Characterization of Aerosol

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Declaration

I hereby declare that the matter embodied in this report is the result of investigation carried out by me in the Department of Physics, Indian Institute Of Technology, Hyderabad under supervision of **Dr. Vandana Sharma.**

In keeping with general practice of reporting scientific observation, due to Acknowledgement has been made wherever the work described is based on the finding of other investigators.

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Approval Sheet

This thesis entitled **"Characterization of Aerosol"** by **Tithi Roy** is approved for the degree of Masters of Science from IIT Hyderabad.

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Abstract

This report will give a review of the result of an experiment which is done to observe the distribution nature of particles when a pulse of Aerosol is injected onto a glass slide through a nozzle (The flow of Aerosol jet is a supersonic flow).3D graphical representation of distribution curve is plotted which is expected to be Gaussian in nature and a brief discussion about it is given.

A description of cluster, how it can be ionized by a laser source and an introduction to 'Time of flight' is also given as it is a very important study for many spectroscopic experiment.

Contents

1. *Introduction*

An aerosol is defined as a colloidal system of solid or liquid particles suspended in air or other gaseous system. Fredrick G. Donnan first used the term Aerosol during world war [1]. The term aerosol has a wide range – from sea salt particles, pollen grains, mineral dust to drop of sulfuric acid and other small particles. Atmospheric aerosols can be from nm to mm range. They are hazard for respiratory system of human body at the high concentrations found in urban environments. . They scatter and absorb visible radiation, limiting visibility. Aerosols originate from the condensation of gases and from the action of the wind on earth's surface. Fine aerosol particles (less than1 mm in radius) originate almost exclusively from condensation of precursor gases. Clustering of gas molecules (nucleation) produces ultrafine aerosols in mm size range. The size range of aerosol particle depends on process through which the individual particle is made .Interaction of aerosol with Electromagnetic radiation or energy play a virtual role in remote sensing. This interaction dictates the spectral regions through which only we can do remote sensing, known as spectral window (region where atmosphere is more or less transparent due to presence of aerosols)[2].

My goal is to analyze the physical characterization of aerosol which is formed on glass slide by a nozzle aerosol source. Boric acid (H_3BO_3) is used here to make aerosol.

2. Experiment

The experimental goal is to find out the distribution curve of aerosol particles i.e. number distribution of particles on a glass slide. The picture of experimental set-up is shown in fig below.

