Fiber Amplifiers and Lasers in Yb:silica

R. B. Wilcox
D. F. Browning
M. D. Feit
B. Nyman

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R. B. Wilcox, D. F. Browning, M. D. Feit, and B. Nyman*
Lawrence Livermore National Laboratory
P.O. Box 808, Livermore, CA 94551
Phone: (510) 423-1343, FAX: (510) 422-7748

*JDS Fitel
Eatontown, NJ

Abstract:

We have measured gain and saturation in single mode Yb:silica fiber, and developed fiber lasers and amplifiers at 1053nm. The lasers are tunable over 10’s of nanometers, with amplifier gain flattened by fiber gratings or dielectric filters.

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High peak power laser systems (such as those for fusion or high field physics) require low
level input pulses for amplification. Since many of these systems use Nd:phosphate glass,
sources and signal amplifiers are needed around 1053 nm. We have developed such
devices in single mode fiber using Yb:silica as the gain medium. This material provides
gain flatness in this region for broadband capability, high saturation fluence for high energy
output, and it can be pumped with commercial 980 nm pumps for EDFA’s.

Based on measurements of gain and saturation in Yb:silica, we have built single and multi-
longitudinal mode lasers, and amplifiers for different applications. Since the application
wavelength is far from the gain peak at 1020 nm, the gain spectrum must be changed as in
gain flattening of EDFA’s. Figure 1 shows a fiber grating used to narrow the gain spectrum
in a double-pass amplifier. This amplifier provides 350 times gain with 1 microjoule
saturation energy, with a 2.8 micron core ytterbium fiber. Gain can be traded with
saturation energy if core size is varied, so a 6 micron core fiber is used in a power amplifier
module with gain 36 and about 5 microjoules saturation. This module uses two different
core size amplifying fibers, co-pumped with a single pump diode, and gain flattens with
narrow-band dielectric filters.
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The laser oscillator source in our systems is a single longitudinal mode, Q-switched ring laser (1). A fiber grating is used as in the amplifier of figure 1, together with an intracavity fiber etalon to select cavity modes. The fiber gratings can be tuned by stretching over 3 nm in wavelength, but the cavity design allows operation over the entire 70 nm bandwidth of Yb:silica by replacement of gratings. A feedback stabilization system controls operating wavelength by piezoelectrically stretching intracavity fibers.

This oscillator produces a smooth, 230 ns long pulse, limited by the 30 ns cavity round-trip time. This pulse length is useful for pulse shaping applications, where a shorter pulse is created by external electrooptic amplitude modulation (2). Fiber preamplifiers are then used to boost signal amplitude while maintaining high signal-to-noise ratio (SNR). An advantage of high saturation energy amplifiers is that signal pulse shape distortion is minimized at higher amplitudes. This is important when the pulse amplitude is modulated over a high dynamic range, a range which is limited by the desired SNR at the lowest signal amplitudes. If modulation has to compensate for excessive signal distortion, the useful dynamic range is further reduced. Thus our fiber amplifier designs maximize the saturation energy parameter.

Using a grating-tuned oscillator, we measured the gain and saturation of a fiber amplifier at several wavelengths, as shown in figure 2. These results indicate that even with large energy extraction, the gain over a 3 nm range is uniform, allowing for amplification of broadband pulses in this wavelength range. A simple Franz-Nodvik saturation model accounts for the apparent roll-off in gain. Parameters derived from this model are used to model pulse power distortion, and optimize amplifier design.
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References


Figure 1. A double pass amplifier. The circulator is a 3-port bulk Faraday isolator. The fiber grating is about 2 Angstroms in spectral width, with >95% reflectivity.
Figure 2. Energy gain measurement for four wavelengths spaced by 1 nm. Variations in fiber coupling loss account for apparent variation in gain between wavelengths. Note that gain nonlinearity is due to saturation.
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