Capacitive Flowmeter for Gas-Solids Flow Applications Exploiting Spatial Frequency

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Agenda

- Introduction
- State of the Art Granular Flow Sensors
- Capacitive Correlator
- Capacitive Spatial Filter
- Advanced Excitation Scheme
- Experimental Setup
- Conclusion

Introduction

Pneumatic conveying:

- Solid particles in gas
- clean, flexible and reliable conveying solution
- applicable for coal dust, wooden- or plastic pellets, salt, sugar, flour, ...

State of the Art Granular Flow Sensors

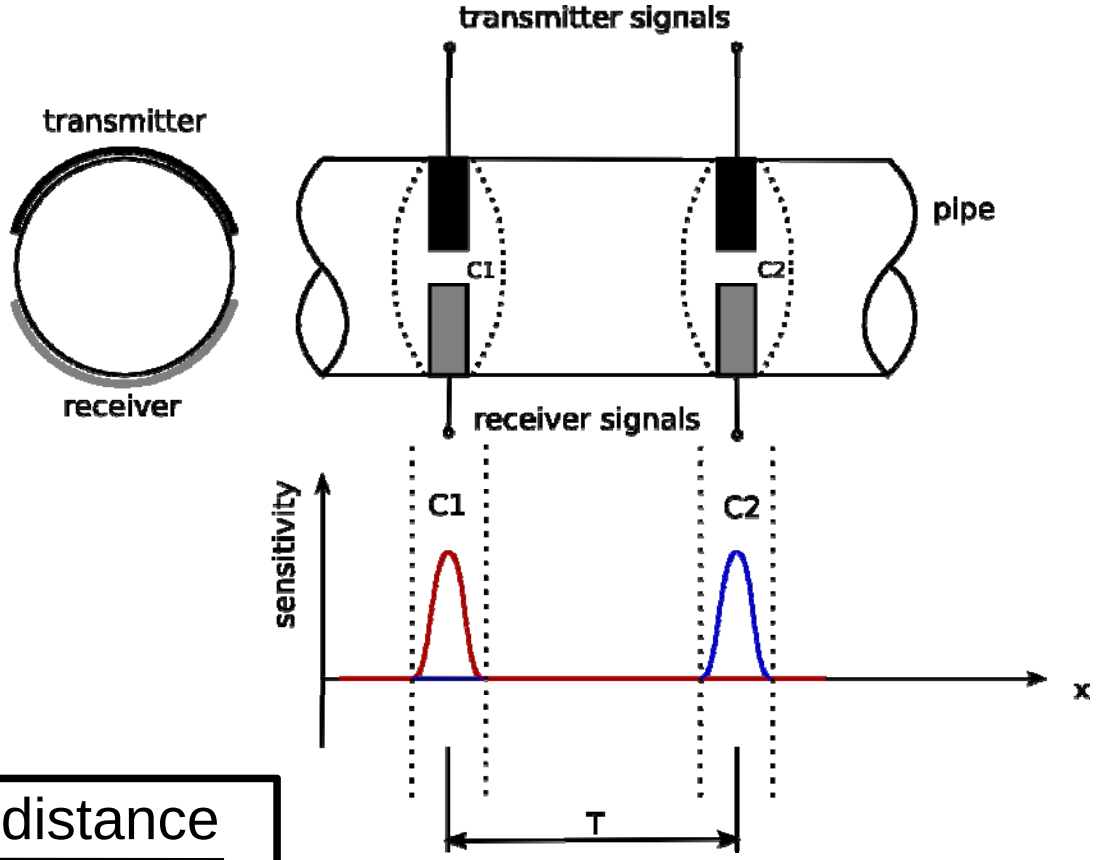
- Optical:
  - PIV
  - problems with dust
- Ultrasonic:
  - doppler shift
  - works only in special cases (low particle number, problems with sound distribution in the pipe material)
- Gamma rays:
  - correlative principle
  - expensive personal, security, import/export, environment, ..
- Capacitive:
  - correlative or spatial filtering principle

Granular flow measurement is challenging!