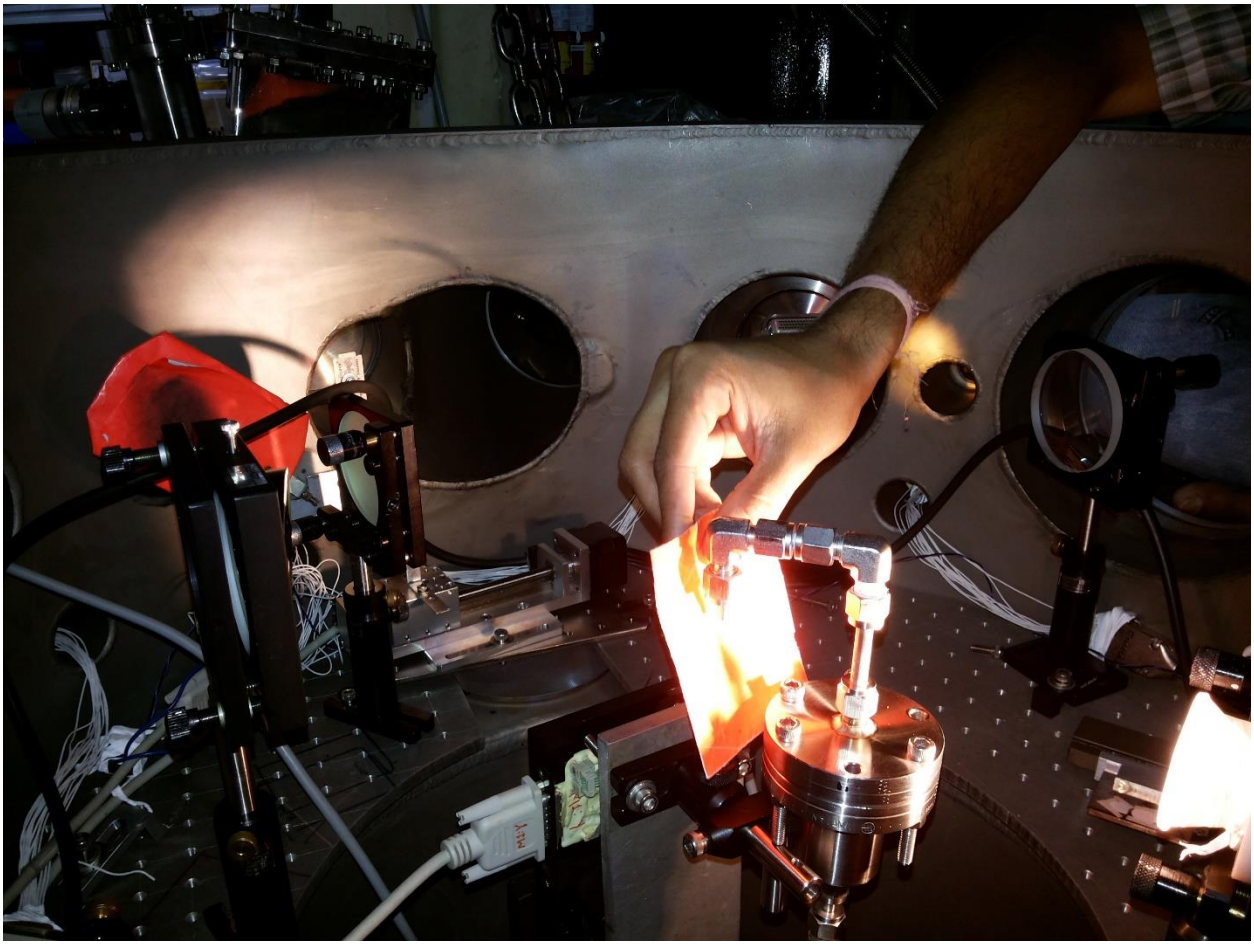


Fig 1: Experimental set up in TIFR HYDERABAD LASER LAB.

2.1 Description of Experimental set-up

This experiment is done in air. Set up consist of a chamber where we place boric acid powder. A gas pulse with 3% duty cycle and 6.5 bar pressure is given to the boric acid chamber. A two end adaptor is there, one end of which is connected with gas cylinder and other end is connected with boric acid chamber. The boric acid chamber is connected with a valve. The valve is pulsed with a 3% duty cycle. Only 1 shot of pulse is injected. On top of this valve a nozzle is connected.

2.2 Process

A certain amount of powder in the form of aerosol will emerge through the nozzle after the pulse is given. They directly stuck into the glass slide. Aerosol comes like a molecular beam. The source is called nozzle source. The idea of this source is the translation of energy into ordered motion of supersonic flow. Nozzle source can provide a molecular beam which has increasing beam intensity and narrowing of its velocity distribution [3]. This source works at a specific gas pressure. We use 6.5bar. A schematic diagram is shown in figure below.

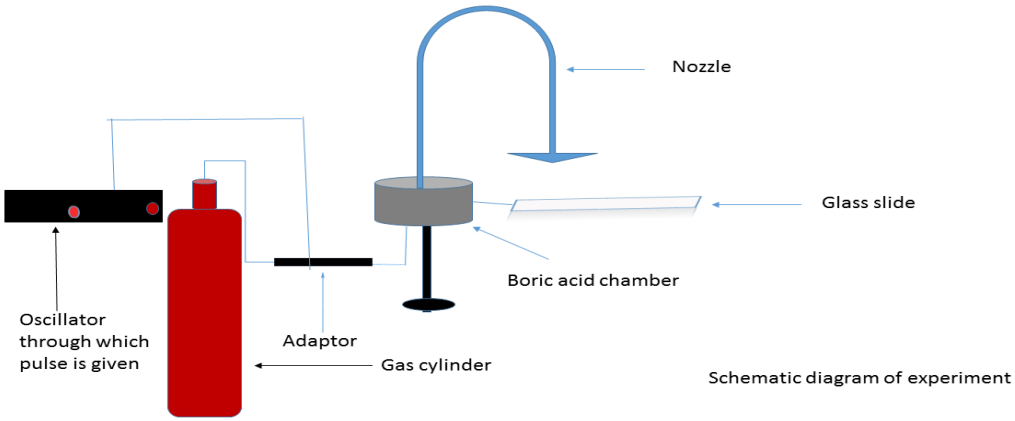


Fig2: Schematic diagram of experiment

2.3 Description of glass-slide

Glass slide should be perfectly cleaned. A thin layer of silicon grease is applied uniformly on the glass slide surface Particles ejected from nozzle directly fall on the slide and stuck into it. We have set glass slide for 5 different distances from the nozzle, 1cm, 2cm, 3cm, 4cm and 5cm.The number of particles should be more for 1 cm distance and less for 5cm distance. The nozzle, 1cm, 2cm, 3cm, 4cm and 5cm.The number of particles should be more for 1 cm distance and less for 5cm distance.

3. Result

3.1 Raster scanning process

The slides were later observed with CCD camera named infinity capture and images were captured. For each distance of slide from nozzle we got a certain amount of particles sticking on the slide. Then slides are put in-front of the camera for taking image of particle distribution all over the slide. At first we fixed the glass slide in a particular position Y (Let's say extreme left position) then scanning along Z from bottom to top. This scanning is known as raster scanning. Here X direction has been taken as focusing of CCD camera. And it is fixed at a particular position for complete scanning of a slide. Y is denoted as horizontal displacement of slide and Z is vertical displacement. Scale reading has been taken. Then again moving the slide along Y by 1cm fixing the position and then again scanning from top to bottom and picture is taken for different regions of slide. Here is a schematic diagram of particle counting method.

