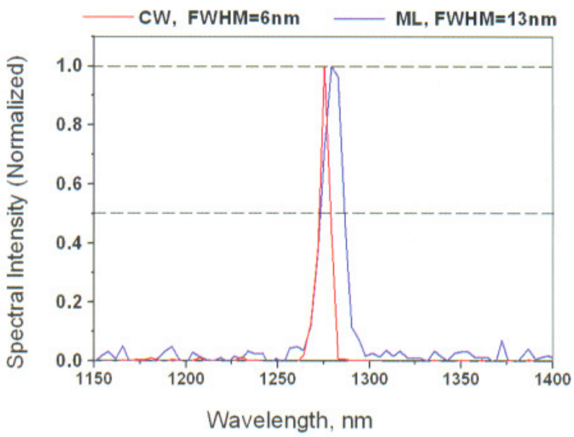

Fig.L.9.3. Wavelength spectra in KLM regime with FWHM of 13 nm at 1280 nm.

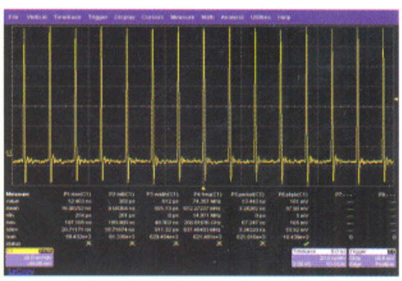

Fig.L.9.4. Temporal spectra of KLM laser recoded with 0.5 ns photodiode FPD510.

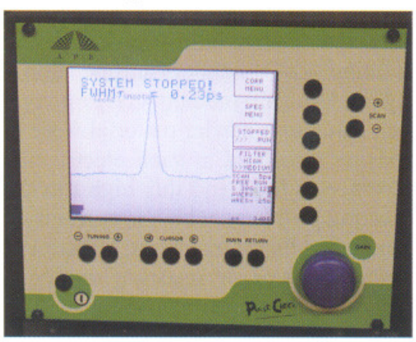

Fig.L.9.5. Autocorrelation trace of ultrafast laser at 1280 nm showing 230 fs FWHM for Sech^2 pulse shape.

The Fourier transform limited pulse duration for 13 nm wide pulses at 1280 nm is ~133 fs. The observed pulse duration of 230 fs may be due to uncompensated positive GVD present in the system. Optimised system operates for arbitrary time ranging from 2 to 5 minutes, decided by the level of environmental perturbation to the cavity. Efforts to reduce pulse duration < 150 fs and to enhance the operational lifetime are underway.

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L.10: Random Lasing in ZnO Nanoparticles

Random lasing (v rl) phenomenon observed in scattering semiconducting gain media such as ensemble of ZnO nanoparticles has recently attracted great deal of attention for the development of Nano-lasers operating in UV spectral region due to their potential applications in to integrated photonic circuits and laser display systems. A unique advantage of random lasers compared with conventional lasers lies in their low-cost and simple processing technology. In contrary to conventional lasing, the random lasing does not require optical cavities and rather feedback loops are formed in the scattering media for the stimulated emission to get amplified. These close loops are formed when the scattering mean free path becomes equal to or less than the wavelength of the emitted light, making the light to return to the scattering point from which it got scattered earlier and thereby forming closed loops paths. If the amplification along such loops exceeds the losses, the laser oscillation could be sustained. The requirement of the phase shift along the loop being equal to an integral multiple of 2π determines the oscillation frequencies. Such random lasers emit light with a reasonably good degree of coherence in the active random medium which in the present case is ensemble ZnO nanoparticles of mean radii ~ 5 nm. Results of our studies on this RL are briefly presented in this report.

The ZnO nanoparticles were grown by wet chemical method using Zinc acetate as precursor for Zinc and without any capping agent. The TEM micrograph and Selected Area Electron Diffraction (SAED) pattern of ZnO nanoparticles are shown in Fig. L.10.1.

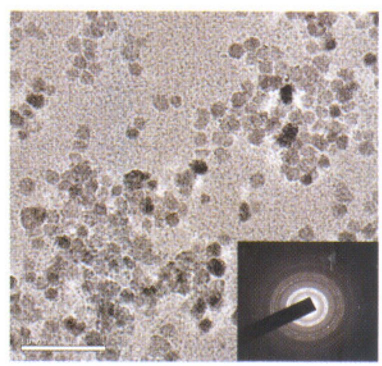

Fig. L.10.1. Transmission electron micrograph of ZnO nanoparticles of size ~ 5 nm. Inset shows the corresponding Selected Area Electron Diffraction (SAED) pattern of the same.

