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CRionScan: A stand-alone real time controller designed to perform ion beam imaging, dose controlled irradiation and proton beam writing

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ABSTRACT

High resolution ion microbeams, usually used to perform elemental mapping, low dose targeted irradiation or ion beam lithography needs a very flexible beam control system. For this purpose, we have developed a dedicated system (called "CRionScan"), on the AIFIRA facility (Applications Interdisciplinaires des Faisceaux d'Ions en Région Aquitaine). It consists of a stand-alone real-time scanning and imaging instrument based on a Compact Reconfigurable Input/Output (Compact RIO) device from National Instruments™. It is based on a real-time controller, a Field Programmable Gate Array (FPGA), input/output modules and Ethernet connectivity. We have implemented a fast and deterministic beam scanning system interfaced with our commercial data acquisition system without any hardware development. CRionScan is built under LabVIEW™ and has been used on AIFIRA's nanobeam line since 2009 (Barberet et al., 2009, 2011) [1,2]. A Graphical User Interface (GUI) embedded in the Compact RIO as a web page is used to control the scanning parameters. In addition, a fast electrostatic beam blanking trigger has been included in the FPGA and high speed counters (15 MHz) have been implemented to perform dose controlled irradiation and on-line images on the GUI. Analog to Digital converters are used for the beam current measurement and in the near future for secondary electrons imaging. Other functionalities have been integrated in this controller like LED lighting using Pulse Width Modulation and a "NIM Wilkinson ADC" data acquisition.

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1. Introduction

High resolution ion microbeams, usually used to perform elemental mapping, low dose targeted irradiation or ion beam lithography needs a very flexible, reliable, fast and precise beam control system. For this reason, we have designed a generic beam scanning system, called "CRionScan", to control the beam on the focused beamlines of the AIFIRA (Applications Interdisciplinaires des Faisceaux d'Ions en Région Aquitaine) facility [1,2]. CRionScan is a stand-alone real time scanning and imaging instrument using a Compact Reconfigurable Input/Output (Compact RIO) device from National Instruments™. Indeed, as other groups [3–6], we chose to base our system on a Field Programmable Gate Array (FPGA). In addition, the Compact RIO is equipped with a real-time controller, input/output modules and Ethernet connectivity. We have implemented a fast and deterministic beam scanning system interfaced with our commercial Data Acquisition System (DAS) without any hardware development. It is used in conjunction with high voltage amplifiers and electrostatic deflections plates to sweep the beam in the sample plane.

We decided to handle the scan control device and the DAS separately like few other microprobes [7–9] for several reasons. First, the scanning of a spatially well-defined beam has to be controlled with high precision. A stand-alone system can be located very close to the high voltage amplifiers (1 m), themselves not so far from the deflection plates (few meters): ground loops are limited and signal to noise ratio is improved. The second reason is that the AIFIRA facility is already equipped with a commercial multiparameter DAS (MPA-3, FAST ComTec GmbH). This DAS is shared with all the beamlines and the nanobeam line specifically requires connecting it with a beam scanning system to perform spectroscopic imaging. In addition, a second fast beam positioning system is required for the cell micro-irradiation beamline. Beyond its use for elemental mapping and cellular targeted irradiation, this device has also been designed to allow Proton Beam Writing (PBW) applications.

2. Hardware description

CRionScan is based on a Compact Reconfigurable Input/Output (Compact RIO) device from National Instruments™. This system

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includes eight hot-swappable I/O (input/output) modules, a reconfigurable chassis housing the user-programmable FPGA and an embedded controller (Fig. 1). It is programmed with NI LabVIEW™ software for rapid real-time and FPGA programming.

The heart of the hardware is the FPGA, a reprogrammable silicon chip interfacing the I/O modules with the benefit of faster I/O response times, rapid prototyping and implementing custom functionality with the reliability of dedicated deterministic hardware. This programmable circuit makes timing correlation between parameters easy to do without any dedicated electronics. This feature makes it ideal to perform high speed imaging from different sources like counters or analog signals. All the functionalities detailed in the following section were first implemented in 2008 on the cRIO-9102 chassis containing a Virtex-2 1Mega Gate FPGA. CRionScan was duplicated in 2011 on a cRIO-9074 Spartan-3 2Mega Gate (46080 Logic Cells & 40 multipliers) FPGA.

The chassis is coupled with a cRIO 9012 controller based on a 400 MHz processor running VxWorks real time operating system. This controller communicates with the FPGA using shared memory and its Ethernet port is used for user control. The main software (real time code) runs when the chassis reboots, configures the FPGA and reacts on user events: that makes CRionScan a complete real time stand-alone instrument.

