Approaching the final frontier in lateral resolution for isotopic and chemical analysis with CHILI

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There is a clear need for improvements in lateral resolution and sensitivity beyond what is available with current state-of-the-art secondary ion mass spectrometry (SIMS) instruments. SIMS lateral resolution has reached ~50 nm and useful yields are at most a few percent. We are completing construction of CHILI (the CHicago Instrument for Laser Ionization), a resonant ionization mass spectrometry (RIMS) nanobeam instrument designed for isotopic and chemical analysis at the few-nm scale with a useful yield of 35–50% [1]. CHILI is equipped with a COBRA-FIB high resolution liquid metal ion gun (LMIG) and an e$^-$CLIPSE Plus field emission electron gun from Orsay Physics, each of which can be focused to <4 nm. The electron gun will be used for secondary electron imaging, as the built-in optical microscope is diffraction-limited to ~0.5 μm. A piezoelectric stage capable of reproducible nm-scale motions and equipped with a sample holder that will accept a wide variety of sample mounts is operational. The flight tube for the time-of-flight mass spectrometer mounted vertically above the sample chamber; this assembly is mounted in the center of an H-shaped laser table equipped with active vibration cancellation devices. The table has been demonstrated to have a vertical vibrational amplitude of less than 0.2 nm. Resonant ionization will be done with six Ti:sapphire tunable solid state lasers pumped with three 40W Nd:YLF lasers, which will allow two to three elements to be analyzed simultaneously. Ion detection in existing RIMS instruments [2,3] is done with a microchannel plate with a single anode. Isotope ratio precision is limited by counting statistics, as no more than one ion of the most abundant isotope of an element can be counted for each pulse. CHILI will initially be equipped with such a detector, but we are developing a multianode detector to significantly improve the count-rate capability.

[1] Stephan *et al.* (2011) *LPS* **42**, #1995. [2] Savina *et al.* (2003) *GCA* **67**, 3215. [3] Veryovkin *et al.* (2008) *LPS* **39**, #2396.

Partitioning of first-row transition elements between peridotite and melt

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To constrain possible lithologies in source regions of OIB [1-3], we experimentally determined partitioning of first-row transition elements (FRTE), Ga, and Ge between minerals in garnet peridotite and near-solidus partial melt at 3 GPa using LA-ICP-MS. $K_D^{Mn\text{-}Fe}$ between peridotite and melt is ~1, so low-degree partial melts of peridotite inherit Fe/Mn of their source, similar to the results of previous studies [1]. $K_D^{Zn\text{-}Fe}$ between peridotite and melt is 0.80, lower than previously determined from intermineral partitioning in natural peridotites (0.85-1) [3], primarily due to a lower measured $K_D^{Zn\text{-}Fe}$ for opx (0.77 rather than 0.96). Most peridotite xenoliths have (Zn/Fe)*10^4 from 4-12 [4], thus partial melts of peridotite may have (Zn/Fe)*10^4 ratios as great as 15. Most primitive OIB have (Zn/Fe)*10^4 from 10-15 [4], so derivation from a peridotite source can only be ruled out for a very few OIB lavas based solely on Zn/Fe. A fertile peridotite with 0.2 wt.% TiO_2 can generate a near-solidus melt with ~3.3% TiO_2. OIB with >3.3% TiO_2 require a non-peridotite or metasomatized source.

D_{Sc}	D_{Ti}	D_V	D_{Cr}	D_{Mn}
0.86	0.062	0.65	4.1	0.81
D_{Fe}	D_{Co}	D_{Zn}	D_{Ga}	D_{Ge}
0.81	1.8	0.65	0.15	0.71

Table 1: Bulk perid./melt partition coefficients averaged from four experiments (assumed mineral mode: 60.8% olivine, 7.7% opx, 22.6% cpx, 8.9% garnet).

[1] Humayun *et al.* (2004) *Science* **306**, 91-94. [2] Sobolev *et al.* (2005) *Nature* **434**, 590-597. [3] Le Roux *et al.* (2010) *Geochim Cosmochi. Acta* **74**, 2779-2796. [4] GEOROC database (http://georoc.mpch-mainz.gwdg.de/georoc/, accessed: 4/13/2011).