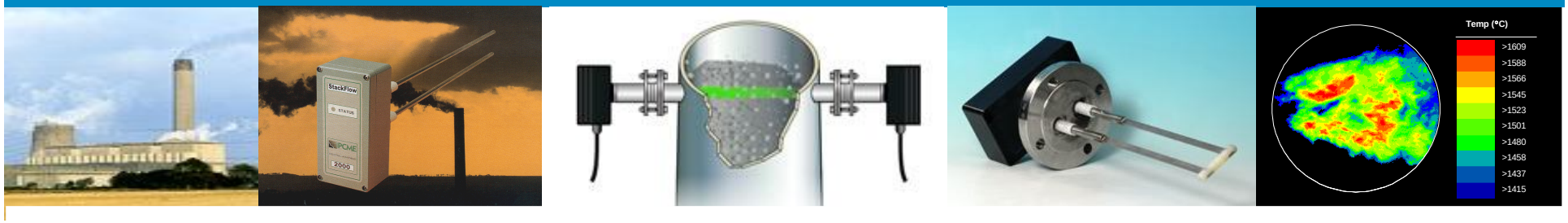
The Coal Research Forum 24th Annual Meeting and Meeting of the Environment Division
Wednesday, 10th April 2013, Cranfield University, Cranfield

Measurement of Particulate Emissions through Electrostatic Sensing and Digital Imaging



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Instrumentation Research at Kent

The Instrumentation Research Group at Kent has established a strong international reputation in developing innovative sensors and instrumentation systems for the power generation, healthcare, manufacturing and food processing industries,

- **Pulverised coal/biomass flow metering**
- **On-line particle sizing**
- **Flame imaging**
- **On-line fuel tracking**
- **Monitoring of particulate emissions**

Outline

- Background
- Electrostatic Technique
- Light Scattering Technique
- Digital Imaging Technique
- Some Results
- Summary

Background

- **Environmental Legislation**
  - EU Directive 96/61/EC: Integrated pollution prevention and control
  - EU Directive 08/1/EC: Integrated pollution prevention and control
  - The UK Air Quality Strategy 2007 (health issues attributed to PM2.5 and PM10-life expectancy of every individual in the UK is reduced by 7-8 months with subsequent costs totalling £20 billion each year).

- **Important in a Range of Industries**
  - Combustion and incineration
  - Metal
  - Mineral
  - Chemical
  - Food processing

Measurands and Challenges

- **Measurands**
  - Mass Concentration [mg/m^3]
  - Mass Emission [kg/h or g/h]
  - Particle Velocity [m/s]
  - Particle Size Distribution

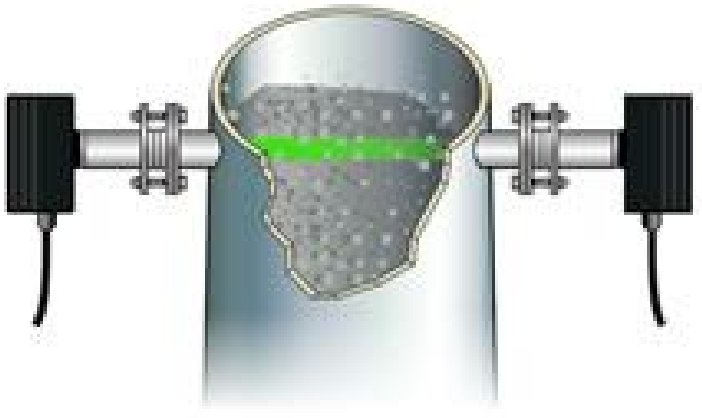
    <2.5μm, 2.5-10μm, 10-25μm, 25-100μm, >100μm

    ↑ PM2.5 ↑ PM10-PM2.5

- **Measurement Challenges**
  - Low level dust density (in the order of 1 mg/m^3)
  - Large stack size
  - Variable particle size
  - Hostile environment (Variable T & RH, presence of fine dust and wet stacks)
  - Installation and maintenance
  - Calibration and traceability issues

