A NEW TIMING SYSTEM AND ELECTRON GUN MODULATOR

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Abstract

In the last decade, Thales Communications & Security has manufactured turnkey linacs for the SOLEIL, ALBA and BESSY II synchrotrons. In the meanwhile, a new timing system and electron gun modulator was designed and a gun pulse length of 600 ps was measured. This paper will describe the system and will present the beam dynamics simulations results, comparing them with those obtained with the previous gun modulator [1].

TIMING SYSTEM AND ELECTRON GUN MODULATOR

The Timing System of the Linac must deliver the trigger and gating signals to the electron gun, klystrons modulators, and RF pre-amplifiers. In the single bunch operation mode, the Linac will deliver a number of micro-bunches with a programmable time interval between them. The resolution of this time interval must be equal to the period of the Storage Ring, approximately 2 ns. Furthermore, it is necessary to precisely adjust the delay between the two RF signals of the accelerating structures in order to optimize the beam loading compensation.

Therefore a specific Timer Unit based on fast ECL counters clocked by the Synchrotron master oscillator signal, up to 600 MHz, was designed. The Trigger signal received starts a set of counters that deliver:

- Two gating signals for the klystron RF pre-amplifiers,
- Two trigger signals for the klystrons modulators,
- The trigger signal for the 500 MHz amplifier,
- The modulation signal for the electron gun.

Width and/or delay of these signals are remotely programmable with the suitable time resolution. The modulation signal for the electron gun is not a simple trigger signal, but a set of 1 ns wide pulses depending on the operation mode as represented hereafter:

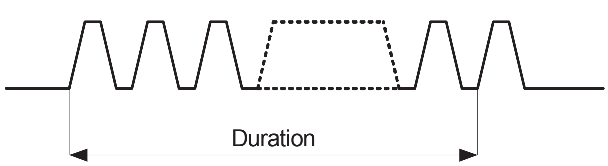

Figure 1: Multi Bunch operation mode.

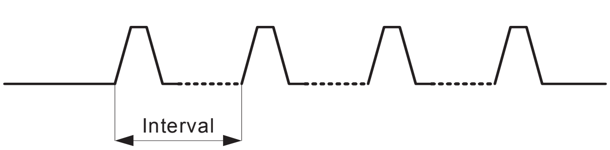

Figure 2: Single Bunch operation mode.

In the multi-bunch operation mode, the total duration of the bunch is programmable from 40 to 1000 ns by steps of 8 ns. In the single bunch mode, the number of micro-bunches is programmable between 1 and 16 and the time interval is programmable from 6 to 256 ns by steps of 2 ns.

Short Pulse Generation

The new Timer Unit and the Cathode Driver Board can deliver pulses shorter than 1ns in two steps.

The first one is realized by the use of two clocks with a phase delay Δϕ like the schematics down side:

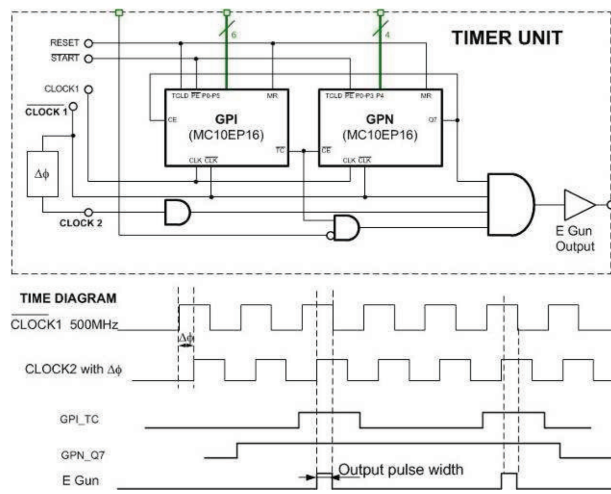

Figure 3: Short pulse generation.

The output pulse width should be equals to ½ clock duration minus phase delay Δϕ.

Electron Gun Modulation

This modulation signal is sent through a high bandwidth analogue optical link toward the electron gun modulator.

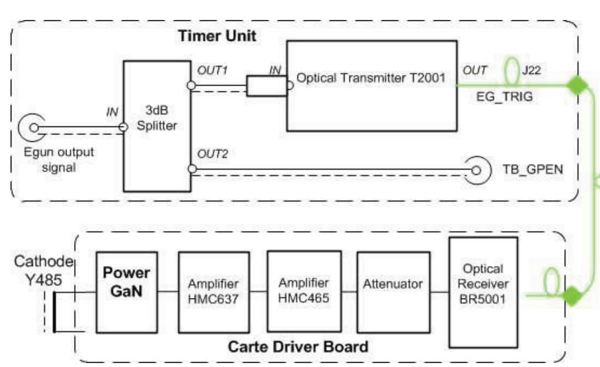

Figure 4: Electron Gun modulator.

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The optical receiver REC sends the modulation signal to a fast GaN HEMT that drives the cathode of an EIMAC Y845 assembly, according to the following design. The cathode is polarized by the power supply PS1 and the filament is powered by PS2.

