THE ORNL MULTICHARGED ION RESEARCH FACILITY (MIRF) HIGH VOLTAGE PLATFORM PROJECT*

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Abstract

A new 250 kV high voltage platform has been installed at the ORNL Multicharged Ion Research Facility (MIRF) to extend the energy range of multicharged ions available for experimental investigations of their collisional interactions with electrons, atoms, molecules, and solid surfaces. A new all-permanent magnet Electron Cyclotron Resonance (ECR) ion source, designed and fabricated at CEA-Grenoble, was installed on the platform to produce the ion beams of interest. Design details of the new platform and beamlines, and their associated beam transport, are presented below.

MIRF UPGRADE PROJECT

The MIRF upgrade project [1] consists of two parts. The first entails the installation of a 250-kV high-voltage platform, for use in conjunction with a new all-permanent magnet ECR ion source. In addition to extending the energy range of multicharged ions available for experimental investigations of their collisional interactions with electrons, atoms, molecules, and solid surfaces, higher energy MCI beams will allow new classes of experiments. In late January of 2005, this first, and most challenging, phase of the upgrade project was completed, and routine operation started. Ion beams were successfully accelerated from the platform at potentials up to 215 kV, and transported with 100% efficiency through the first section of the new high-energy beamline. By end of February, first ion beams extracted from the new all permanent magnet ECR had been transported for initial diagnostics tests to two already installed end stations, the Merged Electron Ion Beam Energy Loss (MEIBEL) experiment, and the Ion-Atom-Merged-Beams Experiment [2]. By end of April, a first experimental run had been completed in which the new platform provided beam for over 100 hours in continuous operation.

The second part of the upgrade project entails relocation of the present CAPRICE ECR ion source with standard 25-kV isolation and beam extraction into a new floating beamline to expand the availability of very low energy MCI beams. Using this approach, beams of 10-20keV/q energy (where q is the charge state of the ion of interest) will be transported with high efficiency and then decelerated to a few eV x q upon entry into various experimental chambers at ground potential, using efficient ion optics already developed for the MIRF floating ion-surface interaction experiment. With these two sources, an energy range of almost five orders of magnitude will be available to the various experiments, a significant improvement over the 1-25 keV/q energy range capability of the present MIRF source configuration. The number of user ports available for non-dedicated experiments will be expanded as well. The final layout of the upgraded facility is shown in Fig. 1.

ECR ION SOURCE

The ECR ion source was designed and built at CEA-Grenoble. The source, shown in Fig. 2, features a 1 T radial magnetic field at the plasma chamber wall, an axial magnetic field maximum of 0.9 T on the extraction side, a minimum axial field of about 0.4 T, and a 1.3 T magnetic field maximum at the injection side, achieved by compact NdFeB permanent magnet assemblies for the radial hexapolar and axial solenoidal fields. The high injection side field was achieved by use of an iron plug inserted from the rear into the plasma chamber, with penetrations for microwave injection, biased disk support, gas feed, and a mini-oven for ion beam production from solids. The plasma chamber has an inner diameter of 50 mm and is double walled to permit coolant circulation for protection of the immediately adjacent permanent magnet assemblies. Beam formation is achieved using a two electrode extraction system, the first of which can be biased at up to – 5kV, with the second at ground potential. The injected microwave power is provided by a 700 W traveling wave tube (TWT) amplifier, whose output can be varied in the frequency range 12.75 – 14.5 GHz. The HV isolation of the source is sufficient to operate at more than +25kV relative to the platform potential. A more detailed description of the new ECR source is presented in [3]. The performances of the new ECR source exceed those of the facility's present 10 GHz CAPRICE source by up to factors of 2-3 in the case of the highest charge state Xe ions.

