## L.7: All-fiber power amplification of mode-locked Yb-doped fiber laser to ~ 20W of average power

Mode-locked fiber oscillator-amplifier systems producing high average power ultrashort pulses in the femtosecond regime is required for many applications such as: precision micromachining, tissue processing, nano-surgery, metrology etc. Earlier we have generated ultrashort pulses by mode-locking of Yb-doped fiber laser in all-normal-dispersion (ANDi) configuration and demonstrated a scheme to obtain clean pulses from the laser. The chirped pulse-duration from the oscillator was measured to be 5 ps which were compressed to 150 fs with clean profile in an external grating pair. In this work we have amplified the output power from the oscillator (~50mW) to more than 20W in all-fiber multistage fiber amplifier segment under the chirped pulse amplification scheme. The output pulse duration was about 30 psec. These pulses were compressed to ~270fs duration using a grating pair with ~55% net power transmission efficiency.

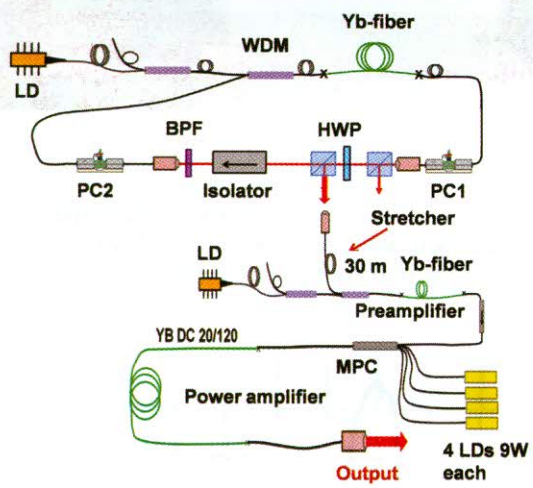


*Fig. L.7.1: Schematic of fiber oscillator-amplifier setup.*

Fig. L.7.1 shows the schematic of the oscillator-amplifier setup. The output from the oscillator is extracted after the NPR port in order to obtain clean pulse profile as well as sufficient seed pulse energy. The all-fiber amplifier segment consists of three parts: stretcher, pre-amplifier and power amplifier. The pulses from the oscillator were stretched to around 30 ps duration in 30 m long single mode fiber (SMF). The preamplifier segment is made of 1 m long Yb-doped SMF pumped by a single-mode fiber laser diode at 976 nm. The power amplifier comprised of an fiber isolator, a (6+1) 1 multiple pump combiner (MPC), double clad Yb doped fiber (YbDF) with 20 μm core diameter and 120 μm of inner clad diameter and an in-fiber collimator. The MPC combined 36W output power from four multimode fiber coupled laser diodes. It also coupled 10 mW of seed signal at 40 MHz repetition rate to preamplifier through the stretcher fiber and amplified to 21.6 W of average power at a total pump power of ~34W corresponding to pulse energy of ~ 560 nJ in pulse of duration ~ 30 psec.

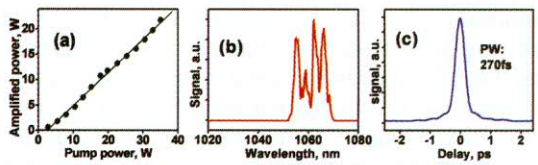


*Fig. L.7.2: (a) Variation of amplifier output power with pump power, (b) spectral profile and (c) autocorrelation trace of the preamplified pulses.*

Fig. L.7.2(a) shows the variation of the amplifier output as a function of the pump power. The output power increases fairly linearly with pump power with more than 62% of slope efficiency. Fig. L.7.2(b) shows recorded spectra of the output beam at the maximum pump power. No significant ASE signal was observed at the gain peak to ~200mW before injecting into the power amplifier fiber through the fiber isolator.

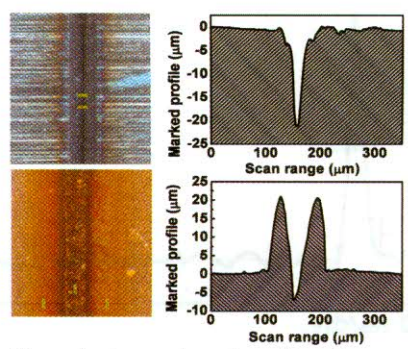


*Fig. L.7.3: Top: photograph and profile of engraved sample with ps pulses. Bottom: photograph and profile of engraved sample with ns pulses.*

The signal is at ~1030 nm. The modulation in the spectra developed due to the SPM induced spectral broadening and intermodal dispersion in the LMA fiber. Fig. L.7.2(c) shows the autocorrelation (AC) trace of the amplified pulses after compression in a grating pair. AC trace is reasonably clean corresponding to pulse duration of ~270fs.

The amplified output pulses of 30 ps duration from the power amplifier were used for engraving on SS plates. The top panel of Fig. L.7.3 shows the microscope image and profile of the engraving on SS plate using the ps pulses. For comparison the same with ns pulses from DPSS laser is also shown in the bottom panel of Fig. L.7.3. It can be seen that engraving with ns pulses leads to the formation of side-hills due to the re-solidification of the molten material whereas ps pulses leads to clean engraving profile with more than 20 μm profile depth showing superior engraving quality.

*Reported by:*
*P.K. Mukhopadhyay (pkm@rrcat.gov.in) and K.S. Bindra*