Study on characteristics of Er/Yb co-doped double cladding fiber laser

Zhou Qu*[a], Qiushi Li[b], Mingliang Yan[a]
[a] Control Department, Armor Technique Institute of PLA, [b] Oral Implant Center, Jilin University School of Stomatology,Jilin Province,PRC.130117

ABSTRACT

An Er/Yb co-doped double cladding fiber laser pumped at 980 nm was optimized. The double-cladding fiber laser with whole fiber was obtained by end-pumping and utilizing fiber bragg grating as a resonator. The output power of laser was analyzed along the changes of output grating reflectance (L=10m) as well as the fiber length (R_2=4%). Consequently, a fiber with 4 m Er / Yb co-doped double cladding was employed as gain medium while a fiber of which the reflectance was approximately 15% was used as output resonator mirror. Thereafter the technical indexes of EYDF(Er / Yb Double cladding Fiber) were measured. The absorption maximum of fiber core Er^{3+} was higher than 30dB/m and material gain maximum was observed at 1535nm. Moreover, the diameters of fiber core and inner cladding of double-cladding fiber grating were 6μm and 125μm respectively however the diameters of fiber core and inner cladding of Er/Yb co-doped double cladding fiber were 7μm and 130μm separately.According to the experimental data, a fiber laser with 4 m Er / Yb co-doped double cladding and launched maximum pump power of 3.4 W was set up. Proposed laser shows the maximum output power of 1.25 W and slope efficiency of 40%.

Keywords: fiber laser; Er/Yb co-doped, double cladding fiber; fiber bragg grating, characteristic study

1. INTRODUCTION

In recent years, fiber lasers have become one of hot spots in laser field. Double cladding fiber laser based on cladding pump technology is attached much importance for its advantages such as good radiating performance, high transfer efficiency, low pump threshold, high output power and good beam quality. It has great application value in laser communication, material processing, aerospace, print and medical field.

To uprate power, the study on erbium-doped optical fiber amplifier has increased since 1990s'. However, excessive concentration of Er can result in two problems: one is it can induce concentration quenching and low amplification efficiency; the other is it can lead to crystallization. Concentration quenching means any two adjacent Er ions which is in $^4I_{13/2}$ excitation state can react to each other when the distance between the two Er is relatively far and such event can trigger energy conversion and ion-exchange. One of Er ions transferred its energy to the other ion and return the basic state $^4I_{15/2}$ itself. Meanwhile, the ion acquiring energy transit to the higher level $^4I_{9/2}$ and the ion in $^4I_{9/2}$ returned to $^4I_{13/2}$ by phonon emission. After this, excited ion transferred its energy to heat energy which can reduce quantum conversion efficiency (QCE)[3]. Obviously there is a best doping ratio to get the best amplification. The current doping weight ratio in pure silicon host is generally hundreds of ppm, therefore there are some limitations when increasing amplification gain by higher ion concentration. Although aluminum can depress concentration quenching and increase doping weight ratio to 1000ppm, it's still not enough. Recently, there is a report holds that changing matrix of fiber core glass may increase the solubility of Er[4].

It is an effective way to adulterate erbium-doped fiber with iron. The way can increase the pumping rate and pumping efficiency. Report shows that the use of ytterbium-doped fiber can effectively control the pulse effect caused by erbium irons in the erbium-doped fiber, improve the pumping efficiency, and provide a stable laser operation. Sanchez[7] believe that the rbium iron can arise pulse operation by saturable absorption when its concentration in erbium-doped fiber reaches a certain value. Satisfied results is obtained by experimental and theoretical verification. Although this does not indicate the existence irons in erbium-doped fiber laser is the only physical cause for the pulse, it does play an important role.
This paper proposes a method that a resonator based on fiber grating in an end-pumped way, achieving the all-fiber structure double-layer laser. In the laser, 4m Er / Yb co-doped double-layer fiber is selected for the gain medium and

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emissivity of 15% fiber as the output resonator mirrors. Experimental results show that the output spectrum of the laser is 0.19nm, wider than that of fiber grating which is small than 0.2nm. The maximum input power to the fiber pumping is 3.4W while the maximum output power is 1.25W, showing that laser's slope efficiency is 40%.

2.The study on Er/Yb co-doped fiber characteristics

2.1 Power distribution characteristic

In the forward pumped fiber laser which is shown in Fig.1, laser grows at the rate of exponential at the beginning of forward transmission in the fiber, tends to saturation when it reaches a certain length. It is converse in backward pumped laser. In the backward laser, the laser decreases exponential at the beginning, trends to stead state when it reaches certain length. For a given pump power and fiber laser, lower emissivity output resonant mirrors should be adopted to avoid excessive power in the fiber and over pump power. This should be considered when designing fiber laser, especially for the high power laser.

