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Improved device for particle concentration detection based on laser scattering and microscopic amplification

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Abstract: With the rapid development of science and technology and industry, the formation of haze has been accelerated. Haze seriously harms our living environment and people's physical and mental health. Among them, atmospheric particulate pollution is the most serious environmental pollution at present. Therefore, timely and effective measures should be taken to detect atmospheric particulates in the environment, and then prevention and treatment of haze can effectively improve the environmental quality. Therefore, this paper designs an improved device for particle concentration detection based on laser scattering and micro-amplification, which is based on the previous designed concentration detection device. This device takes Mie scattering as the theoretical basis. The light source is a semiconductor laser, and the scattered light generated by the light irradiation of particles is further analyzed to obtain the particle property information after amplification by the microscopic equipment. At the same time, the photoelectric sensor absorbs the scattered light, and finally the particle mass concentration is reflected by pulse signal and optical signal together. There are two improvements in this device: 1. The structure of the stray light absorption part is modified to make more accurate measurement of experimental results and reduce the influence of stray light on the whole experiment; 2. Combined with image processing, the morphological features of particles can be acquired more accurately.

Keywords: Laser scattering; Microscopic magnification; Particle concentration detection; The image processing

1. INTRODUCTION

Particles refer to solid powder, liquid and gas with particle size less than 1mm.Particle size distribution and particle size are the main parameters to characterize the properties of particles, so it is of great significance to accurately measure particle size distribution and particle size [1]. The traditional particle detection methods include screening method, filter membrane weighing method [2], sedimentation method, electric induction method and piezoelectric crystal method [3]. Each measurement method has its own advantages and disadvantages. Traditional detection methods use large instruments, which are not convenient for real-time online measurement. However, some foreign laser particle size meters are very expensive and not easy to use on a large scale. Therefore, it is necessary to develop a small size, low cost and high precision particle concentration detection device.

The detection device designed in this paper adopts the method of light scattering [4-6] combined with microscopic amplification. When the incident light irradiates the particles, it will generate scattered light around, because the polarization degree and spatial distribution of scattered light are closely related to the particle size. By measuring these characteristic parameters, the particle size distribution and particle size of measured particles can be obtained. In order to observe the morphological characteristics of particulate matter more intuitively, this device combines the microscopic technology. Traditional microscopes can directly obtain the morphological characteristics of individual particles, but the volume of traditional microscopes is too large to meet the design requirements. This device improves the traditional microscope and realizes the design requirement of small size. But combined with the light scattering method, the stray light is treated. In general, the device designed in this paper can meet the requirements in terms of accuracy and stability, accurately measure the concentration of particles in the atmosphere, and realize real-time detection of the concentration of particles.

2. RELATED WORK

An improved device for particle concentration detection based on laser scattering and microscopic amplification is designed in this paper. In the design process, in order to ensure that each module can meet the application standards of the system, the function of each module is tested experimentally. Then, each module is combined into the final particle concentration detection device, which is used to measure the environmental particles in real time and analyze the measured data. Finally, compared with the measurement results of the particle concentration detector designed by PAN TENG Company, the performance of the device was evaluated. This paper mainly includes the following contents:

- Improvement of the structure of the microscopic device;

- Design of laser scattering device;

- Improvement of light absorption unit improves the absorption efficiency of stray light;

- Image processing and analysis of micro-enlarged images;

- Processing optical signals obtained by photoelectric sensors

Finally, the obtained photometric values and calculated pulse signals are analyzed and processed to deduce the mass concentration of particles.

3. FRAMEWORK

The improved device based on laser scattering and microscopic amplification is mainly used to measure the concentration of particles and directly observe the morphological characteristics of particles. Compared with the traditional indirect observation, this device adopts the direct observation method to conduct qualitative and quantitative research on the particles. Figure 1 shows the overall design of the system, which consists of six parts, including particle detection device, CCD sensor [7], photodiode, amplifier circuit, A/D conversion circuit and PC.

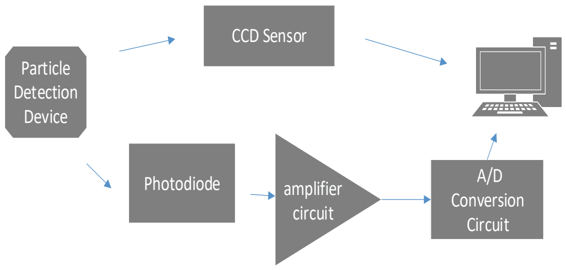

Figure. 1 Overall design of the system

As shown in the above, particle detection device respectively by CCD sensor and photoelectric diode will receive optical signals, and statistical analysis of the pulse signal to upload to PC photodiode will be collected by amplifying circuit to enlarge the weak signal processing, in order to facilitate the experimental calculation, will need to get to the analog signal into digital signal, through A/D conversion circuit to realize the transformation [8]. After data filtering, calculation and table lookup, data information of measured particles will be displayed on PC terminal. Combined with the optical signal obtained by CCD sensor through microscopic amplification, the concentration information of measured particles is obtained.

