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

Project title: Accurate laser spectroscopy of simple diatomic molecules

1.1. Project goals

- Development of a cavity-enhanced spectrometer
- Application of the spectrometer to accurate measurements of rovibrational spectra of simple molecules
- Theoretical calculations of simple molecule properties that are important for these measurements

1.2. Outline

The measurements of the rovibrational spectra of simple molecules is of great importance for studying molecular physics, testing the quantum theory (including the QED corrections), and for applications in other fields that build their approaches upon molecular physics methodology and results (for instance for remote studies of Earth's and other planets' atmospheres). The two main properties at which molecular spectroscopy is focused are line position and intensity. Accurate measurements of these two quantities can be confronted with their ab initio counterparts to validate the theory [1,2]. Furthermore, accurate line-shape measurements provide also collisional line-shape parameters that encode information about collisional process, hence these experiments give also an insight into the physics of collisions at molecular scale [3].

Within this PhD project proposal, the student will focus on developing the cavity-enhanced spectrometer with the frequency axis linked to the primary frequency standard. The very accurate spectroscopic data will be retrieved using ultra-sensitive cavity-enhanced techniques such as cavity ring-down spectroscopy (CRDS) [4] or novel cavity mode-dispersion spectroscopy (CMDS) [5]. The PhD student will also carry out the measurements. The experiments will focus on simple diatomic molecular species that are of great interest from the perspective of fundamental physics such as molecular hydrogen (different isotopologues) and carbon monoxide. Besides the experimental work, the PhD student will undertake theoretical calculations of the properties of the simple molecules that are important for these measurements, such as monomer properties or collisional effects [6]. The student will be also involved in the line-shape analysis of measured molecular spectra using various models including e.g. the speed dependence of collisional width and shift and Dicke narrowing [7].

1.3. Work plan

- Development of cavity-enhanced laser spectrometer
- Spectra measurements
- Theoretical calculations

1.4. Literature

[1] M. Zaborowski et al., Opt. Lett. **45**, 1603 (2020).
[2] K. Bielska et al., Phys. Rev. Lett. **129**, 043002 (2022).
[3] S. Wójtewicz et al., Phys. Rev. A. **101**, 052504 (2020).
[4] A. O'Keefe, D. A. G. Deacon, Rev. Sci. Instrum. **59**, 2544 (1988).
[5] A. Cygan et al., Opt. Express **23**, 14472 (2015).
[6] K. Stankiewicz et al., J. Quant. Spectrosc. Radiat. Transfer **254**, 107194 (2020).
[7] H. Tran et al., J. Quant. Spectrosc. Radiat. Transfer **129**, 199 (2013).

1.5. Required initial knowledge and skills of the PhD candidate

Skills and experience in experimental physics. Skills and experience in electronics, control systems and data collecting systems. Experience in signal processing and data analysis. Experience in programing microcontrollers and DSP/FPGA. Experience in numerical and computational methods (including software such as Mathematic or Matlab). Teamwork ability. Good command of English language. The candidate has to be a PhD student during the entire scholarship period.

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

Knowledge, skills and experience in molecular and optical physics, laser and cryogenic technologies, and in molecular spectra analysis.