Measurement Technologies

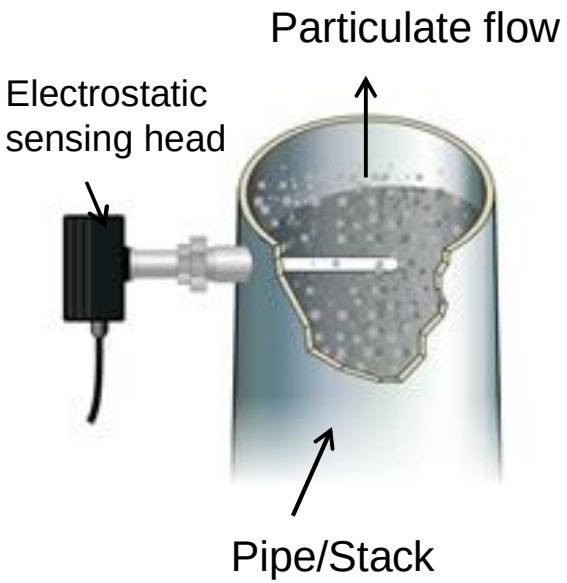
- Opacity (light transmission)
- Electrostatic (electrodynamic)
- Light scattering
- Digital imaging

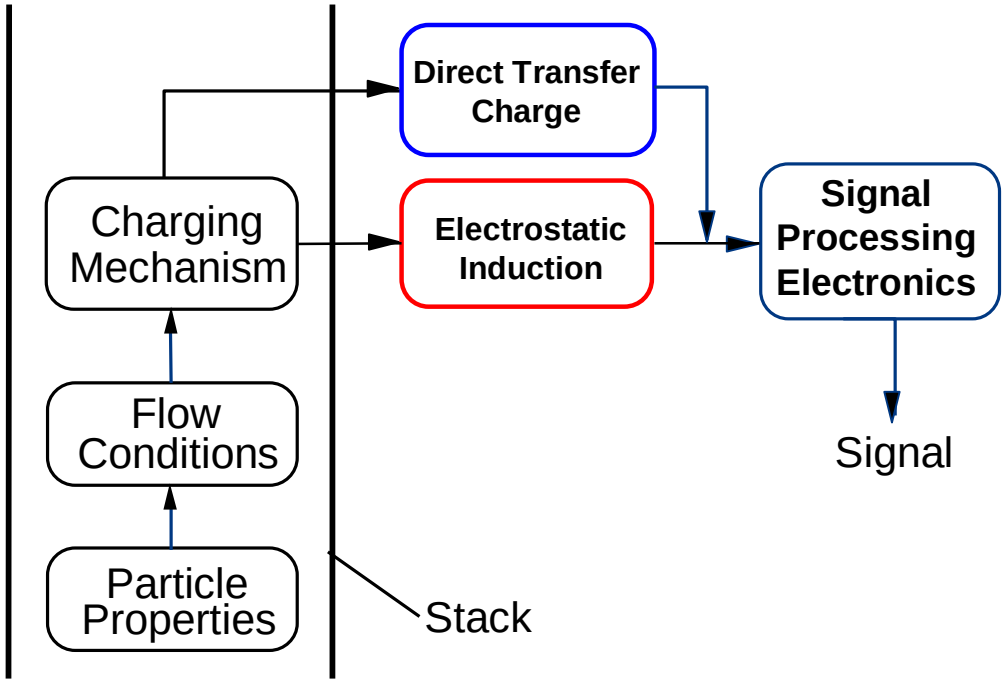


An opacity system (Land Instruments)

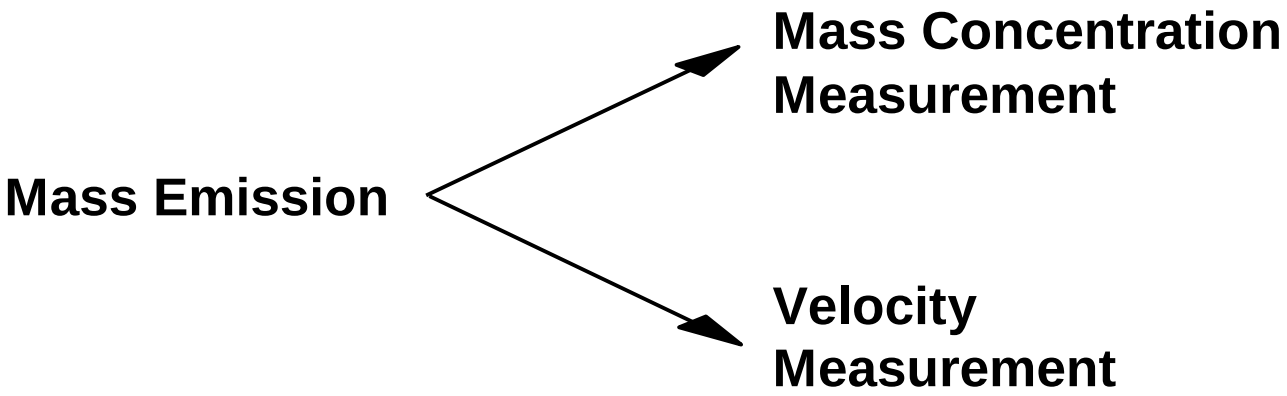
Electrostatic Sensing Principle

Moving particles carry electric charges which can be collected by electro-rods inserted into the particle flow,





