

**AI-DRIVEN SOFTWARE DEVELOPMENT AND MACHINE LEARNING OPTIMIZATION FOR FTICR MASS SPECTROMETRY****W. Kew<sup>1</sup>, K.J. Zemaitis<sup>1</sup>, P. Xiang<sup>1</sup>, R. Chu<sup>1</sup>, Y. Corilo<sup>1</sup>, J. Lindquist<sup>1</sup>, S. Munikoti<sup>1</sup>, J. Strube<sup>1</sup>, T.P. Wörner, M. Biel<sup>2</sup>, A.A. Makarov<sup>2</sup>, L. Paša-Tolić<sup>1</sup>**<sup>1</sup> Pacific Northwest National Laboratory, Richland, WA, US<sup>2</sup> Thermo Fisher Scientific, Bremen, Bremen, Germany

Fourier transform ion cyclotron resonance (FTICR) mass spectrometers operate in a high-dimensional parameter space defined by interdependent voltages, timings, and trapping conditions. Manual optimization using sequential, one-factor-at-a-time tuning is inefficient and poorly suited to strongly coupled variables. Here we demonstrate an AI-enabled framework that combines machine learning–driven design of experiments (DOE) with large language model (LLM)–assisted software development to accelerate optimization and expand experimental capability across 7 T, 12 T, and 21 T FTICR platforms.

On Bruker 7 T and 12 T scimaX/solariX XR systems, we implemented automated parameter modulation through the vendor’s Apache Groovy API. DOE orchestration, signal processing, and modeling were developed in Python using LLM-assisted code generation. Random forest regression models were trained to map multidimensional responses and identify optimal parameters. Compared to pre-generated batch method strategies and manual tuning, this approach enables more comprehensive exploration of coupled parameters and reduces optimization time while improving key performance metrics, including dynamically harmonized cell shimming.

The framework was extended to a hybrid Thermo Scientific™ Orbitrap Exploris™ 480–21 T FTICR MS, where over 50 parameters influence ion transfer into the ICR cell. DOE-guided optimization provided rapid sensitivity gains relative to conventional manual approaches.

Beyond parameter optimization, LLM-based “agentic” workflows were used to accelerate development of experimental infrastructure. Using vendor documentation as structured input, we generated a Python graphical user interface for ultraviolet photodissociation (UVPD) laser control, implemented serial communication protocols, and developed an AI-assisted Arduino-based trigger pulse system. In parallel, a real-time MALDI mass spectrometry imaging (MSI) visualization tool was built enabling feedback during acquisitions.

These results illustrate how AI-assisted software development, coupled with data-driven optimization, can reduce development cycles, improve instrument performance, and increase experimental agility in high-field FTICR MS. Rather than replacing domain expertise, the approach augments it, enabling rapid implementation of sophisticated control and analysis strategies on complex FTMS platforms.

**Keywords**

AI, ML, FTICR, UVPD, Software