DEVELOPMENT OF A BEAM PULSE MONITOR FOR THE HEAVY ION ACCELERATOR FACILITY

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Abstract

The Australian National University (ANU) Heavy Ion Accelerator Facility (HIAF) comprises of a 15 million volt electrostatic accelerator (NEC 14UD) followed by a superconducting LINAC booster. The pulsing system consists of a low energy, single gap, gridded buncher and two high energy choppers. The buncher and choppers need to be set in phase and amplitude for maximum efficiency. The LINAC encompasses twelve, lead tin-plated Split Loop Resonators (SLR). Each SLR, as well as the superbuncher and time energy lens, needs to be individually tuned in phase and amplitude for correct operation. The HIAF pulsing system is based on a few techniques. The first one utilises a U-bend at the end of the LINAC. One special wide Beam Profile Monitor (BPM) is installed after the 90 degrees magnet. The technique allows to set up correct phase by observing the displacement of beam profile versus phase shift of the last phase locked resonator. The determination of beam pulse characteristics are based on γ-ray detection produced by beam striking a tantalum target. In this paper, the HIAF set up for pulsed beam diagnostics with sub nanosecond time resolution is described. The system has demonstrated simplicity of operation and high reliability.

INTRODUCTION

The ANU Heavy Ion Accelerator Facility consists of a National Electrostatics Corporation 14UD electrostatic tandem accelerator and a superconducting LINAC booster accelerator. The LINAC comprises of four cryostats, each consisting of three, split-ring resonators, operating at a frequency of approximately 150 MHz. When the beam needs to be accelerated in the LINAC or when the beam is required by the accelerator users to be bunched, the facility's buncher systems are utilised. The first buncher is installed at the low energy section of the 14UD accelerator. It is a gridded, room temperature, buncher using one or three frequencies to produce the field required for bunching. The resulting bunch has a typical width of 1.5 ns FWHM and the bunching efficiency is approximately 0.25.

A second buncher, Super Buncher (SB), is installed at the LINAC entrance. SB is a superconducting, quarter-wave resonator with β=0.1, developed at the ANU and can further compress the beam to bunches with, typically, 100 ps FWHM.

All bunchers as well as the LINAC, are synchronised to the facility's master 150 MHz clock. The low energy buncher operates on the sub-harmonic frequency of approximately 9.375 MHz (1/16 of the master clock) and the two high energy choppers on 37.5 MHz and 4.6875 MHz (1/4 and 1/32 of the master clock).

When the buncher systems are in use, it is important to have a monitoring system which allows the accelerator operator to measure the characteristics of the bunch in the time domain, to assist with the tuning. This paper describes the system used by the facility to produce a time profile of the pulsed beam. This technique of measuring the longitudinal profile is used by other facilities such as [1]. The output of the pulse monitor is used together with other measurement and tuning techniques [2, 3] to optimise the LINAC beam.

The development of this system has happened through the years and with the scientific contribution of the researchers of the Department of Nuclear Physics.

METHOD DESCRIPTION

The beam pulse monitoring system, shown in Fig. 1 is based on the time difference between prompt γ-rays produced by the beam striking a tantalum target and the reference RF used to synchronise the rest of the accelerator.

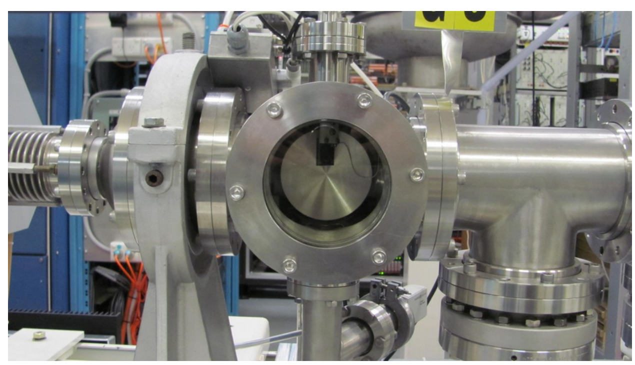

Figure 1: The target station of the beam pulse profile monitor. The target, as seen through the viewing port, can be moved in/out and is rotated by 45 degrees with respect to the beam.

