COMMISSIONING OF THE AUSTRALIAN SYNCHROTRON INJECTOR RF SYSTEMS

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Abstract

On December 16, 2003 the contract for the design, manufacture, installation and commissioning of the turnkey injector system for the Australian Synchrotron Project was awarded to industry. ACCEL Instruments GmbH [1] delivered the turnkey 100MeV linac and the booster RF system. Commissioning of the linac for ASP was performed in December 2005, right after successful commissioning of the Diamond Light Source injection linac [2]. The 500MHz booster cavity and related low level RF system was commissioned after installation of the booster in early 2006. The paper will present design and layout information, as well as commissioning results.

ASP INJECTOR LINAC

As a major subsystem of the ASP injector system the linac was designed and produced at ACCEL. The commissioning was performed by ACCEL with the support of the ASP accelerator group.

Performance

In Table 1 the performance and specification of the electron injector linac for ASP is summarized.

Table 1: Linac performance

Parameter	Multi bunch mode	Single bunch mode
Energy	> 100 MeV	
Pulse duration	150 ns	< 1 ns
Charge in a bunch train	> 4 nC	> 0.5 nC
emittance n, rms	< 50 π mm mrad mrad	
Single bunch purity	n. a.	< 0.01

Production Concept

To minimise installation time subsystems were completely preassembled, tested and shipped as functional units (see figure 1). The linac consists out of five subsystems (electron source, bunching section, two accelerating structures and a medium energy beam transport) and their auxiliaries.

Results

Based on the values reached during the site acceptance test the linac is in standard operation since March 2006. The diagnostics installed in the LTB allowed to measure energy, energy spread and stability.

Figure 1: Linac functional units. In the front: accelerating structures during tuning, in the back left: MEBT; in the back right : bunching section during assembly.

At an energy of 100MeV an upper rms energy spread of 0.5% was measured (emittance content to energy spread was not subtracted) in single bunch mode and 0.7% in multi bunch mode. The pulse to pulse energy jitter within one hour is below 0.5% (figure 2).

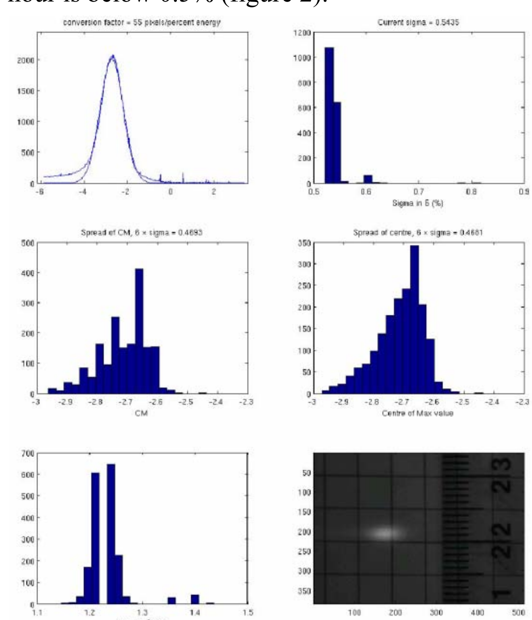

Figure 2: Energy, energy spread and energy stability measurement as performed by ASP for single bunch mode.

BOOSTER RF SYSTEM

The Australian Synchrotron Project booster RF cavity system consists of one accelerating cavity module, comprising of five normal-conducting cells, the low level RF system LLRF and a high power amplifier HPA. The booster RF system delivers energy to the electron beam in order to accelerate the beam from the linac output energy of 100 MeV to the storage ring energy of 3 GeV with a rate of acceleration cycles ≥ 1Hz. The control and regulation of the amplitude, phase, frequency and field flatness of the normal conducting 5-cell booster cavity during the acceleration of the beam is performed by the LLRF system.

Booster Cavity

The 500MHz cavity (see figure 3 and table 2) used for the ASP booster is a five cell slot coupled rf structure with one high power coupler and two tuners. The vacuum in maintained by two 300ltr/h ion getter pumps.

