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Recording of dust particle oscillation path inside electric curtain by laser diode apparatus

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The contribution describes recording of a single dust particle oscillation path inside the electric curtain by a new type of a laser diode apparatus. Visualisation of the particle path trajectory using single pure infrared laser diode, 806 nm, 2 W was analysed. Particle oscillation path was measured from images recorded by CCD monochrome camera. Feasibility of such diode as an efficient light source to illuminate dust particles was verified for experimental investigations in dust technique devices. Particle oscillation paths were recorded throughout changes in the diode beam power and distance. Experimental results were used to determine conditions for the design of a new laser diode apparatus, employing simultaneously several diodes in the laser head. A new type of the laser diode apparatus to record dust trajectory inside electrostatic precipitators and electrostatic separators was developed and tested. A simple high power source of light condensed into a beam proves highly useful in dust technique experiments. Oscillation path and wandering velocity of a single dust particle inside the electric field can be recorded and measured.

Keywords: laser diode, particle path visualisation, electric curtain.

1. Introduction

Measurement of single dust particle wandering velocity inside a precipitator allows to evaluate the actual forces acting upon the particle. This appears to be the basis for understanding some physical mechanisms governing the removal of fine particles inside the precipitator. Visualisation of particle paths in experimental research on electrostatic separators and precipitators, enhances better recognition of such processes. Particle paths in the model of an electrostatic precipitator, employing 6 W argon laser, have been visualised by JĘDRUSIK *et al.* [1]. Particle image velocimetric (PIV) technique can be used to measure velocity of fluids. Such measurements of the particle flow velocity field in a model electrostatic precipitator were carried out by MIZERACZYK *et al.* [2]. A model of 7 wire-two plate precipitator, with cross section of 400×40 mm was analysed. In the model the particle flow was recorded with the use of 530 nm NdYAG laser at 50 mJ power in one pulse [2].

Instead of relatively expensive high power gas lasers or solid state lasers, laser light planes generated by monomode laser diodes may be successfully applied. The laser head proposed by NATH *et al*. [3] incorporates 6 red diodes, 690 nm, 0.3 W. This system emitted a conical light plane, 100 mm in width, of 160 mm operating distance [3]. The author has recorded particle oscillation paths inside the electric curtain using a special trail type apparatus. The electrode system has been axially symmetrical, therefore the path was recorded along the plane perpendicular to the cylindrical electrode axis [4, 5]. The author's measurement setup aims at an original, simple visualisation method based upon a serial laser diode design. Such device may prove particularly useful to visualise particle paths in electrostatic precipitators or in dust technique devices.

2. Visualisation of particle path using a single laser diode

A laser unit incorporating several laser diodes is significantly cheaper and easier to manufacture than a large argon laser. The major objective of recent research has been to verify the possibilities of applying a single laser diode of such type to visualise particle oscillation path. Is such aim possible to achieve at all? The results will be used to develop a new laser design employing several diodes simultaneously. As indicated by literature research carried out by the author infrared high power diodes have never been used for such purposes, not to mention mixed systems where red and infrared diodes work simultaneously.

The electric curtain comprises a series of cylindrical electrodes, insulated from each other, connected to high voltage sinusoidal AC source. Small clouds of charged lycopodium particles of 28 μm in diameter were introduced into the system. Then a charged particle commenced oscillation in accordance with the voltage supplied. The particles were illuminated with 2 W infrared laser diode by Osram; SPLCG_2 of 808 nm wavelength. The initial laser current was 0.7 A. The diode ensured maximum rated current up to 2.3 A at 1.83 V. The diode generated an invisible light beam of vertical divergence angle of 36° and a horizontal one of 18°. The feeder applied ensures smooth power control throughout the range up to the peak value. The diode current may be therefore controlled in a smooth manner. A device incorporating one diode only has been extensively tested. Such measurements will allow to evaluate the particle recording efficiency and to define maximum dimensions of the model, in particular those of the recording plane. Quality of the images recorded must ensure the readout of all parameters of an oscillating particle. Respective conditions of effective imaging have been looked for. The images were recorded using a monochrome CCD high resolution camera; FCH-30C, 570 TVL with 0.14 Lux @ F 1.2 lens.

