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All-fiber Tm^{3+}-doped Fiber Laser Using Pump Combiner and Fiber Bragg Grating Inscribed by Femtosecond

WANG Wei[1,2], ZHANG Yun-jun[1], LI Dong-ming[2], WANG Yue-zhu[1], GE Hui-liang[2]
(1 *National Key Laboratory of Tunable Laser Technology, Harbin Institute of Technology, Harbin* 150001, *China*)
(2 *State Key Laboratory of Oceanic Acoustics, Hangzhou Applied Acoustics Research Institute, Hangzhou* 310012, *China*)

Abstract: All-fiber Tm^{3+}-doped fiber laser can be used as the pumping for (Optical Parametric Oscillator, OPO), realizing 3 ~ 5 μm laser output. All-fiber Tm^{3+}-doped fiber laser was demonstrated more excellent application prospects in lidar and electro-optical countermeasure. An all-fiber cladding-pumped Tm^{3+}-doped fiber laser using pump combiner and double-cladding fiber is reported. The pump combiner and double-cladding fiber are home-made. Home-made fiber bragg grating(FBG) is used as reflection cavity. The double-cladding fiber is cooling by water. The fiber Bragg grating is directly written in the Tm^{3+}-doped fiber through 45 fs, 800 nm femtosecond and a phase mask. The combiner is used to launch the pump light into the Tm-doped inner-cladding fiber. The wavelength of the laser is about 1.96 μm with a slope efficiency of 37% in respect to the launched pump power, the linewidth is narrow only about 72.4 pm.

Key words: All-fiber Tm-doped laser; Pump combiner; FBG; Femtosecond
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0 Introduction

High power laser radiation at wavelengths near 2 μm has recently shown much promising for a number of applications, including various remote sensing applications and in medical and military technology[1-5]. Cladding-pumped Tm-doped fiber lasers offer many advantages to provide a high power laser at the wavelength nearly 2 μm region over solid state lasers, due to the high output power, good beam quality, compact fabric, wide tunable range, and high conversion efficiency[6-8]. The cladding pumped all-fiber lasers are more compact and stable, and are very suitable to couple with the LD output pump light. The high reflectivity FBG reflectors are the most important component in the all-fiber lasers[9]. Recently, a new method using femtosencond for FBG inscription has been researched[10-12]. The ultrafast IR laser inscription of FBG reflectors in active fibers has some important advantages over the more traditional UV laser inscription technique that mostly rely on Ge-induced photosensitivity of the silica fibers. The ultrafast gratings are extremely stable at high temperature and may be useful for very high intensity laser applications[13]. In the cases of ultrafast gratings, the FBG inscription associated loss is very small. The ability of the femtosecond method the write gratings in silica glass irrespective of the doping could also be used to write FBG in the cladding of the active fiber used for cladding pumped laser in order to recycle the pump power. Grobnic et al.[14] have reported the all-fiber laser using a 980/1 550 coupler and a pair of FBGs. The FBGs are made by 125 fs, 800 nm pulses with a 30 mm focal length cylindrical lens through a third order phase mask.

In this letter, a Tm-doped all-fiber laser using a pump combiner and FBG is reported. The FBG is inscribed into the non-photosensitive fiber using 45 fs, 800 nm femtosecond and a phase mask . The maximum output power of nearly 22.2 W is realized at 1.96 μm with the spectrum linewidth of 72.4 pm.

1 Experiment and results

The all-fiber laser experimental setup is

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First author: WANG Wei(1986—), male, M. S. degree candidate, assistant engineer, mainly focuses on fiber Bragg grating and fiber laser. Email: gggmtvww@163.com
Corresponding author: WANG Yue-zhu(1942—), female, professor, mainly focuses on infrared solid laser technology and nonlinear optics technology. Email: juyl@hope.hit.edu.cn
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shown in Fig. 1. The Tm-doped double-clad fiber core has a diameter of 25 μm (NA=0.13) and the inner-clad diameter is 250 μm (NA=0.46), the fiber is put into the water box to cool. The pump source is a 793 nm LD with a 200 μm output pigtail fiber(made by Dilas in Germany).

