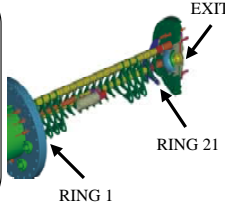


# A High-power Laser Ablation Ion Source for Penning Trap Studies of Nuclear Reaction Products

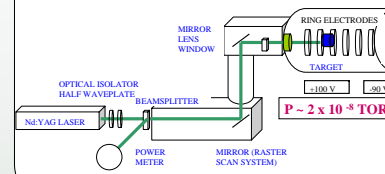
D.A. Davies, D.J. Morrissey, G. Bollen, P.A. Lofy, J. Ottarson, and S.C. Schwarz NSCL, Michigan State University, East Lansing, MI 48824 USA

## HIGH-POWER LASER ABLATION ION SOURCE

A laser ablation system was designed to produce ions for the LEBIT project to be used for calibrations and test beams. A variety of targets were ablated and studied under various conditions. Before running the ablation system in the gas cell under atmospheric pressure, the laser ablation process was studied in a high vacuum chamber. This chamber is the same size as the gas cell and both use an electrostatic potential gradient to focus ions. The laser ablation target is mounted on a removable assembly on a conflat flange, which can be transferred between the ablation chamber and the gas cell.



## ABLATION DETAILS

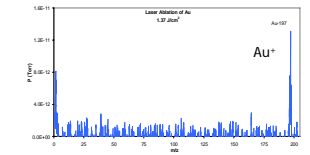
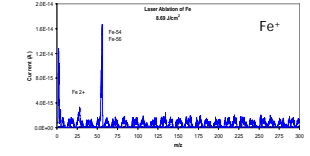


Quantel Q-Switched Nd:YAG LASER

- $\lambda = 532\text{nm}$
- PULSE WIDTH = 4 ns
- AVERAGE ENERGY = 160mJ
- REP RATE = 20 Hz (but variable)
- Laser Fluence Range = 0.2- 18 J/cm<sup>2</sup>
- RASTER SCAN
- motorized actuators minimize drilling

## RESULTS- VACUUM ABLATION CHAMBER

In order to study the laser ablation process, various experiments were performed in the vacuum ablation chamber. Various parameters were varied, and then optimized, including the focal length, potential gradient, position of the ablation target within the ring electrodes, bias on the target, and the laser fluence. The data was averaged over two minute runs, and the background was subtracted. Examples of the effects of the drift voltages and the laser fluence on the ion counting rate are shown in Figures 6 and 7.

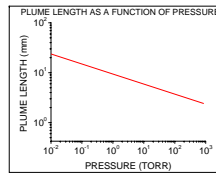
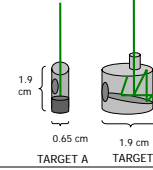
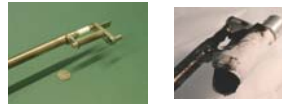


Figures 8, 9

The ablated ions were detected in vacuum using a modified Residual Gas Analyzer. Figures 8 and 9 illustrate the detection of ions from two of the metal targets.

## ABLATION TARGETS

TARGET	ISOTOPIC ABUNDANCE
C	C-12 98.9% C-13 1.1%
Al	Al-27 100.0%
Cu	Cu-63 69.2% Cu-65 30.8%
Fe	Fe-54 5.8% Fe-56 91.8% Fe-57 2.1% Fe-58 0.3%
Zn	Zn-64 48.6% Zn-66 27.9% Zn-67 4.1% Zn-68 18.8% Zn-70 0.6%
Ag	Ag-107 51.8% Ag-109 48.2%
Au	Au-197 100.0%

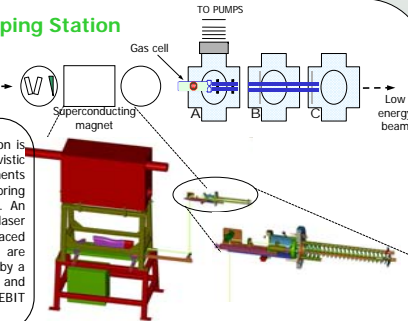


Dyer, P.E. et al., App. Phys. Lett. 57 (1990), 186

A variety of metal targets, in addition to a glassy carbon target, were used for ablation. The target holder surrounds the target, in order to minimize backwards plasma ejection and scattered laser light. Target B allows for more internal reflection, but Target A is better for ablation studies in atmospheric pressure due to the calculated plume length (see Figure 3).

