6 - 41 Research Status of Laser Ion Sources and DPIS at IMP

Zhao Huanyu, Zhang Junjie, Jin Qianyu, Liu Wei, Lu Liang, Sun Liangting and Zhang Xuezhen

In 2014, the study on laser ion sources at IMP was mainly focused on the carbon ion production with a double-pulse laser irradiation scheme, simulations of Direct Plasma Injection Scheme (DPIS), and PoP experiments on laser ion beam acceleration in a Hybrid Single Chamber (HSC) Linac with DPIS.

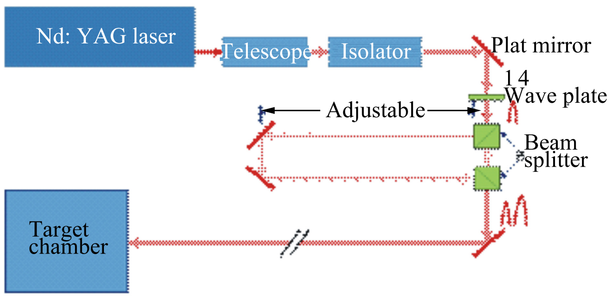

Fig. 1 (color online) Schematic layout of double-pulse laser irradiation scheme.

An optical method was developed to realize the double-pulse laser irradiation scheme, with which one can irradiate a target with two successive laser pulses using only one laser. As shown in Fig. 1, the laser beam output by a 3 J/ 8 ns Nd:YAG laser is split into two beams by a beam splitter, then the two laser beams passing through different optical paths are combined by another splitter and transported by the same optical system. Due to the difference of the optical paths between the two splitter, there is a time delay between the two laser pulses, which can be adjusted from zero to dozens of ns. The energy ratio between the two pulses can be tuned between 3/8 and 8/3 by rotating the quarter wave plate in front of the first splitter. With this system, the influences of the double-pulse laser parameters on the production of C ions was investigated. The main results are shown in Fig. 2, and the result obtained with a single laser pulse, whose energy is equal to the total energy of the double pulses, is also shown to make a comparison.

It turns out that the pulse duration of the ion beam was prolonged to different extents by double-pulse laser, which would be helpful to improve the coupling between a laser ion source and RFQ. As for the relative yield of highly charged carbon ions, the cases of a high energy laser pulse followed by a low energy one or two even laser pulses would be more favorable than the case of a low energy pulse preceding a high energy one.