Capacitive Correlator

Correlative principles can also be used with light, gamma rays, magnetic principles

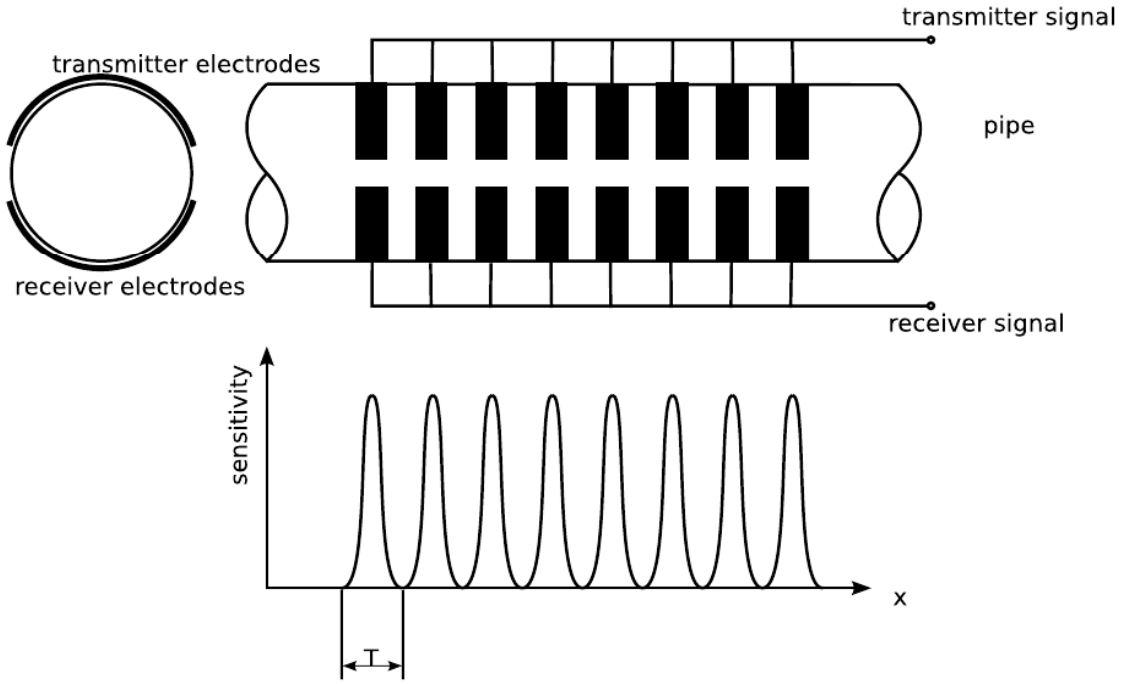
Two sensor positions with known distance in flow direction result in a time shifted measurement signal



$$\text{velocity} = \frac{\text{sensor distance}}{T}$$

Capacitive Spatial Filter

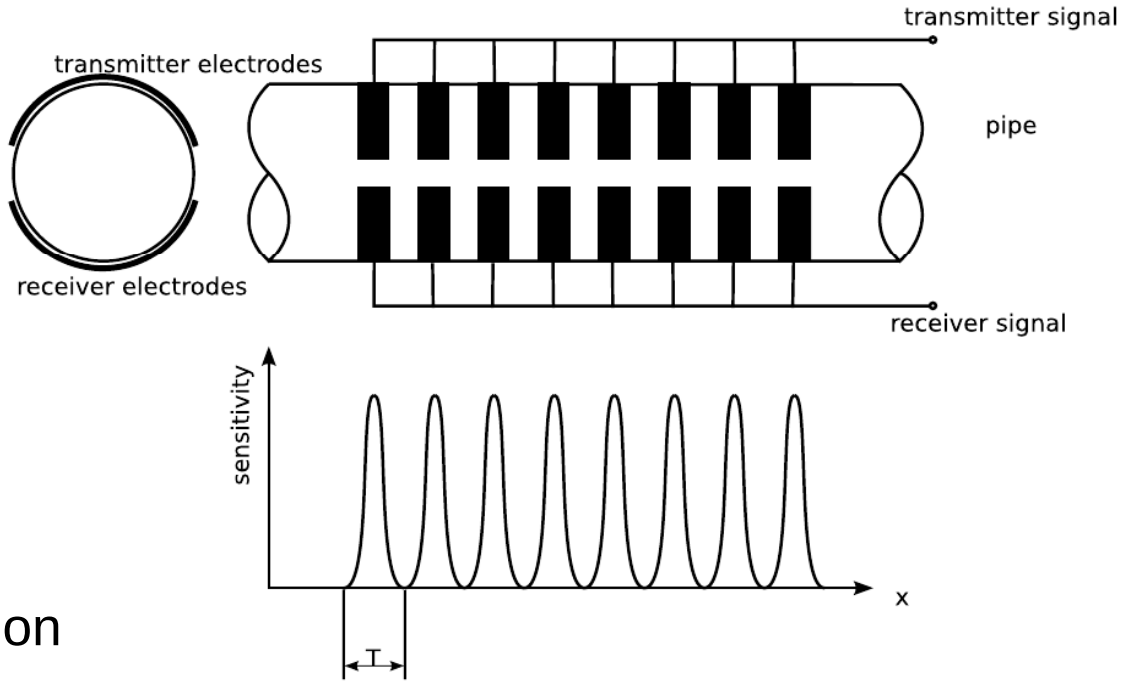
- Principle well known in optics
- Pipe interior seperated into a regular array of different sensitive areas
- Particles with constant velocity cause quasi periodic signal



