AN ULTRA-LOW ENERGY ELECTRON BEAM ION TRAP IN SHANGHAI

J. Xiao, R. Zhao, X. Jin, B. Tu, Y. Yang, D. Lu, R. Hutton, and Y. Zou[#]
Shanghai EBIT Lab, Institute of Modern Physics, Fudan University, Shanghai, China
and The Key Lab of Applied Ion Beam Physics, Ministry of Education, Shanghai, China

Abstract

Electron beam ion traps (EBITs) are very useful tools for disentanglement studies of atomic processes in plasmas. For tokamak edge plasmas, electron energies are in the range of several tens to several hundreds eV, consequently low energy EBITs are strongly needed. In this paper, the progress of an ultra-low energy EBIT in Shanghai, SH-HtscEBIT, is reported. This EBIT is designed for operating in the electron energy range of 30–4000 eV, with a current density of up to 100 A/cm^2. The magnetic field in the EBIT plasma region is designed for 0–0.25 T, produced by a pair of high temperature superconducting coils. Elements for the spectroscopic studies can be injected through an observation port through an injection system. Both the design and the testing results of the SH-HtscEBIT will be presented in this paper.

INTRODUCTION

Electron beam ion traps (EBITs) [1] are sophisticated devices with the capability of acting as both light sources and ion sources of highly charged ions (HCIs). On top of this, EBIT can produce a special kind of plasma with tuneable and almost monotonic electron energy, so can be used as a very good tool for disentanglement studies of atomic processes in plasmas. [2]

In recent years, several low-energy EBITs have been developed to meet the need for high-quality spectroscopic data of moderately charged ions [3-5]. For example, tungsten ions whose data are very little for the charge states between 6+ and 28+ although they are strongly needed for next generation nuclear fusion device, i.e. ITER [6]. One of the key parameters of these EBITs is the lower energy limit. We have successfully set up a low energy EBIT, SH-PermEBIT, whose lower limit of the electron beam energy is 60 eV [5]，which was already the lowest amongst all the low energy EBIT in the world. However, 60 eV is still too high for disentanglement spectroscopic studies of tokamak edge plasmas, so we decided to design and build an ultra-low energy EBIT.

In this paper, we report the progress of this ultra-low energy EBIT. The design of this instrument allows for electron beam energy down to around 30 eV. Some details of the SH-HtscEBIT and some test results are given in the following sections.

EBIT OVERVIEW

A schematic drawing of the SH-HtscEBIT is shown in Fig. 1 and the current parameters are listed in Table 1. As in any EBIT, the electron beam is emitted from an electron gun and is accelerated to the drift tube and confined by a magnetic field produced by a pair of coils. Drift tube assembly traps the ions and a collector electrode decelerates and collects the electrons. The size of the device was reduced to smaller than the SH-PermEBIT, which would be helpful to improve the solid angles for the spectrometers and detectors. The height of the main chamber is 500 mm and the distance between the electron beam and the viewport is 130 mm.

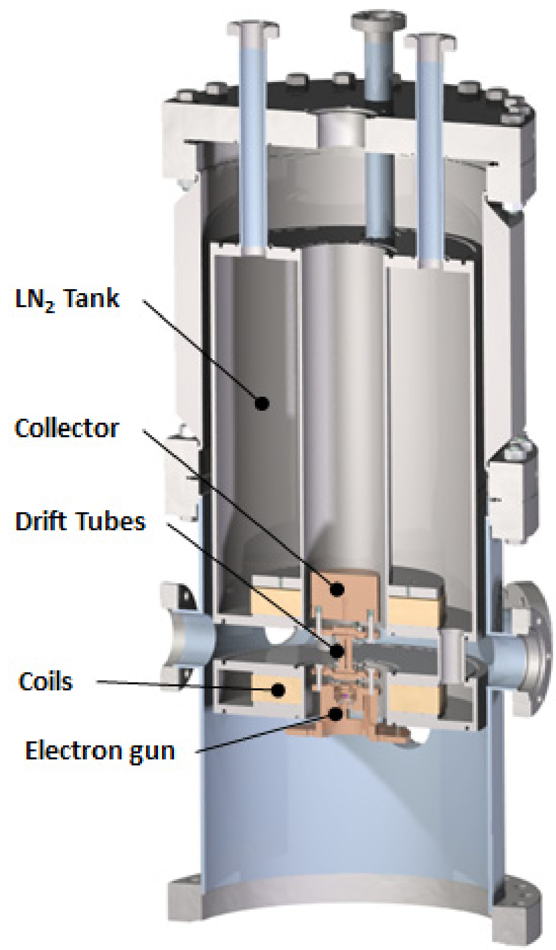

Figure 1: Schematic drawing of SH-HtscEBIT.

