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Effects of the EDF length and Oscillation Reflectivity on the Output Power of a 1.55 μm Ring Fiber Laser System

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ABSTRACT

The effects of varying the Erbium doped fiber (EDF) length and the loop-back reflectivity of an all fiber ring laser system are presented. Two characteristics of the output power, namely the lasing threshold and the maximum power are analyzed. The reflectivity is taken as the percentage of the lasing signal that is fed (or reflected) back into the loop. The maximum output power refers to the power obtained at maximum pump power available, 115 mW. This therefore does not represent the actual maximum output power obtainable with the EDFL system which should be higher. For a particular system, there is an optimum length of EDF that gives the lowest lasing threshold. Smaller reflectivity is found to give a higher maximum output power but at the expense of a higher lasing threshold.

ABSTRAK

Kesan kepelbagaian panjang gentian optik berdop Erbium (EDF) dan kadar pantulan terhadap sistem laser gelung balik dibentangkan di sini. Analisis terhadap dua ciri kuasa keluaran laser iaitu nilai ambang laser dan kuasa keluaran maksima dilakukan. Kadar pantulan adalah merujuk kepada nilai peratusan kuasa isyarat yang dialurkan semula ke dalam gelung laser. Kuasa maksima pula adalah merujuk kepada kuasa keluaran laser pada nilai kuasa pam maksima yang ada, iaitu 115 mW. Dengan demikian, nilai maksima ini tidaklah menunjukkan nilai maksima sebenar yang mampu dihasilkan oleh sistem laser ini yang sepatutnya adalah lebih tinggi. Bagi satu sistem laser tertentu, terdapat panjang EDF optima yang memberi nilai ambang laser yang paling kecil. Nilai pantulan yang kecil didapati memberi kuasa keluaran yang besar tetapi menyebabkan nilai ambang menjadi lebih tinggi.

INTRODUCTION

Fiber lasers especially of the ring cavity configurations have attracted many research works lately (Cochlain et al 1992; Scrivener et. al., 1989; Reekie et. al., 1987). This is mainly due to the quest for alternative light sources to semiconductor laser diodes. So far, many quarters believe that fiber lasers have the potential to compete with laser diodes especially at 1 550 nm wavelength for which the latter are quite expensive. 1 550 nm wavelength is the most popular transmission channel for long haul fiber optic systems because of its low attenuation in silica fibers. To obtain this particular wavelength, Erbium doped fiber is employed as the active material in the fiber laser system. The fact that fiber lasers can give a very high output power with very narrow linewidth is also another factor that makes them attractive. This paper will show that the maximum output power of a fiber laser can be obtained quite easily by using an appropriate length of the active medium with a suitable reflectivity. A more detailed comparison between fiber lasers and semiconductor laser diodes can be found in Jungbluth (1994) and Mohamad K. Abdullah et al. (1996).

EXPERIMENT

In this experiment, a ring EDFL system was developed using components as shown in Figure 1. A laser diode at 980 nm was used as the pumping source through the 90% leg of a 10/90 fused fiber coupler. The other 10% of the pump was used for monitoring purposes. The pump power was launched into the active medium, a length of EDF through a 980 nm/1550 nm broadband wavelength division multiplexer (BWDM). The ring cavity of the system consisted of (in clockwise direction) the EDF, another BWDM via its 1 550 nm leg, an output coupling tapper and an isolator with more than 35 dB isolation. The isolator was used to confine the oscillation in one direction only. This was found (Mohamad K. Abdullah et al. 1997) to give a higher output power. The output power was taken through the tapper leg which is at 90% coupling or 10% reflectivity as in Figure 1.

