BEAM DYNAMICS OF THE 50 MeV PREINJECTOR FOR THE BERLIN SYNCHROTRON BESSY II

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Abstract

A turn key 50 MeV linac is under construction, in order to inject electrons into the booster of BESSY II synchrotron in replacement of the existing microtron. The linac will deliver electron beams according to two operation modes: a Short Pulse Mode (1 to 5 pulses - 0.35nC each) and a Long Pulse Mode (40 to 300 ns - 3nC). We have calculated the beam dynamics, using our in house code, PRODYN [1], from the gun to the end of the linac. This code has been previously used for the beam dynamics of the SOLEIL and ALBA linacs [2] [3]. The beam behaviour, such as the radial control, the bunching process, the energy spread and emittance are analyzed.

INTRODUCTION

Since about 7 years the hybrid filling mode became the standard mode of operation for BESSY II to satisfy simultaneously the multi-bunch users, the femto-second slicing experiments [4] and users running time resolved experiments. In this mode 350 out of 400 buckets are filled with typically 8.3 mA per bunch and a single bunch is filled with 15 mA located in the middle of the filling gap giving a total beam current of 300 mA. This filling pattern is generated by asynchronous injection of the bunch train from the synchrotron with simultaneous RF-knockout of bunches in the filling gap followed by the injection of a single bunch in the middle of the gap. The net filling time for the hybrid mode is dominated by the single bunch filling rate of typically 50 μA /sec limited by the low beam current of the injector microtron.

To improve the conditions for the femto-second slicing experiments and for other time resolved experiments more complex filling patterns with several hybrid mode gaps and/or several single bunches in the gap are needed. Also for the top-up injection mode in preparation for BESSY II a high single bunch current from the injector is mandatory [5].

In contrast to microtrons modern linacs allow to generate high single bunch currents and pulse trains with reasonable flatness and sharpness at the edges. Therefore the population gaps can be produced by synchronous injection of suitable bunch trains into the storage ring making the time consuming knock-out procedure obsolete.

GENERAL DESCRIPTION OF THE LINAC

Fig. 1 shows a schematic layout of the 50 MeV linac. The subsystems are listed below:

- A 90 kV triode gun which derives from a Pierce gun diode geometry.
- Four short focusing shielded lenses between the gun and the buncher.
- A pre-bunching cavity at a sub harmonic frequency of 499.625 MHz.
- A pre-bunching cavity at 2997.750 MHz.
- A standing wave buncher.
- A travelling wave accelerating structure.
- A Glazer lens between the buncher and the accelerating structure.

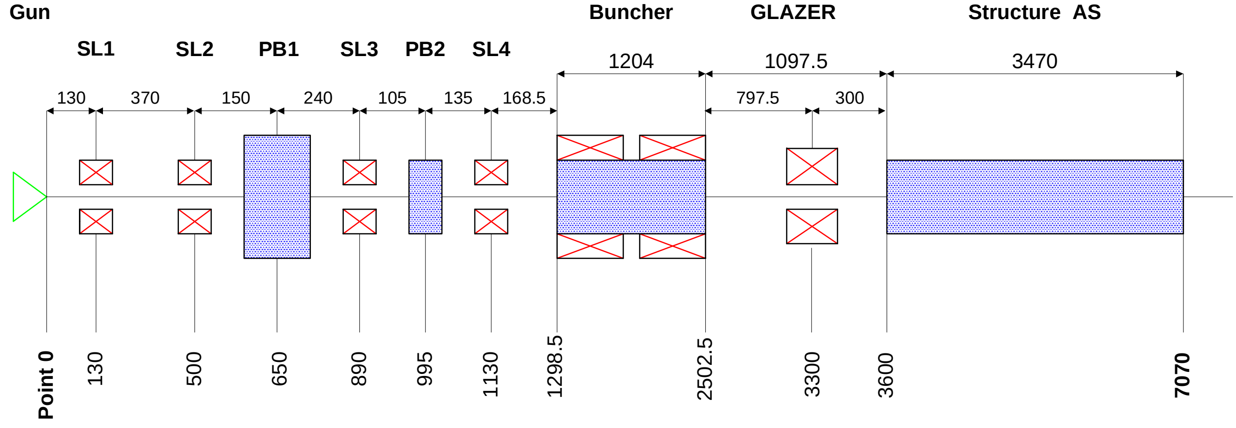

Figure 1: Schematic layout of the 50 MeV linac (unit in mm)

The main specifications of the linac are presented in the following table.

