In the present oscillator design, by applying a 3.4 kV single step pulse to the DPC of cavity dumper, one obtains laser pulses of duration of 800ps (governed by rise time of the HV step pulse). The laser cavity was dumped at a stable point (~4 round trips after the peak pulse buildup) of pulse buildup to minimize the fluctuation in energy of output pulse. Shot-to-shot rms fluctuation was ~2.5% in pulse height over 30 shots has been observed, which may be further reduced by minimizing the fluctuations in the flash lamp output and increasing the pump energy or optimizing the loss level of the cavity. The output laser pulses were synchronized with chirped laser pulse train (100 MHz pulse repetition rate) of 250 ps duration pulses derived from an independent cw mode locked glass laser oscillator (Fig.L.5.2). The temporal jitter between two pulses was measured to be ~200 ps, which is limited by the speed of the electronics circuitry. The oscillator design will be modified to get single longitudinal mode operation and super-Gaussian spatial and temporal profile of output laser beam for efficient optical parametric amplification.

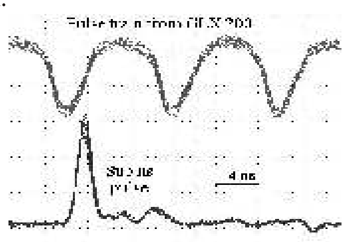

Fig.L.5.2: The laser pulses of sub-ns duration from the cavity dumped oscillator and 250 ps duration laser pulse train derived from an independent femtosecond laser oscillator.

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L.6 : Development of an efficient cw Nd:YAG laser

Solid State Laser Division of RRCAT is engaged in development of high power lamp-pumped cw and pulsed Nd:YAG laser systems for various material processing applications related to DAE. Over the past few years, our home-built pulsed Nd:YAG laser with 250 W average power and 5 kW peak power having multi-port fiber optic beam delivery has been established as a work horse for cutting of up to 14 mm thick stainless steel (SS) and up to 2 mm welding depths in SS and has been efficiently utilized for Indian nuclear power programme, as well as for various industries. However, for a few applications such as deep penetration welding (~5-10 mm) and laser rapid manufacturing, kilowatt power level cw Nd:YAG lasers with fiber optic beam delivery have been recognized as an efficient tool. In an initial effort to fulfill such applications, a cw Nd:YAG laser with maximum output power of 880 W, having an M^2 value of ~110, and 4.4% electrical to laser conversion efficiency, has been developed. The output beam has been efficiently delivered through a 600 μm core diameter optical fiber with a transmission efficiency of 90%. It may be noted that in most of the commercial lamp pumped cw Nd:YAG laser systems, the reported efficiencies are about 3-3.5%. This laser system is based on multi-rod resonator configuration in which two pump cavities have been placed in beam imaging configuration in an optical resonator. Each pump cavity has been individually optimized for maximum efficiency and good beam quality for input pump power from 0-10 kW by means of spectral conversion using a samarium flow tube over the rod and water flow optimization to reduce thermal lensing. Both the pump cavities have been made approximately identical to double the output power and to achieve the same beam quality as from a single pump cavity. During initial welding trials with this system, weld depths of ~1.5 mm with 2 mm weld bead size have been achieved. This laser system is being engineered with safety features and interfacing with CNC work station for commissioning at Material Science Division, BARC, for laser rapid manufacturing.

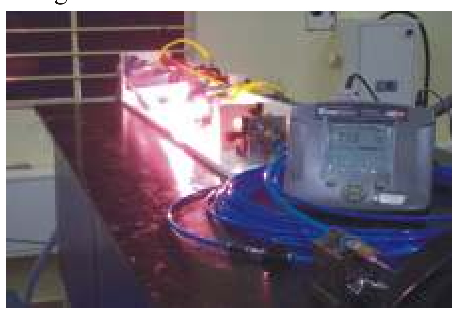

Fig.L.6.1: A view of the cw Nd:YAG laser giving a maximum power of 880 W.

Figure L.6.1 shows a view of developed Nd:YAG laser system. Fig.L.6.2 shows the variations of laser output power as a function of input pump power and Fig.L.6.3 shows M^2 value as a function of input pump power. It may be noted that the output power varies approximately linearly over the whole range of operation and may be used at any power level below the maximum value of 880 W.

