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# Photothermal interferometry for aerosol absorption measurements

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## Introduction & motivation

- Aerosol particles in the atmosphere have health, visibility and climate effects.
- Of particular relevance are soot or black carbon (BC) particles which are highly efficient light absorbers, emitted by combustion processes.
- The commonly used method for quantifying BC mass loadings is based on measuring light absorption of deposited particles on fibrous filters, with large empirical correction factors. Globally, the most widely used instrument is the aethalometer, produced by Magee Scientific.
- We develop a robust field-deployable instrument using photothermal interferometry (PTI), which measures aerosol absorption in situ (Moosmüller et al., 2009) (Fig. 1). This allows for absorption measurements, calibrated, with better accuracy and less artifacts.

## Photothermal interferometry – how?

The aerosol absorption is measured in one interferometer arm due to the heating of the particles as they are exposed to pulses of green light (Fig. 2). The resulting heat is transferred to the surrounding air, changing its refractive index. This change is measured with the interferometer (HeNe laser, 5 mW), i.e. as the phase shift ($\Delta\Phi$, in rad) between the reference arm and the arm with pulsed light.

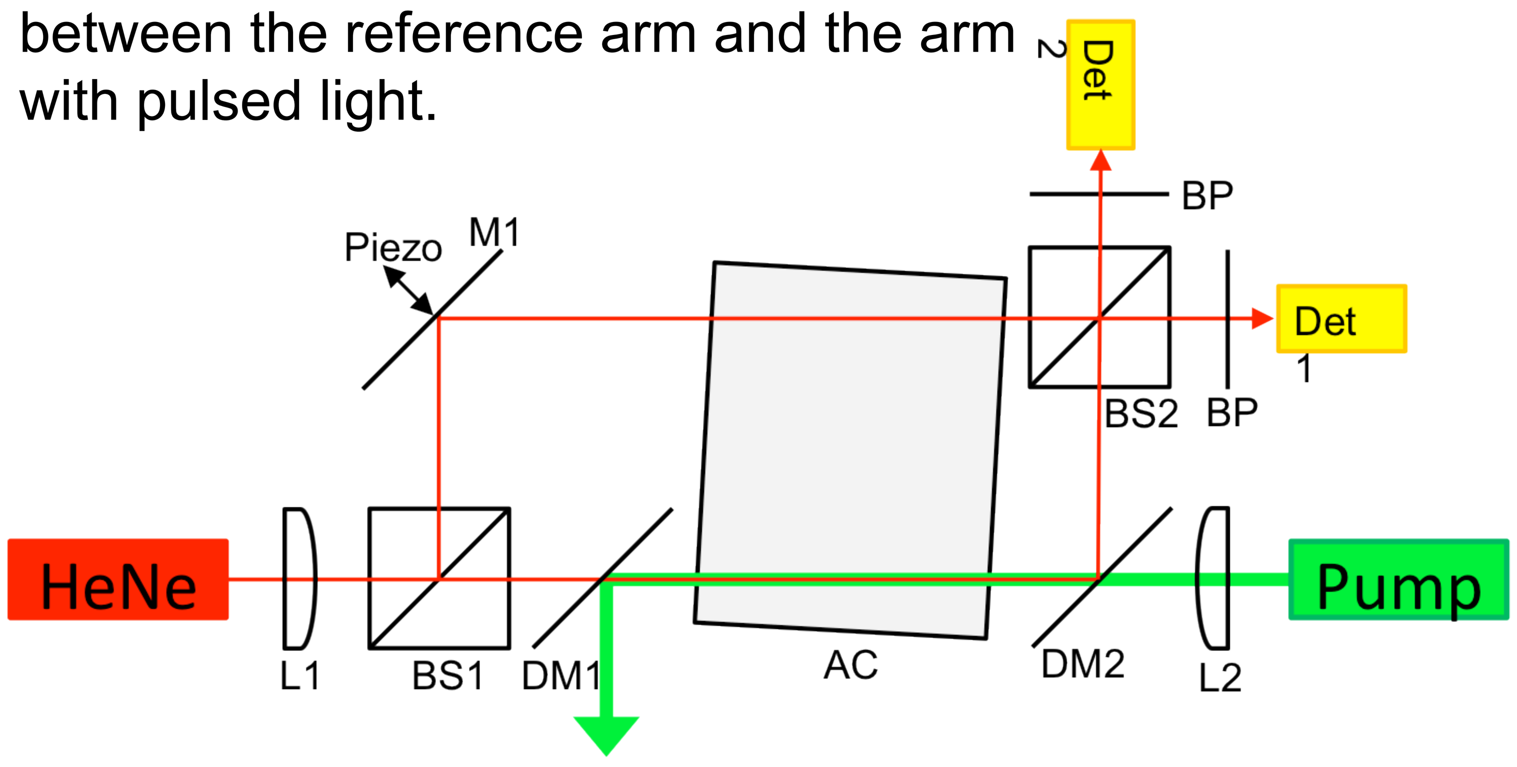


**Figure 2.** Photothermal interferometry exemplified in a Mach-Zehnder configuration. Light absorption measured via the refractive index change induced by a pump light source on the aerosol. BS=beam splitter, M=mirror, AC=aerosol chamber, DM=dielectric mirror, BP=bandpass filter and L=Lens.

