Detection of N,P,K Fertilizers in Agricultural Soil with NIR Laser Absorption Technique

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***Abstract*-Soil is a complex medium that contains minerals, organic matter, micro-organisms, air and water. Recent studies have shown that soil fertility is declining in many farmlands due to insufficient fertilization. Over-fertilization results in groundwater pollution or toxic accumulation of chemicals in the soil. The aim of this experiment is to adjust fertilization based on crop needs and soil properties and to reduce the amount of fertilizer in soil without diminishing yield. The soil analysis technique focus on photon absorption characteristics of the major soil nutrients (nitrogen, phosphorus and potassium). The soil samples under test were first oven dried and and then mixed with four types of fertilizer [KNO_3, TSP, $(NH_4)_2SO_4$, NPK] in the concentration range of 0.02-10%. Near IR laser beam pass through the closed loop Mach- Zander Interferometer to reduce fluctuations related to beam path and interacts with soil sample. When IR radiations are focused onto a sample, the molecules in the sample will increase their vibration energy by absorbing energy at specific frequencies depending on the molecular geometry, bond strengths and atomic masses. The scattered beam is thus modified, creating a signature of the targeted object with peaks at the absorbing frequencies. This technique provided rapid, non-destructive and simultaneous determination of nitrogen, phosphorus and potassium concentrations in soil fertilizer mixtures.**

Keywords—Interferometer, NIR, LabVIEW

I. Introduction

According to Beer's law, the optical absorbance of a fluorophore in a transparent solvent varies linearly with both the concentration and the sample cell path length (L). Absorbance (A_λ) is calculated from the ratio of the light intensity that is incident on the sample (I_0) to the intensity passing through the sample (I) [2]:

$$A_\lambda = \log\frac{I_0}{I} \qquad (1)$$

The absorbance of a sample depends on the molar concentration (c, $[mol\, L^{-1}]$), length of solution the light passes through (L, [cm]), and molar absorptivity (ε, $[L\, mol^{-1}\, Cm^{-1}]$) for the dissolved substance

$$A_\lambda = \varepsilon CL \qquad (2)$$

When Near IR light interacts with a sample under test, the radiations are absorbed and scattered by the sample. By determining the total photon absorption inside a sample, it is possible to know the chemical contents within a particular sample [1].

II. Preparation of Soil Samples & System Setup

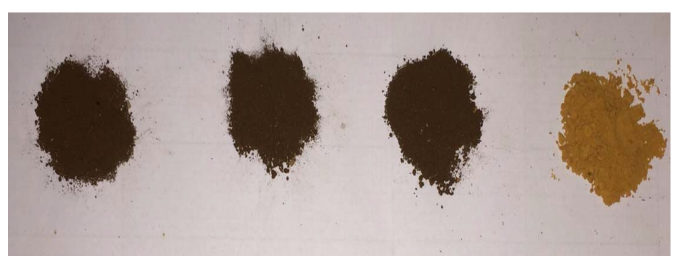

Fig.1: Grinding and drying soil samples

Pure natural soils were used to make sample which is obtained from agricultural farms. Then soil samples are dried at 65 ℃ for 5 hours as shown in figure 1. Then, soil samples are pre-treated by grinding and pressed into 10 mm samples of 2 mm thickness under the pressure of 5 MPa inside a pressure chamber. Three lasers of wavelengths 730 nm, 1300 nm & 1550 nm are used for this experiment. Nitrogen, phosphorus and potassium fertilizers shows absorption wavelength at 730 nm, 1300 nm & 1550 nm respectively [2].

The first part of setup consists of construction of Mach-Zehnder interferometer The beam from interferometer is coupled to multimode fiber with the help of aspheric lens. The purpose of introducing an interferometer in this setup is to nullify instabilities related to misalignment, vibration and temperature fluctuations. The beam splitter divides the beam in two equal parts and both both travels a distance of L_1 & L_2.

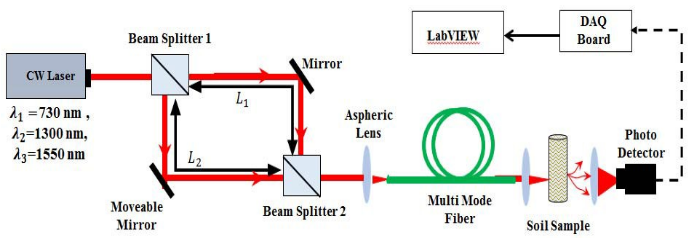

Fig. 2: System setup

The temperature and misalignment instabilities can be compensated by making both distances equal. For this purpose, a piezo actuator operated moveable mirror is used in one of the arm of interferometer. A closed loop feedback control mechanism is used to move the piezo actuator for any change in intensity fluctuations at output.