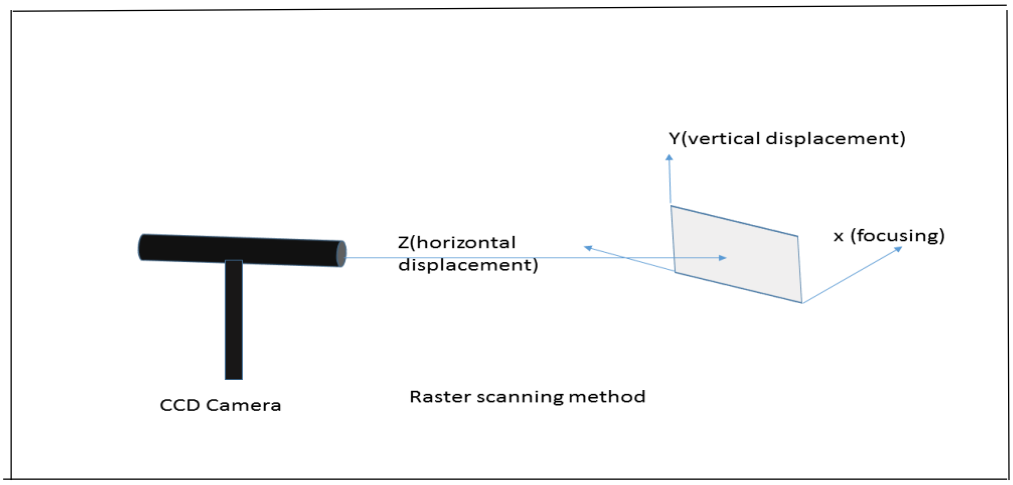


Fig 3: Raster scanning method for particles counting.

By repeating this process, images of particle distribution of whole slide has been taken, from less dense region to denser region then again less dense region. Here are some images of slide containing particles for different distances.

3.3 Images

For 1cm:

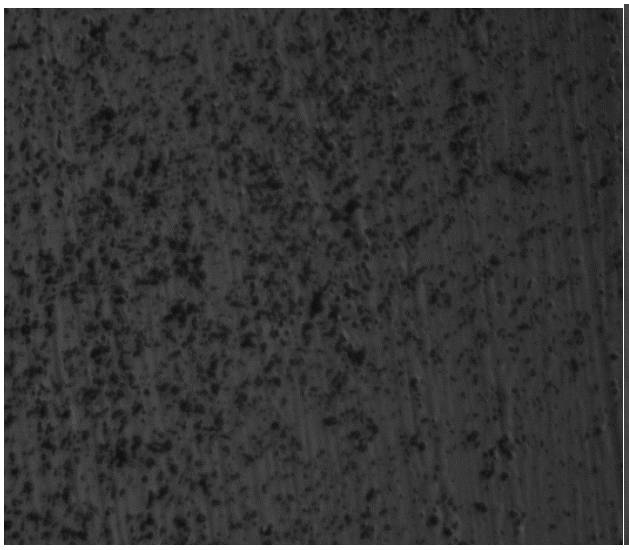


Fig4: Most dense region

No. of particle: 1565 in 1cm

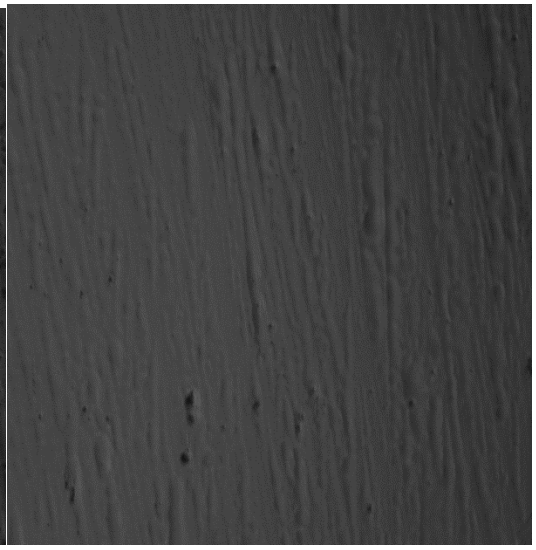


Fig5: Less dense region

No. of particles: 14 in 1 cm

For 2 cm:

