

Rydberg excitation efficiency in nitric oxide using a three photon excitation scheme for a trace gas sensor

Fabian Munkes,¹ Alexander Trachtmann,¹ Patrick Kaspar,¹ Yannick Schellander,² Florian Anschütz,¹ Ettore Eder,¹ Lars Baumgärtner,³ Philipp Hengel,³ Jens Anders,³ Norbert Fruehauf,² Robert Löw,¹ Tilman Pfau,¹ and Harald Kübler¹

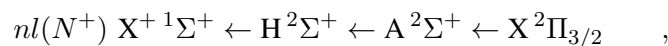
¹ 5th Institute of Physics, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

² Institute for Large Area Microelectronics, University of Stuttgart, Allmandring 3b, 70569 Stuttgart, Germany

³ Institute of Smart Sensors, University of Stuttgart, Pfaffenwaldring 47, 70569 Stuttgart, Germany

At the beginning of the 1990s it was known, that nitric oxide (NO) plays an important role as a signaling molecule in the mammalian system, and a change of its concentration in the exhaled breath may indicate certain diseases [1, 2]. We showed in a proof-of-concept experiment the operation of a NO trace-gas sensor at ambient pressure [3] at a concentration of 10 ppb. At this point we are optimizing the efficiency and sensitivity of our experimental setup. We already resolved the hyperfine structure of the ground state transition $A^2\Sigma^+ \leftarrow X^2\Pi_{3/2}$ [4].

Our detection principle is based on the electronic amplification of a current generated by free charges resulting from collisions of NO molecules in a Rydberg state with background particles. For the excitation we use continuous-wave (cw) laser systems for the transitions



which are at about 226 nm, 540 nm and 835 nm, respectively.

We report on the collisional shift and line broadening of Rydberg states in nitric oxide (NO) with increasing density of a background gas at room temperature [5]. As a background gas we either use NO itself or nitrogen (N₂) and identify pressures for an optimal operation of our sensor.

We also show Stark shift measurements to investigate optimized electric fields for our NO detection.

References

- [1] The Nobel Foundation. The nobel prize in physiology or medicine, 1998.
- [2] ATS/ERS recommendations for standardized procedures for the online and offline measurement of exhaled lower respiratory nitric oxide and nasal nitric oxide, 2005. *Am. Respir. Crit. Care Med.*, 171(8):912–930, 4 2005.
- [3] J. Schmidt, M. Fiedler, R. Albrecht, D. Djekic, P. Schalberger, H. Baur, R. Löw, N. Fruehauf, T. Pfau, J. Anders, E. R. Grant, and H. Kübler. Proof of concept for an optogalvanic gas sensor for NO based on rydberg excitations. *J. Appl. Lett.*, 113(1), jul 2018.
- [4] P. Kaspar, F. Munkes, P. Neufeld, L. Ebel, Y. Schellander, R. Löw, T. Pfau, and H. Kübler. Doppler-free high-resolution continuous-wave optical UV spectroscopy on the $A^2\Sigma^+ \leftarrow X^2\Pi_{3/2}$ transition in nitric oxide. *Phys. Rev. A*, 106:062816, Dec 2022.
- [5] Fabian Munkes, Alexander Trachtmann, Patrick Kaspar, Florian Anschütz, Philipp Hengel, Yannick Schellander, Patrick Schalberger, Norbert Fruehauf, Jens Anders, Robert Löw, Tilman Pfau, and Harald Kübler. Collisional shift and broadening of rydberg states in nitric oxide at room temperature. *Phys. Rev. A*, 109:032809, Mar 2024.