Mass Emission Measurement



$$q_m = 3.6\ A\ v\ \beta_m$$

where q_m = mass emission (g/h)

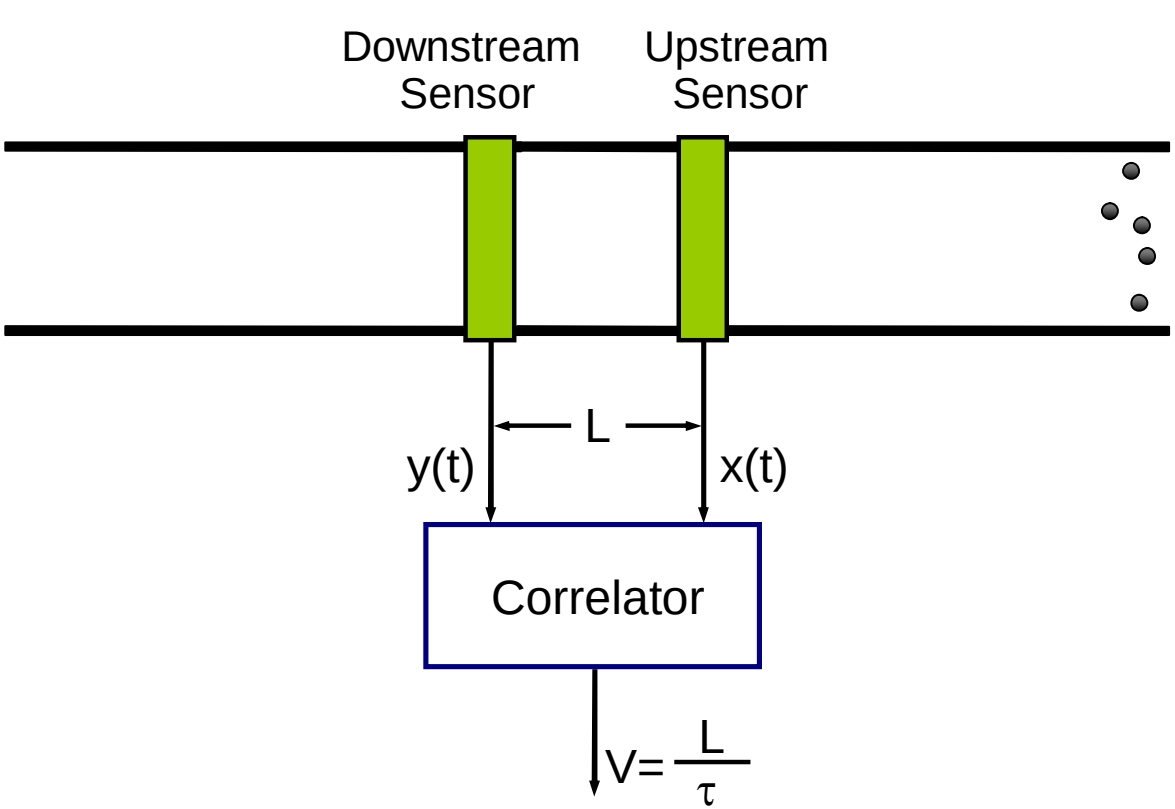
β_m = mass concentration (mg/m^3)

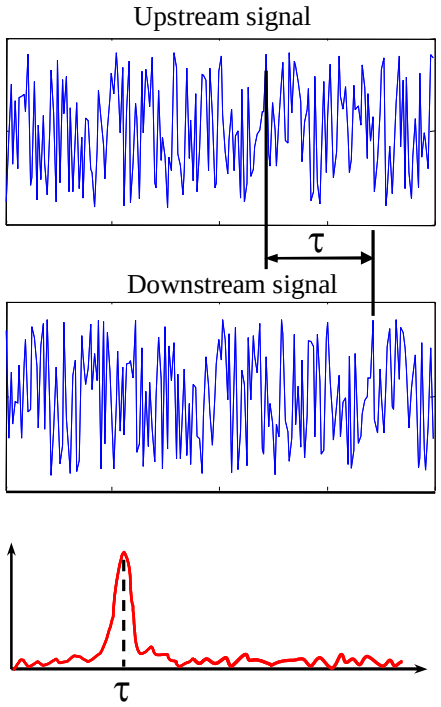
v = particle velocity (m/s)

A = cross sectional area of the stack (m^2)

Particle Velocity Measurement

- Particle Velocity can be measured based on electro-charges collected by downstream and upstream sensors through the correlation method.





