Repetition Rate Tuning of an Ultrafast Ytterbium Doped Fiber Laser for Terahertz Time-Domain Spectroscopy

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***Abstract*— Repetition rate tuning enables the fast acquisition of THz pulse profiles [1]. By using this method we demonstrate a compact and broadband terahertz time domain spectroscopy system (THz TDS) driven by ytterbium doped fiber laser source. The importance of this method is realized in that Yb:doped fiber lasers can be amplified to sub-millijoule pulse strengths more easily than other types of fiber lasers [2]. Hence, it has the potential to be used in excite-THz probe experiments. Furthermore, the repetition rate-tuning adds flexibility in the excite-probe techniques. These attributes as well as THz generation and detection are investigated with the laser that was developed.**

I. Introduction And Background

Terahertz time domain spectroscopy(THz-TDS) has proven to be one of the most productive tools in the far-infrared region (10^{11}–10^{13} Hz) over the past two decades. While its dynamical nature allows excite-probe characterization studies with amplified lasers, costly and complex THz generation systems were a handicap. Typically, amplified Ti:Al_2O_3 systems operating near 800nm are used in THz generation and detection in these methods. Increasing demands in THz TDS and field applications requires compact, portable and robust generation sources. Developing fiber laser technology enables us to produce ultrafast and powerful pulses that can be used in THz generation systems. Yb:doped fiber laser have greater potential in power scalability and robustness [3]. These ultrafast lasers with sub-200 femtosecond pulses enable scientists to use antenna structures, optical rectification, or surface emitters to produce THz [4]. Recent studies showed that GaP is an appropriate crystal for electro-optical rectification near 1µm region.

In this study, we present a compact THz-TDS driven by a robust Yb-doped fiber laser operating at 50 MHz repletion rate, 1035 nm central wavelength and sub-100fs pulse duration. A parallel line photoconductive antenna (PCA) is used as THz emitter and a <110>-cut GaP crystal is used for electro-optical sampling.

II. Results

The fiber laser oscillator was tested for stability during the tuning of the repetition rate. The robust operation allowed for less than 3% drift of power over a tuning range of 60 kHz. After pre amplification stage (Figure 1) the oscillator will be incorporated in the THz system shown in Figure 2. The operation of the system will be analyzed in terms of stability, noise and overall implementation in an excite probe system which can be done after an additional amplification stage on the Yb:doped fiber laser. Consequently, this compact system can be used in pump-probe applications with high energy per pulse.

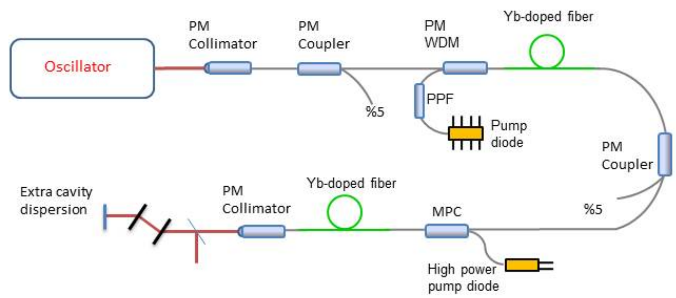

Figure 1: Yb-fiber laser figure,PM: Polarization maintaining, PPF: Pump protection filter, MPC: Multimode pump-signal combiner

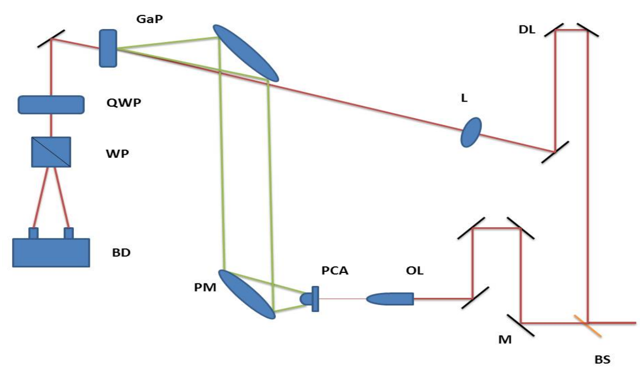

Figure 2: THz TDS system. quarter wave plate (QWP), Wollaston prism(WP), Objective lens (OL)

The Yb-doped fiber oscillator produces ~30 mW power output. Central wavelength of oscillator is about 1040 nm 100 fs pulses were derived from %5-monitoring output port. To implement the system in scheme as shown in Fig. 1, the stability of the oscillator was examined over the entire THz scan length by scanning the collimator over the range of 6 mm. The measured repetition rate and power stability is plotted in Fig. 3.

