Long Beam Pulse Extraction by the Laser Charge Exchange Method Using the 3-MeV Linac in J-PARC

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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 250kW 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 250kW.
• To fulfill 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 LCE experiment was conducted using a linac with energy of 3 MeV in J-PARC.
• In this paper, the results using the bright continuous laser source are presented.

Transmutation Experimental Facility (TEF)

- TEF-P: Transmutation Physics Experimental Facility
  - Purpose: Reactor Physics
  - Material Irradiation
  - Fusion Target Test Facility
- TEF-T: ADS Target Test Facility
  - Purpose: Material Irradiation
  - Fusion Target Test Facility

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 neutronics 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 800~1100nm.
- To eliminate the pre-neutralized protons, we were trying to perform laser injection and beam bending simultaneously in one magnet.

Laser Charge Exchange (LCE) Devices

- Laser system
  • The commercial diode laser from Lumics GmbH, module number L1064C230, was selected. The laser light power at the exit of the diode laser module was 230 W, and the wavelength was 1064±3 nm. The time structure of the diode laser light was continuous.
- The measured laser light power was 198 W at the collision point, when the diode laser module was operated with the rated power of 230 W.

LCE devices of the 3 MeV, 0.45kW linac

- 1-quadruple magnet, 2-bending magnet, 3-quartz viewing port, 4-vacuum chamber, 5-beam dump, 6- stripping foil,
- 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 G beam technique.
- The RMS width in the vertical and horizontal direction (σv, σh) at the collision point was estimated as about 2.0 and 4.3 mm, respectively.

Preliminary results

Current waveforms of the stripped H+ beam with and without the laser light

Change of the stripped H+ beam power as a function of the laser light power

Theoretical estimation

CONCLUSION

- To demonstrate the charge exchange of the H+, a LCE experiment was conducted using a linac with energy of 3 MeV in J-PARC.
- In present experiment, we used the bright continuous laser source. As the result, the stripped H+ beam with a pulse time width of 50 μs and a power of 0.57 mW was extracted.
- If the laser light from this LCE device collided with the H+ beam (400 MeV, 250 kW) delivered from the J-PARC linac, the stripped H+ beam with a power of 0.70 W equivalent was extracted. This value almost satisfied the power requirement (less than 1 W) of the proton beam for the TEF-P.