Table 2: Booster cavity parameters

Parameter	Value	Unit
RF frequency	499.654	MHz
Quality factor Q0	29 000	
Shunt impedance $R_{sh}=U^2/(2P_{in})$	14.5	MΩ
RF power	≤ 75	kW

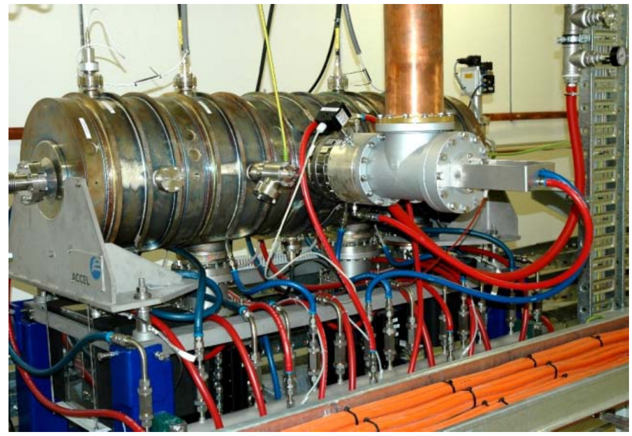

Figure 3: ASP Booster Cavity after installation.

LLRF System

The LLRF system consists out of four independent subsystems (Figure 4):

- Vector control loop, which combines the amplitude and phase control loops
- Tuning loop for cavity frequency adjustment
- Field flatness regulation loop
- Drive power amplifier (DPA)

Table 3 lists the technical specification of the ASP Booster LLRF system.

