National Aeronautics and Space Administration

FY23 Strategic Initiatives Research and Technology Development (SRTD)

Quadrupole Ion Trap Mass Spectrometer (QITMS) for the Supercritical CO_2 and Subcritical H_2O Analysis instrument (SCHAN)

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Strategic Focus Area: In-Situ Extant Life Detection Technology **| Strategic Initiative Leader:** Victor Abrahamsson

Objectives: The three-year objective is to develop an interface between the Quadrupole Ion Trap Mass Spectrometer (QITMS) and the Supercritical CO2 and Subcritical H2O Analysis (SCHAN) instrument. The FY23 objectives were to demonstrate ion transport of externally generated ions into the QITMS operated at vacuum using a breadboard setup and design a compact brassboard instrument based on the lessons learned from the breadboard unit.

Background: The QITMS is a compact and sensitive mass spectrometer for analyzing gases and volatile analytes, which are ionized inside of the ion trap at high vacuum. Non-volatile organics (e.g., amino acids or fatty acids) virtually always require ionization close to ambient pressure (~760 Torr) prior to mass spectrometry analysis. Hence, an interface consisting of ion optics and a gradually increasing vacuum is required to enable organic biosignature detection. This technology has not yet been adapted or matured for spaceflight applications.

Approach and Results: Iterative experimental optimization provided insights into the importance of alignment of ion optic components and flaws in the initial breadboard setup were identified. Optical techniques were developed to achieve a clear line of sight between the inlet and the QITMS (Fig. 1). Ultimately, up to 150 000 ions/s of externally generated ions were detected by a channel electron multiplier (Channeltron) located at the end of the ion transport assembly (Fig. 2). The results demonstrated that the ion transport assembly works as anticipated, however, a new chamber design that allowed for easy and reproducible alignment was required. Consequently, a new brassboard instrument was designed, which also houses the QITMS (Fig. 3).

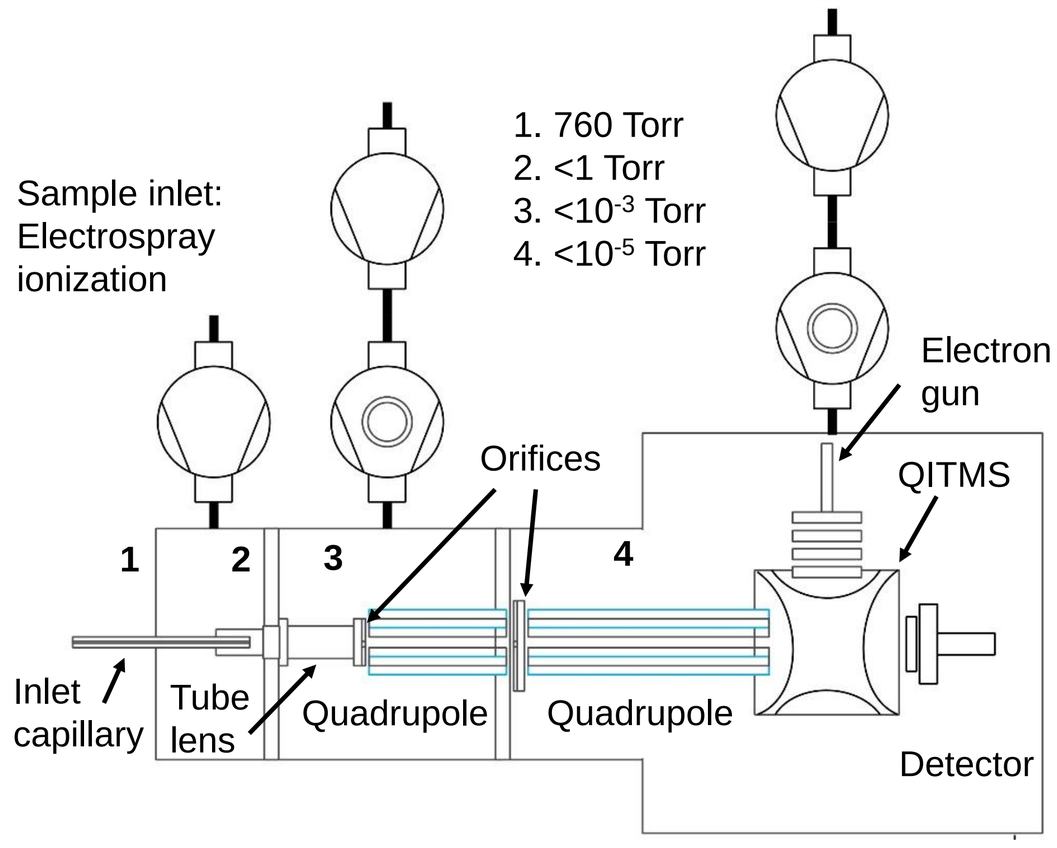

Figure 1. Overview of the experimental setup. Ions are generated by ESI and are pneumatically pulled into the ion transport assembly through the inlet capillary. The ions are guided through the multiple vacuum chambers and are analyzed in the final chamber (right).

