L.9: Fiber Laser Pumped Cr:F based Femto-Second Laser

Ultrasfast broadband light sources at 1.3 μm are important for studies of fibers and photonic devices, as well as for biomedical imaging. To realize ultrafast pulses (< 50 fs) one needs to minimize not only the second order group velocity dispersion (GVD), but also higher order dispersions, and thus necessary to minimize the material medium present in a resonator. A solid-state laser system uses minimum material inside the ultrafast laser cavity, as compared to an all-fiber ring laser system counter part. For example, at 37 MHz operation, a typical solid-state laser based system may have material medium contribution of ~20 mm or small, as compared to an all-fiber ring laser having ~5,000 mm. Thus, the realization of ultrafast laser pulses is far easier in a sold-state laser system, but at the cost of robustness as compared to an all-fiber ring laser based counter part. Cr:Forsterite (Cr^{4+}:Mg_2SiO_4 denoted as Cr:F) crystal has recently attracted attention, since it support ultrafast pulses as low as ~14 fs at 1.3 μm. At Solid State Laser Division (SSLD) of RRCAT, we have taken up the activity to study the feasibility of a fiber laser pumped femto-second laser at 1.3 μm.

The fluorescence bandwidth of Cr:F crystal is very large and we experimentally measured the emission spectrum at three different pumping levels at 1064 nm. Figure L.9.1 shows the fluorescence output with a peak at 1120 nm and FWHM of ~150 nm. Thus by using proper dielectric coated mirrors, one can realize an ultrashort (< 500 fs) laser at 1.3 μm using 1064 nm based fiber laser as the pump source. In addition, a soft aperture based Kerr Lens Modelocking (KLM) along with chirped mirrors can be used for GVD compensation.

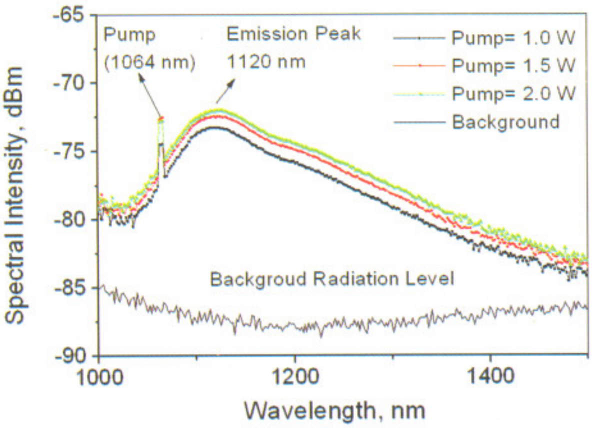

Fig.L.9.1. Fluorescence spectra of Cr:F crystal

We studied Acousto-Optically mode locked operation to generate ps pulses as well as KLM operation to generate fs pulses.

Figure L.9.2 shows the schematic of the experimental setup to realize fiber laser pumped ultrashort laser at ~1280 nm. It consists of a ~2.01 meter long cavity, specifically designed to compensate for astigmatism due to folding of curved mirrors and is able to compensate for very strong pump induced thermal lens in the Cr:F gain medium with focal length as short as 3 mm. The 8 mm long Brewster-cut Cr:F crystal is end pumped by a commercially available polarized fiber laser capable of delivering up to 10 W at 1064 nm. M1 is a wedged broadband output coupler with 2.5 % transmission at 1280 nm, and M2 to M8 are broadband-coated dielectric HR mirrors at 1280 nm. M3 and M4 are curved mirrors with 100 mm radius of curvature and M4 act as in the input coupler at the pump wavelength. M2, M3 and M7 shown in blue colour are negative GVD chirped mirrors. An Acousto-Optic (A/O) Modelocker crystal is kept very close to the output coupler. The cavity can be either driven in the A/O mode locked regime, KLM regime or CW regime with proper adjustment of relevant cavity parameters. The wavelength spectrum is recorded using Avantis spectrometer with ~2 nm resolution. The temporal spectrum is recoded using FPD510 fast photodiode with 0.5 ns rise time.