MAGNETIC FIELD AND LOW ENERGY LIMIT

A pair of high temperature superconducting coils were adopted to produce the magnetic field. The maximum field strength in the central drift tube region of this EBIT

#zouym@fudan.edu.cn

is around 0.25 T with a maximum current of 30 A. The coils are immersed in the liquid nitrogen tank, whose volume is around 4.7 L. The consumption of the liquid nitrogen various from 0.6 to 1.5 L/h according to the operating electron beam energy (different power load of the electron collector).

The key point for a low energy EBIT is that the electron beam is very sensitive to the electromagnetic field distribution on its path through the drift tubes. In order to make sure that the electron beam will pass through the drift tubes with high throughput when the potential difference between the cathode and the centre drift tube becomes very small, the Tricomp (Field Precision [7]) code was used to simulate the electron trajectory under different geometry. Our design for the SH-HtscEBIT was based on the simulations. We chose pure titanium instead of stainless steel for the main structure of the EBIT to make sure a good magnetic property. All the electrodes are made by copper for both good conductivity and good magnetic property.

Table 1: Parameters of SH-HtscEBIT

Parameters	**Achieved**
Electron energy	30-4000 eV
Beam current	10 mA
Beam radius	~65 µm
Vacuum	~1.0×10^{-9} torr
LN_2 consumption	0.6 ~1.5 L/h
Magnetic field	0~0.25 T

OPERATION TEST

During the initial operation of the SH-HtscEBIT, we were able to tune the electron beam energy down to 30 eV with the throughput above 99%. Table 2 show the electron beam current at a number of low beam energies, for the throughput above 99%. Though the electron beam current is relatively small for beam energies below 100 eV, the transmission of electron beam keeps very high. The test run shows that the SH-HtscEBIT can be operating at the electron beam energy as low as 30 eV, although for a lower beam throughput.

Table 2: Electron Beam Current Versus Low Electron Beam Energy

Energy (eV)	**Current (mA)**	**Transmission (%)**
30	1	~99.9
50	2	~99.9
70	3.5	~99.4
100	6	~99.5

In order to test the performance of the SH-HtscEBIT, some spectra from argon have been recorded. Fig. 2 shows a set of visible spectrum of argon taken at the electron beam energy of 600, 700, 800 and 1000 eV, with a beam current of 6.5 mA, and trap depth of 50 eV. The pressure of the gas injection chamber is 5×10^{-6} torr during the data taking. The spectrum was recorded using an Andor Shamrock spectrometer, and the measurement time was 1 hour. The line marked by arrow comes from Ar X $^2P_{3/2}\rightarrow{}^2P_{1/2}$ $M1$ transition. However, the spectra under ultra-low electron beam energy have not been tested, which will be carried out in the next stage of operation.

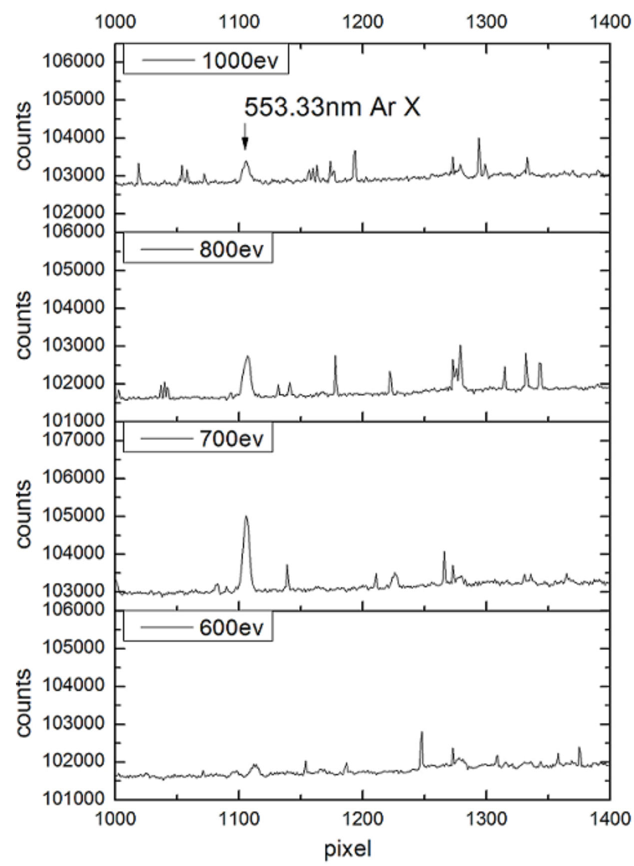

Figure 2: Visible spectra taken at the SH-HtscEBIT, at the electron beam energies of 600, 700, 800, and 1000 eV with a beam current of 6.5 mA, while injecting argon gas. The Ar X $^2P_{3/2}\rightarrow{}^2P_{1/2}$ $M1$ line can be seen to appear with a wavelength of 553.33 nm (marked by arrow).

CONCLUSIONS

Preliminary operation shows that the SH-HtscEBIT has achieved the low electron beam energy to 30 eV. In the next stage of operation, spectroscopic experiments will be carried out.

ACKNOWLEDGMENT

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