

# Compact Ion Mobility Spectrometer with Two Parallel Drift Tubes for Simultaneous Detection of Positive and Negative Ions

*Tim Ostermeier<sup>1</sup>, Timo Jähner<sup>1</sup>, Alexander Nitschke<sup>1</sup>, Moritz Hitzemann<sup>1</sup>, Stefan Zimmermann<sup>1</sup>*

<sup>1</sup>Leibniz University Hannover, Appelstr. 9a, 30167 Hannover, Germany  
 ostermeier@geml.uni-hannover.de, +49 511 762 4222

## Abstract

Rapid and reliable on-site detection of hazardous substances requires analytical instruments that combine high sensitivity, selectivity, and portability. In this work, a compact dual-polarity ion mobility spectrometer (IMS) is presented, allowing the simultaneous detection of positive and negative ions. The IMS is specifically designed with a focus on low weight, reduced power consumption, and compact size, making it suitable for mobile and drone-based applications. By integrating two parallel drift tubes and a single photon-based ionization source, the system shows efficient ion generation for both polarities. Experimental results demonstrate high resolving power and low limits of detection in the low parts per trillion range.

**Keywords:** ion mobility spectrometry, dual-polarity, parallel drift tubes, photon source

Many safety- and security-related applications require fast, sensitive, and compact measuring devices for on-site detection of hazardous substances. Furthermore, reliable detection of target substances in real environments requires appropriate selectivity. Here, ion mobility spectrometers (IMS) are well suited, as they reach detection limits in the low ppt<sub>v</sub> range (parts per trillion) in short measurement time of just one second, while reaching high separation power in relation to instrumental size. The fundamental principle of IMS is the separation of ions based on their specific ion mobility in a neutral gas under the influence of an electric field. If the sample volume is limited or the application requires immediate response, simultaneous detection of positive and negative ions would be beneficial to gather full analytical information of the sample from one single measurement. This can be achieved by using a dual-polarity IMS with two parallel drift tubes. For later use on a drone, the dual-polarity IMS presented here is designed low-weight, low-power and compact targeting < 1400 g, < 14 W and < 15 x 20 x 25 cm<sup>3</sup> with drift tubes made low-cost from standard printed circuit boards. Furthermore, the design requires just one

small high energy photon source efficiently generating positive and negative reactant and product ions to be injected in the two drift tubes.

The dual-polarity IMS reaches outstanding detection limits in the low-ppt<sub>v</sub> range for the compounds tested, such as acetylacetone in both polarities (AcACE(+): 19.35 ppt<sub>v</sub>, AcACE(-): 27.68 ppt<sub>v</sub>), sevoflurane in negative polarity (SEVO(-): 28.67 ppt<sub>v</sub>), and 2-hexanone in positive polarity (MBK(+): 118.39 ppt<sub>v</sub>), all within one second of signal averaging. In addition, the device provides outstanding resolving power of  $R_P = 80$ . Furthermore, the IMS design allows for easy coupling with gas chromatography to allow for analyzing more complex samples or detecting target compounds in more complex environments.

## Acknowledgment

Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) Project number 540972827.

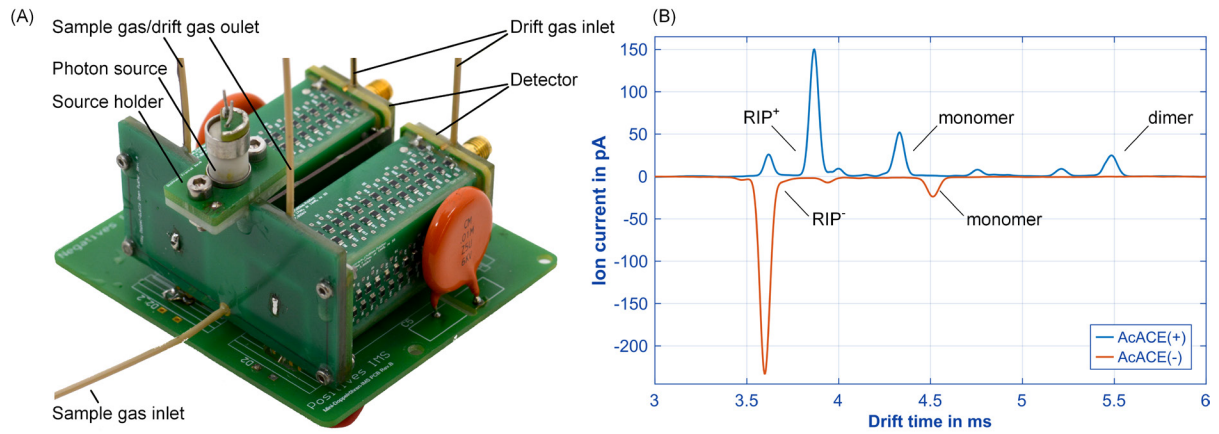


Figure 1: (A) Photo of the dual-polarity PCB-IMS with two drift tubes but just one single ionization source, here a small high energy photon source. (B) IMS spectra of acetylacetone in air in both polarities with the protonated monomer ( $K_0 = 1.81 \text{ cm}^2/(\text{Vs})$ ) and proton-bound dimer ( $K_0 = 1.43 \text{ cm}^2/(\text{Vs})$ ) peaks in positive polarity and the deprotonated monomer peak ( $K_0 = 1.74 \text{ cm}^2/(\text{Vs})$ ) in negative polarity at a concentration of 517 ppt<sub>v</sub>. The ion mobilities of the  $\text{RIP}^+$  and  $\text{RIP}^-$  are  $K_0 = 2.02 \text{ cm}^2/(\text{Vs})$  and  $K_0 = 2.18 \text{ cm}^2/(\text{Vs})$ .