EXCELLIMS

Innovation for Excellence in Detection Technology

MA3100: Enabling High Resolution Ion Mobility Capabilities on Thermo Scientific™ Linear Ion Trap and Orbitrap Mass Spectrometers

When coupled with mass spectrometry (MS), ion mobility spectrometry (IMS) adds tremendous value in the analysis of species that were either previously not resolved by MS or those that may lead to undesirable and highly complex spectra. As ion movement within a drift tube is governed by size/cross-sectional area, effective separation of molecules with slight structural differences such as conformers, isobars, and isomers can be achieved. In order to maximize the advantages of this orthogonal technology, we have developed an ambient pressure IMS device (Excellims MA3100) that readily integrates with the ion trap/orbitrap product lines of Thermo Scientific™ instrumentation (**Fig. 1**).

In recent years IMS-MS instruments have gained popularity in many institutions, with a growing number of publications reported in the literature. Typically these integrated systems are laboratory-built and can be quite customized, which unfortunately limits the widespread availability of such platforms. A few commercially produced IMS-MS instruments are now also available on the market, however they are rather cost prohibitive to many end users. The MA3100 is a modular high performance ion mobility spectrometer (HPIMS) that is designed to be readily interchangeable with the Thermo Scientific™ Ion Max and Ion Max-S atmospheric pressure ionization (API) sources, requiring no hardware modifications or break in vacuum. With the introduction of such a device, the difficultly in constructing a customized IMS-MS system or the expense of purchasing a commercial version are eliminated. At only a fraction of the cost for a commercially available IMS-MS unit, the MA3100 extends the utility of mass spectrometers to incorporate a preliminary stage of IMS separation and selection to gain insight into the behavior of gas-phase ions not possible from mass spectra alone. Available as a powerful add-on feature for existing and newly acquired customer MS instrumentation, the MA3100 is ready to enhance your application.

Fig. 1 MA3100 IMS analyzer and control electronics shown interfaced with a Q Exactive™ orbitrap MS. Ion mobility devices from Excellims are now available for a range of Thermo Scientific™ trap-based instruments.

Ions generated by either our Directspray™, Infusion electrospray ionization (ESI), or Thermal Desorber (Corona discharge or Ni63) sources are controllably introduced into the drift tube by a pulsed Bradbury-Nielsen (BN) entrance ion gate (**Fig. 2**). Acceleration due to the low electric field conditions is counteracted by collisions with the chosen buffer gas. As a result, ions move through the drift tube at a constant and

