Towards long open-path FTIR spectrometry of CO_2 and CH_4 in an urban environmet

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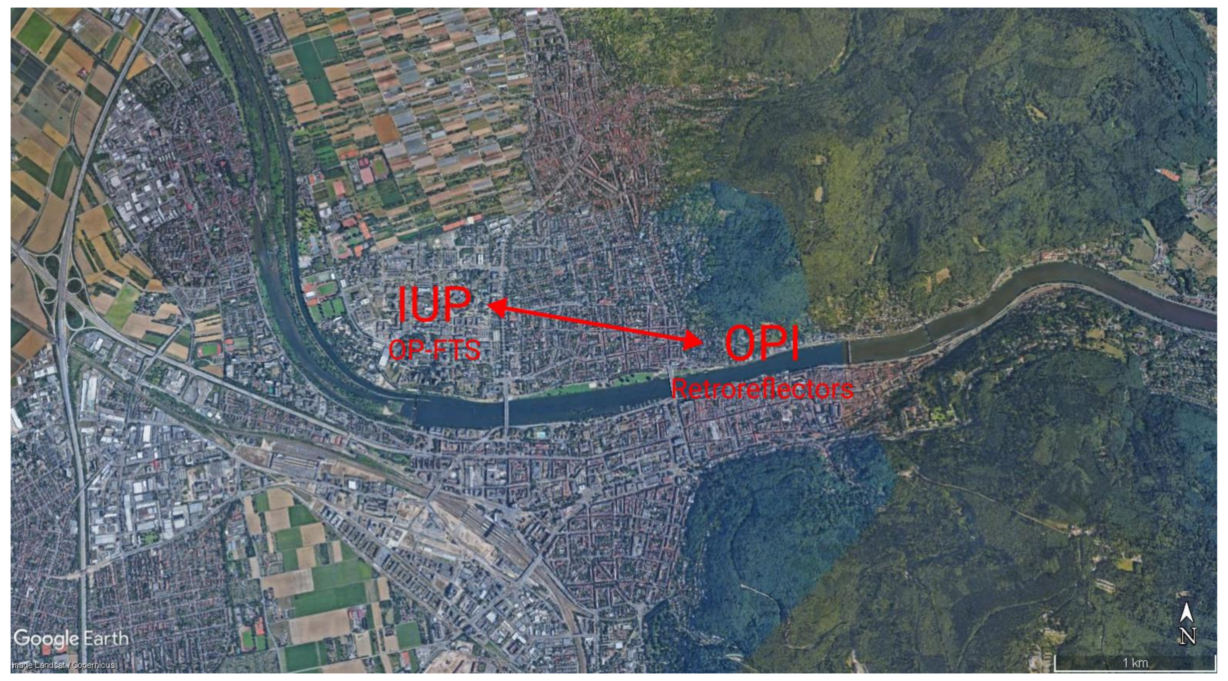
1 Introduction

Quantifying sources and sinks, as well as photochemical activity of trace gases in the lower troposphere, requires accurate measurements of the concentrations of the species of interest. While there exist in-situ measurement techniques, which are highly accurate, point-like measurements tend to suffer from insufficient representativeness, especially true for high-gradient environments, e.g., an urban setting. Hence, measuring those concentrations averaged on the length scales of a few kilometers is desirable. Further, quantifying emissions requires combining the concentration measurements with regional transport models, which cover a comparable spatial resolution.

Here we present our open-path setup in the city of Heidelberg, Germany. We use an Fourier-Transform-Spectrometer (FTS) to modulate a beam of light and send the interferogram (IFG) along a total absorption distance of about 3km to retrieve column averages concentrations of CO_2 and CH_4.

