LASER PROGRAM

L.1 Development of 40 W copper HyBrID laser

Copper HyBrID (Hydrogen Bromide In Discharge) laser is a variant of copper vapour laser in which first copper bromide is generated in the discharge. For this a controlled amount of hydrogen bromide gas is injected along with neon buffer gas into the discharge region causing a reaction of hot metal copper with hydrogen bromide at >500°C. The copper bromide thus produced sublimes, generating copper bromide vapour. Subsequently the copper bromide molecules break in to copper and bromine atoms due to collisions with energetic electrons. Copper atoms thus produced are used in the lasing action. The copper atom density in the discharge tube is controlled by the quantity of HBr gas injected. Main advantages of this laser over metal copper vapour laser, are its lower operating temperature (500-800 °C compared to 1600°C in metal copper vapour laser), short start up time, operation at higher repetition rate, higher efficiency, higher average output power and better beam quality.

We have successfully developed a copper HyBrID laser, which produces 40 W average output power (24 W green and 16 W yellow) at 18 kHz pulse repetition frequency with 1.1% electro-optic efficiency (fig. L.1.1). The lasing action builds up 8-10 minutes after the start up from cold condition and attains full power thereafter within 10-12 minutes (fig. L.1.2). The output power remains quite stable, and has been tested over few hours of continuous operation. The lasing action disappears within 5 minutes after the flow of HBr is stopped.

Fig. L.1.3 shows the discharge voltage, discharge current and laser pulse (both green and yellow) recorded using an oscilloscope. The beginning of laser current approximately at a time when the discharge voltage reaches maximum indicates availability of significantly lower inter pulse electron density of this kind of laser [*D.R. Jones et al, Optics Communication111 (1994), p394-402*]. The laser pulse width (FWHM) is ~55 ns which is also ~40% more than that of elemental CVL.

Fig. L.1.1 *Copper HyBrID laser*

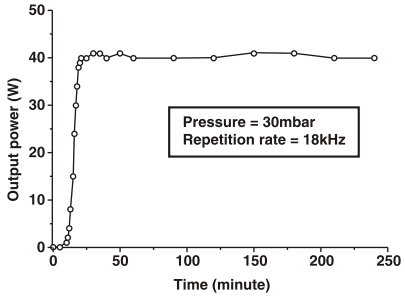

Fig. L.1.2 *Out put power vs. time from cold start up (Input power=3.7kW)*

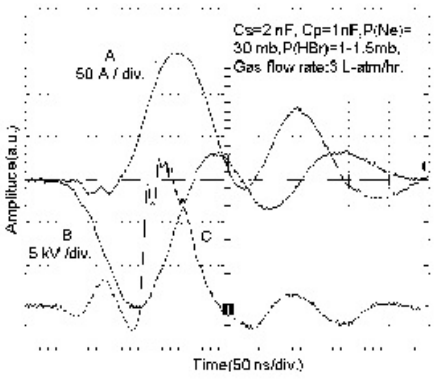

Fig. L.1.3 *Laser Current (A), Discharge voltage (B) & Laser pulse (C)*

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L.2 Photodynamic treatment of oral tumours in hamster cheek pouch model using chlorine p6, a chlorophyll derivative

Studies have been carried out to evaluate use of chlorine p6, a chlorophyll derivative, for photodynamic treatment of oral carcinoma in hamster cheek pouch model. Chlorine p6 (Cp6), synthesized in house, was administered either intraperitoneal (IP) at a dose of 1.5 mg/kg body weight or applied topically at 1.0 mg/kg body weight. The accumulation of Cp6 in tumour, normal mucosa, and abdominal skin was monitored non-invasively via measurement of the 400 nm excited drug fluorescence using a bifurcated optical fibre probe. Intraperitoneal administration of Cp6 was observed to lead to a significant accumulation of the drug in tumour (left panel of fig. L.2.1), if its size was smaller than 5 mm. For larger tumour sizes, poor accumulation of drug in tumour was observed presumably due to poor vasculature of large tumours. Here topical application gave better results. For both routes for drug administration the

tumour selectivity was best 3 to 4 h after administration of the drug. The drug also showed rapid clearance and the drug induced fluorescence from tumour, surrounding tissue, and normal mucosa was not detectable beyond 72 h of its administration. For photodynamic therapy the tumour was irradiated with light at 660 nm (± 25 nm), 4 h after drug administration. The irradiation dose used for the experiments was 100 J/cm^2. Small tumours subjected to PDT became edematous at 24 h and a reduction in tumour size was observed in next 48 h. A week after the PDT the tumour was seen to regress completely and only scar tissue was observed. In contrast, for larger tumours necrosis was confined to the superficial region (300-800 mm) of the tumour. About 20% reduction in the tumour size was observed 72 h after PDT. For one of the animals having large tumour, PDT was repeated at 72 h interval.

