Proton and Lithium Ion Production from Composite Targets with Laser Ion Source

J. J. Zhang[1,2] , H. Y. Zhao[1,2], L. T. Sun[1,2], P. Yuan[1,2] and H. W. Zhao[1,2]
[1]*Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou 730000, China*
[2]*School of Nuclear Science and Technology, University of Chinese Academy of Sciences, Beijing 100049, China*

Abstract

For the potential applications in compact hadron accelerators for tumor therapy and accelerator-based neutron sources, the production of protons and lithium ions with the laser ion source was investigated. Proton beams were produced from a bulk target made of compressed titanium hydride powder. The composition of the produced ions was analyzed with a 90° cylindrical Electrostatic Ion Analyzer. The comparison between the FC and TOF signals obtained with the EIA indicates that the produced ions from the TiH_2 target were mainly composed of protons when the target was irradiated with a relatively low laser intensity. A test of 300 shots demonstrated the pulse-to pulse repeatability better than ±5% of the ion pulses, which confirmed the reliability of the compressed target. Intense Li ion pulses were produced with contaminated pure lithium targets. Due to the active chemistry of lithium, the surfaces of the lithium target were oxidized heavily during the preparation of the experiment. The results showed that the produced ions by the second laser shot were almost lithium ions, while those were mainly contaminant ions in the first shot at the same position, which provide us an approach to produce lithium ions with the laser ion source since the oxidation of lithium is inevitable.

Experimental Setup

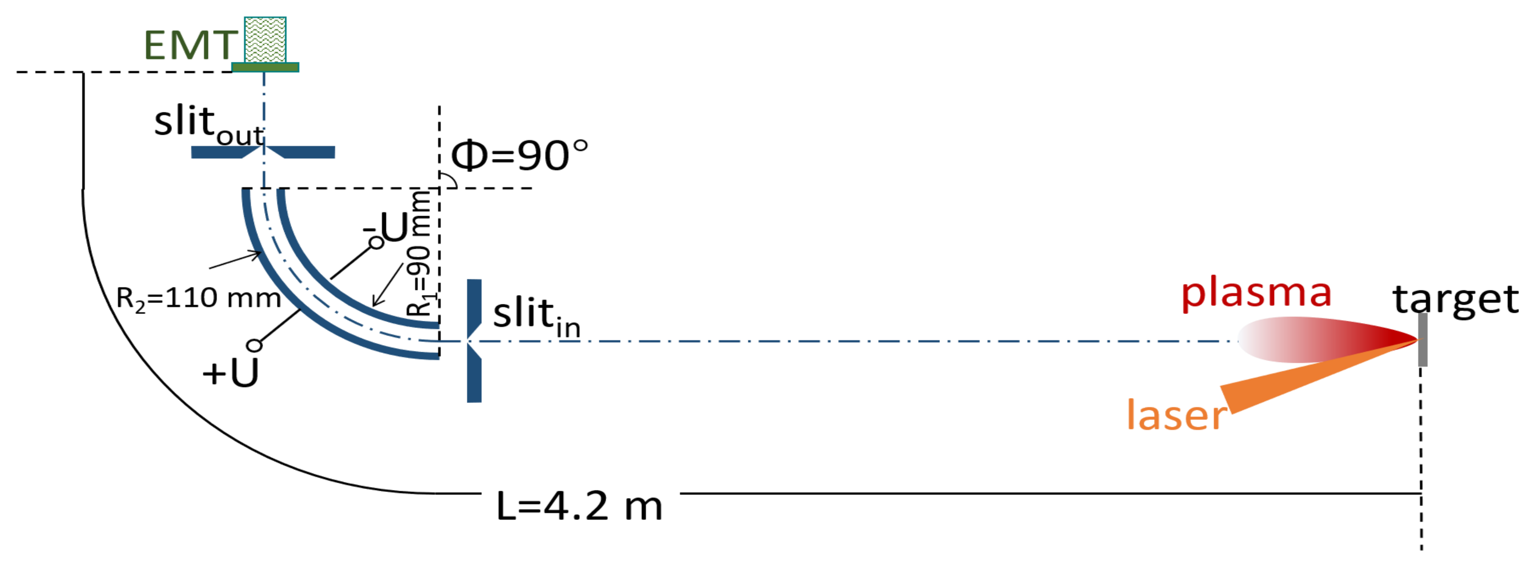

Fig. 1. Schematic layout of laser ion source

Table. 1. Parameters of laser ion source

Parameter	Value
Laser type	Nd:YAG
Wavelength	1064 nm
Energy	5 J
Pulse duration	8 ns
Focal length of lens	250 mm
Power density on focal spots	1×10^{13} Wcm^{-2}
Incidence angle	30°
$Slit_{in}$	0.3 mm×2
$Slit_{out}$	3.0 mm×2

