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Non Invasive Glucose Measurement Using Raman Spectroscopy

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Abstract - *Diabetes mellitus is a serious metabolic disease characterized by hyperglycemia which results from defects in insulin secretion. This causes major complications affecting the patient's internal organs, eyesight and circulatory system. Thus continuous monitoring of blood sugar levels on regular basis becomes very essential for maintaining a proper lifestyle. The traditional methods of glucose measurements require blood samples which involves the use of an automatic lancing device on finger or on less sensitive areas, such as the upper arm, forearm, or thigh. This invasive method is liable to afflict a degree of pain and cause skin injury. The alternative to this traditional method involves non invasive optical measurement of glucose by focusing a beam of light onto the body. In this proposed research, Raman spectroscopy is used as the non invasive method for monitoring the concentrations of blood analytes. This method is based on irradiating the sample with a monochromatic source of light which is used to identify the composition of molecules of blood tissue matrix, including glucose and proves itself as one of the efficient methods of non invasive glucose measurements.*

***Key Words*: Raman, Spectroscopy, non-invasive , glucose.**

1.INTRODUCTION

Glucose is a form of sugar produced when the body digests carbohydrates. Glucose is the body's major fuel for energy. Insulin is a hormone secreted by the pancreas. It is responsible for breaking glucose into an energy unit for the body to use. The absence or ineffectiveness of insulin causes the blood glucose level to increases. High blood glucose levels can lead to both short and long- term problems. Diabetes is the condition in which the body does not properly process food for use as energy .When one is diabetic, his body cannot produce enough insulin or cannot use its own insulin as well as it should. Due to which the level of sugar increases in the blood. Diabetes can cause serious health complications including heart disease, blindness, kidney failure, and lower-extremity amputations. At present, no cure is available for diabetes but if patients adhere strictly to a proper diet, exercise, medication, they are able to maintain their health, and indeed, lead relatively normal lives. The key to maintaining a proper life style is in frequent measurements of blood glucose. Recent research has proved that noninvasive techniques are the best way to measure glucose levels. Over the years, scientists have been trying to develop self-care measurement modalities for people with diabetes. The majority of these modalities require a blood sample. Some devices use automatic lancing device on a finger or on less sensitive area, such as the upper arm, forearm, or thigh. Other devices use a beam of light instead of a lancet to pierce the skin. The invasiveness of the testing procedure for diabetes plays a contributing role to the fact that nearly one- third of the population with diabetes goes undiagnosed. It is for this reason that a method for noninvasively monitoring glucose levels is highly desirable. Such a device will allow for more frequent and continuous glucose monitoring without the pain that is associated with the current commercial glucose monitors.

1.1 Literature Review

The noninvasive measurement of blood glucose by any technique is inherently complex because of the wide range of potentially interfering components such as blood analytes. There are also other difficulties such as the variability and in homogeneity of human skin and the constantly changing human physiology. Noninvasive approach started with studying glucose molecules and the response and effect of glucose presence on optical, acoustic, photo-acoustic, chemical and electrical aspects. Electrical and chemical methods produce acceptable results but its effect on diabetics skin are reddening, irritation and minimal burns.

Near Infrared Spectroscopy

It is a spectroscopical methodology that uses the near-infrared region of the electromagnetic spectrum from about 700 nm to 2500 nm. It relies on the measurements of transmitted or reflected light. The choice of NIR excitation for probing biological tissue is justified by three advantageous features: low-energy optical radiation, deep penetration, reduced background fluorescence, measuring signal has high energy compared with MIR spectroscopy. The complexity of background spectra arising from the

presence of other tissue components such as water, hemoglobin, proteins, fat, etc is a major obstacle in the development of a Near Infra Red Spectroscopy.

