APPLICATION NOTE 3

Reproducibility of Multiple OEA-532 Analyzers

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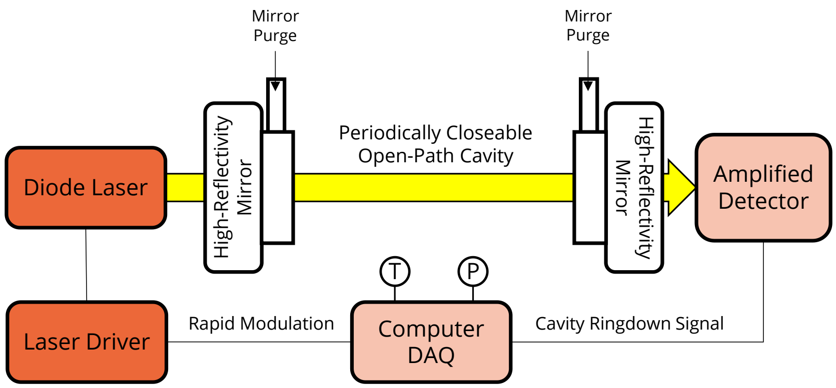
Introduction

In order to address new visibility regulation like the EPA Clean Air Act and Regional Haze Rule, monitoring networks (e.g. the IMPROVE network) use filter-based monitoring and nephelometry to measure particulate composition and scattering. These nephelometers follow a strict check and calibration schedule that typically includes hourly to daily zero checks, weekly span checks with a refrigerant or CO_2, and monthly to yearly overnight zero noise checks.

In this application note, we discuss why the Nikira Labs OEA-532 Optical Extinction Analyzer does not require this sort of calibration and demonstrate this feature by measuring the reproducibility of 5 uncalibrated instruments for ambient air monitoring.

Measurement Principle

Unlike a nephelometer, which measures aerosol scattering using empirical corrections for lamp intensity, detector efficiency, and truncation errors, the OEA-532 utilizes cavity ringdown spectroscopy (CRDS), a first-principles technique that directly determine the optical extinction of the sample with no empirical correction factors. In the OEA-532, ambient air is flowed through an open, high-finesse optical cavity bounded by two highly-reflective mirrors (Figure 1). A 532 nm laser is coupled into the cavity perpendicular to the air flow and rapidly modulated.



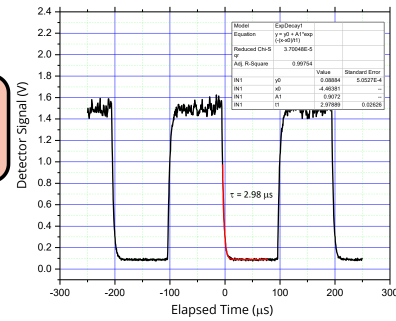


Figure 1: (left) Schematic overview of OEA technology
Figure 2: (right) Sample detector signal fit to a single exponential to obtain the cavity ringdown time.

When the laser is turned off, light decays exponentially out of the cavity (Figure 2) with a time constant, τ, that is direct measure of the optical loss within the cavity with no correction or calibration factors:

$$OL = \frac{1}{c\tau}$$

where OL is the optical loss and c is the speed of light.

This optical loss comes from the mirrors, gases in the cavity, and aerosols in the cavity. Foremost, the mirrors themselves provide optical loss via transmission, absorption, and scattering. Gases in the cavity absorb (e.g. NO_2) and scatter light (e.g. Rayleigh scattering). Finally, aerosols within the cavity also absorb and scatter light. Periodically, the cavity automatically closed and flushed with filtered, ambient air (or other air source provided by the user). During these closed periods, the only optical losses in the cavity are due to the mirrors and gases since the aerosols have been filtered out. Thus, by subtracting the closed values from the open values, the optical losses due to the aerosols can be determined directly from first-principles with no calibration factors.

Data

In order to demonstrate this feature, five OEA-532 instruments were operated in an urban environment for ~100 hours. The raw, measured optical extinction determined by all 5 instruments is shown in Figure 3 using a 5-minute averaging period (~1200 points/analyzer).

