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Beam-line Diagnostics at the Front End Test Stand (FETS), Rutherford Appleton Laboratory, Oxfordshire, UK

Introduction

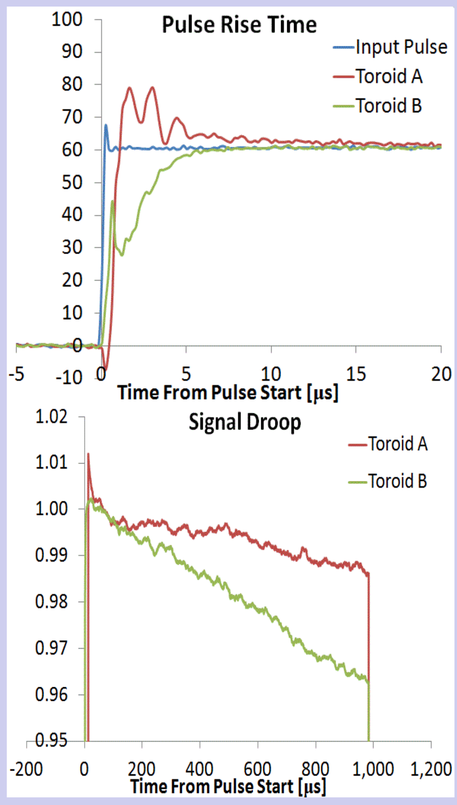
The H^- ion source and beam-line at FETS will require the beam current and beam position to be continually monitored. Current transformer toroids will measure the beam current and beam position monitors (BPMs) will determine the beam position. The signals from the toroids will be digitized and made available via EPICS servers at every pulse. The signal from each BPM electrode is mixed in the front-end electronics and then digitized. A commercial FPGA PXI card processes the resulting BPM IF signals to produce the beam position which is then served by an EPICS IOC. Other diagnostics are the laserwire and slit-slit emittance scanners.

Toroids

Nine toroids will used to monitor the beam current at various locations along the beam-line, eight of which are designed, built and test in-house. The first toroid measures the current out of the ion source, and two measure the current at the end beam-line. The remaining six toroids along the beam-line are paired in order to measure the transmission of the radio frequency quadrupole (RFQ) and the fast and slow choppers.

The toroids were designed to have a rise time of better than 10μs and a droop of less than 1%. The results of testing two of the toroids show the rise time has been met, but the signal droop indicates a possible lower than expected permeability in one of the cores.

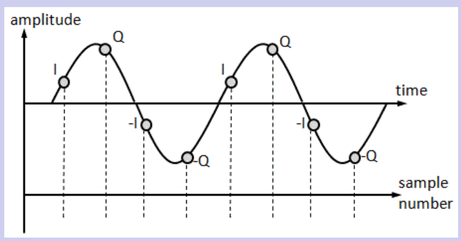
Three of the toroids were installed in the initial part of the beam-line and have been running for over a year with no problem.



Beam Position Monitors

Between three and six BPMs will be installed, depending on the final lattice of the medium energy beam transport (MEBT), each producing a beam position several times during the duration of the accelerated pulse. The BPMs are positioned along the MEBT after the RFQ and between the two choppers. The BPMs will be based on a design used by the LINAC4 collaboration at CERN, since the beam-line characteristics are very similar. The electronics mix the 324MHz BPM signal to an IF of 10.125MHz, which is then digitized at 40.500MHz, creating I, Q, -I and -Q samples.

The magnitude of each signal is calculated and the position determined in a FPGA, with a calculation time of 3.1μs.