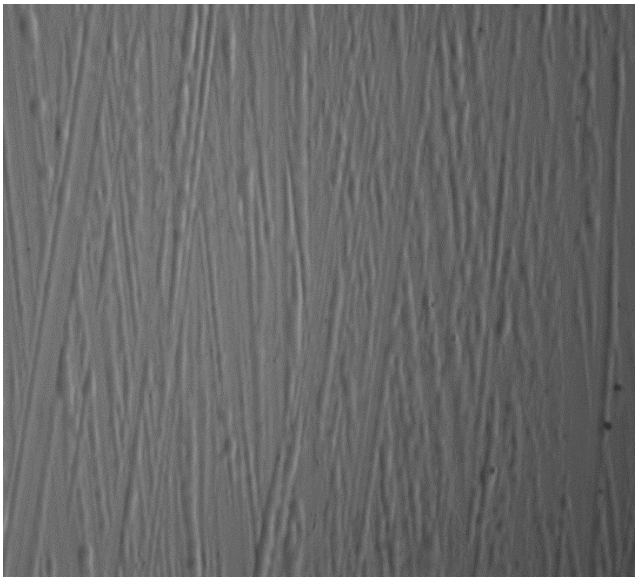
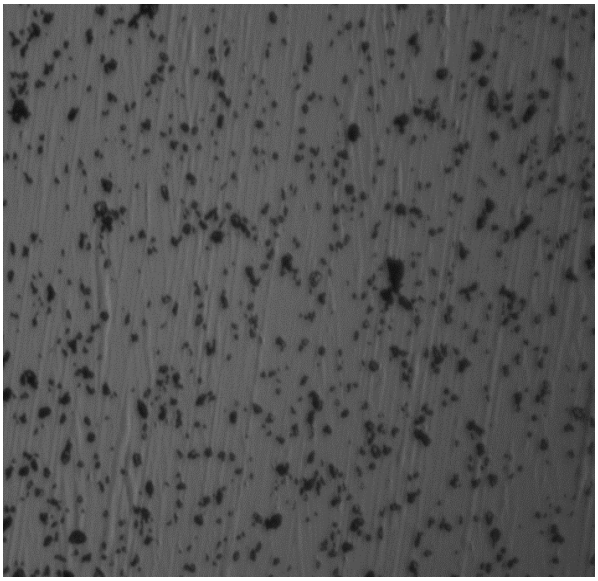


Fig 6: Less dense region

No. of particle: 3 in 1 cm



Fg7: Most dense region

No. of particle: 925 in 1cm

For 5 cm:

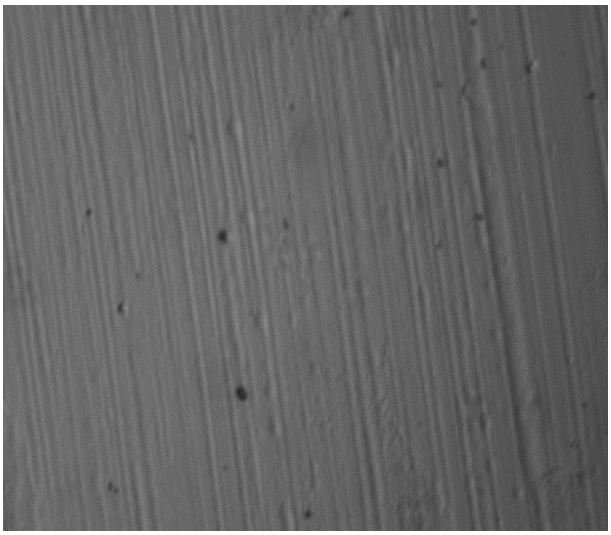


Fig8: Less dense region.

No. of particles : 11

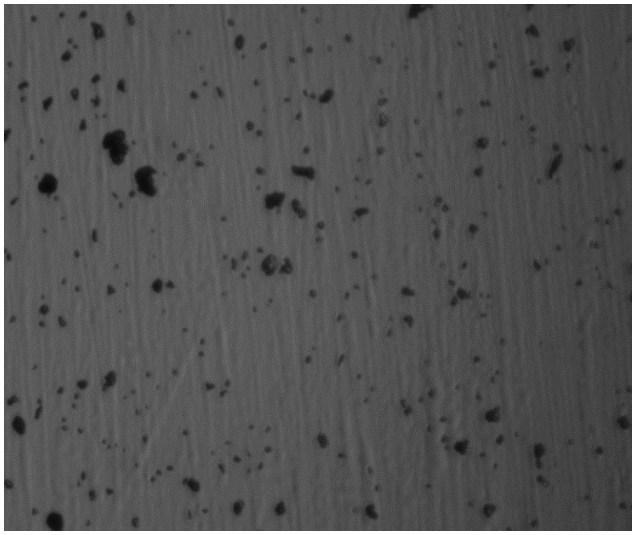


Fig9: Most dense region

No. of particles : 323

For counting no. of particles in each frame Image j software is used.

We could have done this experiment in vacuum also. For this case nothing will change in characterization. The only thing we will get is the purity of the sample slide.

4. Image analysis

4.1 Particle counting Process

It will be easy and more reliable to count number of particles of each image frame using Image j software. Here is a brief discussion of how we counted particle number.

First of all open the paticular image in image j. We should convert it into grey-scale. Process will be,

1. Edit→option→conversion to "scale when converting" Then use Image→Type→16 bit to convert to grey-scale.

Once image is in grey-scale then use,

2.Image→Adjust→Threshold (A particular threshold should be applied to the image to highlight all the structure we want to count).

