MEMS particle sensor for green operation on demand (GOOD)

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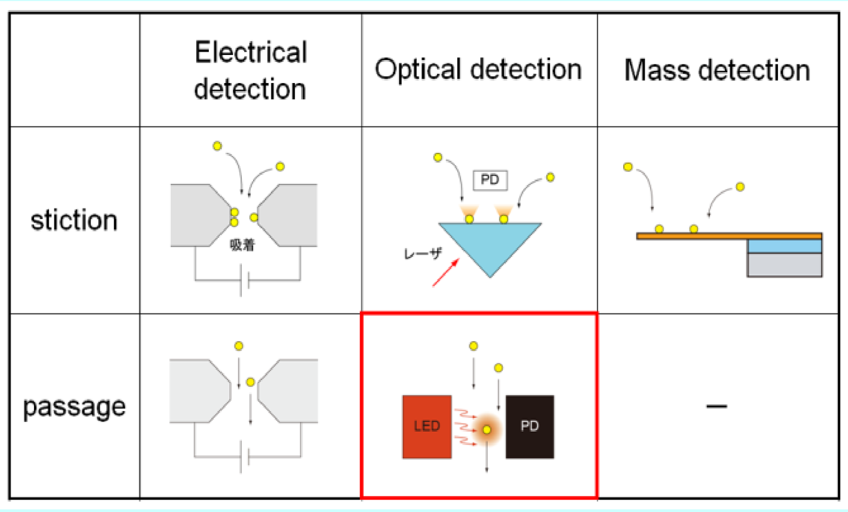
Abstract

Keywords: particle detector, Mie scattering, photodiode

- Low-power laser diode for particle detection
- Omission of flow-enhancing devices (pump, heater) and optical elements (lenses)
- Power-saving MEMS-based sensor of compact size for use in cleanrooms