proton production from TiH_2 target

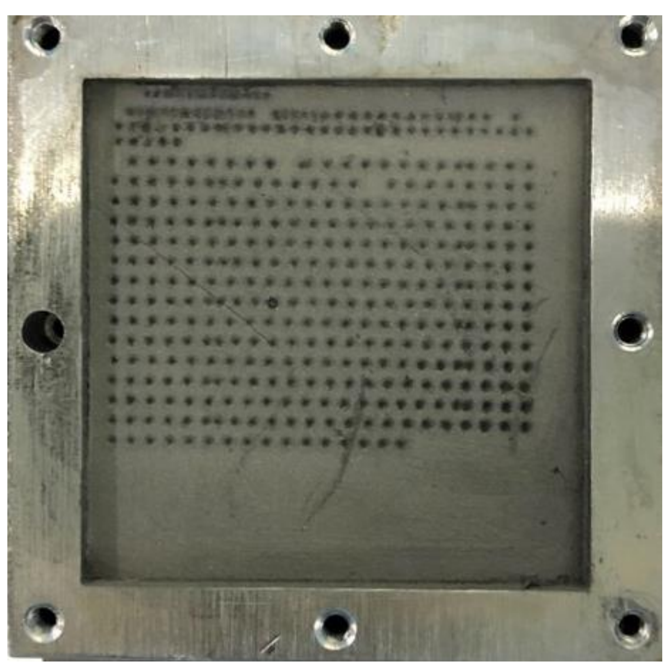

Fig. 2. The target made of compressed TiH_2 powder in a customized shell

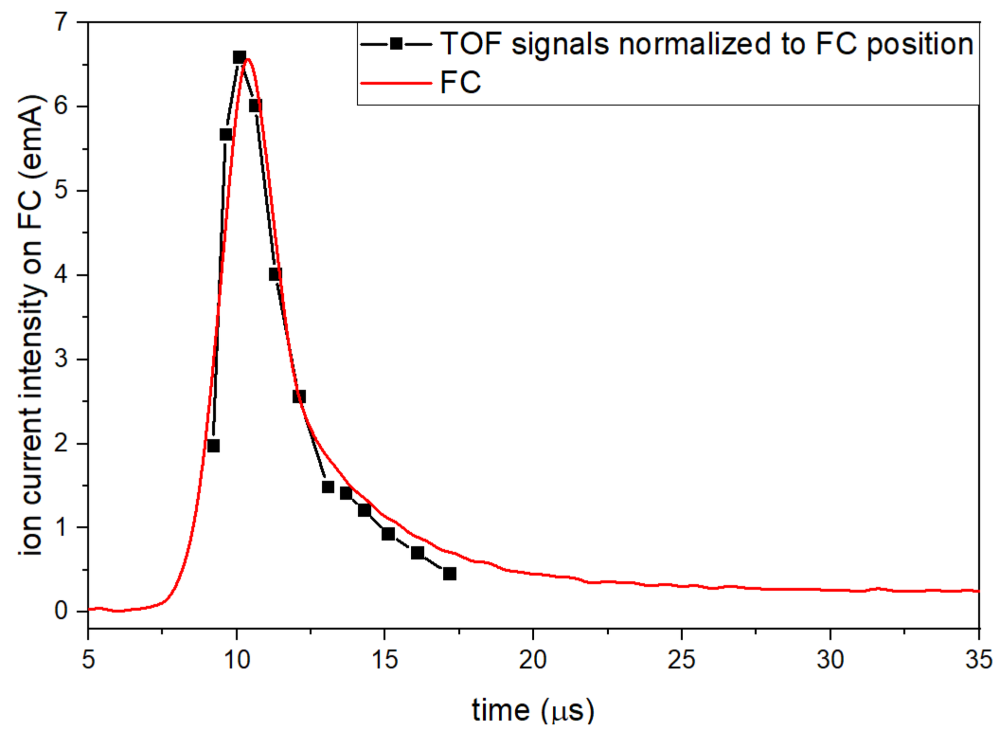

Fig. 3. FC signal and normalized proton TOF signal