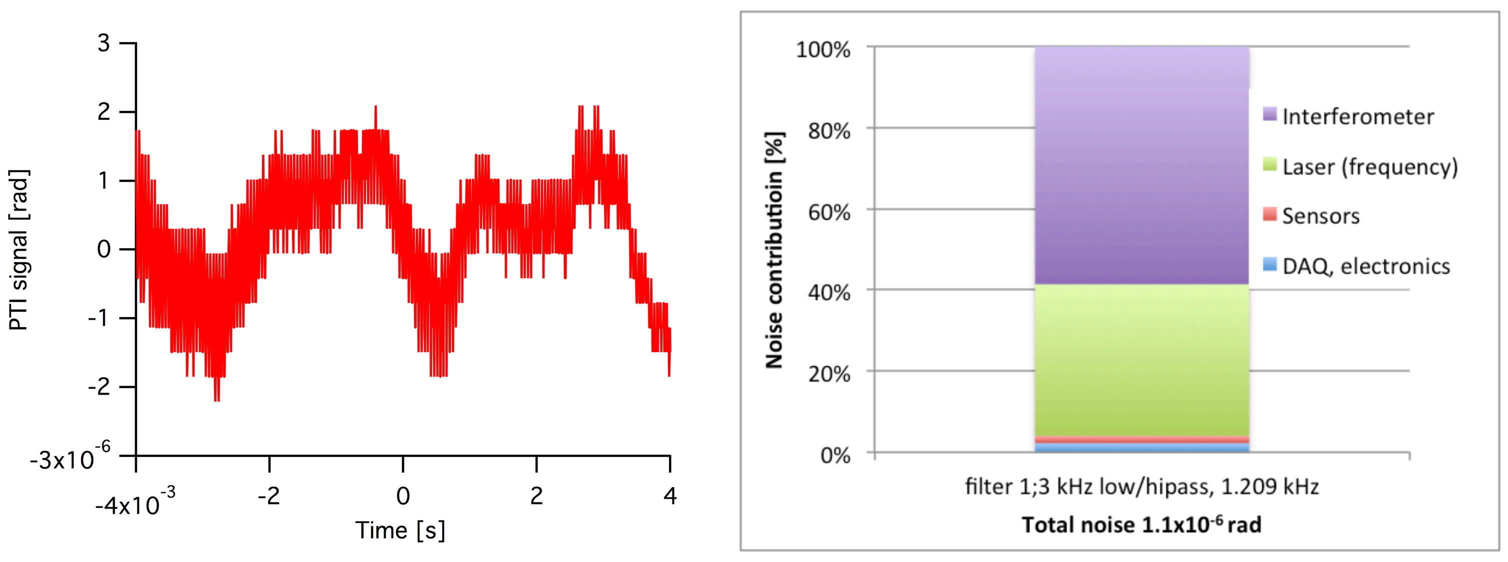


**Figure 3.** Noise of the folded Michelson interferometer, $1.1\times10^{-6}$ rad (10 s). There is mainly vibrational noise but also substantial noise from the HeNe laser (frequency), as multiples of 50 Hz.

## References

Moosmüller, H., Chakrabarty, R. K., and Arnott, W. P. (2009) *J. Quant. Spectrosc. Radiat. Transfer.*, **110** (**11**), 844-878.
Sedlacek, A.J. (2006) *Rev. Sci. Instrum.* **77**, 064903.

