OPTOELECTRONICS AND ADVANCED MATERIALS – RAPID COMMUNICATIONS Vol. 4, No. 9, September 2010, p. 1275 - 1277

An acousto-optic Q-switched Yb^{3+}-doped all-fiber laser pumped by diode-lasers

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The Q-switched fiber lasers are very attractive sources in many applications such as military affairs, surgical operation, laser machining, laser marking, nonlinear frequency conversion, range finding, remote sensing and optical time domain reflectometer**.** In this paper, an acousto-optic Q-switched Yb^{3+}-doped all-fiber laser at 1083 nm is reported**.** The pulse energy of 2.94 mJ has been obtained at the pump power of 8.47 W, and the pulse width is 3 μs**.**

(Received August 5, 2010; accepted September 15, 2010)

Keywords: Acousto-optic Q-switched, All-fiber laser, Yb^{3+}-doped, Pulse width, Pulse energy

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1. Introduction

The Q-switched fiber lasers have many merits, which include high peak power, high pulse energy, high conversion efficiency, excellent beam quality, simple cavity construction, small volume, low cost and fiber-coupled output etc [1, 2]. They are very attractive sources because of their wide applications such as military affairs, surgical operation, laser machining, laser marking, nonlinear frequency conversion, range finding, remote sensing and optical time domain reflectometer [1, 2]. Reviewing the development of the Q-switched fiber laser, we may find that these studies focused very often on the use of the bulk Q-switches [2-6]. However, the experimental equipment seems rather complicated, and it tends toward misadjustment due to the low coupled efficiency between the bulk Q-switches and the gain fiber, and its need of such separate components as lenses and so on. The best way to solve these problems is to develop Q-switched all-fiber lasers. Presently, the researches of the Q-switched fiber focus on the passively Q-switched all fiber lasers based on SBS or SRS effect [7] and the actively Q-switched all fiber lasers guided by dual beam interference principles [8]. Nevertheless, the passively Q-switched fiber lasers based on SBS or SRS effect are imperfect for their unstable and unadjustable repetition rate, and the Q-switched devices guided by dual beam interference principles are considered as slow Q-switches. Besides, there are some other sporadic reports on Q-switching that adopts pigtailed acoustooptic modulator [9], Q-switching that alters the coupling efficiency between the FBG and the medium fiber [10], and Q-switching that employs magnetostriction modulation of a Fiber Bragg Grating [11], but these Q-switches are not technically mature and they are not so effective as expected. In our opinion, the fibered Q-switches of high performance should be endowed with the following qualities, such as stable and adjustable repetition rate, short switching time, and high modulation efficiency. Thus, developing the fibered Q-switches should trend towards active, effective and fast-time fibered Q-switches. The best way to develop such a kind of Q-switches is to combine traditional acousto-optic or electro-optic Q-switches with modern optical fiber technology. In this paper, we will present the good performances obtained with an Yb^{3+}-doped all-fiber laser, which is realized by using a pigtailed acousto-optic modulator (PAOM). The configuration of this source makes it very suitable for use in field systems. This research work in this paper is the continuity of our earlier works [12-15].

2. Experimental setup

The experimental setup is shown in Fig. 1. One of the diode-lasers with output-coupled fiber is F25-975-2 module of Apollo Inc. of USA, and its parameters are as follows, fiber core diameter 200 μm, NA 0.22, maximum power 25 W, central wavelength 975 nm. The other one has the same parameters except that its maximum power is 5 W. So in this experiment both of the two ports are used among the six pump input ports of the multimode combiner. In order to avoid shifting of the pump light wavelength, the temperature of the two diode-lasers is controlled by a water and wind cooling system, whose controlling precision is ±0.1℃. During the experiment, the pump input port of the multimode combiner and the pigtailed fiber of the diode-laser are fused directly in order to realize the all-fiber scheme. The FBG has a high reflectivity (>98%) at the 1083 nm, and its loss coefficient is less than 0.0015 dB/m. The Q-switch operation is achieved by using a pigtailed acousto-optic modulator, whose repetition rate can be tuned between 10Hz-100 kHz and its insertion loss is 2 dB. The gain medium is an 11 m long Yb^{3+}-doped double-clad fiber, which has an absorption coefficient of 1.2 dB/m. The fiber features 30 μm core size with low NA (0.07) core, 350/400 μm D-shaped inner cladding, and Large-Mode-Area (LMA) characteristic, which is suitable for use in single-mode application. The output port of the all-fiber laser has the Fresnel reflectivity (0.04), and it is regarded as one of the reflector of the resonant cavity.