RESULTS AND DISCUSSION

In this experiment, various EDF pieces at different lengths but of the same type were used to study the EDF length variation effects on the lasing threshold and on the maximum output power. The results obtained at various reflectivities are plotted in Figures 2 and 3 for the threshold and output

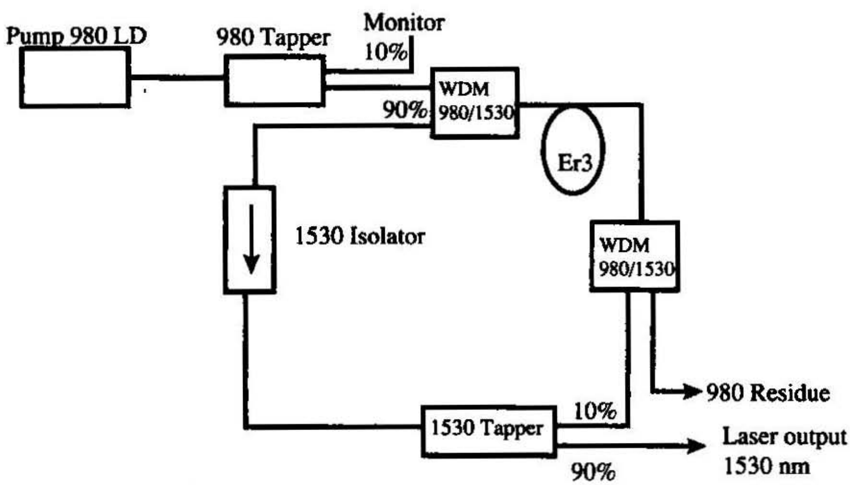

FIGURE 1. The set-up of the EDFL used in this experiment

power respectively. The lasing threshold refers to the minimum amount of the 980 nm pump power required for the system to lase. This was taken by recording the EDFL output power as the pump power was increased gradually. The optical power was measured using an optical power meter with an integrating sphere power collection technique (ILX Lightwave 6810B). A curve of the system output power at 1 550 nm versus that of the pump power at 980 nm is plotted as in Figure 2.

The result shown in Figure 3 suggests that there is an optimum length of EDF that gives the lowest threshold value for a particular system at a fixed reflectivity. This is consistent with the theory (Desurvire 1994). A 3 level lasing transition such as in Er^{3+} ions has an optimum length for the lowest

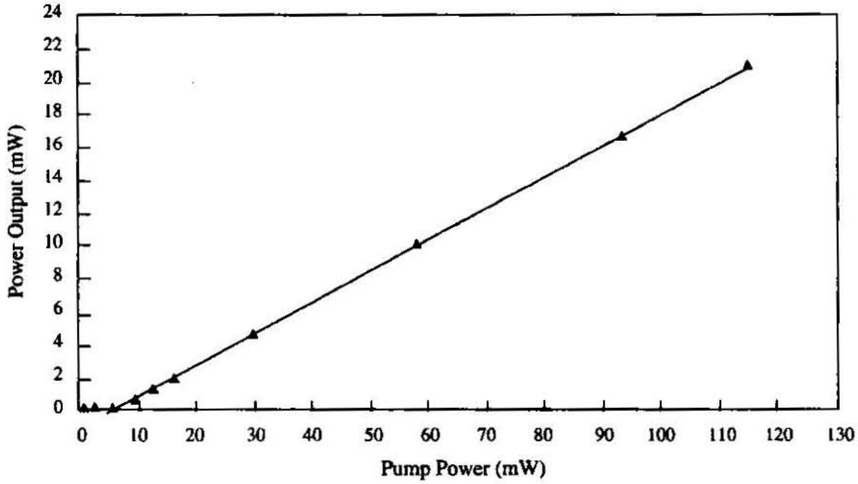

FIGURE 2. A plot of EDFL output power versus 980 nm pump power showing a lasing threshold of about 5 mW.