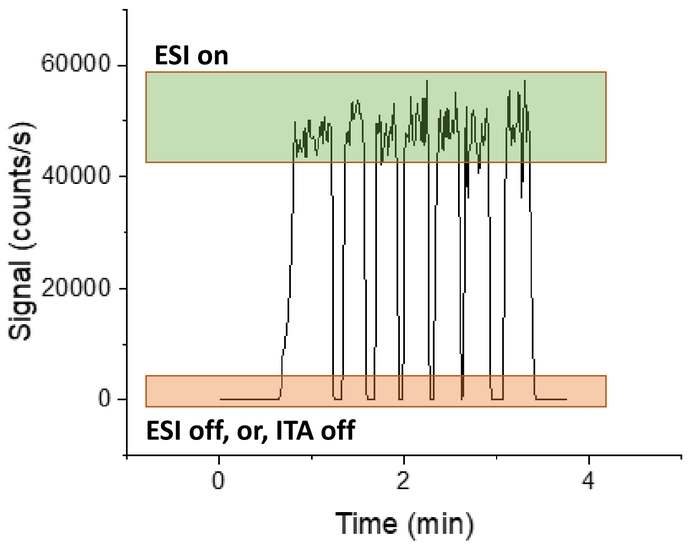

Figure 2. Ions were measured with a Channeltron in place of the QITMS to facilitate quantitative evaluation of the ion transport assembly. These result show that the ion transport assembly worked as expected and that all the observed ions originated from the ESI source.

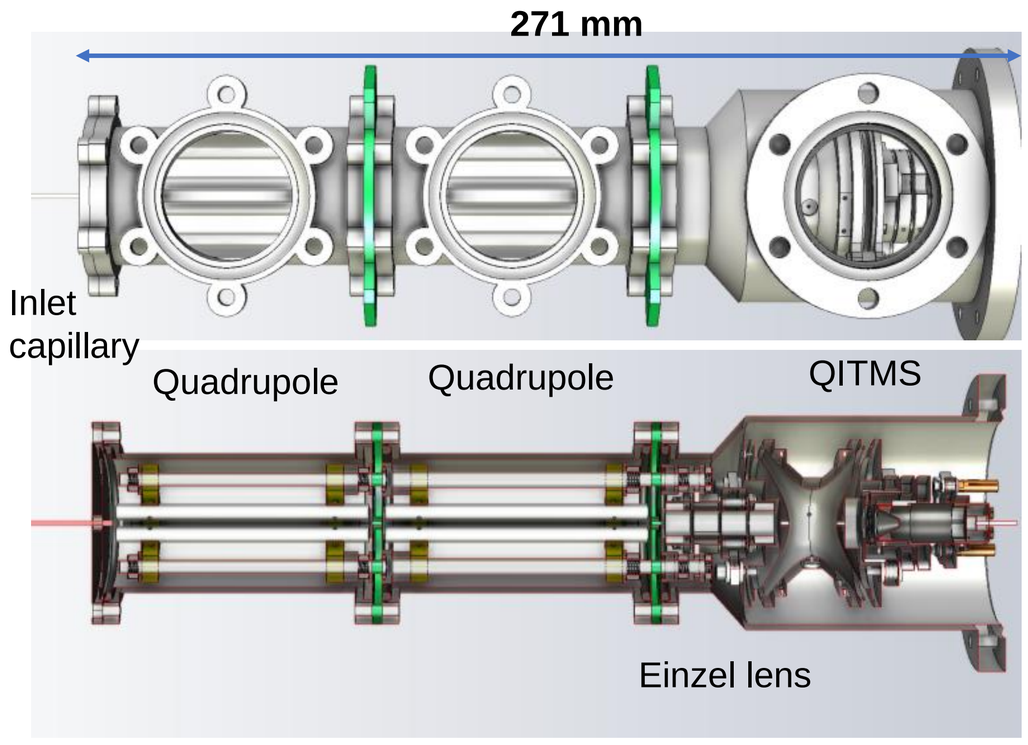

Figure 3. The new brassboard design has incorporated solutions to previously observed issues, primarily irreproducible alignment. Here, alignment rods extend through all chambers, and all ion optics are mounted onto these rods. The new design offers a compact footprint of <300 mm in length.

Significance/Benefits to JPL and NASA: We have identified critical requirements for the brassboard fidelity sub-system through extensive experimental work using a breadboard system. The primary concern has been component alignment, which has been addressed in a new instrument design that will be fabricated and validated in FY24. The long-term benefits for JPL will be the development of a fully integrated and compact interface and mass spectrometer for future in situ space missions dedicated to the search for organic molecules and biosignatures.

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Publications:

[A] Abrahamsson, V., B. L. Henderson, S. M. Madzunkov, P. Backes, F. Zhong, T. Okamoto, M. Badescu, J. Simcic, D. Maletic, J. Prothmann, W. W. Schubert, F. Chen, Y. Lin, A. J. Williams and M. Tuite (2022). A Novel Integrated In-Situ Instrument for Analysis of Organic Biosignatures. AGU Fall Meeting 2022, Chicago, IL, 2022

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