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Beyond High-Ohmic Resistors: Utility of Capacitance-Based Faraday Amplification for Low-Level TIMS Isotope Analysis

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For over 50 years thermal ionization mass spectrometry (TIMS) measurements utilizing Faraday cups have predominately relied on signal amplification through high-ohmic resistors. In that time the fundamental design of Faraday amplification has remained largely unchanged, and the incremental improvements in resistor technology seen over the past two decades are increasingly constrained by the theoretical limits imposed by Johnson–Nyquist noise. Recently, Isotopx Ltd. U.K. released the ATONA amplifier system for their Faraday based instruments, which utilizes capacitance-based amplifiers, promising Faraday measurements with a larger dynamic range (Atto- To Nano-Amp), greater gain stability and lower noise floor.

Here we describe our experience with the performance of the ATONA system using a range of analytes of interest in the field of nuclear forensics, including Nd, Cs, U & Pu. We demonstrate that the optimization of analytical methods with respect to sample size, baseline characterization, and measurement integration time, can significantly improve both precision and accuracy relative to conventional TIMS methodologies. Using repeated analyses of uranium certified reference materials, we show that, with stable laboratory temperatures, high precision and accuracy of minor isotope ratios can be maintained at count rates of <2000 cps.

Finally, we present new data demonstrating the benefits of combining ATONA-equipped Faraday cups with simultaneous multi–ion-counting detection for ultra-low-level plutonium measurements. By extending Faraday measurements into intensity regimes traditionally accessible only by ion counting, the ATONA system can help ion-counter inter-calibration and reduce systematic uncertainties associated with dead time, gain drift, and peak-jumping. This hybrid detection strategy enables high-precision isotope ratio measurements in environmental samples where total ion counts are severely limited and may be applicable to geochemical studies in which sample size or elemental abundance is limiting, including high-precision isotope analysis of trace phases, micro-samples, and environmentally dilute materials. LA-UR-26-21048.