COMMISSIONING OF THE SLS-LINAC

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Abstract

The Swiss Light Source (SLS) pre-injector is a 100 MeV S-band linear accelerator. It has been supplied as a turn-key system by ACCEL Instruments GmbH [3,4]. The accelerating have been manufactures following the design of SBTF (S-band test facility) at DESY [1,2]. We are describing here below the linac, the RF systems and the beam diagnostics equipment. The beam measurements performed during the commissioning are reported as well.

1 INTRODUCTION

The Swiss Light Source (SLS) is a dedicated high brightness synchrotron light source under construction at the Paul Scherrer Institute (PSI) in Villigen. The accelerator complex includes a 2.4 GeV electron storage ring (SR) with 288 m circumference, a full energy synchrotron injector (Booster) and a 100 MeV linear pre-injector[5]. The performance specifications of the pre injector, listed in table 1, are of primary importance to ensure an efficient and fast injection into the SLS storage ring (up to 200 mA/min). The energy spread and emittance are specified to match the narrow apertures of the innovative SLS booster synchrotron [6].

In order to fulfill the different needs of the light source users, two main modes of operation are foreseen: the single bunch mode and a variable multi bunch mode. In addition an optional low current mode is planned to perform a top up injection, keeping the mean current in the storage ring nearly constant.

Max single bunch width	1ns
Bunch train length	0.2 - 0.9µs
Max Charge	1.5nC (both modes)
Energy	>100 MeV
Pulse -pulse energy stability	<0.25%
Relative energy spread	<0.5% (rms.)
Normalized emittance (1σ)	<50 πmm mrad
Single bunch purity	<0.01
Repetition rate	3.125 Hz, 10 Hz (max.)
RF Frequency	2.997912 GHz
Faults	<1 fault/hour

Table 1: Linac general specifications

The charge per shoot has been limited at 1.5 nC essentially for radiation protection reasons. This relatively small charge prevent as well from large beam loading effects in the accelerating structures.

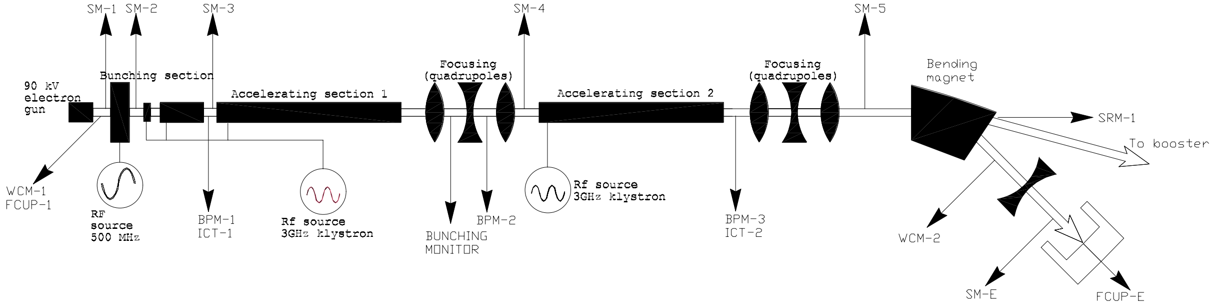


Figure 1: Pre-injector layout.

2 LINAC DESCRIPTION

2.1 General Layout

A detailed description of the 90 kV pulsed gun and of the pre-injector main RF components can be found in [3]. A layout of the complete linac setup with its diagnostics is shown in figure 1. The pre-injector consists of four main parts:

1) The electron source, a 90 kV triode gun with Pierce geometry. In the single bunch mode the cathode is pulsed with respect to the grid. In the multi-bunch mode the grid is modulated at 500 MHz with respect to the cathode.
2) The bunching section including:
   - SPB: 500 MHz sub-harmonic pre-buncher.
   - TWB1: 4 cells traveling wave buncher (β=0.6, 2π/3).
   - TWB2: 16 cells trav. wave buncher (β =0.95, 8π/9).
3) Two traveling wave accelerating structures (β=1, 2π/3, 5.2 m long).
4) The transfer lines to the beam dump and to the booster.

