

Development of Raman Spectrometer

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Abstract

Interaction between matter and electromagnetic radiation can be studied by spectroscopic techniques. Raman Spectroscopy is one of the spectroscopic techniques which is highly developed with the advent of gas lasers and computers. It provides information about the rotational and vibrational motions of a molecule. Main aim of my project work was to make a homemade Raman Spectrometer by using laser source and Spectrometer. This is a strong characteristic study in spectroscopy and for this study we are using the equipments available in the lab. A simpler Raman spectrometer has been made by using laser source, CCD, Spectrometer, Convex lens, Notch filter, Optical fibre and Raman active sample. A diode pump laser has been used to illuminate the sample that is mounted on a translational stage. The sample has been analysed from the obtained spectrum and recorded using the computer software ANDOR Solis. Using the spectrometer, we are able to analyse the spectrum of crystalline silicon and liquid carbon tetrachloride (CCl₄). The Raman peaks have been obtained correctly in case of Silicon as well as in CCl₄.

Keywords: Silicon, Raman Spectroscopy, Charge Coupled Device, Notch Filter, ANDOR Solis.

Introduction

The inelastic scattering of electromagnetic radiation was first proposed theoretically by Adolf Smekal in 1923. Whereas Raman effect experimentally detected by Indian physicist Sir Chandrasekhara Venkata Raman and his student Kariamanickam Srinivasa Krishnan in 1928 Prof. C. V. Raman ^[3] was awarded Nobel Prize in Physics in the year 1930 for this discovery. He discovered that when light pass through a transparent material some of the deflected light changes wave length. This phenomenon is called Raman scattering and is observed only in a small fraction. On further instrumental experiments he obtained Raman spectra. The technique used to observe vibrational, rotational and other low frequency spectra modes in a system is called Raman spectroscopy. Raman and his colleges led experiment on scattering of light and he discovered various spectral lines. Majority of the incoming rays are seen to be of same wavelength as that of the scattered rays which are called as the Rayleigh

scattering. Through his observation he found that only a small fraction of rays is seen to exhibit different behavior. He called it as Raman scattering^[2]. It is process in which emitted photon is inelastically scattered and emitted with different frequency as compared to absorbed photon. This phenomenon is observed as a consequence of the interaction of optical and vibrational oscillations and its probability is small but finite.

In this paper we develop a Raman Spectrometer by using laser source, CCD, Spectrometer, Convex lens, Notch filter, Optical fibre and Raman active samples like Silicon and Carbon Tetra Chloride(CCl_4). We analyse the Raman Spectrum obtained by our approach and compared with the actual Raman spectra of materials.

Material and methods

The apparatus used to obtain the Raman Spectrum consists of a laser source, convex lens, Raman active sample, Notch filter, optical fiber, spectrometer, CCD (Charge coupled device) and a computer. The arrangements are made as shown in the Fig 1

