A MULTICHANNEL DEFLECTION PLATES CONTROL SYSTEM FOR THE ALF FACILITY AT THE APS *

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Abstract

A deflection plates control system was developed as part of SPIRIT (Single Photon Ionization / Resonant Ionization to Threshold), a new secondary neutral mass spectrometry (SNMS) instrument that uses tunable vacuum ultraviolet light from the APS ALF (Argonne Linear Free-electron laser) facility for postionization. The system comprises a crate controller with PC104 embedded computer, 32 amplifiers, and two 1-kV power supplies. Thirty-two D/A converters are used to control voltages at the deflection plates within ± 400 V with 100-mV resolution. An algorithm for simultaneous sweeping of up to 16 XY areas with 10-µs time resolution also has been implemented in the embedded computer. The purpose of the system is to supply potentials to various ion optical elements for electrostatic control of keV primary and secondary ion beams in this SNMS instrument. The control system is of particular value in supplying (1) bipolar potentials for steering ions, (2) multiple potentials for octupole lenses that shape the ion beams, and (3) ramped deflection potentials for rastering the primary ion beam. The system has been in use as part of the SPIRIT instrument at the ALF facility since 2002.

INTRODUCTION

The shaping and steering of charged particle beams using electrostatic potentials is a well-developed technology that has reached a high level of sophistication thanks in part to progress in computer codes that can accurately calculate particle trajectories [1]. This in turn has led to improved designs for instruments that use ion beams and to more precise control of charged particle beams. However, such advances often come at a price, for the number of electrostatic ion optical elements employed may be large and their arrangement complex. A case in point is the newly designed SPIRIT instrument [2], recently installed at the ALF facility at the APS [3]. SPIRIT is a secondary neutral mass spectrometer consisting of a reflectron time-of-flight mass analyzer and designed to incorporate three ion guns for ion beam bombardment [4]. To steer and shape primary ion beams to the sample surface and to direct photoions through the mass spectrometer to the detector requires that more than 60 separate potentials be applied to steering electrodes and Einzel lenses. To control such a large number of power supplies directly from a desktop computer using traditional multifunction boards is cumbersome. Instead, a multichannel deflector control system has been specifically designed for this instrument. The designed and constructed system supplies potentials to four

octupole lens and deflection systems of the SPIRIT instrument. Octupole systems are particularly useful because they can both shape and deflect a charged particle beam without introducing noticeable aberrations. In the SPIRIT instrument, electrostatic octupoles are used to improve both the extraction efficiency (sensitivity) and mass resolution of the mass spectrometer. An additional octupole lens on a primary ion beam is used to maintain the optimal shape of the beam as it is bent onto the axis of the instrument for low-energy, normal-incident ion bombardment [2]. Also incorporated into the deflectors control system is an option for ramping potentials so that octupoles can be used to sweep the primary ion beam across the target surface in a raster patern for ion beam milling (cleaning of the surface).

HARDWARE DESIGN

The system block diagram is shown in Fig. 1. It includes a crate with a proprietary backplane, a crate controller with PC104 embedded computer, four 8-channel high-voltage amplifiers, and two 1-kV power supplies. The system contains 32 analog outputs that can be independently programmed from -400 V to +400 V via a serial port.
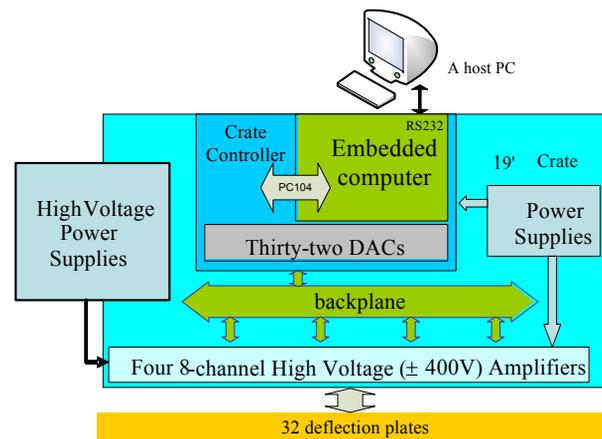

Figure 1: Block diagram of the deflection plates control system.

Crate Controller

The crate controller is a module (Fig. 2) containing two boards: a 3U board with 32 D/A converters and a single-board computer (SBC) with the standard PC/104 bus as an internal interface. Thirty-two D/A converters are used to control high-voltage amplifiers. The SBC AIM104-386EX from ARCOM Control Systems Ltd. has an Intel 386EX 33MHz processor with 1 Mb SRAM and 1 Mb FLASH. This SBC has been earlier employed in other

systems at the APS as an embedded computer and has shown high reliability working in a harsh industrial environment [5].

Figure 2: Crate controller.

Deflection Plates High-Voltage Amplifier

There are eight independent channels in the module (Fig. 3). Each channel contains a high-voltage MOSFET power operational amplifier PA97 from APEX Microtechnology Corp. with maximum supply voltage ±450V, output current up to 15 mA, and a slew rate up to 8 V/µs. The output has a short circuit protection.

Figure 3: Deflection plates high-voltage amplifier.

The address of each module is set via jumpers and can be placed in any position in the crate. All outputs can be programmed either to hold a voltage or to ramp the voltages over a range in order to produce a raster pattern.

Amplifiers supply potentials to the deflection plates within ± 400 V with 100-mV resolution. Bipolar potentials are used for steering ions. Multiple potentials can be applied to octupole lenses for shaping the ion beam [2].

