NEWLY INSTALLED BEAM DIAGNOSTICS AT THE AUSTRALIAN SYNCHROTRON

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Abstract

The Australian Synchrotron (AS) is aiming at implementing Top-Up operations in 2012. To reduce costs only one of the two klystrons in the linac will be used. The electron beam in the linac will only be accelerated to 80 MeV, instead of 100 MeV achieved currently. The injection system will need to be recommissioned. The beam position monitors in the booster have been upgraded and YAG:Ce screens have been added to the booster-to-storage ring (BTS) transfer line. In addition the injection efficiency will be optimized and monitored. For this purpose another Fast Current Transformer has also been installed at the end of the BTS.

INTRODUCTION

The Australian Synchrotron is a a third-generation light source which delivered its first beam to users in 2007. It operates in decay-mode, with two daily injections to 200 mA. The machine has been designed for top-up, which will maintain the stored beam current at a constant value. This mode will keep a stable heat-load on the beamlines. Top-up has successfully been demonstrated during machine studies [1]. Its implementation during user beam will however require further testing, as described in [2]. In particular, only one of the two klystrons in the linac will be used to offset the costs of the equipment running continuously. The maximum energy the electrons will reach at the end of the Linac-To-Booster (LTB) transfer line is expected to drop from 100 MeV, as currently achieved, to 75-80 MeV. This will require the whole injection system to be recommissioned, especially the booster ramp will need to be adjusted. The diagnostics equipment in the booster has thus been upgraded [3]. The extraction into the Storage Ring (SR), which could not be optimized due to the lack of diagnostics at the end of the Booster-To-SR (BTS) transfer line, will need to be improved, as an interlock will be placed on the injection efficiency. The injection efficiency monitoring is therefore being upgraded. Two YAG:Ce screens have also been added at the end of the BTS transfer line in order to improve the beam trajectory through the injection septa.

INJECTION EFFICIENCY

Top-up operation requires a high injection efficiency [1]. The injection efficiency is currently calculated from the readings of two Direct-Current Current Transformers (DCCTs) located in the Booster (BO) and the Storage Ring, respectively. This architecture does not allow for the injection to be optimized at every stage of the injection system. A project to optimize the injection from the linac to the SR has thus been raised. The BTS had been lacking beam current diagnostics equipment at the end of the transfer line. An extra Fast Current Transformer (FCT) from Bergoz has been placed at the end of the BTS, just before the pre-septum, as shown on Fig. 1.

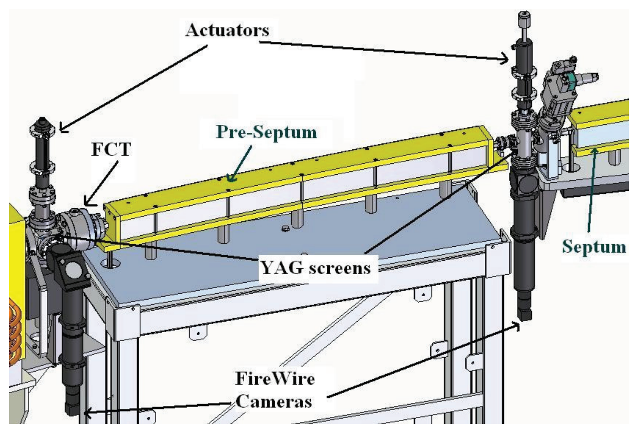

Figure 1: Drawing of the end of the BTS showing the location of the new FCT and the two new YAG:Ce screens, on both sides of the SR injection pre-septum.

A new EPICS-based [4] injection efficiency acquisition system has been designed, which complies with the control system used at AS. It processes the data from the Wall Current Monitor (WCM) in the linac located just after the gun, and five FCTs: two in the LTB, one in the Booster and two in the BTS.

The signals from these six modules were initially used by a 3 GHz scope, via a multiplexer (Agilent 34946A), for tuning the injection. They have been split to provide signals to three Analogue-to-Digital cards (ADCs, Acqiris U1071A from Agilent) used for the injection efficiency monitoring. These cards are located in a computer which serves as Input-Output Controller (IOC).

The three ADCs acquire input signals from the WCM and the first FCT in the LTB, the second FCT in the LTB and Booster FCT, and both BTS FCTs, respectively. Each card receives a trigger signal: the first card is triggered from an Event Receiver (EVR) [5] output with zero delay (injection), the last one with 0.602 s delay (extraction) and the second card with an 'OR' combination of the two EVR signals. This allows for the Booster FCT to be triggered at injection in the Booster and at extraction from it. The LTB FCT2 is triggered in the same way but the signal at extraction is not recorded. The cabling of the ADCs is represented in Fig. 2.