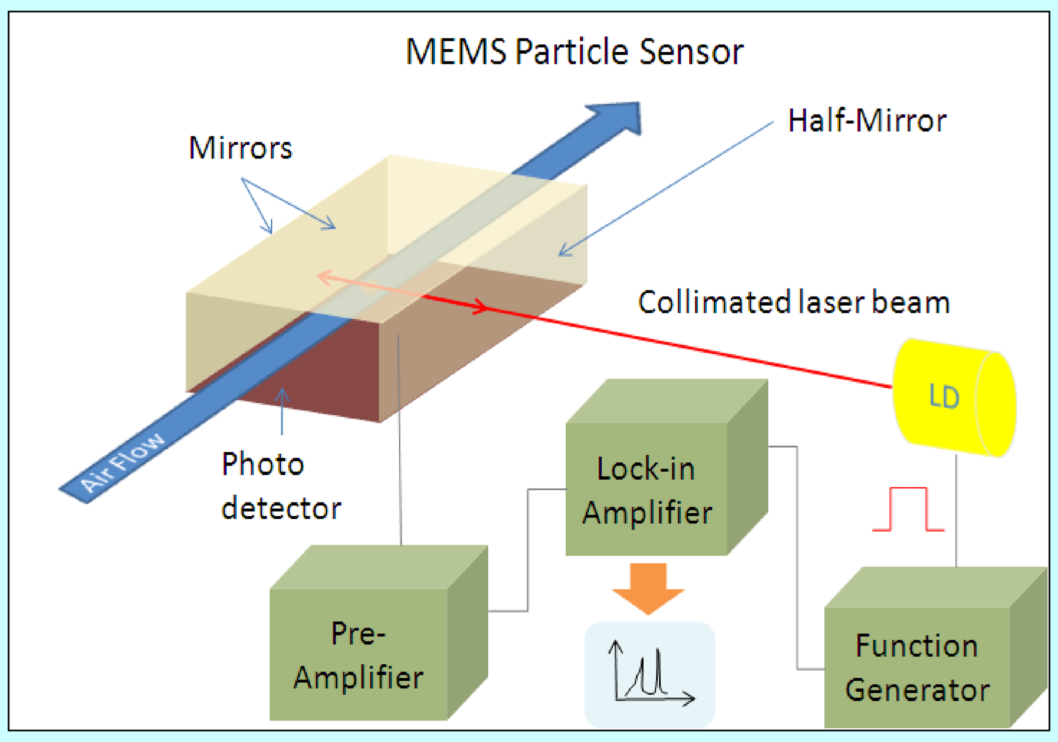
Introduction

Particle detection is possible in many ways. Because of the ease of handling and the potential for miniaturization, optical methods are the most favoured [1], where light scattered by a particle is measured. We investigate the possibility of a MEMS-based miniaturized particle sensor to be used in cleanrooms. The device uses a low-power laser diode (Rohm RLD65MZT7) as light source and a conventional Si-photodiode as detector.



Methods

The measured optical power is expected to be weak as the device is to be used in cleanrooms where the particle concentration is low. Several measures to enhance the signal have to be considered:



- multiple reflection to increase the energy stored in the cavity and to maximise incident power
- using lock-in amplification to improve signal/noise ratio
- pre-amplification
- obscuring entrance and exit of the device to minimise stray light

Results

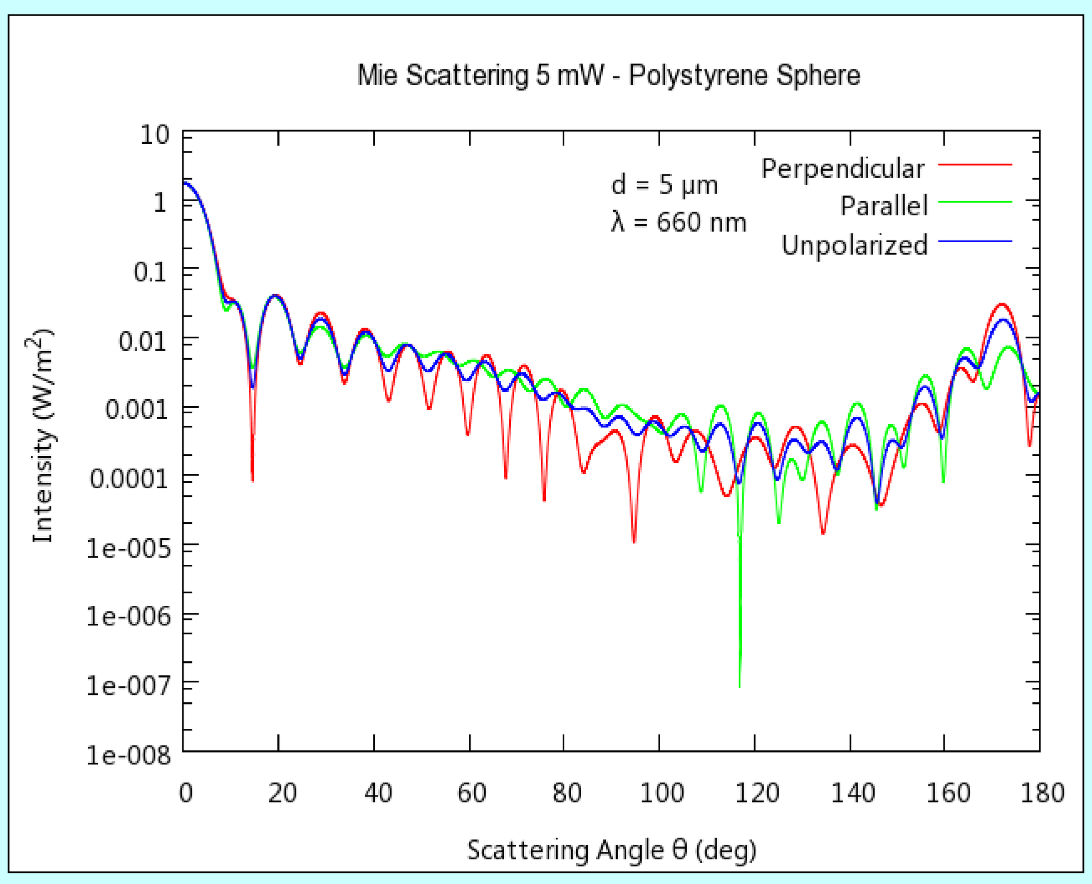


Fig. 1: Calculated irradiance vs. scattering angle for a 5 µm polystyrene particle using Mie theory.