3.Now to count number of particles go to -- Analyse→Analyse particles.

And total number of particle we can get from summary window as shown in figure 8.

4.2 Pictorial Diargam

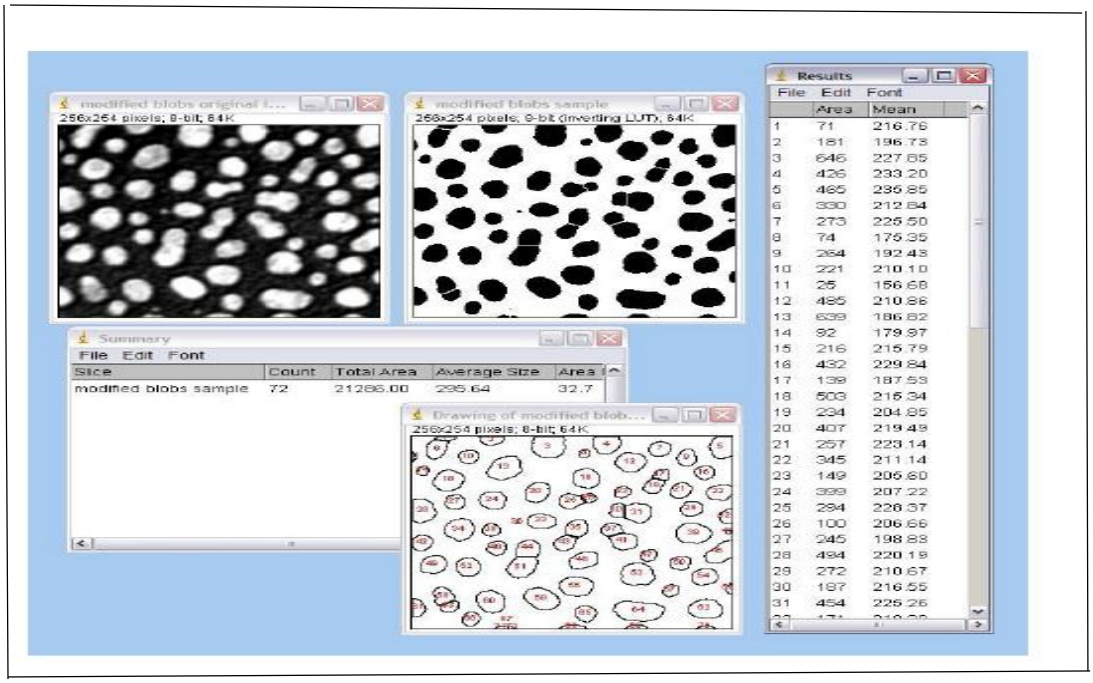


Fig 10: software analysis. Image is Taken from internet.

5. Discussions

5.1 Plots using Origin 6

Particles for each frames of particular height we can plot 3d distribution curve of number of particles vs. frames. Here are the 3D plots given below.

