WD3 High-power tunable erbium-doped fiber laser operating at 1.55 μm

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There is currently considerable interest in lasers based on the fiber waveguide geometry, and crystal fiber Nd:YAG lasers are now commercially available. We recently developed a new fiber laser technology[1] based on doped glass[2] which offers both a wide choice of dopant ions and the possibility of wavelength tunability.[3] The Er^{3+}-doped fiber laser is particularly interesting because its operational wavelength of 1.55 μm coincides with the lowest loss region of silica optical fibers. Furthermore, the fiber can be used as a high-gain optical amplifier,[4] which is compatible with quaternary (InGaAsP) devices.

The low loss and long length of the glass-fiber laser (a 300-m laser has been demonstrated[3]) make it particularly attractive for simultaneous laser action and generation of nonlinear effects. Toward this goal, we present new results on high-power pulse generation in Er^{3+}-doped fibers. Using a modest absorbed pump power (100 mW), Q-switched pulses of 120 W have been obtained, tunable from 1.530 to 1.565 μm. This corresponds to a fiber core intensity of 1 GW/cm^2, which is well into the nonlinear regime. The pulses have been used for Raman generation at a wavelength of 1.65 μm.

The experimental configuration (using a DCM dye laser as the pump) is shown in Fig. 1. The holographic grating provides wavelength selective feedback (600 lines/mm, blazed at 1.6 μm), and the output is taken from the zeroth-order reflection of the grating. Tuning is effected by changing the angle of the mirror. Figure 2 shows the resultant tuning curve. To Q-switch the laser, an acoustooptic modulator is inserted into the cavity so that the feedback is via the first-order deflection. This configuration provides a high extinction ratio and eliminates the possibility of lasing while the modulator is off. The gain of the laser is so high[4] that Fresnel reflection from the fiber ends is sufficient to support oscillation, and index matching of the fiber output is required.

The performance of the laser varies with fiber length and pulse repetition rate. For the doped fiber used in this experiment (Er^{3+} ion concentration, $10^{19}/cm^3$; fiber N.A. = 0.21; second-mode cutoff = 1.4 μm), the optimum length was 2.5 m. Note that this length could be reduced by at least 2 orders of magnitude, if desired, by using a higher-dopant concentration. At a pump power of 220 mW, corresponding to ~100 mW absorbed in the fiber, Q-switched pulses of 32-ns duration and 120-W peak power were generated at a repetition rate of 800 Hz. A typical pulse is shown in Fig. 3. Above a rate of 1 kHz the average power remained constant.

The intensity in the fiber core during Q-switching is ~1 GW/cm^2. Thus the erbium-doped fiber laser is a useful source for nonlinear optics experiments. For example, Raman generation over a 40-nm band centered at 1.65 μm has been observed in a second length of high-birefringence fiber (loss = 1.2 dB/km at 1.6 μm, length = 800 m). This length is well in excess of the optimum, and it was possible to achieve complete depletion of the pump pulse. If the cavity is designed to be resonant at the Stokes frequency, simultaneous oscillation should be possible. Further results are presented.

Summarizing: An efficient cw and Q-switched fiber laser has been demonstrated, which is tunable in the wavelength region of 1.55 μm. The laser has been optimized for high peak power and can be used as a source for nonlinear optics. **(12 min)**

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