First Plasma in the RT-1 Device

Zensho YOSHIDA, Yuichi OGAWA[1)], Junji MORIKAWA, Sho WATANABE, Yoshihisa YANO, Shoichi MIZUMAKI[2)], Taizo TOSAKA[2)], Yasumi OHTANI[2)], Atsuro HAYAKAWA[2)] and Masanao SHIBUI[2)]

Department of Advanced Energy, Univeristy of Tokyo, Kashiwa 277-8561, Japan
[1)]*High-Temperature Plasma Center, Univeristy of Tokyo, Kashiwa 277-8568, Japan*
[2)]*Toshiba Corporation, Yokohama 230-0045, Japan*

(Received 19 January 2006 / Accepted 23 January 2006)

The first plasma experiment using the Ring Trap-1 (RT-1) was performed on January 12, 2006. The RT-1 is a novel plasma device constructed to explore ways to the advanced-fuel fusion. The mechanism of plasma confinement is based on the theory of high-beta equilibrium that is self-organized in a flowing plasma. A super-conducting ring, levitated in the vacuum chamber, produces a magnetic field that traps high-temperature plasma, creating a magnetosphere-like configuration. Plasma is produced by electron cyclotron heating using an 8.2 GHz microwave.

Keywords: flowing plasma, high-beta plasma, double beltrami field, high T_c superconductor

DOI: 10.1585/pfr.1.008

The Univeristy of Tokyo constructed a new plasma device, Ring Trap 1 (RT-1), at the Kashiwa campus. This research project, started in 2004, is a joint work of the Department of Advanced Energy and the High-Temperature Plasma Center of the University of Tokyo. We performed the first plasma experiment using this device on January 12th, 2006.

The RT-1's mechanism of plasma confinement is based on the theory of self-organized states in flowing plasmas [1, 2], which predicts that the hydrodynamic pressure in a fast plasma flow can balance the thermal pressure (Bernoulli's law) creating a relaxed state with very high-beta value. The basic concept of a device realizing such a configuration was developed in the Proto-RT device [3, 4], which employed an internal ring conductor producing a dipole magnetic field. The equilibrium state produced by this device simulates Jupiter's magnetosphere [5]. To avoid interactions of the plasma with supporting structures and current feeds, we constructed the Mini-RT device and developed the technology to levitate a high-T_c superconductor [6]. "Dipole fusion" is also exploring a high-beta confinement with a similar magnetic-field configuration [7], while it does not emphasize the flow effect. The LDX experiment developed by MIT takes this approach [8]. The common goal of these projects is to realize a very high-beta confinement of high-temperature (100 keV level) plasmas that enables the fusion of advanced fuels.

The RT-1 device (Fig. 1, Table 1) employs a high-T_c superconductor (Bi-2223) ring that is levitated in the vacuum chamber and produces dipole magnetic field. The field strength in the confinement region varies from 0.3 T to 0.03 T. The conductor is first cooled to 20 K in the maintenance chamber (located at the bottom of the plasma chamber), and, then, charged to 0.25 MA (the coil consists of 12 pancakes and has a total of 2160 turns). After detaching the current leads and coolant (He gas) transfer tubes, the ring is moved up to the mid-plane of the plasma chamber and is then levitated by a feedback-controlled magnetic field produced by a coil installed on the top of the device. Three-cord laser sensors measure the position of the levitated ring. We can continue the super-conducting operation for 7 hours before the coil temperature increases to 30 K. Current decay is less than 1% after 7 hours.

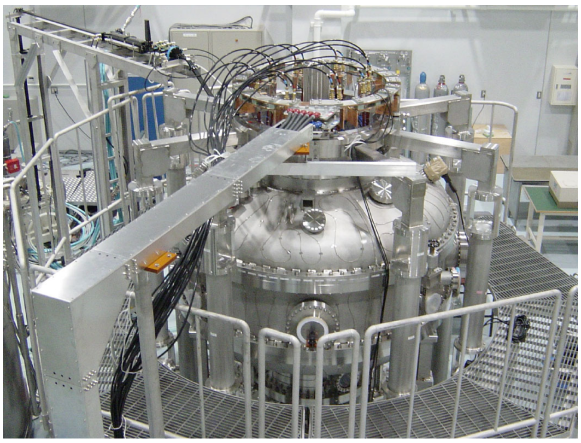

Fig. 1 RT-1 Device. A super-conducting ring, levitated in the vacuum chamber, produces a magnetic field that traps high-temperature plasma and creates a magnetosphere-like configuration.

