Design of a Tunable mid-IR Fiber Laser

Introduction

Lasers operating in the mid-IR wavelength range have been receiving serious attention in the recent past due to the multitude of potential applications in LIDAR, free space communication, spectroscopy and trace gas sensing. The quantum conversion efficiency of thulium doped fiber lasers is poorer compared to erbium and ytterbium doped fiber lasers. However, silica fiber doped with thulium and pumped at 793 nm, is an excellent candidate for the design of a fiber laser to emit in the 1.6–2.1 μm range. The process of cross-relaxation in the thulium ions leads to larger efficiencies in these lasers.

Experimental results

The energy level diagram of Tm^{3+} in silica indicating the allowed transitions and their rates is shown in Fig. 1. A broadband emission in the wavelength range 1600–2100 nm occurs corresponding to radiative transitions between the $^3F_4$ and the $^3H_6$ states. An excited ion in the $^3H_4$ state can radiate to the $^3F_4$ state and simultaneously excite a neighbouring ion from the $^3H_6$ to the $^3F_4$ state through the cross-relaxation process. One pump photon can thus result in two signal photons.

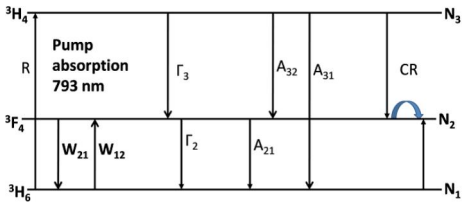

Figure 1. Energy levels of Tm^{3+} in silica .

The absorption and emission cross-sections used for the simulation are shown in Fig. 2 (a). The population in each level of the three level lasing system is solved numerically under steady state conditions, and these are used in tandem to solve the coupled space-varying power equations using the 4th order Runge-Kutta method with a relative tolerance of 10-6 W and a spatial resolution of 8 mm.

Simulation results

The schematic of the ring laser used for simulated is shown in Fig. 2(b). The intra-cavity attenuator is used to achieve tunability.

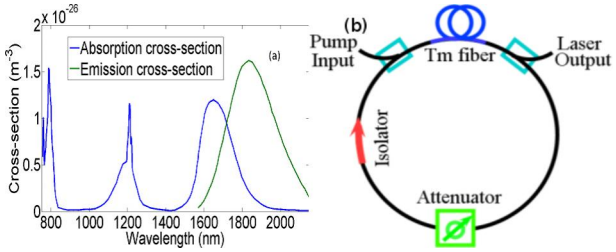

Figure 2. (a) Absorption and emission cross-sections of Tm^{3+} in silica and (b) schematic of a ring laser.

Fig. 3 (a) shows the L-I characteristics of the fiber ring laser. The threshold pump power is 230 mW and slope efficiency is 32.8. The output spectrum for a laser configuration described in Fig. 2 (b), indicating a lasing wavelength of 1969 nm with peak power 30.96 dBm. The pump power used for this simulation is 4 W. The threshold pump power is 230 mW and slope efficiency is 32.8%. The intra-cavity loss (α) is then varied and it was found that the laser wavelength could be tuned from 1969 nm to 1864 nm with change in α from 0 dB to 5 dB. The output spectra for different values of intra cavity loss are also shown in Fig 3 (b).

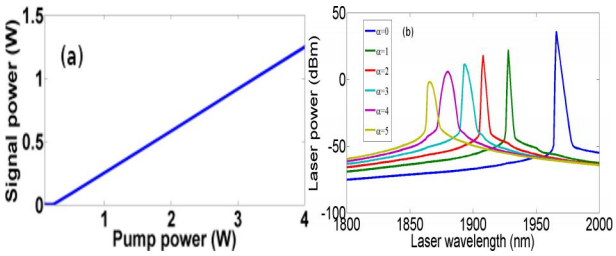

Figure 3. (a) L-I characteristics of the fiber ring laser and (b) laser output with 0.8 m long fiber for different values of α.

Conclusion

A simulation model has been developed to study the characteristics of a thulium doped fiber laser operating as a three level system, including the cross relaxation effects. A ring cavity laser is modelled and the influence of intra cavity attenuation is studied. It is found that, the lasing wavelength could be tuned from 1969 nm to 1864 nm with change in intracavity loss from 0 dB to 5 dB.

Publication

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