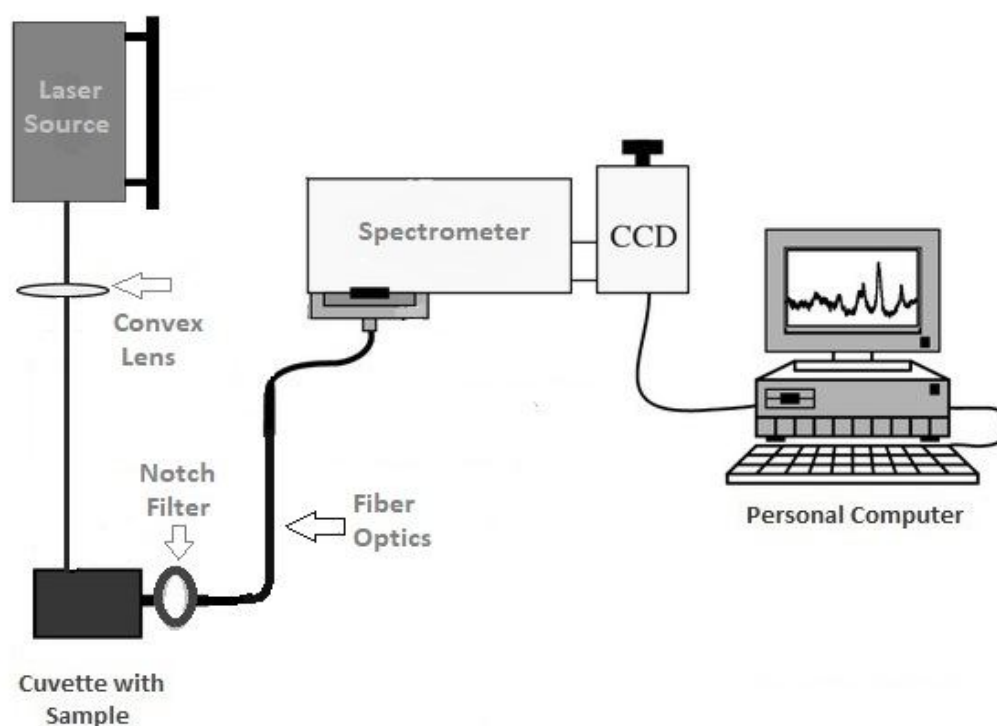


Fig 1 Design of the proposed Raman Spectrometer.

In this project we used our own laboratory equipments to develop a Raman spectrometer of improved efficiency and sensitivity. For this we used a diode pump solid state laser having 532 nm continuous laser beam with output power of 300 mW. A convex

lens of 5 cm focal length is used to converge the incident rays on the sample. This will increase the power of radiation that incidents on the sample. The sample is mounted on a translational stage which can be arranged in such a way that the incident radiation falls directly on it. Liquid samples can be taken in a well cleaned cuvette for proper analysis. A notch filter which is capable of preventing the transparency of radiation of wavelength 532 nm is placed next to the sample. The Raman scattered radiation is transmitted through a 1.5 m long fibre optic cable to the spectrometer and then the output is connected to a CCD Detector of Andori Dus 420 series. This device has a resolution capacity of 1024 pixels **with the ability of** thermo electrical cooling. **Communication between** spectrometer and computer is realized by using ‘ANDOR Solis’ software that is installed in the computer.

Results and discussion

a) Analysis of Silicon sample: -

The Fig 2 shows the Raman Spectrum of silicon that we obtained from our own Raman Spectrometer. From spectrum, we obtained Raman peak value at 547.14 nm (520cm^{-1}).

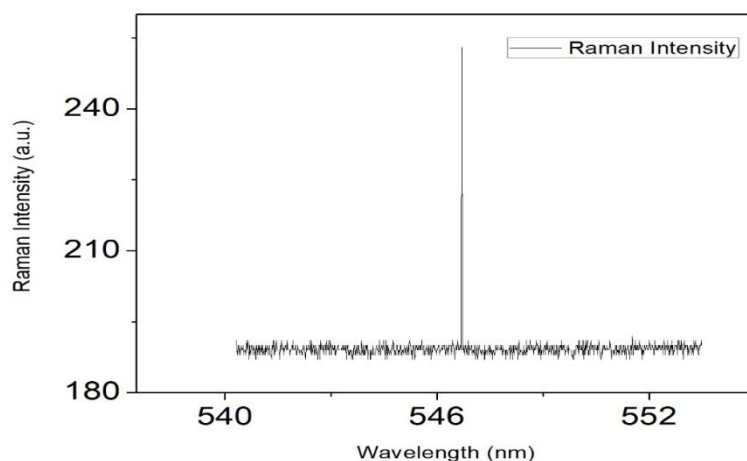


Fig. 2 Raman Spectra of Silicon obtained from our own Raman setup.

Then we compared the obtained data of silicon with reported data, to check the accuracy of spectrometer we have designed. The plot of Raman shift versus Intensity of silicon obtained from literature is shown in Fig 3 for the comparison. The graph explains that the peak obtained is at 520cm^{-1} [1].

