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Surface Temperature Measurement Using He-Ne Laser

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Abstract

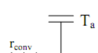
This study introduces a non-contact temperature measurement technique on solid surfaces. Temperature changes will result in the formation of vapor, which will interfere with the rate of reflection of light reflected on it. Helium-Neon (HeNe) lasers are used as reflective light sources, and photodiodes are used to collect and measure the power and energy of reflected light through solid surfaces. Changes in terms of power and reflective energy can translate to changes in temperature on a solid surface. In this study, temperature measurement is performed in 2 conditions: heating and cooling. The temperature change for the heating process is about 30 ° C to 70 ° C in 28 seconds, and for the cooling process is about from 70 ° C to 50 ° C in 320 seconds. Temperature measurement data taken using this technique is then verified using the calibrated temperature data logger, and it is found that the temperature measurement using this technique is dependable and reliable.

Key-word: - He-Ne laser, Non-contact measurement, Temperature

1. Introduction

Temperature is the most frequently measured property in the field of measurement technology. Temperature measurement can be implemented in 2 techniques, namely, contact and non-contact measurement technique. The contact measurement technique is a method that requires direct contact between the measuring instrument and the target to be measured. This is the most commonly used technique for measuring temperature. However, this technique is challenging to adapt to some situations such as dangerous areas, areas with too high temperatures, and tiny size targets such as on the radiator fins of vehicles.

Here, the non-contact measurement technique can solve the problem. The use of a helium-neon (He-Ne) laser can measure the temperature at a tiny target due to its light acuity, which reaches 0.66nm. The light coming out of the He-Ne laser will be directed to the target to be measured, which will then produce a reversal or reflection light. This reflected light can give an impression of temperature changes on the measured solid surface.



2. Methodology

2.1 Introduction

This project aims to instrumentally detect the temperature on a surface using a helium-neon laser. The objectives are to develop a non-contact surface temperature measurement using a helium-neon laser. Non-contact measurement techniques have assumed a critical part in the investigation of thermal and fluid phenomena. They have a few different points of interest over their direct-contact partners, including the non-intrusive nature of the measurement, remote-monitoring, and area of test/analysis equipment, imperviousness to harsh and corrosive environments, high spatial precision, fast response times, and high dependability and repeatability.

One prevalent non-contact instrument is the commercial infrared thermometer, which measures the infrared radiation emitted from an object to determine its temperature. In any case, these devices show low accuracy for low-emissivity materials, for example, liquids and objects with a minimal area. A laser-based temperature measurement technique effectively avoids these disadvantages. Tuomaset. al (2011) present a laser-based system to measure air's refractive index over a long path length. In optical distance measurements, it is essential to know the refractive index of air with high accuracy. A spectroscopic method for online compensation of refractive air index over longer distances had been described and demonstrated experimentally. The technique can measure average air temperature along approximately the same beam path that is used for optical length measurement. The method also provides potentially excellent spatial and temporal overlap and, therefore, accurate air temperature compensation.

2.2 Model geometry development software

Measurement of gas temperature is crucial in laser-induced plasma (LIP) and laser-material interaction (LMI). Temperature monitoring devices such as thermocouple has some limitations. The thermocouple cannot be placed in the laser-focusing region since it will induce an unwanted external effect. To overcome this, Ahmad (2011) proposed a non-contact method by using the interferometric technique. A simple Michelson interferometric was aligned to detect the pressure and refractive index change of ambient air. The temperature gradient of air was recorded and analyzed by using a video camera and phototransistors. From the observation results, it is clearly shown that the change of air temperature in one arm of the interferometer will result in the fringes shift of the interference pattern.

Figure 1 shows the schematic diagram of the optical system of the Michelson interferometer. Helium-neon laser with a wavelength of 633nm and 1mW power was used as a light source. The beam was reflected and steered by a steering mirror and then strike a beam splitter. The beam splitter transmits 50% of the beam (reference beam) to the still mirror and reflects the rest (disturbed beam) to the adjustable mirror. A heating element heats the air at one arm up to 593K. As a comparison, a calibrated type K thermocouple interfaced to a microcomputer was placed at the arm. A video camera recorded the interference formation. A light detector was placed at the interference fringes to detect the edges shift.