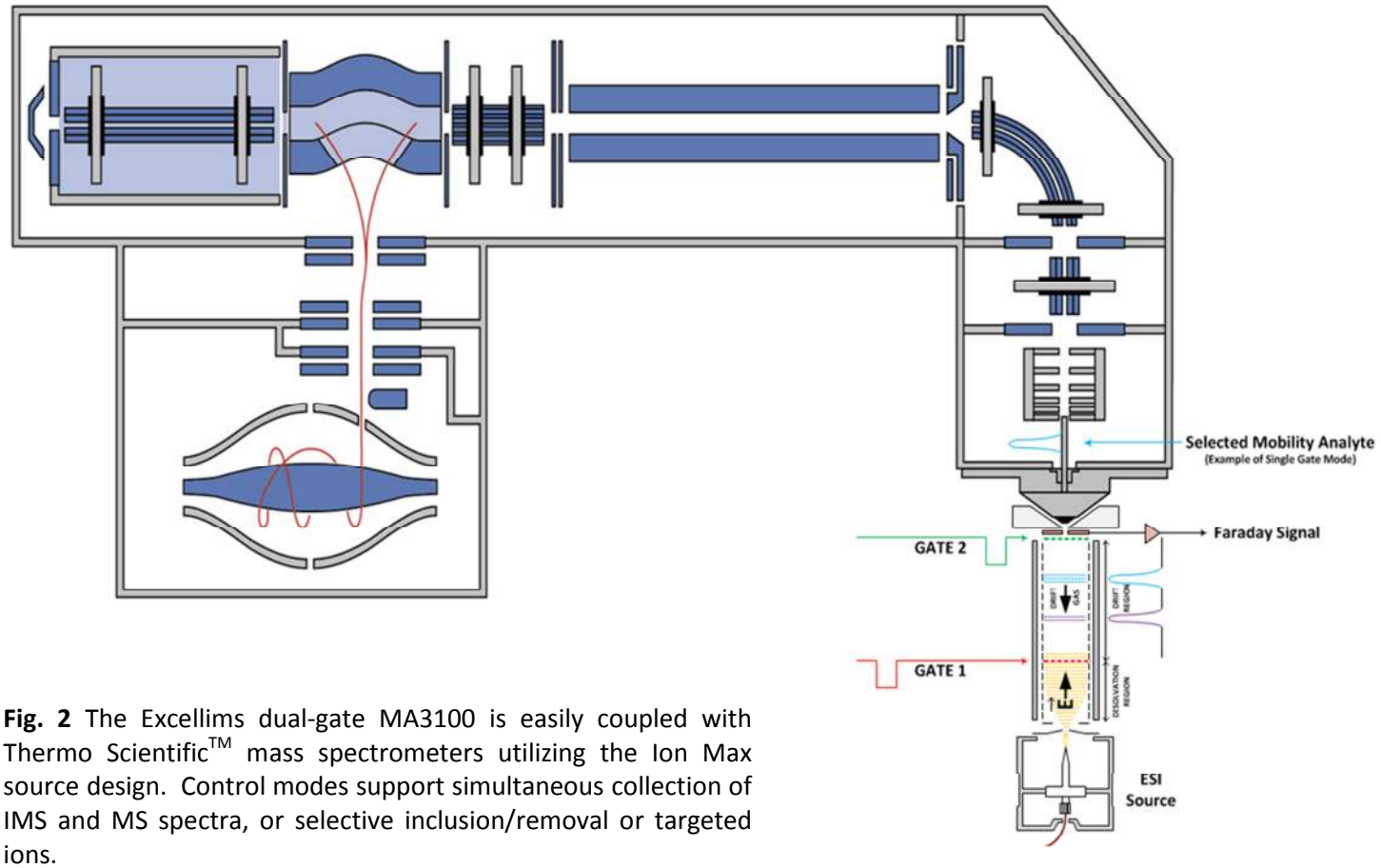


Fig. 2 The Excellims dual-gate MA3100 is easily coupled with Thermo Scientific™ mass spectrometers utilizing the Ion Max source design. Control modes support simultaneous collection of IMS and MS spectra, or selective inclusion/removal or targeted ions.

unique velocity. A second exit BN gate is located directly at the end of the 10.85 cm drift region, effectively allowing a user-defined portion of mobility separated ions to pass. Additionally, the incorporated Faraday plate detector facilitates concurrent mobility and mass spectra to be collected and even creates the flexibility for the MA3100 to function as an independent, stand-alone instrument when detached from the mass spectrometer. This feature greatly improves laboratory efficiency as initial IMS experiments can be performed without hindering another user full access to the mass spectrometer. The required electronics to operate and control our ionization sources, drift tube, ion gates, and Faraday detector are conveniently supplied in a supplemental control box.

Multiple Modes of Operation

The MA3100 proudly surpasses the features and performance of previous commercially available MS coupled mobility devices, and is *the current option* for Thermo Scientific™ MS instrumentation. A dynamic array of methodologies can be developed from our operating modes to best suite your analysis. For users of the Exactive™ series of orbitrap MS, control of the MA3100 is embedded within the latest releases of Tune (**Fig. 3**) with the appropriate license to access "leveraged mode". For non-Exactive™ users, visIon Trap is supplied directly through Excellims Corporation for complete control of the MA3100 and necessary communication with your mass spectrometer.

Working synergistically with Tune, additional advanced control options are made available through Excellims' visIon Trap software for Exactive™ series instruments. An overview of operating modes and associated features is as follows:

TUNING mode: The user has control over the opening/closing of each gate independently from one another. Although not of analytical value, this mode is important for the proper adjustment of gate parameters in order to effectively control ion transfer while minimizing ion loss.

OPEN mode: Ions flow continuously through both ion gates unrestricted into the mass spectrometer. Conventional mass spectral data can still be obtained without physical removal of the MA3100.

