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Development of a Visible Light Transmission (VLT) Measurement System Using an Open-Path Optical Method

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Abstract. This paper describes about a visible light transmission (VLT) measurement system using an optical method. VLT rate plays an important role in order to determine the visibility of a medium. Current instrument to measure visibility has a gigantic set up, costly and mostly fails to function at low light condition environment. This research focuses on the development of a VLT measurement system using a simple experimental set-up and at a low cost. An open path optical technique is used to measure a few series of known-VLT thin film that act as sample of different visibilities. This measurement system is able to measure the light intensity of these thin films within the visible light region (535-540 nm) and the response time is less than 1s.

INTRODUCTION

Visibility is a measure of the distance at which an object or light can be clearly detected. It refers to the maximum distance from which the human eye can see and identify a target's contour from the background of sky in a certain weather condition [1]. Visibility information is also essential in dust and air quality monitoring which often require frequent and accurate real-time observations [2].

The measurement of visibility can be identified by referring to the amount of visible light transmission (VLT). As the percentage of VLT increase, light intensity will also increase. Thus, the visibility will also increase. VLT simply refers to the measurable amount of solar visible light (daylight) that travels through a certain medium. A medium with a high VLT allows most of the daylight to pass through while a lower VLT restricts the majority of light from entering a medium.

Visibility can be measured using a few methods. Traditionally, a human eye is used for observation to determine visibility. With a great technological progress, visibility measurements have modernized from manual observations to automated observations using visibility instruments. Manual observation usually refers to human eye observation. There are several types of visibility instrument and technique to measure visibility has been reported previously.

One of the techniques is called photography technique. This technique is an image processing method using a mathematical operation. It uses a form of signal processing for which the input is an image, a series of images, a video or video frame. The output of signal processing may be either an image or a set of characteristics or parameters related to the image. A few instruments are using this photography technique as their working principle such as a *Digital Visiometer System* (DPVS) for automated visibility observation [3]. Another instrument uses the same technique is a *Forward Scattering Visibility Instrument* (FSVI) [4].

Another technique for visibility measurement is using a Laser Absorption Spectrometry (LAS). LAS refer to a technique that uses laser to assess the concentration or amount of a species in gas phase by absorption spectrometry (AS). It has a vast detection and monitoring of constituents in gas phase. This technique incorporates the measurement of extinction coefficient used in an instrument called Transmissiometer [5]. It operates by sending a narrow, collimated beam of energy (laser) through the propagation medium. The other uses scattering coefficient measurement technique such as used in a Nephelometer [6].

The existing visibility measurement system using a laser absorption spectrometry technique such as Transmissiometer and Nephelometer has a gigantic set up and they are very costly. The other measurement system such as a photography technique fails to function well at night because of the low light condition and it faces a several errors especially in rainy, foggy and smoky conditions. Therefore a new optical method by using a laser pointer as a light source to develop the VLT measurement system is reported. This new technique is believed to cater the problem mentioned above as the experimental set-up is simple and small in size. Besides, it can function well without depending on light condition of surroundings environment.

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THEORY

In optical method measurement, the Beer-Lambert law is used to relate the absorption of light to the properties of the material where light is travelling. The transmittance, T of the travelling light can be calculated from the ratio of the transmitted, I and incident intensity, I_0 as shown in equation (1). Absorbance, A as shown in equation (2) has no unit. If absorbance versus path-length is plotted on a graph, a straight line is produced. Thus the law can also be defined as a linear relationship between absorbance of light and the concentration of the absorbing medium.

$$T = \frac{I}{I_0} \tag{1}$$

$$A = -ln(T) \tag{2}$$

Using this equation, the absorption of light that passed through the air can be determined if the incident and the transmitted intensity is known.

EXPERIMENTAL SETUP

A battery operated laser pointer is used as a light source. It can emit laser emission and has the highest peak at 532 nm and can transmit up to 8000m. The light detector that is used in this experiment is an Ocean Optics HR2000 spectrometer. The spectrometer has a range from 200 to 650 nm and it provides resolution down to 0.65 nm (FWHM). This spectrometer is interfaced with a computer installed with SpectraSuite software. This software is used to display the reading for the spectrometer.

Since the experiment is conducted in a laboratory, there are a few limitations such as the path length between light source and detector. The changes of room light intensity during the experiment is carried out are also ignored. The laser pointer also has unstable intensity. Therefore, changes in light intensity of the laser pointer are also ignored.

At the initial stage, the VLT of the thin films were measured by using a commercial transmission meter. This step is to validate the reading of VLT of each thin film.

Then, the known-VLT thin films were measured by using an optical method. The arrangement for the experiment is shown in Fig. 1 below. Spectrometer will detect the intensity of the light that passed through the thin film and results will be displayed by using SpectraSuite software. Thin films are laminated on a clear glass plate as shown in Fig. 2 so that it can easily stand vertically. This is to ensure that the beam that passes through is perpendicular to the surface of the thin film to reduce any light scattering.