Table 1: Linac Specifications

RF frequency	2997.750 MHz
Energy	55 MeV >E ≥ 50 MeV
Energy spread	< 0.40% rms
Repetition rate	1 to 10 Hz
Normalised emittance $\pi\beta\gamma\sigma\sigma'$	< 50π mm. mrad
Short Pulse Mode	1 to 5 pulses per train
Gun pulse width	< 1 ns full width at 10%
Time between pulses	12 to 400 ns
Output charge per pulse	> 0.35 nC
Long Pulse Mode	
Gun pulse duration	40 to 300 ns
Maximum charge per train	3 nC

According to the two different running modes, two current levels are needed at the gun output: 240 mA for the Long pulse mode at 80 ns and 560 mA for the Short pulse mode.

SIMULATION RESULTS

The Gun and the Pre-bunchers

The proposed gun is a Pierce type geometry using an EIMAC Y-845 cathode with a 0.5 cm^2 emissive area. This gun has been simulated with the EGUN code [6].

For both operation modes, the outgoing beam is practically parallel in order to limit the space charge effects and therefore to reduce the final emittance. The four short shielded lenses between the gun and the buncher ensure the beam focusing at low energy.

The sub-harmonic pre-bunching cavity at 499.625 MHz is a pill box cavity derived from the ELETTRA preinjector and already used at ALBA. The cavity is cylindrical, with a diameter of 460 mm and a length of 140 mm. The drift between the pre-buncher and the buncher is 650 mm long. The beam modulation is about ± 25 kV. The one nanosecond pulse (180 degrees at 499.625 MHz) is bunched with a phase extension of 40 degrees at 499.625 MHz, or 240 degrees at 2997.750 MHz.

The pre-bunching cavity allows for only one pulse at 3 GHz, instead of three, from the one nanosecond pulse. This enables a halving of the energy spread in Single Bunch mode. This effect was measured at ALBA [7].

The beam modulation of the pre-bunching cavity is about ± 10 kV with a 90 W RF feed. The drift between the pre-buncher and the buncher is 30 cm long.

With the two pre-bunching cavities, 86% of the 1ns input pulse falls within a 64 degrees phase extension at the buncher entry and for 75% of the gun current the phase extension is reduced to 43 degrees (i.e. 7 degrees at 499.625 MHz). Fig. 2 shows the phase-energy diagram at the buncher entry.

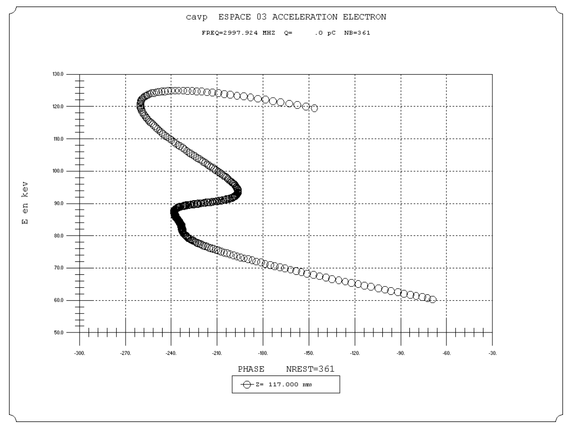

Figure 2: Phase-energy diagram at the buncher entry

The Buncher

The buncher is a 1.1 meter long standing wave structure at the π/2 mode. The beam aperture diameter is ø 27 mm. The first two of the 22 cells have a reduced beta for the bunching process (ß = 0.78 and 0.90).

A 5 MW RF input power increases the energy up to 15.7 MeV with an average electric field on axis of 18.7 MV/m (peak field of 27 MV/m). The beam focusing is ensured by two shielded solenoids surrounding the buncher structure and providing a maximum magnetic field of 0.2 Tesla.

The choice of this high energy buncher avoids the use of solenoids on the accelerating structure. For both modes, around 95 % of the gun current is found at the buncher exit. Without the sub harmonic cavity, the buncher transmission decreases to 80 %.