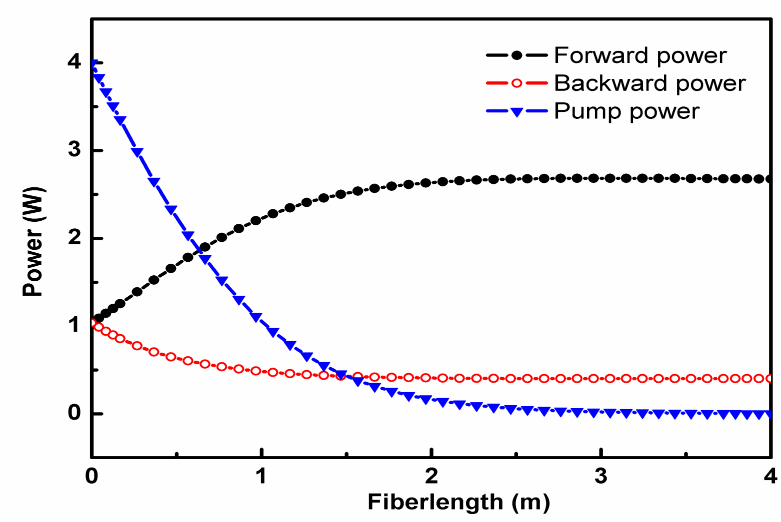

Fig.1. The power of laser along the fiber axial distribution (P=4W , $R_2 = 15\%$)

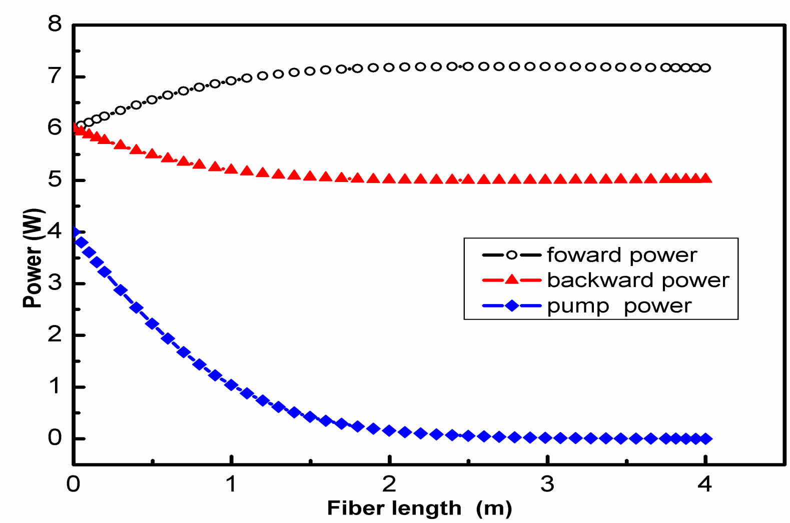

Fig.2. The power of laser along the fiber axial distribution (P=4W , $R_2 = 70\%$)

2.2 Gain characteristic

Fiber laser gain coefficient is expressed by $g = \sigma_{eEr}(\lambda_s)N_2 - \sigma_{aEr}(\lambda_s)N_1$ .Derived from the higher-level particles in the computation which is shown in Fig.3, the fiber laser gain coefficient is very high closing to the near pump end, drops dramatically with the fiber length incensement, becomes state when it reaches certain value and meanwhile the fiber laser gain coefficient is 0. Because of the high gain and uneven distribution, double pump or distributed pump should be the first consideration if the technique support when we design the fiber laser structure. Besides, computation shows that the number of Yb iron is larger on order scale than that of Er iron in the Er/Yb co-doped fiber upper levels. It indicates Yb iron storages a lot of energy and the Er/Yb fiber owns strong gain in the 1μm band.