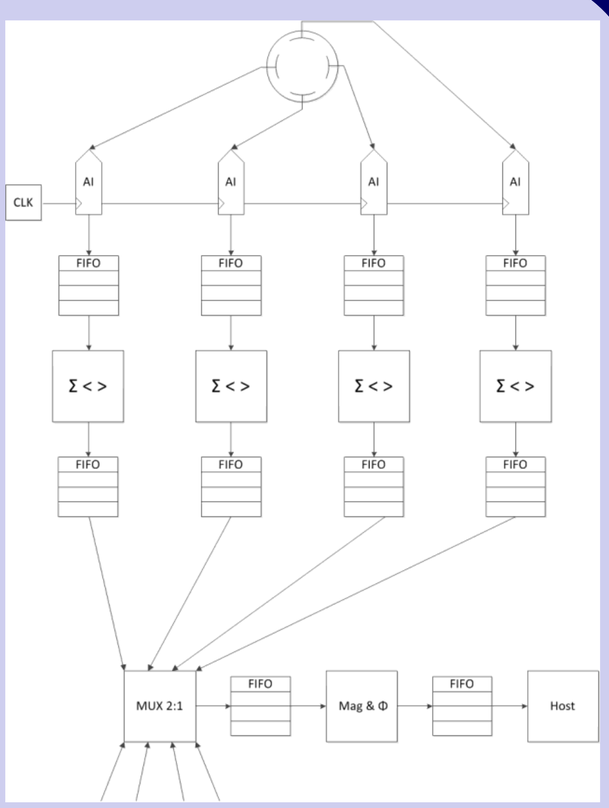


IQ Sampling

$$Position_x = k_x * \frac{V_{right} - V_{left}}{V_{right} + V_{left}}$$

$$Position_y = k_y * \frac{V_{top} - V_{bottom}}{V_{top} + V_{bottom}}$$

Beam position determination



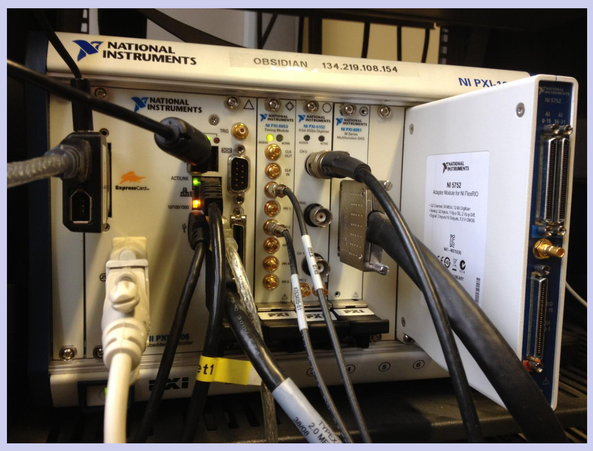
BPM electrode calculation in the FPGA

Other Diagnostics

The beam-line emittance can be determined using either the laserwire or slit-slit scanners. The laserwire uses a pulsed laser which is focussed and scanned across the H^- bunches to strip electrons, with the resulting neutrals passing into a scintillator which is viewed by a camera. The slit-slit scanner has been used for commissioning the low energy beam transport (LEBT) but will not be part of the final beam-line. Various parameters such as temperature will also be continually measured.

Data Acquisition and Processing

Most of the diagnostics' data acquisition and processing is based on DAQ cards housed within a PXI chassis. The BPM processing uses a 32 channel 50MS/s digitizer attached to a Virtex5 FPGA PXI card from National Instruments. Cards to distribute clock signals and (delayed) triggers to other instruments used are also present. The resulting data is served via EPICS IOCs running on the PXI controller.



PXI Chassis with DAQ cards

Future Work

The beam-line LEBT is already running and the RFQ and MEBT, including the BPMs and remaining toroids, are due to be installed in 2014. The FPGA code for the BPM processing has been developed and is now undergoing testing using simulated IF signals. The mixing electronics will be added to the test set-up and BPM-like RF signals used. Development of the EPICS IOCs for the toroids and BPM has started and EPICS clients for viewing and data-logging are being designed.

The Front End Test Stand Collaboration

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Imperial College London

Royal Holloway University of London

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