(η_p) was measured by the "pump power leakage" technique. The pumping efficiency is defined as the ratio of the power absorbed by the rod to the total diode pump power. The pump power leakage from the window of the coated flow tube with 400-µm core fiber, which was directly coupled to the power meter with a filter to block the rod's fluorescence, was measured. The pumping efficiency, as the ratio between the leakage powers from the Nd:YAG rod and that of the reference rod, was estimated and it is approximately ($1-\eta_p$) as shown in Fig.L.7.3. The pump-power-dependent η_p varies from 79% to 94%. The high efficiency of the system can be attributed to wing-pumping method resulting in uniform pump light distribution and better pumping efficiency due to p-polarized pump beams. The resonator was a close-coupled geometry with plane mirror as highly reflecting mirror and 5 m radius of curvature 85 % reflectivity as output coupler mirror. The length of the resonator was 135 mm. The beam quality factor (M^2) was measured to be < 70. Fig.L.7.4 shows the photograph of the system in operation.

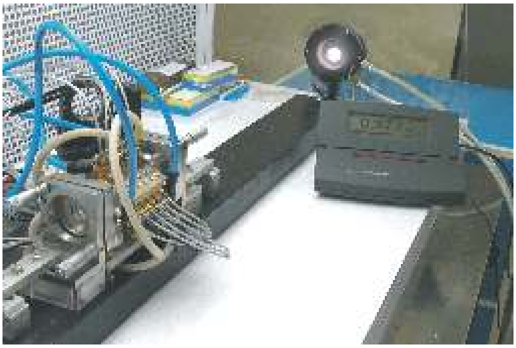

Fig. L.7.4: Photograph of the system in operation

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L. 8 : Development of a sealed-off copper bromide laser

Copper bromide (CuBr) laser is a low temperature variation of copper vapour laser (CVL). In a CuBr laser, copper atoms (lasing medium) are generated in a discharge by dissociation of CuBr molecules. Sealed-off CuBr laser has several advantages over elemental CVL. The sealed-off system eliminates the need of gas and vacuum handling system for the operation of the laser. Operating temperature of the laser tube is around 550 ^{0}C as against 1500 ^{0}C for elemental CVL. Thus, the high temperature problems associated with the laser head are not very severe. The warm up time of the laser system is reduced from around 60-90 minutes (for elemental CVL) to around 10 minutes. The discharge in CuBr laser tends to give better beam quality and higher wall plug efficiency as compared to elemental CVL. Considering these advantages, development of sealed-off CuBr laser was taken up in Laser Systems Engineering Division of RRCAT. A sealed-off CuBr laser delivering 4 W average output power has been developed

Schematic diagram of the laser discharge tube is shown in Fig.L.8.1. It is of fused silica and has 37 mm inner diameter, and the total length of the tube, including the extended window region, is 115 cm. There are five side arms on the discharge tube. The outer most side arm pair is used as electrode pair and middle three are used as CuBr reservoirs. Inter-electrode separation is 50 cm. The electrode pin is of tungsten and is surrounded with OFHC copper turnings**.** The electrodes were sealed to the tube through "tungsten-molybdenum foil fused silica" sealing, which can carry an r.m.s. current of up to 20 A. A thin layer of alumina fibre blanket is wrapped around the laser discharge tube over the discharge zone to avoid heat losses. At the ends of the laser discharge tube, fused silica windows are attached at ~5^0 to prevent undesired resonator formation by feedback from the windows. The three middle side arms are loaded with ~50 g of distilled crystals of CuBr (purity > 99%). External electrical heater is used on these side arms to externally heat them in a controlled way to control the pressure of CuBr vapour in the discharge zone.

Assembly of the laser discharge tube was tested to have a leak rates less than 10^{-9} mbar-ltr/s. It was cleaned by discharge processing and evacuation cycles for about 30 hours before sealing. The laser discharge tube thus processed was sealed with neon buffer gas at 28 mbar pressure. The sealed -off lifetime depends on the mass of the CuBr loaded, vacuum integrity of the electrodes, window coatings, and bromine partial pressure. The laser is operated with CuBr reservoir temperature of around 435 ^{0}C. The laser system is shown in photograph in Fig.L. 8.2.