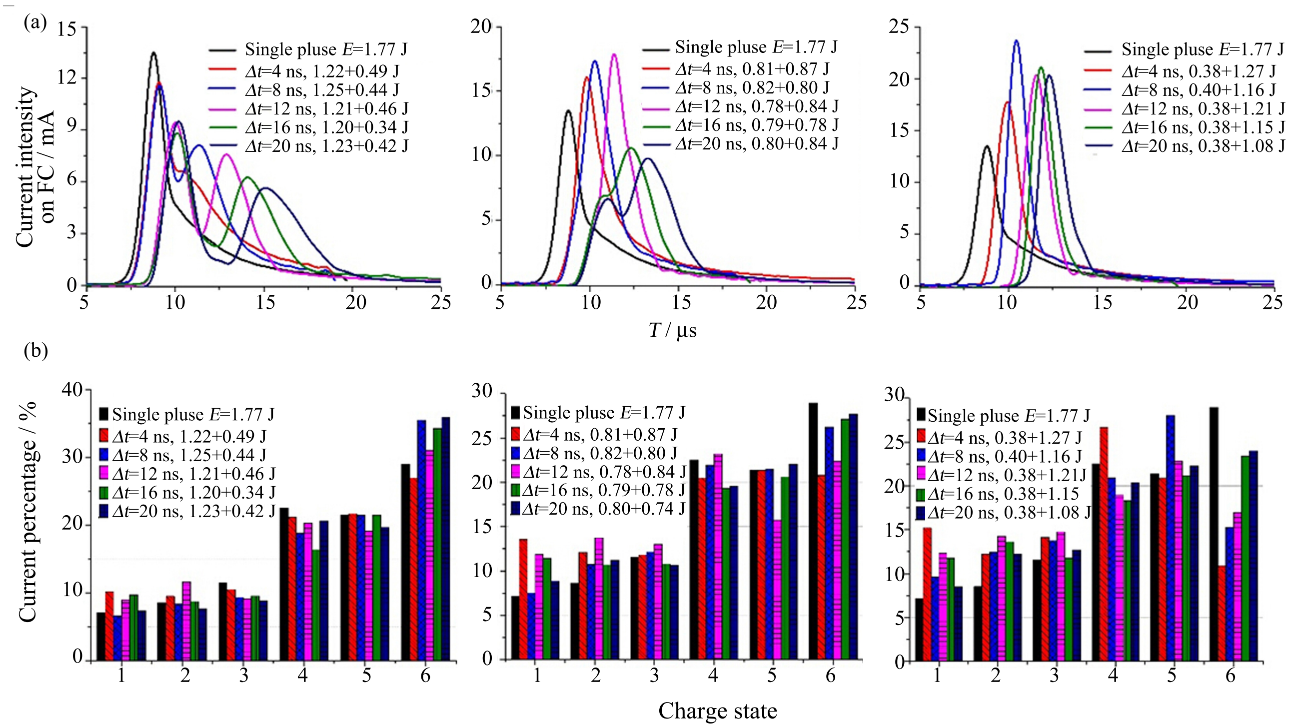

Fig. 2 (color online) Comparison of laser produced ion beams with single-pulse and double-pulse. (a) time structure of total ion beam, (b) charge state distribution.

The experimental research on acceleration of laser ion beams by a RFQ with DPIS had been carried out since 2009, and over 10 emA of C ion beam was obtained at the exit of the RFQ. To better understand its mechanism,

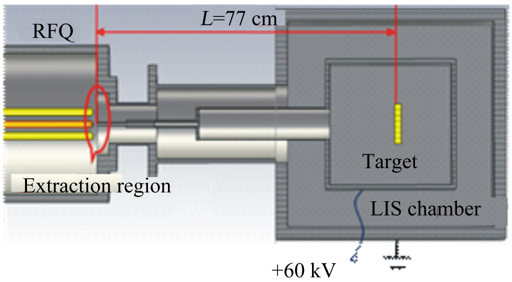

Fig. 3 (color online) Schematic of DPIS configuration.

DPIS was simulated with IGUN in 2014. Since the ion beams produced by a laser ion source varies violently with time in current intensity and charge state distribution, the ion extraction should be considered separately at separate time points during one ion pulse in the simulation. Based on the information about laser produced C ion beams in previous experiments, *i.e.* the time structure and charge state distribution, the injection of the laser produced ion pulse into the RFQ was simulated, as shown in Figs. 3 and 4. The simulated result is in accord with the result got from the previous experiment. It turns out that the total injection efficiency of C^{6+} with our present DPIS configuration is about 50%. And we also found that the injection efficiency could be enhanced by modifying the configuration of DPIS, which need verifying in the future experiments.