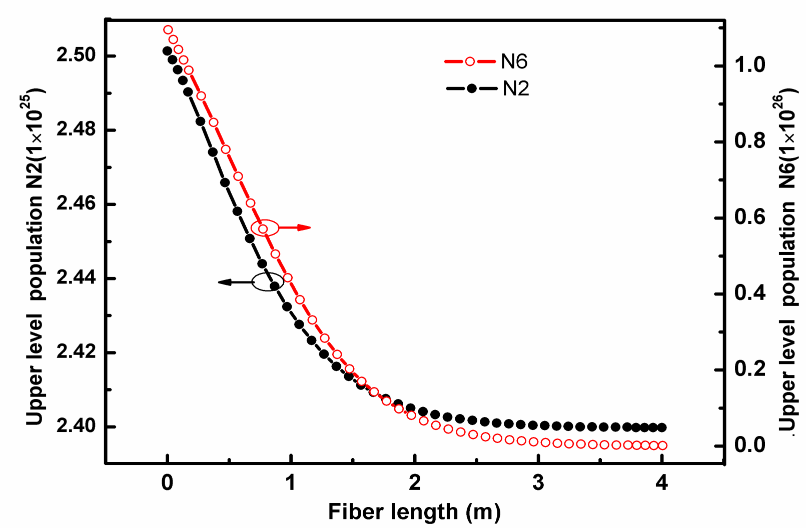

Fig.3. The upper energy level population along the the fiber axial distribution(P_p =4W , R_2 = 15%)

2.3 output characteristic

Pump power and fiber length reach a certain value, the laser output power decreases with the output mirror's emissivity increase, as shown in Fig. 4. The trend becomes more significant when the pump power is higher. The output power reduce faster when output mirror's emissivity is higher.

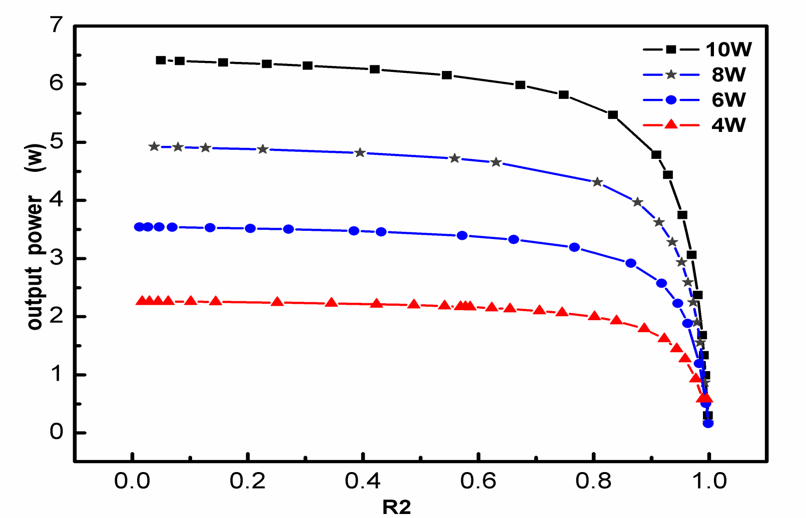

Fig.4. The output power of laser along the changes of output grating reflectance (L=10m)

In the high emissivity region, laser's output power drops in exponential rate. For a given pump power, the output power varies obviously with the length when the gain fiber is of small length, then it trends saturation when the length reaches a certain value, and it reduces at last due to the fiber dissipation. This indicates a optimum length would make the laser output power maximal.

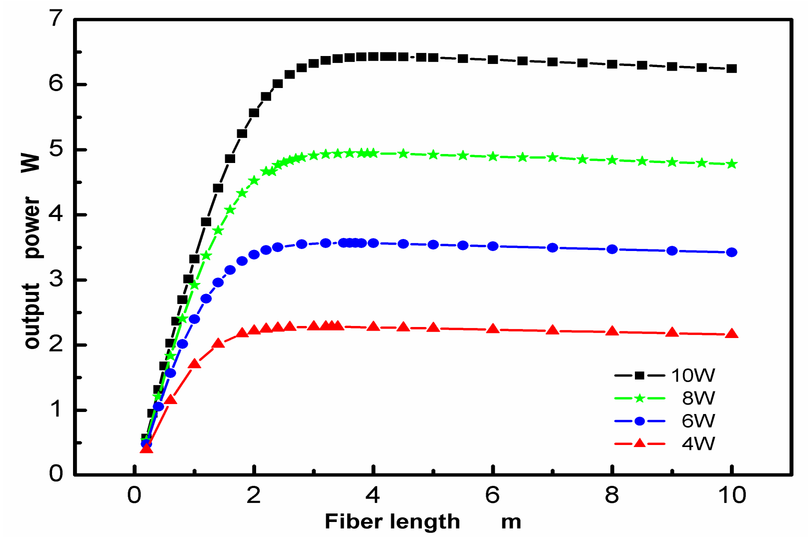

Fig.5. The output power of laser along the changes of the fiber length (R_2=4%)

3. Experiment devices

An all-fiber structure double-layer laser is developed by a resonator based on fiber grating in an end-pumped way. The devices are shown in Fig. 6.