Four different I/O modules are interfaced by the FPGA (Fig. 1):

- NI 9401: high speed TTL digital I/O (16 MHz with 4 input channels) for X & Y Digital beam position generation, Beam blanking, Counters, Spectrometry and LED lightening.
- NI 9263: digital to analog conversions (16 bits, ±10 V, 10 µs conversion time) for beam positioning analog signals generation.
- NI CR9215: analog to digital conversions (16 bits, ±10 V, 100 ksamples/s) for beam current measurement and secondary electron imaging.
- NI 9485: 8 channel solid-state relay module for beam current sensitivity control.

3. CRionScan functionalities

3.1. Arbitrary analog waveform generator (analog outputs)

AIFIRA's micro and nanobeams are scanned over samples by electrostatic deflectors to minimize hysteresis effects at higher scan speed compared to magnetic systems. The nanobeam and the micro-irradiation beam lines are both equipped with two high voltage amplifiers (Physicon Model RS1224-2500; ±1250 V max,

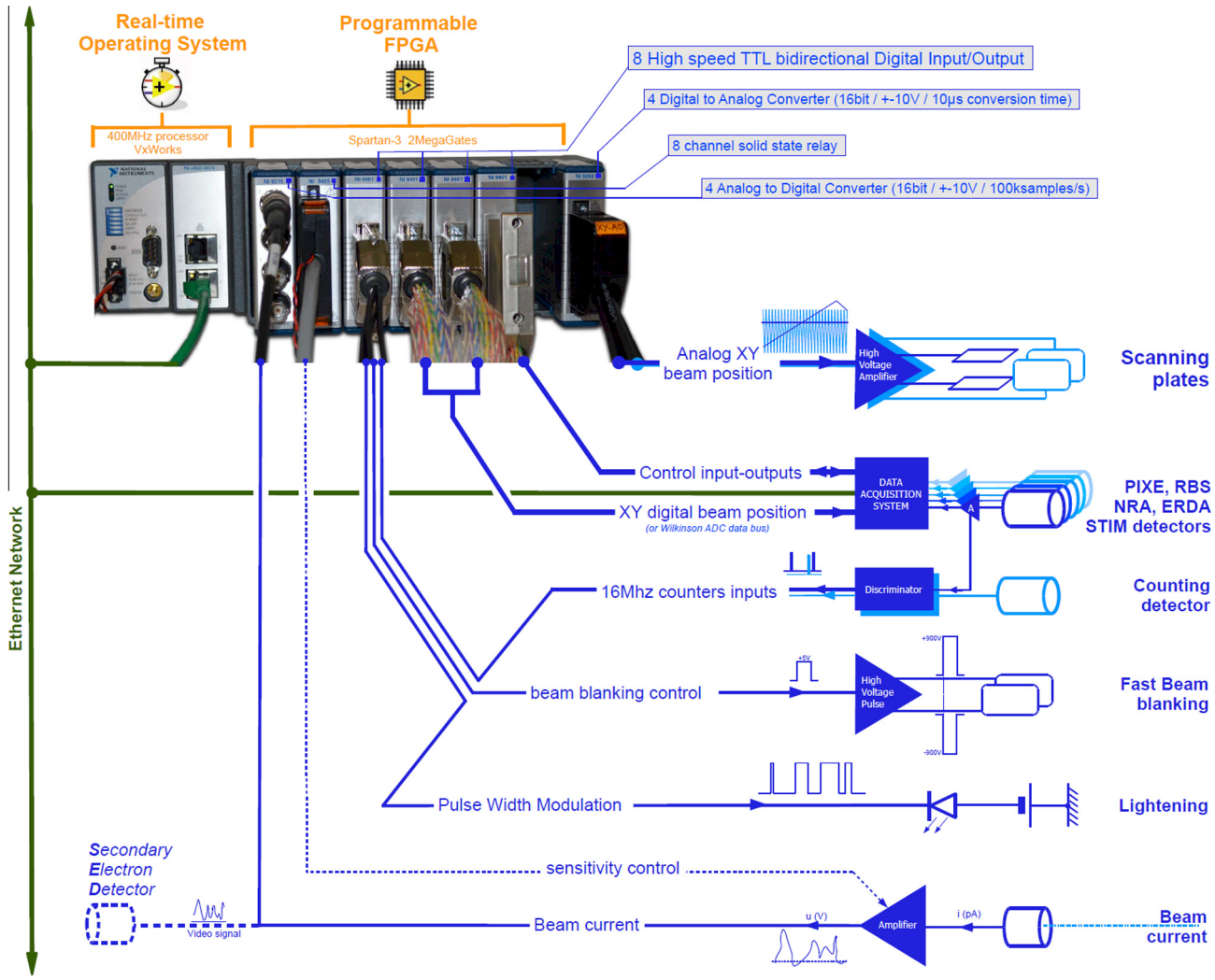

Fig. 1. CRionScan hardware picture, its I/O modules description and the schematic wiring diagram with associated devices. The following functionalities are available: "Arbitrary analog waveform generator", "DAS interface", "fast counters", "beam switch control", "LED lighting", "beam current measurement" and in the near future "secondary electrons measurement".

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