to few hundreds of microns is required to be produced on thin silicon wafers. The UV and visible coherent radiation (~ 250 nm to 600 nm) from a copper vapour laser (CVL) system or second harmonic / sum frequency of CVL are well suited for fast precision processing of silicon.

Laser System Engineering Division of RRCAT has carried out precision etching of bulk Si using 2 W average power CVL (510 nm) radiation (divergence angle of ~60 µrad and pointing angle < 10 µrad). The CVL beam was focussed onto the Si substrate with a lens of 5 cm focal length. The substrate was mounted on a precision 3-axes workstation. The resolution of the workstation was 2 µm. During laser irradiation, the substrate was moved in a predetermined fashion to generate the desired etching pattern. Figures L.3.1a and b show two such results. These pictures were taken by imaging the laser processed Si substrate on a CCD using 100X magnification.

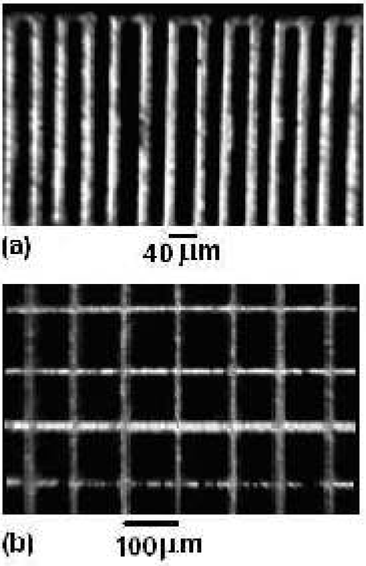

Fig. L.3.1 : Precision etching of silicon with CVL (510 nm) radiation

Laser processing of silicon naturally creates a hazy residue of re-deposited silicon particles. The white tracts, as seen in Fig.L.3.1, are the representatives of this debris. The laser made etched channel is embedded in the debris and is of width much less than 10 µm. The minimum separation achieved between consecutive channels achieved is of the order of 20 µm. In the present experiment, no effort was made to clear the debris. Much higher resolution and cleaner channels are expected in future by utilizing UV radiation and debris cleaning arrangement.

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L.4 : Generation of super-Gaussian beam in a high power transverse flow CO_2 laser

A novel graded phase mirror (GPM) resonator has been designed and developed to generate the lowest order super-Gaussian beam (SGB) with a large user defined waist in a high power transverse flow CW CO_2 laser. The main problem of poor beam quality and inferior focussability in high power TF CO_2 laser is, thus, circumvented by suitably designing an aspheric GPM resonator which efficiently extracts the laser power in single lowest order super-Gaussian mode. The phase profile of the aspheric GPM (Fig.L.4.1) has been designed by using the Fresnel-Kirchhoff's diffraction formulation for wave propagation in an optical resonator and has been fabricated on a copper substrate using a single point diamond turning machine (Nanoform 250, make Taylor-Hobson, USA, available at C.S.I.O., Chandigarh). A thin protective coating of HfO_2 was then applied on the diamond machined aspheric surface.