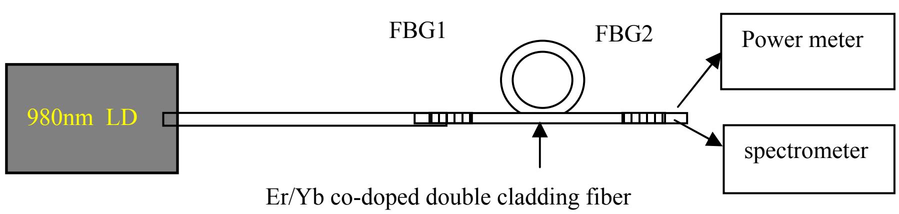

Fig.6. Er/Yb co-doped double cladding fiber laser experiment devices

According to the previous mention, the 4m Er/Yb co-doped fiber is selected as the laser's gain medium and the fiber of 15% emissivity as the output resonant mirror. According to the EYDF specifications which are shown. fiber core owns the large than 30Db/m maximum absorb ability and maximum material gain at 1535nm. Er/Yb co-doped fiber's absorption and gain curves are shown in Fg.7. The pump source is 980nmLD. Fiber gratings' (FBG1 and FBG2) emissivityies are 99.9% and 15% respectively when the maximum power is 4W. Fiber grating reflect bandwidth is smaller than 0.2nm and central wave warp is less than 0.2nm. The fiber core and inner layer diameters are 6 μ m and 125 μ m respectively in the double-layer fiber grating while that are 7 μ m and 130 μ m in the Er/Yb co-doped double cladding fiber core.