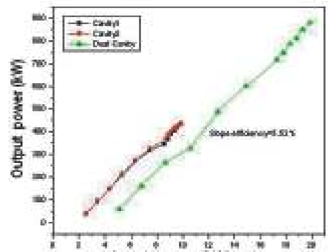

Fig.L.6.2: Output power as a function of input pump

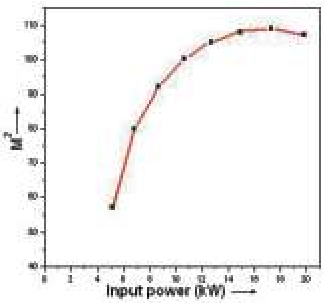

Fig.L.6.3: M² value as a function of input pump

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L.7 : Development and characterization of highly efficient diode-side-pumped cw Nd:YAG laser

Diode-pumping of solid-state lasers offers several advantages such as high optical-to-optical efficiency, long lifetime of laser diodes, and the realization of compact laser system over conventional flash / arc lamp-pumped systems. In order to achieve higher overall efficiency of the system, the pumping efficiency of the pump cavity and pumping uniformity over the rod cross-section is very important. The requirement of better pumping uniformity plays a dual role in providing uniform thermal load in the gain medium and better extraction of the available laser power in the upper laser level for the given resonator geometry. Keeping the above requirement in mind, Solid State Laser Division of RRCAT has developed a highly efficient copper coated optical pump cavity for continuous wave (cw) operation of high power Nd:YAG laser generating 375 W of output power for a diode pump power of 750 W. This corresponds to an optical-to-optical efficiency of 50% and the electrical-to-optical efficiency of 26%. These efficiencies are the highest reported to the best of our knowledge using 4 mm Φ x 100 mm Nd:YAG rod.

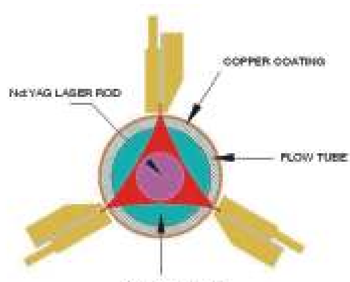

Fig.L.7.1: Schematic of a threefold symmetric pump configuration

The pump head geometry was made up of copper-coated flow tube with three windows of < 1 mm width. Windows are located along the length of the tube and they are at 120 degrees with respect to each other as shown in Fig.L.7.1. Pump light is coupled to the active medium through these windows. The tube is of internal diameter of 8 mm and outer diameter of 10 mm. In the absence of such reflective coatings, the pump beam travels only once through the gain medium. Depending upon the rod size and doping concentration, the absorption of the pump beam varies. Hence, the rest of unabsorbed pump beam is lost, accounting for inefficient coupling of pump beam to the active medium. The pump sources were configured as horizontal stacks of pump diodes, with each stack containing six numbers of 40 W diodes as shown in Fig.L.7.2. The coolant temperature was maintained at 19°C, for both active medium and pump diodes. At this temperature, the central wavelength of the diode modules is about 805.4 nm at the maximum driving current. Although the centre wavelength deviates from the absorption peak of the Nd:YAG laser medium (808.5nm), the output power is maximum due to wing-pumping method. In this method, peak diode emission wavelength is set near the edges of the peak absorption line of Nd:YAG to take advantage of better pumping uniformity over the cross-section of the laser rod.

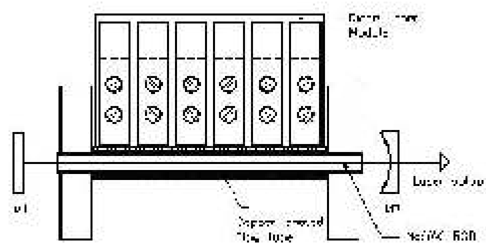

Fig.L.7.2 : Side view of the laser pump head showing only one diode laser module for the sake of clarity and plano-concave resonator for multimode operation

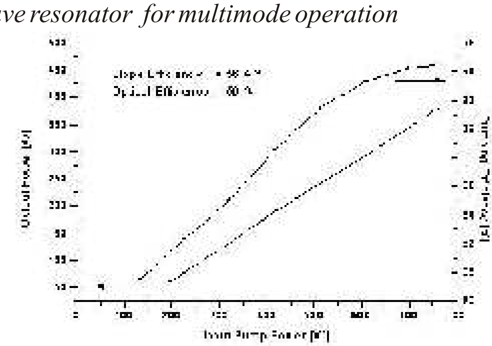

Fig.L.7.3 : Characteristics of the output power and pumping efficiency versus input pump power

The Fresnel loss due to coupling of diode light through flow tube was minimized by using p-polarized diode light. In order to find out the effectiveness of the pumping scheme with polarized pump beam, the pumping efficiency