A high voltage, air cooled, pulsed power supply, operating from single phase mains, has been developed for this laser. Insulated Gate Bipolar Transistor (IGBT) rated for 1200 V, 400 A is used as the pulse power switch and two stages of magnetic pulse compressors are used to obtain pulse voltage of 12 kV with a rise time ~100ns across the laser discharge. Although the power supply has average power capacity of 1.1 kW, the laser is normally operated at around 600 W of average electrical power, at 17 kHz pulse repetition rate. The power supply is accommodated in a 19 inch standard sub-rack with height ~267mm.

The sealed-off CuBr laser is operated with a plane–plane resonator and it gives a maximum average power of 4.5W. During initial 100 hours of operation, the laser power was almost constant. The average laser power reduced from 4.5 W to 3.5 W during the next 100 hours, under the same operating conditions. This power drop is due to the deposition on the discharge tube windows from inside.

The laser can be used for applications like marking on different type of surfaces. Oscillator - amplifier set up of two such CuBr lasers can be used for various micro-machining applications.

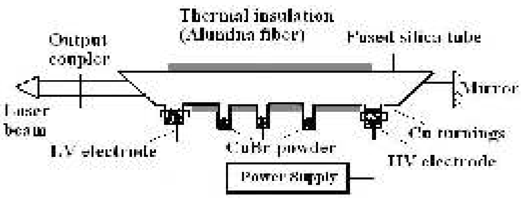

Fig.L. 8.1: Schematic of the CuBr laser

Fig.L.8.2 : Photograph of the sealed-off CuBr laser

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L.9 : Development of Red Diode Lasers

Red diode lasers operating at 670 nm wavelength have been developed at Semiconductor Laser Section of RRCAT. The complete laser structure was grown by metal organic vapour phase epitaxy (MOVPE) technique.

A typical red laser consists of 8 nm thick InGaP quantum well (QW) sandwiched between undoped AlInGaP quaternary waveguide layers. The InGaP QW structure was further sandwiched between n and p type cladding InAlP layers. The epitaxial layers were characterized using several techniques like photoluminescence, surface photo voltage and high resolution x-ray diffraction techniques. The ionized doping and free carrier density were estimated from Hall and ECV experiments. The net ionized doping was also estimated at different depth of the laser diode structures using ECV. Laser diodes were fabricated through standard procedure using photolithography process. Laser diodes were tested for light versus current and longitudinal characteristics using a homemade current source. Laser diodes with different cavity lengths and widths were also developed and tested for measuring the device parameters. About 100 mW peak power was measured for the indigenous laser diodes operating at 670 nm.

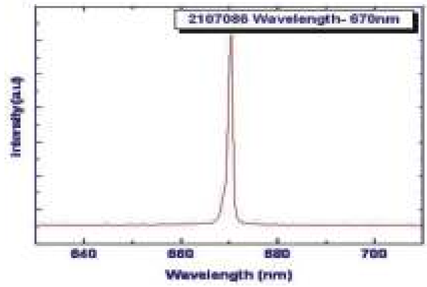

Fig.L.9.1 : A typical lasing spectrum for indigenous red laser diode.

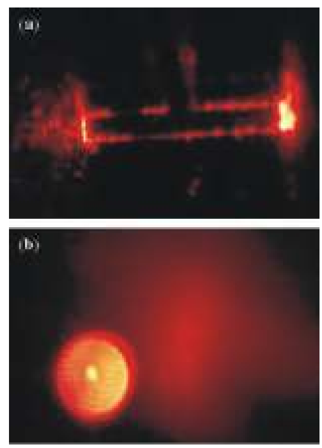

Fig.L.9.2 : Photographs of red laser diode (a) showing emitting light from both facets. (b) photograph of laser diode beam.

Fig.L.9.1 shows a typical longitudinal spectrum. Fig.L.9.2a shows photographs of the red laser diode showing emitting light from both facets and Fig.L.9.2b shows photograph of the laser diode beam.

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L.10: MOVPE growth of quantum dot Structures on GaAs substrate

a. InAs quantum dots :

InAs quantum dots (QD) have been grown on GaAs substrates using MOVPE technique, at the Semiconductor Laser Section of RRCAT. QD structural parameters were fine tuned by varying various growth conditions like In As layer coverage, growth temperature, V/III ratio, growth rate and