Application of Q-switching to Erbium-Doped Fiber Laser

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Abstract-In this paper we present work in progress on short pulse fiber lasers. These lasers are used in the field of laser machining, medicine, range finding and optical communications. To develop a short pulse, high peak power fiber laser we make use of the Q-switching technique. The pulse duration and peak power of the laser are defined by the length of the fiber, repetition rate, output coupler transmission and pump power. The main goal of this project is to experimentally optimize the time duration and the peak power of the pulses.

Index Terms—Short pulse fiber laser, Erbium, Q-switched laser.

I. INTRODUCTION

Nowadays, fiber lasers are more attractive than conventional solid state lasers, because of the beam quality, system compactness and quantum efficiency [1]. Pulsed fiber lasers around 1.55µm find applications in the field of medical surgery, range finding, Lidar and telecommunications. These lasers are characterized by the short time duration and high peak power of the output pulses. To generate pulsed fiber lasers, many techniques have been demonstrated [2]. Q-switched erbium doped fiber laser is a cheap, simple and robust source of generating optical pulses with high peak power [3-5]. Peak power and time duration of pulses from Q-switched fiber lasers are defined by the length of the fiber, repetition rate of the pulses, output coupler transmission and pump power. The optimization of a Q-switched fiber laser system is a challenge. In this paper we propose different approaches to experimentally optimize a Q-switched erbium doped fiber laser and also present the objectives of this research.

II. Q-SWITCHED FIBER LASER OPERATION

Q-switched erbium doped fiber lasers generate intense laser pulses with a time duration in the range of nanosecond. We consider here a ring cavity Q-switched fiber laser configuration, as shown in Fig. 1.

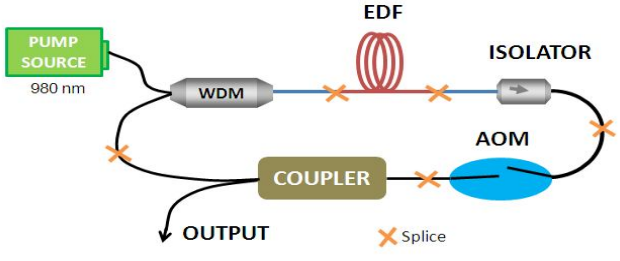

Fig.1. Experimental Setup of Q-switched Erbium-Doped Fiber Laser.

This Q-switched fiber laser is constituted by a pump source emitting light at 980 nm, the ring cavity formed by erbium doped fiber as amplifier, the wavelength division multiplexer (WDM), the isolator, the acousto-optic modulator (AOM) and the coupler. The Pump light is launched into ring cavity through the WDM. The pumped light is absorbed by the erbium doped fiber. The output radiation from the erbium doped fiber is sent to the acousto-optic modulator through an isolator to ensure the unidirectional oscillation of the laser. The laser output is extracted though the coupler. The principle of Q-switched laser is based on keeping the laser cavity opaque (by switching off the AOM) while the gain is building up in the erbium doped fiber amplifier, until the pumped gain medium has stored a certain amount of energy. Then, switching on the acousto-optic modulator allows the intense stimulated laser radiation to establish quickly in the cavity and create high peak power pulse with short time duration [3]. Fig. 2 illustrates the variation of the optical gain and formation of pulse laser in the Q-switching regime.

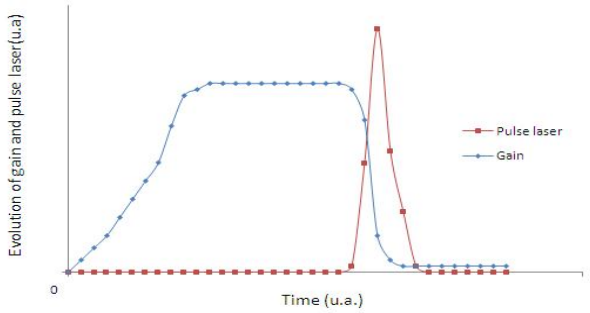

Fig. 2. Formation of Pulse in the Q- switched Fiber Laser.

III. PARAMETERS TO OPTIMIZE

Recent investigations report different methods of increasing the peak power and shorten the laser pulses [4].

A. *Increasing the Peak Power*

Adopting the following actions should be done to increase the output peak power of the laser:

1) Increase the pump power: The higher pump power, the higher the stored energy in the gain medium. This contributes to higher peak power of the laser pulses [2].
2) Optimize the length of the fiber: The pump absorption increases with the increase of the length of the fiber. However, the absorption of spontaneous emissions also increases proportionally to the length of the fiber. Therefore,

for a given pump power, there exist an optimal length of the fiber where the loss is minimized and allow the extraction of high peak power from the fiber laser. [4].

3) Decrease the repetition rate: This parameter defines the time between the pulses. At low repetition rate, the pump has enough time between the pulses to completely buildup the gain in the cavity. Operating at a low repetition rate, can generate high peak power lasing pulses [5].
4) Coherent Combining of several lasers: This technique enable high peak power fiber laser by coupling multi-arm resonator Q-switched fiber laser [6].

B. Narrow the time duration of the pulses

Adopting the following action should be done to reduce the pulse time duration.

1) Increase the pump power: By increasing the pump power, the optical gain in the erbium doped fiber increases. This increases, reduces the establishing time of the pulse and then the pulse durations decrease [7].
2) Reduce the fiber length: The pulse time duration of Q-switched fiber laser is a function of the length of the cavity. For a short cavity length, the homogenization of the pump photon distribution increases, and makes the time of establishing the pulse in different position of active medium the same. In this case, lead to the reduction the time duration of the pulses [8].
3) Increase output coupler transmission: By increasing the output coupler transmission, the cavity round trip loss increases, this makes photons lifetime shorter and reduce the pulse time duration [9, 10].

IV. Project Objectives

The objectives of this research project are: Investigate Q-switched erbium doped fiber lasers in term of high peak power and time durations of the pulses. Design and numerically simulate a Q-switched erbium doped fiber laser system. Implement and characterize a prototype of Q-Switched Erbium-Doped Fiber Laser.

V. Methodology

After a literature study, the following activities must be performed:

1) Numerical and experimental characterization of the erbium doped fiber amplifier in order to optimize the optical gain.
2) Design and numerically simulate a Q-switched Erbium-Doped Fiber Laser.
3) Build and characterize an experimental setup of a Q-switched erbium doped fiber laser source.
4) Optimize the experimental Q-switched erbium doped fiber laser source.
5) Once the Q-switched fiber laser source is optimized, it will be used for basic experiment applications for example range finding, wavelength division multiplexing or fiber sensors systems.

VI. Conclusions

In conclusion, pulsed eye-safe fiber lasers remain a subject of intense research because of its importance in many applications. The combinations of high peak power and short pulse time duration are challenges. Taking advantage of Q-switched fiber laser system and different methods of optimization the laser systems, should be the way to build a cheap and robust pulsed fiber laser source. This pulsing laser source will help for local applications in range finding and fiber sensors system.

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