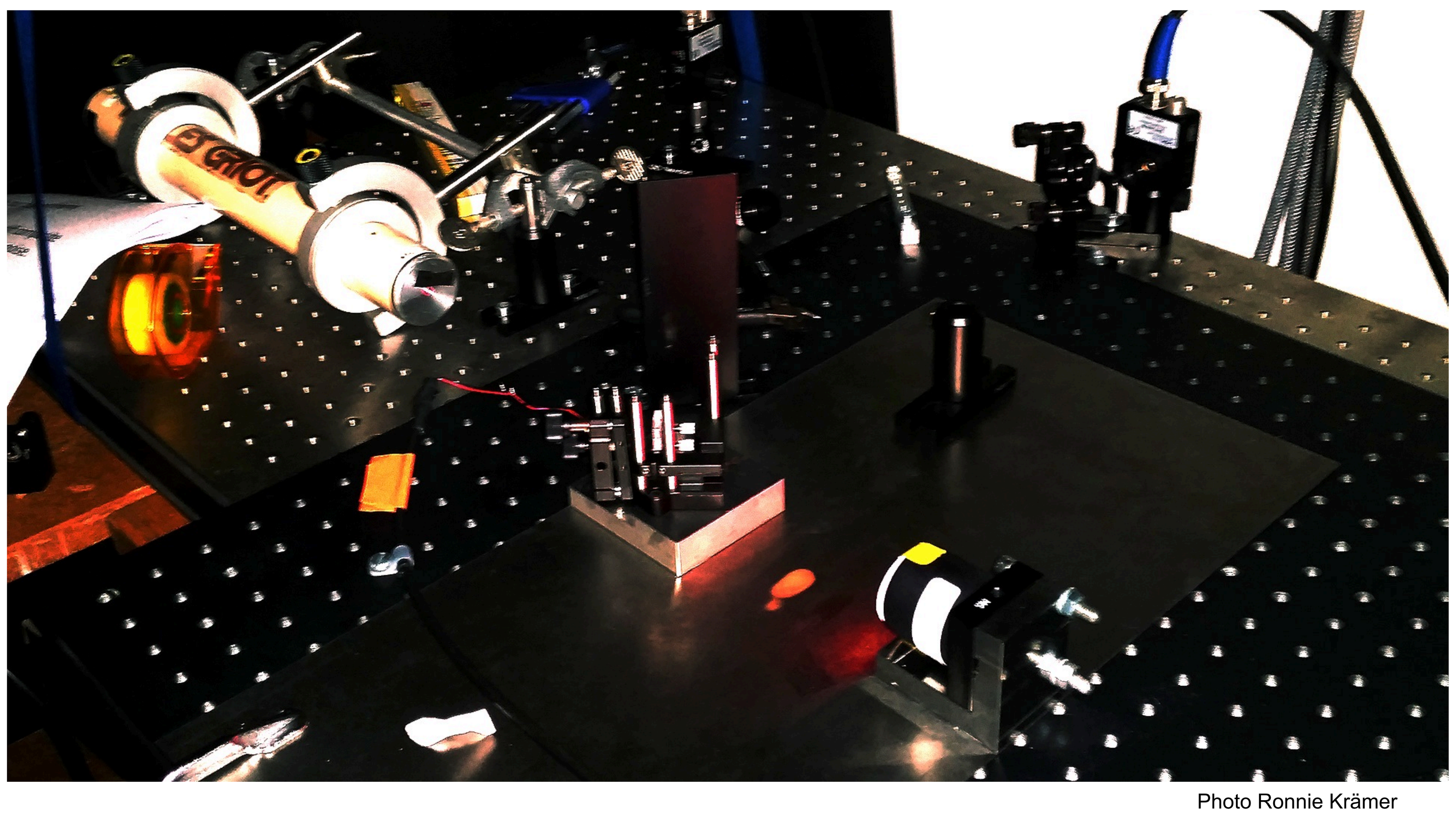


**Figure 1.** Current prototype setup.

## Conclusions

- A photothermal interferometer has been tested.
- Prototype with good stability and easy adjustment.
- Built with OEM components, readily available.
- $\Delta\Phi$ noise is $1.1\times10^{-6}$ rad (10 s average) (Fig. 3).
- Limit of detection (LOD) is about 35 $Mm^{-1}$ (Fig. 4).

Goal, in order to be competitive, is to achieve LOD 1 $Mm^{-1}$. The interferometer absorption measurement allows **comparison with and validation of aethalometer-type instruments. This results in a better accuracy** of aerosol absorption measurements for the community.

## Goals

The relation between phase change and absorption is:

$$\Delta\phi = \frac{2\pi l\,(n-1)}{\lambda \quad T_o}\,\frac{\alpha P_{\mathrm{exc}}}{4\pi a^2 \rho C_p f},$$

where $l$ is the interaction length, $f$ is the pulse frequency and $P_{exc}$ the power of the green light (within the boundary of the interferometer laser), respectively; $n$ is the refractive index of air; $\lambda$ is the interferometer wavelength; $T_0$ is the absolute temperature; $a$ is the radius of the interferometer beam and $\rho$ is the density of and $Cp$ is the specific heat of air (Sedlacek, 2006).
The $\Delta\Phi$ theoretical limit is about $10^{-8}$ rad, so we aim practically to reach $5\times10^{-7}$ rad. The second parameter to improve in order to reach a limit of detection (LOD) of 1 $Mm^{-1}$, is $lP_{exc}/a^2$. We aim to develop our light source to a $lP_{exc}/a^2$ of 10 kW/m. With both, LOD would be 1 $Mm^{-1}$.