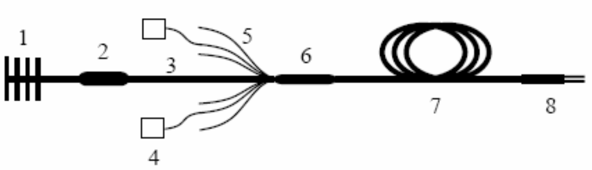

Fig. 1. Setup of the acousto-optic Q-switched Yb^{3+}-doped all-fiber laser. (1) FBG, (2) PAOM, (3) Signal port of multimode combiner, (4) LD, (5) Pump input ports of multimode combiner, (6) Multimode combiner, (7) Yb^{3+}-doped double-clad fiber, (8) Output port of acousto-optic Q-switched all-fiber laser.

3. Results and analyses

(1) Fig. 2 shows the pulse train of the acousto-optic Q-switched Yb^{3+}-doped all-fiber laser when the repetition rate is 500 Hz. Apparently, the pulse train is well inerratic and steady. The oscillograph which receives the input signal from the photoelectric detector shows that the pulse width is 3 μs. The pulse energy is 2.94 mJ when the pump power is 8.47 W, with the peak power 980 W. And then the repetition rate can be adjusted continuously between 10 Hz-100 kHz.

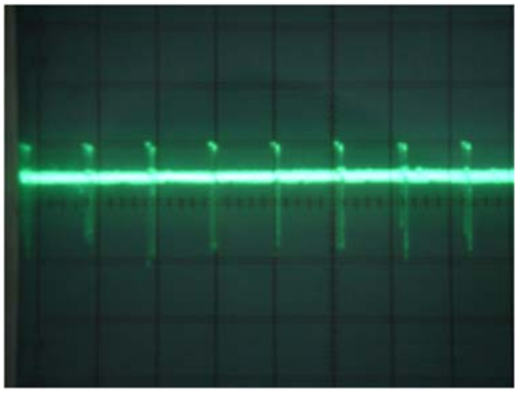

Fig. 2. Pulse train of the acousto-optic Q-switched Yb^{3+}-doped all-fiber laser.

(2) Fig. 3 shows the output spectra of the acousto-optic Q-switched Yb^{3+}-doped all-fiber laser. The central wavelength of the output light is 1083 nm, and the linewidth is about 2 nm. In addition, the light near 975 nm is the pump light remaining. When the repetition rate is adjusted, or the pump power is decreased, the wavelength does not change.

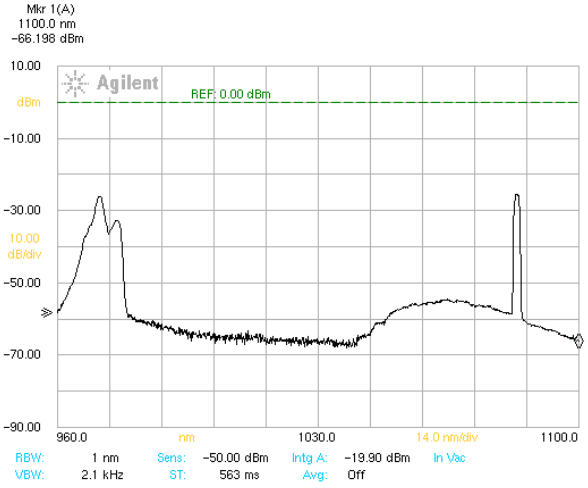

Fig. 3. Output spectra of the acousto-optic Q-switched Yb^{3+}-doped all-fiber laser.

(3) Presently, we have not a cooling system that can match the multimode combiner, so the potential damage will happen if we continue to increase the pump power. After finding a nicer scheme of cooling the multimode combiner, we will increase the pump power so as to increase the pulse energy and the peak power; thereby both of them could be higher.

(4) During the experiment, we do not use any separate components such as dichroic mirrors or coupling lenses. Apparently, we have realized the all-fiberization of the integral structure of the acousto-optic Q-switched fiber laser. We expect that the experimental study in this paper may be helpful to the design of the other actively Q-switched all-fiber lasers.

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