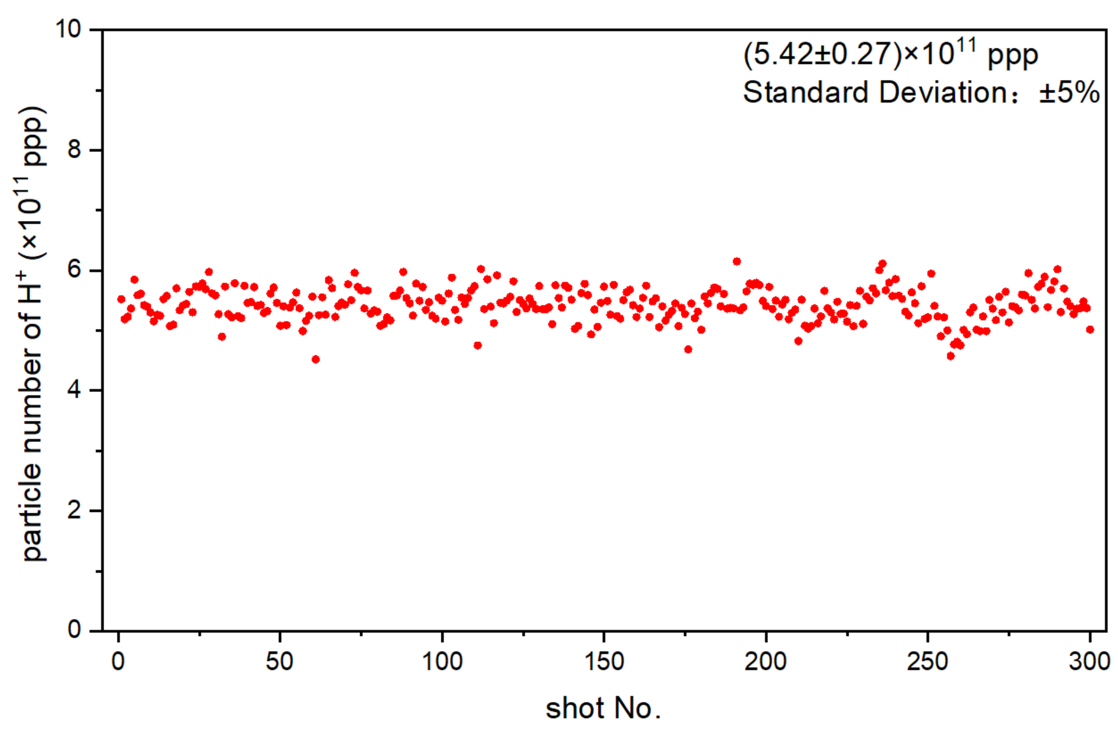

Fig. 4. Repeatability of 300 proton pulses

Li ion production from contaminated lithium target

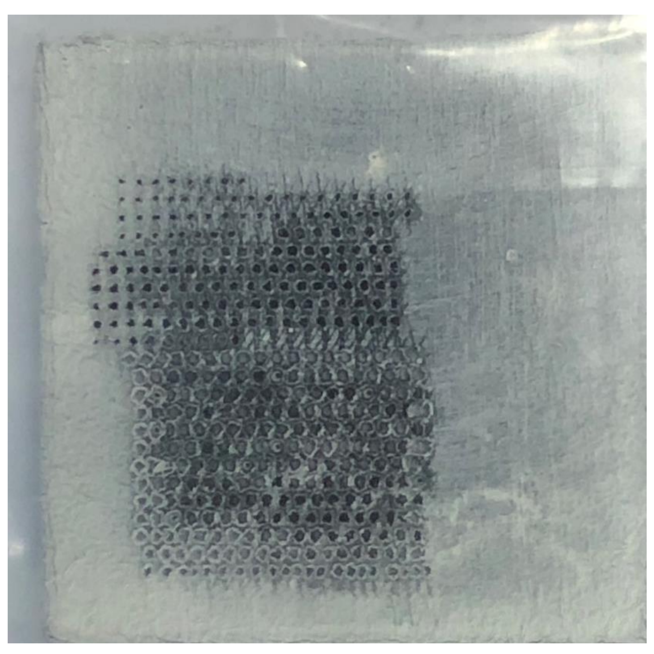

Fig. 5. The surface of pure lithium target seriously contaminated due to short exposure to air

