Chapter 7

General Conclusion and Future Prospects

7.1 General Conclusion
Last part of the 20th century witnessed the emergence of Photonics as a new branch of Science and Technology and it is a field of promise to the years to come. Up to this time Electronics was playing the lead role in the field of science and technology. But now it is giving way to photonics. By this time, Photonics has already established its relevance in communication, instrumentation, measurements and control, optical computing, information processing, displays etc. Photonics encompasses diverse areas such as nonlinear optics, optical fibers, integrated optics, harmonic generation of laser radiation, optical switches and display devices. The discovery of new intense monochromatic light sources and materials with special properties intensified the growth in various fields of photonics. Materials that are very useful for light based applications are collectively called photonic materials and most of the technological applications exploit the nonlinear optical (NLO) properties of these materials in one way or the other. Therefore the investigations of NLO properties of different photonic materials become very important and this led to the discovery as well as characterization of large number of NLO materials. All over the world active research in this field is in progress. In this context, study of NLO properties of certain photonic materials, which include a number of organo-metallic compounds were chosen as the topic of the present research work.

Some of the essential requirements of good photonic materials are large and fast nonlinearity, synthetic flexibility and ease of processing. Wave Mixing, Z-Scan, Optical Limiting, Third Harmonic Generation (THG) etc. are the most commonly used
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techniques for the evaluation of the nonlinear behaviour of most of the NLO materials. Metal substituted phthalocyanines belong to the class of efficient photonic materials and the nonlinearity of these compounds is well studied in various solvents. But there are not many reports on the properties of these materials in solid matrices. When device applications are considered, the incorporation of these materials into solid matrices and the study of their behaviour in different host materials become important. Hence, we studied the NLO properties of Samarium Phthalocyanine in solid (PMMA) as well as liquid (MMA) matrices.

Using the open aperture z-scan technique, the effective nonlinear absorption coefficient $\beta_{\text{eff}}$ and imaginary part of the nonlinear susceptibility ($\text{Im} \gamma_{\text{eff}}^3$) of Samarium Phthalocyanine in Methyl Methacrylate at 532 nm has been measured, in both liquid and solid media. The optical limiting nature of the samples is also studied. The samples exhibit obvious nonlinear behaviour and the nonlinearity originates from the large excited state absorption cross section, the characteristic property of Phthalocyanines. Enhancement in optical limiting property of samples in liquid phase over the solid phase is attributed to the bimolecular processes taking place in liquid media. The measured $\beta_{\text{eff}}$ values as well as the optical limiting curves show that samples in liquid phase are moderately better in their optical limiting efficiency. However, the solid matrix gives rigidity to the nonlinear medium and the handling is more convenient. Therefore for a device application the polymeric solid matrix may be preferred over the monomeric solution phase. The concentration dependence on the optical limiting nature is also studied both in liquid as well as in solid medium and the role of RSA in the limiting behaviour is verified.
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Degenerate Four Wave Mixing (DFWM), Z-Scan and optical limiting studies has been carried out in certain selected metal complexes of QAP’s at 532 nm under nanosecond excitation. For the DFWM measurements the polarization of the interacting beams were so chosen that electronic response is obtained. Third order susceptibility, figure of merit of third order nonlinearity and nonlinear absorption coefficient of these samples are calculated. The measured nonlinear parameters of these samples are explained as due to the combined effect of nonlinear absorption, oscillator strength and resonance effects at the wavelength of excitation. It is observed that Ni (QAP)₂ and Co (QAP)₂ are promising NLO materials and their importance in device applications is confirmed by the optical limiting studies carried out in these samples.

Another NLO material studied is certain selected porphyrins with different peripheral constituents. The effect of peripheral substitution is studied using Degenerate four-wave mixing technique. The nonlinear absorption in these samples was studied using z-scan and optical limiting nature is verified using the graphs generated from z-scan data. Third order susceptibility $\chi^{(3)}$, Figure of merit of third order nonlinearity (F) and Second hyper polarizability $\langle \gamma \rangle$ were measured. TPP with out any peripheral ligands exhibited the highest value of figure of merit as well as second hyper polarizability indicating that it possesses maximum third order nonlinearity for a given absorption loss. The $\langle \gamma \rangle$ values measured were explained on the basis of internal charge transfer mechanism and oscillator strength of the molecules. The effects of wavelength, concentration and solvents on the NLO behaviour of the samples were also studied using the z-scan technique. The optical limiting nature of these samples was studied and it is observed that unsubstituted porphyrin and nitro-TPP shows the best optical limiting.
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The nonlinear behaviour of five Cobalt Ternary Complexes of 2-Hydroxy Acetophenone N(4) Phenyl Semicarbazone containing Heterocyclic Coligands has been investigated using DFWM technique. Third order susceptibility, figure of merit of third order nonlinearity and second hyperpolarizability of these samples are measured and the observed nonlinear behaviour of this class of compounds has been interpreted by considering the influence of oscillator strength and atomic substituents. The \( <\gamma > \) values of metal complexes of semicarbazones studied here is at least one order of magnitude smaller than the same in QAP’s and TPP’s presented. Even though these compounds are not very good NLO materials, detailed studies in these compounds can give better insight into the origin of nonlinear behaviour of various materials.

7.2 Future Prospects
Large and fast nonlinearity, synthetic flexibility, ease of processing and good chemical and thermal stability are being the essential properties of a good photonic material. Search for such a material is highly active all over the world. Material, which satisfies all these qualities are not yet identified. Nonlinearity observed at resonant fields shows very large magnitude but has slow response. On the contrary, non-resonant nonlinearity is very fast in response but low in magnitude. Many organometallic compounds and organic-inorganic systems satisfy many of the essential requirements of good nonlinear material. Organometallic compounds similar to those studied in the present investigations can be tested for various device applications like optical limiters, optical logic gates etc. A good deal of work is required in this field for the realization of an ideal NLO material for various technological applications.

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