Development of Data Acquisition and Advanced Algorithm for Spectrometer for Laser Based Fluorescence Applications

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Abstract - **Emission and reflection of light from the objects depends on their internal energy levels and composition present in the environment. The hot objects emit light while cold objects reflect or absorb light on some specific wavelengths. Spectrometer is the equipment which is used to measure the spectra of light emitted. The project aims to use Ocean Optics USB 4000 spectrometer to measure the intensity spectra of light incident on its input port. The control and data acquisition of spectrometer will be developed under EPICS (Experimental Physics and Industrial Control System). The signals acquired from spectrometer will be then decomposed into small functions by using EMD (Empirical Mode Decomposition). The conspired solution for removing noise from the signals which are non-stationary and non-linear in nature is done by using EMD. This spectrometer find several applications in Agricultural Measurements and Monitoring, Polymer Analysis, Medical Diagnostics etc. Enabling it with EPICS allows it to easily communicate and control along with other device like laser, imaging system, time synchronization etc involved in experiment.**

I. INTRODUCTION

The optical device used to measure the wavelength of light, deviation of refracted rays is known as Spectrometer. Different measurement techniques like environmental or chemical analysis, fluorescence, or Raman are measured using spectrometer. By using spectrometer, we can easily measure the absolute or relative irradiance of different light sources. The software used to control the spectrometer is SeaBreeze. It helps in taking input and analyse them. The EPICS provides the environment to develop the control system for Spectrometer.

II. SPECTROMETER

A spectrometer is normally used to quantify wavelengths of electromagnetic radiation (light) that has associated with a sample. The characteristics of a sample can be recognized by the changes in the incident light which can be reflected off, absorbed by, or transmitted through a sample at different wavelengths. The changes in the incident wavelengths of a light will be measured by a spectrometer. The fluorescence spectrometers are perfect for use in low light fluorescence applications where the capacity to distinguish weak signals is pivotal for proper measurements. Moreover, fluorescence spectrometers highlight broadband spectral response ranges for distinguishing wide wavelength bands alongside a wide opening width for expanded throughput.

III. OCEAN OPTICS USB 4000 SPECTROMETER

Ocean Optics USB 4000 Spectrometer [6] is the USB series spectrometer. It comprises of two types of USB series spectrometer one

is USB 2000+ and USB 4000. USB spectrometers are resourceful, general-purpose UV-Vis-NIR spectrometers. They are mostly used for various measurement techniques like absorption, transmission, reflectance, emission, color and other applications. They are famous in the world for their compact size, handy and easy modularity. One of the advantages of using USB series spectrometer is that they support thousands of applications in the field of research, education, material identification and especially in life sciences.

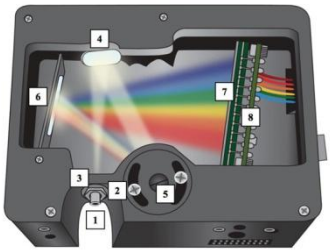

Figure 1 : Ocean Optics USB 4000 Spectrometer

IV. SOFTWARE TOOLS FOR SPECTROMETER

Ocean Optics provides stack full of software to deal with spectrometers. They provides tools to meet a "full spectrum" of spectroscopic analysis and automation needs at multiple levels of power, complexity, and programmability. Ocean Optics provides various software like OceanView, OmniDriver, SPAM, SeaBreeze. OceanView is used for real time acquisition, it graph the results and it includes various built in application wizards for various spectroscopic techniques like absorbance measurement, color measurement or fluorescence. It is driven by OmniDriver which is a compatible with any language. It is a high level driver which is used to provide complete programmatic control over spectrometers. SPAM(Spectral Processing And Math library) includes functions which are pre-tested and validated post-processing used for computing irradiance, Raman shifts etc. SeaBreeze is a device driver written in C and C++. It parse each byte passing between spectrometer and the application.

