Eötvös Loránd University (ELTE)

Faculty of Natural Sciences

Institute of Physics

OPTICALLY DETECTED MAGNETIC RESONANCE SPECTROMETER IN A CONFOCAL MICROSCOPE IN THE STUDY OF SOLID-STATE QUANTUM BITS

2nd semester research report

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Introduction:

An optically detected magnetic resonance (ODMR) spectrometer in a confocal microscope arrangement which is deployed for coherent manipulation of electronic and nuclear spin states of individual room-temperature solid-state quantum bits, such as nitrogen-vacancy center in diamond by using illumination and microwave impulses. A nitrogen-vacancy center (N-V center) is one of numerous point defects in diamond. Its most explored and useful property is photoluminescence, which can be easily detected from an individual N-V center, especially those in the negative charge state (N-V−). Electron spins at N-V centers, localized at atomic scales, can be manipulated at room temperature by applying a magnetic field, electric field, microwave radiation or light, or a combination, resulting in sharp resonances in the intensity and wavelength of the photoluminescence. These resonances can be explained in terms of electron spin related phenomena such as quantum entanglement, spin-orbit interaction and Rabi oscillations, and analyzed using advanced quantum optics theory. An individual N-V center can be viewed as a basic unit of a quantum computer, and it has potential applications in novel, more efficient fields of electronics and computational science including quantum cryptography, spintronic and masers.

N-V− centers emit bright red light which can be conveniently excited by visible light sources, such as argon or krypton lasers, frequency doubled Nd:YAG lasers, dye lasers, or He-Ne lasers. Excitation can also be achieved at energies below that of zero phonon emission. Laser illumination, however, also converts some N-V− into N-V0 centers. Emission is very quick (relaxation time ~10 ns). At room temperature, no sharp peaks are observed because of the thermal broadening. However, cooling the N-V− centers with liquid nitrogen or liquid helium dramatically narrows the lines down to a width of a few megahertz.

Tasks during the research:

1. Finding several types of defects in Non-diamonds for example Nitrogen Vacancy, SiC and Ge vacancy defects etc. (lit review)
2. Characteristics of defects which can be used in real life for instance Telecom, Quantum Computing as well as in medication.
3. Build a set up for optically detected magnetic resonance for Nano diamonds and SiC or to make Nano environment to accomplish the desired goal experimentally.
4. Synthesis in new experimental environment.
5. How we can use the results in the applications.
6. Provide the feedback and conclusion for new developments ideas for future references.

Description of research work carried out in current semester: I participated in two courses one is Lattice defects ii(8 credits) and another was Lattice field theory (8credits) .

Main tasks performed for the project during the semester along with the lit knowledge was:

1. synthesis of SiC with Si Vacancy with different methods and different compositions Al materials for example the standard concentrations of preparing SiC are Si = 2.8g , C = 1.2g , PTFE 0.6g and without PTFE ,EtOH =20g with varying Al compositions and different time intervals.
2. How to use different instruments for carrying out the synthesis of SiC with Si Vacancy For instance Powder methodology for refining the grain size up to 2-3mm with SPD process. In addition, during this semester we prepared disc shape samples with and without PTFE concentration.
3. Observation of Raman spectra with Raman spectrometer under the excitation of different laser power(green 531nm, red laser).
4. Observation of Raman peaks with diffrent compostion of partially and fully prepared SiC of varying time intervals for polytypes (1-100nm) followed with other materials Si (twin peaks), C and SiC.
5. PL spectra with different laser power excitation.
6. X-ray spectrum of SiC.
7. Compare the result with lit research
8. Analysis of SiC samples with new system software called origin and its tools.
9. Handling origin and tools for complex mathematics.
10. Emission energy calculation of SiC with various laser excitations and different target points in the same sample.(every sample with approximately 10 points with 1%,5%,10%,50%and 100% power of laser).

Nitrogen-vacancy centers are typically produced from single substitutional nitrogen centers (called C or P1 centers in diamond literature) by irradiation followed by annealing at temperatures above 700 °C. A wide range of high-energy particles are suitable for such irradiation, including electrons, protons, neutrons, ions, and gamma photons. Irradiation produces lattice vacancies, which are a part of N-V centers. Those vacancies are immobile at room temperature, and annealing is required to move them. Single substitutional nitrogen produces strain in the diamond lattice. It therefore efficiently captures moving vacancies, producing the N-V centers.

