CHAPTER 6

CONCLUDING DISCUSSIONS
Scanning optical microscopy is witnessing a phenomenal growth as regards various modes of imaging as well as collection of novel and optically non-linear informations in microscopic scale. In this thesis, we have demonstrated certain important applications of line scan signals in a SOM geometry and have investigated into performance of various imaging modes. Thus besides investigating into conventional and confocal microscopy, the set-up may be slightly altered to look into the photo-voltaic and photo-conductive modes of information gathering from semiconductor specimens. Besides, the set-up could also be adapted to measure the life-time of excess carriers in a semiconductor specimen on being illuminated. We have also developed instrumentation for storing of line scan signals and for subsequent analysis as regards the maximum and minimum level of signal. After a brief introduction to the developments of scanning
optical microscopy, in chapter 1 of the thesis, we have described the design details of the experimental set-up built in our laboratory in chapter 2 part A. The microprocessor based storage and analysis system outlined in Chapter 2 Part B could conceivably be used for recognition of patterns by comparing the scanned voltage matrix with that stored in the microprocessor that should be obtained for a particular pattern. The system could thus be utilized for various routine R&D and industrial inspection of fabricated device. For example, physicists look for certain patterns in nuclear track emulsion photographs. The corresponding scan voltage matrix generated by light transmitted or reflected from corresponding transparency or photograph of such tracks may be stored in microprocessor based instruments for possible identification of such patterns. Instead of storing the scan voltage matrix, auto correlation functions of the looked-for pattern and the incoming signals may also be compared to ascertain the existence of looked-for pattern in the transparency or photograph studied.

In chapter 3 we investigated various imaging modes of SOM for better single-point resolution and transfer function as well as for optically non-linear information from object specimen. First of all, we considered the effect of introducing coded apertures, both passive and active, in SOM geometry for the extent of reduction that may be possible in the probe-spot. Specifically, we considered an active aperture of thin saturable
absorber that can lead to probe-spot size reduction in various SOM imaging modes. We also notice that the apertures considered suit Gaussian laser sources as compared to those with uniformly illuminated sources. Next we specifically consider confocal SOM mode with one annular and one circular pupil function for two-photon fluorescence imaging as well as phase imaging. We find that the confocal system with one annular and one circular pupil function is preferable as compared to confocal system with both the pupil functions circular or both of them annular in 2-photon fluorescence imaging for single point resolution. The confocal system with one circular and one annular pupil function is further capable of phase imaging with small defocus although for thick objects results may be confusing.

In chapter 4, we utilized the one dimensional scanning system for defect studies of solar cells in photovoltaic mode. We also use this set-up for characteristic studies of p-n junction and transistor in photoconducting mode so that any deviation from ideal characteristic may be monitored during industrial fabrication. We also report that the SOM geometry may be used for measurement of excess life-time carrier. Next we establish the superiority of imaging in confocal mode as against the conventional mode. We also find that confocal system with one circular and one annular pupil function is better performing as compared to confocal system with both the pupil functions circular as regards response to straight edge and bar patterns. Finally we
also demonstrate the capability of confocal mode with one annular and one circular pupil function in phase imaging.

In chapter 5, we consider the possible collection of ordinary, coherent stokes and stimulated Raman signal from specimens in SOM set-up and arrive at the power level to be used for adequate detection level. We also investigated the heat generated in the specimen at various speeds of scanning. We next utilize this knowledge to see under what condition Raman signal can be studied in SOM set-up without producing artifacts in the specimen.

In short, in our effort for investigation into different imaging modes, we have designed a line scan arrangement that can indeed be utilized for studying various modes. This simple method can further be adapted for preliminary investigation into nonlinear optical information in microscopic scale. We have further designed a simple and less expensive system that can record the line scan signals with a sampling rate of 4 kHz which, however, constraints us to lower the frequency of line scan so as to accommodate sampling from each pixel points. Although we have used it for determining the series of maxima and minima and from this the highest peak or the lowest dip of the signal, the sophisticated range of microprocessor based signal processing techniques can now be applied to the digitally stored signals. Specifically for confocal systems where the informations
from planes other than the focal plane are discriminated against and is thus capable of providing 3-D image informations, digital and computer based signal analysis further enlarge the possibility of collecting relevant 3-D information.

The range of experimental studies on various semiconductor specimens also point out the possibility of adopting the SOM for photovoltaic, photoconductive as well as reflection mode studies for routine inspection of semiconductor devices with high resolution. Thus in photoconductive type of monitoring, in addition to the V-I characteristic studies at different bias voltages, we also get a visual clue as to the existence of defects. By transferring such signal to microprocessor or computer system after digitization and suitable interfacing, we may use the software of the microprocessor or computer to compare the incoming signal with the ideal one stored for the corresponding case and thus the inspection may be made fully automated even at this microscopic scale. Application of SOM for such studies are sure to witness a growth in recent future.

We further observe that the use of a thin layer of saturable absorber as a filter holds out the promise of being a practical and useful proposition. Further we have investigated specifically the confocal system with one circular and one annular aperture and have found it to be a promising configuration for investigating thin objects. The improved resolution of
this configuration is, however, at the expense of loss of discrimination against diffuse scattering from planes away from the focal plane [1]. Thus while confocal system with circular apertures prove to be extremely powerful way of investigating microscopic detail in 3-dimension with its optical sectioning properties, the provision for using the system with one circular and one annular aperture would lend extra versatility as regards investigations of thin specimens in terms of both amplitude transmittance/reflectance and related phase information.

Investigations into the Raman signal generation show that a proper choice of laser-source along with suitable detection system would make it possible to have a spatial map of such signals without damaging the specimen. We have worked out the safe laser power in the form of pulsed output that can lead to a successful Raman microprobe without damaging the specimen. However with coherent anti-stokes Raman technique exploiting resonant Raman emission, there is a dramatic rise in the signal level so that necessity of using high power laser sources does not arise and thus the damage to probed-specimen can be easily avoided. Besides with the collection of these Raman signals, localised information polariton, lattice vibration, fluid concentration, combustion diagnostics, life-times and dephasing-times could also be obtained. Further biological specimens are expected to contain concentrations of molecules having particular chemical bond[2]. Hence by the use of Resonant Raman emis-
sion and four frequency mixing technique, it would be possible to have micrographs of molecules having only one particular bond. Thus scanning optical microscope can be adapted for collecting various informations through Raman signals.

Looking ahead, near field microscopy[3,4] should give a new dimension to this scanning method of microscopy because of sub-wavelength resolution that it can provide. In addition to this high resolution that may be obtained in scanning microscopy, now time-resolution is also being added[5] in processes like fluorescence imaging. This provides additional advantage of over conventional fluorescence imaging in its ability to discriminate species in a heterogeneous system on the basis of differing fluorescence life-time. Using picosecond pulsed laser excitation of the sample and collection of the fluorescence through the confocal arrangement, sub-nanosecond fluorescence dynamics has been observed in the well defined volume in a sample. This is indeed a useful technique having a promising future.

Thus this area of scanning optical microscopy promises to be an extremely fertile area where the ideas of traditional optics, quantum optics, electronics and advances in computer software enter into extremely fruitful interaction.
REFERENCES


2. A. Choudhury: Doctoral thesis submitted to Oxford University (1977)