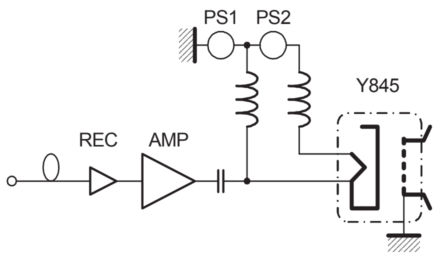


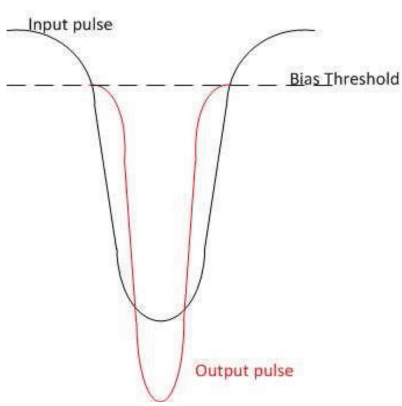
Figure 5: EIMAC – Y845 cathode's polarization scheme.

This design is more efficient and reliable than the classical solution using a RF generator for the multi-bunch mode and a pulse generator for the single bunch mode.

To realize a variable electron current, a variable attenuator is placed after the optical link (so the optical link works with constant dynamics).

Two stages of ultra-bandwidth AsGa MMIC (total gain 30 dB) delivers up to 3V (on 25Ω) to the GaN HEMT, class B polarised.

This polarisation allows to a second step of pulse shortening.



The final width of the Single Pulse Mode electron beam delivered is close to 500 ps at the output electron gun.

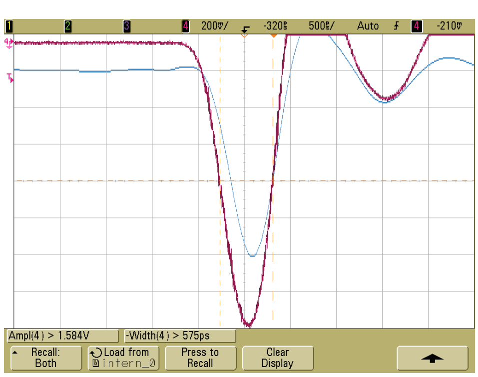


Figure 6: Electron beam gun measurement.

BEAM DYNAMICS SIMULATIONS

The Gun and the Re-Bunchers

The injection line from the gun to the buncher includes two pre-bunching cavities at 499.654 MHz and at 2997.924 MHz for our linacs, except for SOLEIL with a booster not in the sub harmonic range [2]. The drift between the pre-buncher and the buncher is 650 mm long. The beam modulation is about ± 25 kV with a 500 W RF feed. The one nanosecond pulse (180 degrees at 499.654 MHz) is bunched with a phase extension of 40 degrees at 499.654 MHz, or 240 degrees at 2997.924 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 [3].

The beam modulation of the 3 GHz pre-bunching cavity is about ± 10 kV with a 90 W RF feed. The drift between the pre-buncher and the buncher is 300 mm 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 499.654 MHz). Fig. 7 shows the phase-energy diagram at the buncher entry. Fig. 8 and 9 show respectively, at the buncher exit, the energy and the energy histogram.

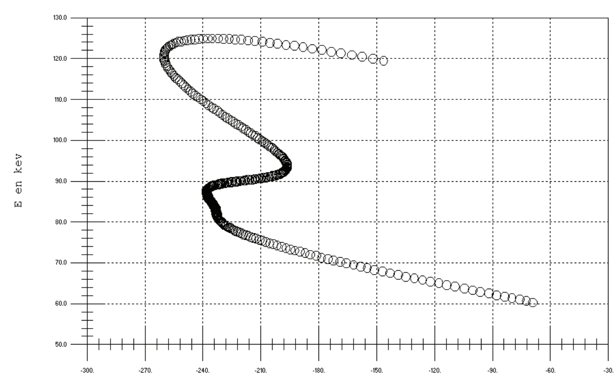


Figure 7: Phase-energy diagram at the buncher entry.

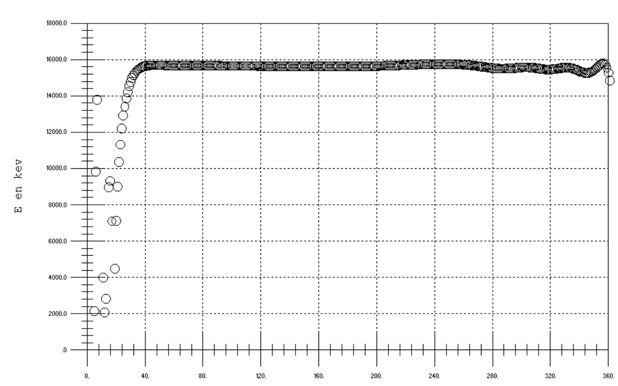


Figure 8: Energy at the buncher exit.