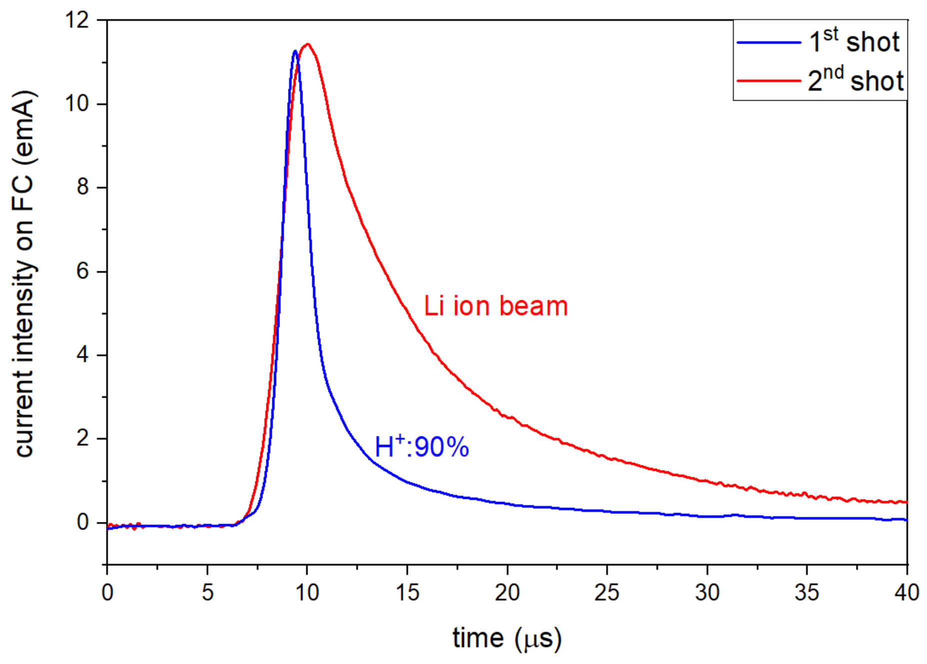

Fig. 6. Ion pulse waveform for two laser pulses irradiating at the same target position.