The focusing in the low energy region (up to 10 MeV) is achieved by means of 31 solenoids. In the drift section at 50MeV, a quadrupole triplet matches the beam through the second accelerating structure.

Two 35MW pulsed klystrons, TH2100 from Thomson, are used to power the traveling wave bunchers and the accelerating structures. The power distribution between bunchers and section 1 is performed by means of two variable power splitters. The RF power needs for a 100 MeV operation are listed in table 2.

500 MHz prebuncher	500 W
4 cell buncher	2.7 MW
16 cell buncher	3.7 MW
Accelerating section 1	11.5 MW
Accelerating section 2	18 MW

Table 2: RF power needs at 100 MeV operation

2.2 Diagnostic Description

Except the Integrating Current Transformers (standard ICT monitors from Bergoz) all the diagnostics have been developed at PSI [7,8] and optimized to cover the large dynamic range of the SLS pre-injector.

Six optical Screen Monitors (SM) have been used during the commissioning. Two different monitors are installed in each SM station, a high sensitivity YAG:Ce detector for low current operation and an Al-foil producing Optical Transition Radiation (OTR) for high resolution measurements of the transverse beam parameters. All SM have been intensively used for fine beam alignment and focus optimization. In addition SM-5 and SM-E have been used for emittance and energy spread measurements. The emittance measurement technique, based on the observation of the beam spot while varying quadrupoles, is described in [7].

FCUP-1 (Faraday Cup)
- transient beam meas. behind the gun at 90 KeV.
- bandwidth: >6 GHz

WCM-1 and WCM-2 (Wall Current Monitors)
- transient beam meas. behind the gun and in the transfer line at 100 MeV
- cutoff: <100 kHz - bandwidth: ~4 GHz

ICT-1 and ICT-2 (Integrating Current Transformers)
- beam transmission efficiency trough Linac
- resolution: <5%

BPM (strip line Beam Position Monitors)
- mismatch design for high sensitivity and max. aperture for low current Top-up mode

Table3: Diagnostics main parameters.

The Wall Current Monitors (WCM) and the first Faraday Cup (FCUP-1) have been designed with suitable bandwidth for transient beam measurements (S-band buckets).

The diagnostic main characteristics are listed in table3.

3 COMMISSIONING RESULTS

3.1 Bunch characterization

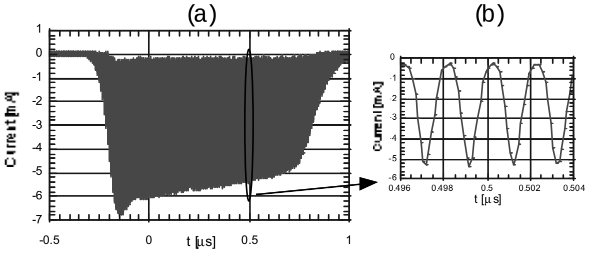


Figure 2: Bunch train envelope (a), current modulation (b)

Figure 2a shows the bunch train envelope measured at 90 KeV with FCUP-1. The magnification in figure 2b shows the 500 MHz modulation of the beam current.

The corresponding measurement in single bunch mode for different currents is shown in figure 3.

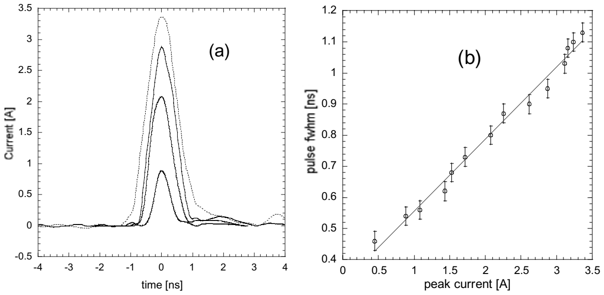
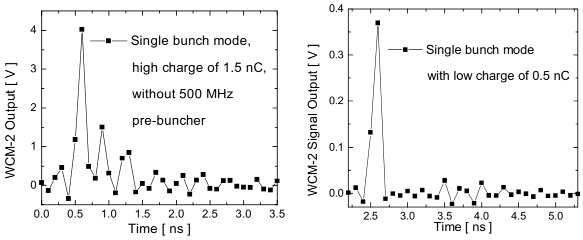


Figure 3: Single bunch pulse at 90 KeV (a), full width at half maximum versus peak current (b).