As grown ZnO nanoparticles were cold pressed to form dense pellet. The optical pumping of ensemble of ZnO nanoparticles was carried out using a pulsed KrF excimer laser of varying energy operating at 248 nm, 30 ns pulse width and at 10 Hz repetition rate. The schematic of setup for optical pumping is shown in fig. L.10. 2. The pump laser was focused to a diameter of about 2 mm and resulting emission was collected and detected using a ½ m spectrograph with a resolution of ~ 0.01 nm coupled with UV sensitive and peltier cooled UV enhanced CCD detector.

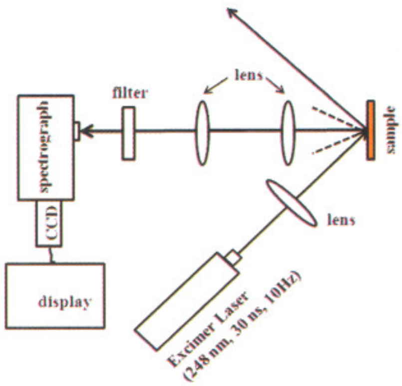

Fig. L.10.2. Schematic of experimental arrangement for observation of random lasing in ZnO nanoparticles at our Laboratory.

The evolution of photoluminescence from the ensemble of ZnO nanoparticles as a function of pumping intensity is shown in Fig. L.10.3. It can be seen in this figure that initially at low pumping intensities the PL spectrum consisted of a single broad spontaneous emission due to excitonic recombination which is centred at ~ 380 nm. The line width of this PL peak is found to be ~ 15 nm which is expected in these nanoparticles due to size dispersion. When the pumping intensity exceeded a threshold value which in our case was found to be ~ 6 MW/cm^2, sharp peaks emerged in the emission spectrum. The line width of these peaks was found to be much narrower which is ~ 0.15 - 0.3 nm as expected due to preferential amplification at the frequencies close to the gain spectrum. With further increase in the pump intensity beyond this threshold the total emission has increased much more rapidly with pump power. Fig. L.10.4 shows the variation of emission intensity with increasing excitation intensity in ZnO nanoparticles. It can be clearly seen in Fig. L.10.4, that

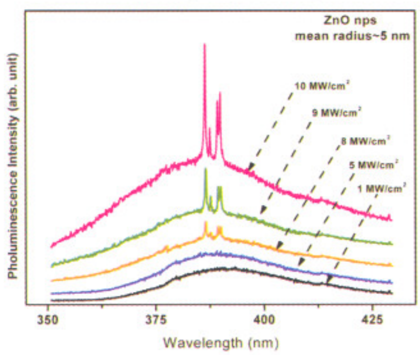

Fig. L.10.3. Photoluminescence spectra of ZnO nanoparticles at different pumping intensities.

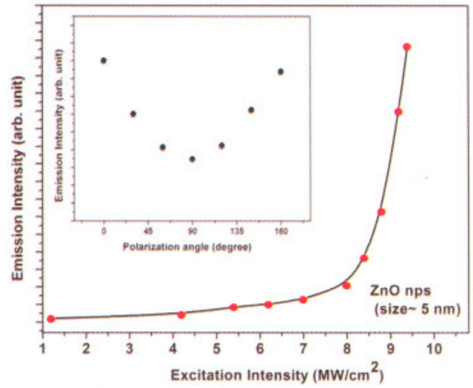

Fig. L.10.4. Photoluminescence peak intensity as a function of pumping intensity. Inset shows PL peak intensity as a function of polarization angle.

there is steep increase in the output intensity as the pump intensity exceeds the threshold value of ~ 6 MW/cm^2. Such a drastic increase in emission intensity and spectral narrowing, which has been observed in our case could also be due to amplified spontaneous emission rather than true lasing as reported in laser crystal powders. To confirm the random lasing we have studied the polarization dependence of emission intensity and the results are shown in the inset of Fig. L.10.4. It can be seen in the inset of this figure that the emission above the threshold is strongly polarized which is confirmation of random lasing.

Recently there have been a few reports on the electrically pumped random lasing in ZnO nanostrutures. In these studies a Metal-Insulator-Semiconductor (MIS) structure containing ZnO nanocrystalline thin films as semiconducting random gain medium and thin layer of MgO or SiO_2 etc as an insulating barrier material were employed. However, the lasing threshold in such electrically pumped random lasers was very high and this high threshold could cause serious heating problems which is currently an area of research. It is expected that if insulating material is replaced by a p-type semiconductor or resistive semiconductor of larger bandgap, the threshold of lasing will go down drastically. Realization of low threshold electrically pumped ZnO based UV random lasers is expected to provide a cost-effective promising light source for the integration of UV photonics and practical laser display. In our laboratory we are currently carrying out studies to develop electrically pumped random lasers based on ZnO and its variants. In this structure doped $Mg_xZn_{1-x}O$ layers will be used as barrier layers and additional scattering centres such as metal nanoparticles will be introduced in the random gain medium of ZnO nanoparticles to achieve lower threshold for the electrical pumping.

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