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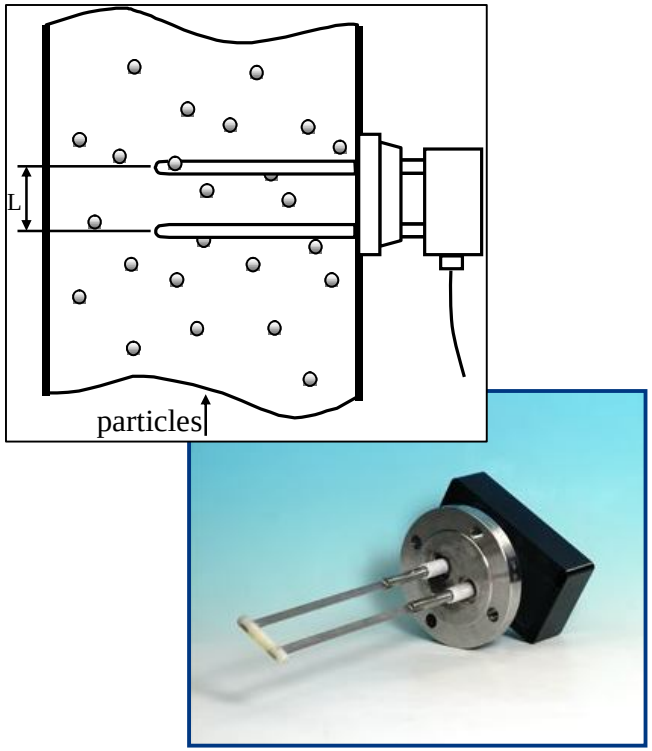
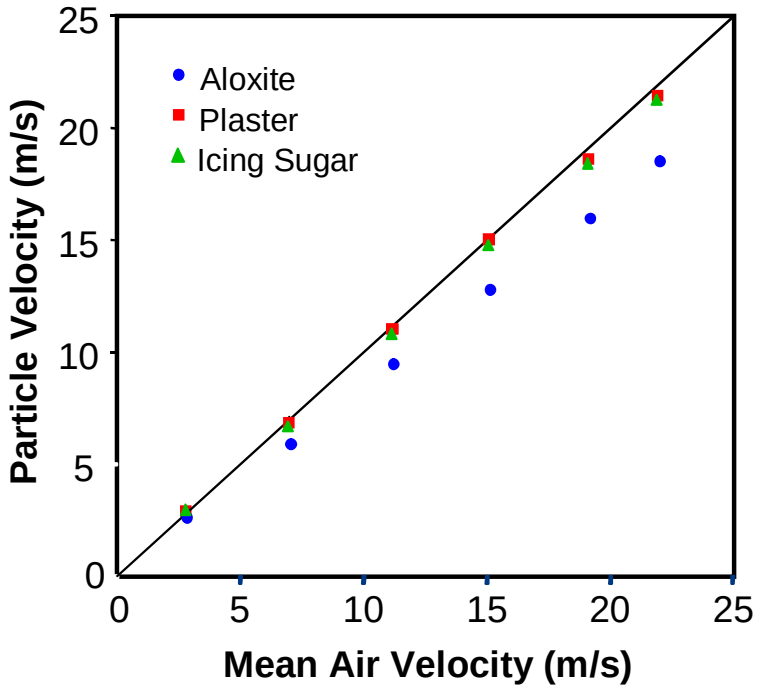
Mass Emission Measurement

- Mass emission measurement system developed by Kent and PCME under a KTP funded project.