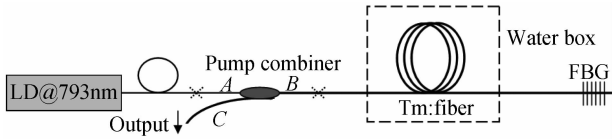

Fig. 1 All-fiber laser experimental setup using pump combiner

In the all-fiber laser scheme, the FBG with 76% reflectivity is inscribed in Tm-doped multimode double-clad silica fiber by femtosecond laser and a phase mask. The fiber is exposed to femtosecond 45 fs, 800 nm pulsed radiation from a regeneratively amplified Ti: Sapphire laser at a repetition rates up to 1 KHz. A 25 mm focal length cylindrical lens is used to focus the pulse through a zero-order-nulled phase mask onto the fiber. The pump combiner made by CETC-23 has three ports and coupling efficiency about 90%. The fiber laser is made up by splicing the pigtail fiber and port A of the pump combiner, matched port B and the Tm-doped fiber. The mirrors of the laser resonator are constituted of the written FBG and the 4% Fresnel reflection of the perpendicularly cleaved end facet on the side of the port C. The laser output is from port C.

The output power characteristics are shown in Fig. 2. The maximum output power is 22.2 W, with slope efficiency of 37% in respect to the launched pump power. It is lower than 40.4%[9], because the reflectivity of the FBG is lower than that of the dichroic mirror.

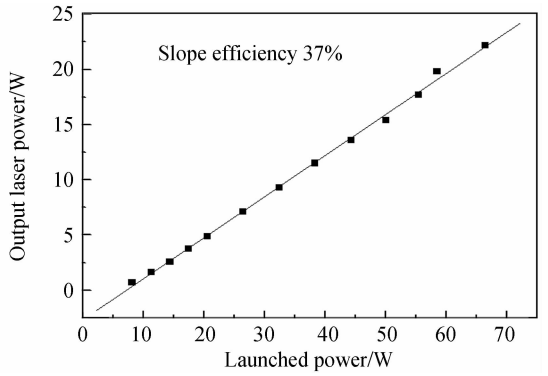

Fig. 2 Evolution of the laser output laser power as a function of the launched pump power

The output laser spectrum is measured by the wavemeter (WA1500, made in Canada by EXFO). Fig. 3 shows the output wavelength of the Tm-doped all-fiber laser when the output power is nearly 0.7 W. The output center wavelength is located at 1 958.8 nm with narrow linewidth of 72.4 pm.

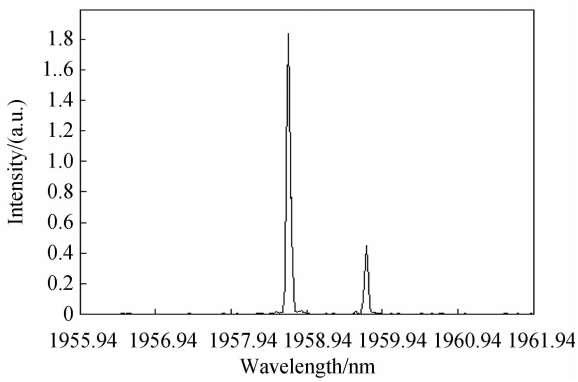

Fig. 3 Laser spectrum at the output power of nearly 0.7 W, the center wavelength is 1 958.8 nm

2 Conclusion

In summary, a cw 22.2 W all-fiber laser output at approximately 1.96 μm is realized using a pump combiner and FBG inscribed by 800 nm femtosecond, the linewidth is narrow only about 72.4 pm. The maximum output power is only limited by the available pump source. The laser scheme has a slope efficiency of 37%. Since no special requirements concerning photosensitivity are necessary, the femtosecond processing approach allows one to write FBGs into various fibers. This opens the possibility for highly integrated fiber laser systems

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运用泵浦耦合器和飞秒刻蚀光栅制作的全光纤化掺铥光纤激光器

王巍[1,2], 张云军[1], 李东明[2], 王月珠[1], 葛辉良[2]

(1 哈尔滨工业大学 可调谐气体激光技术国家级重点实验室, 哈尔滨 150001)

(2 杭州应用声学所 声纳技术国防科技重点实验室, 杭州 310012)

摘 要: 全光纤化掺铥光纤激光器作为光学参量振荡器的泵浦源, 可以实现 3～5 μm 激光输出, 在激光雷达和光电对抗领域有着极为重要的应用前景. 本文运用全国产化的泵浦光耦合器和双包层掺铥光纤实现了全光纤化掺铥光纤激光器. 该光纤激光器采用自制的光纤布喇格光栅作为反射腔镜, 增益光纤采用水冷的方式. 光纤布喇格光栅通过 45 fs、800 nm 的飞秒脉冲光和相位掩模板直接在双包层掺铥光纤上刻蚀得到, 泵浦光通过泵浦光耦合器的一端耦合进入增益光纤, 产生的激光由泵浦光耦合器的另一端输出. 输出激光的最高功率达到 22.2 W, 激光波长为 1.96 μm, 斜率效率约为 37%, 激光线宽为 72.4 pm.

关键词: 全光纤化掺铥光纤激光器; 泵浦耦合器; 光纤布喇格光栅; 飞秒激光