$$\text{velocity} = \text{electrode distance} \cdot \frac{1}{T}$$

Capacitive Spatial Filter II

- many concurrent particles in the volume cause large offset capacity
- low signal power



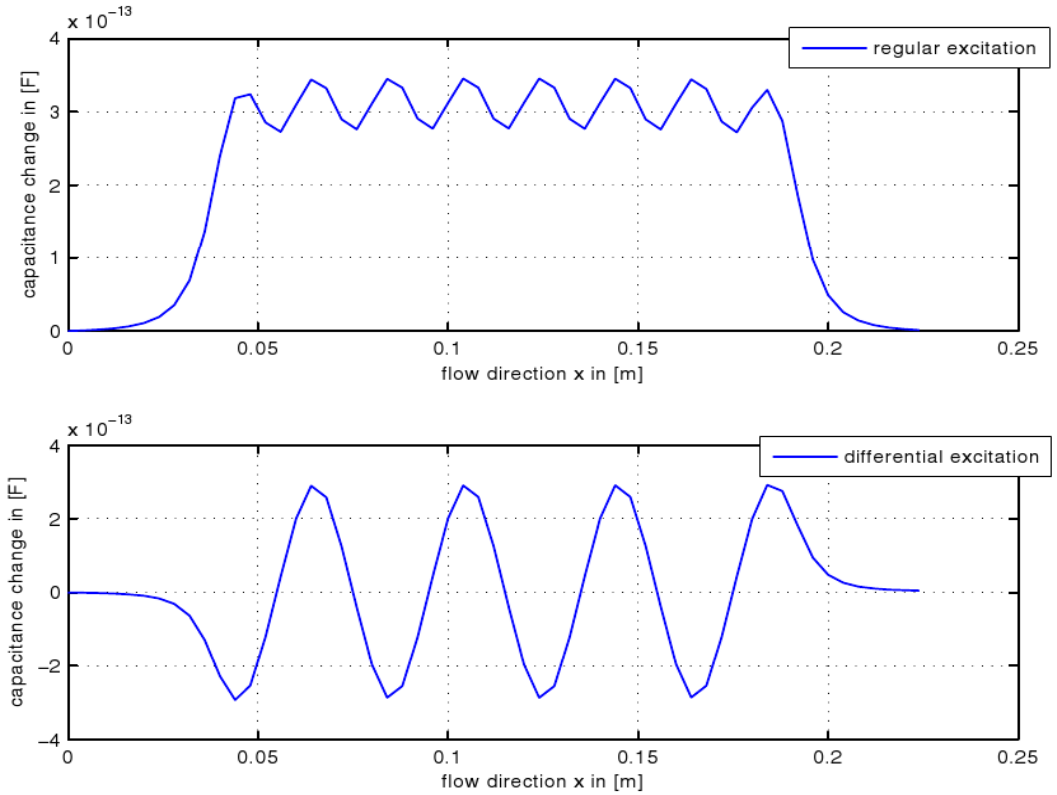
advanced excitation pattern required

$$\text{velocity} = \text{electrode distance} \cdot \frac{2}{T}$$

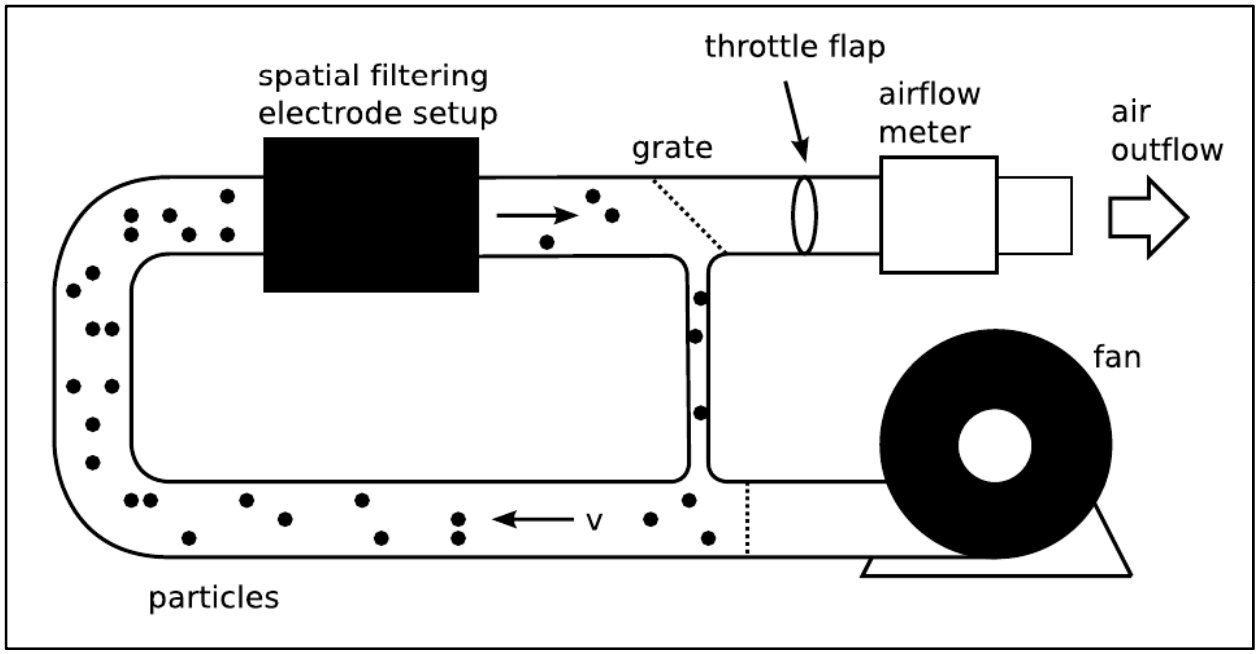
Advanced Excitation Scheme

FEM Simulation shows:

- lower number of periods
- mean free measurement signal
- increased signal power