The target is mounted at a 45 degree angle to the beam and it is placed in the path of the beam. This results in prompt γ-rays being produced, which are detected by a barium fluoride (BaF2) scintillation detector. The detector used at the ANU is made by Scionix Holland BV and is model number 38/25B30/2M BaFX2Neg. The BaF_2 detector signal provides the start signal to a time-to-analog converter (TAC) made by Ortec, model 567. The TAC is set to a maximum range of 100 ns. The amplitude signal from the detector is variable as the energy

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deposited by the detected γ-ray is not always the same, so in order to produce an accurate timing signal that is not depended on the amplitude of the detector pulse, an Ortec 584 constant fraction discriminator (CFD) is placed between the detector and the TAC. The fast logic signal from the CFD is then fed to the TAC's start signal input. The stop signal comes from the reference RF, which at that point is 9.375 MHz. Figure 2 shows the electronic modules comprising the monitor system. This configuration results in an event rate of the order of 5000/s for a typical beam of 50 nA, which implies that substantially less than one γ-ray per beam pulse is produced. The output of the TAC is connected to a multi-channel analyser (MCA) which produces a histogram representing the time profile of the beam. Since a single beam pulse results in less than one gamma ray detected, over time, the profile of the beam pulse produced in the histogram is considered to be a faithful representation of the profile of the pulse.

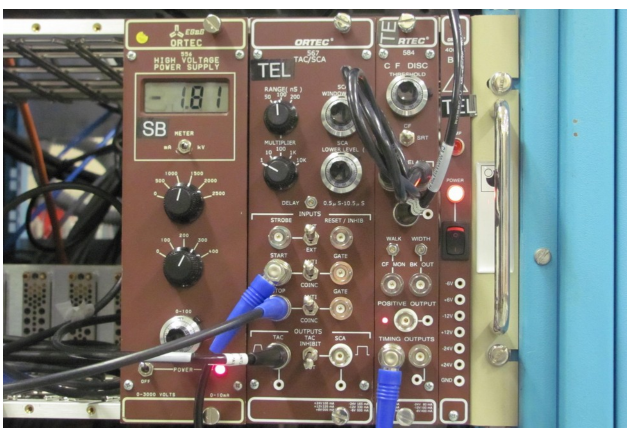

Figure 2: The electronic modules used by the beam pulse monitor system. From left to right: high voltage supply for the BaF2 detector (Ortec 556), time-to-analog converter (Ortec 567) and constant fraction discriminator (Ortec 584). The Single Channel Analyser in the TAC module is not used. The modules are installed in an Ortec 4001C NIM bin.

The MCA used to produce the histogram is a FAST ComTek MCA-3FADC, used on a laptop with a PCMCIA to PCI bridge. This MCA has a maximum conversion range of 8192 channels, which is adequate for this task. The software used to collect the data is written by the manufacturer and the data is stored in ASCII files which can be read and processed by other applications. The histograms presented in this paper were collected at a conversion range of 1024, a range that is adequate for measurements of the beam before the superbuncher.

Calibration of the system is essential in order to produce an absolute measurement of the pulse's FWHM. An Ortec 462 TAC calibrator has been used for this purpose. This TAC calibrator has good long-term stability and absolute accuracy, the latter being ±10 ps for a 10 ns period according to the manufacturer. For the measurements presented in this paper, the calibration factor was found to be approximately 8.47 channels per nanosecond. There are two beam pulse monitor systems, one before the superbuncher and one after the time-energy lens. Their locations are shown in Fig. 3.

