L.6: Development of 30kV, 22J/pulse Solid State Pulse Power Supply for pulsed xenon chloride excimer laser repetitively pulsed gas Laser

An all-solid-state pulse power supply (ASSPPS) for the excitation of repetitively pulsed gas lasers was designed and developed at Laser Systems Engineering Division (LSED) of RRCAT. This was based on semiconductor device as main switching element (thyristor) followed by a Met-glass core pulse transformer to step up the voltage and a four-stage Ni-Zn ferrite based Magnetic Pulse Compression (MPC) system using associated dc biasing for MPC switches. The pulsed power supply was tested with an Excimer laser. The system operated up to 100 Hz repetition rate and the output voltage rise time is less than 100 nsec at 30 kV and per pulse energy output is 22 J. The ASSPPS system recorded an electrical conversion efficiency of 85% and obtained using commercially available ferrite materials.

The use of all solid-state pulse power supply offers several advantages over conventional excitation circuits. ASSPPS employs solid-state switches, which are combinations of high power semiconductor switches, and magnetic switches. These are less expensive and more reliable, and are able to operate at high repetition rates. They do not have lifetime limitations also. Moreover, there is no warming-up time required as in the case of thyratron.

Figure L.6.1 shows the schematic of the All- Solid State Pulse Power Supply. The pulse generator section consists of a distributed gate fast thyristor (NGR395CH18F2KO9829) as main switching device, 72 uF/2 kV energy storage capacitor C_0, a magnetic assist (L_A), high voltage step-up pulse transformer having a turns ratio of 1:34, resistance-diode clamp and R-C snubber. The MPC section consists of 4 stage pulse compressors using 48 nF/40 kV high voltage capacitor (C1-C4), and non-linear inductor with Ni-Zn ferrites (L1-L4). These saturable inductors used are made of 20 nos. of Ni-Zn ferrite cores of dimensions OD=150 mm, ID=100 mm and 15 mm thick. The no. of turns of these saturable inductors are 27, 9, 3 and 1 respectively. The energy storage capacitor C_0, is initially charged by a 1200V, 6 kJ/sec, constant current capacitor charging switch mode power supply. At the end of charging, the thyristor is turned on and energy stored in the capacitor will be discharged in the primary, as shown in Fig.L.6.2 and simultaneously charges the secondary side 48 nF/40 kV capacitor C_1 to 34 kV in 8μsec, shown in Fig.L.6. 3. The pulse transformer is made-up of met-glass and all the four stages of MPC are made by Ni-Zn ferrites (CMD 5005).

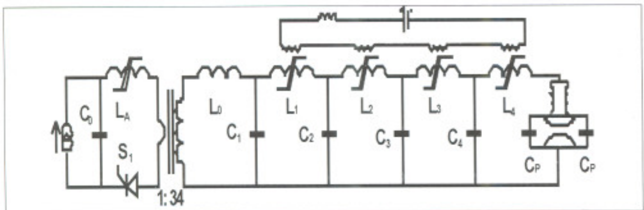

Fig.L.6.1 : The Schematic power circuit of All Solid State Pulse Power Supply (ASSPS).

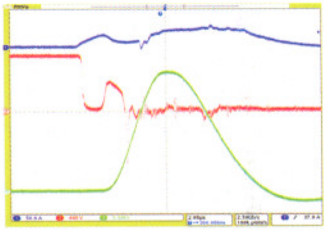

Fig.L.6.2: Experimental result with RC and spark gap load. Ch1: Thyristor Gate Current 50A/div., Ch2: Anode Voltage 400V/div. and C1 charging voltage 5kV/div. time 2usec/div.

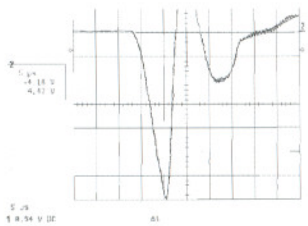

Fig.L.6.3 : Experimental result with actual load (Excimer laser). Ch2 : C1 charging voltage 5kV/div. time 5usec/div.

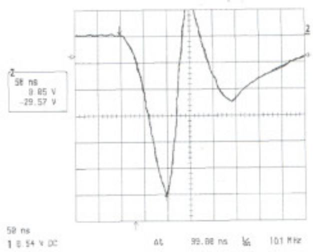

Fig.L.6.4: Experimental result with actual load (Excimer laser). Ch2: Voltage at Laser Head

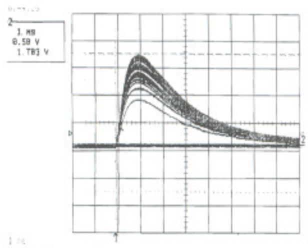

Fig.L.6.5: The Laser Output pulse energy (Excimer laser). Ch2: 50mJ/div. time 1msec/div

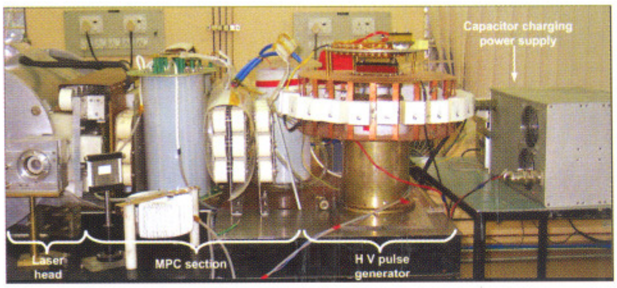

Fig. L.6.6: All Solid State Pulse Power Supply Prototype

A magnetic assist L_A is used to delay the thyristor anode current by 1.5 usec. The input to MPC1 (C_1) is 34kV pulse with a rise time of 8μsec and it is compressed to less than 100 nsec using four-stage MPC as shown in fig.L.6.4. Each MPC stage has a gain of around three. The over all gain of compression stages is around 80. All the saturable cores are re-setted using a 5A DC current source to get maximum flux density swing.