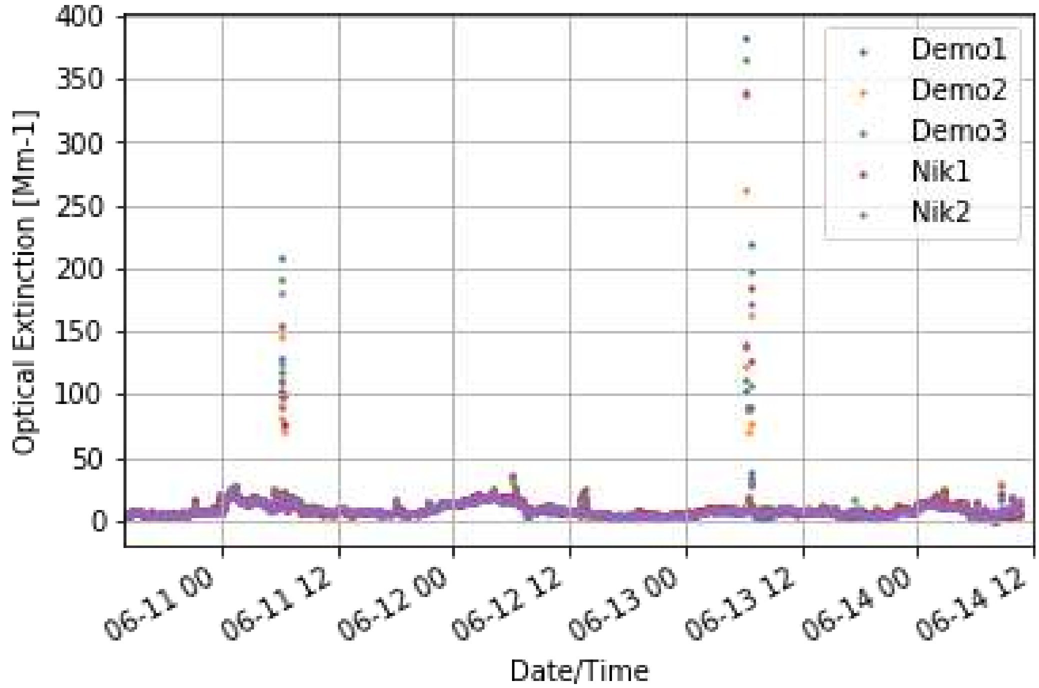


Figure 3: **Measured visibility taken by 5 different OEA-532 units.**

With the exception of two large, fast events, the ambient optical extinction due to aerosols ranged from ~2 – 30 Mm^{-1}, consistent with clean air and local visibility measurements. Comparing all 5 measurements to the mean value (Figure 4) shows excellent reproducibility that is within ± 2 Mm^{-1} over this range. Note that this reproducibility was achieved with no calibration or span measurements.

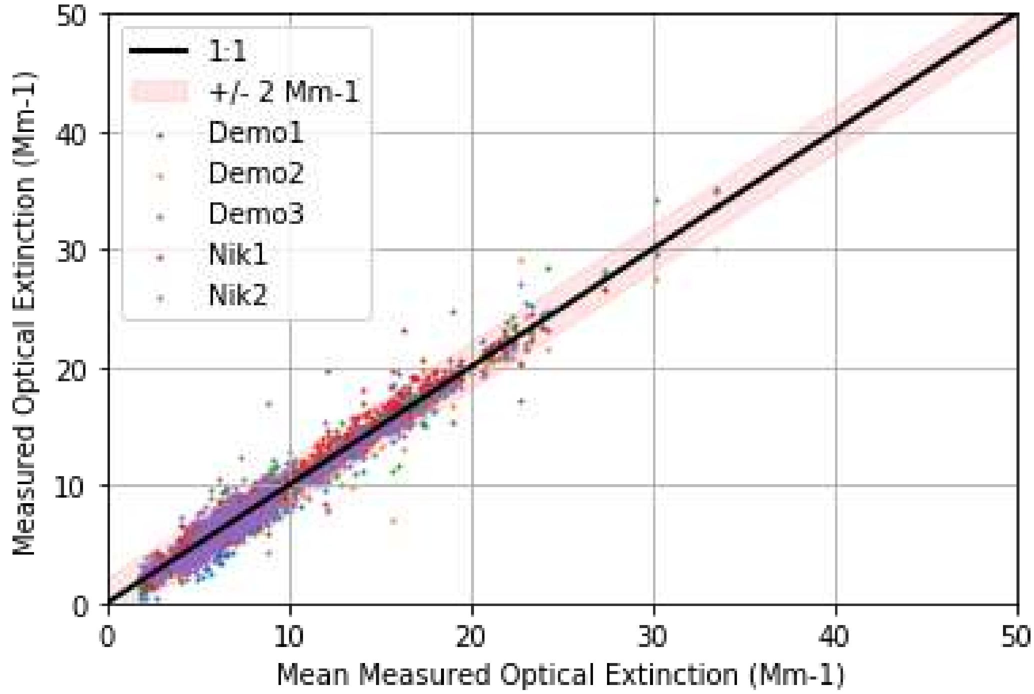


Figure 4: **Reproducibility amongst 5 different OEA-532 analyzers.**

Further Work

This work can be extended and modified in a variety of ways, including:

- Periodically measuring a span gas to show that the span measurement remains constant, further emphasizing that the analyzer does not need a span calibration
- Using the autonomous measurements of aerosol-free air to quantify instrument noise and provide an additional quality metric
- Extend this study to more polluted areas to evaluate agreement at higher optical extinctions