R&D Item

1. Feasibility Study(Optimization of Basic Specifications for Accelerator System, 1-A Deuteron Linear Accelerator, CARA＋Plasma device)

Progress Status as of FY2025

1. Overview

This project aims to create **"novel high-intensity, compact accelerators"** to advance the realization of fusion energy.

As a feasibility study, this research focuses on clarifying how accelerator-driven beams are utilized in fusion and on identifying accelerator configurations capable of meeting these requirements while demonstrating their feasibility.

Fusion energy, generally recognized as the *"ultimate energy source,"* requires an intense neutron source for testing reactor materials and advanced beam technologies for efficient plasma heating.

To address these requirements, two novel accelerator systems are being developed:

- a **1-A-class deuteron linear accelerator (Fig,1-1)**
- and the **CARA (Cyclotron Auto-Resonance Accelerator) (Fig. 1-2)**.

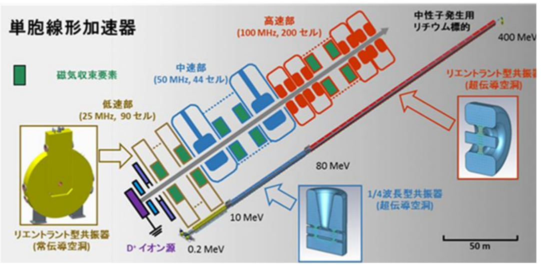

Fig. 1-1 1-A-class deuteron linear accelerator

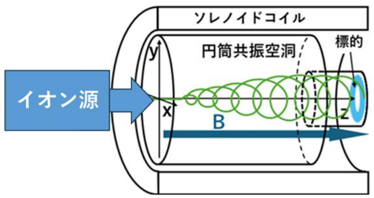

Fig. 1-2 CARA (Cyclotron Auto-Resonance Accelerator)

Through these developments, the project aims to overcome the remaining critical challenges in fusion research. In addition, the developed technologies will enable applications beyond fusion energy in medicine, materials science, and radioisotope production.

2. Outcomes as of FY2025

(1) Progress in the fundamental design of accelerator systems

The required beam parameters—energy, current, frequency, and magnetic field—for fusion applications have been systematically identified, and an optimized conceptual design of the accelerator has been established. For the 1-A-class deuteron linear accelerator, beam-dynamics calculations incorporating space-charge effects have been performed (Fig. 2-1), and a lattice structure with practical realizability has been developed.

(2) Demonstration of the applicability of CARA technology

A technique for extracting the rotating beam from CARA to the external region has been established. In addition, a method for achieving deep confinement in plasma by charge exchange has been verified. These results demonstrate the feasibility of applying CARA to high-intensity neutron sources and compact fusion systems.

(3) Clarification of requirements in fusion

Through workshops and symposia, beam performance requirements and application areas have been systematically organized. This has led to clarification of the specifications required for accelerator systems in fusion applications.

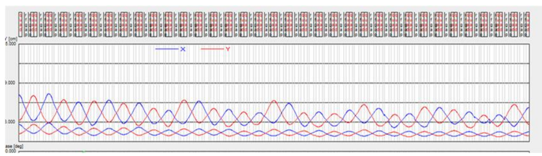

Fig. 2-1 Planar Position of the beam in the accelerator

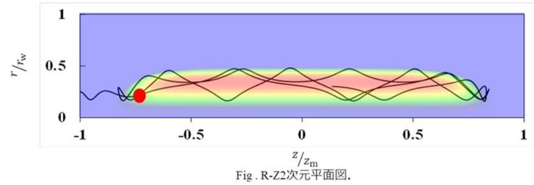

Fig. 2-2 Ion capture into the plasma by charge exchange

3. Future Prospects

(1) Demonstration of ion acceleration using CARA

Experiments will be conducted to demonstrate, for the first time, ion acceleration using CARA. This will demonstrate the feasibility of utilizing accelerator technologies developed for electrons in fusion and will be of strong interest to the international community.

(2) Realization of a high-intensity neutron source

By combining a 1-A-class deuteron linear accelerator with CARA, neutron yields equivalent to ten times that of IFMIF will be targeted. This will significantly accelerate irradiation testing of fusion reactor materials and strongly promote materials development.

(3) Development of a beam-driven compact fusion concept

If beam-confinement techniques using CARA are established, a beam-driven compact fusion reactor concept will be enabled. This approach provides an alternative pathway to realizing compact and efficient fusion systems.

(4) Expansion of applications beyond fusion energy

The developed technologies are expected to expand into a broad range of fields beyond fusion energy, including medical radioisotope production, materials science, and muon imaging. Stable and high-quality beam generation will support diverse applications across industrial, medical, and scientific domains.