CHILI—THE FINAL STAGES OF BUILDING A CHALLENGING INSTRUMENT. T. Stephan[1,2,3], A. M. Davis[1,2,4], M. J. Pellin[1,2,3,4], D. Rost[1,2,3], M. R. Savina[2,3], R. Trappitsch[1,2,3], and N. Liu[1,2,3], [1]Department of the Geophysical Sciences, The University of Chicago, Chicago, IL 60637, USA, [2]Chicago Center for Cosmochemistry, [3]Materials Science Division, Argonne National Laboratory, Argonne, IL 60439, USA, [4]The Enrico Fermi Institute, The University of Chicago, Chicago, IL 60637, USA. (tstephan@uchicago.edu)

Introduction: For the last five years, we have been designing and building CHILI (Chicago Instrument for Laser Ionization) [1–5] at the University of Chicago, which is poised to perform well beyond the capabilities of the previous resonance ionization mass spectrometry (RIMS) instruments, CHARISMA [6] and SARISA [7], developed at Argonne National Laboratory.

Technical Challenges: The major technical capabilities compared to earlier instruments are increased lateral resolution and useful yield, which should allow detection of nearly every second atom of up to three elements simultaneously in a volume as small as $(10\ \text{nm})^3$. To achieve these goals, a new design was necessary for CHILI, which has only very few parts in common with earlier instruments and which pushes technical specifications to their physical limits. Last year, a summary of measures taken to achieve the technical goals was given [5]. Here, we will focus on further developments achieved over the last 12 months.

Ion Gun: For maximum lateral resolution in RIMS analyses, CHILI uses an Orsay Physics COBRA-FIB Ga liquid metal ion gun that can be focused to 2.5 nm. While such ion guns are mainly used for focused ion beam (FIB) applications where they run with constant current, CHILI's time-of-flight mass spectrometer requires a pulsed ion beam. Since using existing beam blanking plates causes the ion beam to sweep across the sample each time the beam is blanked, a motionless blanking system was developed: A second pair of plates compensates for beam motion until the beam is completely blanked. This required design and construction of dedicated fast switching electronics that is currently in its final testing phase.

Scanning Electron Microscope: CHILI operates as a field-emission scanning electron microscope for sample imaging by using an Orsay Physics e⁻CLIPSE Plus field-emission electron gun, which can be focused to 4 nm, and a secondary electron detector (SED). The SED initially delivered by Orsay Physics showed very high sensitivity to ambient light, which is counterproductive for a system that needs windows to bring in laser light. The detector has now been replaced by a newly designed SED that is much less sensitive to light.

Desorption Laser: For analytical problems where a lateral resolution of ~1 μm is sufficient, a Photonics Industries DC150-351 (351 nm, 1.5 W) Nd:YLF laser is implemented for laser desorption. The UV laser deposits more energy in a spot than the ion beam, allowing higher sample removal rates for minor and trace element analysis. The laser has been implemented, is aligned, and showed the expected lateral resolution of <1 μm, near the diffraction limit, at the sample.

Laser Ionization: Six tunable Ti:sapphire lasers for simultaneous resonance ionization of three elements have been assembled. They are pumped by three Photonics Industries DM40-527 (527 nm, 40 W) Nd:YLF lasers. The newly developed laser design surpassed the expectations with regard to laser beam power and stability. A three-prism beam combiner is currently being built to bring laser beams of different wavelengths into the analysis chamber along a single line.

Fast High Voltage Electronics: The increase in acceleration voltage for the photoions from 1–2 kV in previous instruments to 9 kV represented a major design challenge for CHILI. Fast switching of such high voltages required liquid-cooled solid-state switches built by Behlke Power Electronics GmbH. Due to a massive backlog at the manufacturer, delivery of these state-of-the-art switches was delayed by about two years. However, all but the least important unit have arrived by now. Implementation of the switches is under way and is expected to be finalized by the end of January 2014.

Software: All major subsystems of CHILI are controlled by our own software. Significant coding has been done to allow easy location of spots on images made with external instruments such as scanning electron and optical microscopes, and we are developing 3D imaging of isotopic and chemical composition as samples are sputtered or ablated away. Recently, we added the ability to control the ion and electron guns as well as mass spectrometer voltages and their pulsing.

Remaining Technical Challenges: CHILI presently suffers from some electromagnetic interference (EMI). A company specializing in EMI mitigation is now working on a solution, with the goal of reaching limits set by the spot sizes of the ion and electron guns.

Scientific Challenges: CHILI will soon be ready to be applied to a multitude of cosmochemical problems such as the analysis of cometary and interstellar Stardust samples, presolar dust grains and subgrains therein, and anything else that requires ultimate lateral resolution and sensitivity.