*Work supported by OBES and OFES of the U. S. Department of Energy under contract DE-AC05-00OR22725 with UT-Battelle, LLC
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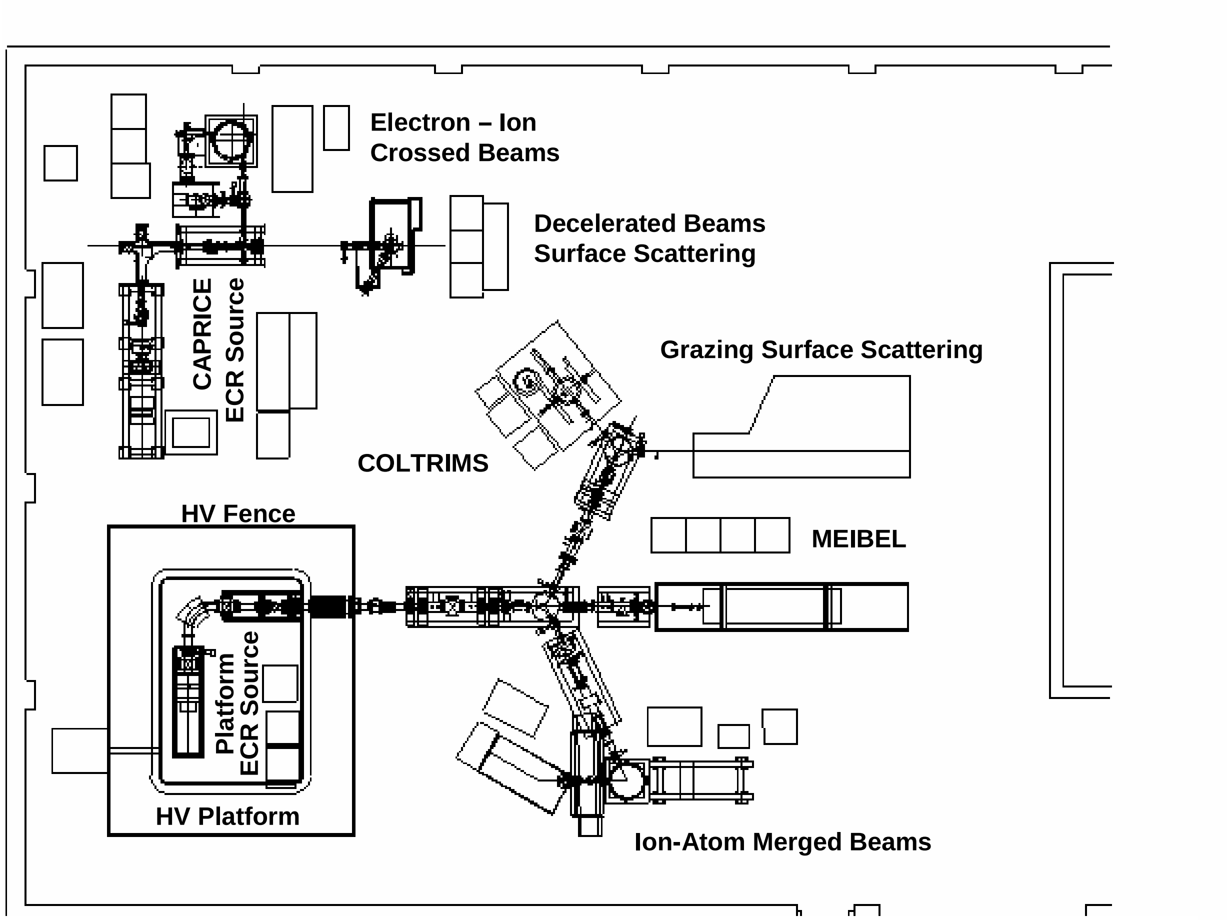

Figure 1: Layout of the upgraded ORNL Multicharged Ion Research Facility, showing the new 250 kV High Voltage platform and the relocated CAPRICE ion source with floating beamline.

BEAM TRANSPORT SYSTEM

The design energy range of the high voltage platform is 20 – 270 x q keV. To achieve this wide energy range with maximum beam transmission, a number of specific

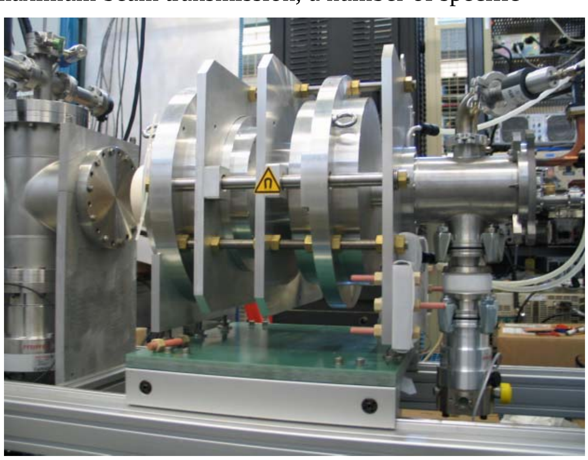

Figure 2: High Voltage platform all permanent magnet ECR ion source from CEA-Grenoble.

features were incorporated into the design of the beam transport system. All effective optic element apertures on the platform (including the usable analyzing magnet gap) and up to, and including, the first 65 degree spherical deflector beam switcher, shown prior to installation in its vacuum chamber in Figure 3, were designed for 100% beam transport for beams having an unnormalized emittance of 160 π·mm·mrad at 20 x q keV. This large acceptance was achieved for the electrostatic beam switcher by the use of two interchangeable sets of deflection electrodes, the first with a 2.5 inch gap to handle beams up to about 150 x q keV, and the second set with a 1.5 inch gap to handle the lower divergence-angle beams at energies beyond this value. In addition, two einzel lenses were added on either side of the acceleration column to permit refocusing of the beam at the entrance waist of the tandem quadrupole triplet section for low platform voltages where the focusing of the acceleration column itself is weak or non-existent. Finally, large 2-inch-acceptance-aperture quadrupole lenses were used in a tandem configuration before the first beam switcher to achieve both high transmission at low energies and sufficient focusing power with ± 20 kV electrode potentials at high energies. Calculated beam envelopes for the two energy extremes are shown in Figure 4.

