L.4: Development of 2.5J, 7ns Oscillator and Amplifier system

A high energy 2.5J flash lamp pumped Electro-Optically (E-O) Q-switched Nd:YAG laser system is developed at SSLD for laser shock peening (LSP) applications. Earlier a 1.1J oscillator system was reported in the Newsletter. Oscillator output energy was further enhanced to 1.25J and a single stage amplifier was added to obtain 2.5J energy per pulse

Two Krypton filled lamps with bore diameter of 8mm and arc length of 76mm were used in the oscillator to pump the ϕ10mm x 100 mm Nd:YAG rod with 1.1% doping. The rod was barrel grooved and end faces were cut at 2^0 to its normal. Grooved Nd:YAG rod was used to avoid any gain to parasitic modes which may set in at high pumping. Active medium with two degree wedge at end faces was used to prevent oscillations due to reflectivity from end faces. Laser pump head was made of powder filled cavity with Samarium doped flow tubes, housing the laser rod and the lamp. Role of samarium doped flow tube is to absorb the 1.064 micron radiation which may lead to amplified spontaneous emission (ASE) at high pumping. With good quality polarizer, pockels cell, quarter wave plate (E-O Q-switching elements) and with samarium doped pump chamber, pumping up to 5 to 5.5 times above the threshold was achieved. Powder filled pump chamber ensures uniform pumping of the active medium, which may not be possible in the case of pump chamber with specularly reflecting elliptical reflectors. Pump head is of similar design for both oscillator and amplifier.

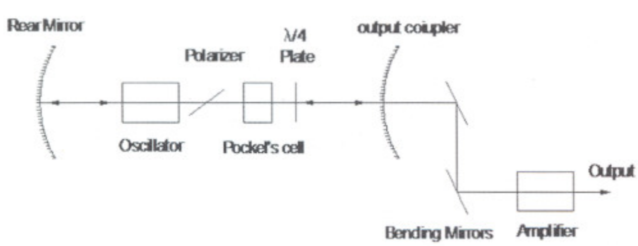

Fig. L.4.1: Oscillator amplifier schematic

Output from the oscillator was coupled to a single stage amplifier by beam bending optics as shown in Fig. L.4.1. For an oscillator output of 810mJ Amplifier output of 2.520mJ was recorded, this corresponds to a single pass gain close to 3. Oscillator output was not increased further as it may result in damage to the dielectric coating of the Nd:YAG rods. Fig. L.4.2 shows the amplifier output energy and single pass gain for various amplifier input energies from the oscillator.

The laser pulse width for different oscillator pump input energy varied from 35ns at 1.5times the threshold to 7ns at > 5.5times the threshold as shown in Fig. L.4.3.. The output energy varied from 300 mJ to 1.25 J in the above pumping range. As the output pulse width and output pulse energy are not independent of each other, for peening studies with long pulse widths, a higher gain in the amplifier was required to achieve the required energy. Fig. L.4. 4 shows the energy and the pulse widths recorded in our system. Photograph of the system is shown in Fig. L.4.5.

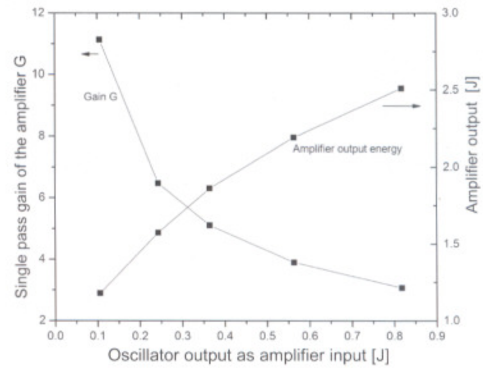

Fig. L.4.2.: Amplifier output energy & gain for the input from the oscillator

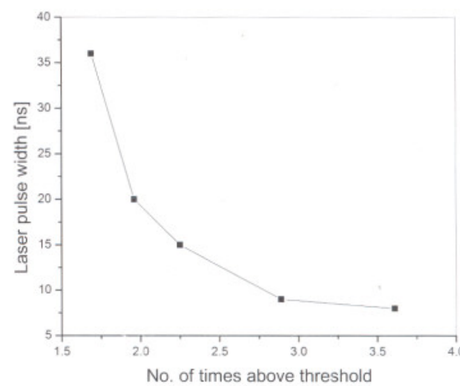

Fig. L.4.3: Laser pulse width versus oscillator pump energy in terms of its threshold

