Wavelength-tunable all-fiber actively Q-switched fiber laser by a pair of temperature controlled fiber Bragg gratings

Fang-Wen Sheu [a,b]（許芳文）and Jung-Jui Kang [b]（康榮瑞）

[a] Department of Applied Physics, National Chiayi University, Chiayi 60004, Taiwan
[b] Graduate Institute of Optoelectronics and Solid State Electronics, National Chiayi University, Chiayi 60004, Taiwan
（國立嘉義大學 [a]應用物理學系，[b]光電暨固態電子研究所）
Telephone: 05-2717993; Fax: 05-2717909；E-mail: fwsheu@mail.ncyu.edu.tw

(NSC-93-2112-M-415-004)

Abstract --- *We construct an all-fiber actively Q-switched Erbium-doped fiber laser, where the linear laser cavity mirrors are composed of two fiber Bragg gratings (FBGs). The laser oscillation wavelength could be tuned by this pair of temperature controlled FBGs. The Q-switching is achieved by an all-fiber phase modulation device. Using this system, we could obtain stable Q-switched laser pulses output, which could be optimized by tuning the reflection wavelengths of the two FBGs to be adjacent to each other. In stead of driving the FBG filter in high-speed, we turn to Q-switch the fiber laser system with the all-fiber phase modulator, obtaining a wavelength tunable and more stable laser output spectrum.*

Keywords: *Fiber lasers; Q-switching; Fiber Bragg grating; All-fiber*

1. Introduction

In recent years, because of better beam quality, quantum efficiency, and system compactness, fiber lasers are more attractive than conventional solid state lasers in many aspects. High power or pulsed fiber lasers often become a superior alternative for various practical applications. Q-switching is a well known technique to generate pulses laser output, and many ways have been demonstrated [1, 2, 3]. In Ref 3, a wavelength-tunable Q-switched Erbium-doped fiber (EDF) laser using two fiber Bragg gratings (FBGs) is proposed. The FBG has excellent wavelength selectivity and is used as a laser-cavity reflector, filter, and Q-switching device. The FBG matches easily with the fiber laser system and makes the system design more compact. The wavelength of the reflected light from the FBG could be controlled by applying a tensile force to the FBG. Bending a metal rod to which one FBG is attached, could tune the laser oscillation wavelength shift. Driving a piezoelectric transducer to which another FBG is attached in 1-kHz high speed, could modulate periodically the Q-value of the laser cavity and thus produce Q-switched laser pulses with a 2.46-μs pulse width.

However, in this method, it is very easy to crack the fiber grating if the FBG is stretched and relaxed in high speed. Another drawback is that the laser output center wavelength will be also oscillating slightly during the process of driving the FBG back and forth. Therefore we present in this report another wavelength tunable Q-switched fiber laser system utilizing a pair of temperature controlled FBGs, in which the Q-switching is carried out by driving an all-fiber phase modulation device. When the modulating frequency or the pulse repetition rate was 37 kHz, the produced actively Q-switched fiber laser pulse had a pulse width of about 2 μs. The laser wavelength shift is tunable by controlling the temperatures of the FBGs, and the laser output spectrum is more stable because we turn to Q-switch the fiber laser system with an all-fiber phase modulator in stead of driving the FBG filter in high-speed.

2. Experimental system and device characteristics

2.1. Q-switched fiber laser system

The experimental configuration of the Q-switched fiber laser is shown in Fig. 1. The reflection mirrors of the linear fiber laser cavity are two short-period FBGs. A 10-m-long EDF is used as a gain medium to produce laser light at a wavelength of 1550 nm nearby. The EDF is pumped by the 980-nm laser light at about 130 mW pump power which is coupled into the linear laser cavity from the laser diode (LD) through a wavelength division multiplexer (WDM). A one-by-two 10/90 optical coupler is used to dump 10 % of the Q-switched fiber laser light out of the cavity. The pulse waveform of the laser output is monitored by a home-made fast photodetector and an oscilloscope. The phase modulation device of this actively Q-switched fiber laser is a section of single-mode fiber wound around a cylindrical tube made up of piezoelectric material, which is driven by an alternating voltage to produce deformation and birefringence on the fiber.

