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A passively Q-switched Yb^{3+}-doped all-fiber laser based on SBS effect

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The SBS effect of the single-mode fiber is an appealing method to narrow pulse width of the Q-switched fiber laser. In this paper, by using the SBS effect, the operation of a passively Q-switched Yb^{3+}-doped all-fiber laser is realized. The pulse width 17ns is obtained at the repetition rate 30MHz. Furthermore, the output wavelength is 1083nm, with the pulse energy 0.014μJ and the peak power 0.7W achieved.

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

1. Introduction

The Q-switched fiber lasers 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, the various actively Q-switched all-fiber lasers are reported, whose pulse width is from several microseconds to dozens of microseconds, and whose repetition rate is from several hertz to several megahertz. As to these actively Q-switched fiber lasers, it has been proved from both the theories and the experiments that the pulse width is somewhat proportional to the cavity length. So, reducing the fiber length is a good method to narrow pulse width; but it may decrease the cavity energy, with the pulse energy and the peak power both decreased. If increasing the doped concentration of the gain medium, which is a remedy for the above problems, the concentration quenching may happen because of the excited state absorption. Furthermore, it is not allowed to dope the high concentration of the active particles in the fiber. In 1964, R. Y. Chiao and his colleagues firstly observed the effect of Stimulated Brillouin Scattering (SBS) [3]. After that, many scientists are engaged in the researches of SBS [4-9]. Meanwhile, the SBS in fiber is explored profoundly [10-19]. In addition, by using the SBS in fiber, some researchers have reported the results of the Q-switched nanosecond pulse [20-26]. So far the SBS Q-switched mechanism has been a simple and feasible means to narrow down the pulse width. In this paper, we present a good performances obtained with an Yb^{3+}-doped all-fiber laser, which is realized by using the SBS effect in a single-mode fiber. The configuration of this source makes it very suitable in some kindred systems. This research in this paper is the continuity of our earlier works [27-31].

2. Experimental scheme

The experimental scheme is shown in Fig. 1. Among the six pump ports of the fiber combiner, only one port is used in this experiment. The diode-laser with output-coupled fiber is made in China, and its parameters are as follows, fiber core diameter 200μm, NA 0.22, maximum power 4.5W, central wavelength 975nm. In order to avoid shifting of the pump light wavelength, the temperature of the diode-lasers is controlled by a TEC system cooled by electricity, whose controlling precision is ±0.1℃. During the experiment, the pump input port of the fiber 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 1083nm, and its loss coefficient is less than 0.0015dB/m. The Q-switch operation is achieved by using the SBS effect in a single-mode fiber. The sing-mode fiber, 6m long, has a core whose diameter is 10μm. Because of the difference between the single-mode fiber core and the signal port core of the combiner, the fusing loss here is larger than the loss at the other fusing points. The gain medium is an 11m long Yb^{3+}-doped double-clad fiber, which has an absorption coefficient of 1.2dB/m. With its parameters being 30μm core size with low NA (0.07), 350/400μm D-shaped inner cladding, and Large-Mode-Area (LMA) characteristic, the fiber is suitable 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.

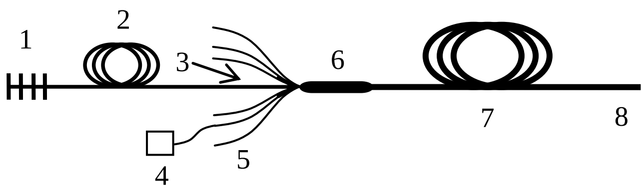

Fig. 1. Schematic structure of the passively Q-switched Yb^{3+}-doped all-fiber laser: (1) FBG, (2) Single-mode fiber, (3) Signal port of fiber combiner, (4) LD, (5) Pump ports of fiber combiner, (6) Fiber combiner, (7) Yb^{3+}-doped double-clad fiber, (8) Output port

3. Results and analyses

(1) Fig. 2 shows the pulse train of the passively Q-switched Yb^{3+}-doped all-fiber laser based on the SBS effect when the pump power is 2.18W. From Fig. 2, the pulse width is 17ns with the repetition rate 30MHz, and the interval between two pulses is about 33ns.

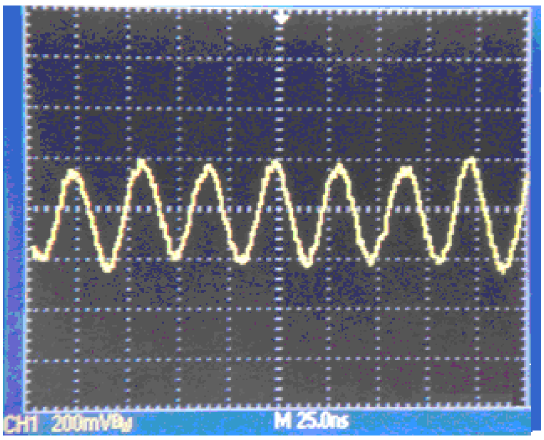

Fig. 2. Pulse train of the passively Q-switched Yb^{3+}-doped all-fiber laser based on SBS

(2) Fig. 3 shows the output spectra of the passively Q-switched Yb^{3+}-doped all-fiber laser. The central wavelength of the output light is 1083nm, and the linewidth is about 2nm. In addition, the light near 975nm is the pump light remained.

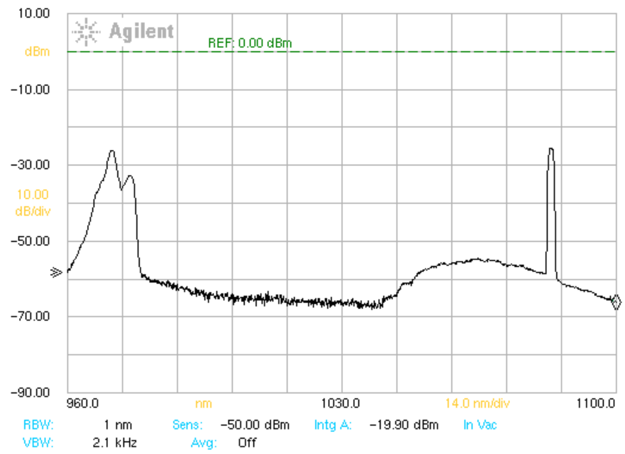

Fig. 3. Output spectra of the passively Q-switched Yb^{3+}-doped all-fiber laser based on SBS

(3) We measure the output power by the power meter, and find that the average power is 0.41W. Using the above results, we know by calculation that the pulse energy is 0.014μJ, and the peak power is 0.7W. If we increase the pump power appreciably, the pulse width didn't change, but the pulse train will have a little undulation. So in this experiment, the appropriate pump power is necessary.

(4) During the experiment, we also find that the pulse amplitude and the repetition rate are dependent on the length of the single-mode fiber. If the single-mode fiber is reduced to 1m, and the other conditions are not changed, the results will be that the regularity of the pulse train is very bad and the pulse amplitude is not stable.

(5) We compare the obtained pulse width with the numerical simulation result discussed in my Doctoral Dissertation [32] and find that they are basically consistent. Also we have measured the laser's operation characteristics for about 30 minutes, finding that both the stability of the pulse width and the repeatability of the frequency are well.

(6) We think that the results we obtained can satisfy a good many requirements. And similar reports about the passively Q-switched laser based on SBS effect inside single-mode fiber are rarely seen. We expect that the experimental study in this paper may be helpful to the design of the other passively Q-switched fiber lasers.

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