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Letter to the Editor

Production of multicharged metallic ions by the association of an excimer laser and an ECR ion source

L. Bex [a], P. Lehérissier [a], J.F. Hamet [b]

[a] *GANIL, Grand Accelerateur National d'Ions Lourds, P.O. BOX 5027, 4021 Caen Cedex, France*
[b] *CRISMAT ISMRA - Universite de Caen, Bd du Maréchal Juin, 14050 Caen Cedex, France*

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Abstract

This letter reports on the production and the acceleration, with the GANIL 100 kV high voltage platform, of high charge state uranium ions ($^{238}U^{25+}$). A pulsed excimer laser, injecting a beam axially through the extraction hole of an ECRIS, has been used for ablation on a rotating uranium target. The particles ejected from the solid surface of the target are ionised in the plasma of the source which is fed with oxygen support gas. A 3 eμA average beam of $^{238}U^{25+}$ has been measured with a solid material consumption approximately of 1 mg/h. A laser pulse of ≈ 30 ns duration (FWHM) generates a plume of emitted particles of ≈ 200 μs duration (FWHM) which is transformed in the plasma into a beam pulse of ≈ 20 ms duration (FWHM). Time delays between the start of the laser pulse, the plume and the beam pulse have also been measured.

The mass range of elements accelerated at GANIL [1] extends from carbon to uranium. Many of these elements are solids at standard temperature and pressure (STP). The technique currently used for the production of ions from solid material in the ECRIS is the evaporation of this solid material in electrically heated ovens. An other technique consists in evaporating at the boundary of the source plasma rods made with metal or oxide. A new technique using a pulsed excimer laser (UV radiation) for evaporation of solid material into the source plasma has been tested in our laboratory in April 1995. The laser beam was axially injected through the extraction hole of the source. A similar study has recently been performed [2] at Argonne National Laboratory. Their tests involved a pulsed Nd:YAG laser beam (IR radiation) passing through a radial port of an ECRIS. During the course of these laser studies they discovered a new method [3] involving the ion sputtering technique used previously in PIG ion sources [4]. Plasma ions, accelerated toward the negatively polarised sample, sputter solid material into the plasma. This promising method will be tested soon at GANIL.

The interaction between excimer laser irradiation and metallic materials has been studied [5]. The process of material ablation starts when the laser pulse energy per area (fluence) reaches a threshold measured at ≈ 0.5 j/cm^2 for uranium. The ablation is a rapid removal of material resembling an explosive evaporation.

The laser ablation method seems to be attractive as it may be applied to conductive and to non-conductive materials. The excimer laser offers significant advantages over Nd:YAG laser (IR radiation) as it is less dependent on the properties of the metals. Due to the high absorption in the UV, radiation energy is deposited in an extremely thin layer and the absorbed energy is carried off with the ejected material so there is little or no thermal effect on the target.

The set-up used for the laser experiment is shown in figure 1. A KrF excimer laser from Lambda Physik (EMG 103 MSC) with the following characteristics has been used to induce ablation:

-emission wavelength:	248 nm
-pulse width:	30 ns (FWHM)
-maximum pulse energy:	250 mj
-maximum repetition rate:	200 Hz
-maximum beam power:	30 W
-focal length of the lens:	2 m

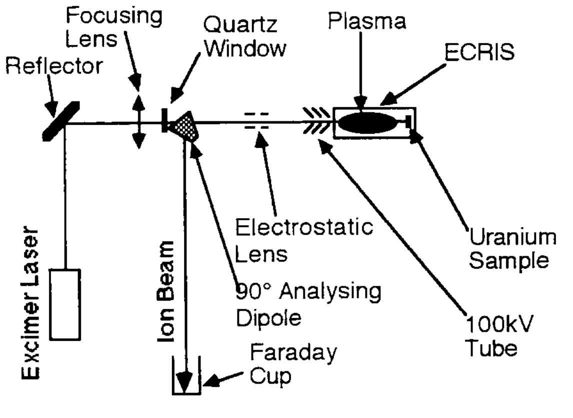


Fig. 1. Experimental set-up used in the laser ablation tests.

The uranium sample was approximately 30 mm outside of the ECR plasma and placed on the axis of the source. The ablation was performed with a fluence of 0.6 to 0.8 j/cm^2 on the target. To avoid craters formation, the sample was rotated at 2 Hz. The sample consisted of a cylinder (diameter: 8 mm; weight: 6 g) inserted in a stainless steel holder. The focusing lens produced a measured laser spot of 1 by 4 mm on the sample.