3.1 Structural improvement of microscopic devices

Special treatment was made on the structure of the microscope tube. The modified structure of the mirror tube was only about 2cm, so the whole microscope device has the characteristics of small size, easy to carry and accurate observation value. The design changes parts of the microscope tube to reduce its size, allowing it to be completely contained in a small box. By using the reflection principle of prism [9], the image transmitted from the objective lens can be seen completely and the focal length can be adjusted to obtain a clear and complete particle image for easy observation and counting. The specific design scheme of the whole device is shown in figure 2.

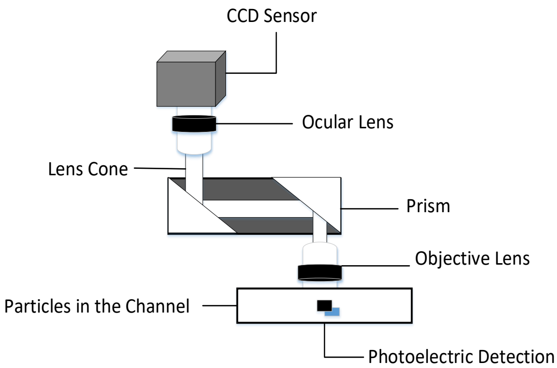

Figure. 2 Structure improvement of the microscopic device

3.2 Structure design of laser scattering device

3.2.1 Laser scattering device before improvement

The particle concentration detection device before improvement is shown in figure 3.According to the particle size measured by the device, the semiconductor laser [10] with the wavelength of 650nm is finally selected. The reason for choosing the semiconductor laser is that it has low cost compared with He-Ne laser [11] and has uniform light intensity in the photosensitive region compared with white light source. The laser passes through the collimator and the focusing lens through the sample pool, which is pumped through a device that allows particles to pass freely through the cavity. The photodiode connected to the focusing mirror and the diaphragm receives the scattered light generated by the particle, and then the photodiode gets the concentration information of the measured particle through amplification and analog-to-digital conversion. The acquisition device, which consists of a microscope and CCD sensor, allows researchers to see the light and shadow information left by particles passing through the particle cavity directly through the PC. The CCD captures the enlarged particle image, and then gets more accurate data through image processing.

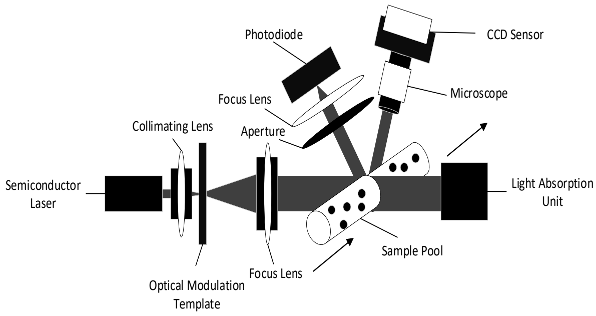

Figure. 3 Laser scattering device before improvement

3.2.2 Improved laser scattering device

For example, the detection device designed in the figure above is not very efficient in absorbing stray light in the light absorption unit, and the noise signal generated has a great influence on the experiment [12]. Therefore, the light absorption unit was improved, and the structure of the light absorption unit was designed into a spiral structure. Stray light can be ignored after several reflections, which improves the accuracy of the experiment. The improved laser scattering device is shown in figure 4.