An important property of the luminescence from individual N-V− centers is its high temporal stability. Whereas many single-molecular emitters bleach after emission of 106–108 photons, no bleaching is observed for the N-V centers at room temperature.

Because of these properties, the ideal technique to address the N-V centers is confocal microscopy, both at room temperature and at low temperature. In particular, low temperature operation is required to specifically address only the zero-phonon line (ZPL).

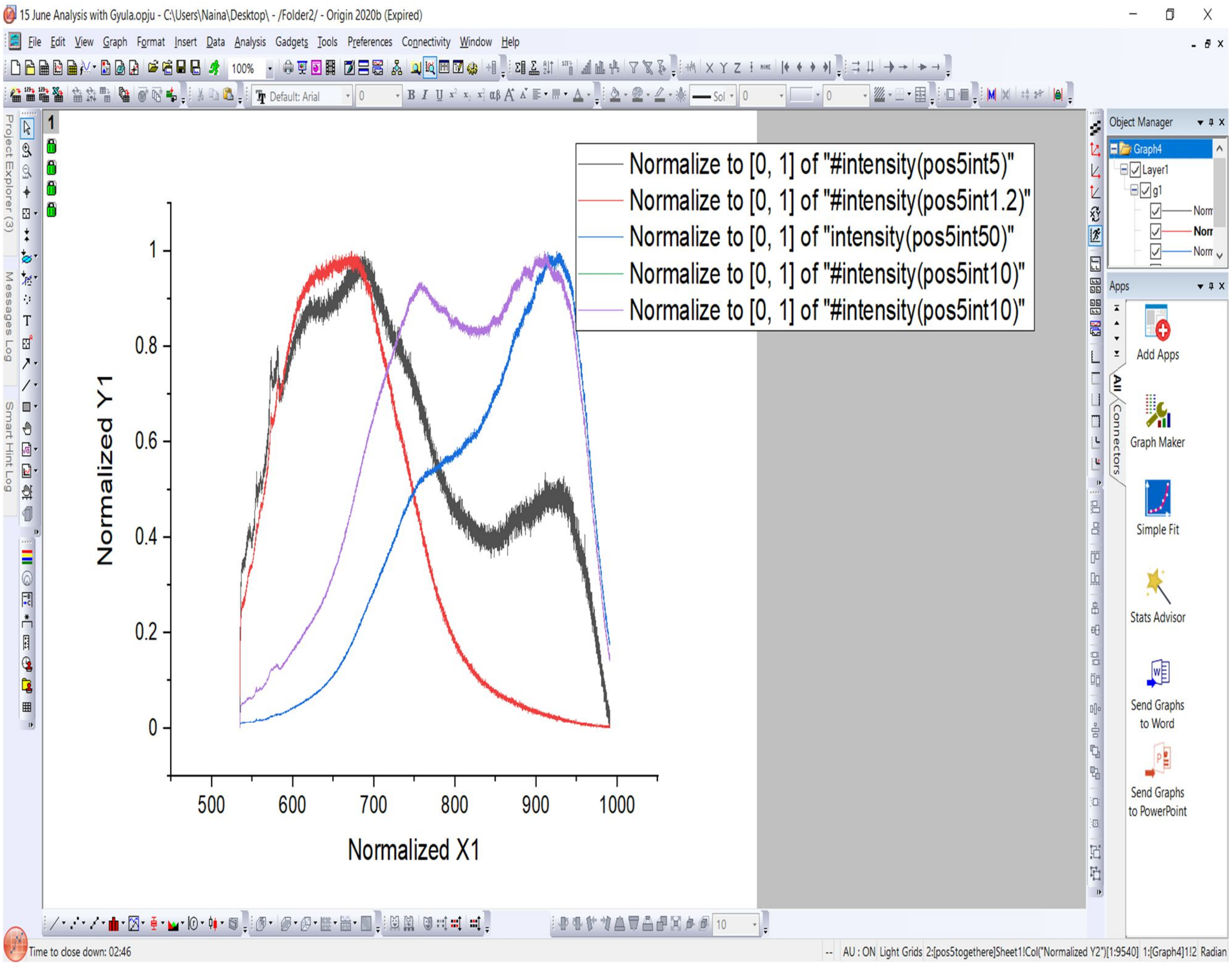


Fig 1 : System software outlook: Analysed data of SiC by Raman spectrocopy

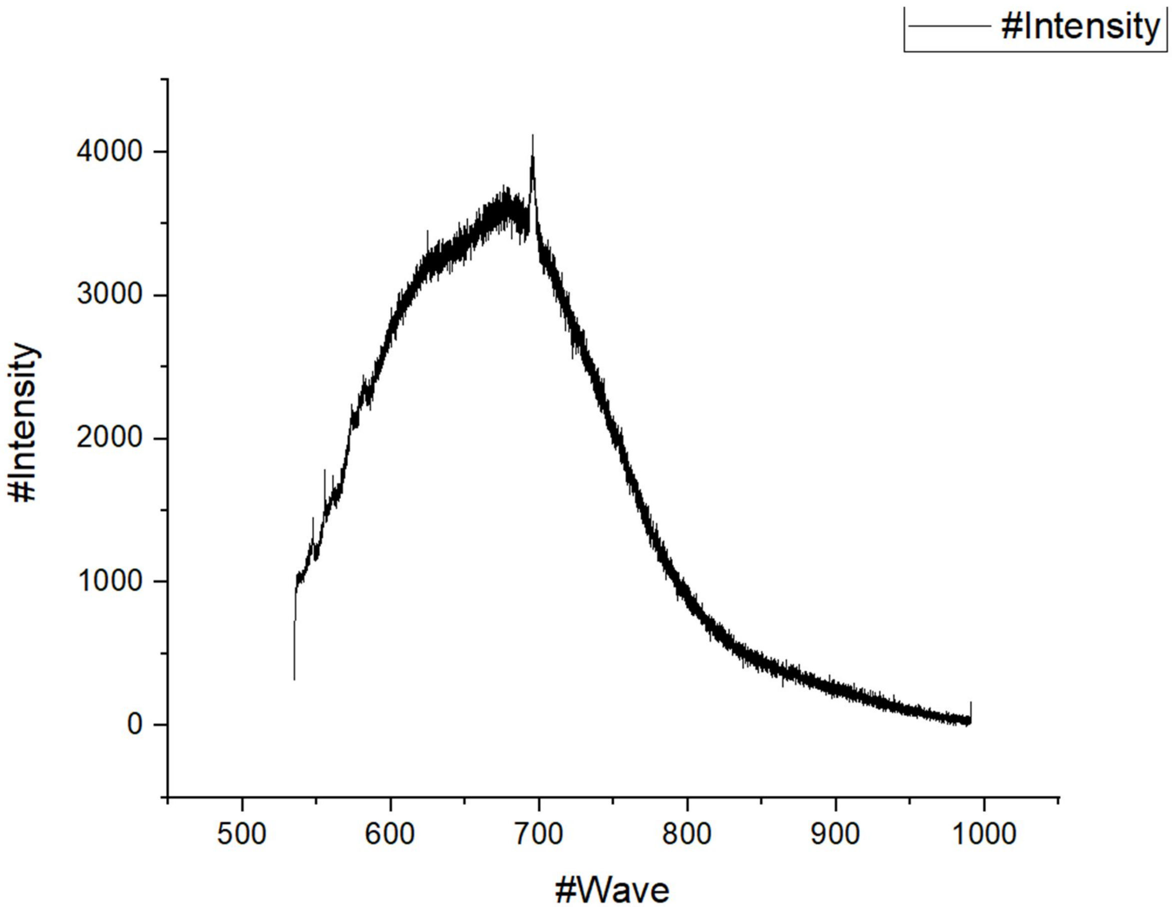
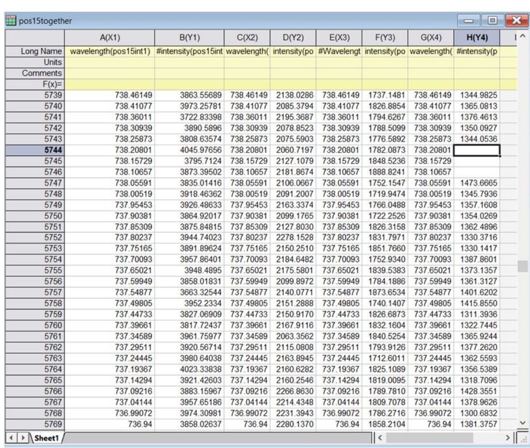