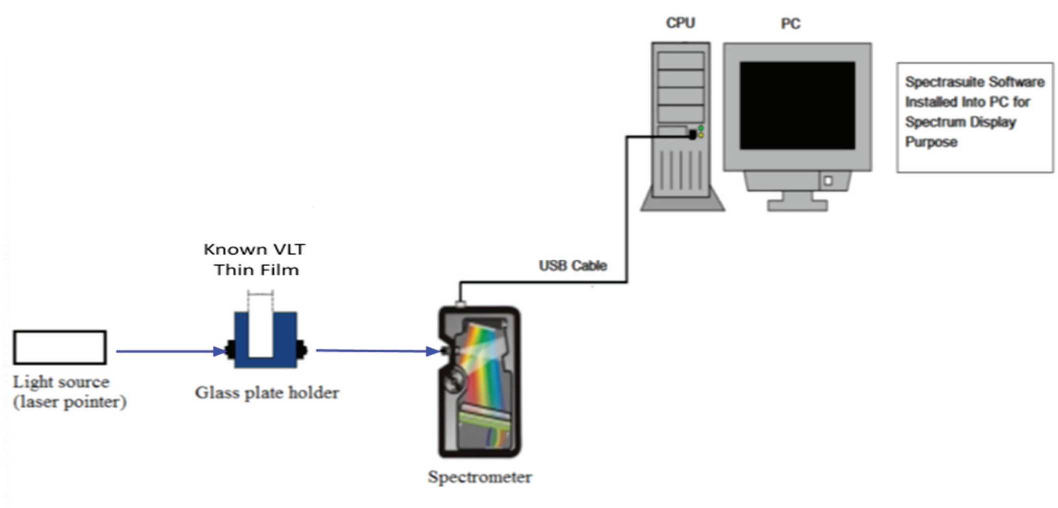

FIGURE 1. Experimental set-up

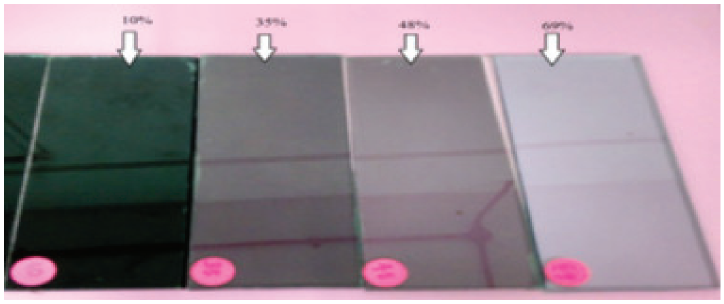

FIGURE 2. Thin films on glass plate holder

RESULTS AND ANALYSIS

Initially, the VLT-of known thin films were measured using a commercial transmission meter. The percentage of VLT-thin films that had been recorded by transmission meter was 10%, 35%, 48% and 69% as shown in Table 1. Once the VLT of the thin films are measured, the measurement using an optical method is initialized. During the initial stage of this measurement, Spectrasuite software is used to record the intensity and the integration time of the measurement is set to 0.1 s. The developed measurement system displayed the best peak that light transmits is in between 536-539nm as shown in Fig. 3 below. Thin film with high percentage of VLT will allowed more light to pass through it. As the percentage of VLT-thin film increase, the light intensity is also increase. The result is shown in Table 1 below;

TABLE 1. Result

VLT of thin film (%)	Intensity (Counts)
10	11154
35	15767
48	29918
69	35575

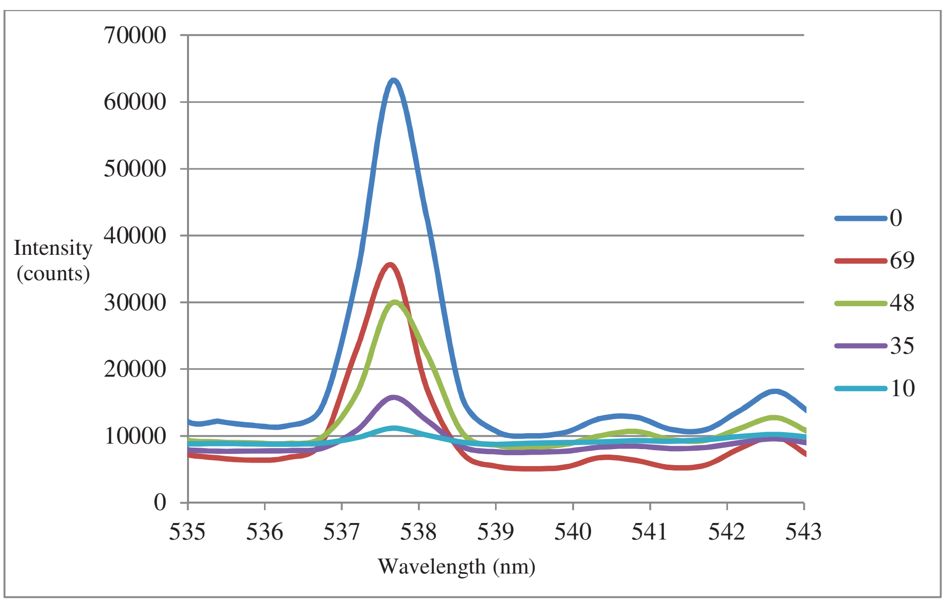

FIGURE 3. Intensity of light vs. Wavelength of VLT thin film

CONCLUSION AND FUTURE WORK

Based on the results, the developed measurement system is capable to measure intensity of different set of thin film visibilities at the region between 536-539nm. It also shows that the measurement system shows a fast response time which is 0.1 s. This research was carried out to develop a VLT measurement system by using an optical method and at the same time can be used to measure the visibility in open air. This system is expected and able to measure the visible light transmission with simple experiment set-up. After all, we can transform the visibility measurement from bulky and costly instrument to a simple structure and easy to operate. For future works, this optical method can be used to measure the visibility in all kind of weather with long path distance. Besides, this research can also be used to monitor the air quality index. It can even help to monitor the haze level in our country by measure the visibility according to the air pollution level.

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