FARADAY mode: Parallel ion mobility and mass spectra are generated. Mobility information obtained from the Faraday plate detector can be used to rapidly direct gate settings to be adjusted for targeted IMS-MS analysis. Currently this mode is only supported by Excellims' visIon Trap software package.

SCAN mode: A selected window of variable drift width is sequentially stepped across the chosen drift time range. A mobility spectrum can be reconstructed from the MS total ion chromatogram (TIC), and used to generate a multidimensional IMS-MS plot.

GATED mode: Single or multiple mobility window(s) can be specified for targeted ion transmission or removal, adding an additional dimension of discernment during ion accumulation.

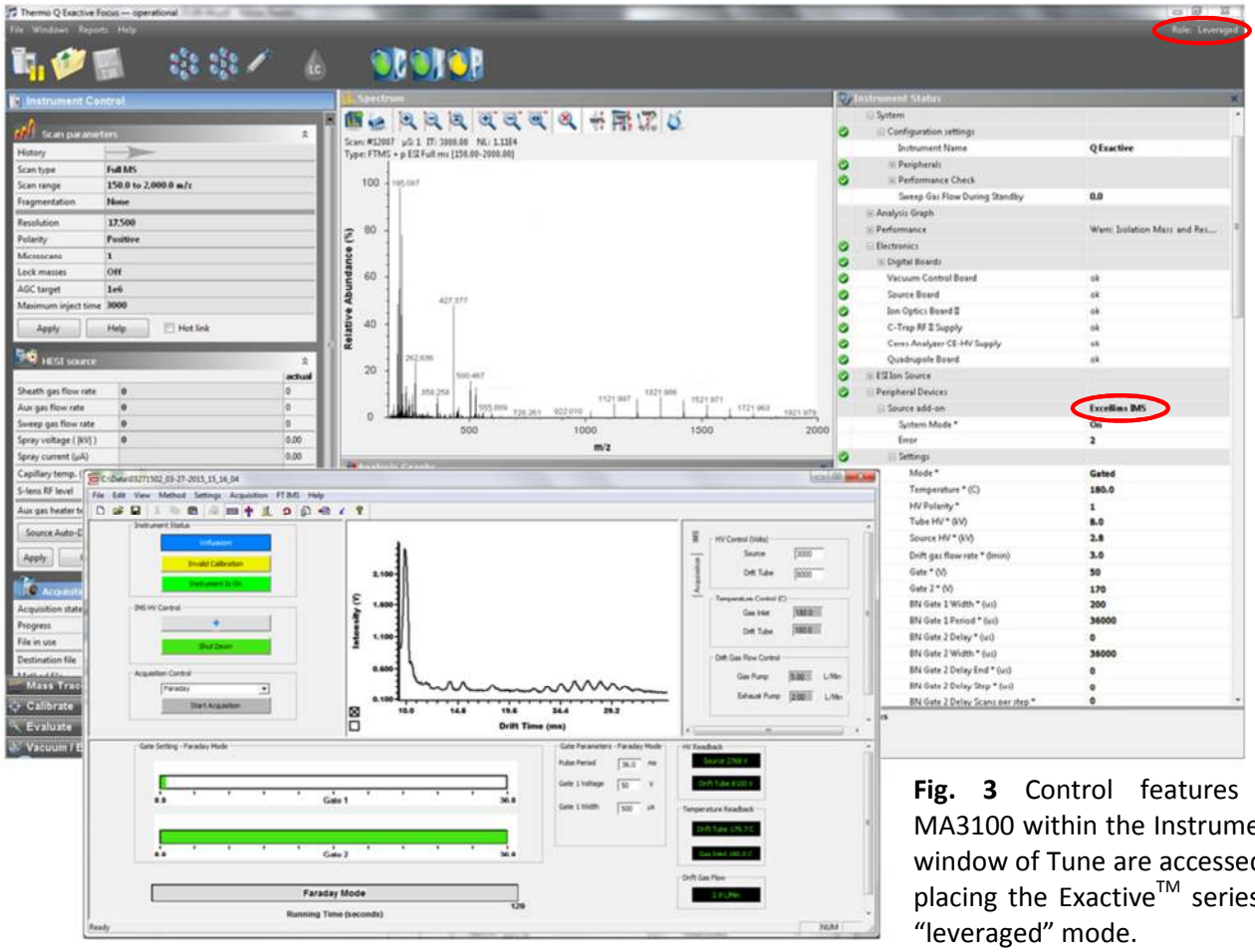
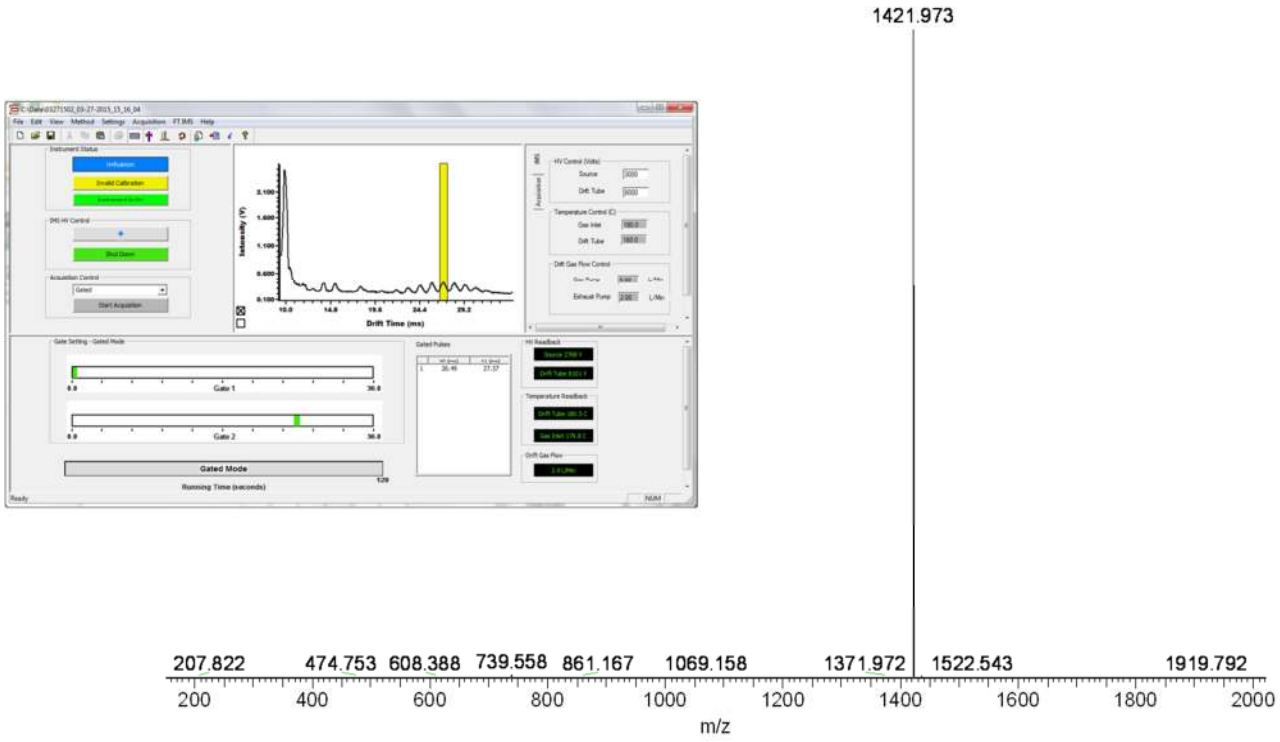


