

LINAC GUN DRIVER FOR THE SWISS LIGHT SOURCE 2.0

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Abstract

The Paul Scherrer Institute has developed advanced Linac gun driver electronics designed for use in Linear Accelerators, particularly for modern Synchrotron Light Sources. A prototype of this innovative gun driver was successfully evaluated during the final three months of user operations at the Swiss Light Source (SLS). The finalized design is now installed and is integrated into the upgraded SLS 2.0, which just started operations in 2025.

The new gun driver is engineered to achieve extremely short electron bunch lengths, a key requirement for SLS 2.0 top-up operations. It delivers single pulses with the following specifications: 80 ps fall-time, 120 ps FWHM, and a -300 V peak amplitude, with a jitter of less than 5 ps rms.

These enhanced performance parameters will facilitate a future redesign of the SLS Linac, making it more compact while further improving its functionality.

This presentation will outline the implementation of the new gun driver and showcase the results obtained during its evaluation.

INTRODUCTION

The SLS 2.0 [1, 2] Linac [3] is composed of an electron source (also known as the “electron gun”), a sub-harmonic pre-buncher and two travelling wave accelerating sections amongst others, as shown in Fig. 1.

The electrons are extracted from a thermionic cathode in the electron source by applying a high voltage of 90 kV between cathode and anode and a negative voltage pulse at the cathode.

The two travelling wave accelerating structures are each 5.2 m long and operate at an RF frequency of 3 GHz. They increase the energy of the electrons to 100 MeV and their speed to almost the speed of light.

A 16 m long beam transport system, composed of several magnets, guides the electrons towards the booster, into which they are injected using kicker magnets. For diagnostic purposes, the beam from the Linac can also be diverted to a beam dump.

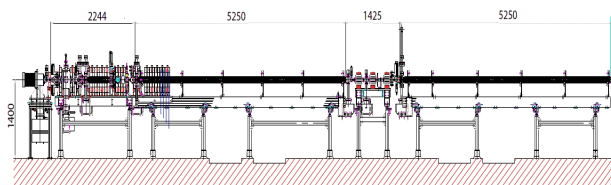


Figure 1: SLS 2.0 Linac.

In the last years the SLS accelerator complex has been configured for Top-up operation. For this type of operation, a single electron bunch without satellites at the exit of the Linac is preferred. This single electron bunch is injected

into the booster accelerator where its energy is further raised up to 2.7 GeV and is then, with the help of our timing system, used to evenly refill the electron buckets of the SLS Storage Ring in order to keep the charges of all buckets approximately equal and constant.

THE LINAC GUN

Figure 2 shows the configuration of the SLS 2.0 Linac Gun, which is of type floating ground at -90 kV. The accelerator structures are at ground level 0 V. Because of the Miller capacitance the excitation at the grid is expected to be very slow (fall-time around micro-seconds range). On the other hand, the cathode excitation presents no Miller capacitance, leading to much faster operation. Due to this a negative excitation at the cathode was chosen.

The impedance of the cathode to ground is quite non-linear due to the space charge effect (Child-Langmuir relation), which leads to compression effect at low pulse levels near the grid voltage.

The capacitance of the cathode to ground is expected to be mostly linear with small non-linear effects which are difficult to parametrize.

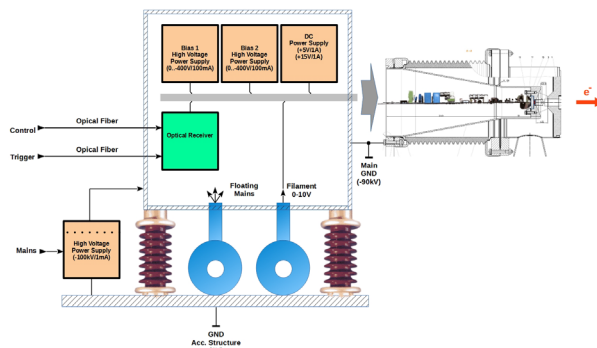


Figure 2: SLS 2.0 Linac gun configuration.

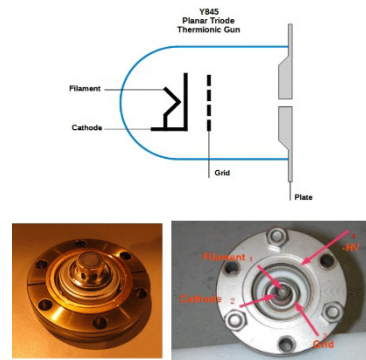


Figure 3: Y845 planar triode.

Figure 3 shows the thermionic planar triode, which is of type Y845 [4, 5] originally produced by EIMAC (now CPI). The approximated parameters of this planar triode,

which are estimated for a grid voltage around -50 V and an anode voltage of -90 kV, are shown in Table 1.