Figure 2 shows the average extracted beam current as a function of the analysing dipole current using uranium ablation and oxygen support gas in the ion source. This measurement was realised at 65 kV extraction voltage and 30 Hz laser frequency. An average beam current of 3 eµA of $^{238}U^{25+}$ has been measured. The solid material consumption was approximately 1 mg/h.

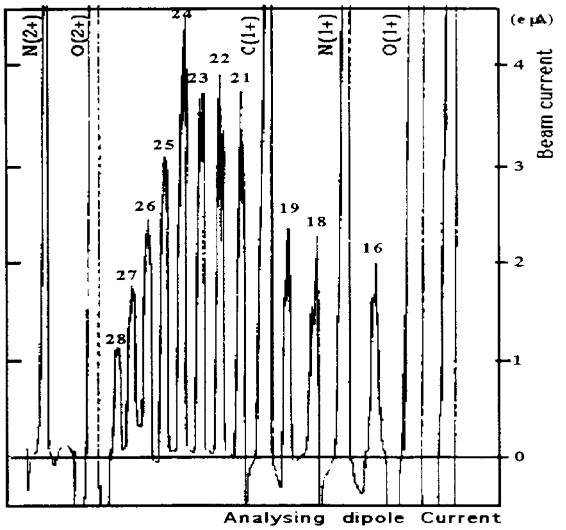


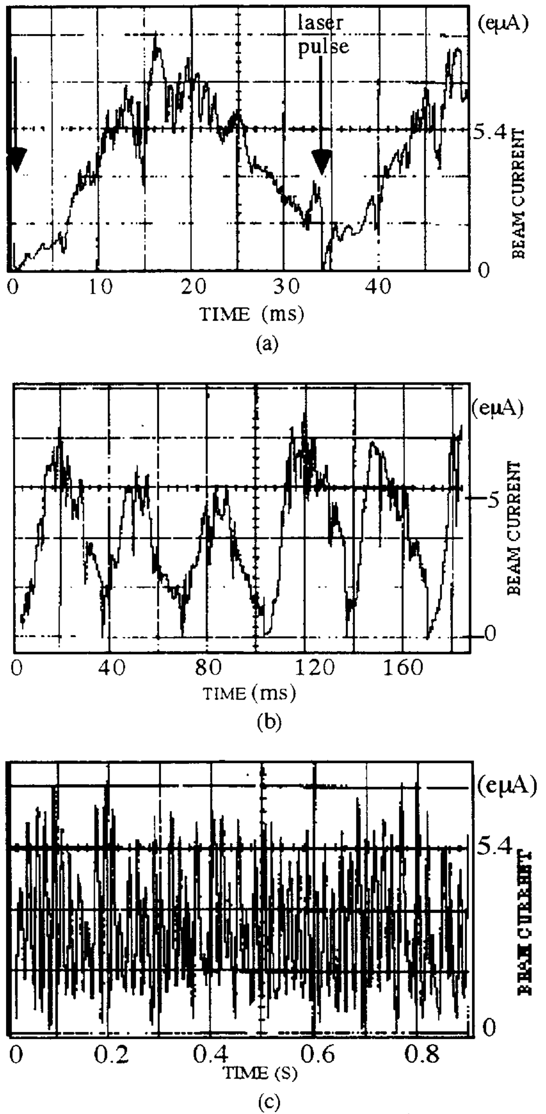
Fig. 2. Charge state distribution of $^{238}U^{25+}$ using ^{16}O as support gas and excimer laser ablation..

The Faraday cup was connected to an oscilloscope triggered by the laser pulse to monitor the charge analysed $^{238}U^{25+}$ beam current after each laser pulse. Figure 3 shows the measurements realised at a 30 Hz laser repetition rate with three different time scales.

The $^{238}U^{25+}$ beam pulse characteristics are:

-rise time:	17 ms
-decay time:	25 ms
-pulse duration (FWHM):	20 ms
-beam peak current:	9 eµA

The instability from pulse to pulse is probably due to the laser which is an old generation one. We noticed that the beam is cut to zero by the laser pulse of 30 ns duration. An interpretation of this laser effect is that the prompt introduction of dense neutral material into the plasma eliminates hot electrons and consequently high charge state ions are transformed to lower charge state ions.



