Broadband Mid-infrared Spectroscopy Based on Supercontinuum Sources: Towards Real-Life Applications

A. Khodabakhsh, K. E. Jahromi, M. Nematollahi, R. Krebbers, F. J. M. Harren, and S. M. Cristescu

Life Science and Trace Detection Lab, Department of Analytical Chemistry, Institute for Molecules and Materials, Radboud University, 6525 AJ Nijmegen, the Netherlands

Trace gas detection has numerous applications in many scientific and industrial fields such as environmental monitoring, medicine, combustion analysis, and process/quality control. Among different trace gas detection methods, broadband absorption spectroscopy is one of the key techniques which can provide selective, sensitive and multispecies gas detection using a single system. Particularly, broadband spectroscopy in the mid-infrared wavelength range (2-20 μm) is quite interesting, since most of the molecules have their distinct and strongest absorption features in this "fingerprint" region. Recent developments in mid-infrared supercontinuum (SC) sources have demonstrated enhanced spectral coverage, lower relative intensity noise and higher output powers [1, 2]. These novel sources can be used in absorption spectroscopy in combination with broadband detection techniques, providing multispecies detection. Furthermore, high spatial coherency of the SC beam enables the possibility of using multipass cells to increase the light-matter interaction length (for a very broad spectral bandwidth) and achieve high detection sensitivities [3]. We are currently involved in two different projects on broadband spectroscopy using mid-infrared SC sources for different applications. The first project is Ultra-broadband Infrared Gas Sensor for Pollution Detection (TRIAGE, EU Horizon 2020 Industrial Leadership Programme) in which we develop a smart, compact and cost-effective air quality sampling sensor network for the hyperspectral detection of all relevant atmospheric pollution gases [4]. In the TRIAGE project, the emphasis is on the better performance of the sensor on resolution, selectivity, and sensitivity as well as cloud-based deep-learning algorithms which will enable automated short-term alerts and long-term trend analysis for different applications. The second project is Maximizing Freshness and Minimizing Losses of Agriculture Products Through Automated Atmosphere Management in Storage Facilities (MAX-FRESH, EU Horizon 2020 Fast Track to Innovation Programme) which aims to minimize the waste in the stored fresh fruit and vegetables by developing an automated multispecies trace gas sensor allowing the detection of seven volatile gases that indicate ripening, fermentation, damage or rotting of the produce [5]. In the MAX-FRESH project, the key feature is the cost-effectiveness and simplicity of the overall system. Therefore, the detection system is based on a simple but effective scanning-grating spectrometer utilizing a single point detector [6]. We will cover the most recent developments and results of these two projects in our presentation.

[1] C. R. Petersen, U. Møller, I. Kubat, B. Zhou, S. Dupont, J. Ramsay, T. Benson, S. Sujecki, N. Abdel-Moneim, Z. Tang, D. Furniss, A. Seddon, and O. Bang, *Nat. Photonics* **8**(11), 830–834 (2014).
[2] I. Kubat, C. R. Petersen, U. V. Møller, A. Seddon, T. Benson, L. Brilland, D. Méchin, P. M. Moselund, and Ole Bang, *Opt. Express* **22**, 3959-3967 (2014).
[3] M. A. Abbas, K. E. Jahromi, M. Nematollahi, R. Krebbers, N. Liu, G. Woyessa, O. Bang, L. Huot, F. J. M. Harren, and A. Khodabakhsh, *Opt. Express* **29**, 22315-22330 (2021).
[4] https://triage-project.info/
[5] https://cordis.europa.eu/project/id/958840
[6] K. E. Jahromi, Q. Pan, A. Khodabakhsh, C. Sikkens, P. Assman, S. M. Cristescu, P. M. Moselund, M. Janssens, B. E. Verlinden, F. J. M. Harren, *Sensors* **19**, 2334 (2019).