References: [1] Davis A. M. et al. (2009) *LPS 40,* #2472. [2] Stephan T. et al. (2010) *LPS 41,* #2321. [3] Stephan T. et al. (2011) *LPS 42,* #1995. [4] Stephan T. et al. (2012) *LPS 43,* #2660. [5] Stephan T. et al. (2013) *LPS 44,* #2536. [6] Ma Z. et al. (1995) *Rev. Sci. Instrum., 66,* 3168–3176. [7] Veryovkin I. V. et al. (2004) *Nucl. Instr. and Meth. B, 219–220,* 473–479.

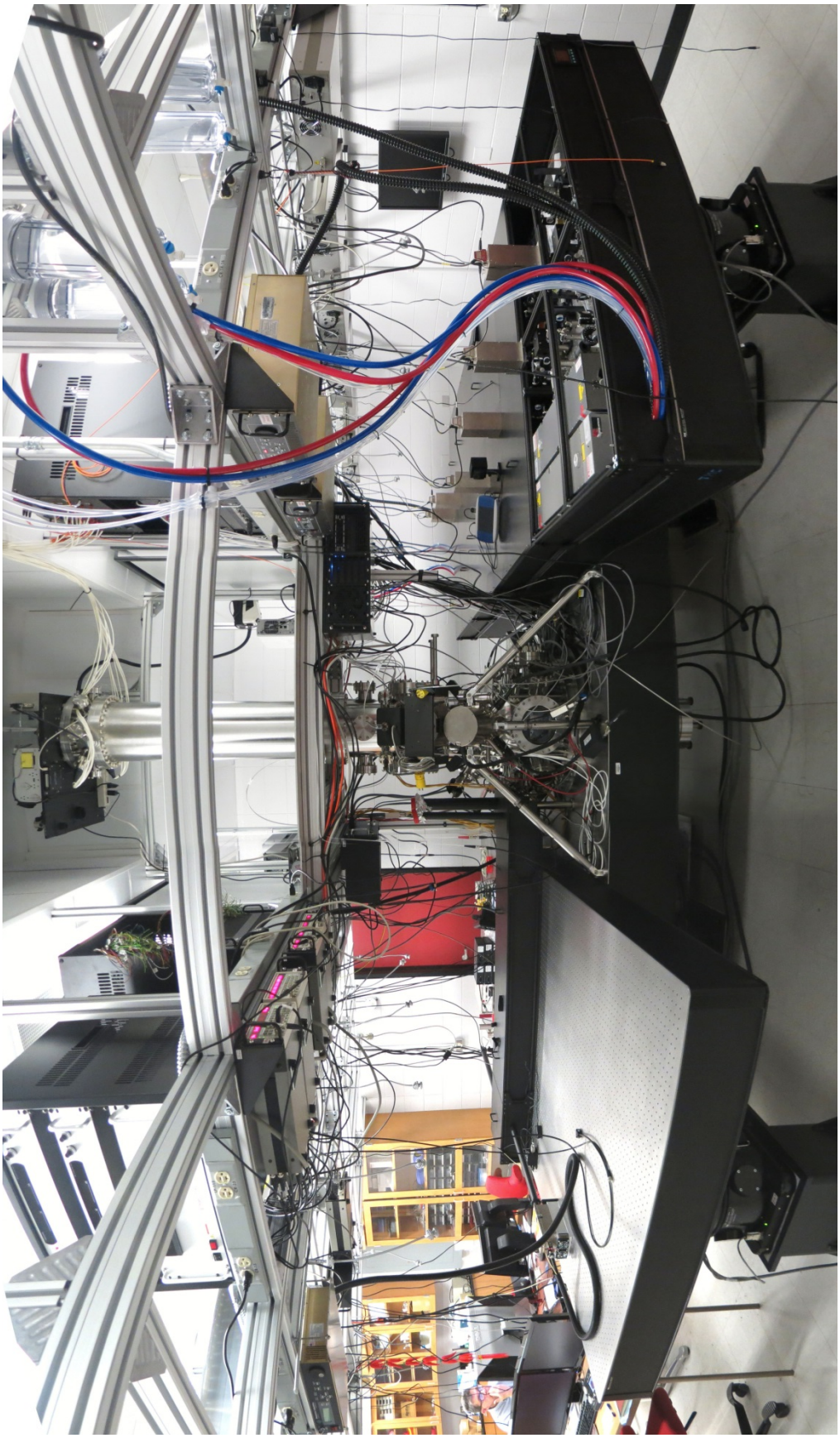

Fig 1: CHILI rests on an H-shaped laser table, 4.27 m × 3.66 m in size, with active piezoelectric vibration cancellation. The vertical flight tube of the mass spectrometer is located in the center of the photograph above the sample chamber and reaches to an absolute height of the instrument of 3.45 m. All three Nd:YLF pump lasers as well as the six Ti:sapphire lasers for resonance ionization are located on the right part of the laser table in an enclosure. A few panels from this enclosure were removed for the photograph. The desorption laser is sitting on the left part of the laser table, where there is ample room for future addition of resonance ionization lasers. Most electronics have been mounted on an aluminum grid structure suspended from the ceiling above the laser table in order to minimize transmission of vibration from fans, etc. to the floor and to provide easy access to lasers and the sample chamber.