TUP5 Mode-locking of a Yb:Er fiber laser at 1.56 μm

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We describe the first operation of an actively mode-locked Er fiber laser at 1.56 μm. Short pulse laser sources operating in the 1.5-μm spectral range are needed for two reasons. First, current fiber optical communication systems operate in this spectral region because of the low loss of silica fibers. Second, 1.56 μm falls in the region of the negative group velocity dispersion (GVD) of silica. It is well known that by combining the effects of a Kerr nonlinearity to produce a frequency chirped pulse and negative GVD, significant pulse compression can be achieved. The laser we describe is of particular significance because it has all the ingredients needed to produce significant nonlinear propagation effects. In addition to operating at a suitable wavelength, the doped silica fiber already incorporates the Kerr nonlinearity and negative GVD. Thus, in contrast to other nonlinear laser systems[1] which introduce an external cavity to produce the nonlinearity, in this laser the necessary nonlinear element is an integral part of the laser cavity. Currently the pulse peak powers in our laser are approaching the level at which nonlinear effects become significant.

The active medium consists of a single mode silica fiber codoped with Yb and Er. Pump light at 1.06 μm is absorbed by the Yb. The excitation is efficiently transferred to the Er which lases at 1.56 μm. One cavity mirror is butted to the fiber end. The other end is terminated in index matching liquid. A microscope objective focuses the exciting light through a $LiNbO_3$ phase modulator onto the output coupler (5% transmission). Polarization control to match the Brewster cut ends of the mode-locker is achieved through the use of fiber loops.[2] Without rf power the laser threshold occurs at ~50 mW coupled into the fiber. Damage to the input mirror currently limits the input power to 150 mW giving a cw output power of 560 μW at 1.56 μm.

Applying rf power of <1 W near 98 MHz to the modulator leads to a mode-locked pulse train. To date pulses of 70-ps duration have been achieved with a time–bandwidth product of 0.8. Presently the peak power is 90 mW coupled out, corresponding to an intracavity power of 2 W (4.5% output coupling). Current efforts are aimed at improvements to the cavity which are expected to increase significantly the peak power. Possibilities for such improvements include the use of a dichroic coupler to couple more pump power into the cavity, pumping at a shorter wavelength to increase the Yb absorption, or using novel types of rf modulator which can be directly attached to the fiber.[3,4]

We estimate that in the present arrangement single pass frequency chirping due to self-phase modulation is of the order of 200 MHz. By increasing the peak power so that the frequency chirping becomes a significant fraction of the pulse bandwidth (measured at 11.5 GHz), it is expected that the combined effects of self-phase modulation and negative dispersion will lead to pulse compression. **(12 min)**

1. L. F. Mollenauer and R. H. Stolen, Opt. Lett. **9**, 13 (1984).
2. H. C. Lefevre, Electron. Lett. **16**, 780 (1985).
3. D. B. Patterson, A. A. Godil, G. S. Kino, and B. T. Khuri-Yakub, to be published.
4. M. W. Phillips, A. I. Ferguson, and G. S. Kino, in preparation.