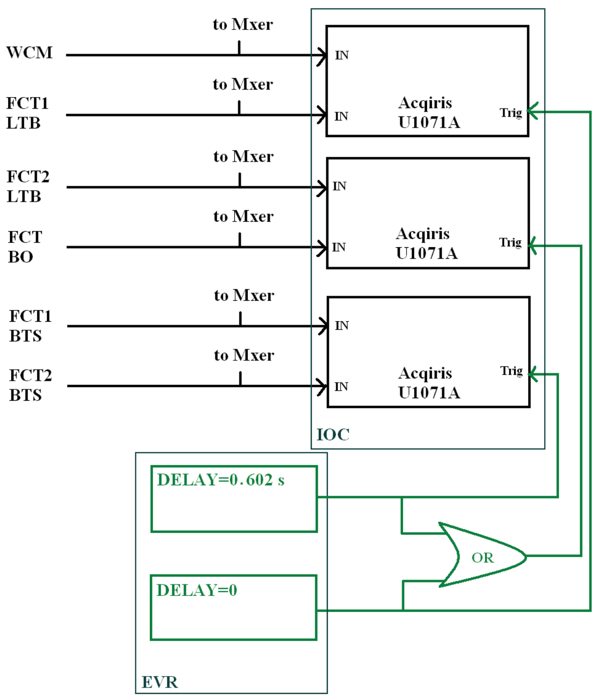

Figure 2: Schematics of the Acqiris cards cabling. All abbreviations are detailed in the text, except Mxer: Multiplexer.

The ADCs have a 200 MHz bandwidth. As the radio frequency (RF) of the machine is 499.65 MHz (1 bucket every ∼ 2 ns), the ADC bandwidth is too low to distinguish between individual buckets. Figure 3 illustrates this point in the case of the WCM.

The bandwidth limited signal is nevertheless a good representation of the transferred current as the absolute current value in nC can be extracted by simple calibration.

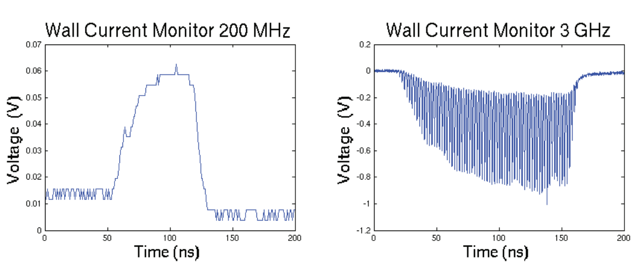

Figure 3: WCM signal observed at 3 GHz (right) with an oscilloscope and 200 MHz (left) with the Acqiris card [6].

At the time of writing the EPICS driver is still under development. Moreover as the signals appear noisy, low pass-filters shall also be added.

CAMERA UPGRADE

As part of the diagnostics equipment upgrade two YAG:Ce screens have been placed in the BTS, one before the pre-septum and one between the pre-septum and the septum (see Fig. 1). The two fluorescent screens will be used to observe the beam spot position, stability and shape. They will also allow for the beam direction to be calculated. Their use will be restricted to machine studies, as they are opaque to the beam. They have therefore been made retractable and can be moved in and out of the beam pipe with air-controlled actuators activated by the Programmable Logic Controller.

The cameras used to look at the beam spot on the screens are FireWire (IEEE-1394) greyscale Flea2 from Point Grey. The camera are fixed below the beam level to prevent radiation damage, on light-tight mounts designed in-house with ThorLabs products. The acquisition hardware has been fully provided by Point Grey and includes a 160 MB/s data transfer PCIE card (FWB-PCIE-02) and two long distance repeaters (FWB-LDR-CAT5) that can transmit 800 Mb/s data over 100 m Category5e (Cat5e) cable. Since the decay time of the YAG screens is 70 ns the cameras need to be triggered correctly to observe the beam pulse. The 1 Hz injection trigger is delivered by a EVR output and duplicated with a repeater to provide for the two cameras [5]. Figure 4 illustrates the architecture of the cabling.