Beam power measurements were taken for 806 nm, 2 W pure laser diode, no other optical systems incorporated. Dispersion power was measured with a power meter throughout a circular absorbed surface of 1 cm^2. Figure 1 illustrates changes in

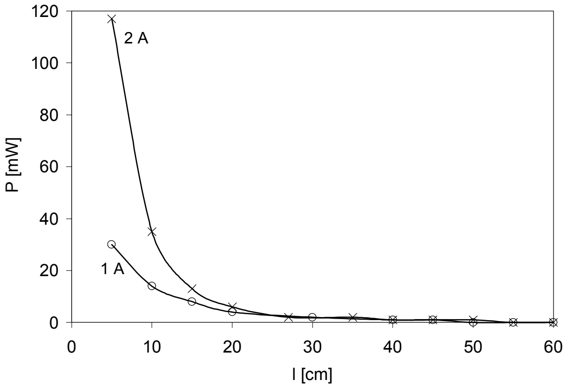

Fig. 1. Power of the diode laser beam as a function of distance (power 2 W, wavelength 806 nm).

the light beam power along the diode axis in the function of distance. As indicated, successful measurements may be taken only within the range of 30 cm.

As indicated in the records the total output power of the diode is the linear function of current, within the range of 0.6–2.5 A. An important feature of the radiation source has been efficient continuous and pulse operation. The lateral laser aperture is 200 μm. Figure 2 presents the relation of the emitted laser beam power to the current input at 30 and 60 cm from the diode. The graph illustrates the actual dispersed power, throughout the surface of 1 cm^2. As indicated, the effective performance of the diode starts above 1–1.5 A, despite laser operation effective at 0.7 A. Illumination of small models requires a laser diode, no additional optical systems needed. The images were recorded along the plane perpendicular to the diode axis at 30 cm distance. Fixed focus of the camera was maintained. Distribution of the dispersed power measured along X and Y axes is illustrated in Fig. 3.

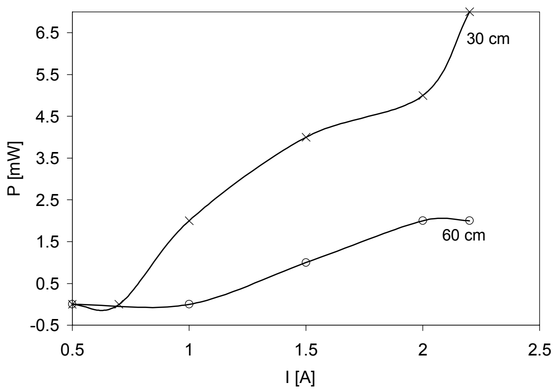

Fig. 2. Laser diode beam power related to current input and distance.

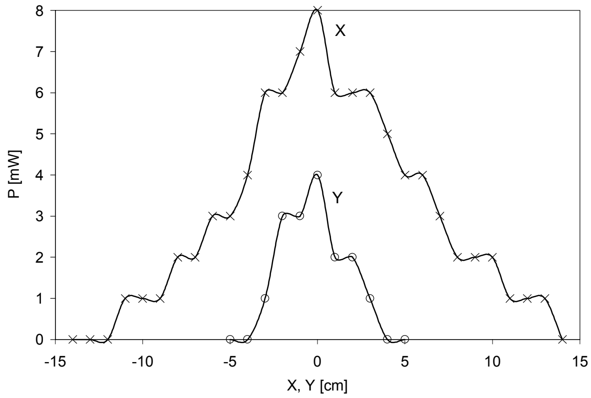

Fig. 3. Distribution power along *X*, *Y* axis, perpendicular to the electrodes axis.

Comparative results of a single radiation source, characterised by a Gaussian intensity profile, prove to be consistent with the measured curves illustrated in Fig. 3. Measured peak power values occur in the centre of the evaluated plane.

Experimental measurements of oscillation paths determine whether the images are of quality high enough to read oscillation path parameters of a single particle. Figures 4

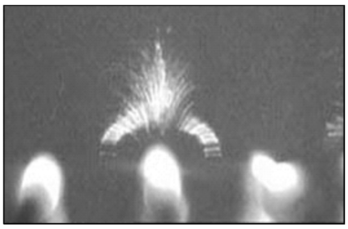

Fig. 4. Particle oscillation paths recorded at laser diode power of 2 W, $m = 1$.