Fig. 3 Control features for the MA3100 within the Instrument Status window of Tune are accessed through placing the Exactive™ series MS into "leveraged" mode.



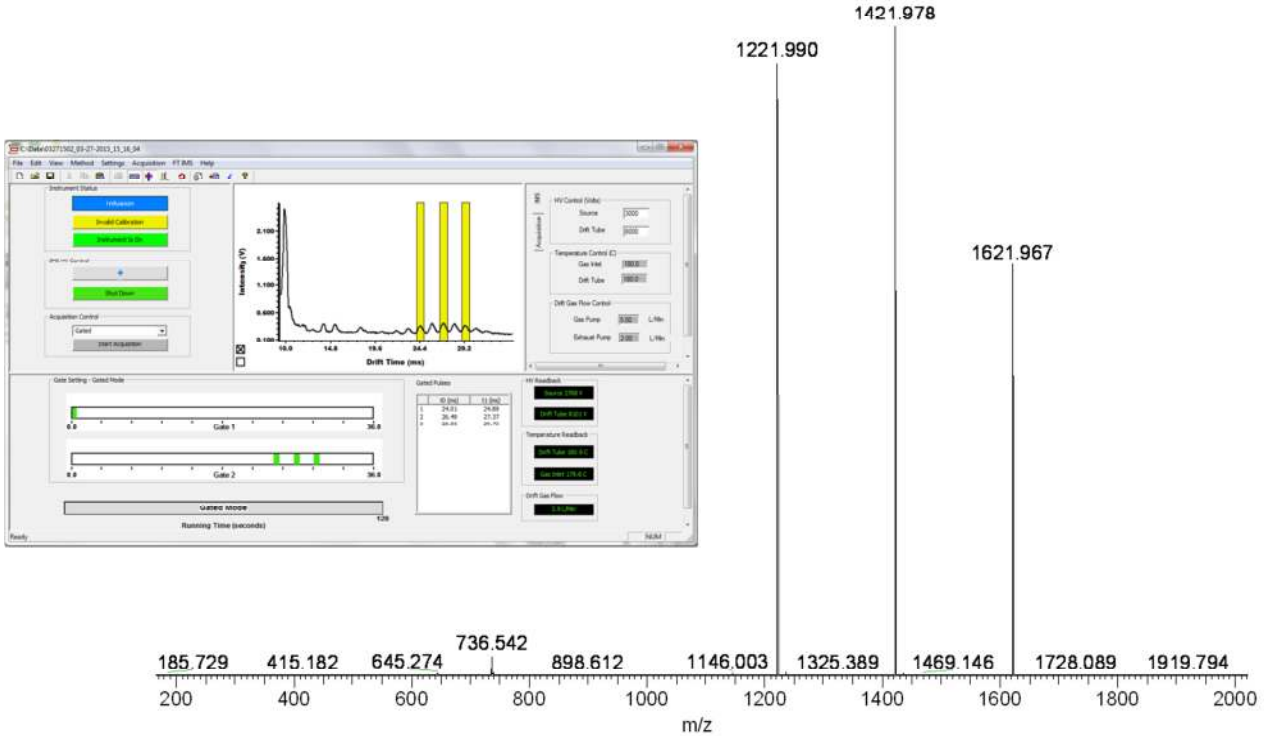


Fig. 4 (Above) GATED mode for selection of a single mobility window from 26.49 to 27.37 ms. (Below) GATED mode for selection of multiple mobility windows including 24.01 to 24.89 ms, 26.49 to 27.37 ms, and 28.85 to 29.73 ms.

Mobility Added Value

Mobility spectra obtained from the incorporated Faraday plate detector can be viewed together with the real-time MS data displayed when running your established MS method (**Fig 3**). In this way, succeeding experiments can be strategically designed based upon the gathered IMS information. Using Thermo Scientific Pierce™ Calibration Solution, selection of a single mobility peak (i.e. UltraMark 1621: $C_{28}H_{19}O_6N_3P_3F_{44}$ at *m/z* 1421.973) or multiple mobility peaks (i.e. UltraMark 1621: $C_{24}H_{19}O_6N_3P_3F_{36}$, $C_{28}H_{19}O_6N_3P_3F_{44}$, $C_{32}H_{19}O_6N_3P_3F_{52}$ at *m/z* 1221.990, 1421.973, and 1621.967) showcase the capability afforded by high resolution mobility separation prior to MS analysis (**Fig 4**). Effective removal of co-ionizing calibrant species result in highly specific trap accumulation events.

Unlike quadrupole mass filters (QMF) found on Q Exactive™ MS instruments which only traverse ions within a chosen *m/z* range, the MA3100 has the unique ability to dynamically remove ion(s) based upon mobility. This complimentary approach (**Fig 5**) is an answer to analysts seeking a technique that inhibit certain background/interference ions from dominating the mass spectrum or reducing useful storage capacity, while maintaining the injection of all other desired ions. With other trap-based instrumentation, single or multiple frequency resonance ejection methods have been shown to remove background interferences by applying a waveform containing the fundamental secular frequencies of motion for the ions to be excluded (trapping instabilities). Although these methods reduce the effects of interferences present, this approach is not found on commercial instruments.