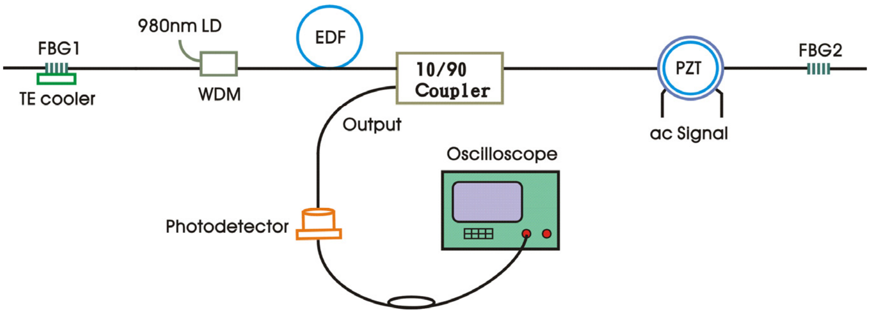

Fig. 1. The experimental configuration of the Q-switched fiber laser.

2.2. Characteristics of the FBG components

The two FBGs are used as laser-cavity mirrors and optical filters, too. To explore the reflection spectra of the two FBGs, we set up a broadband light measurement system. The center reflection wavelengths of the two FBGs are measured to be 1554.14 nm (FBG1) and 1554.20 nm (FBG2), respectively, at room temperature.

In the experiments, we attach the FBG1 onto the hot plate of a thermoelectric (TE) cooler to increase its temperature, grating pitch spacing, and reflection wavelength. The temperature of the TE cooler could be increased from 25 °C to 100 °C when the dc drive current is varied from 0.0 A to 1.4 A [Fig. 2(a)]. As the dc drive current of the TE cooler is increased successively from 0 A, the reflection wavelength of FBG1 [Fig. 2(b)] will be shifted gradually toward that of FBG2, then equal it at 0.8 A, and finally go beyond it above 0.8 A.

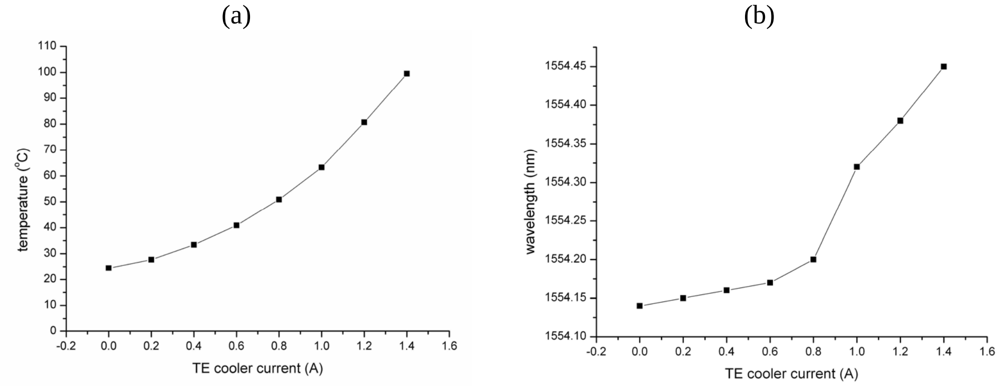

Fig. 2. (a) TE cooler temperature characteristics curve, and (b) FBG1 reflection wavelength by increasing the dc drive current of the TE cooler.

3. Experimental result of Q-switched fiber laser

We apply a sinusoidal alternating voltage signal of 1.77-Vpp amplitude and 37-kHz frequency (in resonant operation regime) on the piezoelectric tube (PZT) to periodically modulate the birefringence of the optical fiber wound around it, tune the phase of the laser light, and change the Q-value of the laser cavity. Under these conditions, the Q-switched fiber laser will produce a stable pulse train output. The dc drive current of the TE cooler is then varied from 0.0 A to 1.4 A successively at a step of 0.2 A, to increase the temperature and the reflection wavelength of FBG1. This will adjust the maximum Q-value obtained in the laser cavity and influence the properties of the generated laser pulses.

The spectra of the laser output at various TE cooler currents are also shown in Fig. 3. We also plot the peak intensity and the pulse width versus the laser oscillation wavelength in Fig. 4. This suggests the best resonant wavelength of this fiber laser system is at 1554.27 nm, where the reflection spectra of the two FBGs coincide with each other due to the temperature control of one FBG by the TE cooler.

As the dc drive current of the TE cooler and its temperature as well are increased successively, the reflection spectrum of FBG1 will approach gradually to that of FBG2. When the center reflection wavelength of FBG1 comes to equaling that of FBG2 at 0.8-A TE cooler current, the resultant pulse width reaches a minimum of 2.0 μs (Fig. 4). This is due to the fact that the loss of the laser cavity could be reduced down as the band-pass filtering effects of the two FBGs are close to each other. We find that when the TE cooler current goes beyond 1.0 A, no laser pulses could be observed. This is because the difference of the reflection wavelengths of the two FBGs is enormously enlarged, and consequently the cavity loss is too big for the light in the fiber laser cavity to start resonant lasing.