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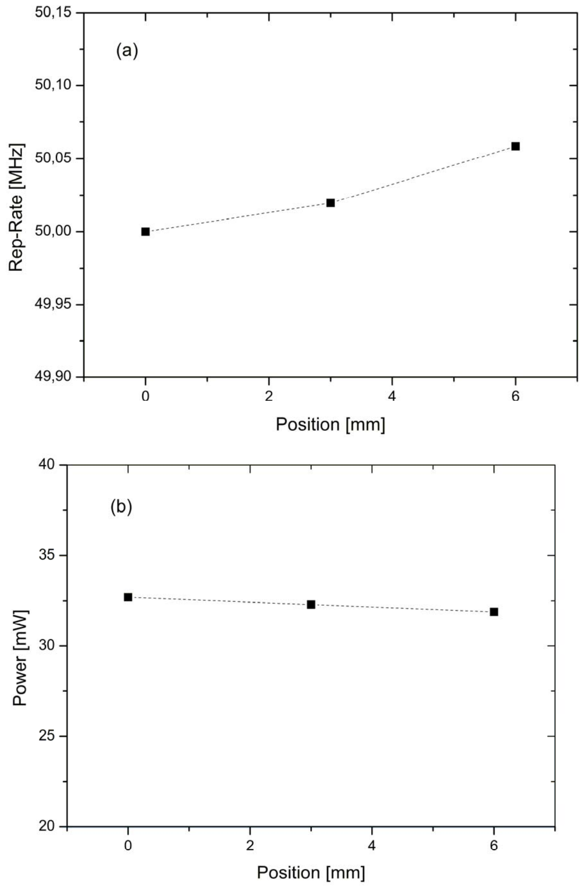
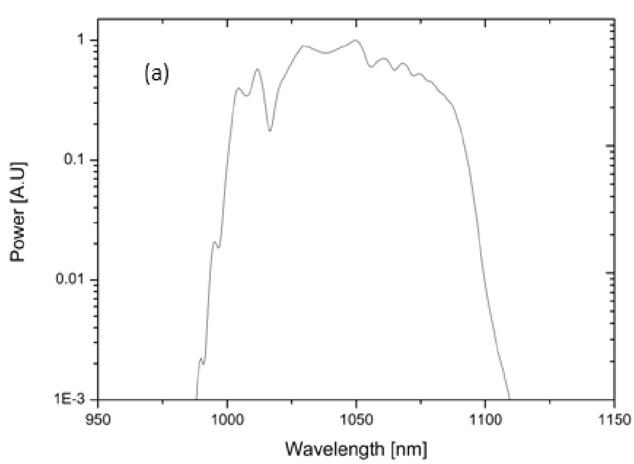


Figure 3 a Repetition rate change; b Power fluctuation as oscillator cavity is scanned

At the same time in order to observe stability of laser oscillator spectra were recorded during the scan interval. The obtained spectra show that the output has a center wavelength of about 1040 nm with a FWHM of 65 nm as shown in Fig 4a. Spectrum was observed to be stable with changing cavity length. Pulse durations for scan points are also measured as we scan 6 mm of cavity length. Autocorration (AC) signal of scanned pulses is show in Fig 4b. Intensity of oscillator output is normalized to 1.



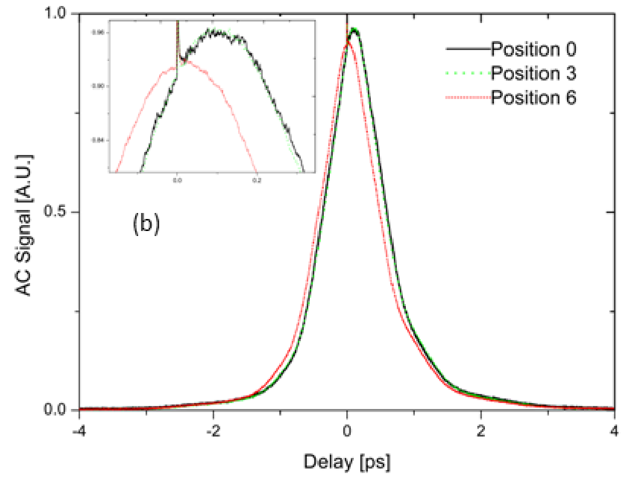


Fig. 4 a Spectrum output of oscillator; b Pulse profiles obtained during the scan length

Although there is some change at third position, the overall stability of the system is quite good with respect to expected measurements in the THz-TDS system. The pulse width change is below 1.01 % and measured pulse durations of first, second and third positions are 965.05 fs, 969.47 fs and 974.78 fs respectively assuming pulse shape is Gaussian. This pulse will seed the amplifier stages and subsequently be compressed before being used in the THz generation and detection arms as shown in Fig. 1.

These results show that the oscillator can scan the THz waveform without the use of any external delay lines, thereby shortening the data acquisition times throughout the measurements. The oscillator for the amplified Yb-doped fiber laser system was constructed with a repetition rate of 50 MHz. In order to scan a length of 100 ps, the cavity needs to be tuned over +/-25 kHz. Oscillator cavity is scanned over 6mm range, for which the laser system exhibited little or no difference in output pulse duration, power and spectrum characteristics which is a testament to the stability of these lasers compared to other solid-state mode-locked lasers.

III. ACKNOWLEDGMENTS

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