Photo-acoustic spectroscopy

Photo acoustics is the production of acoustic waves by the absorption of light. Photoacoustic spectroscopy (PAS) involves irradiation of intermittent light onto a sample and then detecting the fluctuations in temperature in the sample as pressure fluctuations. The photoacoustic effect involves excitation of a sample by intermittent pulses of electromagnetic radiation. The generated pressure is proportional to the sample optical properties and is used to predict the concentration of constituents in sample. The advantage of photoacoustic spectroscopy is that it can be performed on all phase of matter. The disadvantages are that it is sensitive to environmental parameters and this technique is also subject to chemical interferences from biological interferences.

Optical coherence tomography:

Optical coherence tomography is an optical signal acquisition method .It consists of a low coherence light, such as a super luminescent light, an interferometer with a reference arm and a sample arm, a moving mirror in the reference arm. A photodetector is used to measure the interferometric signal which is the result of the combination of light backscattered from tissues and light returned from the reference arm of the interferometer. The limitation of this technique is its sensitiveness to individual's motions.

Ocular Spectroscopy:

This spectroscopy technique is based on the use of a specially designed glucose sensitive hydro gel contact lenses. The illumination of the lens by laser source results in changes in the color of the resultant reflected light depending on the entity of the binding phenomenon. This color change is then detected by spectrometer. The significance of this method is that the preferential area of this technique is the aqueous humor beneath the cornea which has the property of low scattering. Limitations are that subjects may be uncomfortable with contact lens and it may also lead to some contact lens related infections.

1.2 Raman Spectroscopy

Raman spectroscopy named after its inventor, C.V. Raman, who, along with K.S. Krishnan, published the first paper on this technique. Dr. Raman won the Nobel Prize in Physics in 1930 for this discovery using sunlight, a narrow band photographic filter to create monochromatic light, and a crossed filter to block the monochromatic light. Raman spectroscopy is a technique which can be used for analysis of a wide range of forensic samples. It resolves most of the limitations of other spectroscopic techniques. It can be used for both qualitative as well as quantitative purpose.

Raman spectroscopy is a scattering technique. It is based on Raman Effect, i.e., a change of wavelength exhibited by some of the radiation scattered in a medium. This effect is specific to the molecules which cause it, and can be used in spectroscopic analysis. Raman spectra contain information about the change in molecular energy levels under the influence of laser light irradiation, and subsequent detection of light scattered from the sample inelastically at different wavelengths than the excitation laser wavelength. The state of the chemical bonding and atomic nuclei within a molecule, as well as the interactions between the molecule and its local chemical environment is revealed by Raman scattering. Employing Raman techniques to directly measure glucose concentration in plasma, serum, and whole blood have met with encouraging success in vitro as well in vivo measurements. Raman Spectroscopy is promising due to its chemical stability and good penetration depth with near-infrared sources.

2. METHODOLOGY

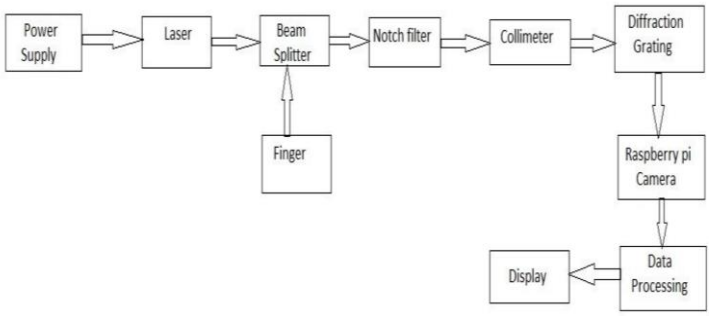

Fig -1: Block Diagram

The setup uses an 830 nm diode laser as the Raman excitation source. The current trend is towards the use of external cavity laser diodes because they are compact and of relatively low cost. Raman scattering occurs at the same energy shift regardless of the excitation wavelength, narrowband excitation must be used to prevent broadening of the Raman bands.

The filtered laser light can be delivered to the sample either through free-space or through an optical fiber. In the free-space embodiments, beam shaping is usually performed to correct for astigmatism and other laser light artifacts.