Fig 2: Analysis of SiC spectra with 531nm laser power of 1%. And eventually the wavelenth can be converted in emission energy in ev by multiplying with the factor 1240.



pos15together

	A(X1)	B(Y1)	C(X2)	D(Y2)	E(X3)	F(Y3)	G(X4)	H(Y4)
Long Name	wavelength(pos15int1)	#intensity(pos15int	wavelength(	intensity(po	#Wavelengt	intensity(po	wavelength(	#intensity(p
Units								
Comments								
F(x)=								
5739	738.46149	3863.55689	738.46149	2138.0286	738.46149	1737.1481	738.46149	1344.9825
5740	738.41077	3973.25781	738.41077	2085.3794	738.41077	1826.8854	738.41077	1365.0813
5741	738.36011	3722.83398	738.36011	2195.3687	738.36011	1794.6267	738.36011	1376.4613
5742	738.30939	3890.5896	738.30939	2078.8523	738.30939	1788.5099	738.30939	1350.0927
5743	738.25873	3808.63574	738.25873	2075.5903	738.25873	1776.5892	738.25873	1344.0536
5744	738.20801	4045.97656	738.20801	2060.7197	738.20801	1782.0873	738.20801	
5745	738.15729	3795.7124	738.15729	2127.1079	738.15729	1848.5236	738.15729	
5746	738.10657	3873.39502	738.10657	2181.8674	738.10657	1888.8241	738.10657	
5747	738.05591	3835.01416	738.05591	2106.0667	738.05591	1752.1547	738.05591	1473.6665
5748	738.00519	3918.46362	738.00519	2091.2007	738.00519	1719.9474	738.00519	1345.7936
5749	737.95453	3926.48633	737.95453	2163.3374	737.95453	1766.0488	737.95453	1357.1608
5750	737.90381	3864.92017	737.90381	2099.1765	737.90381	1722.2526	737.90381	1354.0269
5751	737.85309	3875.84815	737.85309	2127.8030	737.85309	1826.3158	737.85309	1362.4896
5752	737.80237	3944.74023	737.80237	2278.1528	737.80237	1831.7971	737.80237	1330.3716
5753	737.75165	3891.89624	737.75165	2150.2510	737.75165	1851.7660	737.75165	1330.1417
5754	737.70093	3957.86401	737.70093	2184.6482	737.70093	1752.9340	737.70093	1387.8601
5755	737.65021	3948.4895	737.65021	2175.5801	737.65021	1839.5383	737.65021	1373.1357
5756	737.59949	3858.01831	737.59949	2099.8972	737.59949	1784.1886	737.59949	1361.3127
5757	737.54877	3663.32544	737.54877	2140.0771	737.54877	1873.6534	737.54877	1401.6202
5758	737.49805	3952.2334	737.49805	2151.2888	737.49805	1740.1407	737.49805	1415.8550
5759	737.44733	3827.06909	737.44733	2150.9170	737.44733	1826.6873	737.44733	1311.3936
5760	737.39661	3817.72437	737.39661	2167.9116	737.39661	1832.1604	737.39661	1322.7445
5761	737.34589	3961.75977	737.34589	2063.3562	737.34589	1840.5254	737.34589	1365.9244
5762	737.29511	3920.56714	737.29511	2115.0808	737.29511	1793.9126	737.29511	1377.2620
5763	737.24445	3980.64038	737.24445	2163.8945	737.24445	1712.6011	737.24445	1362.5593
5764	737.19367	4023.33838	737.19367	2160.6282	737.19367	1825.1089	737.19367	1356.5389
5765	737.14294	3921.42603	737.14294	2160.2546	737.14294	1819.0095	737.14294	1318.7096
5766	737.09216	3883.15967	737.09216	2266.8630	737.09216	1789.7810	737.09216	1428.3551
5767	737.04144	3957.65186	737.04144	2214.4348	737.04144	1809.7078	737.04144	1378.9626
5768	736.99072	3974.30981	736.99072	2231.3943	736.99072	1786.2716	736.99072	1300.6832
5769	736.94	3858.02637	736.94	2280.1370	736.94	1858.2104	736.94	1381.3757

