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Suspended Aerosol Particulate Matter Counter

Pratap Singh D Naik[1], Dr Vijay Mishra[2], Dr Kiran Gupta[3], Avinash Kumar[4], Puneet Sharma[5]

M.Tech Student, Dept. of ECE, VLSI Design and Embedded Systems, DSCE, Bangalore, India [1]

Chief Technology Officer, Centre for Nano Science and Engineering, IISc, Bangalore, India [2]

Professor and PG Coordinator (VLSI Design &ES), Dept. of ECE, DSCE, Bangalore, India [3]

Facility Technologist, Centre for Nano Science and Engineering, IISc, Bangalore, India [4, 5]

Abstract: A complicated blend of solid and liquid particles result in Particulate Matter particles. These particles are to be monitored and regulated for various reasons, and human health being one of them.This paper discusses about the monitoring of particulate matter particles (aerodynamic in nature) in the range of 2.5 µm to 10 µm. Here, a new technique is proposed for counting of particulate mattersusing optical analyser. Optical method uses light blocking or scattering property, where the flow of Aerosol particles causes illumination. Their interaction with electromagnetic waves causes change in light scattering which is detected by the Photodiode. An effort is put to achieve maximum optimization in terms of technology and cost. The main focus of this project is to implement a design which counts the number of particles and determines thesize of theparticlesthat are less than 2.5 µm (course fine particle) to 10 µm (total suspended particle).

Keywords: Particulate Matter, Python IDE, Microcontroller, NX SIEMENS

I. INTRODUCTION

In today's fast growing world, the atmosphere is being polluted due to various reasons leading to rise of dust particles.Particulate Matter (henceforth referred as PM) is a complex mixture of various combinations of solid and liquid particles suspended in air.This Complex Mixture contains for instance soot, dust, smoke, pollen, and liquid droplets.PM is classified according to its Aerodynamic diameter with the smaller particles having greater health impact on the living bodies. Because of the irregular geometric diameter of the PM,they are difficult to measure. The present day systems are based on complex computations and are very much expensive. The paper explain the new proposed theory for measurement of PM's by using numeric analysis and curve fitting to design a new PM counter and a measuring system.

The optical concepts of laser diode and photodiode are explained in [1]. The output of the photodiode is observed only when a particle is detected in the sensing region of the experimental setup. Reference[2] gives the idea about the sensor design for the counting of PM in the range of 2.5 um to 10 um. The sensor is comprised of photo-voltaic cell coupled with LED for PM counting. PM counting is also done using Multimode technique [3], which uses the light scattering principle for the aerosol particles.In brief,it says that the number of particles in the chamber are counted and measured in terms of mg/cm3, which in turn is determined by the constant flow rate in the channel inside the chamber. The Particle counter Grimm 1.107 model is developed using light scattering phenomena.The laser used is a low cost Nd-YAG laser [4], furnished with a 620Hzfrequencymodulation which is provided by same frequency quartz oscillator. The oscillator also acts as a reference for the Lock-in and demodulation.

The receiver is a refractive telescope followed by an interference filter (for reduction of background light) followed by the photodiode array.PMcounting is carried out by using light scattering methodology by adhering to CEPA (Canadian Environmental Protection Act, 1999) [6]. Aphotodiode sensor has been developed which can detect the low range of current pulses for counting the number of particles in [7]. The reference [8] reviews about the counting of particle using Raman spectroscopy with MATLAB interface programming which counts the number of different size of particles depending upon the peak spectrum. The paper discusses about the airborne particles collision with electromagnetic radiation in the dark chamber. This results in scattering of light at a particular angle. This deviation of scattered light is observed by the photo detector and the output current is measured. Anefficient system is developed with low cost to count the number of aerosol particles.

The paper is structured as follows. Chapter II focuses on the background theory and design implementation of the project. Chapter III shows the results obtained. Paper is then concluded with Chapter IV that describes the future scope and concluding remarks on the paper.

