TUG4 Diode-laser-pumped Er^{3+}/Yb^{3+}-doped fiber laser operating at 1.57 μm

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Erbium-doped fibers[1] show promise as stable narrow-linewidth laser sources and optimum amplifiers operating in the third telecommunications window around 1.55 μm. Diode laser pumping is possible[2] using the weak pump-band located at 807 nm, although this band suffers severely from excited-state absorption (ESA), which reduces gain and pump efficiency. At the low pump power available from diode lasers the Er^{3+} fiber laser prefers to oscillate around 1.62 μm, where Er^{3+} behaves as a quasifour-level system. However, by codoping the core glass heavily with Yb^{3+}, it is possible to excite the Er^{3+} ions indirectly using energy transfer. The Yb^{3+} provides an intense broad pump-band centered at 900 nm, which reduces the effect of ESA. As a consequence of the resulting higher pump efficiency, the laser will oscillate at the required shorter wavelengths.

We report the first, we believe, diode-laser-pumped fiber laser operating at the telecommunications wavelength of 1.57 μm. The laser has an output power in excess of 1 mW, and pulse powers of 6.5-W peak are obtainable by Q-switching.

A range of Er^{3+}/Yb^{3+}-doped single-mode fibers with 550-ppm Er^{3+} and up to 3 mole% of Yb^{3+} concentrations was fabricated using the solution-doping technique.[4] The core glass was silica based with a concentration of 5-mole% Al_2O_3 and 2-mole% P_2O_5 to ensure good solubility of the rare-earth ions. For the fiber reported here the dopant ratio was ~30:1 (1.8-mole% Yb^{3+} and 0.055-mole% Er^{3+}). The transfer efficiency was calculated to be ~37% from measurements of the fluorescence decay time.[5] The absorption spectrum is shown in Fig. 1 where the relative contributions of Er^{3+} and Yb^{3+} to the absorption are indicated.

A laser cavity for cw operation was produced by butting the two cleaved ends of the fiber against dielectric-coated mirrors. The input mirror was chosen to have a high transmission at the pump wavelength ($T \geq 80\%$) and a high reflectivity at the lasing wavelength ($R > 99\%$). The pump power was provided by simultaneously launching light from two GaAlAs laser diodes into the fiber via a polarizing beam splitter. Pump wavelengths of 810 and 826 nm were both investigated. Similar results were obtained, but lowest threshold and highest slope efficiencies were achieved using the 810-nm pump.

A typical laser characteristic is shown in Fig. 2. The maximum output power was >1 mW at a wavelength of 1.57 μm. The lasing threshold occurred at a pump power of 2.2 mW, and the slope efficiency was relatively high at 13%. This result was obtained using 37.5-cm fiber and an output mirror with a transmission of 18%. Further improvements in laser performance are projected by optimization of the Er^{3+}/Yb^{3+} ratio, fiber length, and mirror reflectivity.

In contrast to diode lasers, fiber lasers may be Q-switched to give high pulse powers which are useful for nonlinear optics and measurements. Q-switched operation was demonstrated using an acoustooptic modulator operating in zero order. Again similar results were obtained using 810- and 826-nm pump wavelengths, and a typical pulse is shown in Fig. 3. The output coupler had a transmission of ~25%, and the repetition rate was ~60 Hz. The pulse was characterized by a peak power of 6.5 W and a FWHM of 60 ns. The roll-off frequency was 67 Hz, but a peak power of ~1 W was obtained at a petition rate of 800 Hz. Considerable increases in power can be expected, making the fiber laser an attractive source for long-distance OTDR measurements.

In summary: A diode-laser-pumped fiber laser using a codoped Er^{3+}/Yb^{3+} fiber as the gain medium has been demonstrated. The codoped fibers show an improvement in output power (>1 mW) over fibers doped only with Er^{3+} ions at wavelengths useful for telecommunications. The laser can provide pulse powers in excess of 6 W, and, as with previous fiber lasers, fiber gratings may be employed to produce a very narrow linewidth (1-MHz) stable source, which may rival the DFB laser in some applications. (12 min)

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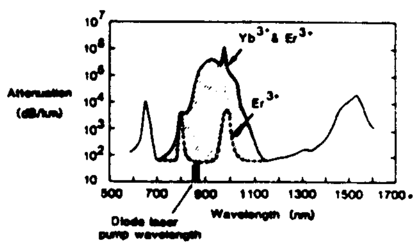
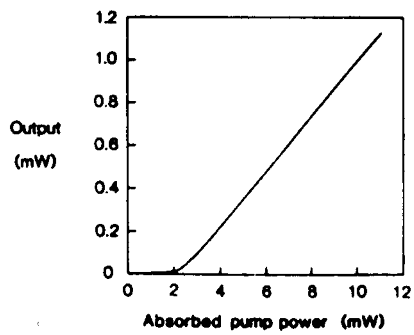
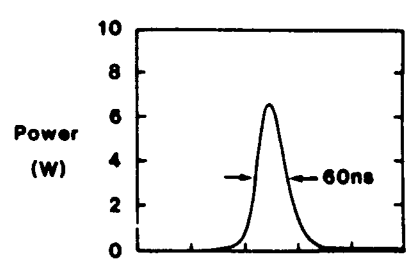


TUG4 Fig. 1. Absorption spectrum of Er^{3+}/Yb^{3+} codoped fiber.



TUG4 Fig. 2. Lasing characteristic of diode-laser-pumped cw Er^{3+}/Yb^{3+} single-mode fiber laser.



TUG4 Fig. 3. Pulse obtained from diode-laser-pumped Q-switched fiber laser.