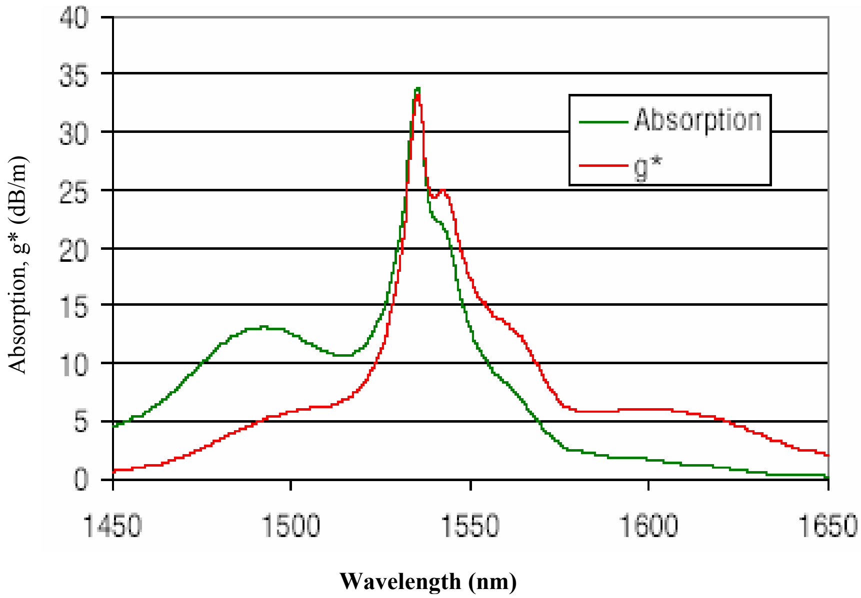

Fig.7. Er/Yb co-doped double cladding fiber absorption and gain

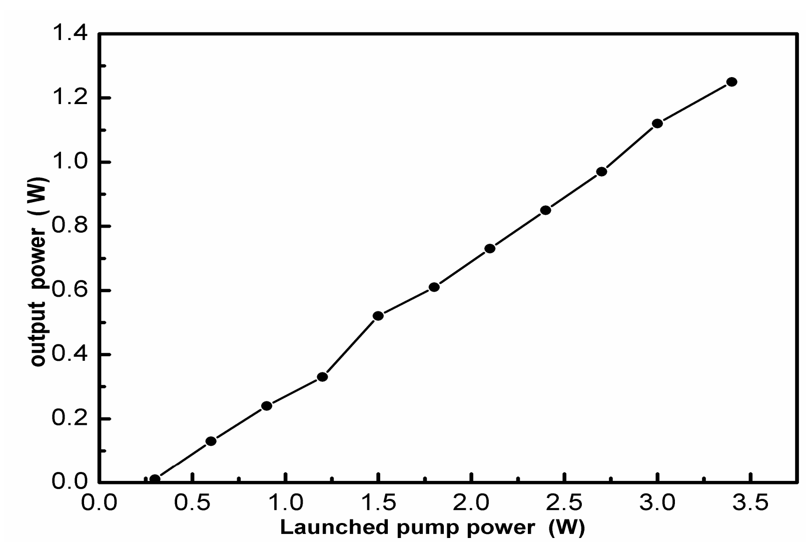

Fig.8. The output power of laser along the changes of launched pump power

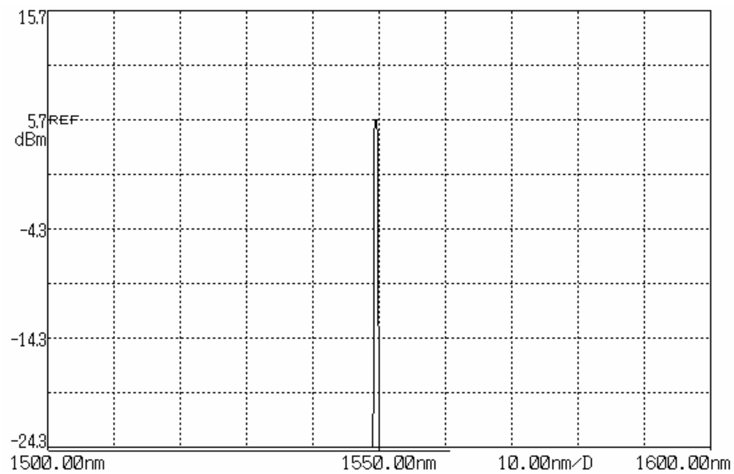

Fig.9. The changes of fiber laser spectral width along the wavelength

4. Conclusion

The output power of laser was analyzed along the changes of output grating reflectance (L=10m) as well as the fiber length (R_2=4%). The power of laser was assayed along the fiber axial distribution(P=4W , R_2 = 15%, R_2' = 70%). The upper energy level population was analyzed along the the fiber axial distribution(P_p =4W , R_2 = 15%). Laser output spectrum is 0.49nm, shown in Fig.9, wider than the fiber grating spectrum width. This is caused by central wave warp in the fiber grating. Maximum input power is measured as 3.4W while maximum output power is 1.25W, showing the slop efficiency of 40%.

REFERENCES

[1] R.J.Mears, L.Reekie, I.M.Jauncie et al , "Low-noise erbium-doped fiber amplifier operating at 1.54μm," Elect. Lett., 23(19),1026-1028 (1987).

[2] E.Desurvire, J.R.Simpson and P.C.Becker, "High-gain erbium-doped traveling-wave fiber amplifier," Opt. Lett., 12(11),888-890(1987).

[3] S. Sudo Editor, "Optical fiber amplifiers: Materials, Devices and Applications," First edition, Artech House, Inc, Boston, 174(1997).

[4] K. Arai, H. Namikawa, K. Kumata et al, "Aluminum or phosphorus co-doping effects on the fluorescence and structural properties of neodymium-doped silica glass," J.Appl. Phys., 59(10),3430-3436(1986).

[5] Kringleboin J T, Archambault J L, Reckie L et al, "Highly efficient, low noise grating feedback Er:Yb codoped fiber laser," Electron. Lett., 30(12),972-973(1994).

[6] Sinivasagam V, Abdullah M K, Ahmad H., "EYDFL giving higher efficiency and smaller power fluctuation as compared to EDFL," IEEE. ICSE'98, Proc., Malaysia Bangi, 11,117-120(1998).

[7] Ding Ming, Peter K, "Effects of Yb:Er-codoping on suppressing self-pulsing in Er-doped fiber lasers," IEEE Photon. Technol. Lett.,9(3),324-326(1997).

[8] Shooshtari A, Meshkinfam P, Touam T et al, "Ion-exchanged Er/Yb phosphate glass waveguide amplifiers and lasers," Opt Engng, 37(4),1188-1192(1998).

[9] JIA X J,GUO ZH CH, "Experimental investigation on co-doped double-clad high-power fiber laser in L-band,"

Opt.precision Eng., 14(3),341-345(2006).

[10] ZHAO C G,NING Y Q, "Numerical analysis of Yb/Er co-doped double cladding fiber amplifier,".Opt.precision Eng., 16(8),1349-1353(2008).