Sheet1

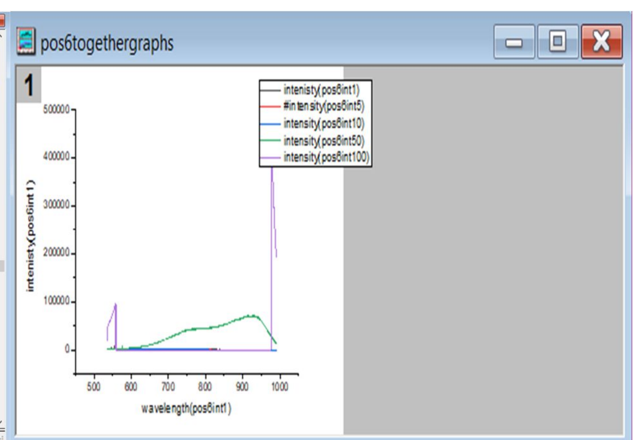


Fig 3: Extracted data of SiC and deleting the mismeasured point i.e. natural cosmic photon in the graph during analysis.

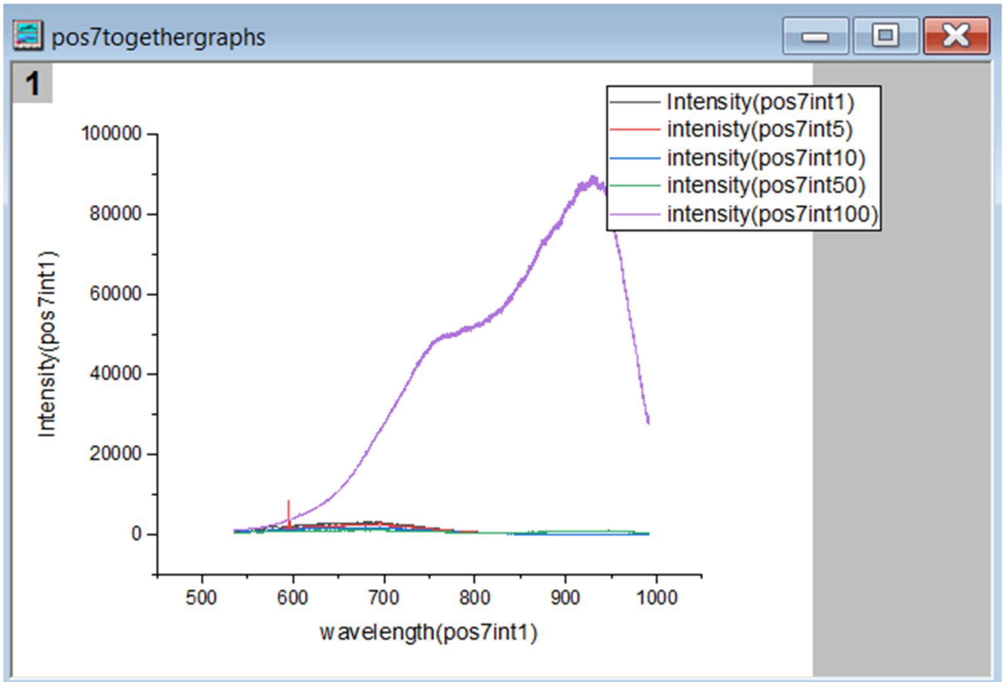


Fig 4: After formatting the wrong data point, Graph for SiC sample for various laser power excitaion at position 7(every sample is measured approx at 15 different position with different mode of excitation of 1%,5%,10%,50% and 100%).