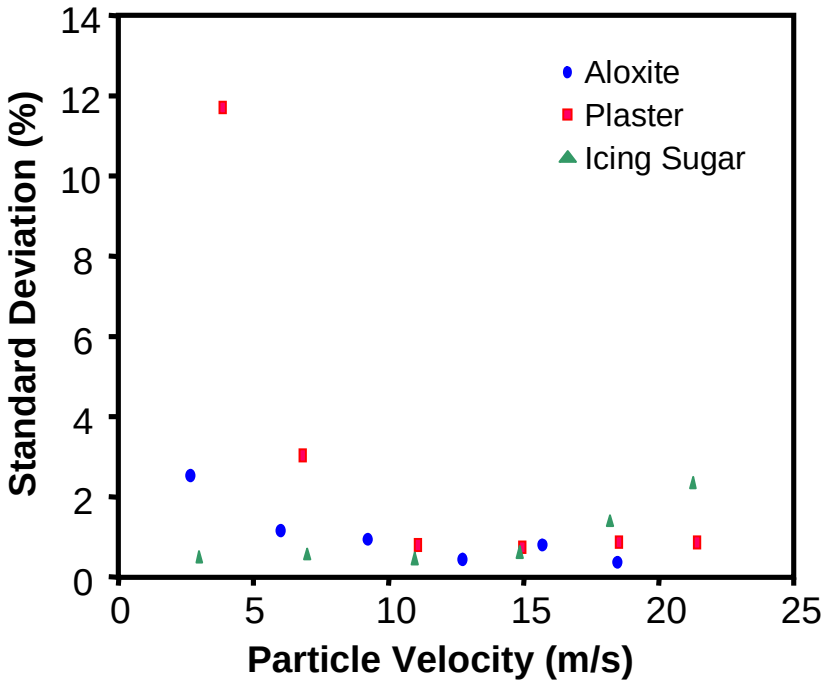


Particle Flow Test Facility (PCME ltd)

Typical Test Results



Particle Velocity versus Mean Air Velocity



Repeatability

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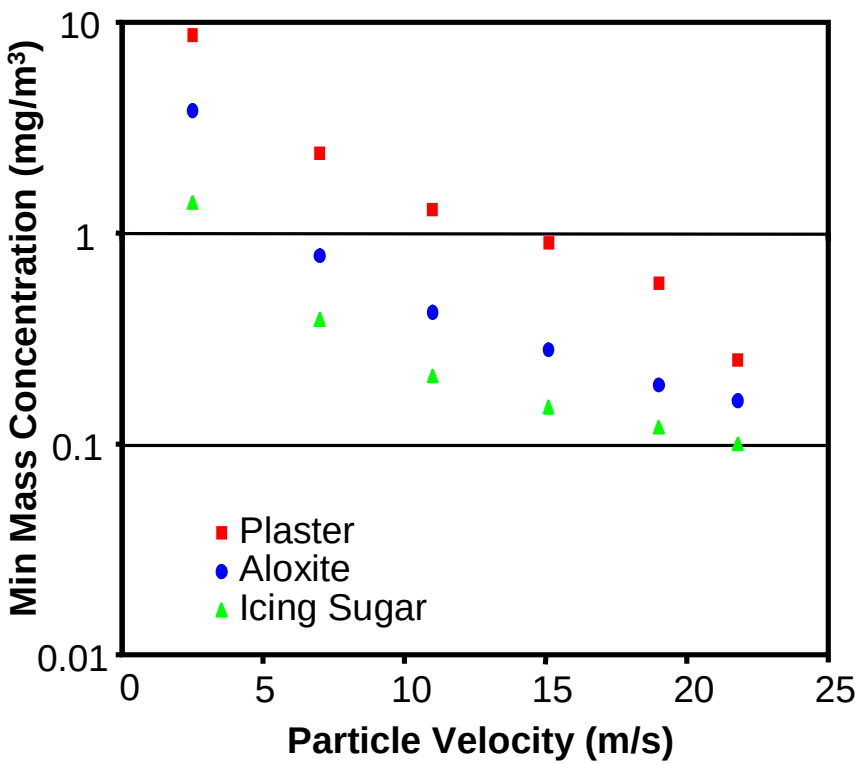
Typical Test Results



