L.4: Development of high energy nanosecond acousto-optic Q-switched Yb-doped fiber laser

High energy and short pulse fiber lasers are attractive for many applications such as marking, cleaning, decontamination, nonlinear frequency conversion, range finding, remote sensing, medical, and industrial processing. Compact nanosecond duration fiber lasers with pulse energy of a few millijoules are preferred for such applications. Yb-doped fiber lasers in master-oscillator power-amplifier (MOPA) configuration can deliver pulse energy in the range of a few millijoules to hundreds of millijoule. In such configurations, one or more power amplifier stages separated by optical isolators are used to amplify the low-energy pulses derived from master oscillator. In this direction, a 3.3 mJ pulse energy and 100 W average power acousto-optic (AO) Q-switched Yb-doped fiber laser operating at 1064 nm has been developed.

Figure L.4.1 shows the schematic of the experimental set-up of 100 W average power AO Q-switched fiber laser, which consists of three stages. The first stage is an oscillator, which contains an acousto-optic Q-switch for loss modulation in the resonator to generate Q-switched pulses and this stage works as a seed source for the next stage. The second and third stages are amplifier stages, which amplify the signal pulse from the seed source. Oscillator stage consists of a 2.5 m long octagonal inner clad Yb-doped fiber (YDF) as the gain medium having a core/inner clad diameter of 15/125 µm with NAs of 0.075/0.46, respectively. Two 10 W fiber pig-tailed diode lasers at 976 nm with fiber core/clad diameter of 100/125 µm and NA of 0.22 have been used to pump Yb-doped fiber. For pumping of YDF, a multimode pump combiner has been used, which has two pump input ports, one input signal port, and one output port. Two fiber Bragg gratings (FBG), one having 99.8% reflectivity and another having 10% reflectivity at the center wavelength of 1064 nm have been used to form the linear cavity for master oscillator. At the output port of the pump combiner, YDF has been spliced, which is further spliced with a compatible fiber optic AOM. The 10% OC FBG has been spliced with the output end of the AOM. The pulse repetition rate of this AO Q-switched oscillator has been controlled using a 20 MHz signal generator, which modulates the radio frequency applied on the AO Q-switch. From the oscillator stage, 1 W of average power at 30 kHz of repetition rate with 175 ns pulse duration was achieved, which was fed to the first amplifier stage. In order to separate the oscillator stage/seed source from the amplifier stages, polarization insensitive in-line isolators have also been spliced in series to prevent any backward propagating signal causing any damage to the other fiber components in the oscillator stage. For the pumping of 1st amplifier stage, 10 W fiber coupled laser diodes at 915 nm were used. Such six pump diodes of the same power were spliced with pump input ports of (6+1)x1 pump combiner. The output of the pump combiner was then spliced with another 4 m long YDF. This fiber has a core/inner clad diameter of 20/125 µm with NAs of 0.075/0.46, respectively. From this stage, an average output power of 16 W was achieved. Further, the output signal was fed to the second amplifier stage. For the pumping of second amplifier stage, fiber coupled laser diodes at 975 nm having a maximum of 70 W of CW output power have been used. Such three pump diodes of the same power were spliced with three pump input ports of (6+1)x1 pump combiner. The output of the pump combiner was then spliced with another 1.5 m long YDF having a core/inner clad diameter of 48/400 µm with NAs of 0.075/0.46, respectively. At a repetition rate of 30 kHz, an average output power of 100 W, 3.3 mJ of pulse energy with 175 ns pulse duration and an optical to optical conversion efficiency of 54% was achieved. This resulted in a peak power of ~ 19 kW. Figure L.4.2 shows an oscilloscope trace of the laser pulse at the maximum average output power of 100 W. Output spectrum is peaked at 1064 nm with a FWHM linewidth of 1.5 nm. Due to larger core size of gain fiber in the 2nd amplifier stage, output is multi-moded. This laser is being engineered for cleaning and decontamination applications.

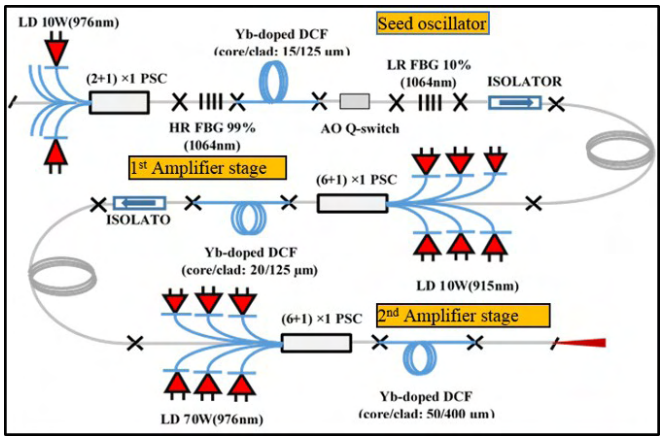

Fig. L.4.1: Schematic of 100 W average power AO Q-switched fiber laser.

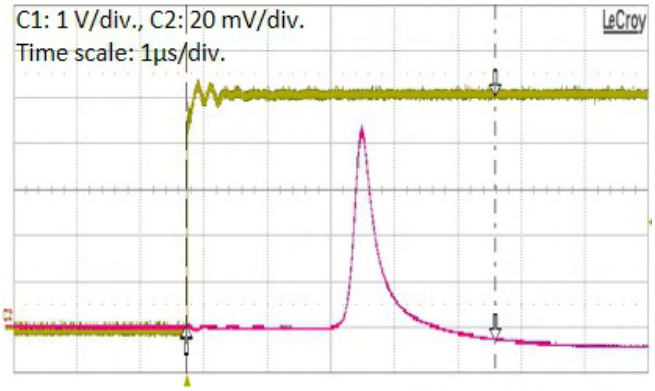

Fig. L.4.2: Oscilloscope trace of laser output pulse at 100 W of average output power (laser pulse (pink), modulation signal (green)).

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