The slope efficiency curve was highly linear without any sign of power rolling-off. However the heat load at the KTP crystal was very high because KTP has significant absorption at 532 nm. This shifts the phase matching direction significantly away from the resonator axis and the green power could not be scaled up further by increasing the pump power. Moreover, at this high power the formation of gray tracks and subsequently damage of the KTP crystal is highly probable. Hence efforts are currently in progress for simultaneous cooling arrangement for the KTP crystal.

Contributed by:
P. K. Mukhopadhyay (pkm@cat.ernet.in),
S.K.Sharma, K.Ranganathan, and S.M.Oak

L.9 : Demonstration of > 3.4 mW laser at 266nm by intracavity doubling

Solid State Division has demonstrated an all solid-state Single Longitudinal Mode (SLM) UV laser at 266nm with more than 3.4mW output power by intracavity doubling of single frequency green laser at 532nm in a frequency locked slave ring cavity. Fig.L.9 shows the schematic of the set-up. The major parts of the design were the diode pumped single frequency pump laser at 532nm and the frequency locked slave ring cavity. Special design techniques were used to generate the required single frequency CW pump laser at 532nm with the highest ever-reported optical-to-optical conversion efficiency from 809nm pump laser to 532nm. Hansch-Couillaud frequency locking technique was used for frequency error signal generation and special home-made control electronics with SCAN/LOCK facility was used both for slave cavity fine-alignment and frequency locking.

The single frequency pump laser was based on a diode end pumped Nd:YVO_4/KTP laser along with an intracavity Brewster plate. Special design techniques were adopted to enhance the optical-to-optical conversion efficiency at 532nm in the CW single frequency operation with respect to the absorbed pump power at 809nm. This includes selection of a proper V-shaped cavity allowing larger focussing ratio in the NLO crystal, utilization of short absorption depth effect in the semi monolithic gain medium, active etalon effect in the gain medium with 66GHz FSR, a loss discriminating type of birefringent filter based on KTP/Brewster plate with 250GHz FSR and a gain discriminating type of birefringent filter based on a-cut Nd:YVO_4/KTP crystal with 250GHz FSR etc. These measures along with the gain aperture effect in the gain medium resulted in highly efficient single frequency laser at 532nm with more than 271mW of output power from an absorbed pump power of 934mW at 809nm. Accounting for the 86% transmission efficiency of the collection optics at 532nm, the estimated optical-to-optical conversion efficiency was 33.7%. The highest efficiency reported in single frequency laser at 532nm is 29.3% with only 55% useful output at 532nm, and is based on a linear cavity. The useful output was 86% in our design and was limited mainly by dielectric coating on the green output coupler. The single frequency operation was confirmed by analyzing the spectral output at 532nm using a scanning confocal FPI with a finesse of 200 and FSR of 1.5GHz (Coherent). The measured beam quality factor at 532nm was 1.07 using Mode-master from Coherent and was nearly circular in shape.

Intracavity doubling in a frequency locked slave ring cavity was used to generate SLM 266nm. Hansch-Couillaud scheme was used for the frequency locking of the slave cavity with the free running single frequency laser at 532nm. We used a Bow-Tie-Ring cavity geometry for the slave cavity, and also ensured proper mode matching and optimum impedance matching. A plane-plane input coupler (M4) with 2.1% transmission at 532nm resulted in impedance matching of the pump beam with the slave cavity. In order to generate frequency error signal with sufficient magnitude, the polarization of the incident beam was rotated by ~10^0 with respect to the polarization supported by the ring cavity with in intracavity Brewster cut SHG crystal by means of a Half Wave Plate (HWP) at 532nm. Since 100% mode-matching results is zero magnitude frequency error signal in an impedance matched cavity and maximum possible real enhancement factor (ratio of circulating pump power to the incident pump power at 532nm in this case), an optimum value of mode matching (lower than 100%) is necessary to optimize frequency error signal and the real enhancement factor. A beam transfer optics with 10X magnification resulted in an optimum mode matching of ~81.6%. Though the incident pump power was only ~200mW(on the ring cavity), the circulating pump power at 532nm was estimated to be ~7.9W resulting in a real enhancement factor of the cavity of ~39.5. The theoretically expected value of real enhancement factor based on the input coupling and the mode matching was ~38.8 for the same configuration and was found to be closely matching with the observed value within 2%.

