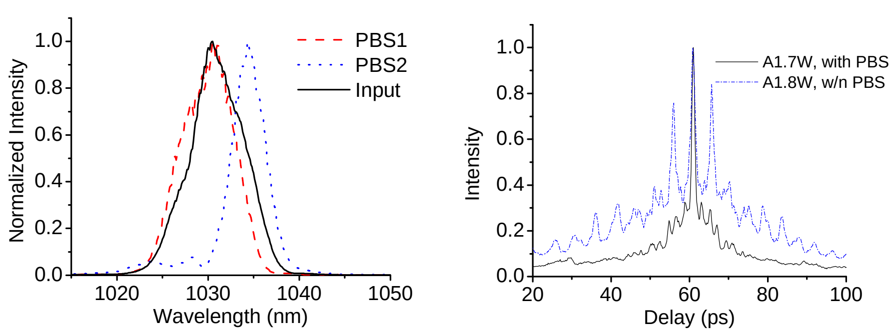


Figure 2 (a) Spectra by using PBS. PBS1 and PBS2 refer to the two output ports of the PBS. (b) Compressibility improvement by using PBS

However, by manipulating the polarization dependent spectrum (polarization shaping), this can turn into a good method to mitigate the gain narrowing effects in high power amplifiers. The spectral dependent polarization is more prominent for the wider bandwidth in ultrafast fiber lasers. This method provides the flexibility to play with the spectrum and polarization simultaneously with an inline fiber polarizer or a polarization beam splitter (PBS) to realize the best compressibility and pulse shapes. Fig. 2 shows the spectra from different ports of a PBS and autocorrelation traces of a laser amplifier with and without PBS. It can be seen obviously that the pulse compressibility was largely improved by the using the PBS to shaping the spectrum. The side pulses, wings and the high pedestals disappear after using PBS.

Fig.3 shows the compressed pulse duration for different energy level up to 250 uJ and output average power and contract ratio as a function of pump power. It does show that at energy level larger than 50 uJ, about 200 fs pulse width were achieved for up to 250 uJ pulse energy. This is due to the combined contribution of polarization shaping for mitigating gain narrowing in amplifiers, matching stretcher, and nonlinear compensation of TOD. The contract ratio (over 4000) indicates an excellent single pulse quality and low ASE background. Beam quality is better than 1.2 (M2).

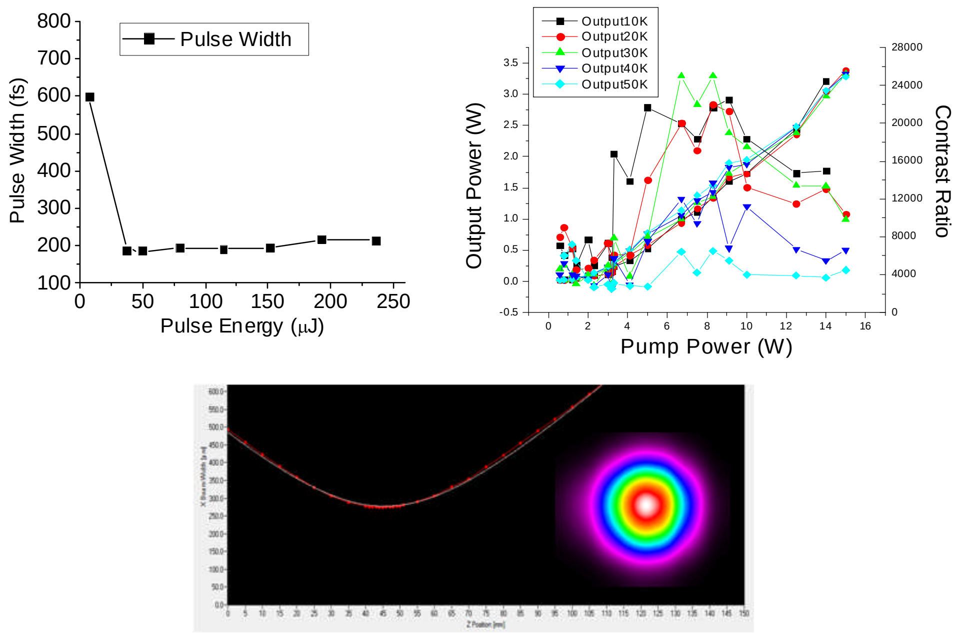
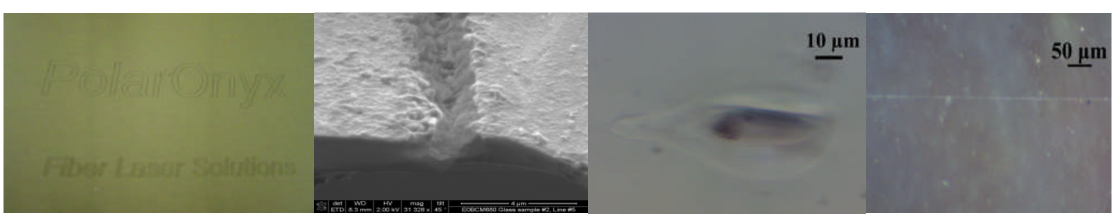


Figure 3 Pulse width as a function of energy level (Left) and Summary of output power and contrast ratio (Right)

3. Material Processing Applications with fs Fiber Lasers

One of the major applications for fs fiber laser is micro and nano material processing. We have demonstrated that fs fiber lasers can ablate micro-structures and drill holes on metals, glasses, ceramic, plastics, and tissues. Feature size as narrow as 50 nm was achieved in our application labs. Figure 4 shows some of the direct writing examples. Figure 4(b) shows the SEM image of surface linear direct writing of soda lime glass (scalar bar is 4 µm). Figure 4(c) shows the microscope view (cross section) of glass internal waveguide writing. The laser beam was incident from right side and was focused below the surface. The microscope view of surface linear writing of fresh bovine bone is shown in Fig. 1(d). The ablation line width is close to the beam focal spot size (5 µm). No crack or thermal damage was found after processing.



(a) (b) (c) (d)

Figure 4 Results of fs laser direct writing: (a) Stainless steel surface scanning; (b) Soda lime glass surface; (c) Soda lime glass interior; (d) Bovine bone surface.

4. References:

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