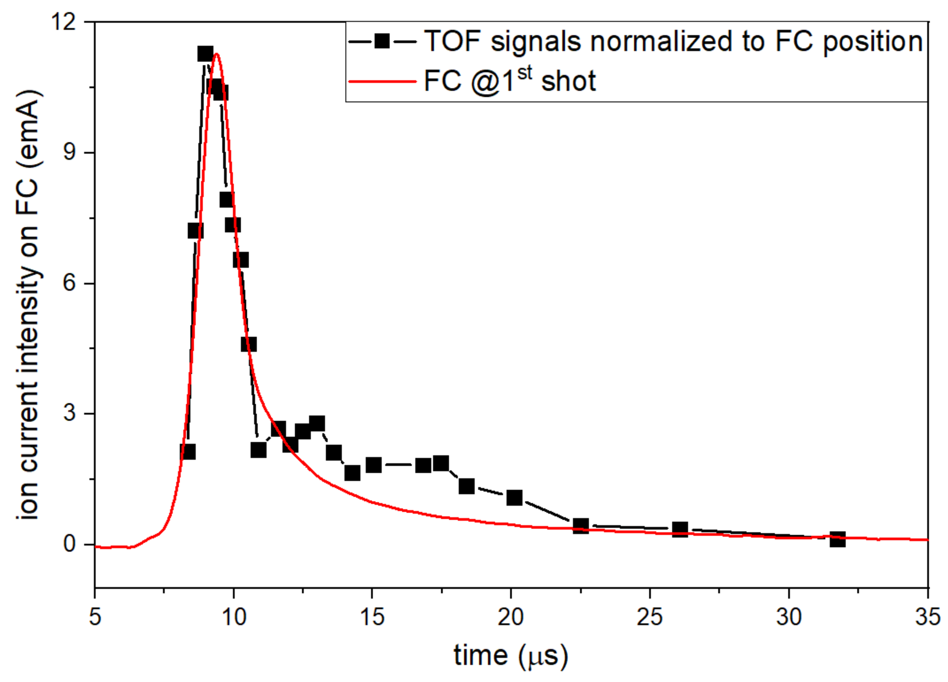

Fig. 7. FC signal and normalized proton TOF signal produced by 1st laser shot.

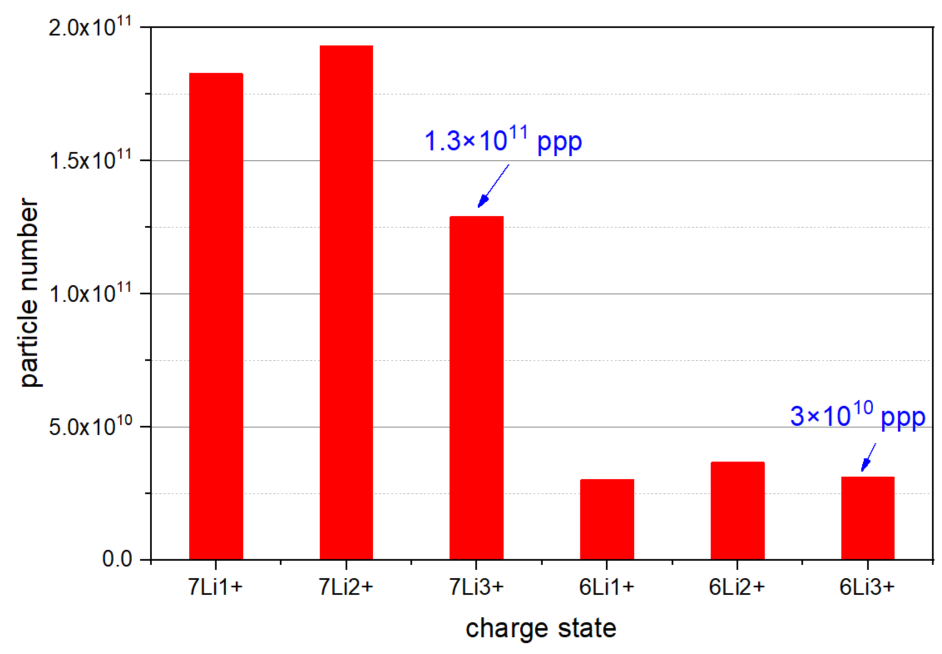

Fig. 8. The yields of differently-charged lithium ions produced by 2nd laser shot (normalized to the distance of 1m to target, ϕ10 mm aperture).

Summaries and Conclusions

- With the target made of compressed TiH_2 powder, proton beams were successfully produced by the laser ion source, and the current intensity was optimized to 5.4×10^{11} ppp with the laser intensity of 1×10^{13} W/cm^2.
- The agreement of the FC and normalized H^+ TOF signals indicates that the contribution of titanium ions in the total beam was negligible at laser intensity below 1×10^{13} W/cm^2 .
- The pulse-to-pulse repeatability of proton beams produced by TiH_2 target was better than ±5% for 300 ion pulses.
- Due to the severe reaction of lithium even with a short exposure to air, the first laser shot on the Li target yielded mainly contaminant ions, while the Li ions in absence of contaminant ion were produced by the second laser shot irradiating at the same position, and the current intensity of $^6Li^{3+}$ and $^7Li^{3+}$ were 3×10^{10} and 1.3×10^{11} ppp, respectively.

Acknowledgments

The support by the National Natural Science Foundation of China (Grant No. 11722547) and by the Key Research Program of Frontier Sciences, CAS, (Grant No. QYZDBSSW-SLH041) is gratefully acknowledged.

Institute of Modern Physics
Chinese Academy of Sciences

ICIS'21