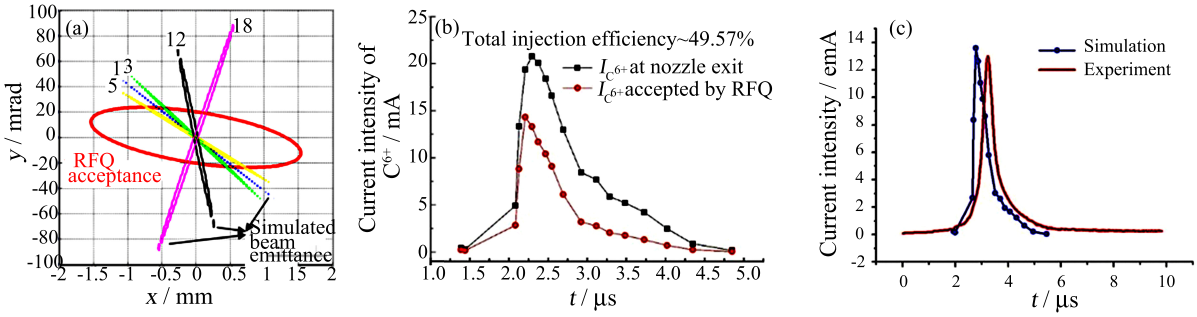

Fig. 4 (color online) Simulation results of DPIS (a) beam emittance at different time point, (b) C^{6+} ion beam at the nozzle of LIS and entrance of RFQ, (c) simulated beam at the exit of RFQ compared with experimental result.

Under the collaboration with Japanese colleagues, PoP experiments on C^{6+} acceleration with a Hybrid Single Chamber (HSC) Linac, which combines RFQ and DTL structure into one chamber, were performed. The HSC was designed to accelerate the ions with the charge-to-mass ratio higher than 1/2 to the energy of 2 MeV/u. In the PoP experiments, the laser ion source and HSC were connected with the DPIS configuration similar to that shown in Fig. 3. The beam with the amplitude higher than 1 emA was obtained at the exit of the HSC. Nevertheless, to verify the component and energy of the accelerated beam, further research is necessary.

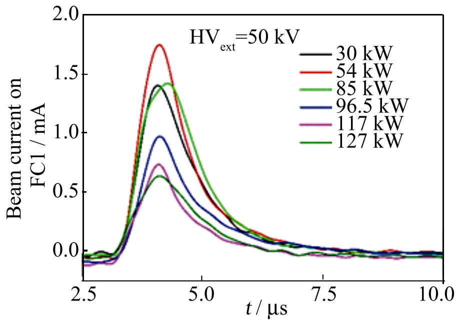

Fig. 5 (color online) Beam current at the exit of HSC.

By the end of 2014, one of the LIS test bench had been moved and installed in situ in the clean experimental room, which was built specially for high energy laser experiments. A preliminary experiment on the C ion production by a 10 J/15 ns Nd:YAG laser was performed. Both the current intensity and relative yield of C^{6+} were higher than those got with 3 J laser. The optimization of the 10 J laser is still ongoing.

Except the 10 J laser, another commercial 8 J/8-18 ns Nd:YAG laser has been ordered, and it is supposed to be shipped and installed at in situ by the end of March, 2015. With these two high energy laser, more flexible experimental research on laser produced ions are expected in 2015.

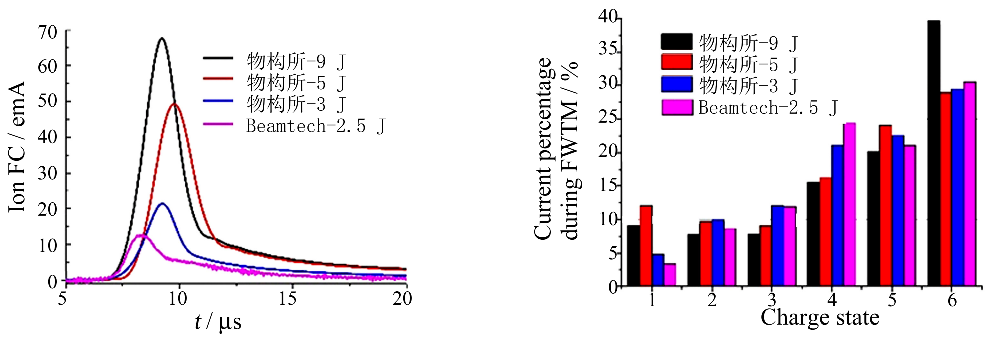

Fig. 6 (color online) Comparison of 10 J & 3 J laser produced C ion beams (a) total ion beam current (b) charge state distribution.