L.4 : Nonlinear optics from an excited state in strongly correlated systems

Strong electrostatic repulsions among electronic charges of electrons is the origin of a large number of phenomena in condensed matter physics. For example, superconductivity, magnetism, magneto-transport etc. Electronic correlations in solids, oligomers / polymers / thin films can also influence optical nonlinearities very strongly.

Strongly correlated quasi one-dimensional materials like Sr_2CuO_3, halogen bridged Ni compounds etc. have a large number of excited one and two photon allowed states very close in energy with unusually large dipole coupling between them *[H. Ghosh, Physical Review B 75, 235127 (2007)]*. It turns out not only the first two excited odd and even parity states, but also higher energy excited odd and even parity states are very close in energy. For example, the ratio of dipole moments between the optical state to the first two photon state, to that from the ground state to the optical state, could be as large as two orders. It is seen that various nonlinear optical properties of strongly correlated electron systems are enhanced when nonlinear properties are calculated from an excited state (see Fig. L.4.1). Furthermore, it has been confirmed experimentally as well as theoretically that the two-photon state could be slightly lower in energy than the one-photon state *[H.Ghosh, AIP proc. 1014, 260, (2008)]*. Thus these systems may be ideal for studies of non-linear optical properties measured from an excited appropriate excited state.

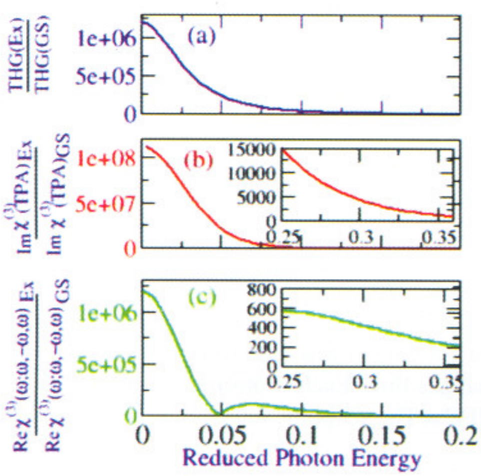

*Fig. L.4.1: Various excited state non-linear optical properties of quasi one dimensional inorganic strongly correlated electron systems. For such studies of π-conjugated polymers see, Synthetic Metals **158**, 320.*

Several orders of magnitude enhancement in the excited state optical nonlinearities in the wavelength region suitable for terahertz communications were predicted. These results are based on exact numerical solutions of finite size one dimensional two band extended Hubbard model. π-conjugated oligomer like poly-para-phenylene-vinylene has also been studied theoretically and found to have two-three orders of enhancement in excited state nonlinear optical properties *[H.Ghosh, Synthetic Metals 158, 320 (2008)]*.

Reported by:
Haranath Ghosh (hng@rrcat.gov.in)

L.5 : Real time *in-vivo* imaging of Zebrafish brain using optical coherence tomography

Zebrafish (Danio rerio) is a popular model system to understand a variety of human biological processes. As vertebrates, Zebrafish provides a good model for humans and is extensively used in medical research. These studies often require measurements of the morphological and physiological parameters of Zebrafish. Therefore, development of non-invasive imaging techniques for this purpose is of considerable interest. *In-vivo* anatomical structures of adult Zebrafish have thus far been studied by the use of high-resolution magnetic resonance microscopy. However, the resolution obtained was ~78 m and required a relatively long imaging time of about 8 minutes.

Optical Coherence Tomography (OCT) can provide non-invasive cross-sectional images in real time with spatial resolutions down to few micrometers. However, a limitation of OCT is that the depth of imaging is limited by scattering of the medium that destroys the coherence of the probe beam. Thus, while for non-scattering ocular structures, OCT can be used to image the entire structure *[K. D. Rao et al, Curr. Sci. 90, 1506 (2006)]*, imaging of scattering tissue like brain is usually limited to a few mm. OCT has therefore been used to image excised or exposed brain tissue. Non-invasive, *in-vivo* OCT imaging of adult brain, however, has not been possible so far. Laser Bio-medical Applications & Instrumentation Division of RRCAT has recently demonstrated non-invasive real-time *in-vivo* optical imaging of Zebrafish brain using OCT *[K. D. Rao et al, J. Biophotonics, In press]*.

