Thulium-doped monomode silica fiber as a laser medium

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Tm^{3+} is an interesting activator ion for a glass fiber laser because it emits in regions of the spec-trum where such lasers have not previously operated. The fiber waveguide geometry confers a low threshold for laser action. Therefore, semi-conductor diode laser pumping is a possibility since Tm^{3+} has an absorption band at $\simeq$800 nm.

We have observed laser emission at a number of wavelengths over the 1.88–1.96-μm band from a germanosilicate fiber which has Tm^{3+} ions incorporated into the core at a concentration of $\simeq$830 ppm. Figure 1 shows the fluorescence spectrum of the $^3H_4$–$^3H_6$ transition responsible for laser action. $^3H_6$ is the ground multiplet of the Tm^{3+} ion, so ground multiplet absorption losses cut off laser action on the short wavelength side of the band.

The laser cavity was formed by butting dielectric coated mirrors against the cleaved fiber ends. The fiber had a cutoff wavelength of 1.7 μm and was, therefore, always monomode at the lasing wavelength. A Styryl 9 dye laser operating at 796 nm was used to excite the Tm^{3+} ions at the peak of the $^3H_6$–$^3F_4$ (laser diode pumpable) absorption band. Efficient operation depended on reducing ground multiplet absorption by either using a short fiber length or immersing part of the fiber in liquid N_2 to depopulate the upper Stark levels. A 27-cm length of fiber at room temperature lased with an incident pump threshold of 30 mW (21 mW absorbed) and a slope efficiency of 13 % with respect to absorbed power for 3 % output coupling. In this configuration the laser wavelength was 1.94 μm, and a maximum power of 2.7 mW was achieved. Operation at 1.88 μm could be obtained using a 1.3-m length of fiber of which all except 10 cm near each end was cooled in liquid N_2. The laser operated at progressively longer wavelengths with higher thresholds as the length of the cooled portion was reduced.

We have also studied the blue $^1G_4$–$^3H_6$ fluorescence band, one of the few visible fluorescence bands with a long decay time ($\simeq$300 μs) found in rare earth-doped silica. Figure 2 shows the spectrum of blue light emitted from a fiber doped with $\simeq$800 ppm of Tm^{3+} and $\simeq$3 % of Yb^{3+} under IR excitation at 840 nm. The exciting light is chiefly absorbed in the wing of the $^2F_{5/2}$–$^2F_{7/2}$ Yb^{3+} band, and the $^1G_4$ multiplet is populated by multiphoton sequential summation through energy transfer.[1]

The lifetime of the $^1G_4$ excited state is not measurably shortened in the presence of the Yb^{3+} ions. Further measurements will be reported which are aimed at characterizing the Yb:Tm system as a potential candidate for an upconversion laser.

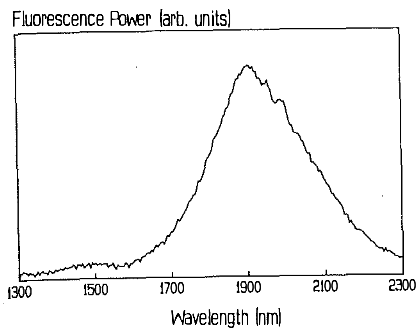

Fig. 1. Endlight fluorescence spectrum of Tm-doped fiber.

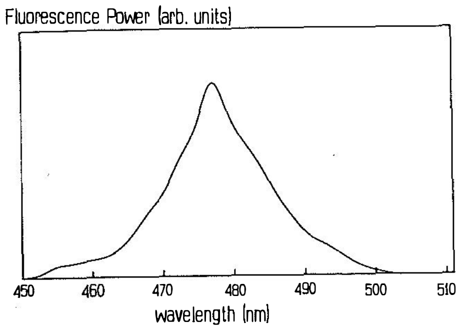

Fig. 2. Sidelight fluorescence spectrum of Yb:Tm-dopped fiber.

Reference
1. F. E. Auzel, Proc. IEEE **61**, 758 (1973).