## The Gas Stopping Station

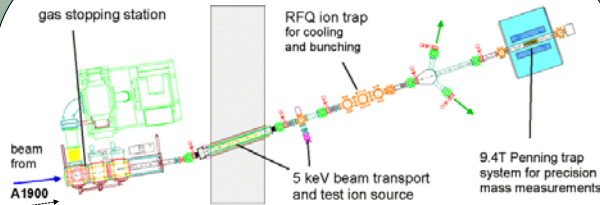
IONS FROM PROJECTILE BEAM OR LASER ABLATION SYSTEM



The NSCL gas stopping station is designed to slow down relativistic velocity projectile fragments produced at the NSCL and bring them to rest in helium gas. An alternative ion source is a laser ablation system which is placed into the gas cell. The ions are then extracted from the gas by a differential pumping system and delivered to the LEBIT experimental set-up.

L. Weissman, et al., Nucl. Instrum. Meth. A 540 (2005) 245

## LEBIT OVERVIEW



ABLATION PRODUCTS

## The Penning Trap

The Penning Trap uses a 9.4 T superconducting magnet to measure an ion's mass ( $m$ ) of known charge ( $q$ ) by measuring the ion's cyclotron frequency ( $\omega_c$ ) in a magnetic field ( $B$ ) according to the following equation:

$$\omega_c = \frac{q}{m} B$$

The resonances (Figures 1, 2) were obtained by driving the motion of the ions with a radiofrequency source. When an RF field matches the cyclotron frequency of the ion, the ion's kinetic energy increases, the time of flight drops and a resonance can be detected, from which the ion's mass can be calculated.

G. Bollen, et al., Nucl. Instrum. Meth. A 532 (2004) 203

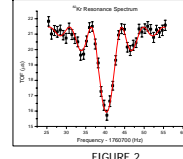
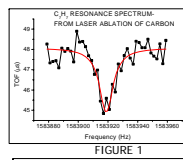
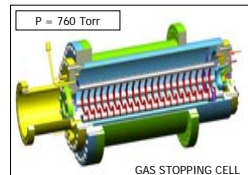


FIGURE 2

## CALCULATIONS



### Ion Transport

The ions are created in the gas cell at 760 torr of helium. Ring electrodes create a potential gradient which move the ions through the gas cell towards the exit nozzle. Once the ions are within a few mm of the nozzle, movement through the nozzle is due to helium gas flow. The nozzle itself also has an electrical gradient. Once the ions leave the gas cell, they are both transported and selected using a series of RFQ (radiofrequency quadrupole) ion guides.

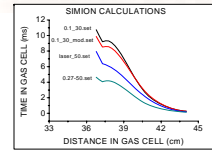


FIGURE 4

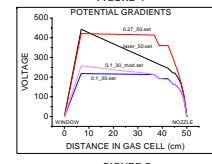


FIGURE 5

SIMION, which models ion trajectories in an electric field, was used to model the gas cell. Figure 4 illustrates the calculated time from SIMION for an ion to travel through a fixed distance in the gas cell, within various potential gradients and viscous drag due to the gas. These potential gradients are shown in Figure 5.

## LASER ABLATION STUDIES IN THE GAS CELL TO LEBIT

In order to study ion collection from the gas cell, the laser ablation system was used to ablate a carbon target. The ions were detected by a MCP to give a time-of-flight profile triggered by the laser pulse. Various information was obtained from these measurements, including the time for ions to travel through the gas cell, the ion mobility constant and the effect of the potential gradient on the ion transport can be compared to calculations.

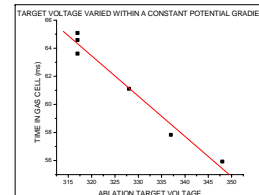


FIGURE 10

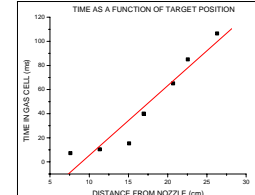


FIGURE 11

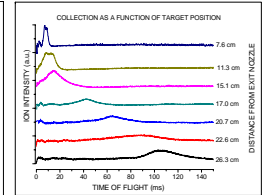


FIGURE 12

Figure 10 shows the effect of changing the voltage on the target, within a constant potential gradient. The higher the positive bias on the target, the faster the ions leave the gas cell. Figures 11 and 12 illustrate the effects of changing the position of the laser ablation target within the gas cell. Figure 12 shows the overall distribution is a Gaussian peak at different target positions. From Figure 11, the ion mobility constant  $K$  can be deduced from the slope of the line, since  $K$  is equal to the velocity of the ions divided by the electric field strength. In addition, the time for ions to travel through the gas cell was also determined, and is in agreement with the SIMION calculations (left). These measurements are summarized in Table 1.

MEASURED ION MOBILITY CONSTANT (K)	28 cm <sup>2</sup> (Vs) <sup>-1</sup>
TIME IN GAS CELL (50cm total) (position-dependent)	7 ms to 106 ms
TIME FROM EXIT NOZZLE TO HIGH PRESSURE REGION (80cm)	620 $\mu$ s
TIME FROM HIGH PRESSURE REGION TO MCP DETECTOR (~520cm)	30 $\mu$ s

TABLE 1