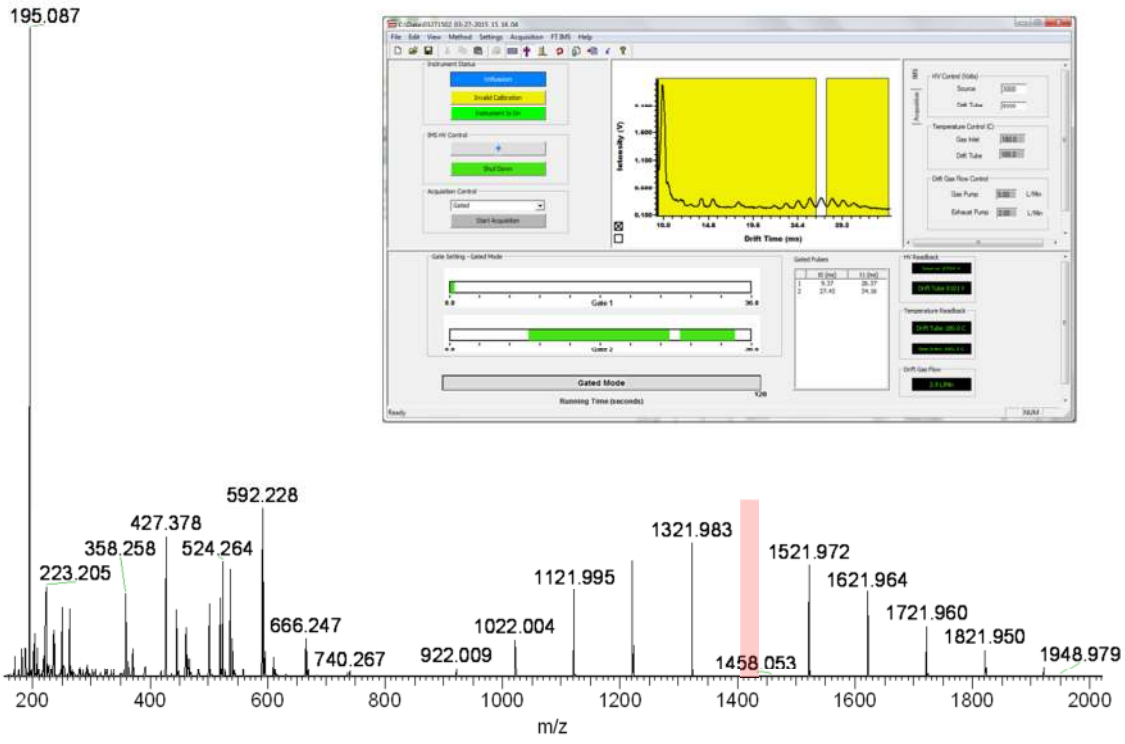


Fig. 5 GATED mode for targeted removal of ions within specified mobility range consisting of 26.37 to 27.43 ms.