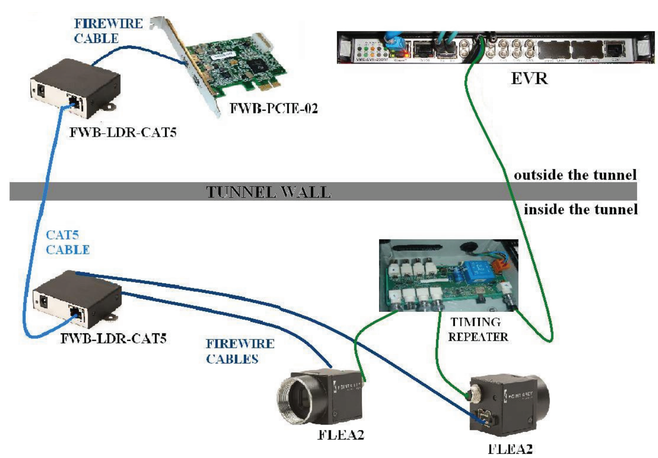

Figure 4: FireWire camera cabling, blue: signal cables, green: timing cables. Details in the text.

The acquisition system used to control the cameras is derived from the AreaDetector driver [7] and is similar to the one developed at the DIAMOND Light Source [8]. It is EPICS based [4].

The Graphical User Interface (GUI) software uses the existing AS GUI framework, which is based on the Borland Delphi development environment. It creates a Windows executable that runs both natively on Windows boxes and under Wine on Linux machines. Figure 5 shows an example of the GUI.

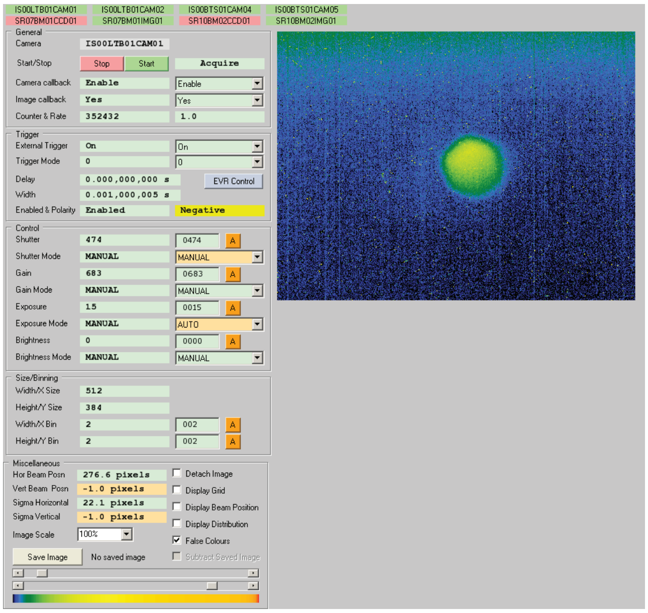

Figure 5: FireWire camera GUI.

Another type of camera, from JAI, has been implemented by Danfysik as part of the turn-key delivery of the injection system. The acquisition system of these cameras is based on Coreco Imaging products. The cameras are connected to a Windows XP machine with a video capture card (PC2-Vision) and use Imaging Foundation Classes Camera Configuration as GUI. There is a project to substitute all these cameras by Flea2 models for homogeneity of hardware and software. The cameras in the linac and the LTB have already been replaced.

CONCLUSION

The diagnostics equipment in the injection system of the Australian Synchrotron has been improved in order to reach the requirements for top-up. Table 1 lists the distribution of the diagnostics hardware in the machine. The injection efficiency monitoring is being upgraded such that the injection quality can be assessed and refined at every stage of the injection system. The driver for the new injection efficiency monitor is almost complete.

More projects need to be finalized before top-up can be used during user operations. They include developing various interlocks (on radiation level and injection efficiency, for instance), adding a variable aperture at the beginning of the BTS to prevent the electron beam from damaging insertion devices with closed gaps, and delivering the timing system to all beamlines, to allow them to make use of a ”injection gate” trigger and possibly conduct time-resolved studies.

Table 1: Diagnostics Equipment at AS. The SR diagnostics is detailed in [9]. Abbreviations are listed in the text, except BLM: Beam Loss Monitor, SLM: Synchrotron Light Monitor.

	Linac	LTB	Booster	BTS	SR
Faraday Cup	1	-	-	-	-
WCM	1	-	-	-	-
FCT	-	2	1	2	-
DCCT	-	-	1	-	1
screens	4	3	4	5	1
SLM	-	-	2	-	2
strip line	-	-	1	-	1
BPM	-	32	-	-	98
BLM	-	1	2	-	14

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