author's e-mail: yoshida@k.u-tokyo.ac.jp

ring magnet (HTS)	size	R = 250 mm, cross section (casing): w = 195 mm, h = 150 mm
	current	250 kA (2160 turns)
	weight	110 kg
	operating temperature	20 K – 32 K
lifting magnet	current	88 kA (68 turns)
	dynamic range	f < 10 Hz (feedback controlled)
plasma chamber	size	R = 1000 mm, h = 560 mm
RF heating (1)	frequency	8.2 GHz
	power	100 kW (1 sec pulse)
RF heating (2)	frequency	2.45 GHz
	power	20 kW (2 sec pulse)
refrigerator	power	50 W at 20 K
	maximum flow	2 g/sec

Table 1 Machine parameters of the RT-1 device.

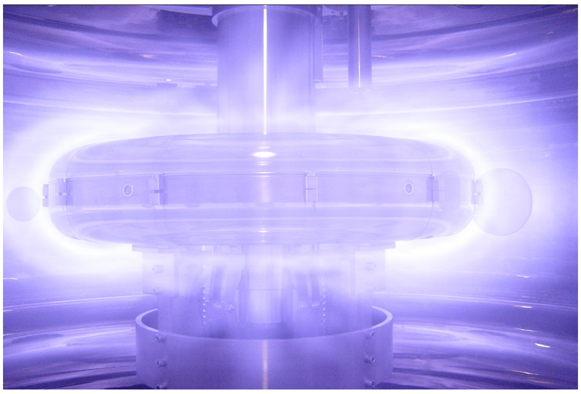

Fig. 2 First plasma produced by the RT-1 device. The plasma is produced by ECH using an 8.2 GHz microwave.

We produce plasma by injecting an X-mode microwave (8.2 GHz). The maximum power of the klystron is 100 kW (1 sec. pulse operation). The first plasma was obtained with 1.5 kW ECH (Fig. 2). The superconductor ring was levitated about 30 mm over the lifter. After testing the ring's catcher, which can catch the ring in case of an accidental drop, we will operate the device while moving the lifter away from the plasma region. Optimization of the plasma and measurements of the parameters will be performed after completing detailed evaluations of the machine‘s performance.

The authors are grateful to Professor T. Mito and Dr. N. Yanagi of the National Institute for Fusion Science for their advice regarding the design of the magnet cooling system. The authors also thank all the collaborators who helped to design and construct the RT-1.

[1] S.M. Mahajan and Z. Yoshida, Phys. Rev. Lett. **81**, 4863 (1998).
[2] Z. Yoshida and S.M. Mahajan, Phys. Rev. Lett. **88**, 095001 (2002).
[3] Z. Yoshida *et al.*, *17th IAEA Fusion Energy Conference*, Yokohama, 1998, IAEA-CN-69/ICP/10.
[4] H. Saitoh *et al.*, Phys. Rev. Lett. **92**, 255005 (2004); H. Saitoh *et al.*, Phys. Plasmas **11**, 3331 (2004).
[5] J. Shiraishi *et al.*, Phys. Plasmas **12**, 092901 (2005).
[6] Y. Ogawa *et al.*, J. Plasma Fusion Res. **79**, 643 (2003).
[7] A. Hasegawa *et al.*, Nucl. Fusion **30**, 2405 (1990).
[8] J. Kesner *et al.*, *17th IAEA Fusion Energy Conference*, Yokohama, 1998, IAEA-CN-69/ICP/09.

Video: The first plasma experiment performed on the RT-1 device. The plasma is produced by ECH using an 8.2 GHz microwave. The pulse duration was 1 sec, as determined by the microwave operation. In the second video, the ring magnet was levitated about 30 mm over the lifter, while in the first video it was placed on the lifter.