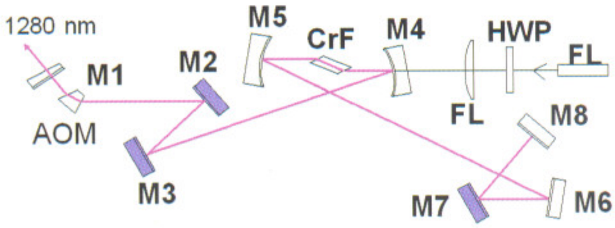

Fig.L.9.2. Schematic of the fiber laser pumped ultrashort laser capable of operation in CW, AOM or KLM regime.

At 7W of pumping, the A/O mode locked cavity resulted in pico second pulses at 1290 nm with ~100 mW output average power at 1290 nm with 74.4 MHz pulse repetition rate. The pulse duration was about few hundred pico seconds. The FWHM of the emission spectrum was ~6 nm, and was similar to the CW operation.

To generate fs pulses, the laser cavity was operated in KLM regime. The RF power to the modelocker is switched-off and the output coupler is mechanically disturbed to initiate soft aperture (aperture provided by gain) based KLM. The pulse width is measured using a commercially available APE based Pulse Check autocorrelator capable of measuring up to 15 fs minimum and 15 ps maximum.

In the Kerr Lens mode locked regime, the output power was reduced to 80 mW, but the FWHM of the wavelength spectrum became wider and was measured to be ~13 nm. Figure L.9.3 shows the measured wavelength spectra for CW as well as ML regimes. Figure L.9.4 shows the temporal spectra measured using FPD510. The repetition rate was measured to be ~74.4 MHz. Figure L.9.5 shows the measured Autocorrelation trace in the KLM regime. The FWHM of the ultrafast pulse was ~230 fs assuming Sech^2 pulse shape.

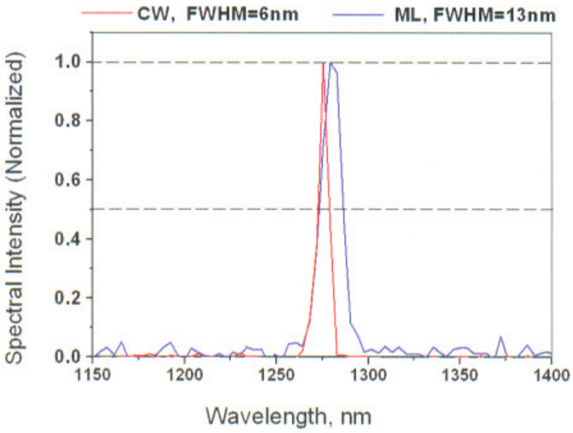

Fig.L.9.3. Wavelength spectra in KLM regime with FWHM of 13 nm at 1280 nm.

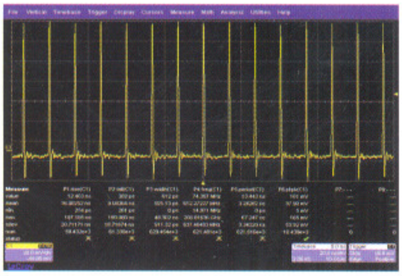

Fig.L.9.4. Temporal spectra of KLM laser recoded with 0.5 ns photodiode FPD510.

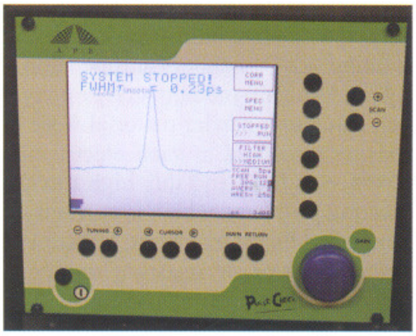

Fig.L.9.5. Autocorrelation trace of ultrafast laser at 1280 nm showing 230 fs FWHM for Sech^2 pulse shape.

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.

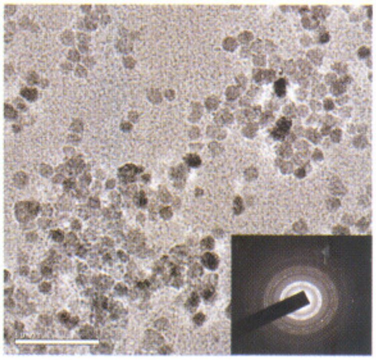

Fig. L.10.1. Transmission electron micrograph of ZnO nanoparticles of size ~ 5 nm. Inset shows the corresponding Selected Area Electron Diffraction (SAED) pattern of the same.

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