A Progress Report of 320 kV Multi-Discipline Research Platform For Highly Charged Ions

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Abstract. A dedicated platform for multi-disciplinary research with highly charged ions has been constructed, and an all-permanent magnet ECR ion source was built and installed in the beamline. Five experimental terminals are established for interdisciplinary research. The high voltage supplied to the platform has reached 320 kV. The commissioning of the platform is successful, different ion beams have been provided for experimental studies, and the current status will be reported.

1. Introduction

The interactions between highly charged ions and materials (atoms, molecules, clusters, surfaces, and bio-molecules, etc) have attracted more and more interest not only in fundamental research but also in many application fields [1]. Low energy highly charged projectiles are usually provided by ECRIS, where their extraction voltage is below 50 kV. EBIS can provide even higher charge state ions but relatively low beam intensities. Several laboratories established very low energy setups or beamlines for surface and/or ion-atom/molecule studies, such as low energy beam line (LEBL) at CIRIL France, [2, 3], or the slow highly charged ion facility at RIKEN. Most big-scale laboratories provide projectile beam energies from several MeV/u up to GeV/u. At Frankfurt university the 14GHz ECRIS was complemented by a beamline for post accelerating ions [4]. As it is well known the stopping power of ions reaches a maximum (the Bragg peak) when the projectile energy is reduced down about from below hundreds keV/u to 1 MeV/u for different target materials. Due to the high density of ionization near the Bragg peak, it is of great importance for radiation therapy, surface modification, and radiation defects, etc. This energy range is therefore of practical interest for interdisciplinary research.

A dedicated platform for multi-disciplinary research with highly charged ions has been constructed at the Institute of Modern Physics (IMP) in Lanzhou, where the projectile energy range was extended to 320q keV (where q is the projectile charge state). The dynamical range of the projectile velocity will be extended from 0.1 a.u. to 2 a.u. covering electron capture dominant channels to ionisation dominant channels. Five experimental beamlines are equipped and the commissioning of the platform has been successful. The recent progress will be reported in the following.
2. **The design and the performance of the platform**

The new facility includes a 320kV high voltage platform, transport beamline, and five experimental terminals. The platform itself sits in an individual room. The new platform facility was planned to be installed in an existing building, where the space is very limited. According to this circumstance the layout of the facility was designed as shown in figure 1. The platform has the dimensions 3000×3100×1600mm. An ECR source, a Glaser lens, an analyzing magnet, electrostatic lens, correction magnets, microwave machine, power supplies, and some diagnostic devices are installed on the platform. All the devices on the platform are powered by an isolating transformer (400kV maximum, 80kW). The maximum voltage applied to the platform is designed to be 320kV.

![Figure 1. Layout of the high voltage platform and equipped experimental terminals.](image1)

To reduce the power load to the platform, an all permanent magnet ECR ion source was designed, which has a dimension of magnetic body of Ø650 mm × 562 mm. Its total weight is 950kg. The overall magnetic field has been measured and compared to the theoretical results; good agreement was obtained. The injection magnetic field of the source is 1.28 T and the extraction magnetic field is 1.07 T. The details of the magnetic design can be found in reference [5]. The ion source is implemented with an oven which can evaporate metallic elements. The ions extracted from the ECR source are first charge-state analyzed and then accelerated when leaving the platform. The extraction voltage of the ECR source can be varied from 7 kV to 30 kV. The ions can also be delivered to experimental area directly without post-acceleration. The beam envelopes for ion transport are shown in figure 2.

![Figure 2. The beam envelopes of the ions from the ECR ion source to experimental terminal No.3.](image2)

The static vacuum of the transport beam line is better than 5×10^{10}mbar. The vacuum is maintained at the 10^{-6}mbar level during operation. The base vacuum condition is 2.0×10^{-6} mbar at the injection side and 9.5×10^{-7} mbar at the extraction side during the run of the facility. The control of the beamline and of the platform are done by a host computer in the control room. All the devices on the high voltage platform are controlled by a local computer which is accessed by the host computer at control room.
via wireless network. The controlling system functions very well for high voltages up to 320kV.

The commissioning of the beamline has been carried out successfully. During the preliminary commissioning, a 14.5 GHz microwave generator has been used to feed rf power directly into the plasma chamber through a WR62 rectangular wave guide. Highly charged ions such as Ar$^{13+}$ and Xe$^{30+}$ have been provided for radiation damage studies and surface experiments. The typical ion currents measured on the platform are listed in table 1. The transport efficiencies are from 60% to higher than 90% for post-accelerated ion beams. Figure 3 shows a typical charge state distribution spectrum optimized for highly charged Xe ions (microwave at 350W, extraction field at 22 kV). Several ion beams were accelerated to 320q keV already (q is the charge state of the ions) and provided to experiments.

![Figure 3. Typical charge state distribution spectrum for highly charged Xe ions.](image)

| Ion species | Charge states | Beam intensities (eµA) | Extraction field (kV) | Microwave power (kW) |
|-------------|---------------|------------------------|-----------------------|----------------------|
| O           | 6+            | 1000                   | 20                    | 1                    |
|             | 8+            | 460                    |                       |                      |
|             | 11+           | 166                    |                       |                      |
| Ar          | 12+           | 60                     | 20                    | 1                    |
|             | 14+           | 15.5                   |                       |                      |
|             | 16+           | 2                      |                       |                      |
| Xe          | 20+           | 83                     |                       |                      |
|             | 23+           | 75                     |                       |                      |
|             | 26+           | 46                     | 23                    | 0.4                  |
|             | 27+           | 27                     |                       |                      |
|             | 30+           | 7.5                    |                       |                      |
| Ne          | 7+            | 65                     | 15                    | 0.4                  |
|             | 8+            | 50                     |                       |                      |
| C           | 4+            | 155                    | 15                    | 0.35                 |
|             | 5+            | 72                     |                       |                      |
| Bi          | 19+           | 23                     |                       |                      |
|             | 21+           | 28                     | 15                    | 0.35                 |
|             | 31+           | 4.6                    |                       |                      |
3. Experimental terminals
The beamlines are equipped with five experimental terminals as numbered in figure 1 [6]: (1) ultra-high vacuum chamber for surface studies, (2) reaction microscope for atomic physics collision dynamics as well as spectroscopy with atomic or molecular target beams, (3) multi-purpose experimental terminal for material science. (the design is flexible and allows the external users to bring their own set-ups for experiments), (4) atomic physics terminal for atomic collision and micro-capillary experiments, and (5) biophysics research, respectively. A photo of the five terminals is shown in figure 4. Experiments using the ions listed in table 1 have been carried out and part of the results are presented in these conference proceedings.

![Figure 4. A photo of the transportation beam-line and the experimental terminals.](image)

4. Outlook
The successful commissioning of the 320 kV multi-disciplinary research platform allow new opportunities for atomic physics, surface studies, and materials research. Various highly charged ions of metallic elements will be provided to experiments. A chopper will be implemented into the beaml ine soon to provide pulsed ion beams. This facility is open to outside and international users.

This work was supported by the key projects of Pilot Project of the Knowledge Innovation Program launched by the Chinese Academy of Sciences and partly by the National Nature Science Foundation of China under grant No. 10434100

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