FIRMWARE AND SOFTWARE

Firmware

The firmware for the embedded computer has been developed using Borland C++ 5.02 and Remote Turbo Debugger. The firmware provides communication with a host computer over a serial port. The following commands are implemented:

C0   X – Raster control (X=0, stop sweeping; X=1-start sweeping)

C1   – Clear communication port buffers

C2 $Vx(0)Vy(0)Vx(1)Vy(1)…Vx(15)Vy(15)$ – Write DC values. DACs are addressed sequentially in pairs. The string can be truncated at any pair of values.

C3 $Rx(0)Ry(0)Rx(1)Ry(1)…Rx(15)Ry(15)$ – Write raster range values.

C4 $n\ Vx(n)\ Vy(n)\ Rx(n)\ Ry(n)$ – Write voltage and range values for a specific XY pair.

C5   xStep Ystep nCycles End – Write raster parameters. xStep and yStep are the numbers of voltage steps to raster the xRange and yRange during a raster sequence, accordingly. nCycles is the number of raster frames before stopping the raster sequence. END is a flag that controls the voltage after the raster sequence: if END=0, the output will be set to 0 volts after the raster is complete; otherwise, it will stay at a previously set DC value.

C6 $F(0)\ F(1)…F(15)$ – Selectively enable channels for rastering. If F(n)=0, the output pair XnYn remains in DC mode during the raster; otherwise, it will be ramped during the raster.

C7   Time – Set dwell time for each point during a raster sequence. Time is between 50 µs and 0.32 s.

C8 $n\ Vx(n)Vy(n)$ Write DC values individually. Where n is the XY pair of channels given as a decimal number between 0 and 15; $Vx(n)$ and $Vy(n)$ are the DC voltages.

C9   Baud – Change the baud rate of the communication port.

C10 Set all outputs to 0 volts.

C11 Flags – Enable/Disable rastering for all channels. If Flags=0 – disable all channels; otherwise, enable all channels.

C12 Ranges – Set raster ranges for all channels to one value within ± 400 V.

C13 Volts – Set DC voltages for all channels to one value within ± 400 V.

Raster Scan Algorithm Implementation

An algorithm for rastering the primary ion beam has been implemented in the embedded computer (Fig 4). For this purpose, the outputs are grouped into X (all even channels) and Y (odd channels) deflections. When

communicating with the crate controller, each XY pair is addressed together. Data for simultaneous scanning of up to 16 XY areas can be downloaded into the embedded computer. Each area is described by center of the area Vx(n)Vy(n) and width of raster Rx(n)Ry(n). The raster time sequence is controlled by interrupts from internal timers of the embedded computer. The X and Y deflection ramps are stepped in a "snake" pattern from upper left to lower right corner and then backward. When a raster is started, the sync pulse is provided by the crate controller for synchronization with the SPIRIT instrument. The pattern is repeated a set number of times. When finished, the voltages are set to the predefined DC values.
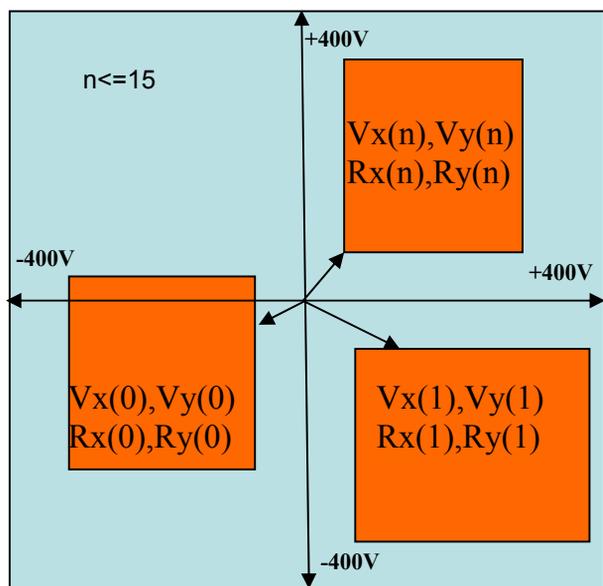

Figure 4: Raster scan algorithm.

Software

A single executable file controls all aspects of the SPIRIT instrument including instrument operations, data collection, display, and data storage. Code was incorporated into this software for operation of the multifunction deflectors control system using the instruction set defined above. The operator interface was in the form of an interactive window that allowed potentials on the electrostatic octupoles to be modified to produce deflection and/or stigmation/shaping of the charged particle beam.

Shown in Fig. 5 is the octupole control window for the SPIRIT software.
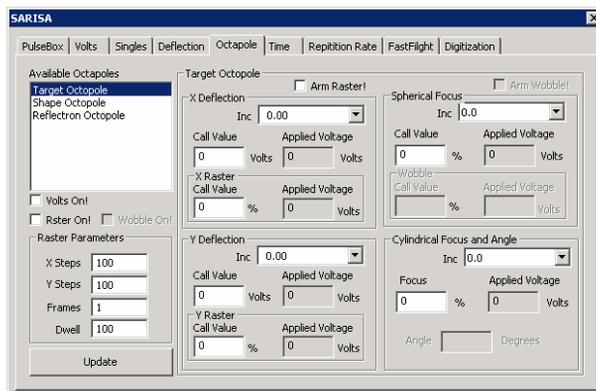

Figure 5: The window in the SPIRIT software that is used to control the multifunction deflection plates control system connected to the octupole lenses.

Since instructions to deflect or to focus an ion beam require the potentials on all eight elements of an octupole to be modified, algorithms were written that convert these higher-level instructions to commands that make appropriate changes to the potentials of all the octupole elements.

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