THE NEW ORNL MULTICHARGED ION RESEARCH FACILITY FLOATING BEAMLINE*

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Abstract

We report on the development and implementation of a new beam line at the ORNL Multicharged Ion Research Facility (MIRF) that is floatable at up to -12 kV and injected by a 10 GHz CAPRICE ECR ion source and is part of a major facility upgrade project [1,2]. With the floating beam line operating at negative high voltage, and the ECR source at ground potential, intense dc beam deceleration into grounded experimental chambers to energies as low as a few eV/q is made possible. The primary application of these ion beams is to study fundamental collisional interactions [3] of multicharged ions with electrons, atoms, and surfaces. Design details of the floating beam line, including source extraction, deceleration optics and voltage isolation will be presented at the conference. The novel features of a LABVIEW-based computer control system developed for the floating beam line will be described as well.

INTRODUCTION

After the recent installation of a new 250 kV HV platform together with a new all-permanent magnet ECR ion source that significantly increased the energy range of ion beams available at MIRF for atomic physics research, the second phase of the facility upgrade was begun. In this phase, the existing CAPRICE ECR ion source was relocated within the laboratory and coupled to a new electrically floating beam line to permit efficient deceleration of intense beams into grounded experimental chambers down to a few eV/q, and thereby enable investigations of low energy gas phase collisions and ion-surface interactions in an energy regime where only few measurements exist to date. With the recent completion of this upgrade phase, the range of available ion energies at MIRF has been increased to cover more than five orders of magnitude.

FLOATING BEAMLINE

The beam line vacuum pumps, ion gauges, vacuum valve controls, as well as the analyzing magnet body, were kept at ground potential by addition of suitable HV isolation between these components and the beam line and/or magnet vacuum box. The analyzing magnet gap was increased to permit insertion of Teflon sheeting between the grounded pole pieces and the floating vacuum box, as shown in Figure 1. The ECR beam extraction section was modified by addition of HV isolation capable of standing off up to -15 kV between source body and beam line even in the presence of the substantial magnetic fringe field that exists in the extraction region when the ECR source is in operation.

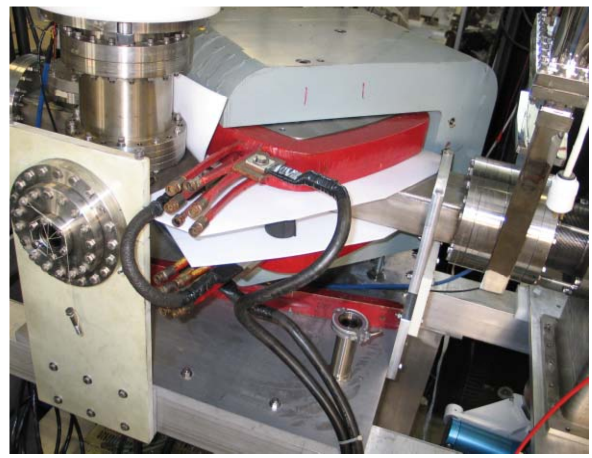

Figure 1: HV insulation of the main analyzing magnet.

This was achieved by replacing the aluminum extraction insulator clamp by one of slightly smaller OD machined from Delrin, and adding Delrin insulation between the grounded extraction side source body and the nearby floating extractor assembly, as illustrated in Figure 2.

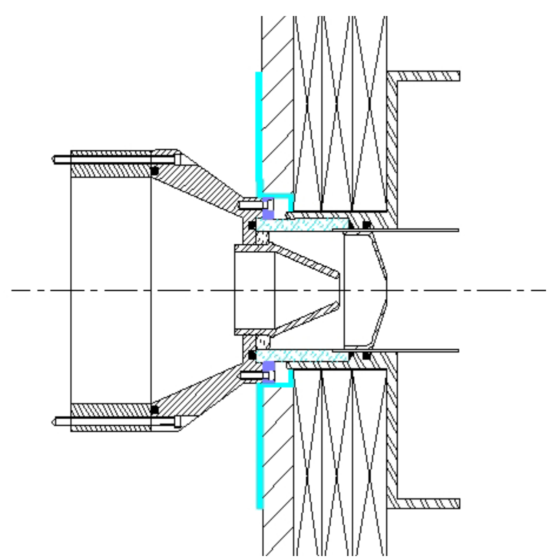

Figure 2: HV insulation of the source extraction region, showing the two added Delrin insulators (solid colors). The main extraction insulator is indicated by blue zipping.