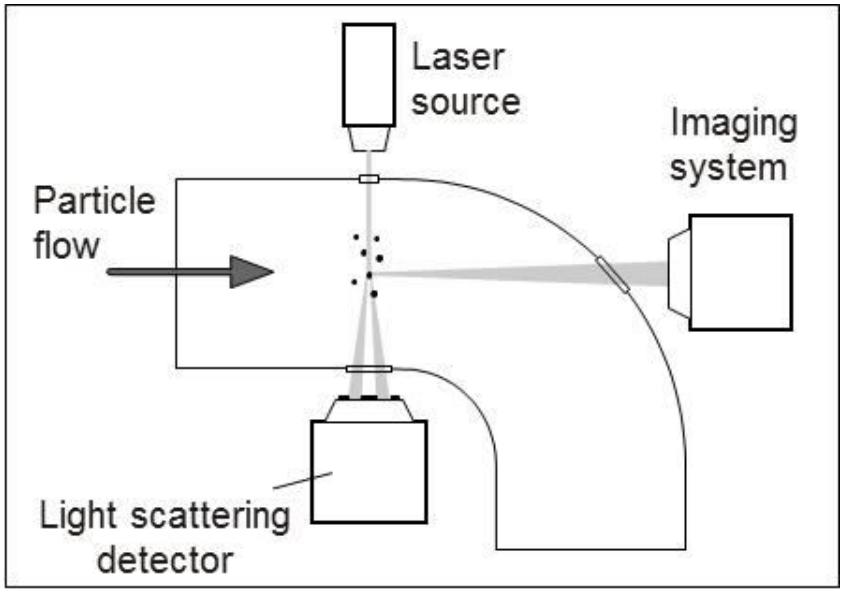
Lower Limit of Mass Concentration

Electrostatic Technique
- Key Features

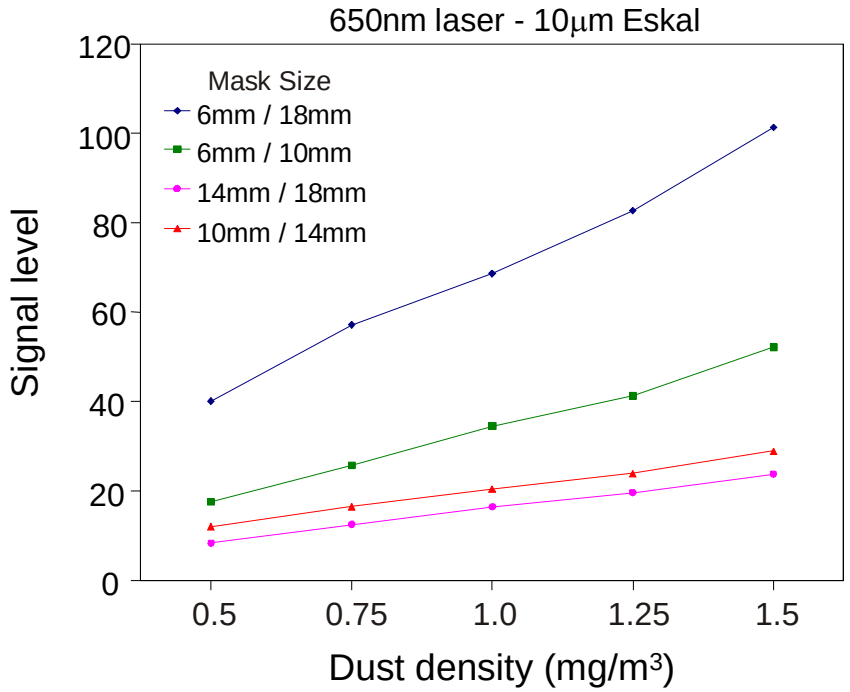
- Robustness
- Cost-effectiveness
- Easy installation
- Very high sensitivity (<0.01mg/m^3)
- Suitable for a wide range of stack sizes
- 3 parameters measured simultaneously
- Poor accuracy (charge on particles depends on many other factors, e.g. particle velocity)

Digital Imaging Technique

- Imaging and scattering techniques can be combined to measure the particle concentration.
- Laser scattering technique for measuring the particle concentration.