The real-time OCT system developed at RRCAT utilized a high power broadband superluminescent diode as optical source, coupled to a single mode fibre (λ_0 = 1310 nm, $\Delta\lambda$ = 43 nm, power ~ 18 mW). A Fourier domain based rapid scanning optical delay line (scanning frequency of 2 kHz) was used in the reference arm to achieve path length scan of about 3 mm. Lateral scanning was done at 8 Hz using a single-axis galvanometer-driven mirror. The free space axial and lateral resolutions of the setup were both estimated to be 20 μm.

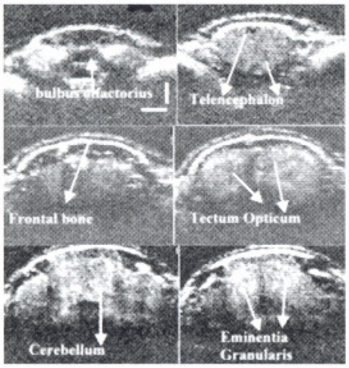

Fig. L.5.1: 2-D cross sectional OCT images showing internal structures of Zebrafish brain. Scale bar is 0.5 mm.

The real time OCT setup was used to acquire two-dimensional cross sectional images of the adult brain of anaesthetized Zebrafish. About 90 cross-sectional images (XZ plane) of the brain were taken by moving the sample in the Y direction in a step of 0.05 mm. Fig.L.5.1 shows the 2-D cross-sectional images of Zebrafish brain. Internal structures such as bulbus olfactorius, telencephalon, tectum opticum, cerebellum, frontal bone and eminentia granularis were clearly distinguishable in these images. The raw images were thresholded for minimizing the speckle noise. Using these images, a three-dimensional model of the Zebrafish brain was constructed in the axial plane (Fig.L.5.2) with *AMIRA* software. To the best of our knowledge, this is the first report of *in-vivo* imaging of Zebrafish brain structures using OCT.

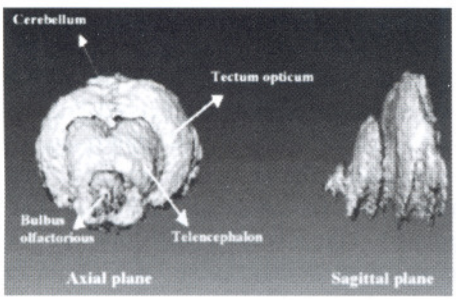

Fig. L.5.2: 3D reconstructed view of the Zebrafish brain in axial plane.

Reported by:
K D. Rao (kdivakar@rrcat.gov.in) and P.K. Gupta

L.6 : Development of supervisory control for Gallium Nitride metal organic vapour phase epitaxy (GaN MOVPE) system

Metal Organic Vapour Phase Epitaxy (MOVPE) is a highly controlled method for the deposition of semiconductor epitaxial layers and heterostructures, which are required for the development of several opto-electronic and electronic devices. A commercial MOVPE system has been installed at Semiconductor Laser Section of RRCAT to develop III-V semiconductor based laser devices and related material research. In view of the increasing interest in nitride based semiconductor materials for UV/near UV opto-electronic devices and high power electronics, a nitride MOVPE system is being developed for the growth of nitride based semiconductors like GaN, AIN, InN, etc. Laser Electronics Support Section of RRCAT has designed and developed a supervisory control and data acquisition system for the above MOVPE system.

The control of MOVPE machine involves precise control of gas mixture, temperature and pressure inside the reactor. This is essential in order to maintain the quality of growth. Also, since hazardous gases like ammonia and hydrogen are involved in the process, a separate interlock circuit is needed which must shut down the system in case of malfunction or gas leak.

The MOVPE machine consists of 31 mass flow controllers, 24 sensors (both digital and analog), 24 solenoid valves, compressor, vacuum system, temperature controller, and a pressure controller unit. Intelligent controllers for the control of these units have been developed. The system includes a PC for user interface, which has software running on *LabView* platform, while various intelligent controllers located inside the MOVPE machine perform the actual control task. The communication between these distributed controllers and PC is established using RS-485 network. Modbus protocol is used for data transfer. The schematic of the control system is shown in Fig.L.6.1.

Analog Input Output (AIO) controller provides the set point for Mass Flow Controller (MFC) and reads back the actual gas flow. Each controller is capable of connecting eight MFC's. The set point and read back accuracy is 12-bit. Digital input output controller can set 32 digital outputs and can read 32 digital inputs. The digital inputs are connected to sensors through signal conditioning circuits. The digital outputs are used to control ON/OFF operation of various solenoid valves connected in the gas line. In the interlock logic, sensor signal and control signal are compared and if