II. SCATTERING THEORY AND DESIGN IMPLEMENTATION

Scattering theories is categorized in terms of two theoretical frameworks. One is the theory of "Rayleighscattering"i.e., strictly speaking as originally formulated, applicable to small, dielectric (non-absorbing), spherical particles which can be used to count the number of aerosol particles.

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The second theory is the "Mie scattering Theory" that encompasses the general spherical scattering solution (absorbing or non-absorbing) without a particular bound on particle size. Equation (1)describes Rayleigh scattering as shown below:

$$\alpha = \frac{2\pi a}{\lambda} \qquad (1).$$

Where,
α=radius of spherical Particle,
λ=relative scattering wave length,
'α'and 'm' lie in the range such that as α<< 1 and m << 1.
Equation (2) describes Mie scattering as shown below:

$$m=n-ik \qquad (2).$$

Where,
m = the refractive index of the scattering particle,
n = refraction of light.

The instruments for calculating the number of particles such as laser, lens and the sample are placed in line for counting the numberof particles. When the Photodiode (PD) is placed in line with the collimating lens and Laser diode (LD), the intensity of light falling on PD is in the absence of sample and hence the PD reads high voltage. But, when the sample is placed as shown in the Figure 1, the sample particles scatter light in all directionswhich reduce the intensity of light falling on the photodiode.

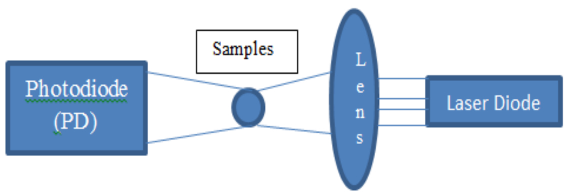

Fig 1: Schematic of optical experiment

To overcome this drawback, laser, sample and the lens with photodiode with focal length are placed at 90° in the dark chamber as shown in Figure 2.Laser diode operates at 680 nm wavelength.Multi interaction of particles inside the optical chamber is avoided and the voltage of Photodiode is biased and doesn't reach the saturation point.

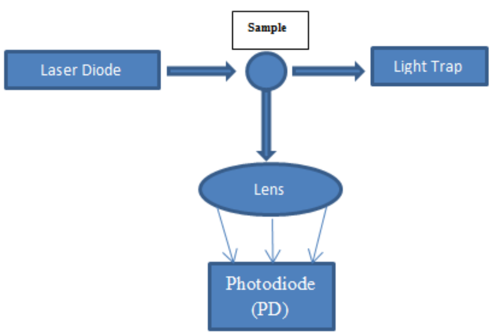

Fig 2: 90°scattering principle

The generalized implementation of the particulate matter system and the optical design chamber is used with the scattering principle to detect the number of counts in suspended aerosol matter as shown in Figure 3.

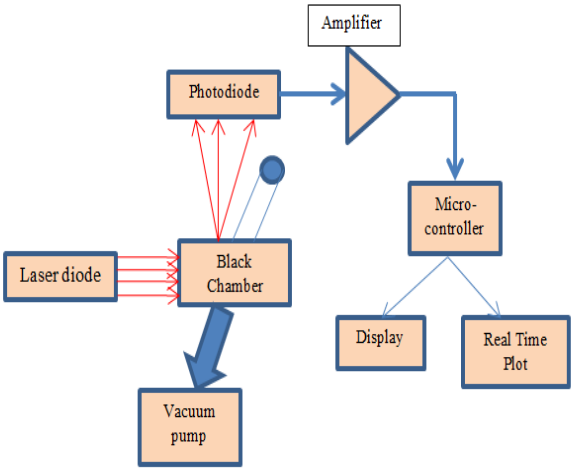

Fig 3: Generalized Block diagram of Particulate Matter system

The system is designed such that vacuum pump is used to collect the air samples which has inlet and outlet to the pump with a sample rate 0.8 Litre/min.