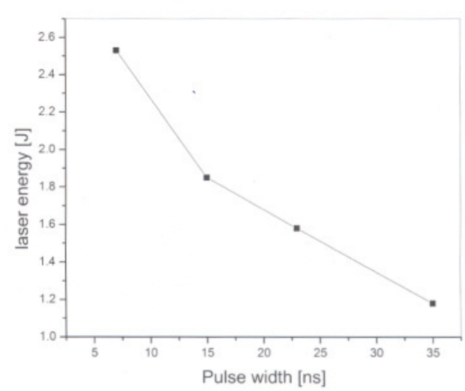

Fig. L.4.4: Amplifier output energy versus to its input laser pulsewidth

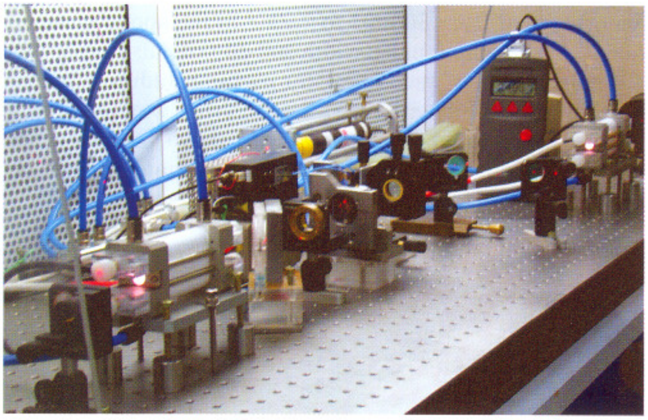

Fig. L.4.5: Photograph of the system in operation

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L.5: 3D simulation of relativistic electrons from laser driven wakefield acceleration

Activity on 3D simulation of laser based wakefield acceleration of electrons was started in Sep. 2006 at Laser Plasma Division, RRCAT, in collaboration with Laser & Plasma Technology Division of BARC, Mumbai, where a general-purpose serial Particle-in-Cell (PIC) code PICPSI-3D existed. This code has been upgraded at RRCAT to facilitate study on laser based electron acceleration. Recent simulation results have shown mono-energetic electron beam at ~23 MeV, with an energy spread of ±7.5 MeV for a plasma density of 3.5×10^{19} cm^{-3}.

Laser wake-field acceleration (LWFA) of electreons has drawn considerable attention due to the possibility of developing a compact table-top accelerator. High intensity laser pulses propagating through an under-dense plasmas are known to produce accelerating field of upto ~1 TV/m over a few millimeters, which have been used worldwide to accelerate electrons to an energy up to 170 MeV. At RRCAT, we have also experimentally demonstrated mono-energetic electrons with low divergence (<10 mrad) with good monochromaticity ($\Delta E/E<10\%$). [For more details, please see; S. R Bobbili *et al., New J. Phys.*, 12, 045011, (2010)].

Simulations provide insight into the internal dynamics of the laser-plasma interaction, to optimize LWFAs and to explain electron injection and self-consistent acceleration. Several codes like VLPL, OSIRIS, VORPAL are in use for such studies and the behaviour predicted by these codes has been subsequently verified in experiments. Using our code PICPSI-3D, we have studied the interaction of intense laser pulse with preformed plasma, and the subsequent evolution of the plasma and the field parameters.

In our simulation, a laser pulse of intensity ~ 1.5×10^{19} W/cm^2 (a_0=10), and 18 fs pulse duration, focussed to a Gaussian spot of 10 m in to a plasma of uniform density 3.5×10^{19} cm^{-3} was taken. Each macro-particle consisted of 78,368 particles. The plasma consisted of 7×10^7 macro-particles and was inside a simulation box of volume 25×25×260 μm^3, with a mesh-size of 0.2 m. The total number of mesh-cells was 2.03×10^7, resulting in approximately 3.5 macro-particles per cell. The code was run for 11000 time-steps, with each time-step being 0.0962 fs. Since the laser period ($c\tau$ = 5.4 μm) was equal to the plasma wavelength (λ_p= 5.4 μm), the acceleration was expected to be in the bubble regime of acceleration. For this plasma density, the dephasing length was ~255 μm, the critical power for self-focusing was 0.8 TW, and the expected maximum electron energy was 46 MeV.

The run took ~72 days to simulate as a stand-alone job on our workstation. In Fig. L.5.1, one clearly observes growth of a bubble after 1600 time-steps (~154 fs). The bubble breaks at 4000 time-steps (384 fs), resulting in the launch of electrons inside the bubble. At 6800 time-steps (654 fs), the electron energy spectrum starts to show a peak. The electron energy spectra in Fig. L.5.2 shows observation of monoenergetic electron beam at ~23 MeV, with an energy spread of ±7.5 MeV.

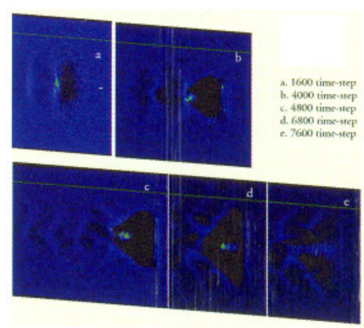

Fig. L.5.1: Electron density plot.

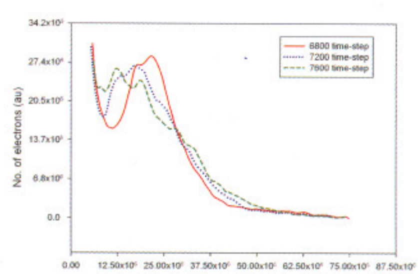

Fig. L.5.2: Electron energy spectrum.

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