Present Status of the Laser Charge Exchange Test Using the 3-MeV Linac in J-PARC


Introduction

In the framework of J-PARC project, JAEA plans to be built a Transmutation Experimental Facility (TEF), which consists following two buildings;
- ADS target test facility (TEF-T) for material irradiation tests using 250 kW Pb-Bi spallation target, and
- Transmutation Physics Experimental Facility (TEF-P), which set up a fast critical/subcritical assembly.

Since the TEF-P requires a stable proton beam with a power of less than 10W, a stable and meticulous beam extraction method is required to extract a small amount of the proton beam from the high power beam using 250 kW.

To fulfil this requirement, the Laser Charge Exchange (LCE) method has been developed. The LCE strips the electron of the H- beam and neutral protons will separate at the bending magnet in the proton beam transport.

To demonstrate the charge exchange of the H-, a preliminary LCE experiment was conducted using a linac with energy of 3 MeV in J-PARC.

In this paper, present status of LCE tests is presented.

Transmutation Experimental Facility (TEF)

Laser Charge Exchange (LCE) Method to extract a small amount of the proton beam

- TEF-P Critical Assembly simulates neutronic performance in very low thermal power.
- To simulate ADS neutronic very low power proton beam should be extracted from J-PARC intense proton accelerator.
- Using Laser Charge Exchange (LCE) Method, low power beam can be easily extracted by no influence of J-PARC accelerator operation.
- Since the outer electron of the H- is very weakly bound to the atom, it can easily be stripped by a laser light in the wavelength range of 800~1100 nm.
- To eliminate the pre-neutralized protons, we were trying to perform laser injection and beam bending simultaneously in one magnet.

LCE devices of the 3 MeV, 0.45 kW linac

- Beam width and emittance of the H- beam were obtained with the beam emittance monitor placed 30 cm downstream of the quadrupole magnet by using Q-scan technique.
- As a result of the measurement, the RMS width in the vertical direction (σz) at the collision point was estimated as about 2.8 mm.

Nd:YAG Laser

- The commercial high power Q-switched Nd:YAG laser (Continuum, Powerlite DLS 9025, 1.6 J/pulse, 25 Hz) was located on an anti-vibration table.
- The laser light was reflected by ten plane mirrors and transmitted through one quartz viewing port from the laser main body to the collision point. This optical path length was 4.25 m.
- After the collision with the H- beam, the laser light was propagated to the termination point in the light-blocking box used for the laser light diagnostics. During the propagation, which was 3.16 m in length, there were five reflections by the plane mirror and one transmission through the quartz viewing port.
- Quartz viewing ports (effective diameter: 35.6 mm, thickness: 3.2 mm, laser damage threshold for 1064 nm Nd:YAG laser: 10 J/cm2 for 10 ns pulse) were fitted to the vacuum chamber.

Two-dimensional profile of the Nd:YAG laser light at (a) the exit of the laser main body and (b) the termination point.

The diameter of the Nd:YAG laser light could be estimated as 9.3 mm (FWHM) at the collision point with the H- beam.

Preliminary results

- The rapid rise and fall part surrounded by the white dotted circle is due to the lack of the H- beam caused by the LCE.
- This lack was observed from the first shot of the Nd:YAG laser light after beginning the LCE experiment.
- Power of the H- beam was 0.026 W from the time integral of the H- beam current inside the dotted-red rectangle.
- If the laser light from this Nd:YAG laser system collided with the H- beam delivered from the J-PARC linac, a stripped H+ beam with a power of about 5 W would be obtained.

CONCLUSION

- For the extraction of the low power H+ beam (less than 10W) from the high power H- beam (4000 MeV, 250 kW) by the LCE technique, a preliminary LCE experiment to measure the power of the stripped H+ beam was conducted using the H- beam with energy of 3 MeV from the RFQ linac in J-PARC.
- As a result of this experiment, the stripped H+ beam with a power of about 5 W equivalent was obtained under the J-PARC linac beam condition, and this value almost satisfied the power requirement (less than 10W) of the proton beam for the TEF-P.
- In this experiment, we focused on the power of the stripped H+ beam. We will conduct a further experiment to confirm the beam quality of the laser and the H-, as well as the long-term power stability of the stripped H+ beam.