L.2: Fiber optic front end laser system for high energy laser

High energy lasers (HEL) find numerous applications in study of material behavior at extreme pressures and temperatures, fusion research, nuclear waste management, astrophysics research, etc. RRCAT has an ongoing program to develop a HEL based on Nd:Glass with an output energy of 1 kJ. Such HELs require a front end laser system to provide seed pulses with desired temporal pulse width and pulse shape. Commercially available pulsed lasers such as Q-switched or mode locked lasers are not suitable for this application as user can not control pulse shape and pulse width with required accuracy. Hence, an all-fiber front end system is developed based on external modulation scheme starting with a CW laser source for the aforementioned application. The all-fiber architecture has been adopted due to inherent advantages of fiber optic systems. These advantages include alignment-free system, ruggedness, compact and non-existent exposed intermediate optical surfaces except for single surface exposure at output port.

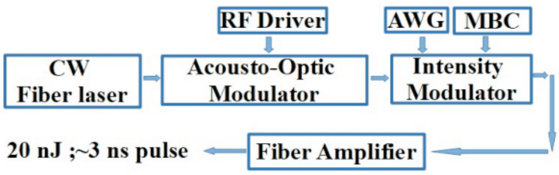

Fig. L.2.1: A schematic of FOFES.

Figure L.2.1 shows a schematic of fiber optic front end system (FOFES) operating at wavelength of 1053 nm. A narrow linewidth CW ytterbium-doped fiber laser is used as input source. An acousto-optic modulator (AOM) constitutes first stage of a two stage external modulation system. The 150 MHz carrier of AOM is modulated at 100 kHz by a function generator to convert CW output from the laser into a pulse train of 100 kHz with a pulse width of 300 ns. Its main function is to reduce average power of signal without affecting peak power. The second stage of modulation is carried out by an amplitude / intensity modulator using a $LiNbO_3$ device in Mach-Zhender configuration and it works on electro-optic effect. The intensity modulator is driven by an arbitrary waveform generator (AWG) through a RF amplifier to temporally shape pulses. A modulation bias controller (MBC) is used to stabilize operating point of amplitude modulator at minimum of transmission. This stage generates a 100 kHz wave train of square shaped pulses with a pulse width of ~3 ns (Figure L.2.2) with pulse energy of 20 pJ. These pulses are amplified in ytterbium-doped fiber amplifier (YDFA) to pulse energy of 20 nJ. Figure L.2.2 indicates no distortion in output pulse shape.

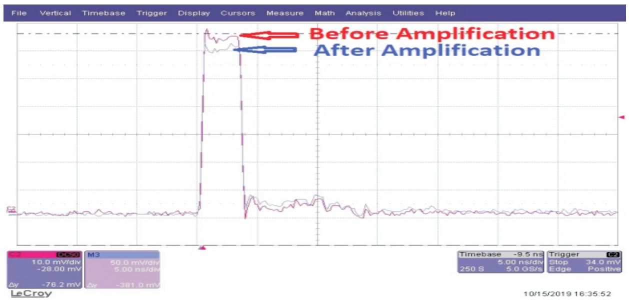

Fig. L.2.2: Input and output pulses of fiber amplifier of FOFES in arbitrary units with a pulse width of ~ 3 ns.

The all-fiber architecture uses polarization maintaining (PM) fibers with a linearly polarized signal aligned to slow axis. Concatenation of PM fibers is known to cause depolarization and consequent modulation effects. A fiber optic polarizer is used to improve polarization extinction ratio of the signal to more than 25 dB post amplification. FC/APC connectors are chosen for interconnecting various fiber components to improve return loss. The estimated pre-pulse contrast is more than 30 dB. The current operational parameters (repetition rate, pulse energy etc.,) of FOFES are limited by available YDFA. The system is tested at maximum output pulse energy of 40 nJ (80% of max. pulse energy permitted by YDFA). The FOFES design allows tunability of pulse width, pulse repetition rate and pulse energy. Due to the tunability of these parameters, the system can also be used for characterization of fiber/free-space optical amplifiers, in addition to serving as a front end of HEL. The photograph of the system in modular unit is shown in Figure L.2.3.

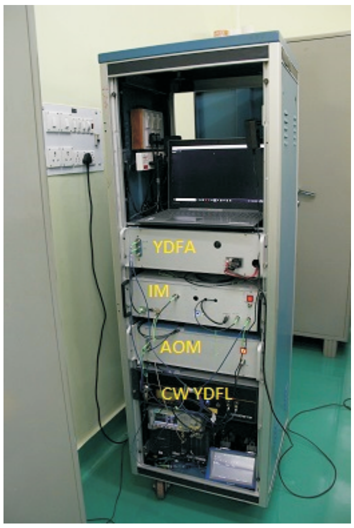

Fig. L.2.3: Photograph of an engineered fiber optic front end system.

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