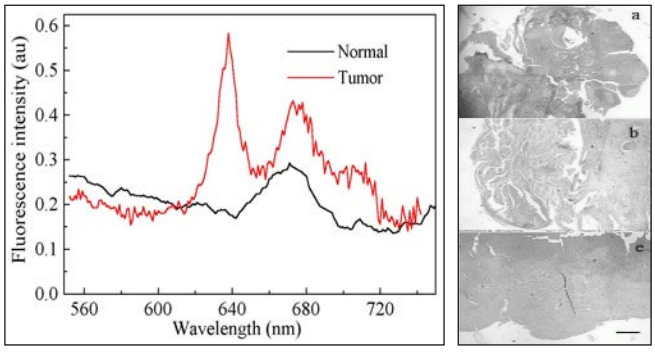

Fig. L.2.1 *Left panel: Fluorescence spectra collected from tumour (red) and normal mucosa (black) at 4h after intraperitoneal administration of Cp6. Fluorescence band with peak at 672 nm corresponds to Cp6 and that with peak at 635 nm arises due to endogenous porphyrin. Right panel: (a) Photomicrographs showing histology of tumour tissue from control animals that received drug but not light irradiation and (b) tumour subjected to PDT 4h after intraperitoneal administration of Cp6. Hematoxylin stain can be seen in dark control tumours due to the presence of intact nucleus. In contrast, photodynamically treated tumours showed little staining because of cellular necrosis and loss of nuclear material. Magnification used is 5X.*

Complete tumour regression was observed after three PDT treatments. For histological examination a few of the photo dynamically treated and dark control animals (animals that received drug but not light) were sacrificed 48 h after PDT. The photomicrographs (fig. L.2.1, right panel) suggest that photodynamic treatment leads to cellular necrosis and loss of nuclear material. [*Alok Dube, Sulbha Sharma and P K Gupta, to appear in Oral Oncology*].

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L.3 Observation of spin-independent transverse shift of the center of gravity of a reflected Laguerre-Gaussian optical beam

Some time ago Fedoseyev predicted (Opt. Comm. 193, 9, 2001) that when a linearly polarized Laguerre-Gaussian (LG) beam undergoes reflection from a refractive index interface, a transverse displacement of the center of gravities of the refracted and the reflected beams should occur with respect to the positions predicted by the geometrical optics. This kind of shift is different from the longitudinal shift observed earlier in total reflection regime (Goos-Hänchen effect) as well as from the spin dependent transverse shift (Imbert-Fedorov effect). We have carried out the first experimental measurement of the predicted shift using linearly polarized 632.8 nm He:Ne laser beam that was transformed into a LG beam by use of computer generated holograms. A glass prism (refractive index 1.5) that was mounted on a rotational stage was used to reflect the LG beam. By rotating the prism, the angle of incidence of the beam on the reflecting surface of the prism could be varied from 0° to 90°. The reflected LG beam was imaged using a CCD camera. Since in our experiment the plane of incidence was parallel to the horizontal plane, the predicted linear transverse shift (LTS) should result in a vertical shift of the reflected beam with respect to the plane of incidence. The predicted LTS is small, at best ~ a few l , with LTS for p- polarized beam being significantly larger than that for s- polarized beam. Therefore, to avoid interference with any vertical shift of the beam that may occur due to insertion of hologram used for generation of LG beams, we measured the difference in LTS for s- and p-polarized beams, keeping the hologram fixed. For the measurement of these small shifts we used the cross-correlation method [*J. Gelles, B. J. Schnupp, M. P. Sheetz, Nature 331, 450, 1988*] to determine the centroid of CCD images and thus locate the center of gravities of the incident and reflected beams. The estimated resolution of our position measurements was 162 nm and 138 nm in x and y directions respectively.

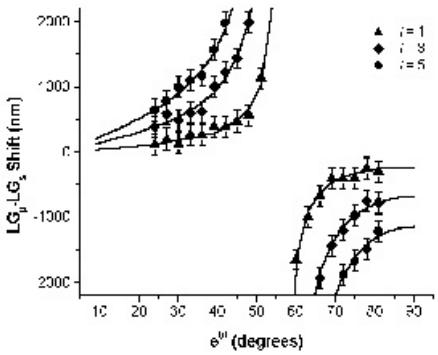

Fig. L.3.1 *The observed transverse shifts of reflected LG beams on partial reflection from air-glass interface*