The 65^{o} spherical sector electrostatic deflector beam switchers, together with the slit assemblies, are mounted on turntables supported by a ceramic ball bearing race. The turntables are externally rotated about a vertical axis to one of three positions: the first two direct beam either into the left or right beamline, by a rotation of 115° that reverses entrance and exit planes of the deflector, and the "straight-thru" position allows the beam to pass undeflected through the chamber past the outside of the "outer" electrode structure, which has a milled slot to accommodate up to 1 in. diameter beams.

CONTROL SYSTEM

As described in greater detail elsewhere in this conference proceedings [4], monitoring and control functions on the HV platform as well as the beamlines leading to the various end stations are achieved via Allen-Bradley ControlLogix I/O modules located in four separate chassis linked by Ethernet-bridge-driven fiber-

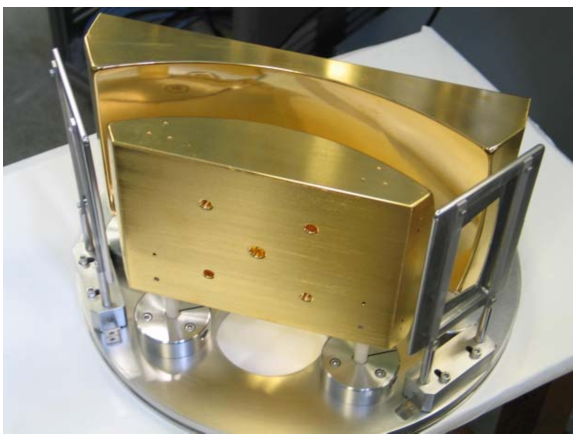

Figure 3: Large-aperture 65 degree spherical sector beam switcher on an externally rotatable turntable for directing beam to the various on-line experiments.

optic cables and controlled by a single Logix5555 processor at ground potential. Several devices employ serial protocols over RS-232 or GPIB communication channels. All devices are integrated into a Linux-hosted, EPICS-based distributed control system which provides device independent, uniform access to all hardware via a distributed real-time database.

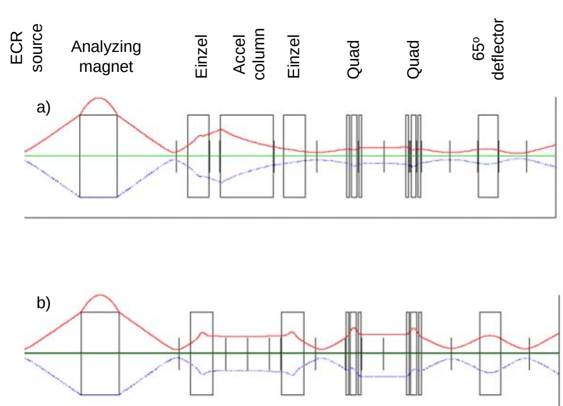

Figure 4: Beam envelopes for the highest and lowest design energies: (a) 270 keV/q and (b) 20 keV/q.

PLATFORM COOLING AND POWER

All active cooling of platform components is achieved "on-board", and is thus independent of the Holifield Radioactive Ion Beam Facility (HRIBF) cooling tower. The microwave power amplifier for the ECR source is cooled by 250 CFM of forced air flow. Sufficient cooling of the ECR source to permit operation at injected microwave power levels up to 750 W is critical in order to avoid irreversible de-magnetization of the NdFeB permanent magnet structures. It is achieved using a NESLAB recirculating chiller with deionizer, operating at platform potential. The resistive losses in the analyzing magnet coils approach 10 kW when transporting beams with maximum magnetic rigidity. This heat load is dissipated by closed-loop circulation of cooling water through a finned-coil radiator with forced air flow of 1500 CFM. The water circulation is achieved by a centrifugal water pump capable of providing a 2 GPM flow rate at 80 psi head pressure, and the necessary air flow is achieved using a directly driven ducted fan. For optimum space utilization, the heat exchange/fan assembly was installed above the analyzing magnet.

Electrical power to the platform is supplied by an efficient 250 kV mineral-oil-filled isolation transformer capable of providing up to 30 kW of three-phase 208 V power. This power is distributed to the various platform and source potential electrical components via a balanced single and three phase distribution network fed from the isolated transformer Y-connection with loadable midpoint (N) at the end of an oil-filled nylon pylon extending across the 29 inch gap between ground enclosure and HV platform. Total power required by platform components in the present configuration is a little over 20 kW, leaving almost 10 kW available for future expansion.

ACKNOWLEDGEMENTS

DH gratefully acknowledges L. Guillemet, J. Chartier, and G. Rey-Giraud (CEA-Grenoble) for their work during the conception and construction of the ECR ion source.

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 0-7803-8859-3/05/$20.00 ©2005 IEEE