Mie theory [2] delivers a rigorous solution to the problem of light scattered by a sphere illuminated by a plane wave. The intensity of the scattered light depends strongly on the angle between the incident laser beam and the detector. Forward and back scattering exhibit the highest scatter intensities but interfere with the source.

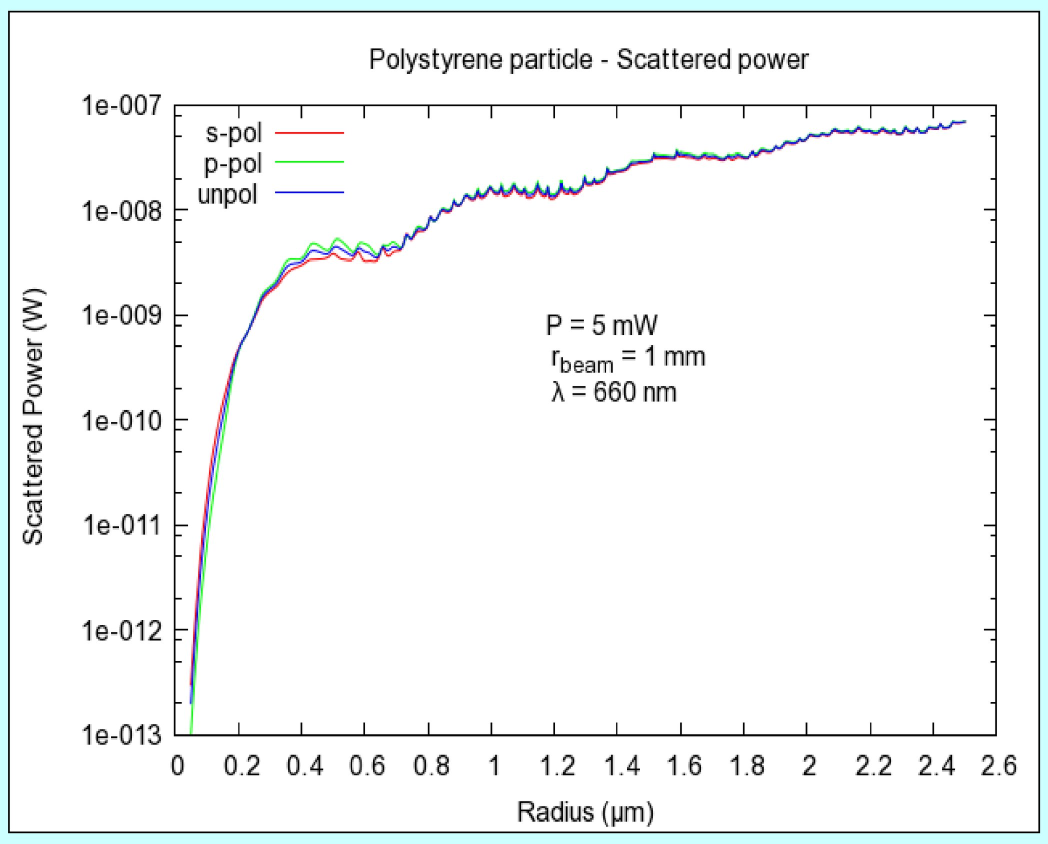


Fig. 2: Scattered power vs. particle radius calculated for a polystyrene particle. Particle sizes range from 0.1 – 5 µm as specified in ISO classifications.

There are 2 distinctive ranges when comparing the total scattered power in dependence of the particle size (diameter). In the range from ca 0.8 – 5 µm Mie scattering applies, whereas the range below is typical for Rayleigh-scattering. In case of Rayleigh scattering, the scattering is no longer shape-dependent, however, the low intensity requires more sensitive detectors.