Light Scattering Results

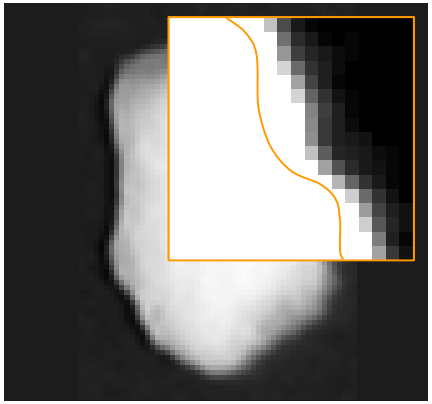


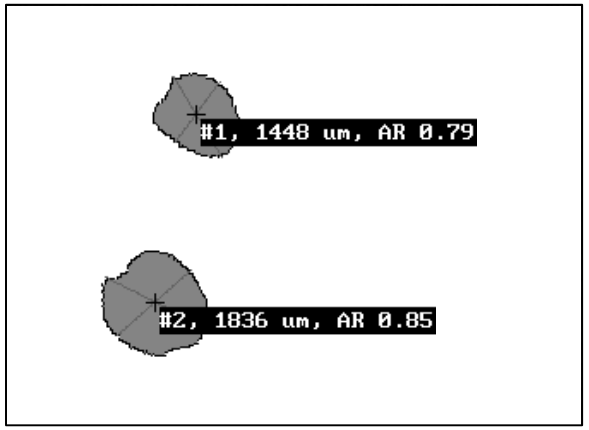
Scattering Technique - Key Features

- High sensitivity (<0.1mg/m^3)
- Good for small particles (<10μm)
- Localised measurement
- Relatively complex optical system

Digital Imaging Technique

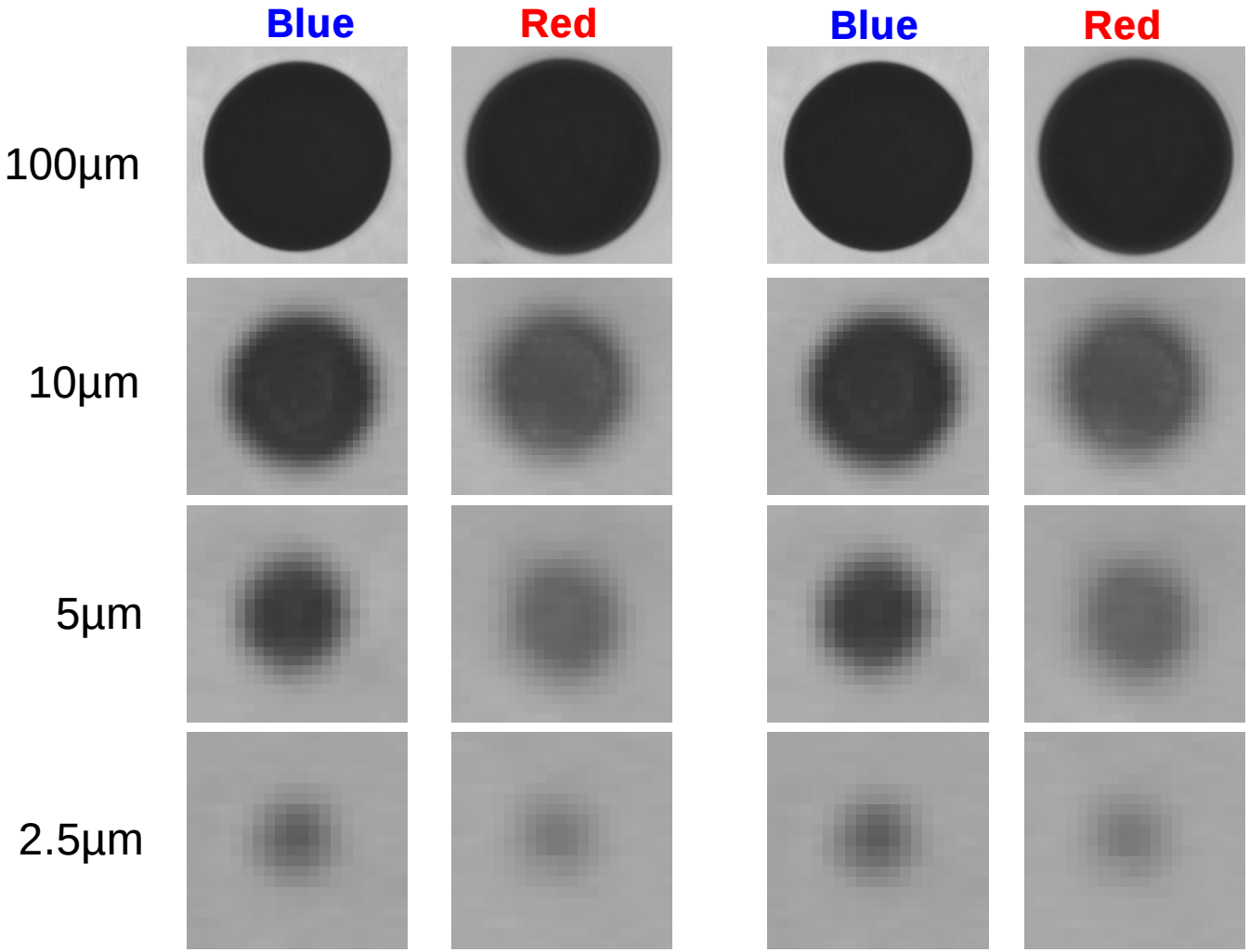
- Particle separation is a complex operation
- Novel processing algorithms are used
- Optimised for operation with rugged low cost optics





