JOURNAL OF OPTOELECTRONICS AND ADVANCED MATERIALS Vol. 9, No. 8, August 2007, p. 2354 - 2355

Experimental study of ytterbium-doped double-clad all-fiber laser at 1083 nm

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The double-clad fiber lasers are very attractive sources in many applications such as military affairs, biomedicine, industry, nonlinear frequency conversion, remote sensing and space communication. In this paper, an ytterbium-doped double-clad all-fiber laser at 1083 nm is reported. The output power of 3.426 W has been obtained at the pump power of 12.007 W. The optical to optical conversion efficiency is about 28.5%.

(Received December 20, 2006; accepted June 27, 2007)

Keywords: All-fiber laser, Ytterbium-doped, Double-clad, 1083 nm

1. Introduction

The double-clad fiber lasers (DCFL) have many merits, which include high conversion efficiency, excellent beam quality, simple cavity construction, small volume, low cost and fiber-coupled output etc. They are very attractive sources because of their wide applications such as military affairs, biomedicine, industry, nonlinear frequency conversion, remote sensing and space communication [1-6]. In the recent years, the ytterbium-doped double-clad fiber lasers are preferred thanks to their nice character [1-6]. Particularly, the development of fiber lasers experienced very important advances since Fiber Bragg Grating (FBG) came out. The FBG, a substitute for reflecting mirror or reflecting film of resonant cavity, has become a hot issue. FBG is a low-loss wave-selecting device, the application of which simplifies the structure of fiber lasers, increases the signal noise ratio, narrows the line width and improves the light beam quality. With FBG, the medium fiber and the diode-laser's pigtailed fiber can easily be fused directly. If the size of the two fibers mentioned above is not the same, the fusion can also be successful through a taper fiber. This fusion will avoid the large-loss caused by the dichroic mirror and lens, decrease the pump threshold, and at the same time facilitate the practicability and commercialization of the fiber laser. In this paper, by using a FBG and a multimode combiner, we have designed an ytterbium-doped double-clad all-fiber laser pumped by a diode-laser, whose output power reaches 3.426 W at the pump power of 12.007 W. The research work in this paper is the continuity of our earlier works [7].

2. Experimental setup

The experimental setup is shown in Fig. 1. The diode-laser (LD) 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. In order to avoid shifting of the pump light wavelength, the temperature of the diode-laser is controlled by a water and wind cooling system, whose controlling precision is ±0.1℃. The multimode combiner has six pump input ports, among which only one port are used. During experiment, the pump input port of the multimode combiner and the pigtailed fiber of the diode-laser are fuse 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 gain medium is an 11 m long Yb^{3+}-doped double-clad fiber, which has an absorption coefficient of 1.2dB/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.

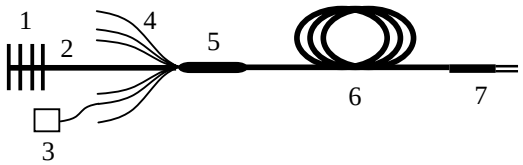

Fig. 1. Setup of ytterbium-doped double-clad all-fiber laser. (1) FBG, (2) Signal port of multimode combiner, (3) LD, (4) Pump input ports of multimode combiner, (5) Multimode combiner, (6) Yb^{3+}-doped double-clad fiber, (7) Output port of double-clad all-fiber laser.

3. Results and analyses

(1) Fig. 2 shows the output power as a function of the pump power. When the pump power is 12.007 W, the output power is 3.426 W. Accordingly, the optical to optical conversion efficiency achieves about 28.5%. And the pumping threshold is about 110 mW, which is consistent with the theoretical calculation [8-9]. At the same time, we have confirmed that the output laser mode is a single transverse mode.

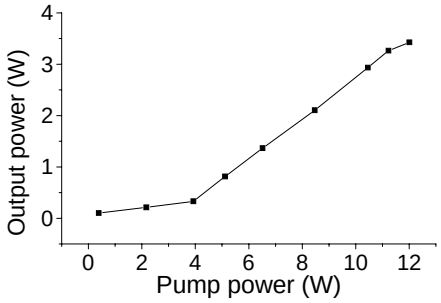

Fig. 2. Output power as a function of pump power.

(2) Fig. 3 shows the output spectra of the ytterbium-doped double-clad all-fiber laser. The central wavelength of the output light is 1083 nm, and the linewidth is about 2nm. In addition, the light near 975 nm is the pump light remaining.

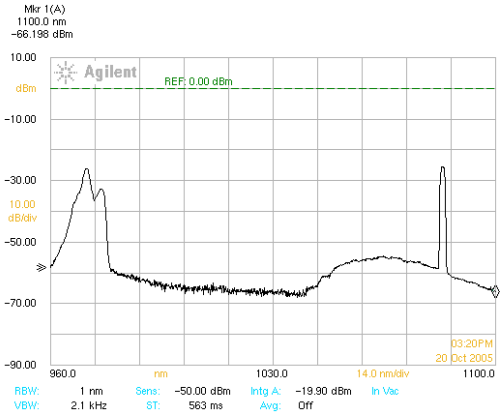

Fig. 3. Output spectra of ytterbium-doped double-clad all-fiber laser.

(3) We have measured the operating stability of the 1083 nm ytterbium-doped all-fiber laser for about 30 minutes, finding that the instability of output power is less than 1%.

(4) The output power of 3.426 W is not the saturated maximum, so the output power may increase in case of increasing the pump power, but the stability and optical to optical conversion efficiency might decrease. Besides, the pump power that per input port of the multimode combiner can endure is limited, so we have not done the experiment in the condition of pumping higher power. We think that the output power of 3.426 W is a nicer level, which can satisfy a good many requirements.

(5) Presently, we have no a cooling system that can match the multimode combiner, so the potential damage exist 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 output power; thereby the output power could be higher.

(6) During the experiment, we have not use any separate components such as dichroic mirrors or coupling lenses. Apparently, we have realized the all-fiberization of the integral structure. We think that the experimental study in this paper may be helpful to the design of the kindred all-fiber laser.

Acknowledgements

This research is supported by the National Foundation (number: 10674101), China.

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