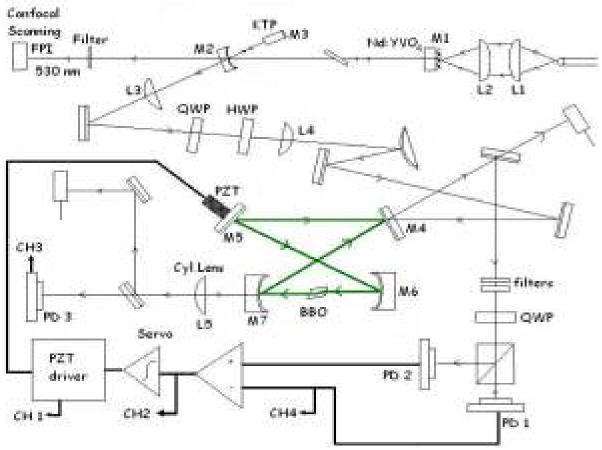

Fig.L.9 : Schematic of an all-solid-state SLM UV laser by intra-cavity doubling in a frequency locked slave ring cavity.

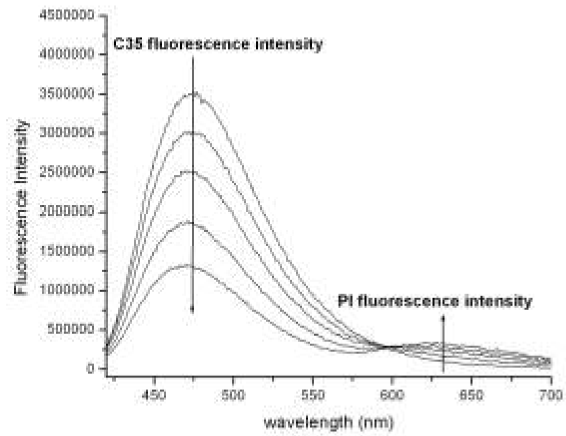

Figure L.10.1: FRET between C35 doped Si-NP and DNA labeled with PI. The arrows denote successive addition of DNA.

A relatively new concept to design optical resonators, known as the Degree of Optical Stability (DOS) or the S parameter has been used. This express the stability in a numerical scale ranging from zero to 100% with 100% corresponding to $g_1 g_2$ of ½ (Thermal lens insensitive design) and zero corresponding to marginally stable cavity. It was also found experimentally that the misalignment tolerance of a resonator is larger if the S parameter lies in the range of 60%-100%. For example, the ring cavity under consideration had ~100% DOS in the sagital direction and it was ~94% in the tangential direction. The equivalent free space distance between the curved mirrors (M6-M7) was ~109.1mm and the total length of the cavity was ~823mm.

The system generated more than 3.4mW of SLM UV laser at 266nm from an incident pump power of 200mW at 532nm. Accounting for the 26% reflection at the Brewster surface for the s-polarized UV laser at the BBO crystal, the effective collection efficiency at 266nm was only 71%, and so the estimated value of the generated UV power was ~4.78mW at 266nm. The measured short-term power stability was ~1% over 24 s.

In conclusion, an all solid-state SLM UV laser at 266nm has been demonstrated with more than 3.4mW output power by resonant cavity doubling of a highly efficient single frequency green laser at 532nm generated by diode end pumping an Nd:YVO_4/KTP laser with a 1W laser diode at 809nm.

Contributed by:
J. George (jogy@cat.ernet.in) and S.M.Oak

L.10 : Preparation of dye-doped silica nanoparticles and exploration of their use as fluorescent probe

Silica based nanoparticles, being biocompatible and non-toxic, are receiving considerable attention for possible applications in bio-imaging and drug and gene delivery. To initiate activity in this direction, Bio-Medical Applications and Instrumentation Division has prepared silica nanoparticles (Si-NPs) in the hydrophobic core of a micellar template. Transmission electron microscopy showed a narrow size distribution with >60% particles having a diameter of ~26 nm. The Si-NPs were loaded with a fluorescent dye, Coumarin 35 (C35), and functionalized with a positively charged amino group so that they can bind to negatively charged DNA. To confirm the binding of Si-NPs with DNA, fluorescence resonance energy transfer (FRET) between the C35 (loaded in the core of the Si-NPs) and propidium iodide (PI) which is used as a stain for DNA, was investigated. Fig.L.10.1 shows the reduction in fluorescence of C35 and appearance of the band at 625 nm (that is characteristic of PI fluorescence) with an increasing concentration of DNA labeled with PI. The observation of FRET between C35 & PI confirmed electrostatic binding between DNA and the amine functionalized Si-NPs.