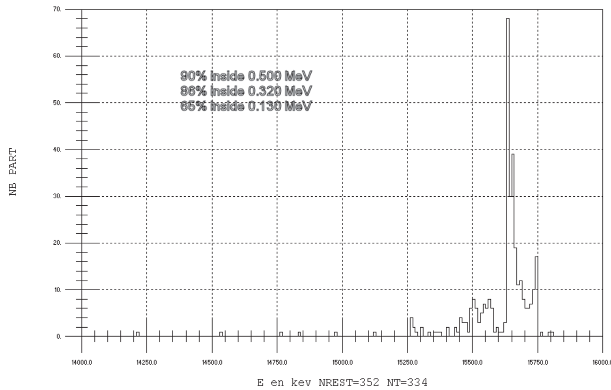


Figure 9: Energy histogram at the buncher exit.

The same simulations done with an input beam of 500 ps, give the following results seen in Fig. 10, 11 and 12.

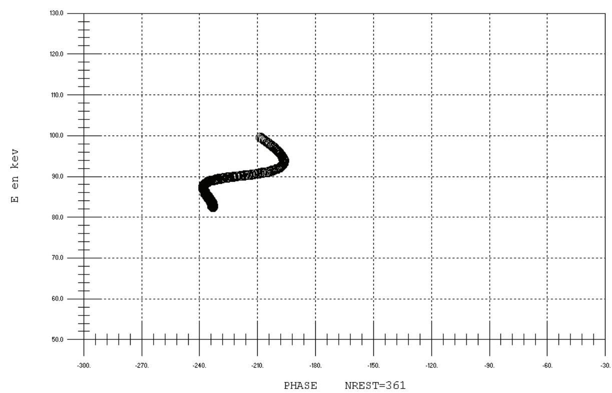


Figure 10: Phase-energy diagram for 500 ps.

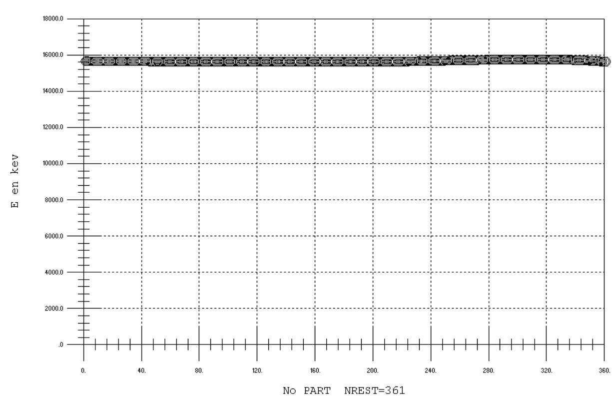


Figure 11: Energy at the buncher exit for 500 ps.

Table 1 gives the beam properties with respect to the gun pulse length, at the buncher exit and for 15.7 MeV.

Table 1: Beam Properties at the Buncher Exit

Gun Current	1000 ps	500 ps
Transmission in:		
ΔE = 120 keV	64 %	100 %
Δφ = 6 degrees	69 %	100 %

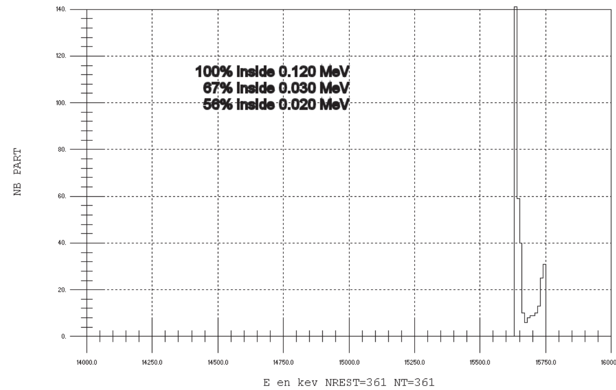


Figure 12: Energy histogram at buncher exit for 500 ps.

The simulations carried out for the whole linac by adding two accelerating structures, give the following results for 120 MeV resumed in table 2.

Table 2: Beam Properties at the Linac Exit

Gun Current	1000 ps	500 ps
Transmission in:		
ΔE=1.0MeV ±0.42%	80 %	
ΔE=0.3MeV ±0.13%	66 %	100 %
ΔE=0.2MeV ±0.08%	61 %	98 %
Δφ = 20 degrees	89 %	
Δφ = 6 degrees	66 %	100 %

CONCLUSION

The ALBA pre-injector linac for the Spanish synchrotron light source was successfully installed and commissioned during the year 2008 [3]. The measured linac parameters fitted well with beam dynamics simulations.

In the meanwhile, a new timing system and electron modulator was designed and measured. Together with the simulations done recently with a 500 ps gun pulse we can then expect with this new system, an output beam of 120 MeV with an energy spread of 0.2 MeV i.e. ±0.08% and a phase extension of 6 degrees at 3 GHz.

REFERENCES

[1] A. Setty, "Beam dynamics of the 100 MeV preinjector for the Spanish synchrotron ALBA", PAC07, Albuquerque, USA, June 2007.
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