- LED illumination was tested at both 625nm (red) and 470nm (blue)
- Calibrated polymer microspheres in 2.5-100µm range were tested

Digital Imaging Technique (initial results)



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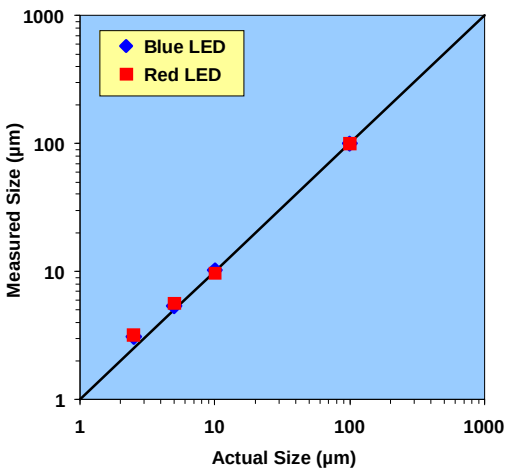
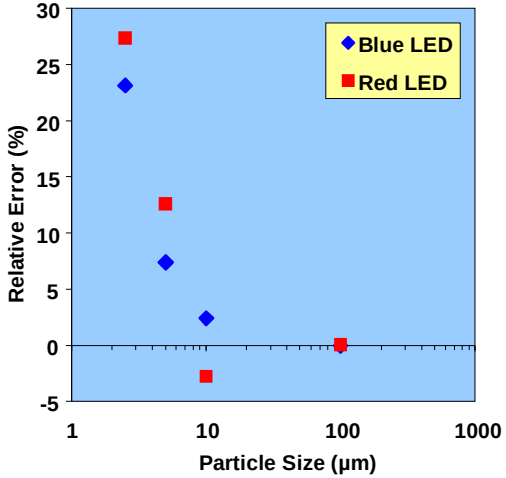
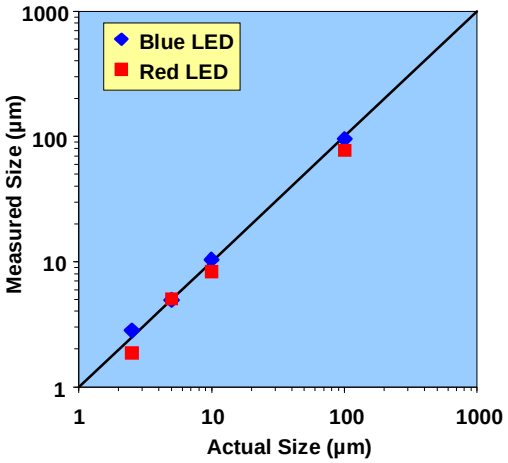
Initial Results with 100 and 50μm Calibration

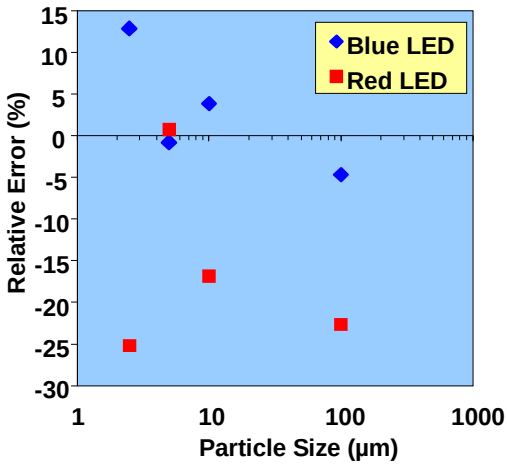
100 μm Calibration





50 μm Calibration





Imaging Technique - Key Features

- Good for large particles (>1μm)
- Automatically accommodate changes in particle size distribution
- Can distinguish dust particles from droplets in wet stacks
- Cost-effective

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Summary

- It is difficult to measure particulate emissions on an on-line continuous basis.
- Substantial further research is required to meet environmental legislations.
- Electrostatic techniques for mass emission monitoring have many advantages over other techniques.
- The rod sensors are suitable for the measurement of both mass concentration and particle velocity for a wide range of stack sizes.
- The imaging technique may provide a suitable solution to on-line particle sizing and emissions monitoring.
- Imaging and scattering techniques can be combined to accommodate a wide range of particle sizes.