2 Location

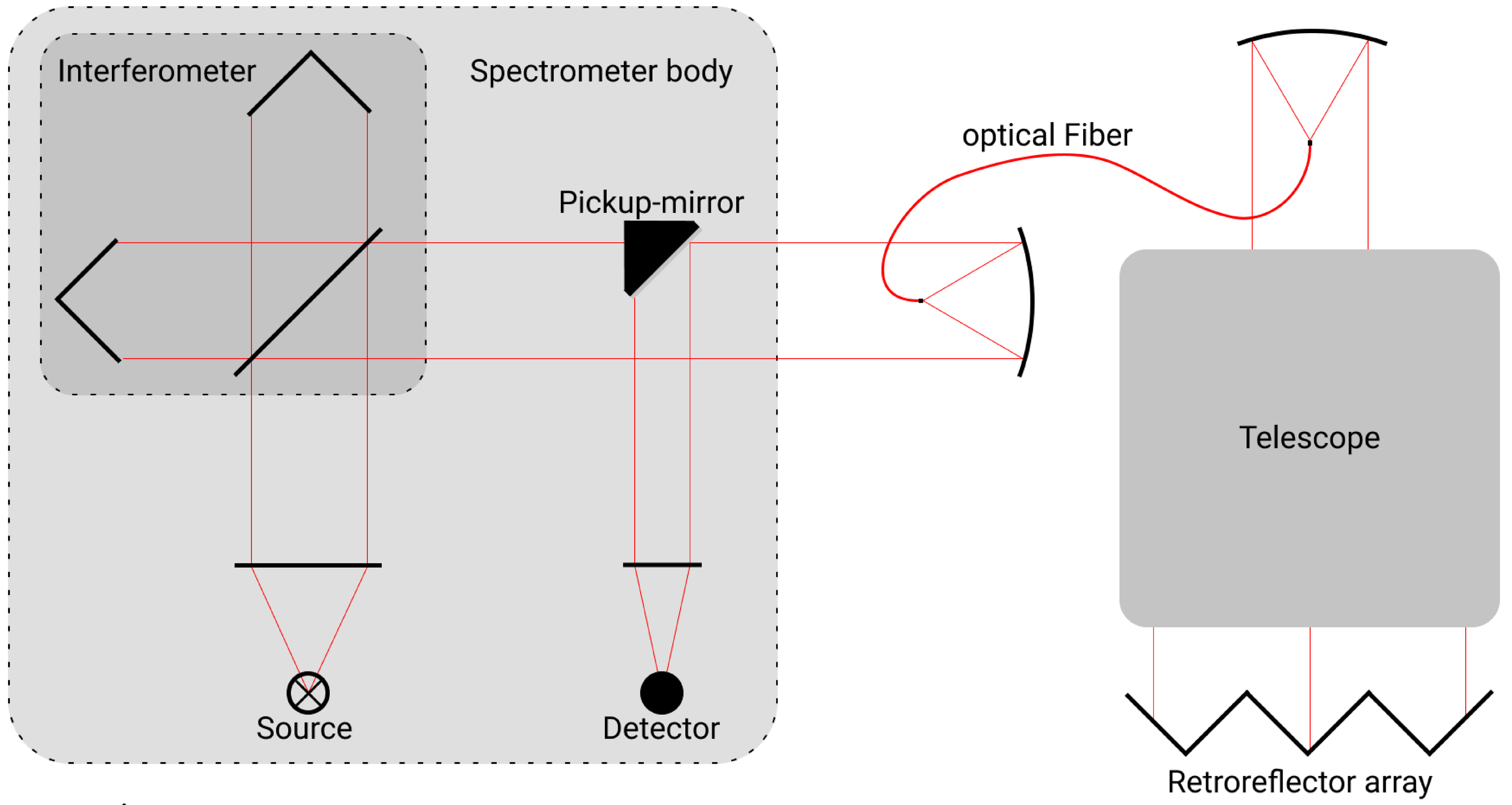


Measurement path:

- About 1.5 km long (one way).
- Located in the northern part of Heidelberg.
- Mostly over residential area and one major commuting artery.
- Light is sent from the Institute of Environmental Physics (IUP) where the instrument is located to a reflector array at the old Physics Institute (OPI).
- Was used before in a pilote study (Griffith 2018).

3 Optical Setup

- The core of the setup is a modified Bruker IFS 125HR.
- A common halogen lamp serves as the light source in this early iteration.
- After the light passed through the Interferometer of the Instrument, the modulated beam of light leaves the instrument.
- The connection to the telescope is done via an optical fiber to facilitate aiming the telescope at target sites.
- A Telescope sends the widened modulated beam towards an array of retro reflectors.
- The reflected light is received using the same telescope and via the fiber then transmitted back into the spectrometer
- A pick-up mirror that covers about half the beam area reflects some of the returning light on a detector
- A InGaAs diode serves as detector in this first iteration.