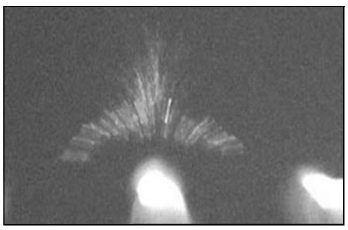

Fig. 5. Particle oscillation paths recorded at laser diode power of 1.5 W, $m = 1.5$.

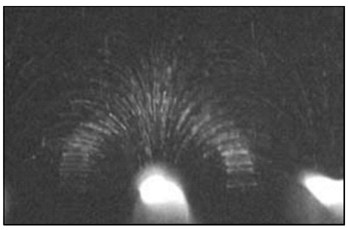

Fig. 6. Particle oscillation paths recorded at laser diode power of 1 W, $m = 1.5$.

through 6 illustrate such records produced by Ganz FCH-30C monochrome CCD camera for different beam values at magnification *m*.

3. New laser unit design

As proved experimentally a single 808 nm, 2 W infrared diode may be used to visualise particle oscillation in the electric curtain. The measurements effected in a new diode laser design incorporating several diodes. The laser head is a system of two 2 W, 808 nm diodes, two 0.5 W, 660 nm diodes and a red 50 mW leading beam diode. All 2 W and 0.5 W diodes were placed along the linear pattern. Red wave range diodes of 500 mW output and 1–1.2 A current at 2.2–2.5 V voltage were located in the centre of the laser head. Red 0.5 W diodes show 45° divergence angle along the horizontal plane and 12° along the vertical one. The laser head features a common 6 mm cylindrical lens and a collimator to ensure parallel beam in the shape of a "knife". The cross-section of the generated beam is 100×1 mm. A pulse feeder was constructed to supply laser diodes within the frequency range of 1–10 000 Hz, which allowed for generation of flashes at proper frequency. The feeder features two independent supply voltage tracks, which can perform separately or together, for 660 and 808 nm diodes. Four diodes are connected to the optical condenser and the supplementary system emits an almost parallel sheet of light. Application of two different types of diodes was caused by higher laser power demanded as well as low cost requirement. The use of two wavelengths makes such measurement arrangement feasible for measurements of variety of dust types, as well as for the recognition of their physical properties. It will be possible to measure dust aerosol and liquid flow rate in chambers and pipelines.

The arrangement will also be used to analyse the structure of corona discharge, spark-breakdown, back corona, as well as electrical properties of dielectric liquids. At present the device is undergoing the test phase and the results will soon be published. The use of such apparatus will improve the accuracy of oscillation path trajectory and wandering velocity records for particles inside electrostatic precipitator and electrostatic separator models.

4. Conclusions

The following conclusions have been drawn from the experimental research into laser diodes:

1. Efficient visualization of particle path records is possible even with a single infrared 808 nm, 2 W laser diode used for illumination.

2. Computer filed images may be used to read out oscillation path trajectory parameters for a single dust particle.

3. The dispersed light power at the recording points proves crucial for the measurements.

4. It is possible to design a laser diode unit employing a series of laser diodes to visualize the process. Such lasers may use diodes of different power and wavelength.

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References

[1] JĘDRUSIK M., GAJEWSKI J.B., ŚWIERCZOK A.J., *Effect of the particle diameter and corona electrode geometry on the particle migration velocity in electrostatic precipitators*, Journal of Electrostatics **51-52**, 2001, pp. 245–51.

[2] MIZERACZYK J., KOCIK M., DEKOWSKI J., DORS M., PODLINSKI J., OHKUBOB T., KANAZAWA S., KAWASAKI T., *Measurements of the velocity field of the flue gas flow in electrostatic precipitator model using PIV method*, Journal of Electrostatics **51-52**, 2001, pp. pp. 272–7.

[3] NATH B., LÖBER W., BAETZ W., HOLZAPFEL W., *Laser light sheet imaging of gas flow with laser diodes*, Optical Diagnostics in Engineering **3**(1), 1999, pp. 102–9

[4] DUDZICZ Z., *The path oscillation of dust particles in the field of the electric curtain of the plane type supplied ac voltage*, Journal of Electrostatics **23**, 1989, pp. 207–14

[5] DUDZICZ Z., *Electrodynamics of charged dust particles and repulsion force within plane-type electric curtain*, Journal of Electrostatics **51-52**, 2001, pp. 111–16.

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