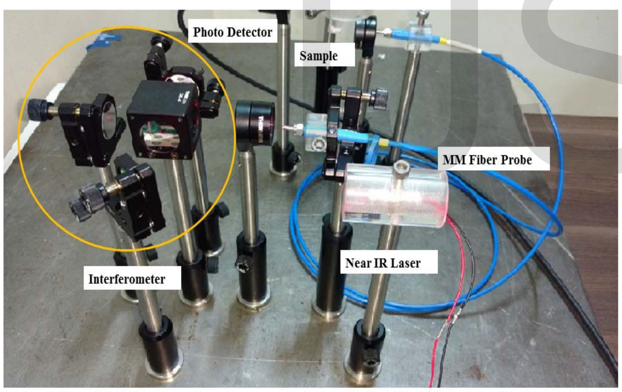

Fig. 3: Optical setup for soil testing

The laser from multimode fiber is injected to soil sample. Fig. 2 and fig. 3 shows optical setup for this experiment.

III. Analysis of Soil Samples

When IR beam interacts with soil sample, the scattered light is detected at photo detector. The amount of photon absorption by a particular sample can be easily found out by calculating transmitted light intensity at detector. It is observed that N, P & K rich fertilizers show different peak of absorption for different wavelengths of laser [3]. The plots for transmitted and absorbed photons characteristics of particular fertilizers are plotted with LabVIEW interfaced with DAQ board. Figure 4 shows transmitted light intensity from two different samples, one without nitrogen solution and other with 10% aqueous nitrogen fertilizer.

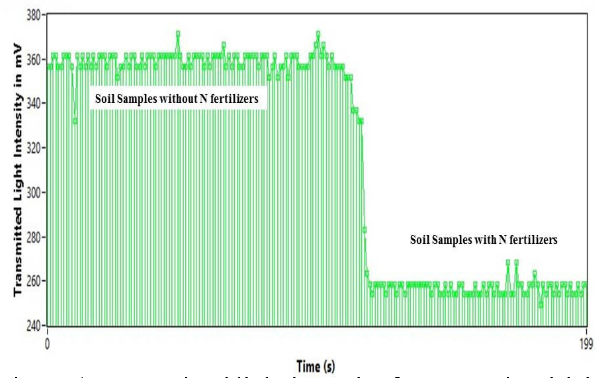

Figure 4: Transmitted light intensity from samples rich in nitrogen

It clearly shows that soil samples with nitrogen content shows high absorption characteristics of photons. The same process is repeated for potassium and phosphorous. From fig. 5, it is possible to determine the content of specific fertilizer by looking into its photon absorption characteristics [4]. The power of tunable CW laser used in this setup is 50 mW.

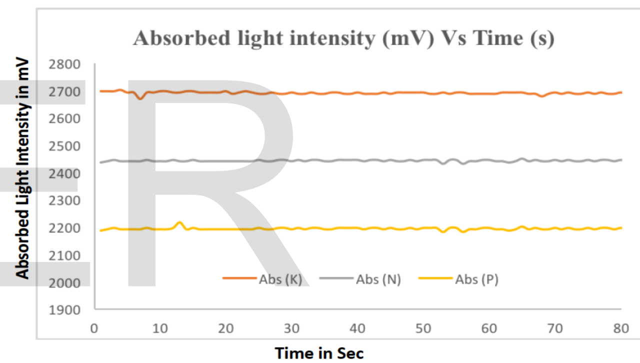

Fig. 5: Photon absorption characteristics of soil samples with N,P,K fertilizers

IV. Conclusion:

Photon absorption technique is a simple and non-destructive analytical method that can be used to quantify several soil properties simultaneously. The main challenge for the evaluation of soil properties is to find suitable data pre-treatment and calibration strategies. In this study, a tunable laser is used to find reflectance and absorption photon data and values for soil properties.

References

[1] Krishnan R et.al. "Reflectance technique for predicting soil organic matter." Soil Sci. Soc. Am. J. 44:1282-1285, 1980

[2] Ben-Dor E. et. Al "Near infirared analysis as a rapid method to simultaneously evaluate several soil properties". Soil Sci. Soc. Am. J. 59:364-372, 1995

[3] Piekarczyk, J "Effects of Soil Surface Roughness on Soil Reflectance Measured in Laboratory and Outdoor Conditions." IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens. 9, 827–834, 2016

[4] Zhang, Y "Prediction of stratified soil nitrogen content in near infrared spectral analysis." J. Agric. Eng. 31, 121–126., 2015