L.6: Development of a 7 J / 10 ns Nd:YAG laser oscillator-amplifier system

High energy (~J), short pulse (~10 ns) solid state lasers find numerous applications in research and industry. Among them, one of the emerging and potential application includes surface modification of materials by process of laser shock peening (LSP). In LSP process, a high energy/peak-power laser pulse is utilized to generate shock wave that propagates into the material resulting deep compressive residual stresses, which improves their fatigue life and damage tolerance. At HPLDL, LDIAD of RRCAT, to augment the ongoing LSP activities, an Nd:YAG laser master-oscillator-power-amplifier (MOPA) system has been developed delivering energy in excess of 7 J with pulse duration of about 10 ns at repetition rate of 1 Hz and total electrical input energy of ~388 J.

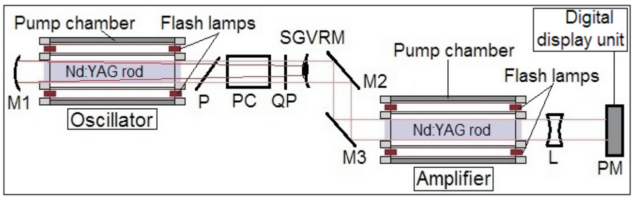

Fig. L.6.1: Schematic of the developed high energy (7 J / 10 ns) Nd:YAG laser oscillator-amplifier system.

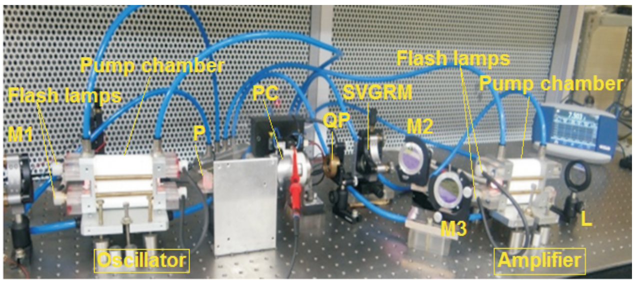

Fig. L.6.2: Photograph of the developed high energy (7 J / 10 ns) Nd:YAG laser oscillator-amplifier system.

The laser system consists of a master oscillator and single stage, single pass amplifier of identical pump heads (Figure L.6.1 and Figure L.6.2). Each pump head consists of 15 mm dia. and 100 mm long barrel grooved Nd:YAG rod (1.1 at% Nd with wedged end-faces). These have been pumped by a pair of Kr-filled flash lamps housed inside a diffusively reflecting pump chamber made up of samarium doped quartz tubes encapsulated within a teflon jacket with $BaSO_4$ powder. The Q-switched oscillator consists of a concave mirror of focal length 2.5 m as rear high reflector (M1) and a super Gaussian variable reflecting convex mirror (SGVRM: ω = 5, n = 5) of focal length 0.5 m as output coupler with intra-cavity polarizer (P), Pockels cell (PC) and quarter wave-plate (QP) making overall resonator length of about 0.55 m. The oscillator output has been coupled into the amplifier through a pair of high reflecting plane mirrors (M2 and M3). The flash lamps for both the oscillator and amplifier have been energized by a dual channel precision high voltage power supply (M/s Ekspla) having provision of temporally-controlled triggering of voltage to the PC.

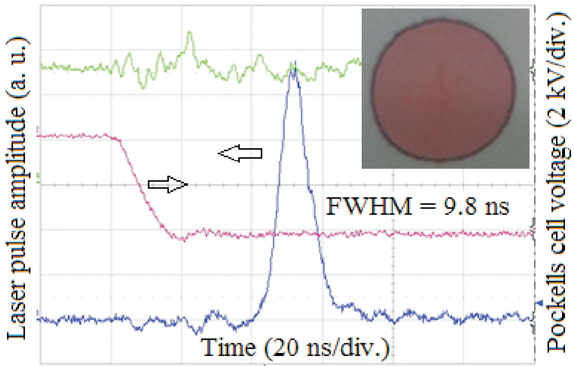

Fig. L.6.3: The laser pulse and near-field beam burn spot (inset) of the developed MOPA.

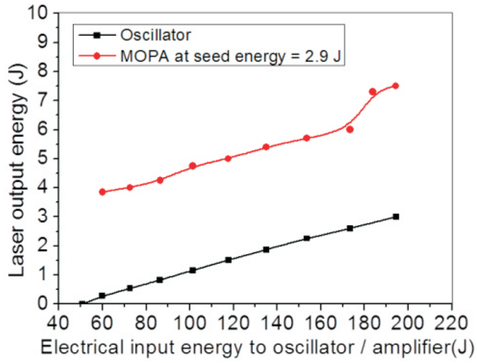

Fig. L.6.4: Variation of laser output energy (oscillator and MOPA) with electrical input energy.

Initially, the oscillator output has been maximized in free running mode for different parametric conditions followed by that of in Q-switch mode. At the maximum electrical input of ~194 J (limited by power supply), the oscillator produced ~3 J energy within pulse width (FWHM) of ~9.8 ns (~3.3 J in free running mode) (Figure L.6.3 and Figure L.6.4). Further, using a pair of folding mirrors, the oscillator beam has been launched through the amplifier and the MOPA output has been studied for different parametric conditions. At the seed energy of ~2.9 J, maximum laser energy of ~7.5 J, from the MOPA system, was achieved with excellent spatial beam homogeneity (inset of Figure L.6.3). This corresponds to amplifier gain/efficiency of ~1.5/~2.3% with overall conversion efficiency more than 1.8%.

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