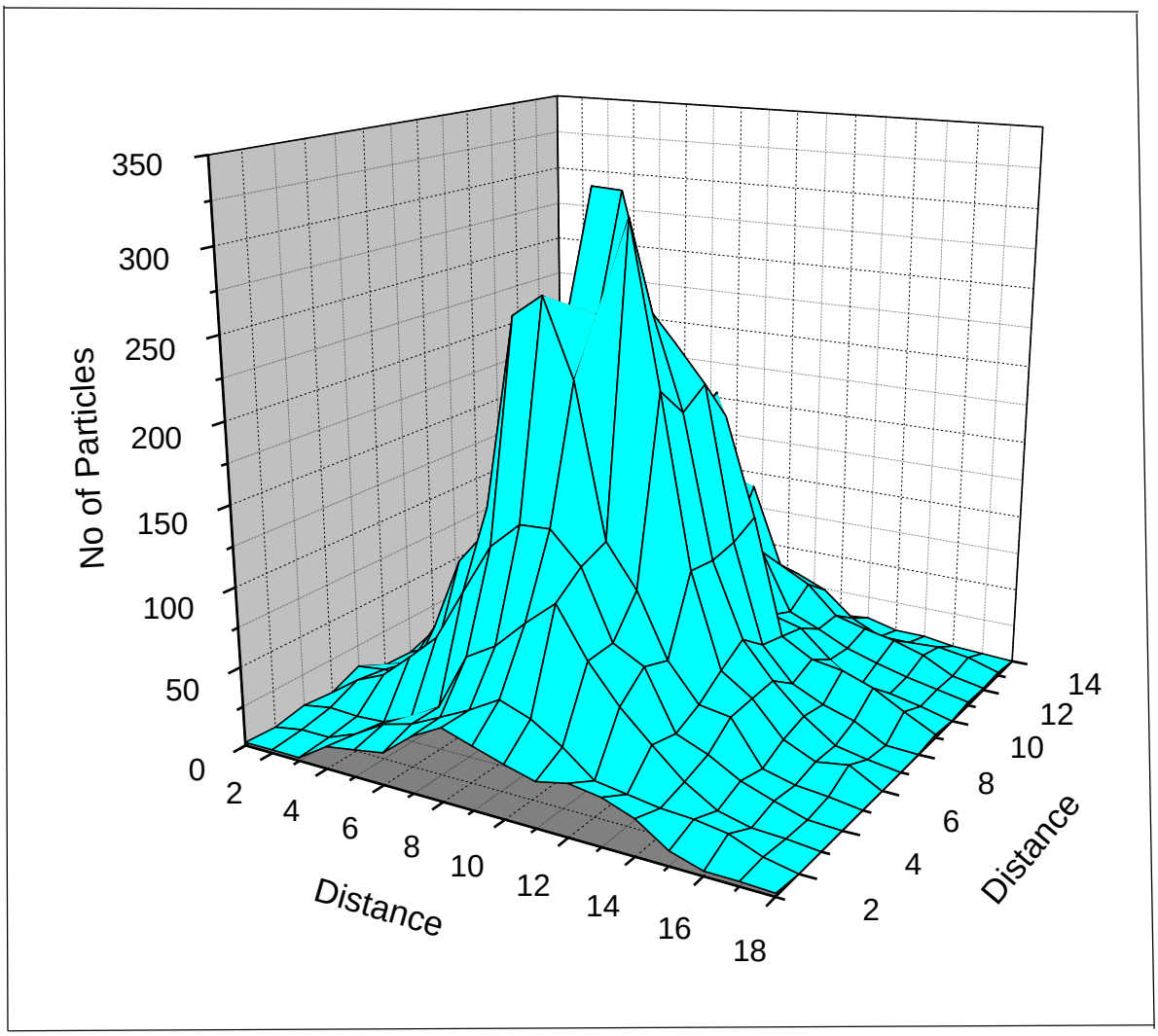


Fig11: 3D distribution plot for 5cm

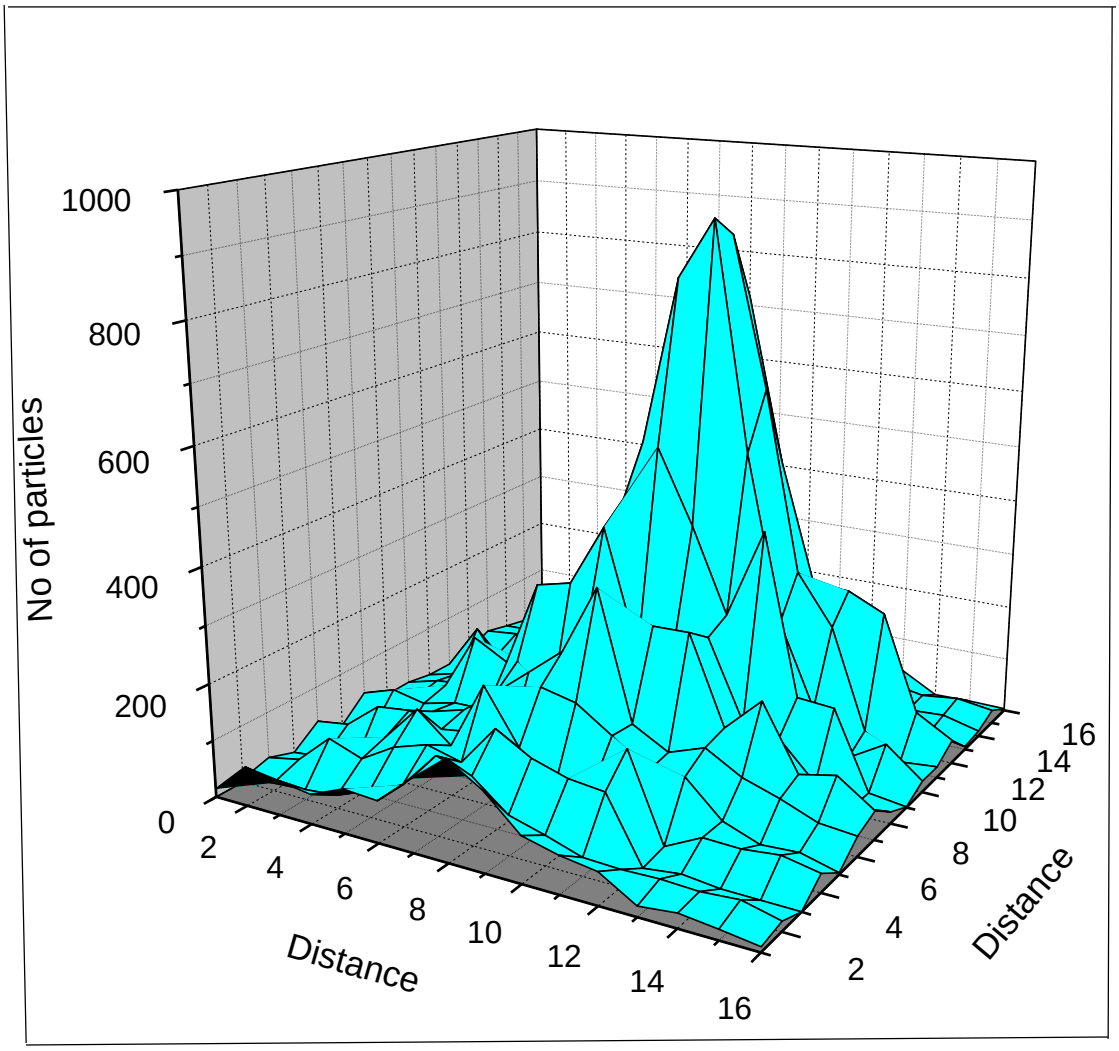


Fig 12: 3D distribution plot for 3cm

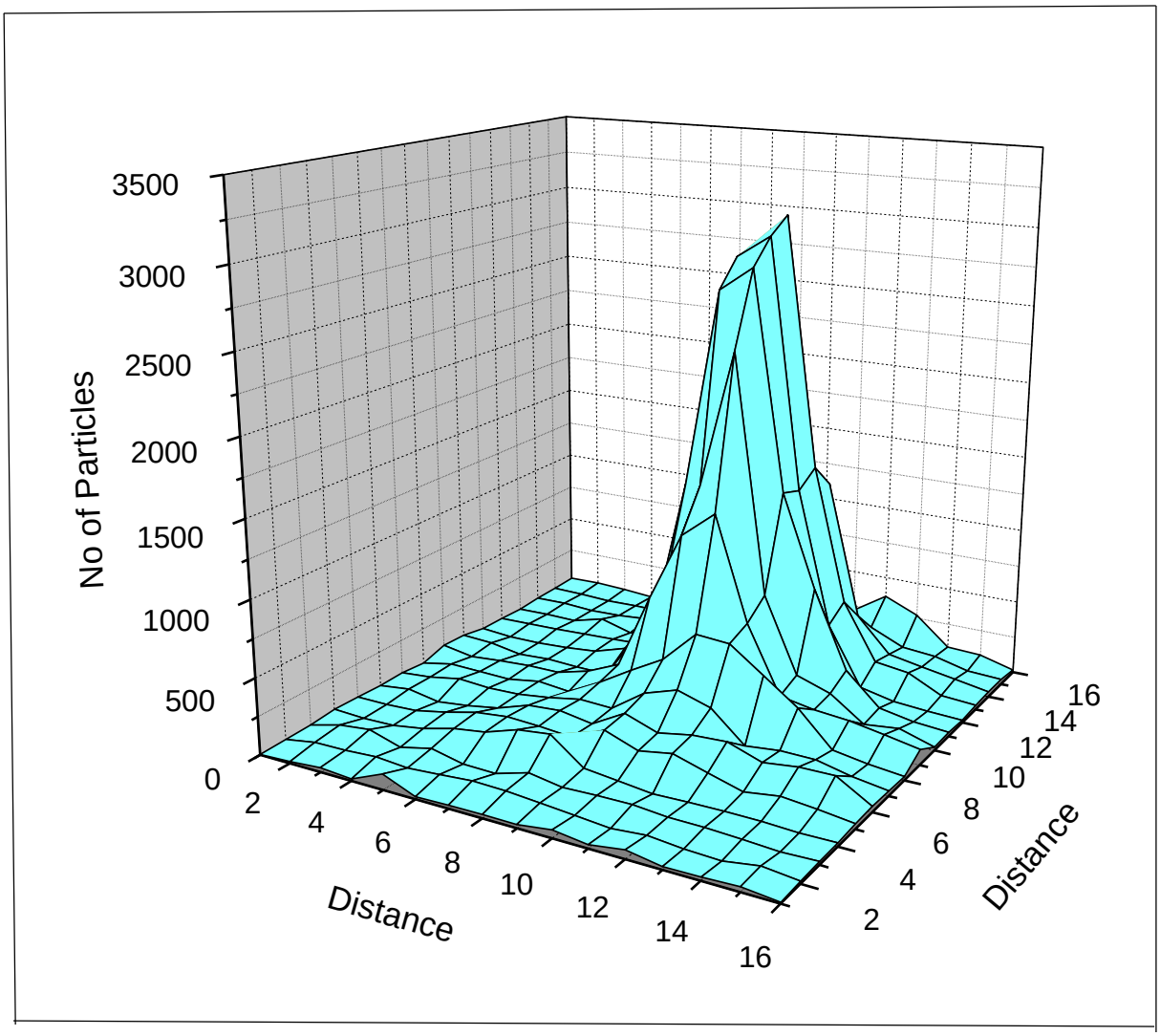


Fig13: 3D distribution plot for 2cm.

All 3D plots are plotted by using Origin 6 software.

6. Conclusion & Summary

We expected and observed a Guassian Distribution upto about 5cm height. The study does not stop here. We have already designed the Time-of-flight spectrometer to further characterize the aerosol size and mass which is not a part of this thesis.

