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Revolutionizing In-Situ Elemental and Isotopic Analysis: Breakthroughs in Matrix-Array Femtosecond Laser Ablation and Multi-Technique Coupling for Geoscience

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The demand for high-spatial-resolution, high-precision, and non-destructive elemental and isotopic analysis has driven rapid advancements in laser ablation (LA) technologies [1]. Shanghai ChemLab Instrument introduces a suite of world-first innovations in matrix-array femtosecond laser ablation (fsLA) systems, designed to overcome long-standing challenges in geosciences.

We will present groundbreaking advancements in matrix-array fsLA technology at ChemLab.

For example, our flagship, GenesisGEO, revolutionizes fluorite and quartz dating with unmatched precision and versatility. Using flat-bottom ablation and adjustable spot sizes (1–500 µm), it delivers micron-level U-Pb and Rb-Sr dating with high energy density (>50 J/cm^2), ensuring exceptional accuracy even for low-U/Pb quartz samples. It supports geochronology, mineral exploration, and lunar/planetary research [2] (Figure 1).

Second, ChemLab excels in fluid inclusion analysis because of its cutting-edge GenesisRaman system, the world's first all-in-one platform combining fsLA, Raman spectroscopy, and thermal stage control. This system eliminates sample transfer errors, achieves ±10% quantification accuracy for micro-inclusions (<10 µm), and preserves volatile elements using cryogenic ablation at -90°C. It also features dynamic Z-axis focusing and coaxial observation for precise targeting, reducing errors from ±20-30% to <10% while increasing throughput (Figure 1).

Additionally, GenesisGEO achieves sub-micron (500 nm) elemental and isotopic imaging, enabling non-destructive, in-situ visualization of trace elements (e.g., Au, As, Co, Ni) in e.g., individual pyrite grains. Our flat-bottom ablation and Z-axis dynamic focusing ensure precise quantification and minimal thermal fractionation, revealing growth zonation or fluid-mineral interactions (Figure 2).

The GenesisGEO system also excels in analyzing frozen seawater by leveraging advanced cryogenic fsLA technology, which preserves volatile elements and ensures unmatched precision and sensitivity (Figure 2). The system maintains samples at -40°C, effectively stabilizing volatile compounds and preventing element loss during analysis. This cryogenic approach enables detection limits <2 ng/L for gold and achieves a standard curve correlation of r ≥0.999 for concentrations ranging from 0-200 ng/L, making it ideal for trace element analysis in high-salt matrices like seawater.

Additional applications and innovative techniques will be presented during our talk.

[1] Chew, D. *et al.* (2021) *Chemical Geology* 559, 119917.
[2] Zhou, Q. *et al.* (2025) *Nature* 643, 371-375.