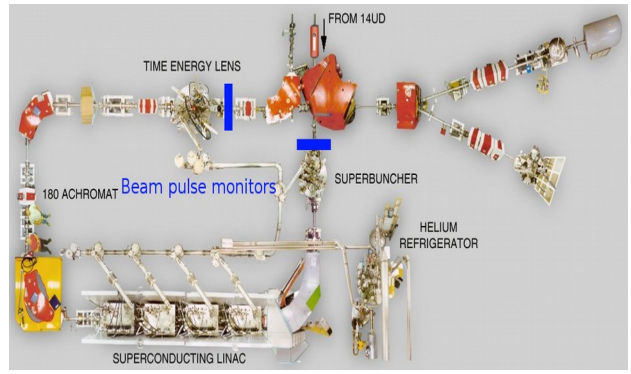

Figure 3: Composite photo of the ANU LINAC facility; the locations of the beam pulse monitor systems are marked in blue colour.

RESULTS

The plots depicted in Fig. 4 are typical plots obtained by the beam pulse monitoring system. The data in this figure are collected by the MCA connected to the first monitoring station, located before the superbuncher. The beam is 72 MeV $^{16}O^{+6}$, produced by the 14UD accelerator with single electron stripper at the terminal.

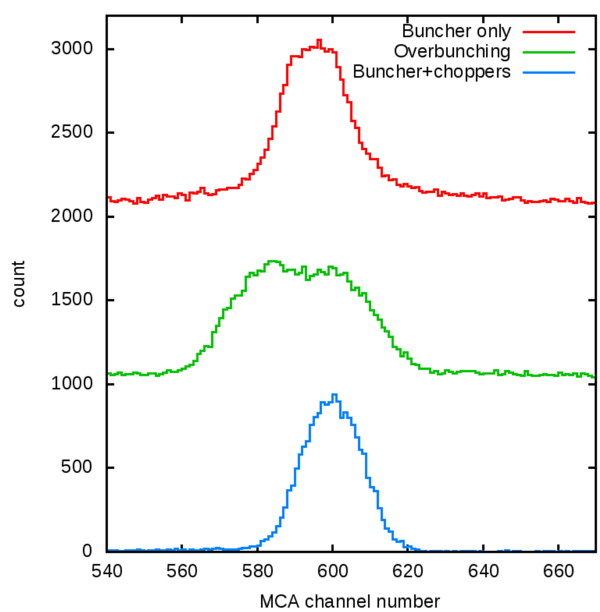

Figure 4: The top histogram (shifted up by 2000 counts) shows the beam pulse with only the low energy buncher enabled. The middle histogram (shifted up by 1000 counts) has a double peak which is typical of overbunching. The bottom histogram is produced with both the low energy buncher and high energy choppers enabled. The collection time for all histograms was 60 seconds.

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DISCUSSION

On the top trace in Fig. 4, only the low energy buncher is in operation. The middle plot shows the characteristic pattern of double peaking which occurs when overbunching. The bottom plot is obtained after the buncher settings are optimised and the high energy choppers are turned on. The reduced background between beam pulses is an effect of the choppers operation.

The process of pulse optimisation consists of adjustment of amplitude and phase of the bunchers and choppers with feedback provided by the beam pulse monitor.

In the latest of a series of LINAC tests, the beam pulse monitor system was found to be affected by mains power noise. The noise is picked up by the lengthy, approximately 100 m, coaxial cable connecting the monitor station to the control room where the MCA is located. This noise results in an artificial widening of the recorded pulses and is currently the subject of an investigation. The noise was found to be about 40 mV peak to peak which, for the selected range conversion of 1024, translates to 3.4 channels or 0.4 nanoseconds. This error is too large for measuring accurately the pulses after the superbuncher. A solution to this problem is the relocation of the MCA computer from the control room to the LINAC hall, combined with remote access to the computer.

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REFERENCES

[1] J. L. Vignet, R. Revenko, "A Bunch Extension Monitor for the SPIRAL2 LINAC", Proceedings of IBIC2014, Monterey, CA, USA, MOPD26, http://www.jacow.org/

[2] N. R. Lobanov, P. Linardakis and D. Tsifakis, "Tuning the superconducting linac at low beam intensities", to be published in the proceedings of SRF2015, Whistler BC, Canada.

[3] N. R. Lobanov, P. Linardakis and D. Tsifakis, "Tuning the linac with superconducting resonator used as a phase detector", to be published in the proceedings of SRF2015, Whistler BC, Canada.

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