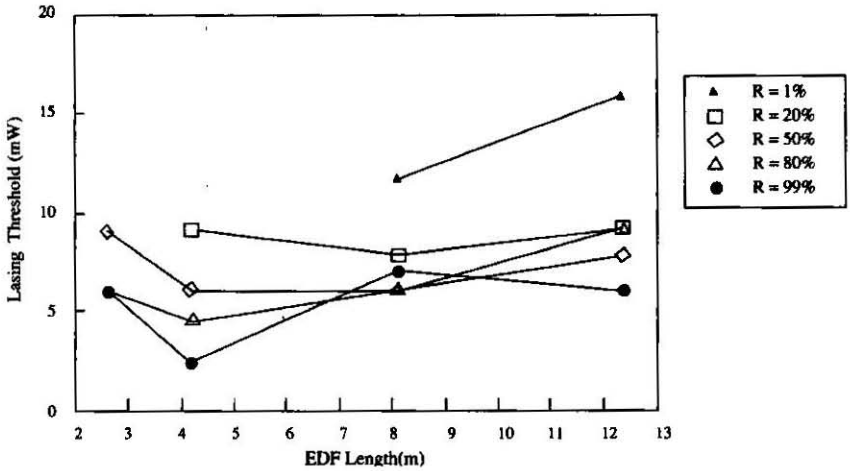

FIGURE 3. EDFL lasing threshold versus EDF length at various reflectivities. R is the reflectivity.

lasing threshold. For example the EDFL system at 80% and 99% reflectivities both have an optimum EDF length of about 4 m. Notice that the actual optimum length can be anywhere between 2.60 m and 8.12 m.

A more accurate result can be obtained had more EDF lengths between these points were available. Comparing with the curves at other reflectivities, it is expected that the optimum length of the 99% reflectivity should be shorter than that at the 80% reflectivity.

The dependence of the maximum output power on the EDF length is shown in Figure 4. The maximum output power refers to the power obtained at maximum pump power available, that was about 115 mW.

We believe that our EDFL system could give a higher power had a higher pump power was available. This is indicated by the straight curve as shown in Figure 2 after the threshold point, which indicates that the output power has not yet reached its saturated level. Had the saturated level been reached, ideally all the extra pump energy will no longer be absorbed by the Er^{3+} ions and come out as the excess pump. Therefore the output power versus pump power curve would have levelled off after the saturation point.

Figure 4 also shows that at high reflectivities, increments of the EDF length after a certain value which is 4 m at 99% and 80% for this particular system, do not contribute to significant increment of the maximum output power. Notice also, that all the results were taken at the pump power of 115 mW. So, the 4 m length can be concluded here as the saturation length for the system pumped at 115 mW of 980 nm source with 80% and 99% reflectivities. Notice that the 4 m length is only the indicating point to qualitatively show the saturation length. More lengths of EDF must be used to determine the actual saturation length. At small reflectivities, the oscillation energy is not enough to lase the system if the EDF length is too short (less than about 4 m for 20% reflectivity and less than about 8 m for 1%

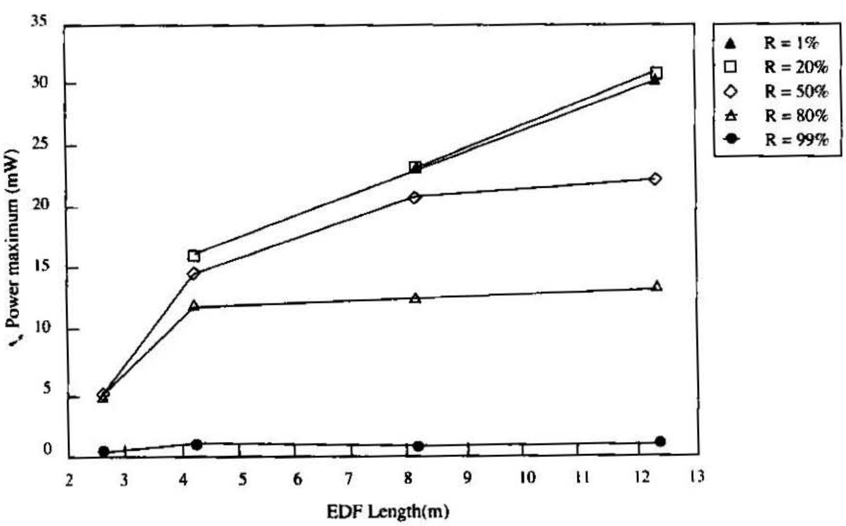

FIGURE 4. EDFL maximum output power versus EDF length at various reflectivities.

