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The ORNL multicharged ion research facility upgrade 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. For the production of the multiply charged ions, a new all-permanent magnet electron cyclotron resonance (ECR) ion source, designed and fabricated at CEA/Grenoble, is being used. After a brief summary of the project background and the expanded research program made possible upon its completion, design details of the new platform, associated beam transport and control system are presented, together with information on the design and performance of the new ion source.

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1. Introduction

While developed initially as an injector for high-energy accelerators, in recent years the electron cyclotron resonance (ECR) ion source has become an indispensable tool in the field of multicharged ion (MCI) collision physics. In fact, the availability of low energy, intense, high charge state, high duty factor, ion beams from ECR sources has opened many areas of MCI research that have previously been inaccessible. Examples include investigations of low-energy collisions involving bare ions of $Z > 5$, merged-beams experiments, studies of electron–ion collisions and investigations of MCI–surface interactions [1]. Due to their great utility in atomic physics research, the number of ECR sources available, at least part time, for use in the study of MCI collisions has grown dramatically over the past 10–15 years.

At Oak Ridge, the ECR-source-based ORNL multicharged ion research facility (MIRF) has been in existence since 1984. The original ORNL ECR source, locally designed and built, was the first such source completely dedicated for use in atomic physics studies, and was able to provide fully stripped low-Z ions up to Ne of sufficient intensity to enable among the first collision studies with such ions. With the installation of a 10-GHz CAPRICE ECR ion source in 1992, carried out as part of a DOE-funded upgrade project to take advantage of ECR source developments that had occurred since the commissioning of the first generation ORNL ECR source, significant increases in ion beam intensities and attainable charge states were realized.

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2. The MIRF upgrade project

In FY 1997, a capital equipment project was initiated for a major facility upgrade. The upgrade project 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 expanding the capabilities of present on-line experiments, higher energy MCI beams will allow new classes of experiments. The second part entails relocation of the present CAPRICE ECR ion source with the standard 25-kV isolation, to extend the availability of very low-energy MCI beams. By using a floating beamline approach, keV-energy beams will be transported with high efficiency and then decelerated to a few eV $\times q$ (where q is the charge state of the ion of interest) 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 layout of the upgraded facility is shown in Fig. 1.

3. Expanded research capabilities

The energy range between 25 and $250 \times q$ keV is at present virtually inaccessible for highly charged ion collision experiments requiring beam intensities in the particle-μA range. The maximum energy with the present CAPRICE ECR ion source is $25 \times q$ keV, typical of most ground-based ECR and electron beam ion sources. Conventional accelerators cannot produce highly charged ion beams with sufficient intensity at energies below a few hundred keV per charge, due to the inefficiency of gas or foil stripping at lower energies.

Upon completion of the MIRF upgrade, a broad range of new experiments involving high charge state ions will be possible. In this energy range, the behavior of MCI collision systems evolves from the low-energy "molecular" to the intermediate-energy "atomic" regime, and experimental data are essential for benchmarking calculations in this theoretically challenging transition range. The near-threshold behaviors of, e.g. heavy-particle collisional ionization, inner shell excitation and vacancy transfer processes are still not fully elucidated and require additional experimental data to validate progress in theoretical understanding.

In addition, all the online experiments at MIRF will benefit greatly from the higher energy beam capability developed by this project. For example, the merged

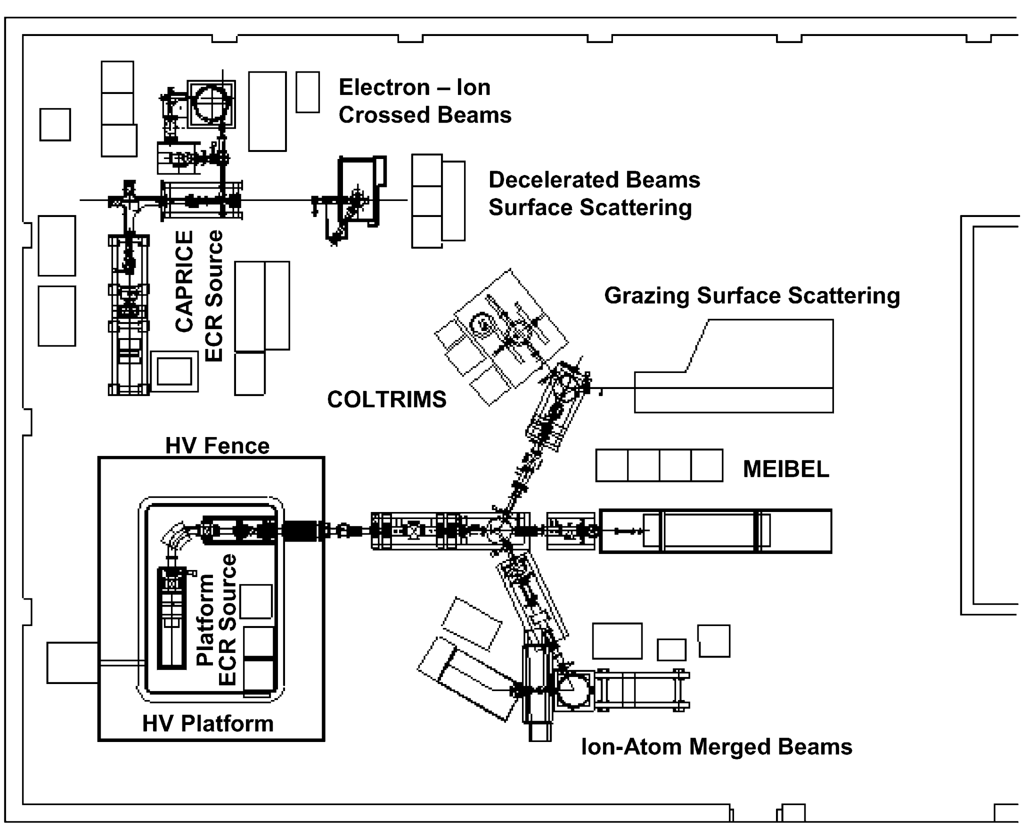

Fig. 1. The layout of the upgraded MIRF.