1. PHD PROJECT DESCRIPTION (4000 characters max., including the aims and work plan)

Project title: Direct frequency comb spectroscopy in 6-9 µm spectral range

1.1. **Project goals**

The aim of the project is to perform precise and accurate measurements of N_2O and NO_2 spectral line positions in the 6-9 µm wavelength range with a direct frequency comb spectrometer. A sub-goal of the project is to establish detection limits for both species.

1.2. **Outline**

Direct frequency comb spectroscopy [1] enables fast, broadband, accurate and sensitive spectroscopic measurements. The instrumental-line-shape-free method allows achieving comb-resolved resolution with the well-established Fourier-transform spectroscopy technique [2]. While originally developed in the visible and in the near-infrared region, these techniques can be transferred to the mid-infrared region. The mid-infrared region (>3 µm) is of great interest for molecular physics, chemistry and applications of molecular spectroscopy, because it contains the frequencies of many fundamental vibrational modes. The 6-9 µm region in particular includes the fundamental modes of N_2O, NO_2 molecules, and the C=C stretch, which are particularly important in climate science, pollution science, plasma diagnostics and breath analysis. Performing detection of these species by probing the fundamental transitions has a potential to significantly reduce the detection limits. Low detection limits are crucial in monitoring of greenhouse gases [3] and in breath analysis [4], whereas broad spectral coverage is important in chemical kinetics studies. For fundamental studies into molecular structure, the high frequency precision and accuracy of our frequency comb source will enable state-of-the-art determination of the measured line positions and accurate values of molecular constants.

1.3. **Work plan**

As a first step the PhD candidate will characterize the stability of the mid-IR frequency comb source [5], including: the stability of the spectral envelope, intensity and optical frequency. If required, the PhD candidate will develop an active stabilization scheme for any of these properties. Next, the candidate will build a Fourier-transform spectrometer and verify its proper operation. Subsequently, the PhD candidate will perform absorption measurements of transitions in ν_3 band (asymmetric stretch) of NO_2 and ν_1 band (symmetric stretch) of N_2O, and analyze the data to retrieve the line positions from measured spectra. The PhD candidate will be required to develop the necessary technical and problem-solving skills required to complete these tasks with guidance from the supervisor.

1.4. **Literature**

[1] N. Picqué, T. W. Hänsch, Nature Photonics, 13(3), 146–157 (2019).

[2] P. Masłowski, et al. Physical Review A, 93(2), 021802 (2016).

[3] C. Zellweger, et al., Atmospheric Measurement Techniques, 12(11), 5863–5878 (2019).

[4] K. Isensee, et al., The Analyst, 143(24), 5888–5911 (2018).

[5] J. Sotor, et al., Optics Express, 26(9), 11756–11763 (2018).

1.5. **Required initial knowledge and skills of the PhD candidate**

- Experience in building optical and optoelectronic systems
- Experience in LabView programming and Matlab or Python programming
- English language knowledge at the level enabling reading/writing scientific articles

1.6. **Expected development of the PhD candidate's knowledge and skills**

The candidate will learn the skills necessary to complete the project including: characterization and stabilization of laser frequency comb sources; building and performing measurements with Michelson interferometer using the instrumental-line-shape-free method; analyzing broadband, high-precision spectra to retrieve physical parameters of the sample with well-established uncertainties.