In the range from 0.5 to 3.5 A of peak current the half-bunch-width is increasing linearly with the current, but remain always <1.1ns. The short bunches at low charge may increase significantly the overall transmission of the pre-injector.



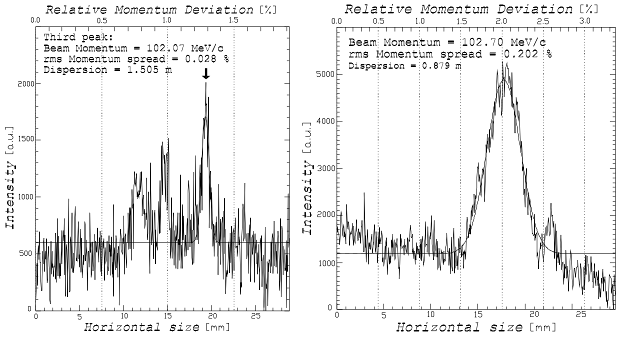
a) b)

Figure 4: (a) three S-band buckets in single bunch mode with 1.5 nC charge, (b) single bunch of 0.5 nC. (both measurements without 500 MHz pre-buncher).

Two examples of S-band buckets at 100 MeV are shown in figure 4: the three S-band buckets observed without sub-harmonic pre-buncher (4a) can be reduced to one by decreasing the charge(4b). As predicted by Parmela simulations, the same effect can be obtained at full charge when activating the sub-harmonic pre-buncher. The energy spectrum measurements on SM-E (see below) show clearly this phenomena. Measurements in figure 4 were performed with WCM-2 using the fast oscilloscope Tektronix TDS 604 C (3GHz bandwidth).

3.2 Linac Energy Spread Measurements

The energy spread is calculated from the measured dispersion at SM-E. The optics is optimized using the information given by the emittance measurement, in order to minimize the β function on SM-E resulting in a minimized emittance contribution to the beam size.



a) b)

Figure 5: Energy spread measurements at SM-E with SPB OFF (a) and SPB ON (b).

Figure 5 shows the energy spectrum measurements for two cases, without (5a) and with sub-harmonic pre-buncher (5b). Without SPB three electron bunches at different energies can clearly be seen. The time domain measurement shown on figure 4a, and energy spread measurements of figure 5a were taken simultaneously. From the charge distribution of the three S-band bunches, we can clearly identify the "high charge/high energy" bunch as the first S-band bunch in the time domain; the "medium charge/medium energy" bunch as the second and the "low charge/low energy" as the third. This occurs when a ~1ns long bunch is captured directly by the S-band bunchers. The "three pecks" energy spectrum is related to the beam loading in the accelerating structures. The effect of the 500 MHz pre-buncher can be clearly seen merging the three S-band buckets. The resulting energy spread of 0.2% meets the beam specification.

3.1 Commissioning Summary

During the acceptance tests, the long term stability of the system has been demonstrated within the specified beam parameters, as shown in table 5.

	single bunch	**multi-bunch**
Single bunch width	1 ns	
Multi bunch width		0.5 μs
Charge in a bunch/ bunch train	2 nC	2.1 -2.3 nC
Energy	102 MeV	103 MeV
Pulse to pulse energy stability	<0.1%	<0.1%
Energy spread (rms)	0.2%	0.3%
Normalized emittance (1σ)	50 mm mrad	40 mm mrad
Single bunch purity	<0.01	
Repetition rate	3.125 Hz	3.125 Hz
RF reflected power interlock trips	1 trip/4hours	2 trips/4hours

Table 5: Measured beam parameters.

4 CONCLUSIONS

The SLS pre-injector has been successfully installed and commissioned during April 2000. The beam parameters specified for an efficient beam injection into the storage ring have been reached. According to Parmela simulations a even better optimization of the emittance at 1.5 nC seems to be possible. This will be experimentally investigated later.

Beginning of July 2000 the full injector commissioning (linac and booster) will start as scheduled.

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