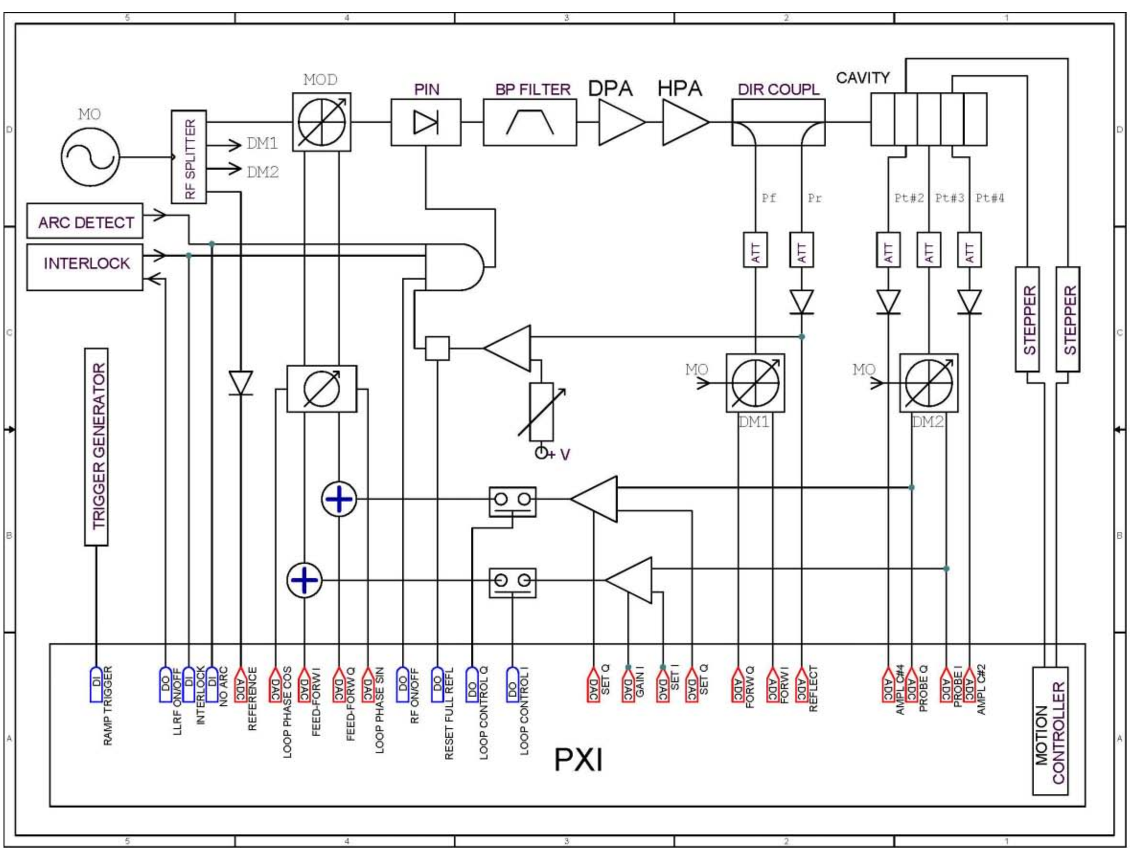

Figure 4: ASP booster LLRF diagram.

Table 3: Booster LLRF Design Parameters

Parameter	Value	Comment
Nominal RF frequency	499.654 MHz	+/- 250 kHz
RF power	≤ 75 kW	Full scale power
RMS amplitude stability	1 %	over 26dB cavity voltage range
Phase control range	± 180 deg	
Phase resolution	0.5 deg	over the phase control range
RMS phase stability during cw operation	± 0.5 deg	over 26dB cavity voltage range
RMS phase stability during ramping	± 2 deg	over 26dB cavity voltage range
Loop Bandwidth	4 kHz	
Tuning range (max)	+/- 250 kHz	
Tuning speed	up to 1 kHz/s	
Tuner step (min.)	10 Hz	
Sensitivity	± 10 to 1000 Hz	programmable

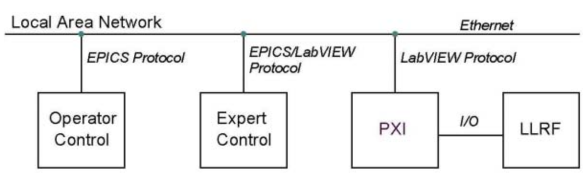

Figure 5: Booster LLRF Communication Network.

The organization of the communication network between the booster operator and LLRF is shown in Figure 5. The Experimental Physics and Industrial Control System (EPICS [3]) communication standard is used at LLRF operator level. The lowest LLRF control level is performed using National Instruments LabVIEW program running on the PXI real-time controller. The LabVIEW – EPICS data transformation was realised using the LabVIEW / EPICS Shared Memory Interface [4], running on the Expert PC.

The commissioning of the ASP Booster LLRF system was started in the middle of the February 2006 and finished at the end of March. The commissioning has been started with the booster cavity conditioning (65kW RF-power), which has been finished during one week.

The test of the cavity phase and amplitude stability parameters has been performed for both continuous wave (CW) and ramp modes. The cavity phase noise is less than 1° (peak-to-peak) and amplitude noise less than 0.5% (peak-to-peak) have been measured for CW mode (beam injection and extraction), and the phase noise less than 3° (peak-to-peak) during the ramp operation over the 26dB range. The achieved phase and amplitude LLRF stability parameters are essentially better than specified.

SUMMARY

Within the ASP project a 100 MeV linac and the RF system to boost the electron energy to 3 GeV were delivered and commissioned within specification. It turned out that especially due to the personal engagement of the ASP accelerator group working with our staff commissioning was successful in a remarkably short period. From first linac operation to linac acceptance it took only 3 months. In parallel to the linac commissioning also booster operation started and beam was stored in the booster and ramped immediately after full performance of the linac.

REFERENCES

[1] http://www.accel.de
[2] C. Christou et al. , "Commissioning of the DIAMOND pre-injector linac", EPAC'06, Edinburgh, June 2006
[3] EPICS at http://www.aps.anl.gov/epics/
[4] Copyright © 2003, <Oak Ridge National Laboratory and other copyright holders>, W. Bloakland (SNS)