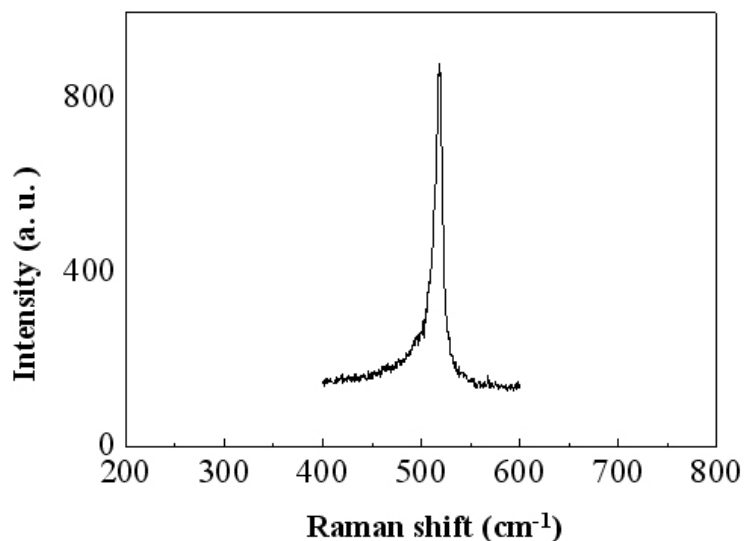


Fig.3 Raman Spectrum of Silicon^[5].

b) Analysis of CCl₄ sample

Raman spectra of CCl₄ was also analysed using the instrument which we made. Fig 4 denotes the graph of Raman spectrum of CCl₄ that we get from our Raman Spectrometer. We get Raman peaks at 538.25 nm, 541.06 nm and 545.26 nm.

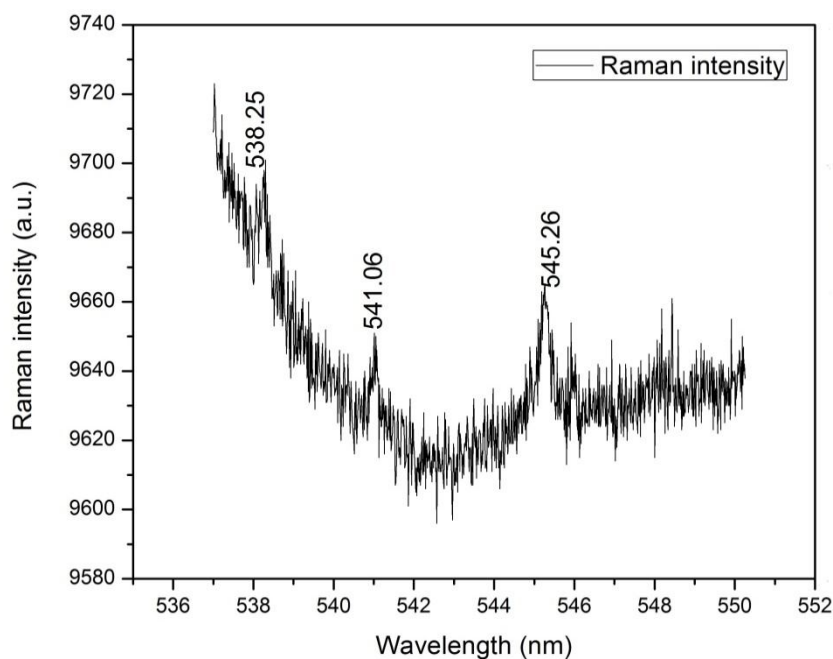


Fig. 4 Raman Spectra of Carbon Tetra Chloride (ccl₄) obtained from our own Raman setup.

Now we compare the obtained spectrum with reported Raman spectrum of CCl₄. The Raman peak we obtained is similar to that of the already reported peak values of 545.3 nm (459 cm⁻¹), 538.21 nm (217 cm⁻¹) and 541.04 nm (314 cm⁻¹)^[4]. So, by using our Raman

Spectrometer we got sustainable output of Raman peaks. The plot of Raman shift versus Intensity obtained from an actual case of CCl_4 is shown in Fig 5.