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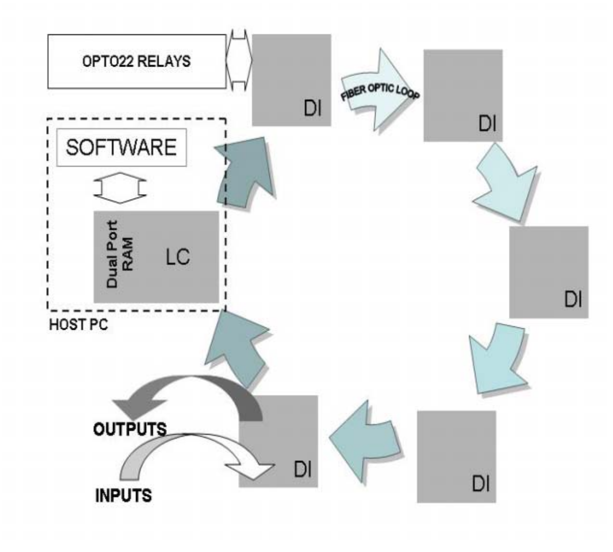

Figure 3: Caprice ECR/Floating beam line control system network diagram. Communication between the host PC loop controller (LC) and the device interfaces (DI) is via fiber optic cables.

Prior to resumption of routine operation, tests of beam extraction from a grounded source into the beam line biased at -10 kV verified proper operation of the floating beam line ion-optic components, and the integrity of the HV isolation.

Routine ion beam delivery to end stations relocated and connected to the new beam line started April 2006, with the beam line operated at ground potential and under manual control. In January 2007, a LABVIEW and PC-based control system became operational, using in large part components originally used on an EN-Tandem control system. The control system is described in greater detail in the following section.

CONTROL SYSTEM DETAILS

In contrast to the control system for our new HV platform, based on Allen Bradley ControlLogix hardware and the EPICS interface [4], the control system for the floating beam line was implemented using Group3 ControlNet and OPTO22 hardware controlled in a LabVIEW visual programming environment.

Group3 ControlNet [5] hardware is a fiber optically linked distributed control system that serves as the hardware backbone of the floating beam line control system. The fiber optic communications link allows for high speed data transmission and high voltage and noise isolation. Data is sent over a fiber optic ring network topology to small intelligent Device Interfaces (DI's) that contain up to three different I/O boards each – ADC's, DAC's, digital I/O, etc. Up to 16 DI's can be placed on a single fiber optic loop and/or individual loops can be operated in the interest of update speed or system size. The DI's are controlled via a PC card loop controller which contains dual port RAM accessible by both the loop controller and the host PC. The loop controller also handles all fiber optic communications so that the host PC experiences no communications overhead. To read inputs and set outputs, the control computer merely reads and writes to the dual port RAM on the loop controller. The microprocessor on the loop controller then lifts this information, packages it appropriately and sends it out on the fiber optic loop. Within each DI is a processor that decodes the information in the message packet and sets outputs accordingly for its I/O boards, repacks the message with any input information, and sends it back on the loop. The loop controller in the control computer then unpacks the input information and stores it in the dual port RAM, from where a control program can retrieve the values of interest. In this manner, information is transmitted over the loop at up to 1.152 Mbaud, continually refreshing outputs and scanning inputs in a transparent manner. Figure 3 shows a schematic overview of the floating beam line Group3 ControlNet system. The current system uses five DI's, with three I/O boards each, on a single fiber optic loop. OPTO22 [6] 110VAC reed relays are used to control pneumatic values and linear actuators. This is easily implemented, because the Group3 Digital I/O board connects directly to the OPTO22 digital I/O mounting rack system.

