International Traveling Summer School on Terahertz Sciences and Technology (ITSS-TSaT) 2024

Student challenge project

Title: Integrated Photonic Terahertz Breath Analyzers
Supervisor: Shihab Al-Daffaie

General description

Spectroscopic methods for detecting and identifying gases have shown promise because of their inherent non-invasive nature, relative simplicity, and high selectivity. The vast majority of work in this area has relied on "fingerprint" absorption in the mid-infrared ($\lambda \approx 2$–20 μm), where molecular vibrations often provide a unique signature. Both incoherent sources (e.g. Fourier transform infrared, FTIR) [1] and laser-based coherent sources [2] have been commonly used. This has demonstrated the sensitive detection of many gases, including greenhouse gases such as carbon dioxide, carbon dioxide and methane, other chemicals such as hydrochloric acid and HF, and common exhaust pollutants such as sulfur dioxide and nitrous oxide and many other gases as shown in Figure 1[3]. Despite these promising results, significant challenges remain, particularly in expanding the range of spectroscopically detectable gases. In contrast to gas sensors in the mid-infrared range, the use of far infrared or terahertz radiation for sensor purposes is still in its infancy. In this frequency range from $\lambda \approx 3$ mm to 50 μm (corresponding to frequencies between 0.1 and 6 THz), many polar molecules show unique spectral signatures arising from transitions between spin quantum levels.

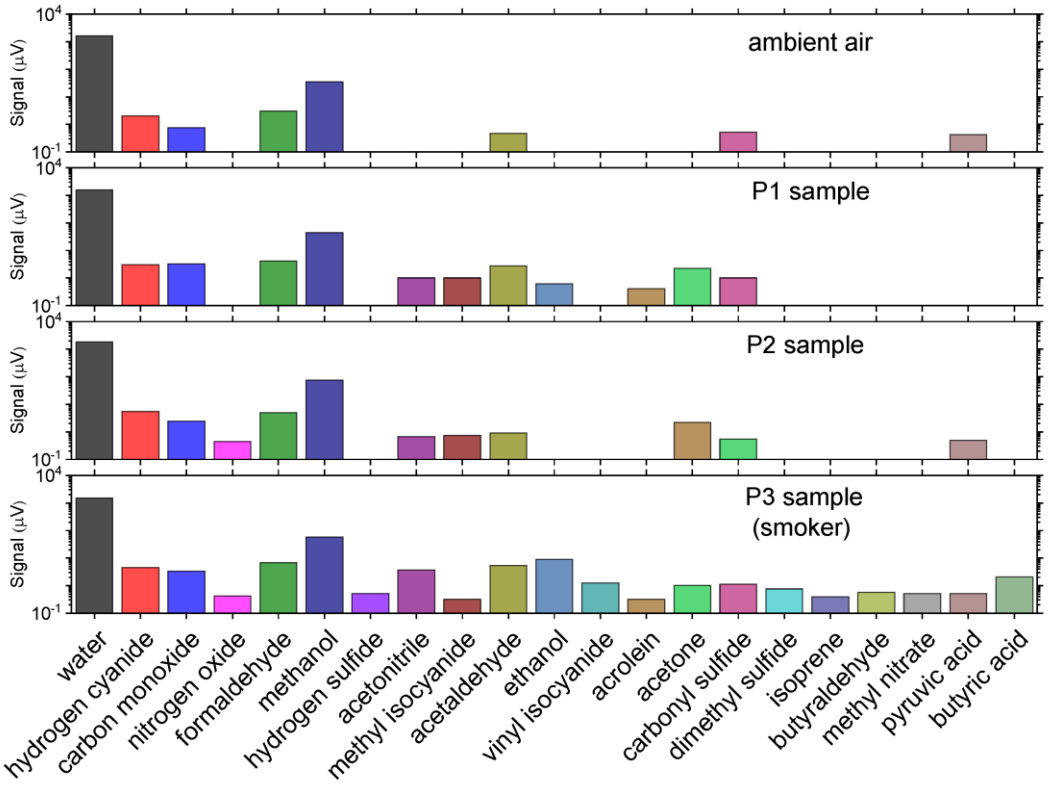

Figure 1: Gases detected in exhaled Human Breath

Students task description

Task 1: Explore the most used (existing) methods/technologies of gas sensing.

Task 2: What is the state of the art in gas spectroscopy?

Task 3: Is THz gas sensing better than others? Why? and which gases do you need for breath analysis?

Task 4: Which requirement/specification you will need to integrate a THz breath analyser system in an airplane for example?

References:

[1] O'Neill, J. A., Passow, M. L., & Cotler, T. J. (1994). Infrared absorption spectroscopy for monitoring condensible gases in chemical vapor deposition applications. Journal of Vacuum Science & Technology A: Vacuum, Surfaces, and Films, 12(3), 839-845.

[2] Petrov, K. P., Waltman, S., Simon, U., Curl, R. F., Tittel, F. K., Dlugokencky, E. J., & Hollberg, L. (1995). Detection of methane in air using diode-laser pumped difference-frequency generation near 3.2 μm. Applied Physics B, 61(6), 553-558.

[3] Rothbart, N.; Holz, O.; Koczulla, R.; Schmalz, K.; Hübers, He. Analysis of Human Breath by Millimeter-Wave/Terahertz Spectroscopy. Sensors 2019, 19, 2719

[4] Chen, J., Nitta, K., Zhao, X., Mizuno, T., Minamikawa, T., Hindle, F., ... & Yasui, T. (2020). Adaptive-sampling near-Doppler-limited terahertz dual-comb spectroscopy with a free-running single-cavity fiber laser. Advanced Photonics, 2(3), 036004.

[5] D'Arco, A., Rocco, D., Magboo, F. P., Moffa, C., Della Ventura, G., Marcelli, A., ... & Petrarca, M. (2022). Terahertz continuous wave spectroscopy: a portable advanced method for atmospheric gas sensing. Optics Express, 30(11), 19005-19016.