V. EPICS (EXPERIMENTAL PHYSICS AND INDUSTRIAL CONTROL SYSTEM)

EPICS[3] provides an environment to easily communicate with other devices. It comprises of set of software tools and applications. It helps in building different control systems to operate different devices. The data acquisition from spectrometer is done by EPICS. Dalesio[4] paper defines EPICS as a software infrastructure for developing control systems. It also provides collaboration between industries and collaboration labs. The architecture of EPICS include different subsystems like alarm handler, achiever and sequencer, display manager. EPICS provide better communication between these subsystems.

The front end tools for the development of EPICS software (sub-systems) are MEDM, EDM, CSS BOY, EPICS Qt etc., which are open source software and are easily available.

VI. EMPIRICAL MODE DECOMPOSITION (EMD)

The algorithm used for the decomposition of an original signal is EMD (Empirical Mode Decomposition). In EMD the signal has been breakdown into small functions by using sifting process. These small functions are known as IMFs (Intrinsic Mode Function). Each intrinsic mode which is either straight or nonlinear, represent to a straightforward oscillation, which contains same number of extreme and zero-crossing.

In the wake of applying the EMD, IMFs can be removed from the particular signal which will dependably be of lower frequency

than already extricated IMF and the principal IMF will dependably contain high frequency segments while the last one will dependably contain the single frequency.

Oumar[1] describe that the function will become an IMF if and only if it satisfies following two conditions:

The number of extrema and the number of zero crossing must be either equal or differ by one (at most) and

At any point, the mean value of the envelope defined by the local maxima and local minima must be zero.

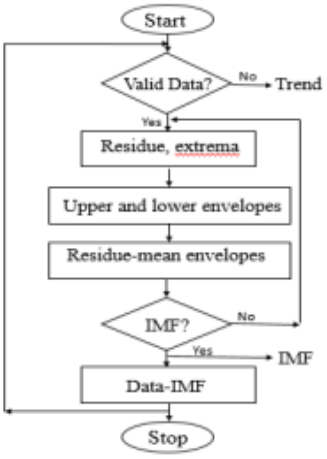

Figure 2: EMD Computation flowchart

VII. PROBLEM DEFINITION

In a spectrometer, the light is made to falls on a grating which separated different wavelengths into spectrum. These wavelengths are incident at the different positions of linear CCD, which is then is sent to the computer via USB interface for further processing. In the proposed work the signal acquired is further analysed by using signal decomposition technique known as EMD. EMD is used for denoising, signal enhancement, economic data analysis. We have many advantages of using EMD i.e. they are adequate for both non-linear and non-stationary data and it gives sharp spectrum.

VIII. METHODOLOGY

In the project ocean optics USB 4000 spectrometer is used. The input is taken by using SeaBreeze software which is designed especially for embedded applications. It is low -level device driver which is supports multi-development environment and runs on Windows, Linux and MacOs. It does not contain any advanced spectroscopic processing and manipulation. It allows raw USB access, probing for available spectrometer features, acquire maximum Intensity at wavelengths, set integration time, set/get acquisition delay, and assign number of pixels for binning, Calibration functions and several other functions. The applications developed are needed to run in resource-constrained hardware environments.

STEPS:

- The narrow aperture or entrance slit in the spectrometer is used to direct light through optical fibre cable into the spectrometer. It is the first step in the process.
- After that the photons get converted into the electrons when the light gets imaged onto the detector. The electrons get digitized and they are read out through a USB (or serial port) to a computer.
- The digitized signal get insinuate by SeaBreeze embedded Device Driver which is used to take the input.
- EMD algorithm is then applied on these signals.

- On applying the EMD the signals are breakdown into small functions.
- This data can then be used and manipulated for countless spectroscopic applications, like fluorescence, color measurement, irradiance.

IX. CONCLUSION

The accurate measurement of spectrum makes the accurate calculation. In this paper we analyse the signals of fluorescence light and analyse the signals using EMD. EMD has been implemented using the cubic natural spline as it is very simple to implement and very flexible too and on other hand it has also been noticed that definition of IMF cannot be rigorously realized: number of shifting will strictly meet the IMF definition but obtaining IMF like this wouldn't be physically meaningful. To find the exact number of the sifting to find out the IMF is illusive.

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