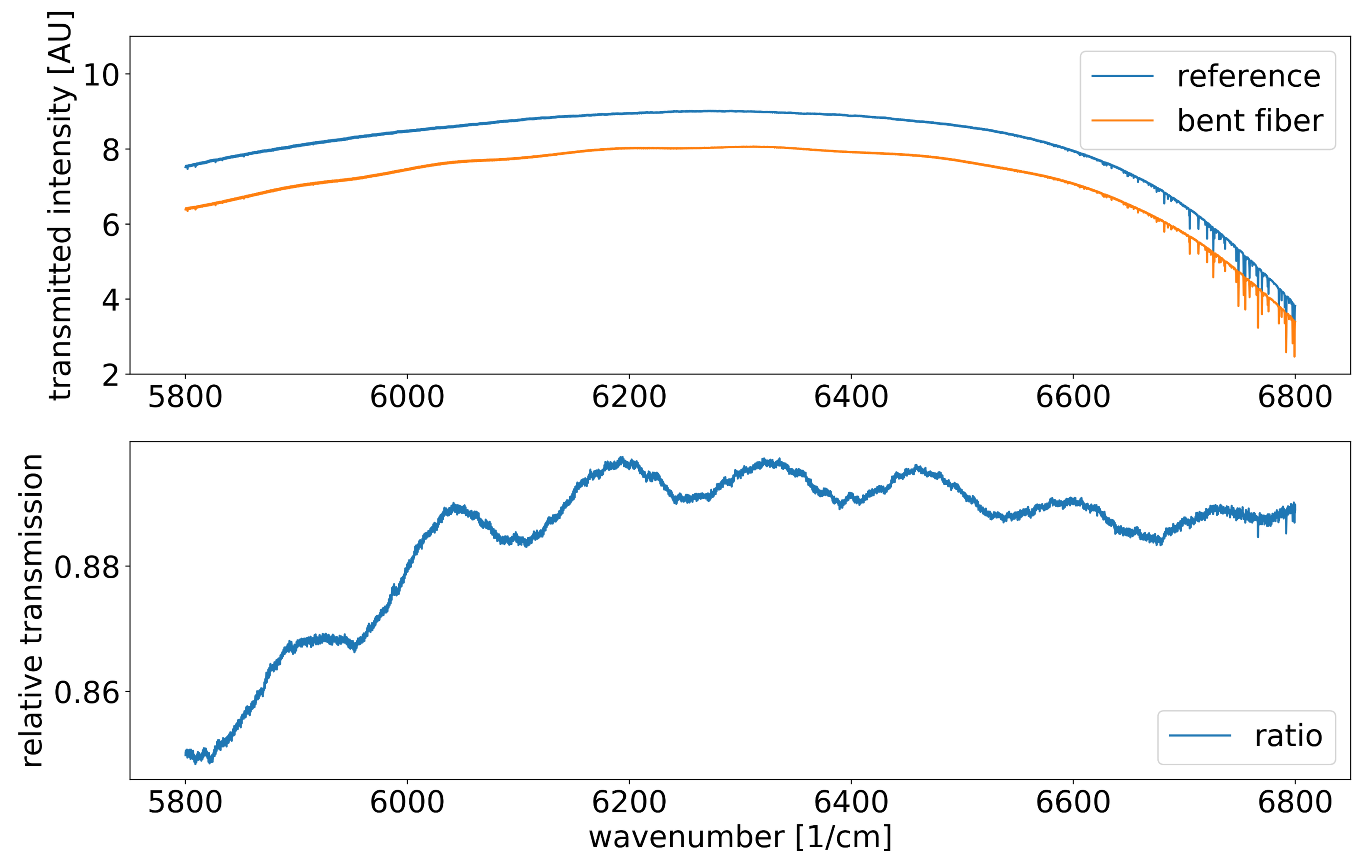
Remarks:

- Sending the modulated beam of light, i.e. having it pass the Interferometer before the absorption path greatly reduces the susceptibility of the setup to stray light. The stray light only increases the shot noise on the detector, but does not add any spectral information. This due to the frequency of the observed IR radiation (> 10^{13} Hz) being several orders of magnitude larger than the sampling frequency (10^4 Hz) and thus adding the same constant offset to any sampled point of the IFG.

- While similar single telescope open-path FTIR designs use a beam splitter to reflect a fraction of the returning light towards a detector, we use a pick-up mirror. This is only possible as a side effect of using an optical fiber in the transmission path: The fiber mixes all modes of one incident angle. The returning collimated beam is thus always rotationally symmetric with respect to the optical axis.

4 The fibers influence on the IFG

There are glass optical fibers that do not show any narrow optical features in the IR frequency range of interest. But still moving, and with that bending, the fiber might result in varied transmission through the fiber. To analyze this, we ran several tests without the telescope and a static fiber, bent at varying strengths. Applying a lot of force on the fiber resulted in the following:



- Bending the fiber results in a general drop of the transmission, as expected
- An etalon like structure appears with a width in the range of 100 cm^{-1}, which corresponds to a Fabry-Pérot-Resonator of $nL \approx 50$ µm.
- This does not impose any problems, since these effects only really occur at unreasonable levels of stress on the fiber and are slowly varying compared to molecular absorption features.

5 Outlook

- Completing the telescope setup and measuring first open-path spectra within the next weeks.
- Retrieving first column averaged concentrations of CO_2 and CH_4 within the next few months
- Using the first results to increase the SNR by appropriate measures, like enhancing the coupling to the fiber, switching out the light source, increasing the area of the reflector array and applying filters to reduce shot-noise on the detector.

References

Griffith, 2018: Long open-path measurements of greenhouse gases in air using near-infrared Fourier transform spectroscopy, Atmos. Meas. Tech., 11, 1549–1563, https://doi.org/10.5194/amt-11-1549-2018