Upgradation and Second harmonic conversion of 100GW, 25 ps Nd:phosphate glass laser chain for dual operation at 0.527 μm and 1.054 μm wavelength

High power pulsed Nd:glass lasers delivering peak power of hundreds of gigawatt in multi-picosecond duration pulses are widely used for a variety of scientific investigations such as intense x-ray generation, laser-plasma interaction, nonlinear harmonic generation etc. Second harmonic conversion of the output at 1.054μm is of great interest in view of several advantageous features of laser-plasma interaction using shorter wavelength laser radiation, e.g. better absorption, higher x-ray conversion, less amount of hot electrons generation etc. In addition, conversion to second harmonic greatly increases the peak to foot intensity contrast ratio of the laser pulse, which is required to prevent formation of a low temperature, long scale length plasma on the target prior to the arrival of the main laser pulse. At laser Plasma Laboratory, we had earlier set up a 100 GW, 25ps Nd:phosphate glass laser chain for laser plasma interaction studies. This has been recently upgraded by adding one more amplifier stage enhancing its output power to 160 GW and frequency up-converted it to second harmonic using a KDP crystal. This laser chain can now be operated either at the fundamental (1.054μm) or the second harmonic (0.527μm) wavelength as required for various laser plasma interaction studies.

A schematic diagram of the Nd:phosphate glass laser chain operated in 1.054μm and its second harmonic conversion set-up is shown in Fig.1. A mode locked Nd:YLF oscillator operating in the TEM_{00} mode provides a train of 0.5mJ/25ps laser pulses. After passing through a single pulse selector (PS) and an electro-optic pulse-cleaner stage (PC), the laser pulse is amplified by five stages of Nd:phosphate glass amplifiers (A1 to A5) of successively increasing laser rod diameters from 10mm to 65mm. One spatial filter (SF 1-2) and two vacuum spatial filters (VSF) cum image relay systems are placed in between different amplifier stages to remove high frequency spatial noise from laser beam profile and to minimize the effect of diffraction during propagation. Two Faraday isolators are placed in the laser chain, one after the single pulse selector and the other after the last amplifier, to prevent any back reflected laser radiation from the plasma from entering the oscillator, which could otherwise cause extensive optical damage. The laser beam after the second Faraday isolator passes through a pulsed Faraday rotator (FR) to get the beam polarization either horizontal or vertical as may be required in the laser plasma experiments. A vacuum spatial filter (VSF 5-P) is also incorporated after the Faraday rotator to smoothen the beam profile on the target in the plasma chamber. Power conditioning and temporal synchronization of various amplifier stages and Faraday isolator is accomplished by an in-house built electronic control system. Starting with an oscillator pulse of 0.5mJ in 25ps, the output from the last amplifier is ~ 4J in 25ps (FWHM), i.e. a peak power of ~160 GW. The laser beam diameter after the last amplifier stage is ~ 56mm (FWHM) and the beam divergence of ~100 μrad. This provides a focused laser intensity of ~ 2.5×10^{15} W/cm^2 on the target.

A type I, KDP crystal (45mm×45mm, 22mm thick : grown and cut by LMDDD, RRCAT) has been used to convert the fundamental laser beam into second harmonic. The crystal was cut at phase matching angle of 41°. It was placed in a hermetically sealed housing filled with index matching fluid (FC-32) and having entrance and exit glass windows AR coated at 1.054μm and 0.53μm respectively. Since the laser beam size was larger than the crystal size, a 0.5X de-magnifier (BDM(ω)) was placed before the crystal. The peak input laser intensity for second harmonic conversion was ~ 25 GW/cm^2. An output second harmonic energy of 1J is obtained at input laser energy of 3J, corresponding to a conversion efficiency of ~33%. The change from the fundamental beam at 1.054μm to the second harmonic output at 0.527μm and vice versa can be accomplished by simply inserting / removing the mirror M8 and M11 in the beam path after the last vacuum spatial filter stage. As the laser can be used in both, fundamental as well as in second harmonic, and the beam intensities are comparable, it can be very useful in carrying out experiments on wavelength scaling of various laser-matter interaction processes.

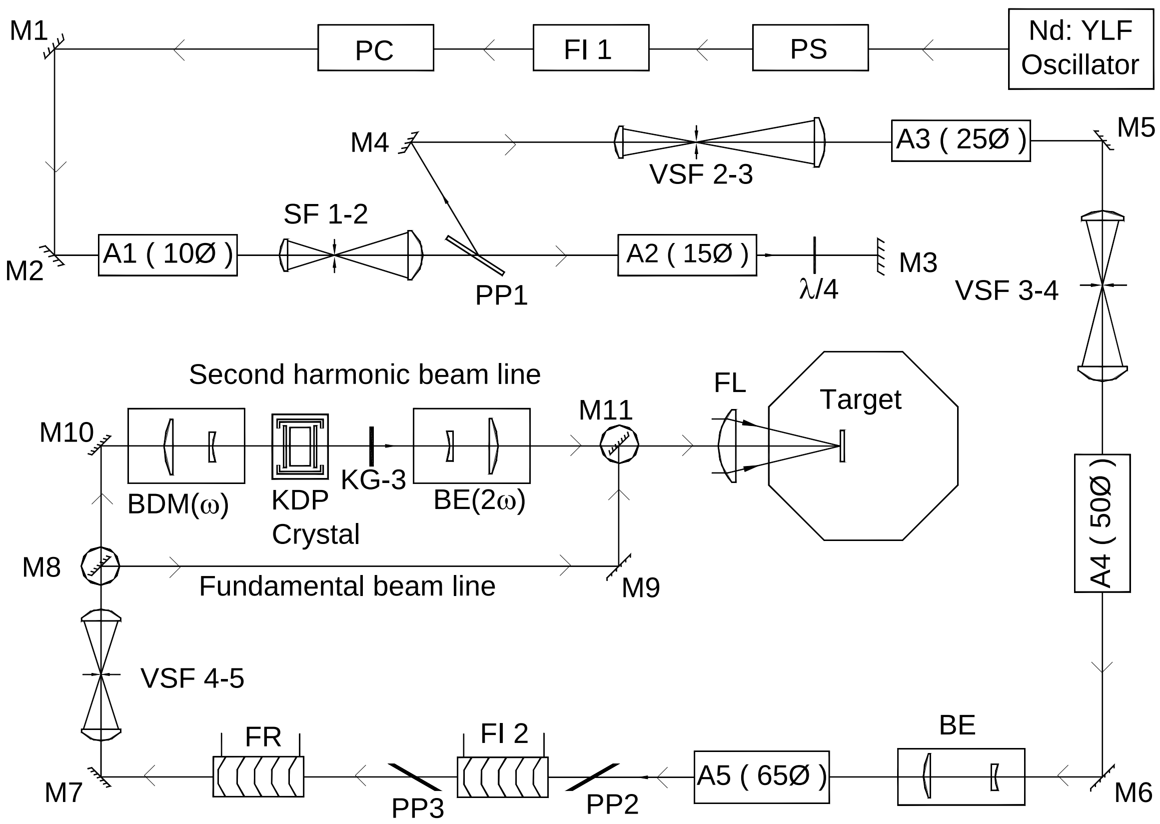

Fig.1: Layout of the Nd:glass high power laser chain including frequency doubling set-up