Table 2 gives the beam properties, at the buncher exit, with respect to the gun current at 15.7 MeV.

Table 2: Beam Properties at the buncher exit

Gun Current	0 mA	240 mA	560 mA
Transmission in:			
ΔE =400 keV	87 %	74 %	66 %
ΔE = 300 keV	85 %	69 %	59 %
Δφ = 20 degrees	89 %	73 %	66 %
Δφ = 16 degrees	85 %	67 %	60 %

The accelerating section

The main accelerating structure is identical to those made for the ALBA preinjector [7].

It is a travelling wave $2\pi/3$ mode section designed with a constant gradient. The iris diameter varies from 22.4 mm to 16 mm, giving a group velocity c/v_g from 51 to 149 over 96 cells including the couplers cavities ones.

The filling time is 0.88 µs and the power attenuation is equal to 5.6 dB.

A peak electric field of 23.4 MV/m on axis (36.1 MV/m on copper) provided with an 18 MW RF feed, allows an energy increase of 52 MeV. A 5 MW RF input power for the buncher together with an input power around 8 MW for the accelerating structure, give a final energy of 50 MeV at the end of the linac.

The section is used without external focusing, except for a Glazer lens between the buncher and the section.

The phase adjustment between the buncher and the section insures the radial focusing.

Table 3 gives the beam properties at the linac end for both operation modes at 240 mA and 560 mA.

Table 3: Beam properties at linac end

Injection mode	LPM–240mA	SPM–560mA
Final average energy	53.5 MeV	53.5 MeV
Total transmission	68 %	61 %
Particles ratio of the output beam in:		
$\Delta\varphi$ = 15 degrees	90 %	87 %
Δ E/E = 0.33% rms	96 %	95 %
Δ E/E =0.17% rms	84 %	84 %
Beam radius < 3mm	92 %	82 %
$\pi\beta\gamma\sigma\sigma'$ (mm.mrad) average value for 69%	19 π	30 π

Figures 3 and 4 show, at the linac end, respectively the X-X' plane emittance for the 240 mA and the energy histogram for the 560 mA.

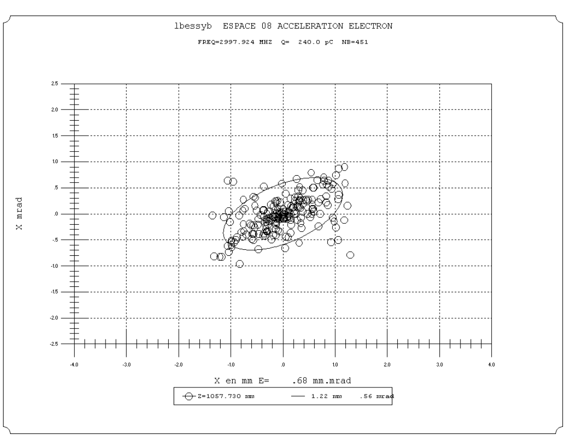

Figure 3: Emittance at the linac end for the 240 mA mode.

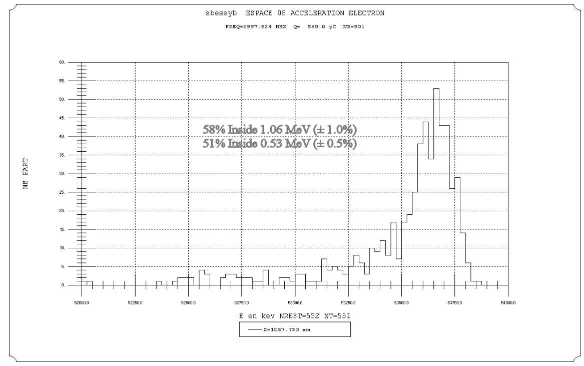

Figure 4: Energy histogram at the linac exit for the 560 mA mode.

CONCLUSION

Beam dynamics for the two operation modes at 240 mA and 560 mA, meet the specified values.

The expected low energy spread is achievable thanks to the small phase extension, at the buncher exit, due to the use of the two pre-bunching cavities.

Emittance growth is kept moderate by the adjustment of the magnetic field at the injection level between the gun and the buncher.

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