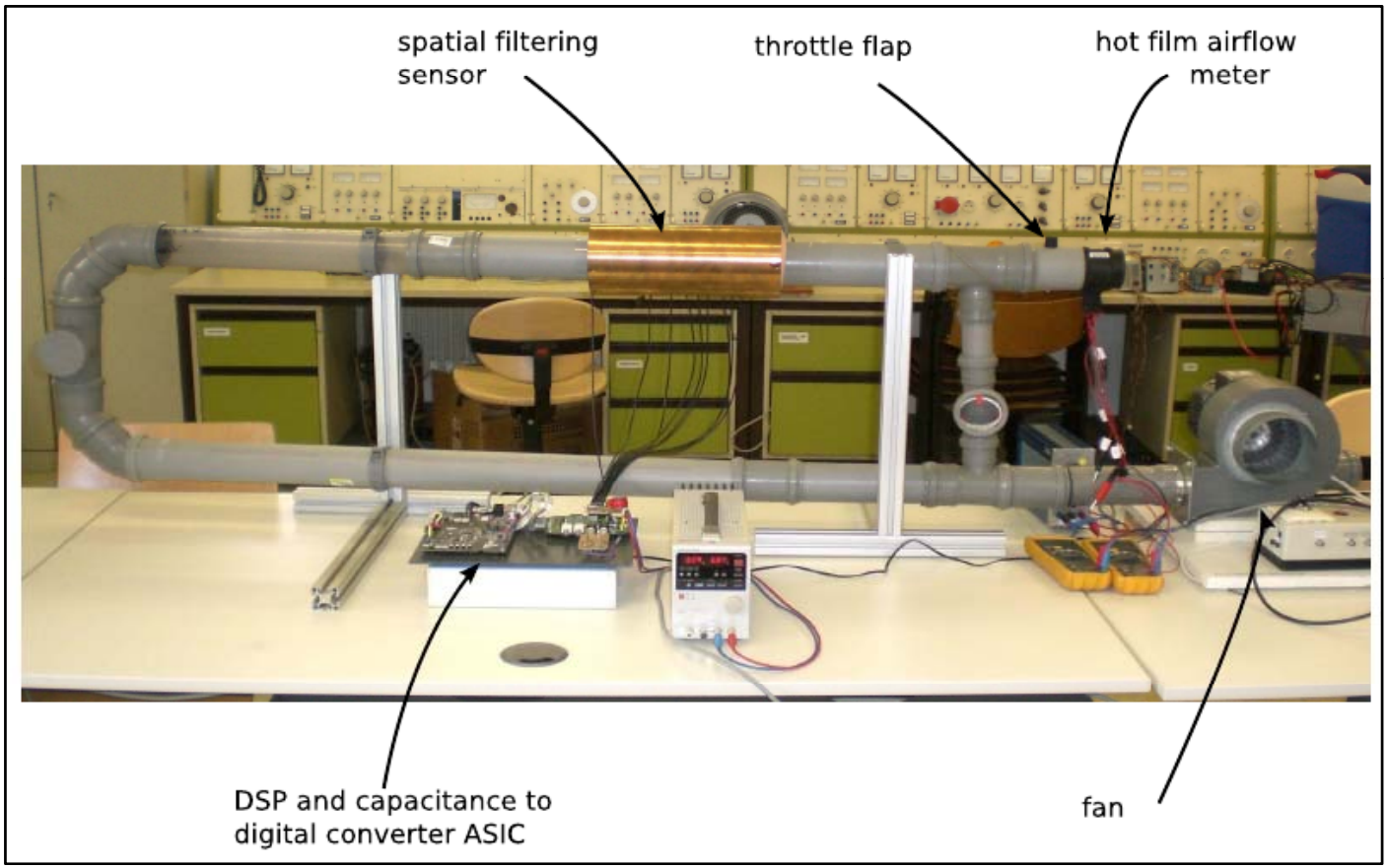


Experimental Setup



- variable speed fan
- pellets with a diameter of 3 mm and a permittivity of about 3
- Hot film anemometer