To summrise, during this last three months we designed and fabricated an aerosol source chamber and performed some experiment to characterize the size distribution of aerosol at different height. We also have designed a TOF spectrometer (discussed below) whose fabrication is under process and it is expected to realise experimently in next few weeks from now. The TOF analysis will give us more details about the exact size distribution of aerosols. Further looking into future, our ultimate goal will be to study the photochemistry of aerosols and further study the time resolved dynamics of aerosols using ultrashort laser source.

7. Cluster preparation & ionisation

Clusters are intermediate state of matter between isolated atoms and molecules. These are aggregates of atoms or molecules which are bounded together by Vander walls forces due to induced or in other cases by matalic or even ionic bonds. Properties like melting point, optical absorption depends on size and morphology of cluster. We will be interested only in rare gas cluster. All rare gas cluster formed in solid phase, except Helium [4]. Rare gas cluster can be produced using a supersonic expansion. To form a stable cluster system a certain temperature is required such as $K_B T$ is smaller than the binding energy of the cluster. A gas is expanded through an orifice. Due to so many collisions within the jet, the velocity of individual molecules approaches to the group velocity. The width of the velocity distribution along expansion of gas jet i.e. lateral velocity is decresses. So, temperature also decreases. Growth of cluster depends on the formation of dimer. It needs a three body collision. After that a trimer can be produced directly by collision of a dimer and a monomer. The length of orifice can influence the degree of condensation. Supersonic expansion is a very well-known process of production of cluster which consist of more than one atomic or molecular species. In this process we can constitute a bulk molecule, called Cluster [5].

In order to examine or ionise atomic and molecular cluster we can use laser-vaporization supersonic-expansion cluster beam source and Time Of Flight Spectrometer.

8.Time of flight mass spectrometer

Time of flight mass spectrometer usually designed and fabricated for measuring the charge state distribution of target ions which are produced from intraction of photons with target atoms or molecules. The Time of flight of an ion is defined $\sqrt{(\frac{m}{q})}$, where q is the charge state and m is the mass of ion. This spectrometer consist of a mass analyzer and a detector. Linear flight tube can be used as Mass analyzer. As a ion detector generally, microchannel plate detector or channeltron has been used [6].Here is a schematic diagram of TOF mass Spectrometer.

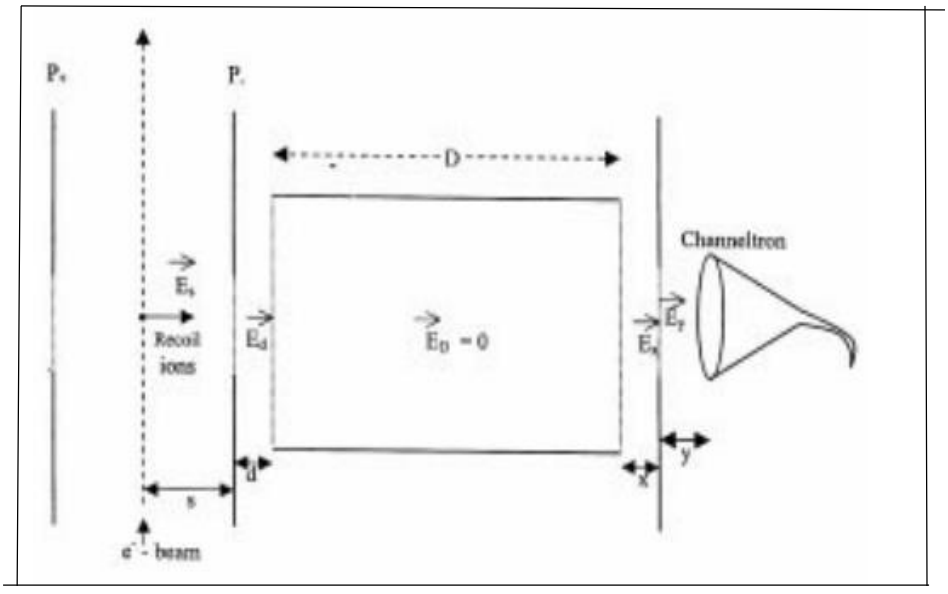


Fig14: TOF mass spectrometer.Image is taken from ***Pramana- J.phys, vol 58, no. 4, April 02***

Ions are accelerated by an electric field of known strength say E. This acceleration results an ion having the same kinetic energy as any other ion that has the same charge. The velocity of ion depends on square root of mass-to-

charge ratio of the particle. The time taken by the ion to reach the channeltron detector is measured. From this measured time and known experimental parameter we can find the mass-to-charge ratio of the ion which is known as Time Of Flight [7].

9.Future plans

We have already studied about the generation of cluster and its ionisation process. Our next step is to make cluster and also fabricating Time Of Flight Mass Spectrometer and study the dynamics of aerosols and clusters.

10. Acknowledgement

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11.References

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