The laser output pulse is shown in fig.L.6.5 is measured with pyro-electric detector. The measured output energy was 150mJ/pulse at 100 Hz. Fig.L.6.6 shows the first prototype of this power supply.

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L.7: Development of 300J pulse energy long pulse Nd: YAG Laser

The diode-pumped Nd:YAG and fiber lasers are not easy to operate in high energy, long pulse mode due to switching requirement of pump diodes. Therefore, flash-lamp pumped pulsed Nd:YAG lasers with long pulse duration in the millisecond range are still important for various material processing applications. For deep penetration welding applications, it is desirable to have high energy and long duration pulses. However, beam quality from high power Nd:YAG lasers is limited by strong thermal lensing and stress induced birefringence. Further, power scaling from single Nd:YAG rod is limited due to pump input and available rod length defined by thermal fracture limit of the rod, which is ~ 200 W/cm. Thus, power scaling can be achieved by using multi-rod resonator or master oscillator power amplifier configuration (MOPA). Although, it is easy to design MOPA configuration, but due to variation in thermal focal length of amplifier stage with variation in input pump power, it is difficult to achieve fiber optic beam delivery for the entire range of pump power. Thus, for fiber optic beam delivery, it is a better choice to use multi-rod resonator. It has already been reported that two-rod resonator with plane-parallel configuration has a wide stable range, when the two rods are symmetrically positioned inside the resonator. We have carried out design and development of a pulsed Nd:YAG laser providing 300 J of pulse energy with 40 ms pulse-duration using dual-rod resonator configuration.

There are two identical pump chambers within the laser resonator. Each pump chamber is having a Nd:YAG rod, a lamp, and two halves of gold plated elliptical reflector. Each pump chamber contains 1.1 at.% Nd-doped rod of 10 mm diameter and 150 mm length. In each of the pump chambers, a 10% samarium oxide doped glass plate is inserted between the lamp and rod to absorb the UV radiation from the lamp and convert the UV radiation into the useful visible light, thereby contributing to the laser output power. Both the pump chambers were cooled by closed-loop de-ionized water chillers. Two high voltage power supplies with master-slave configuration and rectangular current pulse profile of variable duration from 2 ms to 40 ms along with capability of pumping both the cavities synchronously has been used. Figure L.7.1 shows the schematic of symmetric dual cavity resonator and Fig. L.7.2 shows a view of the in-house developed. 300 J pulse energy Nd:YAG laser with fiber optic beam delivery. Dual cavity resonator is constructed using a plane-plane

Fig. L.7.1: A schematic of the symmetric dual cavity resonator.

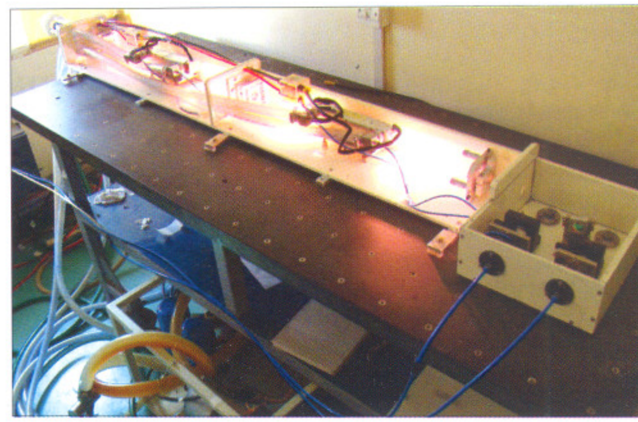

Fig. L.7.2 : A view of the in-house developed 300 J pulse energy Nd:YAG laser with fiber optic beam delivery.

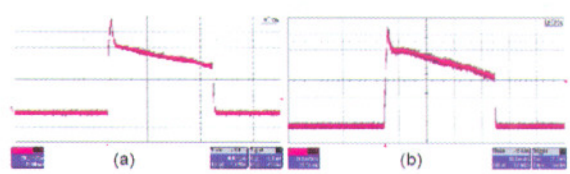

Fig.L.7.3 : (a) Flashlamp pump-pulse, and (b) laser output pulse of 300 J, 40 ms fiber-coupled pulsed Nd:YAG laser.

symmetrical configuration with d: 2d: d configuration, where d is the distance between mirror and the principal plane of the rod.

Figure L.7.3 shows the pump pulse and laser output pulse for 300 J pulsed Nd:YAG laser with fiber optic beam delivery. With dual rod resonator, a maximum average output power of 500 W was achieved with maximum pulse energy of 300 J at 40 ms pulse-duration. Maximum peak power of this laser is 10 kW. Laser pulse duration can be varied from 2-40 ms with variation in pulse frequency from 1-100 Hz. Output pulse energy varies linearly with increase in input pump energy. Electrical to laser conversion efficiency is about 5% with beam quality of better than 20 mm.mrad for the whole range of operation from 0-10 kW. Laser beam has been delivered efficiently through an optical fiber of 400 μm core diameter and 0.22 numerical aperture with 90% transmission at the fiber exit end. There are two fiber ports, which can be used on time sharing basis for different applications. Laser cutting up to a depth of ~ 20 mm and welding in SS up to a