Structures for Lossless Ion Manipulation (SLIM)

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SUMMARY

Advances in medicine, clean energy, and environmental management are held back by the ability to quickly distinguish the presence, structure, and abundance of different molecules in a sample. Current ion separation and analysis technologies meant to tackle this problem can be large and cumbersome, involving slow, complex processes that lack the sensitivity and resolution to clearly distinguish among molecules with similar mass but different structures. Ions also tend to suffer loss during the separation process, preventing significant portions of the sample from reaching the analysis instrument—typically a mass spectrometer (MS)—and reducing sensitivity. For example, though protein biomarkers can help doctors predict, diagnose, and treat diseases, many such proteins are effectively invisible to current MS instruments because separation approaches with even current state-of-the-art instruments lack sufficient resolution or sensitivity, or both.

Structures for Lossless Ion Manipulations (SLIM), developed by researchers at Pacific Northwest National Laboratory, breaks through these analysis boundaries. At up to 1,000 times faster than current methods, the technology can help identify trace amounts of very similar molecules with slightly different structures in even complex samples containing many different compounds. And SLIM can help identify such differences in samples as small as a single cell.

SLIM can use a highly advanced form of ion mobility (IM) separations that allows complex mixtures of ions to be quickly separated for characterization and quantification in a way that is lossless, thus achieving extremely high sensitivity. Constructed from robust and inexpensive conventional printed circuit-board technology, SLIM uses arrays of mirror-image electrodes patterned on closely spaced surfaces. Applying electric potentials to the electrodes on the surfaces creates electric fields defining a path in the space between the surfaces where ions can be moved or trapped. SLIM uses moving electric fields (so-called traveling waves) to rapidly transport ions in a lossless fashion so that they can be separated. The ions never touch the surfaces, so none are lost, and enabling the use of much longer paths providing much better separations than previously feasible.

In traditional approaches, the longer the paths, the greater the resolution of the results. Instrument sizes are limited by the space in typical laboratories. The compact design of SLIM allows ions to move around corners, and follow serpentine paths, resulting in very long paths (for example, a pair of 30-cm x 30-cm SLIM boards creates a 13-m path) that provide very high resolution IM
separations. SLIM can also accumulate ions for ease of analysis and selectively switch them as a group to other locations, all without any losses.

The SLIM technology is designed to be very flexible and low cost to produce. Recent advances even resolve the problem of manipulating ions of the same or opposite polarities using adjacent radiofrequency electrodes that are out of phase by approximately 180 degrees. This alternating arrangement inhibits the ions from approaching the electrodes. The confinement can be provided over a range of pressures, from less than 0.1 torr to over 10 torr, and over a broad and adjustable mass-to-charge range for the ions.

SLIM allows the separated ions to be further reacted and their products to be separated again, providing an even greater ability to distinguish different compounds, even isotopic and isomeric differences. This development makes it practical for SLIM to be used as a standalone device, without the need for an MS, if the compounds it is analyzing are known in advance, such as a doctor searching for a particular molecule in a blood sample as a biomarker of a particular disease.

SLIM is the winner of the coveted R&D 100 Award for the top 100 technological advances for 2017.

**APPLICABILITY**

The combination of increased throughput, sensitivity, and resolution makes SLIM a disruptive technology that could completely change how samples are analyzed in any field that requires molecule separation and identification in a rapid, efficient, and precise manner. Applications include chemical process, quality assessment and assurance, and environmental monitoring, among others.

**ADVANTAGES**

- Provides high-resolution, lossless ion mobility separation
- Allows for flexible, low-cost manufacturing
- Enables new applications utilizing ion mobility and trapping that are not possible with current technology

**STATE OF DEVELOPMENT & AVAILABILITY**

- For information on the availability of SLIM for use in health and life sciences applications, contact MOBILion Systems (http://www.mobiliionsystems.com/)

[Link to detailed information](http://availabletechnologies.pnnl.gov/technology.asp?id=396)
RELATED LINKS

- "Characterization of Ion Dynamics in Structures for Lossless Ion Manipulations"
  Tolmachev, AV; Webb, IK; Ibrahim, YM; Garimella, S; Zheng, X; Anderson, GA; and Smith, RD. Accepted in Anal. Chem., 2014
  http://pubs.acs.org/doi/abs/10.1021/ac502054p

- "Experimental Evaluation and Optimization of Structures for Lossless Ion Manipulations for Ion Mobility Spectrometry with Time-of-Flight Mass Spectrometry"
  Webb, IK; Garimella, SBV; Tolmachev, AV; Chen, T-C; Zhang, X; Norheim, RV; Prost, SA; LaMarche, B; Anderson, GA; Ibrahim, YM; and Smith, RD. Accepted in Anal. Chem. 2014
  http://pubs.acs.org/doi/abs/10.1021/ac502055e

- "Design of a TW-SLIM Module for Dual Polarity Confinement, Transport, and Reactions."

PATENTS & INTELLECTUAL PROPERTY

- 10,224,194
- 8,835,839
- 8,901,490
- 8,907,273
- 9,704,701
- 9,812,311
- 9,966,244

TECHNOLOGY PORTFOLIO(S)

- Analytical Instrumentation

POTENTIAL INDUSTRY APPLICATION(S)

- Chemicals

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