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Optical switch by direct modulated laser diode using fiber laser for pulse picking

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Summary: We propose a new method of direct modulating pre-amplifier laser diode as an optical switch. To modulate the laser diode with lower repetition rate, the repetition rate in the kilohertz region can be achieved using a source laser of 100 MHz without electro-optical modulators (EO) or acousto-optical (AO) modulators. Using direct modulated laser diode, ON/OFF ratio (extinction rate) of 25 dB was demonstrated in this study.

Keywords: optical switch, fiber laser, pulse width modulation, direct modulation, burst mode

1. Introduction

Ultrashort pulses can be advantageous for high efficiency and flexibility for laser system. A duration of 200 fs with peak power ~ 2.5 kW has been reported [1,2]. Since mode locking is used for the laser system, the repetition rate is given by the cavity length. The repetition rate of 100 MHz can be easily obtained, however it is difficult to produce the repetition rate below 100 MHz with extra cavity length. The repetition rate in the kilohertz region is required for a regenerative amplifier, or fluorescence lifetime measurements, for example.

In order to produce the repetition rate in the kilohertz region, pulse pickers such as electro-optical modulators (EO), acousto-optical (AO) modulators or Mach-Zehnder modulators are often used. However they require large size and high cost, and restrict the choice of repetition rate.

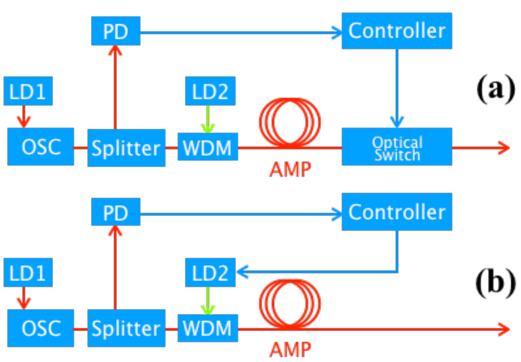

Figure 1 Schematic of pulse picking laser system. (a) ordinal pulse picking system with optical switch and (b) direct modulating pumping LD system.

Q-switch lasers, for an example, have shown great successes due to their simple and stable schemes. We previously proposed slower Q-switched YAG method to reduce its repetition rate and to increase its power. The system was used as a laser source for a pulsed laser deposition (PLD) system [3]. Only the Q-switch is modulated with lower repetition rate than the original repetition rate of flash lamp (slower Q-switched system) in order to obtain high energy fluency. Although the duration time become slightly wider (from 10 ns to 13 ns), the fluency becomes enough to produce an ablation on the target in the system, and a variety of high quality epitaxial films [4-6] including graphene[7] have been reported. In this presentation, we will propose a new method for pulse picking using a fiber laser.

2. Experimental

An all polarization-maintaining (PM) fiber mode-locked laser contains a passively mode-locked oscillator and a fiber pre-amplifer. The laser oscillator is based on a Fabry Perot (FP) cavity configuration with wavelength 1030 nm at repetition rate of 98 MHz. And extended cavity length of approximately 210 cm produced 35 MHz from the oscillator. A PM fiber Bragg grating (FBG) is used as the output mirror of the FP cavity, and the FBG has a reflection peak wavelength of 1030 nm with bandwidth (FWHM, full width at half maximum) of 0.8 nm.

The 1030 nm laser generated by OSC was pumped by a 30 cm PM Yb-doped gain fiber with a 980 nm laser diode (LD) via a PM wavelength division multiplexer (WDM). At an end reflector of the FP cavity, a saturable absorber mirror (SAM)

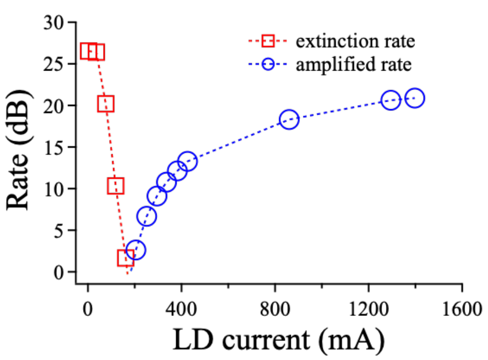

Figure 2 Extinction and amplified rate with 1030 nm laser at 98 MHz. The extinction rate of 25 dB was achieved.

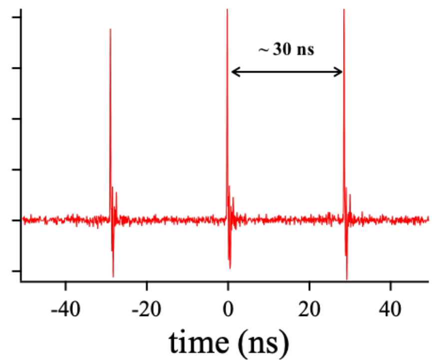

Figure 3 Reduced repetition rate with an extra length cavity. The repetition rate changed from 98 MHz to 35 MHz.

directly butt-coupled was used for self-started passive mode-locking of the fiber laser.

In order to reduce repetition rate, some ratio of the laser is directed out by optical PM coupler for producing a delayed gate signal for pulse picking. A fiber-based acoustic optical modulator (AOM), for example, is typically used for pulse picker with the delayed gate signal (Figure 1(a)). In this study, the pumping LD was modulated by a controller with 50% duration of pulse width at 1 MHz without any optical switch such as EO (Electro-Optical) or AO (Acousto Optical) modulator, as shown in Figure 1(b).

3. Results and Discussion

The 1030 nm laser generated by the oscillator showed a power of 10 mW with a pulse width of 6 ps. The 98 MHz, pumped by a 980 nm laser diode (LD2 in Figure1). In this study, the modulated LD2 was used as an optical switch, as shown in Figure 1(b).

One of important factor for an optical switch is the ON/OFF ratio (extinction rate), which is expressed as the ratio of two optical power levels of a digital signal generated by an optical source, e.g., a laser diode. Typical extinction rates for commercial products using AO or EO modulations are ranging from 15 to 45 dB. Figure 2 shows the extinction rate as a function of applied LD (LD2 in Figure 1(b)) current in this study. Without using typical AO or EO modulator, extinction rate of 25 dB was achieved by direct modulated LD system.

With 98MHz repetition rate, 1030 laser modulated by pre-amplifier (LD2) showed slow rise profile and did not reach its maximum power of the source laser. In order to properly modulate the LD, the repetition rate of the source laser was reduced with an extra cavity length employed in the OSC. Figure 3 shows reduced source laser repetition rate of 35 MHz instead of 98 MHz with an extra cavity ~70 cm. Using the reduced repetition rate of the source laser, LD modulated by pulse width can generate pulse width modulation with the further low frequency. We will present the latest results on the pulse width modulation as a burst mode.

4. Summary

We proposed a new method of direct modulated preamplifier laser diode as an optical switch, and showed the capability of signal generation with extinction ratio more than 25 dB.

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