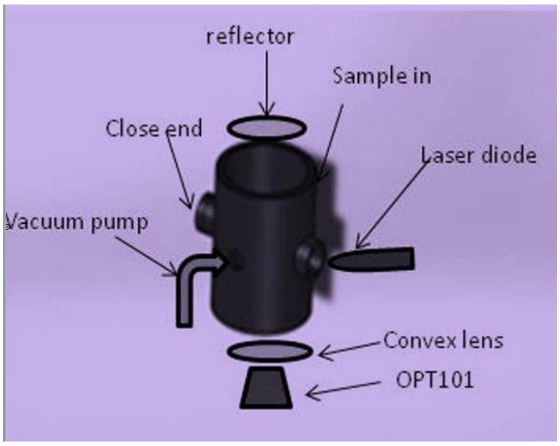

Fig 4: Optical Chamber of Particulate Matter system

The dark optical chamber for particulate matter system and the overview of the optical chamber is as shown in the Figure 4. When the laser light strikes with the particle, light is scatteredon to the convex lens andis focussed on the photo-diode. Photo-diode voltageis used to plot the graph of ADC value vs. the samples. Fromthe plot, we can calculate thenumber of particles and their size.

Photodiode OPT101 is used to collect the sample of data and amplifier circuit is usedfor 10 bit Analog to digital conversion (ADC). The vacuum pump controls the flow of air containing aerosol particles inside the optical chamber. Photodiode sensor observes the change in light intensity that isobserved as voltage peaks. Python IDE is used to plot these real time graphs.

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III.RESULTS

Above observed Data depends on the intensity of light of the laser where the wavelength of the laser used is 680 nm with respect to which the maximum output voltage is 4.2 volts.The output voltage of photodiode is scaled down to 3.3 Volts and so as to support the ADC voltage requirement of the Microcontroller.Table 1 gives the observed data in the laboratory for analysing the scattering theory, which determines the sensitivity of the photo diode.

Table .1: Photodiode voltage observed

CHANGE IN LIGHT INTENSITY	OUTPUT VOLTAGE IN VOLTS
Dark offset error	0.0075
Less intensity	0.0172
Maximumintensity	4.299

To determine the concentration of PM in aerosol sample, size of that particle has to be determined. From the scattering theories,the output of photo diode is taken to the Arduino board for getting real time plot in python. There is a peak detected for each particle. So the total number of peaks in a given time gives the total number of particles.As shown in Figure 5, the number of peaks counted is 168 samples with respect to ADC Values.

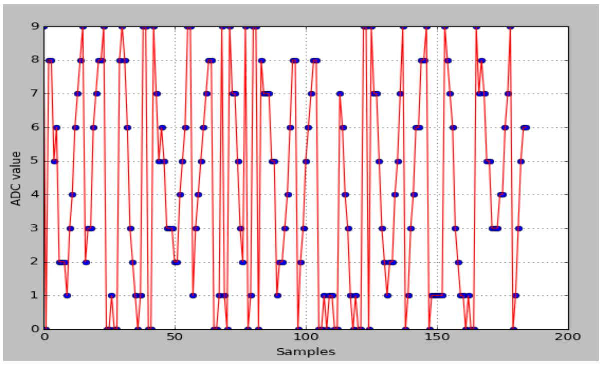

Fig.5:Particulate Matter Counter (Real time Plot)

IV. CONCLUSION AND FUTURE WORK

A Particulate Matter counter system is developed to count the number of particles anda demo chamber is created for the same. Two separate thin Teflon coated wires of size 20 µm and 60 µm are placed inside the chamber to detect the Output voltage peak. The Photo diode used is fast enough to detect pulse of light when a laser light is passed inside the chamber. Further, for better analysis, the dark chamber is created from the machining and blackening to obtain the better results. Dark chamber creates better analysis of scattering theory for micron particles. The lens is fitted into the chamber using focal length calculation.Convex lens then converges the scattered light inside the chamber onto the photodiode which improves the efficiency. Anarray of photodiodes is used for detecting the scattering pattern.For the future the implementation of the system, model can be built with real time analysis with greater efficiency and implementation of better algorithm using numerical analysis for counting the number of particles and determining the various sizes of particles.

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