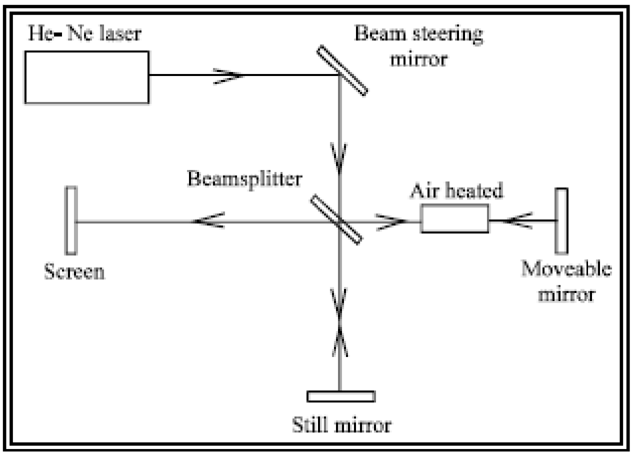


Figure 1 Detecting air temperature at one arm of a Michelson interferometer.

Based on the research by previous researchers, it can be concluded that a non-contact measurement device is the better solution in measuring temperature due to its non-intrusive nature of the measurement, remote-monitoring, and area of test/analysis equipment, impervious to hand corrosive environments, high spatial precision, fast response times, and high dependability and repeatability. The infrared-based device was the most commonly used commercially due to its less expensive and less complicated setup. However, for high accuracy temperature measurement, which involved minimal specific area, a laser-based non-contact temperature measurement device would be a better solution with its sensitivity towards a low-emissivity material and a tiny specific detection area. Numerous researchers used a Helium-neon laser tube with a 632nm wavelength as the light source in their experimental and system setup, which will be a point at the detection area, and the energy and power of the reflection will be measured using either a photodiode, camera, etc. The measured data then could be interpreted to a temperature reading using a virtual instrument to reduce the complexity of the physical setup of the system

2.3 Experimental

In this study, part of the methodology was applied to accomplish the study's objective, to develop a non-contact temperature measurement that is monitored by a computer. They are the physical experimental setup, which consists of the experimental apparatus; 10mW cylindrical helium-neon laser, FieldMax Top power, and energy meter, and high sensitivity semiconductor detector head. Figure 2 shows the schematic diagram of the experimental setup that had been carried out. The detector will capture the laser beam from the 10mW cylindrical helium-neon laser, and then it will be analyzed by the FieldMax power meter to determine the beam power.

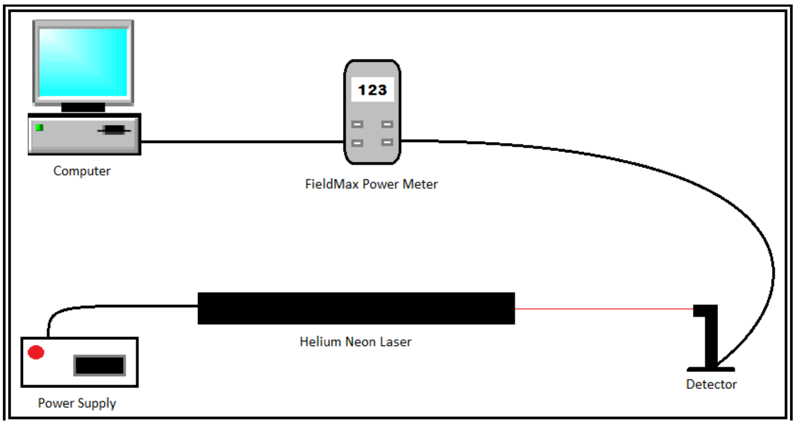


Figure 2 Experimental setup schematic diagram.

The main objective of the research is to develop a non-contact laser-based temperature measurement system. Therefore, the optimal distance must be determined to ensure the most accurate temperature measurement could be obtained. Figure 3 shows the actual experimental setup based on the schematic diagram shown in Figure 2.

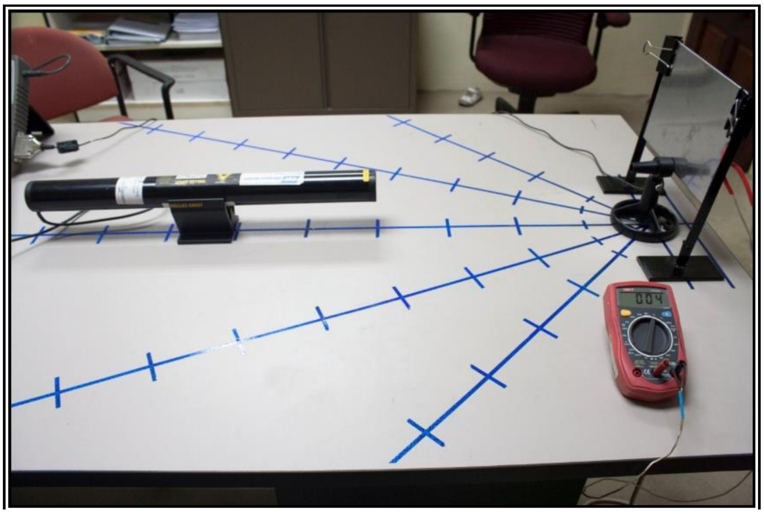


Figure 3 Experimental setup.