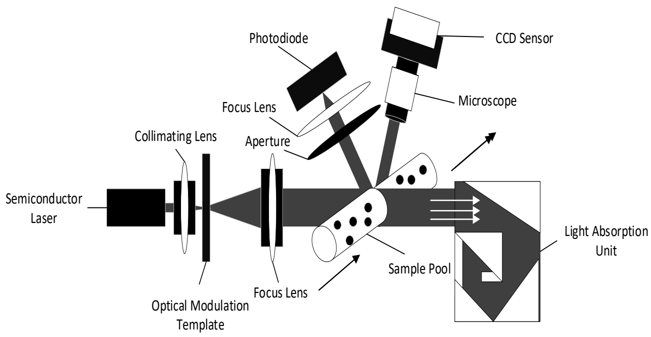

Figure. 4 Improved laser scattering device

3.3 Visual Angle recognition algorithm

As can be seen from the above figure, the collection device design of special micro-camera and laser instrument captures clear and enlarged particle images, and then gets more accurate data through image processing [13]. Therefore, the amplification multiple and precision of the collection device directly affect the accuracy of experimental results. Microscopic amplification design is adopted to amplify the particle signal. Image analysis method is adopted to distinguish the size and properties of particles by combining the reflection of camera exposure rate, particle motion rate, particle size and other characteristics on the image. For the same particle, different wind speed and exposure time will affect the length of particle shadow. For different particles, under the same wind speed and exposure time, particle size will directly affect the width of particle shadow and the smoothness of surface. Therefore, in conclusion, the length (P_L), width (P_W) and smoothness (P_S) of particle shadow are directly related to particle velocity (V_P), camera exposure time (t) and particle morphology.

When the same particles pass through the particle cavity, the exposure time of the camera is fixed, only the wind speed is changed. When wind speed gradually increases, the length of particle drag shadow also increases, so the length of particle drag shadow is proportional to the speed of particle motion, that is, $P_L \propto V_P$. When the same particles pass through the particle cavity, the fixed wind speed only changes the exposure time of the camera. When the exposure time of the camera gradually increases, the length of particle drag shadow decreases, so the length of particle drag shadow is inversely proportional to the exposure time of the camera, that is, $P_L \propto \frac{1}{t}$.

In summary, if the particle is moving at a faster speed, a slightly increased camera exposure rate will yield a clear image. If the particles aren't moving fast, the camera shouldn't be exposed too fast. That is, the particles move faster and faster, and the corresponding camera exposure time gradually increases.

When different kinds of smooth particles pass through the particle cavity, the size of the fixed wind speed and the exposure time of the camera, the smoothness of the particle shadow only depends on the flatness of the particle itself.

Define the particle as a_i on each scale from left to right of its transverse width and a_j on each scale from bottom to top of its vertical height, then the relation between the width of particle shadow P_W and the width of particle W and the height of particle H is as follows.

$$P_W = \frac{\min(W,H)}{\max(W,H)} \quad (1)$$

$W = \max(a_i) - \min(a_i)$, $H = \max(a_j) - \min(a_j)$. That is, when the particle is of slender length, P_W is the smallest. And vice versa.

4. EXPERIMENT

If the influence of background noise on experimental results can be reduced by improving the device, and the visual observation of experimental results can prove the stability and practicability of the device, then the concentration measurement of particulate matter will be more accurate.

4.1 Experiment preparation and setup

The particle concentration range used in this experiment is 40mg/m^3~1400 mg/m^3. According to the concentration range, several samples are extracted with concentrations of 40 mg/m^3, 100 mg/m^3, 300 mg/m^3, 400 mg/m^3, 570 mg/m^3, 780 mg/m^3 and 1336 mg/m^3 respectively.

4.2 Comparison of experimental results

Figure 1. Due to its vulnerability to the influence of tiny particles in the air, this experiment was conducted in a completely closed test chamber. In order to verify the accuracy of the experimental results, the concentration detector of PAN TENG Company was used as the standard to measure the particulate matter with different concentrations. Because the signal collected by photodiode will have the background noise caused by stray light and electrical noise. Before the addition of the improved light absorption device, due to the low concentration of particulate matter and the influence of noise, the photodiode receives very few scattered light signals. As shown in figure 5, the comparison between the measurement results and those of PAN TENG concentration meter is not ideal.

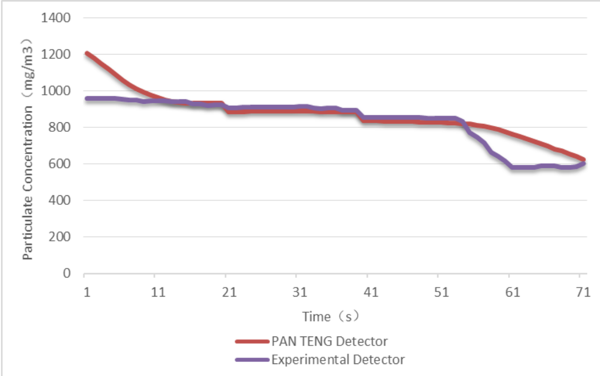

Figure. 5 Experimental results of noise effect

The experimental results of the improved over-light absorption device are shown in figure 6. The results of the improved experimental instrument are basically consistent with that of the climbing detector. Therefore, the improved experimental device in this paper can be fully applied in industry and meet the requirements of low cost and high precision.