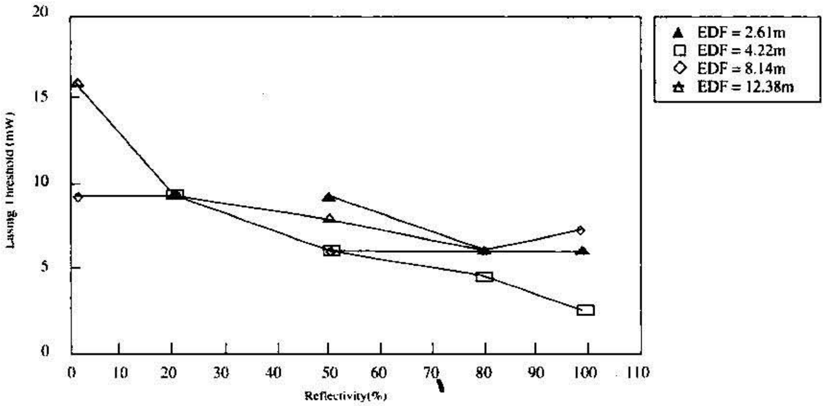

FIGURE 5. Lasing threshold versus reflectivity for various EDF lengths

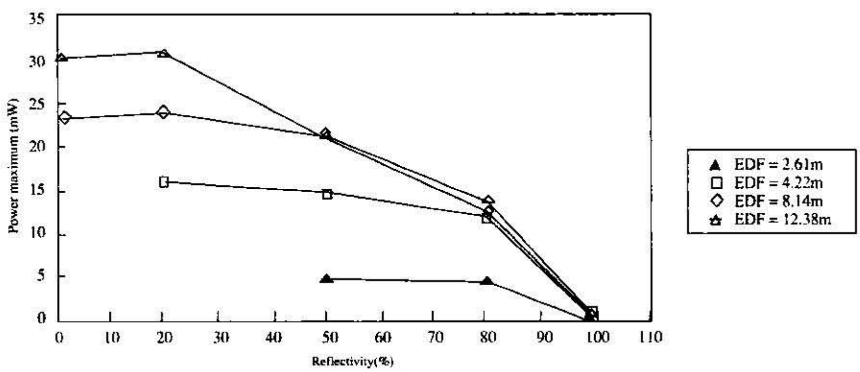

FIGURE 6. Maximum output power versus reflectivity at various EDF lengths

reflectivity). Figures 5 and 6 show the effect of oscillation reflectivity on the lasing threshold and maximum power respectively. These results were taken for four different EDF lengths. The term reflectivity here refers to the coupling percentage of the oscillation signal power that is looped back into the cavity ring. This was varied by using tappers at different coupling ratios; 1/99, 10/90, 20/80 and 50/50, thus giving seven different reflectivities.

From Figures 5 and 6 above, it can be concluded that increasing reflectivity will reduce both the lasing threshold and the maximum output power. This can be understood by the fact that reflectivity increment means oscillation energy increment, thus a smaller pump power is required to lase the system. The higher oscillation energy also means that a smaller power is coupled out, therefore a smaller maximum power.

CONCLUSION

In this paper we have shown the effects of EDF length and reflectivity on the lasing threshold and the maximum output power of a ring fiber laser system. There exist an optimum length of the EDF that gives the smallest lasing threshold. Increasing the EDF length tends to increase the maximum output power until a saturation point is reached. Above this saturation length, increment of the EDF length will no longer increase the output power. It is also shown here that a higher reflectivity reduces both the lasing threshold and the maximum output power. It is important to point out here that a reduction of reflectivity will increase the maximum output power much more than it will increase the lasing threshold. A reduction of reflectivity from 80% to 20% at EDF length of 12.38 m doubles the output power while only slightly increases the threshold by less than 30%. However, since high power 980 nm pump sources are quite easily available at a relatively low cost, the issue of threshold pump power is not a critical one.

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