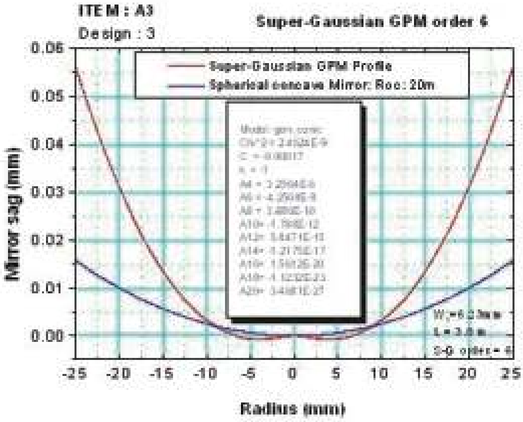

Fig.L.4.1 : Phase profile of the GPM

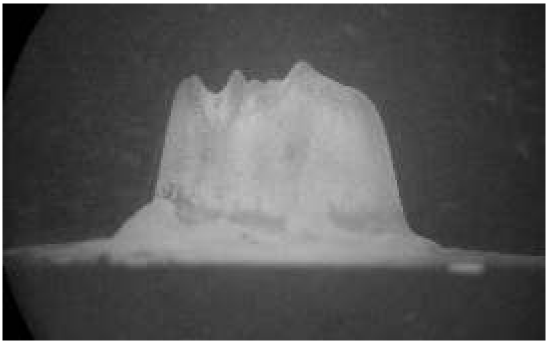

Fig.L.4. 2 : Near-field intensity of SGB

Experiments with the stable super-Gaussian GPM resonator have been carried out in a 3 kW transverse flow CW CO_2 developed at the ICL section, RRCAT. Near field intensity distributions produced by this custom GPM resonator have been measured with a rotating wire based laser beam analyzer (LBA). The experimental near field closely resembled the desired distribution. Fig.L.4.2 shows the PMMA burn pattern at 1.5 kW laser power. Measurements of laser power have been done both with the conventional spherical stable resonator and with the super-Gaussian GPM resonator. In conventional stable resonator a maximum of 3.2 kW power was obtained in a multimode laser beam while with the GPM resonator 2.8 kW power (η=10%) could be extracted in the super-Gaussian mode with an internal aperture diameter, 2a =22 mm, placed in front of the output coupler (Fig.L.4.3). With 18 mm aperture the GPM resonator yielded a maximum laser power of 1.8 kW in the lowest order mode. This indicates a remarkable enhancement in laser power extraction in single lowest order mode with large waist of the super-Gaussian beam compared to the power extracted by conventional (concave-plane) stable resonator with an internal limiting aperture diameter, 2a=19 mm, placed in front of the rear mirror which generates only 1.2 kW laser power in a mixture of TEM_{00} and TEM_{01}^{*} modes. The experimentally obtained far field distribution (Fig.L.4.4) of the generated super-Gaussian beam shows a single sharp maximum with negligible side lobes as predicted by the theory. Beam propagation studied with LBA also revealed the characteristic propagation behaviour of super Gaussian beam**.**

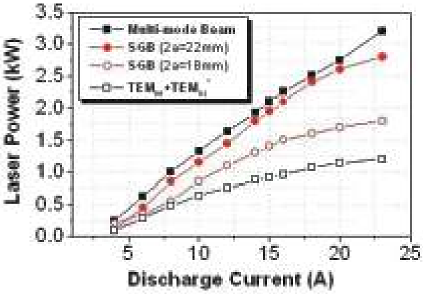

Fig.L.4.3 : Laser power with input current

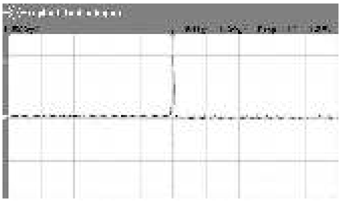

Fig.L.4. 4: Measured Far field intensity of SGB

Thus with this novel approach it has been possible to enhance remarkably the power extraction in single lowest order mode in transverse flow CO_2 laser and this will widen the range of laser material processing applications at ICLS, RRCAT.

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L.5 : A novel Nd:glass laser sub-nano second oscillator

Laser pulses of duration in the range of few hundred picoseconds to few nanoseconds find wide ranging applications in many areas such as laser plasma interaction studies, optical parametric chirped pulse amplification (OPCPA), non linear optics, fiber optic sensors etc. The OPCPA technique has now-a-days become popular for setting up prepulse-free, ultrashort, ultrahigh power laser systems. In this scheme, parametric amplification of a temporally stretched (chirped) seed laser pulse (typically of duration in the range of 200-400 ps) is achieved in phase-matched nonlinear crystals. This requires a good temporal/spatial overlap between the pump laser and the seed laser pulses/beams. Moreover, any fluctuation in the pump pulse energy or in the temporal overlap causes fluctuation in the optical parametric amplification gain and bandwidth, affecting the energy and duration of the compressed laser pulse. Hence, highly stable pump lasers, delivering synchronizable pulses of duration about twice that of the seed pulse, are desirable. Laser Plasma Division of RRCAT has developed a novel, flash lamp pumped Nd:phosphate glass based Q-switched and cavity dumped laser oscillator, which combines the techniques of full-wavelength switching and passive stabilization, to generate stable, synchronizable laser pulses of duration in the range of ~ 800 ps [A.K. Sharma, R.A. Joshi, R.K. Patidar, P.A. Naik, and P.D. Gupta, *Optics Communications 272, 455, 2007*].

A schematic layout of the laser oscillator is shown in Fig.L.5.1. It consists of three main parts: a) Q switch unit, b) flash lamp pumped Nd:phosphate glass laser rod (5 mm dia., 100 mm long) with reflector cavity, and c) cavity dumper unit. While the Q switch unit uses a deuterated KDP (DKDP) crystal based Pockels cell, the cavity dumper consists of a DKDP based double Pockels cell (DPC) in combination with a thin film polarizer kept near the DPC. The resonator cavity is formed by two ~100% reflectivity dielectric mirrors (one plane, other one with 6 m radius of curvature) kept 90 cm apart (round trip time of 6 ns). The active medium is kept closer to plane mirror side to improve the stability of oscillator. A typical spatial profile of laser beam is also shown in Fig.L.5.1. The beam diameter (1/e^2 points) was estimated to be ~2 mm.

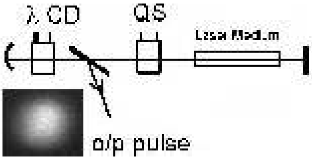

Fig.L.5.1 Optical layout of the cavity dumped oscillator and typical spatial profile of the output laser pulse.