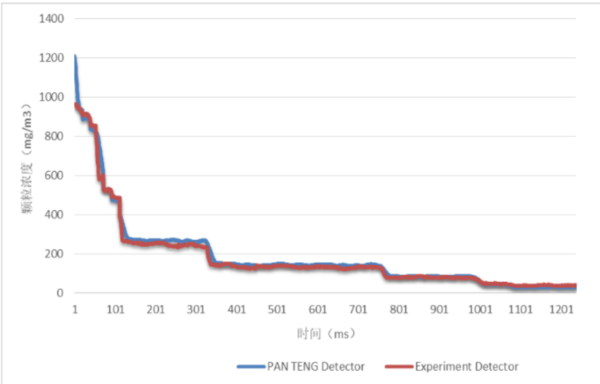

Figure. 6 Improved experimental results

4.3 Experimental results of image processing

The experimental results were simulated by Matlab. When a large number of flue gas particles passed through the particle cavity, the CCD sensor connected to the microscope equipment quickly photographed the particles directly below the microscope equipment in a short time, and then transmitted the acquired images to the computer for image processing. Figure 4.1 and figure 4.2 are images after grayscale and binarization processing. The size and distribution of particles can be seen more clearly after image processing.

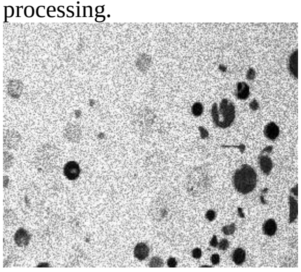
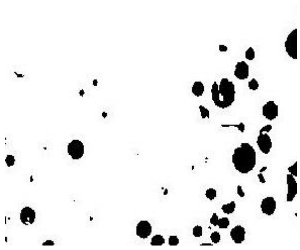

Figure. 7.1 Grayscale processed image
Figure 7.2 Binarization image

5. CONCLUSION

In this paper, an improved device for particle concentration detection based on laser scattering and microscopic amplification is designed. Based on the scattering signal of particles, the pulse signal and optical signal are used to invert the particle mass concentration. The improvement of light absorption unit greatly reduces the influence of noise signal on the experimental results, and the combination of image processing technology makes the experimental results more accurate. Through comparison and analysis with the concentration detector of PAN TENG Company, the device designed in this paper can meet the requirements in terms of accuracy and stability, accurately measure the concentration of particulate matter in the atmosphere, and make a certain contribution to environmental protection.

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7. REFERENCES

[1] MICHAEL B, CABMEN A, TERESA I F, et al. Air pollution and retained particles in the lung [J]. Environmental Health Perspectives, 2001, 109 (10):1039-1043.

[2] Feng J, Han P. Automatic monitoring instrument for atmospheric particulate matter based on filter membrane weighing method [J]. Computer and modernization, 2013(07):94-97+134.

[3] Chen S. Determination of airborne dust concentration by quartz piezoelectric crystal [J]. Environmental science and technology, 1985(01):19-20.

[4] Zhang S. Study on measurement technology of exhaust particulate matter based on light scattering principle [J]. Computer and digital engineering, 2019, 47(05):1254-1257+1263.

[5] Zhang Y. Research progress of PM2.5 detection technology [J]. Sensor world, 2019, 25(03):13-16.

[6] Zhou X. Performance comparison and optimization of PM2.5 sensor by light scattering method [J]. Journal of environment and health, 2016, 33(8): 739-743.

[7] Shen P. Design of linear CCD image acquisition and processing system based on FPGA [D]. Hubei University of technology, 2017.

[8] Jiang y, Zhou H, Zhan X. Circuit design of a dual-pole analog signal A/D conversion of single-chip microcomputer [J]. Electronic science and technology, 2014, 27(04):121-123.

[9] Gao Y, Sheng C, Liu Y. Study on phase diagram for measuring refractive index of prism by total reflection method [J]. College physics experiment, 2019, 32(02):34-36.

[10] Liu Z. Response characteristics of semiconductor laser and photodetector [D]. Xi 'an university of technology, 2019.

[11] Zuo C, Zhang X, Chen B, Wang C, Wang L. Study and design of light intensity of he-ne laser irradiated seeds [J]. New agriculture, 2017(07):4-6.

[12] Zhang J, Pan S, Zhu J, Chen Z, Hu B, Chen N, Zhang H. Research on calibration method of forward scattering visibility meter based on laser cavity enhancement technology [J]. Journal of light scattering, 2019, 31(02):160-165.

[13] Li J, Liu Y. Frequency domain optimization design of image system [J]. Applications of electronic technology, 2019, 45(07):107-111+116.