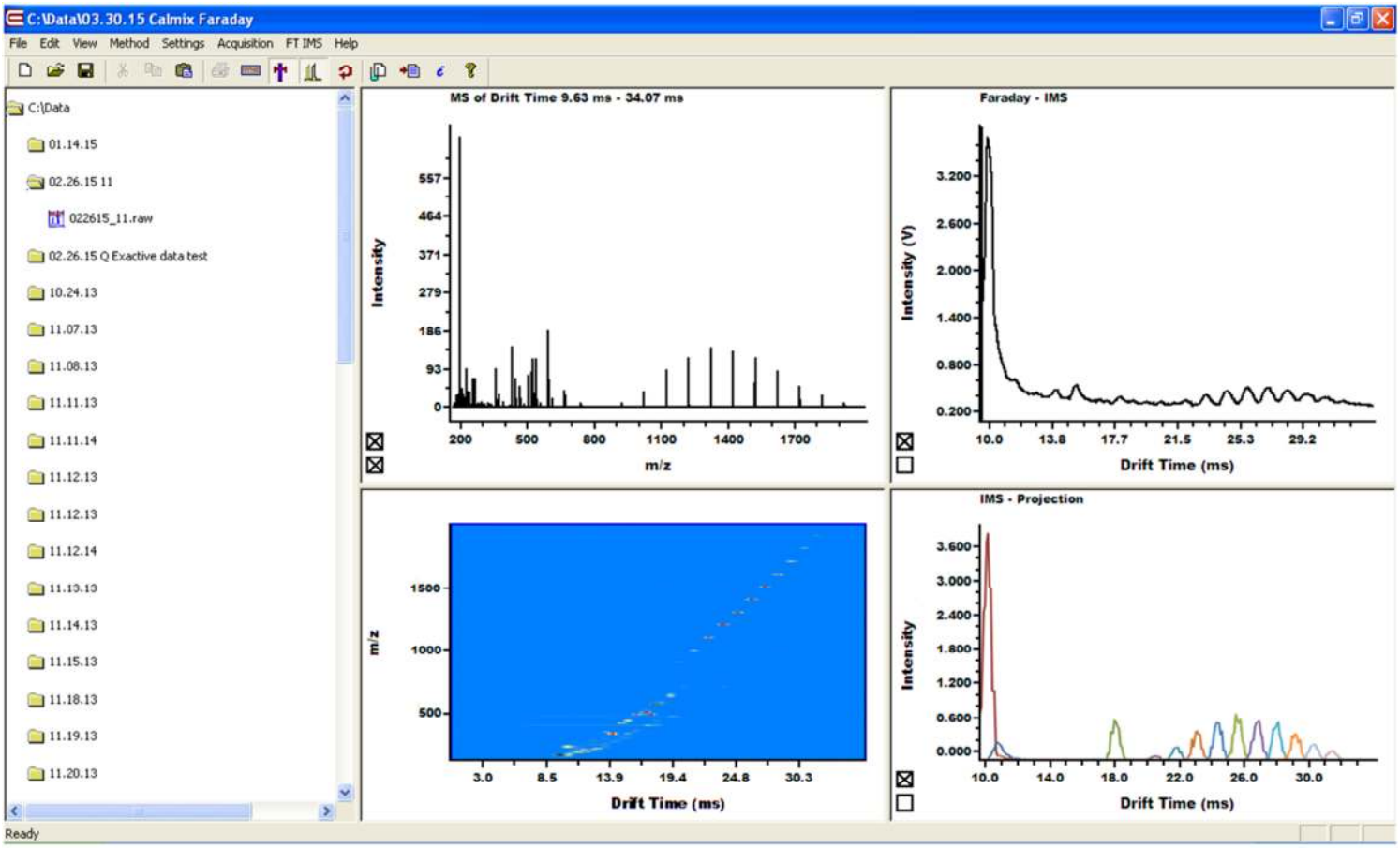


Fig. 6 Excellims visIon Trap Analysis package (top left): mass spectra viewing window, (top right): Faraday plate IMS data, (bottom left): multidimensional IMS-MS plot from SCAN mode, (bottom right): IMS spectrum from SCAN mode MS data.

Powerful Plotting Features

Post acquisition processing software through visIon Trap delivers a panel of comprehensive IMS-MS data viewing options at your fingertips. After defining the directory for your raw MS destination file, MS TIC data acquired by operating in SCAN mode is automatically retrieved, converted, and loaded within visIon Trap Analysis (**Fig 6**). This produces an IMS spectrum similar to the previously attained spectrum from the Faraday plate detector. The user has full control over plotting features, and as shown in the bottom right side of Figure 6, extracted ion chromatograms (EIC) for ions of interest (caffeine, MRFA, and UltraMark 1621) can be displayed.

Processing abilities found in Thermo Xcalibur Qual Browser are also incorporated within the visIon Trap Analysis package. Single, selected, or averaged mass spectra can be viewed as well as complete multidimensional plots. As complex sample sets can be summarized succinctly in our IMS-MS plots, the inherent advantage in increased separation peak capacity is clearly seen. With the MA3100 paired with our suite of data analysis tools, valuable structural information once hidden within mass spectra is readily made visible and available for users of Thermo Scientific™ linear ion trap and orbitrap mass spectrometers.