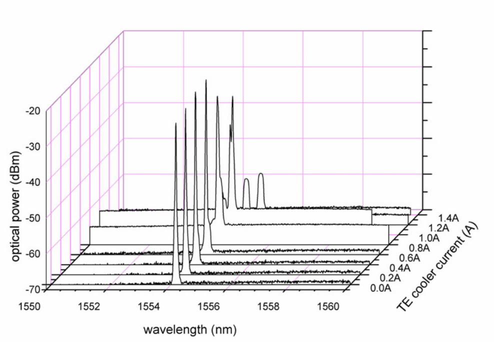

Fig. 3. The spectra of the laser output at various TE cooler currents.

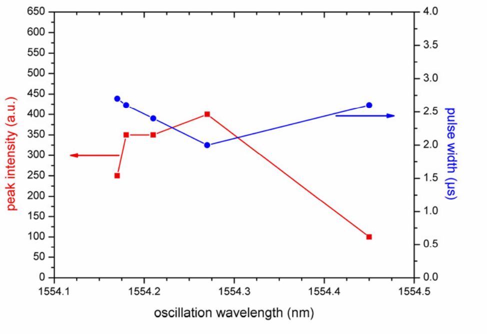

Fig. 4. The peak intensity and the pulse width versus the laser oscillation wavelength.

These results also reveal the influence of the overlapping degree of the reflection spectra of the two FBGs on the laser system output. As illustrated in Fig. 5, due to the multiplication effect of the two FBG filters, the laser output spectrum is confined by the reflection spectra of the two FBGs, and located between them. When the reflection wavelength of the FBG1 is tuned to be close to that of FBG2, the laser output spectrum looks stronger and narrower [Fig. 3 and Fig. 5(b)], indicating that a better resonance condition has been achieved. Nevertheless as the reflection wavelength of the FBG1 is tuned to be far beyond that of FBG2, the laser output spectrum becomes weaker and broader (Fig. 3).

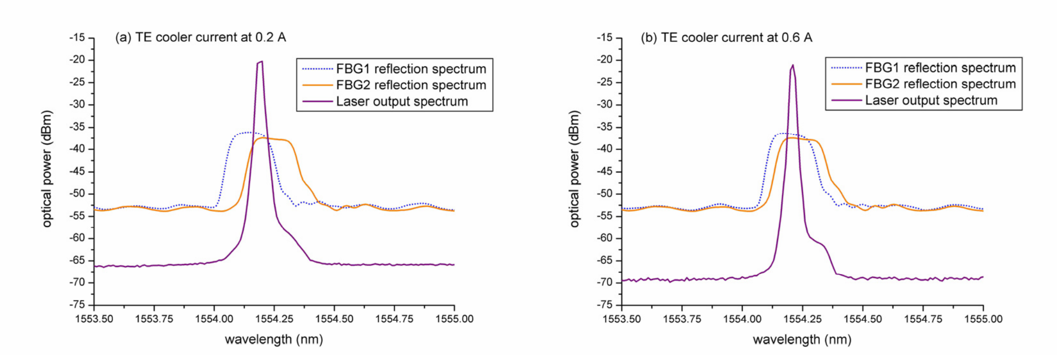

Fig. 5. Illustration of the laser output spectrum confined by the reflection spectra of the two FBGs, as the TE cooler current is set at (a) 0.2 A and (b) 0.6 A, respectively.

4. Conclusion

We have demonstrated an all-fiber actively Q-switched Erbium-doped fiber laser with a phase modulation mechanism, where the laser oscillation wavelength could be tuned by a pair of temperature controlled FBGs.

References

[1] J.A. Alvarez-Chavez, H.L. Offerhaus, J. Nilsson, P.W. Turner, W.A. Clarkson, and D.J. Richardson, “High-energy, high-power ytterbium-doped Q-switched fiber laser,” *Opt. Lett.* **25**, 37 (2000).

[2] M. Laroche, A.M. Chardon, J. Nilsson, D.P. Shepherd, and W.A. Clarkson, “Compact diode-pumped passively Q-switched tunable Er Yb double-clad fiber laser,” *Opt. Lett.* **27**, 1980 (2002).

[3] Takeshi Imai, Tetsuro Komukai, Takashi Yamamoto, and Masataka Nakazawa, “A wavelength tunable Q-switched fiber laser using fiber Bragg gratings,” *Electronics and Communications in Japan* (Part II: Electronics) **80**, 12 (1997).