Novel high power femtosecond photonic crystal fiber laser amplifier with high repetition rate and its applications

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Abstract: Photonic crystal fibers have been the focus of increasing scientific and technological interest. A review of our recent work on high power femtosecond photonic crystal fiber laser system is presented. The applications of this system also demonstrated in this report.

Keywords: femtosecond, photonic crystal fiber, second harmonic generation, forth harmonic generation,

1. INTRODUCTION

Rapid progress in fiber lasers expands the horizons of laser technologies and laser science [1], leading to the development of a new generation of compact and robust laser sources for the fundamental research and numerous applications, including life sciences, optical communications, information technologies, ultrafast science, and high-field physics. The advent of new types of optical fibers, such as photonic-crystal fibers (PCFs) [2, 3], and a conceptual progress in understanding regimes of short-pulse dynamics in laser systems, including ideas of self-similar pulse generation and amplification [4,], have led to revolutionary breakthroughs in the development of fiber-laser sources of ultrashort pulses. The use of large-mode-area (LMA) PCFs [5, 6] has made it possible to lower the nonlinearity in fiber lasers and amplifiers without sacrificing the beam quality, enabling the generation of high-peak-power, high-energy ultrashort light pulses directly at the output of a fiber system[7-10]. In this work, we demonstrate a high-power stretcher-free all-polarization-maintaining femtosecond laser system where both an oscillator and an amplifier are based on a diode-pumped Yb-doped single-polarization LMA PCF.

2. EXPERIMENTS

In this high power femtosecond laser system, the oscillator and amplifier are based on the same Yb-doped single-polarization large-mode-area photonic crystal fiber. As for the oscillator, different mode locking regimes are obtained by varying net cavity dispersion. In the soliton regime with large anomalous dispersion, the laser directly generates 19 nJ pulses with 600 fs of duration which can be extracavity dechirped to 194 fs. In the stretched-pulse regime with near zero dispersion, the output pulse energy is a little lower, while sub-100 fs pulses can be obtained after extracavity dispersion compensation. In the all normal dispersion regime, 50 nJ laser pulses with 4.2 ps of duration are obtained and then extracavity dechirped to 410 fs.

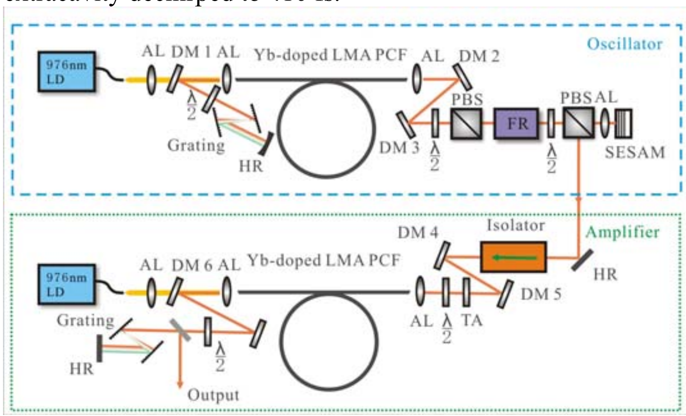

Fig. 1 Experimental setup: AL, aspheric lenses; DM, dichroic mirrors; PBS, polarization beam splitters; λ/2, half wave plate; HR, 45° high reflector; TA, tunable attenuator.

In the amplifier, after carefully analyze the dependence of the output pulse duration on the pulse energy, duration and chirp of seed light from oscillator and the pump power of amplifier, Nonlinear amplification of a 600-fs, 900-mW fiber laser output in an LMA-PCF amplifier in this system yields, upon grating-pair-based compression, laser pulses with an average power of 23 W, a pulse duration of 110 fs, and a peak power of 5 MW at a repetition rate of 50 MHz. Second harmonic (SH) generation and forth harmonic (FH) generation is obtained with this system. At pump power of 20 W, 8.88 W frequency doubled green laser is obtained with the maximum conversion efficiency up to 45.5%, and 1.6W frequency quadrupled UV laser is also achieved with a single pulse energy of 30 nJ. Increasing the pump power, the BBO2 crystal is broken due to the heat overload. A higher UV laser can be obtained if a nice cooling device is used for the BBO crystal. The SHG is about 12 nm (the pulse duration is about 100 fs, with a cross correlation method) and FHG is about 3.7 nm (27 fs assumed for a transform-limited pulse).

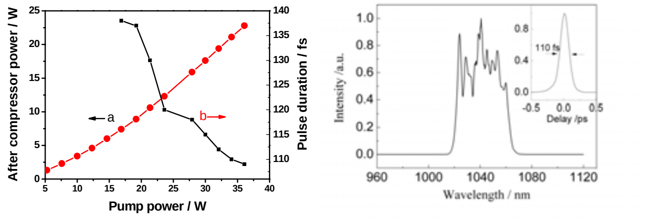

Fig 2.In the A, Line a is the output efficiency corresponding to pump power after compressor, Line b is the dependence of the output pulse duration on pump power; B is the spectrum from the amplifier and the corresponding autocorrelation trace

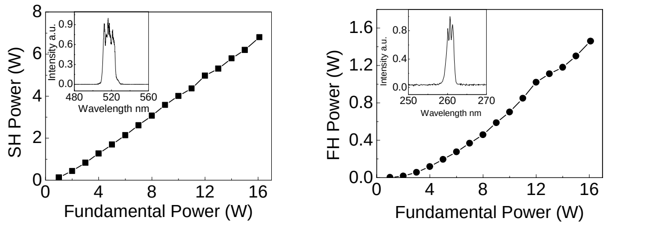

Fig.3 Output power of the SH as a function of the fundamental power. (Inset: spectrum of the SH). Output power of the FH as a function of the fundamental power. (Inset: spectrum of the FH)

Based on this high power femtosecond fiber laser system, the high power ultrafast terahertz radiation was obtained through optical rectification with GaP crystal. The output power is as high as 12 µw which is increased by two orders as that pumped by Ti:sapphire femtosecond laser oscillator. The experiment results are shown in the fig.5. The clear micromaching with high speed was also realized with this laser system and the experiment result is shown in Fig 4.

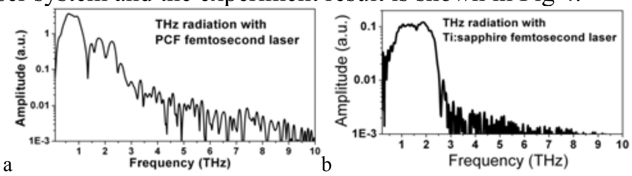

Fig.4 THz radiation spectrum generation with PCF femtosecond laser(a) and Ti:sapphire femtosecond laser (b)

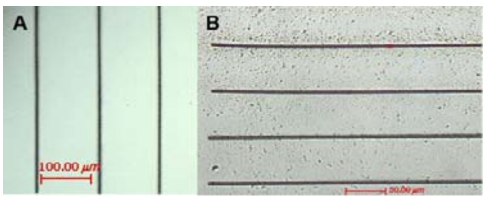

Fig.4 Optical micrograph of a micropattern produced by PCF femtosecond laser(A) and Ti:sapphire femtosecond laser (B) on a silicon wafer

3. Conclusion

We demonstrate a compact high power femtosecond fiber laser system, which can deliver femtosecond laser pulse at wavelength 1040nm, 520nm and 260 nm. The applications of this system on terahertz generation, micromaching, and high power nonlinear process are also demonstrated in this report.

ANKNOLEDGEMENTS

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