The software side of the control system is based on a client/server architecture with a database acting as an intermediary between the human interface and the Group3 control hardware. The open source LuaVIEW [7] data logging package was chosen to serve as the basis for a database-driven Supervisory Control And Data Acquisition (SCADA) system with client/server architecture to allow for remote operation. LuaVIEW implements the Lua scripting language in the LabVIEW environment. The prepackaged LuaVIEW data logger can be easily used to establish a database of process variables represented as tags. The tags can then be given limit and/or warning values, in which alarms or errors can be registered or logged. Tag values can also be logged to disk using a number of different logging algorithms, e.g., time-based, event-based, threshold-based, or a combination of these. The LuaVIEW documentation suggests that it is possible to obtain a processing performance of 5,000 -10,000 number tags per second per GHz of CPU, including logging to disk. The current host control PC has a hyper threaded CPU running at 2.8 GHz with 1 GB of RAM. This has proven to be adequately fast for operation of the floating beam line and ECR source. It is more likely that the Group3 update speed is the bottleneck in performance.

The server side of the control system consists of a continuously iterating loop which reads and writes values between the Group3 hardware and the database. The human interface control screen, shown in Figure 4, is produced by an event-driven client that writes control values to the database and continuously reads back acquired values for display. In this way, the human interface client can be located anywhere on the network and is not required for continued operation of the hardware, since data logging operations and hardware interlocks are contained on the server side. This client/server architecture also allows for other specific use programs to be developed, e.g., mass scanning utilities, strip chart recorders, etc. An example of this is shown in Figure 5, which shows a floating beam line mass scan

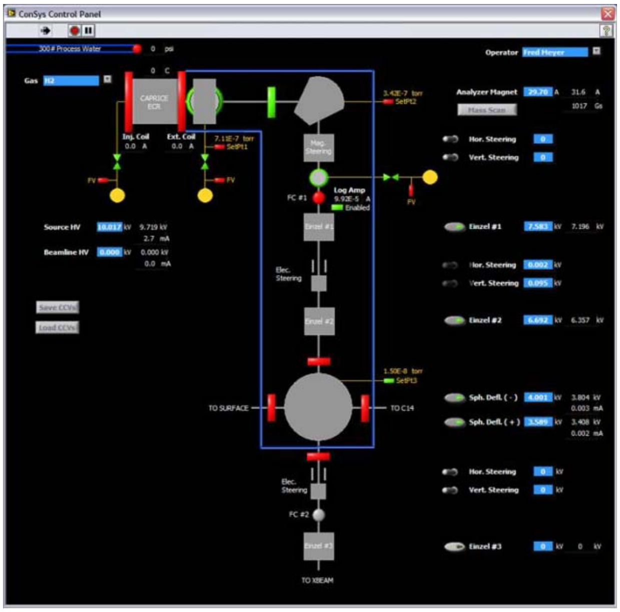

Figure 4: Control screen for monitoring and control functions.

utility screen. Using this utility, mass scans can be displayed either as function of analyzer magnet current or magnetic field. Peak identification is facilitated by an optional display of the m/q value of selected peaks based on the known scaling as function of analyzer setting.

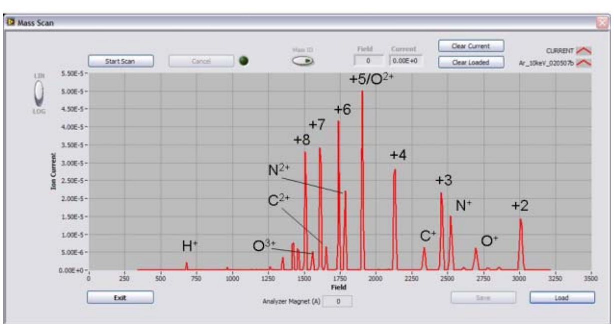

Figure 5: Control screen of the mass scan utility, showing an unoptimized Ar charge state distribution.

SUMMARY

In this article a brief description has been given of the new Caprice Floating Beam Line and associated control system recently developed at the ORNL Multicharged Ion Research Facility, which, together with the construction of a 250 kV high voltage platform and acquisition of an all permanent magnet ECR ion source, was part of a major, multiyear, facility upgrade.

With the new floating beam line, efficient ion beam deceleration down to a few eV/q is achieved, which will permit investigation of new low-energy collision and interaction experiments at the facility.

Development of a computerized control system has greatly facilitated beam transport to the on-line end stations. The control system is convenient and easy to use, and is enhanced by the capability of data logging of vacuum, ion beam intensity, and other process variables, the implementation of a tuning parameter data base for easily restoring prior settings, and various ancillary utility programs.

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[6] http://opto22.com/

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