The laser light is then given to the beam splitter which splits the laser beam into two beams. One of which is focused onto the finger and the other is passed through a notch filter to reject the backscattered Rayleigh peak and the specular reflection at 830 nm. Then it is passed through a collimator that narrows the beam of particles. The collimated beam is then passed through a diffraction grating which splits and diffracts light into several beams travelling in varied directions.

The filtered light may be transferred to a spectrometer by means of an optical fiber bundle which converts the circular shape of the collected light to a single row of fibers, in order to match the shape of the spectrometer entrance slit. The spectra is collected by a cooled charge coupled device array detector and binning process is done in the vertical direction, which results in a spectrum with intensities at 1340 frequency intervals.

After data collection, pre-processing steps are undertaken to improve data quality. The pre-processing steps chosen can lead to different calibration results. The image of the spectra is captured on a Raspberry camera on which processing is carried out and the final output is displayed on the LCD display.

Raman spectrometer needs a dedicated software that can perform effective measurements and data processing. Spectra has to be processed at different stages to detect automatically, or with very limited operator involvement, various substances or mixtures. The process of Raman spectra recognition comprises of three main stages. Initially, a background signal has to be removed from the spectrum. This signal is a result of fluorescence, background noise of CCD detector and other light sources present in field measurements. Subsequently, the spectrum signal should be smoothed to reduce its random error and random spikes. Then, the preliminary processed spectrum is parameterized to get a set of parameters (positions of the spectra peaks, their relative amplitudes and widths) that gives necessary information about the spectrum, required for detection of the investigated chemicals. Detection algorithms that are used in Raman spectroscopy employ various methods that identifies similarity between the estimated parameter set and the set established for reference spectra.

2.1 Raman Spectrum

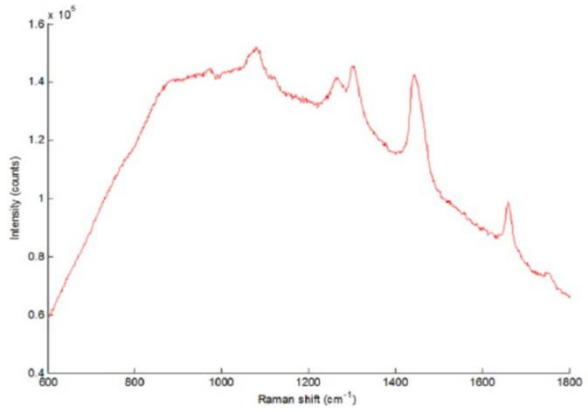

Fig -2: Raman Spectrum of Human Skin Tissue

The amount of shift in the frequencies as a result of the different vibrational levels of the molecules in the sample, provides information regarding the composition of the sample. In the typical Raman spectrum displayed above, specific regions attribute to specific groups. The recorded Raman spectrum gives information about proteins, nucleic acids, lipids, salts, and carbohydrates (such as glucose).

Designation of Distinct Raman Signals.

Raman shift (cm^{-1})	Designation
1004	Phenylalanine
1020-1140	Carbohydrates
1220-1340	Collagen, nucleic acids
1400-1520	Fatty acids
1620-1700	Proteins
1720-1780	Esters

Table -1: Designation of Distinct Raman Signals

3. CONCLUSION

Raman spectroscopic analysis is a light scattering technique. It may be delineated as a method where a photon of light interacts with a sample to provide scattered radiation of various wavelengths. Quantitative Raman spectroscopic analysis is a promising technique for noninvasive glucose sensing because it combines the benefits of Near-IR spectroscopic analysis with the benefits of Infrared spectroscopic analysis. For Raman spectroscopy to be a viable clinical technique, successful prospective studies should be dispensed. It is undoubtedly a significant analytical tool offered, that has some clear benefits over other methods of research. Raman spectroscopy could be back within the minds of analytical chemists worldwide, if the various benefits of this Spectroscopy is taken into consideration.

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