Portable MALDI-TOF Mass Spectrometer for Bioaerosol Detection

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Rapid, real-time pathogen identification is required to protect humans from either natural or manmade aerosolized biological particles, including bacteria, viruses and toxins. In a biothreat detection system based on MALDI (matrix assisted laser desorption/ionization) mass spectrometry, developed at Zeteo, aerosol is deposited by virtual impact concentrator on a reusable metal disk. The disk is robotically transferred into the vacuum chamber and analyzed in a linear time-of-flight (TOF) mass spectrometer. Through subsequent maturation of the technology, and business evolution, the system, now known as BioTOF™, is being productized and manufactured by a spin off partner company from Zeteo known as BioFlyte, Inc. While the performance of the current BioTOF™ system has been outstanding, the detection capability has been focused on identification of single individual threat agents in a series of modestly cluttered backgrounds. For more complex concepts of operation, the mass spectral resolution must be increased to enable accurate deconvolution of the more complex spectra arising from mixtures of threat agents in highly cluttered environments.

The energy focusing and ion collection properties of ions created by the UV laser pulse were modeled using industry standard SIMION ion trajectory modeling software. The time between ion creation and striking the detector (the time-of-flight) was calculated and recorded. Modeling demonstrated that a small (about 0.5 m total length) TOF mass analyzer comprised of a two-stage acceleration ion source and a single-stage reflectron significantly improves mass resolving power compared to the BioTOF™ system, particularly with the addition of delayed extraction.

Based on simulation results, a TOF mass spectrometer was designed and built. The system can be operated in linear and reflectron modes. MagneTOFTM series ion detectors with increased robustness and extended dynamic range were used for ion detection. Vacuum was provided by a small turbomolecular pump backed by a diaphragm pump. Vacuum was typically about 4·10-7 Torr during experiments. High voltages were supplied by high stability, low noise HV power supplies from Spellman. A compact solid state laser provided a short UV pulse at 349 nm.

Testing of the system was performed using peptide and protein standards. The laser pulse energy was finely adjusted using a circular gradient neutral density filter. It was found that in static mode mass resolving power is extremely sensitive to pulse energy. Delayed extraction diminished this sensitivity and improved resolving power (up to 1400 in linear mode, in good agreement with modeling). In reflectron mode with delayed extraction, resolving power increased to ~3500, as predicted, for medium size peptides. Additionally, we compared performance with commercial systems: Microflex from Bruker and BioTOF™ using the same sample of Bacillus globigii (Bg) bacterial spores. It showed comparable performance to Microflex in terms of mass resolving power and signal to noise ratio and substantially improved performance compared to BioTOF™.