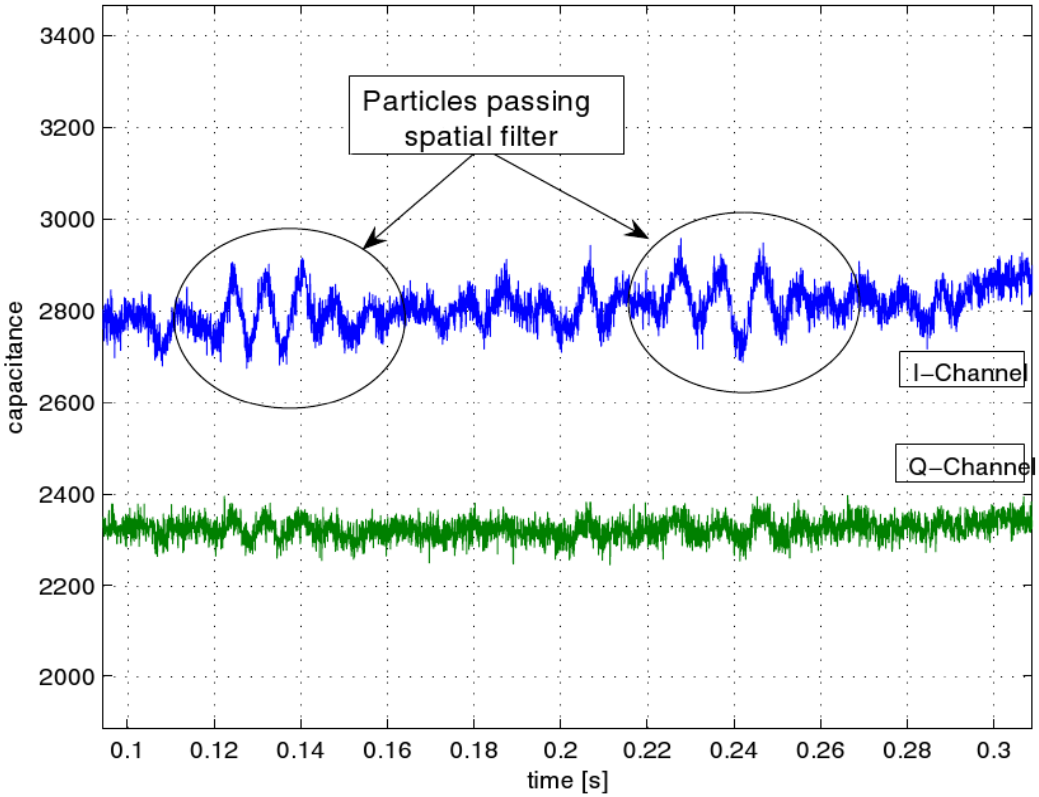
Experimental Setup II



Experimental Setup III

- in-/quadrature phase measurement
- sampling rate approx. 8 kHz

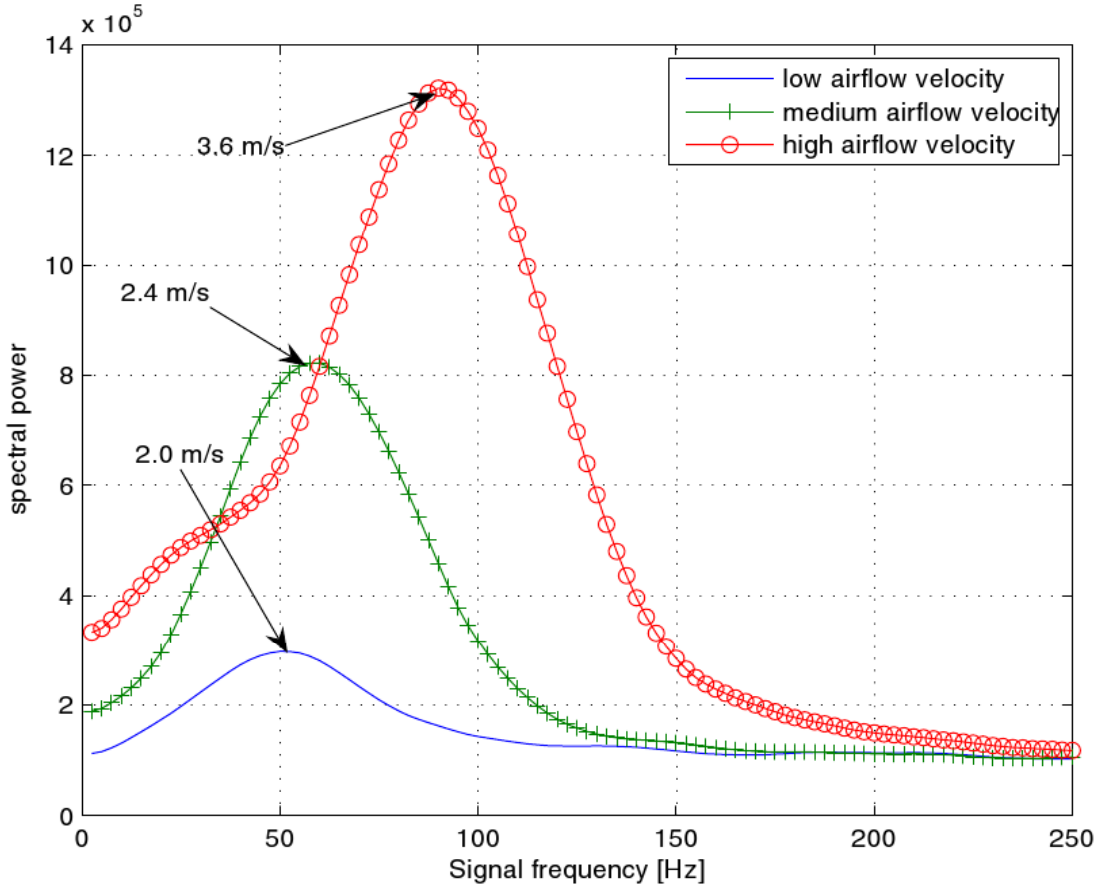
Particle velocity determination by means of frequency estimation



Experimental Setup IV

Periodogram calculation:

- Frequency estimation using overlapping FFTs
- higher airflow velocity (higher particle number) causes higher amplitude in frequency spectrum
- Sensor principle works!



Conclusion

- Non invasing measurement system for particle velocity
- Based on capacitive spatial filtering
- Advanced excitation pattern presented
- Differential excitation allows higher gains
- Laboratory test results presented

- Principle of spatial filtering IS applicable to capacitive flow measurement

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Thank you!