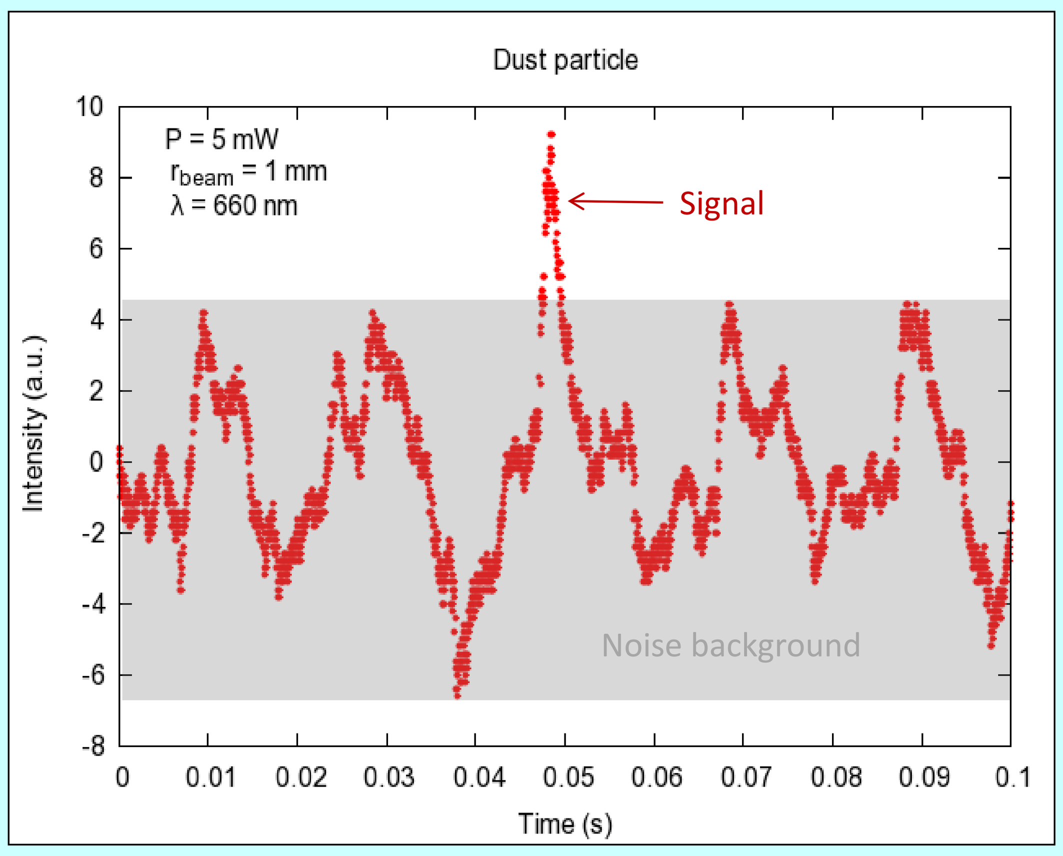


Fig. 3. Measured scattered intensity for a dust particle passing through laser beam.

Lock-in amplifier reading of photodiode signal taken from dust particles of a brush passing through the laser beam in a 90 deg (angle between laser beam and photodiode) configuration. It is not possible to determine the particle size from these measurements. The high noise level suggests that improvements in the electronics set-up are required.

Summary

(i) Total scattered power of single 5 µm polystyrene particle ca. 70 nW

(ii) Detectable using Si-photodiode and lock-in method

(iii) Usable in cleanrooms up to ISO4

References

[1] W. W. Szymanski et al. : Optical particle spectrometry—Problems and prospects, Journal of Quantitative Spectroscopy & Radiative Transfer 110 (2009) 918–929

[2] J. L. Huckaby et al. : Determination of size, refractive index, and dispersion of single droplets from wavelength-dependent scattering spectra, Applied Optics **33**[30](1994) 7112-7125