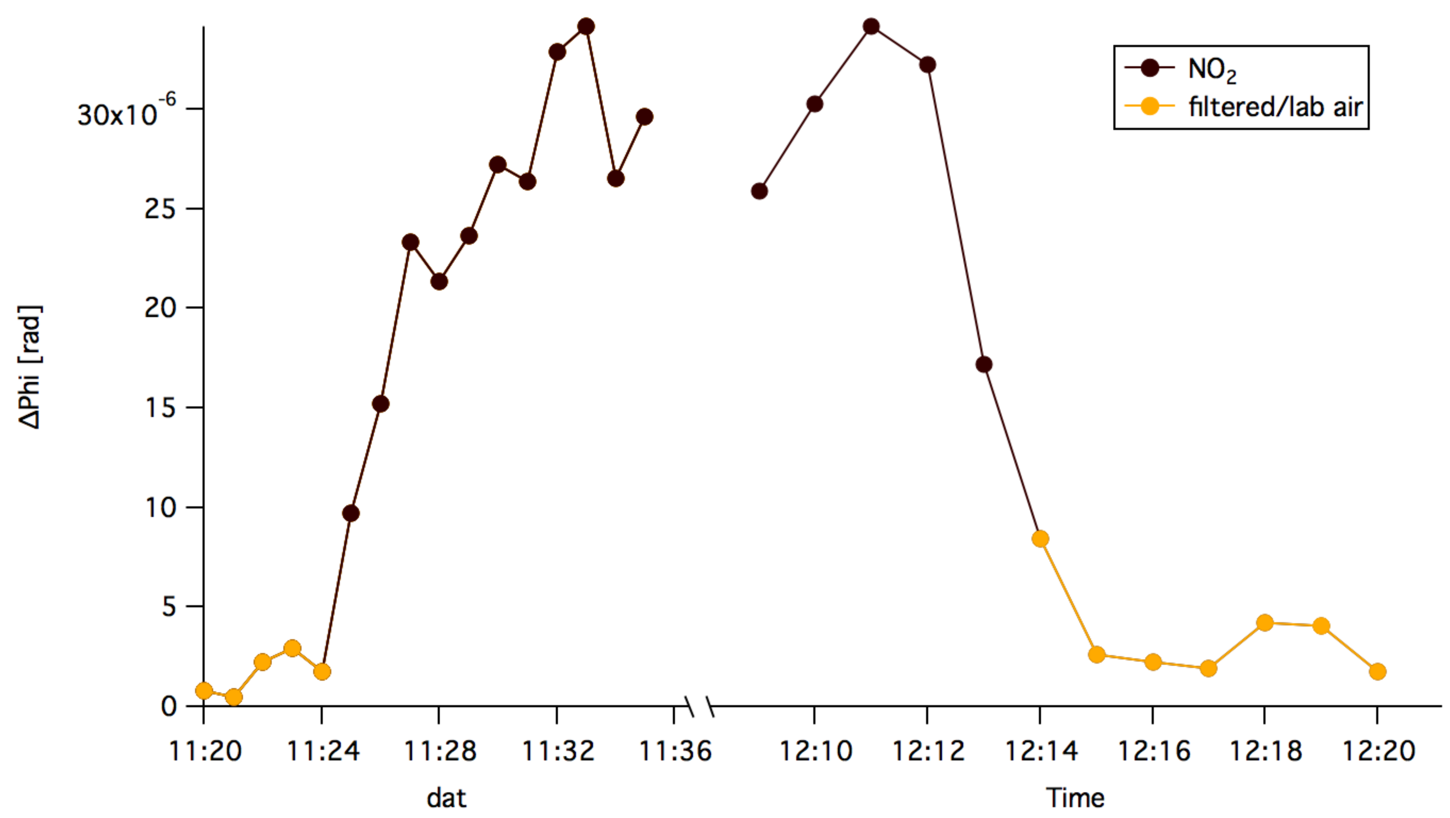


**Figure 4.** Typical measurement of 1 ppm $NO_2$ (absorption coefficien 345 $Mm^{-1}$ at 25°C, 1000 mbar and 1 ppm) with the photothermal interferometer prototype.