Microsecond Pulse Generation in an Actively Q-Switched All-PM Fiber Laser Based on an Electro-Optic Modulator

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***Abstract*—Active Q-switching of an all polarizationmaintaining (All-PM) erbium fiber laser by an electro-optic modulator (EOM) is reported. Cavity loss modulation is achieved via an external modulation signal generated from an electrical signal source. The Q-switched pulsed laser operates in the 1.5 μm region with 0.83 nm linewidth. The shortest pulse width obtained is 1.06 μs. We believe that this combination between all-PM configuration and EOM offers an ideal method to design single-polarization pulsed laser sources with high environmental stability towards temperature variations and mechanical perturbations.**

***Index Terms*—Q-switched pulse, electro-optic modulator, fiber laser, amplified spontaneous emission (ASE)**

I. Introduction

Fiber lasers have been widely used in various medical applications [1], distributed fiber sensing [2], frequency comb generation [3], and gas detection [4]. Specifically, the Qswitched fiber lasers which can generate short pulses using passive and active techniques. For passive Q-switching, saturable absorber materials are used [5]. Here, the pump power determines the repetition rate of the generated pulses, restricting control over the output pulse characteristics when the maximum pump power is reached. In actively Q-switched laser operation, unlike passive Q-switching, the pulse characteristics may be changed independently of the pump power by utilizing an external electrical signal generator, allowing for flexible laser pulse control for the desired laser application [6].

In general, active Q-switching in fiber lasers can be obtained by inserting a piezoelectric actuator (PZT) [7], an acousto-optic modulator (AOM) [8], or an electro-optic modulator (EOM) [9] into the laser cavity in order to rapidly modulate the intracavity losses and thus the quality factor (Qfactor) of the laser resonator. Recent reports have shown narrow Q-switched laser pulses operating at 1 μm [10] and 1.5 μm [11] with pulse widths of 64 ns and 429 ns, respectively.

Nevertheless, to the best of our knowledge, no work has been done to generate actively Q-switched laser pulses using an all polarization-maintaining (All-PM) fiber laser architecture. Environmentally stable lasers cannot be obtained with standard (non-PM) fibers since the fiber's birefringence is sensitive to changes in the environment.

In this work, we experimentally demonstrate an all-PM actively Q-switched erbium-doped fiber laser based on EOM. The pulse width was 1.06 μs at 130 kHz repetition rate with a maximum average output power of 4.8 mW.

II. Experimental Setup

The proposed experimental setup of the actively Qswitched erbium fiber laser is shown in Figure 1. A laser diode with 980 nm wavelength and a maximum power of 300 mW is used to pump the erbium-doped fiber via the 980/1550 nm wavelength-division multiplexing (WDM). The isolator is used to ensure unidirectional operation in the ring cavity and reduces the backward amplified spontaneous emission (ASE) noise. After the amplification process, 20% of the light power is extracted from the coupler for output measurements, and 80% of the light power enters into the fiber-pigtailed EOM (Mach-Zehnder, COVEGA), which is used as the Q-switch device.

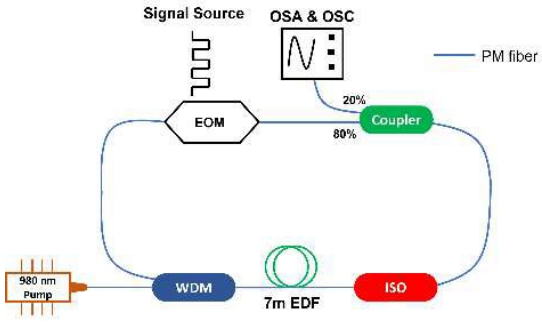

Fig. 1. Experimental design of the actively Q-switched erbium-doped fiber laser. WDM, wavelength-division multiplexing; EDF, erbium-doped fiber; ISO, isolator; EOM, electro-optic modulator; OSA, optical spectrum analyzer; OSC, oscilloscope.

The optical insertion loss of the EOM is around 6.9 dB with an extinction ratio of 24.86 dB. The modulator's maximum operating point is set by adjusting the DC voltage to 3.58 V, which is the half-wave voltage (V_π). Radio frequency (RF) signal generator (Keysight, 81150A) is used to drive the EOM with the modulation signal to generate Q-switched pulses. The

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