L.2: Development of a chirped pulse amplification based 40 TW Nd:glass laser system

Development of short pulse, high energy, high power laser systems has opened up new vistas in developing secondary sources of radiation (terahertz to gamma rays) and generation of charged (e.g. electrons, protons, neutrons and also ions) and neutral particles, for a variety of scientific and industrial applications such as studies of high energy density science, processes relevant to fast ignition in an inertial confinement fusion etc. While laser power is increased by increasing laser pulse energy for a given pulse width in master oscillator power amplifier scheme, laser power can also be enhanced by reducing pulse duration for a given pulse energy. Direct amplification of ultrashort laser pulses is difficult due to optical nonlinearities and optical damage. An indirect pulse amplification scheme called chirped pulse amplification (CPA) is used to amplify short and ultrashort laser pulses. The limitations of laser amplifiers (such as gain narrowing, generation of pre-post pulses etc) are also avoided in optical parametric amplifiers (OPAs), which offer ultra-broad amplification bandwidth over much smaller interaction length, thus leading to a pre-pulse-free ultra-broadband amplification, smaller B-integral and a better pulse fidelity. The scheme using OPA to amplify chirped laser pulses is known as optical parametric chirped pulse amplification (OP-CPA). Although low/moderate energy PW class CPA laser systems are now commercially available, the high energy high power laser systems are developed exclusively in-house word wide to facilitate experiments in area of high energy density science.

Laser Plasma Division has developed a CPA/OPCPA based 40 TW hybrid Nd:phosphate glass laser system. The multi-terawatt laser system deliver laser pulses with energy of 24 J in 600 fs (40 TW), at a pulse repetition rate of 1 shot in 20 minutes. An overall gain of the amplifiers in excess of 10^{10} has been achieved. The laser system involve a 100 fs Ti:sapphire laser oscillator (at 1054 nm), a grating pair based pulse stretcher, a single pulse selector, multistage barium beta borate (BBO) crystal based optical parametric amplifiers, several power amplifiers in linear geometry using water cooled Nd:phosphate glass laser rods pumped by air-cooled xenon based flash lamps, spatial filter cum image relay cum beam expander systems, permanent / pulsed magnet Faraday rotator and isolators, beam optics, and finally a large aperture tiled pulse compressor in a triangular geometry (shown in Fig. L.2.1). Except for the femtosecond laser oscillator, all other opto-mechanical and electrical sub-systems of the laser system have been indigenously built in-house. All the sub-systems of this laser are controlled by an in-house developed PC based control system. Stretched pulses are amplified either in a high gain (> 10^7) regenerative amplifier or in a BBO crystal based OPA and multiple Nd:phosphate laser amplifiers. Any tiled optical system, which is to mimic a monolithic optical element, one needs to align and control the individual optical elements to sub-wavelength precision in both, linear translation, and angular rotation. To accomplish this challenging task, two different approaches (techniques of far-field and 2D interferometry) have been developed and compared for performance. Two optical surfaces were aligned with an accuracy of 50 nm (hardware / environment limited) using interferometry diagnostics.

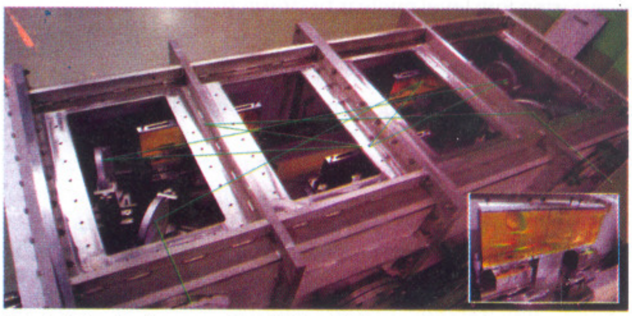

Fig.L.2.1: A photograph of the tiled grating pulse compressor; Insert shows a three grating system.

The compressed laser pulses were temporally characterized using home-built tilted pulse front autocorrelator coupled with a dedicated home-built graphical user interface. The pulse spectrum was measured using a spectrograph and the pulse energy was measured using a pyro-electric energy meter. The spatial profile was recorded on burn paper and was digitally scanned. Figure L.2.1 show typical experimental results on beam parameter measurements in spatial, spectral, and time domain. This laser system will now be used for high energy density physics experiments.

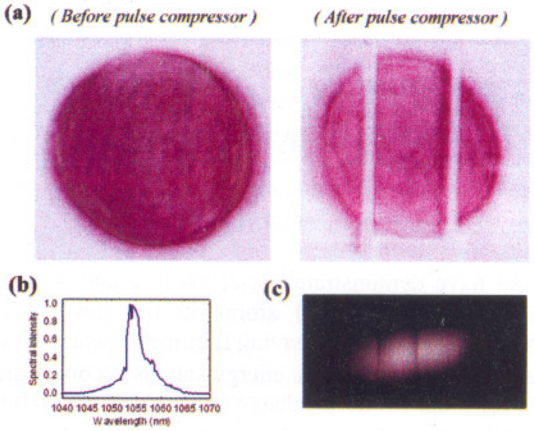

Fig.L.2.2: a) Typical beam profile, b) pulse spectrum, c) Autocorrelation trace

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