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.

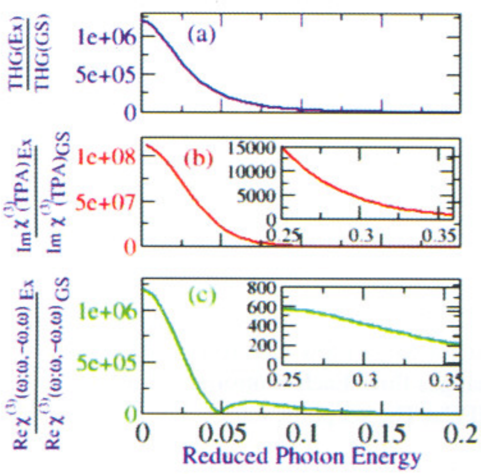

*Fig. L.4.1: Various excited state non-linear optical properties of quasi one dimensional inorganic strongly correlated electron systems. For such studies of π-conjugated polymers see, Synthetic Metals **158**, 320.*

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)]*.

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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