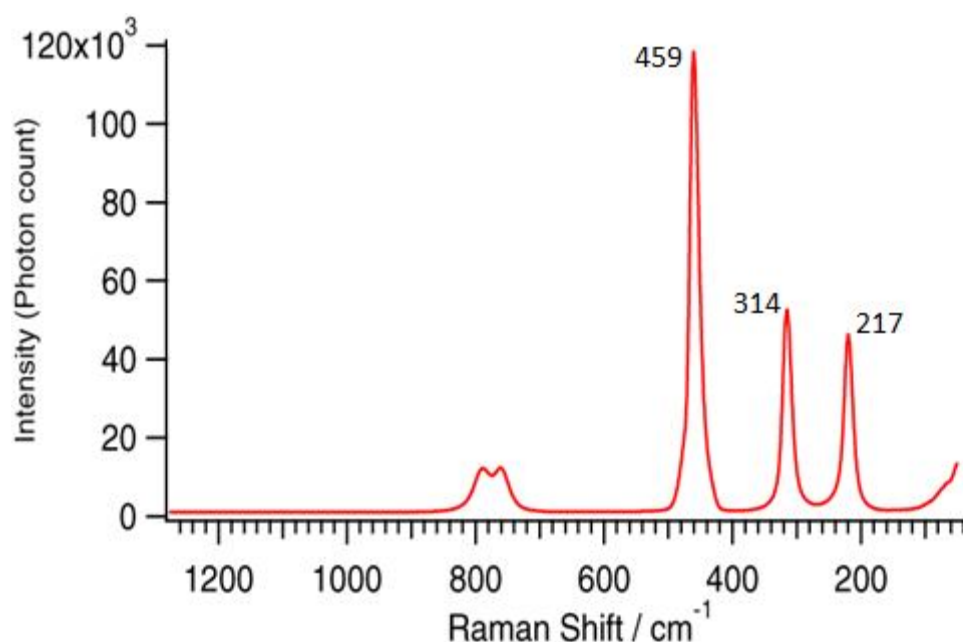


Fig.5 Raman Spectrum of ccl_4 ^[6].

Conclusion

We have developed Raman spectrometer successfully by using the equipments that are available in our optical laboratory. Materials such as Silicon and CCl_4 were analyzed using this homemade setup to check the accuracy of the spectrometer. Raman peak of Silicon was obtained at 520 cm^{-1} which is same as the reported peak of Silicon. Raman peaks of CCl_4 were observed at 538.25 nm, 541.06 nm and 545.26 nm. These values showed fair resemblance to the three major peaks of CCl_4 (545.3 nm, 538.21 nm, 541.04 nm) ^[4] in literature. Since the recorded spectra agree well with the actual Raman spectra of materials examined, we can say that our intention to build an indigenous Raman Spectrometer succeeded to a great extent. By doing this project we were also able to reduce the cost of production of the Spectrometer. Hence we solved one of the most important issues in the development of a Raman instrument.

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References

- [1] Deschaines and Hodkiewicz and Henson, Characterisation of Amorphous and Microcrystalline Silicon using Raman Spectroscopy, Thermo Fisher Scientific, Madison, USA, (2009).
- [2] Hasna, Development of metal and metal oxide Nanostructures for surface enhanced Raman Scattering, Cochin University of science and Technology, (2016).
- [3] Raman and Krishnan, A new Type of Secondary Radiation. Nature, Vol 121: Page No 501, (1928).
- [4] Shuruell, The Raman Spectrum of Solid CCl_4 and isotropically enriched $\text{C}^{185}\text{Cl}_4$. Spectrochimica.Acta, Vol 27A: Page No 2375- Page No 2383, (1971).
- [5] Sui and Leong and Herman, Raman Analysis of Light-Emitting Porous silicon. Appl.PhyLett, Vol 60: Page No 2086, (1992).
- [6] Tokmakoff and Lang and Fleming, Two dimensional Raman Spectroscopy of Vibrational interactions in liquids. Physical Review Letters, Vol 79: Page No 2703, (1997).