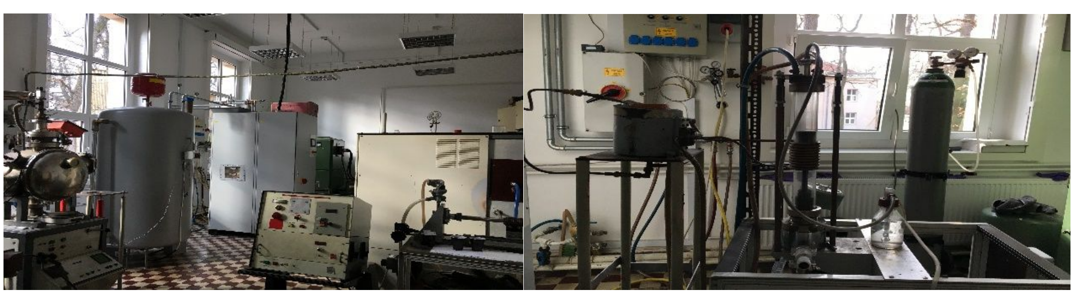


Fig 5(:a,b)Processing of bulk ultrafine-grained metals and alloys by powder metallurgy with Hot pressing technique. It is same as previos semester but this time the sample is not only fine powder but disc types as as well.

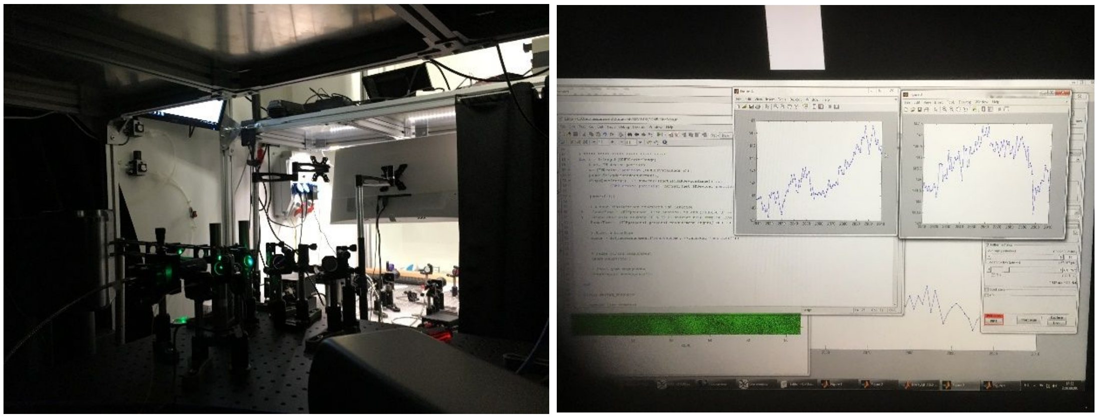


Fig 6(left and righ):left:optical arrangement for ODMR signal at cryogenic temp
Image right: Resulted Signal different from the expected one.This fig is also same as previous semester.

Softwares: MES (measurement experiment science) software has been used to extract the ODMR signal with the compatible Matlab Script. The system software has shown remarkable results from surface scanning to point scanning of nano diamond and SiC.

Origin is a proprietary computer program for interactive scientific graphing and data analysis. It is produced by OriginLab Corporation, and runs on Microsoft Windows. It has inspired several platform-independent open-source clones like SciDAVis. Graphing support in Origin includes various 2D/3D plot types.

Data analyses in Origin include statistics, signal processing, curve fitting and peak analysis. Origin's curve fitting is performed by a nonlinear least squares fitter which is based on the Levenberg–Marquardt algorithm. Origin imports data files in various formats such as ASCII text, Excel, NI TDM, DIADem, NetCDF, SPC, etc. It also exports the graph to various image file formats such as JPEG, GIF, EPS, TIFF, etc. There is also a built-in query tool for accessing database data via ADO.

In the previous semester I gave the demonstration of origin software for data Analysis. During this semester I have learned to use it for SiC samples basically. The extracted data measured by Raman spectroscopy i.e. Raman signal and PL spectra is then analyzed with origin software by using different tool directory. I tried to show with the help of pictures, The graphs and data points of measured data. Gaussian algorithm is used for fitting the curves and for approximation. Gaussian fitting is suggested also because of different energy states of a particle and its relaxation time and stage.

There are various tools in origin system software for normalization, Plotting, manipulation the script etc. It is sophisticated system software for scientific measured data analysis. With the help of it you can get very precise results of analysis.