(a)

(b)

(c)

Fig. 3. Beam pulses intensity of $^{238}U^{25+}$ versus time measured in the Faraday cup. Note the different time scales for the three pictures (a), (b) and (c). The vertical arrow indicates the time at which the laser was pulsed (laser pulse width ≈ 30 ns).

While keeping the ECR plasma off, the laser was tune at 2 Hz repetition rate for ablation on the uranium target in the source. The same measurements as previously with an oscilloscope connected to the Faraday cup show charge analysed ion beam current produced by the laser pulse (fig. 4, 5 and 6). Very low charge states were observed (U^{1+},...U^{5+}, O^{1+} and H^{+}).

The $^{238}U^{1+}$ beam pulse characteristics (fig. 4) are:

-time delay:	90 µs
-pulse duration (FWHM):	170 µs
-beam peak current:	2.5 eµA

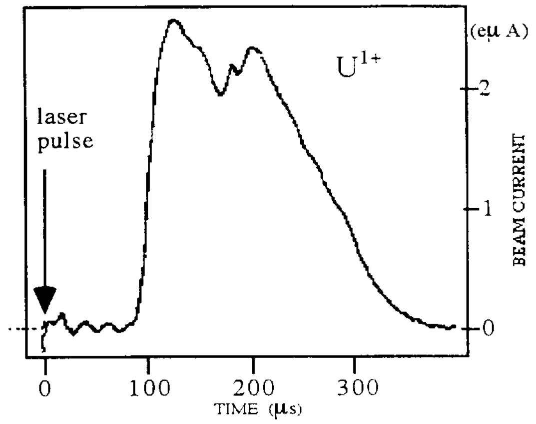


Fig. 4. Beam pulse intensity of $^{238}U^{1+}$ versus time measured in the Faraday cup while keeping the ECR plasma off and the laser pulsed at 2 Hz. The vertical arrow indicates the time at which the laser was pulsed (laser pulse width ≈ 30 ns).

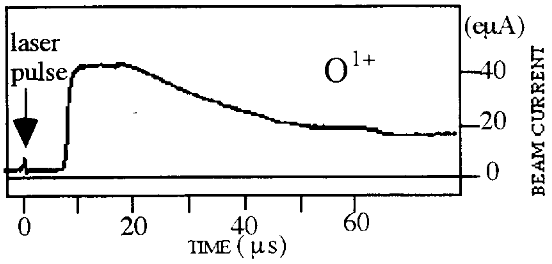


Fig. 5. Beam pulse intensity of O^{1+} versus time measured in the same conditions as in figure 4.

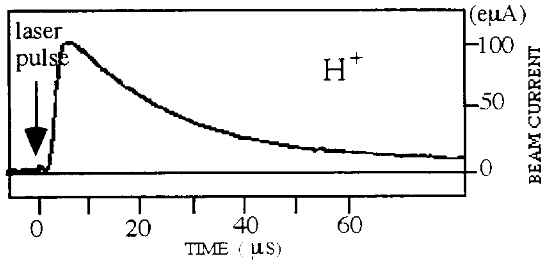


Fig. 6. Beam pulse intensity of H^+ versus time measured in the same conditions as in figure 4.

The flight time of $^{238}U^{1+}$ ions leaving the target and travelling to the extractor of the source (distance: 18 cm) corresponds to the measured 90 μs time delay between the start of the laser pulse and the beam pulse produced by laser ablation assuming that the flight time of ions travelling from the extractor to the Faraday cup is negligible. Table 1 gives time delays measured for some ions obtained by laser ablation.

Ions	Time delays (μs)
$^{238}U^{1+}$	90
$^{238}U^{2+}$	60
$^{16}O^{1+}$	7
H^{1+}	3

Table 1
Comparison of time delays between the start of the laser pulse and the beam pulse produced by laser ablation while the ECR plasma is off.

These preliminary results show that the laser ablation technique can be used in an ECRIS to produce beams from conductive and non conductive solid materials in run time operation. This technique should be compared with the sputtering technique for conductive material. An other application could be the production of radioactive beams by laser ablation on a radioactive target. For on-line production of radioactive beams the laser beam could be replaced by a high energy ion beam travelling on the axis of the source and interring trough the extraction hole allowing a very short transit time for radioactive particles produced in the target to be ionised in the ECR plasma.

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