3.1 Introduction

The results were obtained from the experiments conducted in a cubical room with an average temperature of 32oC that being lightened by a fluorescent lamp. This is to ensure that the results obtained are reliable and dependable. The converted power to temperature results measured from the reflected laser beam was compared and verified with a K-type thermocouple.

3.2 The laser beam to object distance

The laser beam distance has to be determined to obtain the optimal detection signal by the photodetector. Therefore, an experiment had been carried out by placing the cylindrical Helium-Neon laser tube at a certain distance from the photodetector. Table 3.0 shows the data obtained from the experiment.

Table 1 Laser beam power versus laser beam distance.

Data	0cm	10cm	20cm	30cm	40cm	50cm	60cm	70cm	80cm	90cm
λ (nm)	633	633	633	633	633	633	633	633	633	633
Power (mW)	16.6	16.4	15.98	14.52	12.60	12.42	12.18	10.48	9.90	8.02
Area (W/m^2)	2.090	2.076	2.056	1.880	1.794	1.598	1.565	1.460	1.222	1.046

Based on the result in Table 1, it is observed that the value of power decreased with the increment of the distance between the helium-neon laser diode and the photodetector. The spread's increment also affected the value of power per area of detection, which is decreasing 2.090W/m to 1.96W/m with the increment of 10cm from 0cm to 90cm. The detection signal power and power per area were visualized in Figure 4 and Figure 5, respectively.

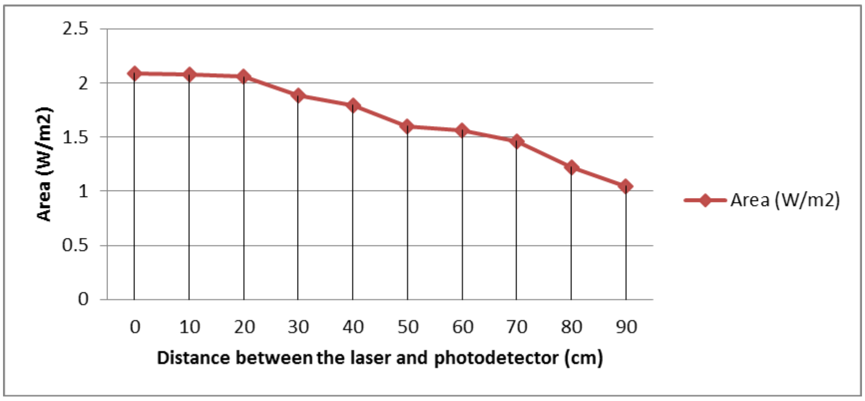


Figure 4 Laser beam power versus distance (Area).

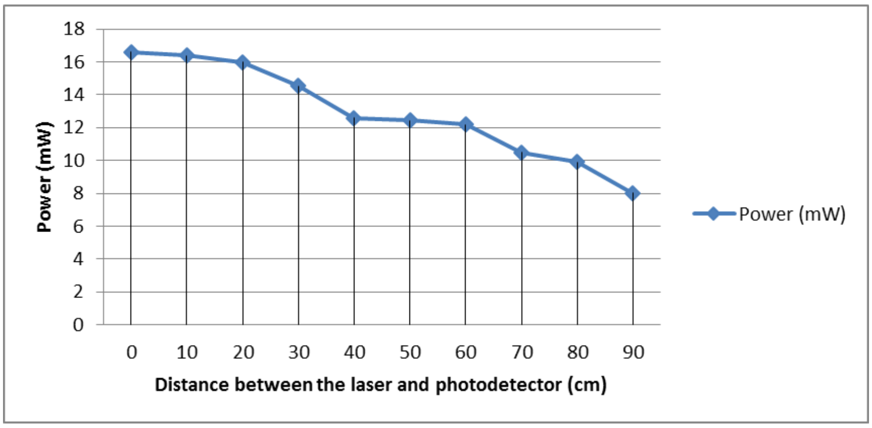


Figure 5 Laser beam power versus distance (Power).

4. Conclusion

This work presents a laser-based non-contact temperature estimation method. The activity's standard depends on the adjustment in the index of vapor density due to temperature changes, which brings about a distinction in a difference in the reflected beam from the measured surface. A 10mW helium-neon laser act as the light source for the system, and the reflected beam being focused back by plano-convex lenses. Then the reflected beam power is monitored and captured using a semiconductor photodiode. Results obtained from the laser-based temperature measurement system were then compared to a calibrated, reference temperature measurement, using a K-type thermocouple data logger to ensure the measures' acceptability using a helium-neon laser.

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