DREEBIT EBIS/T FOR APPLICATIONS IN ACCELERATOR PHYSICS

M. Schmidt*, A. Thorn, DREEBIT GmbH, Dresden, Germany
G. Zschornack, Technische Universität Dresden, Dresden, Germany

Abstract

Electron Beam Ion Sources and Traps (EBIS/T) provide light up to heavy ions of low up to high charge states for various applications in accelerator physics such as medical particle therapy and charge breeding. Beside the well-known but quiet costly superconducting EBIS/T type systems compact and permanent magnet-operated EBIS/T from the DREEBIT GmbH are available, favorable for low-budget projects. Moreover, the "flagship" of the DREEBIT ion source family, the superconducting EBIS-SC features operating parameters comparable to the complex and expensive systems in the EBIS/T community.

HIGHLY CHARGED IONS

Properties

Highly charged ions yield interesting properties, in particular for accelerator physics. They feature a very efficient acceleration potential since the kinetic energy gain increases linearly with the charge state for electrostatic accelerator and even quadratically with the charge state for circular accelerators. Furthermore, the potential energy of highly charged ions leads to high power deposition into surfaces connected with higher secondary particle emission at ion solid interactions.

Production

However, the production of highly charged ions (HCIs) has led to different technological approaches, such as ion stripping in ion accelerator structures, ECR ion sources, laser ion sources and Electron Beam Ion Sources/Traps (EBIS/T). Beside the mentioned technologies EBIS/T systems have proved as reliable and stable working sources of HCIs of the highest charge states.

EBIS/T

EBIS/T ionize initially neutrals and low charged ions in magnetically compressed high-dense electron beams up to high and very high charge states. Already small amounts of bare uranium ions have been produced.
Normally, such EBIS/T facilities feature special, sophisticated and complex laboratory installations of the superconducting ion source type.
There are only two suppliers in the world offering commercial EBIS/T systems. One of them is the DREEBIT GmbH Dresden (Germany) marketing a whole family of EBIS/T systems.

The room-temperature Dresden EBIS/T with permanent magnets feature operating parameters which suit most of the user requirements at by far lower initial as well as maintenance costs (see Fig. 1). In addition, in order to satisfy the need for increased ion output, a liquid helium free superconducting EBIS (Dresden EBIS-SC) with closed-cycle refrigerator technology is available complementing the ion source portfolio of the company (see Fig. 2).

USER-SPECIFIC ION IRRADIATION FACILITY

Based on its ion source knowledge the DREEBIT GmbH has designed and comissioned several customer-specific ion irradition facilities equipped with Dresden EBIS/T systems (see Fig. 3). The facilities are complemented with the necessary ion optics and ion diagnostics such as Einzel lenses, deflectors, quadrupol beam bender, accel/decel lens systems, Wien filter, Pepper-Pot-Emittance Meter, Retarding-Field Analyzer, Faraday cups. Individual target chamber and target transfer systems. In dependence on the user need different configurations of ion sources and beamline equipment as mentioned above have been accomplished.

Figure 1: Room-Temperature EBIS/T.

APPLICATIONS

EBIS/T systems have been succesfully operated in low energy beamlines so far. In order to extend the application potential investigations on charge breeding as well as in medical particle therapy have been done.

* mike.schmidt@dreebit.com

Figure 2: EBIS-SC.

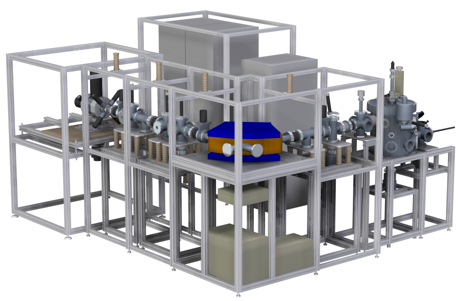

Figure 3: Ion Irradiation Facility L.

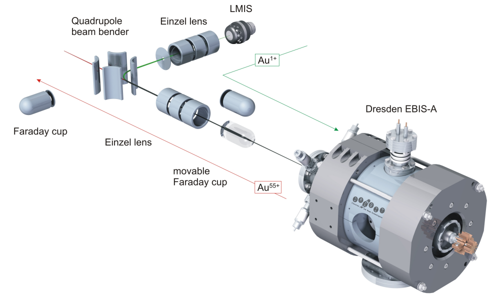

Figure 4: Charge breeding setup with an EBIS-A.

Charge Breeding

Charge breeding via external injection in EBIS/T complements the portfolio of available elements for the production of highly charged ions. In particlular the production of short-living radioactive isotops and their efficient post-acceleration as well as the exact mass determination of them makes efficient charge breeding necessary. [1]. Thereby the species of interest is produced outside the ion source and subsequently injected into the EBIS/T, e.g. as an beam of low charged ions. In the EBIS/T charge breeding converts the low charged ions to highly charged ions.
Proving the charge breeding ability and efficiency experiments with gold have been done with a Dresden EBIS-A [2]. A liquid metal alloy ion source was used for producing low charged gold ions extracting them and subsequently injecting them into the EBIS-A for charge-breeding and reextraction after ionizing (see Fig. 4).

Medical Particle Therapy

Cancer is the second most common cause of death in the industrial nations. Hence every 3rd person will confront some kind of cancer in its life. About 45 percent of cancer patients can be treated, mainly by surgery and radiation therapy, respectively [3]. Thereby hadron therapy with protons and carbon ions is the second most successful technique in cancer treatment, outmatched only by surgery. Up to now about 71000 patients were treated by particle therapy at 32 particle therapy centers (Europe, USA, Japan, China, South Africa). The trend is increasing.

In contrast to other radiation therapies the ion therapy features a high biological efficiency causing lethal damage in the tumor cells and leaving the healthy tissue intact (BRAGG interaction).

Compared to currently used ionsources (primarily ECR ion sources) in medical particle therapy facilities EBIS/T systems feature significantly better beam quality (emittance). Furthermore the beam purity, a stringent requirement for patient irradiation is much higher since plasma ion sources like ECR work at operating pressures in the order of 10^6 mbar (mixing of C, N and O in the plasma) but EBIS/T usually with 10^{-8} mbar and better.

In addition, EBIS/T suit the pulse mode operation regime required by accelerator facilities such as synchrotrons and cyclotrons since they are normally operating in pulsed mode anyway.

Preliminary proof-of-concept experiments with Siemens Medical have been accomplished. As a next step experiments with a Dresden EBIS-SC at the Heidelberg Hadron Therapy Facility HIT are scheduled for 2013.

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