Table 1: Y845 Planar Triode Estimated Parameters

Parameter	Value	Remarks
Gm_grid	0.017 nC/V	Vgrid=50 V
Gm_cathode	1.6 nC/V	Vgrid=50 V
Perveance	0.12 μperv	
Capacitance	10 pF	Cathode Input
Resistance	~25 Ω	Cathode Input Vpulse > Vgrid
Rp	~100 kΩ	Vanode=90 kV

LABORATORY MEASUREMENTS

Figure 4 shows the low jitter set-up used for the laboratory measurements, which are performed using a Tektronix oscilloscope type CSA803C with SD-26 dual-channel sampling heads. The bandwidth available is 18 GHz.

Figure 5 shows the fast pulse obtained with the output of the pulser terminated by a 50 Ω load. The peak power exceeds 2 kW. Other output pulse parameters are listed in Table 2.

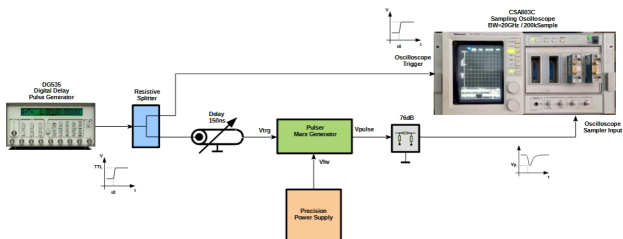


Figure 4: Low jitter measurement-setup.

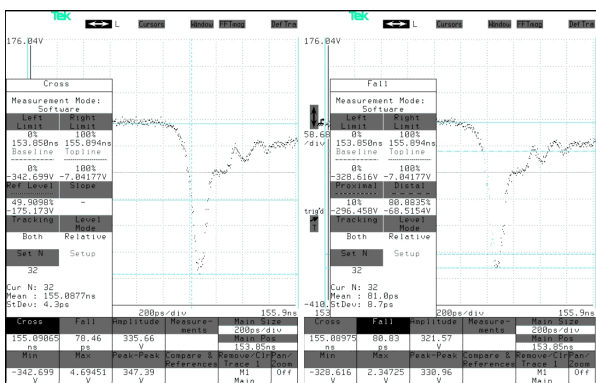


Figure 5: Output pulse measurement. Repetition Rate = 100 Hz and Pulser High Voltage = 155.2 V.

In the laboratory, we performed fail-free long-term tests with 100 Hz repetition rate, which are equivalent to more than 10 years operation at our Linac trigger rate of 3 Hz.

We qualified this pulser for operation with repetition rates up to 1 kHz. These tests were also performed without failures.

Table 2: Output Pulse Parameters

Parameter	Value	Remarks
Peak Voltage	-330 V	50 Ω Load
Peak Power	>2k W	50 Ω Load
Fall-Time	80 ps	
FWHM	120 ps	
Jitter	5 ps rms	50% cross, 3min

LINAC MEASUREMENTS

A variety of diagnostic [6] components were used to characterize the new fast pulser, among them are ICTs (Integrated Current Transformer), WCM (Wall Current Monitor), FCUP (Faraday-Cup) and BBPs (Broadband Pickups).

The Linac measurements may have been bandwidth limited because of measurement-setup constraints.

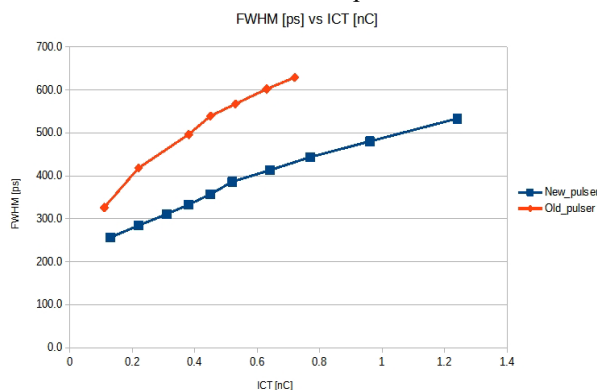


Figure 6: Faraday-cup performance comparison of old pulser vs. new pulser.

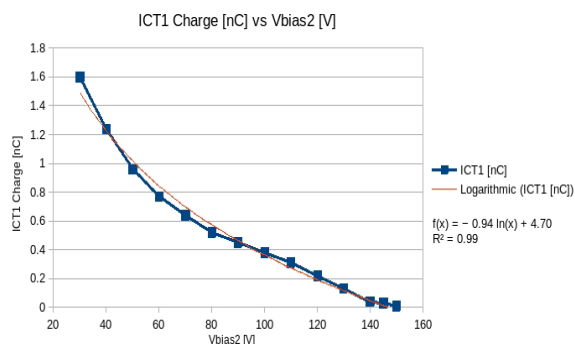


Figure 7: Beam charge vs. grid bias (Vbias2 = Vgrid).

A comparison of Faraday-cup measurements between the old pulser and the new pulser described in this article is shown in Fig. 6, The Faraday-Cup was inserted just after the gun. Figure 6 confirms the performance improvement of the new pulser.

The delivered electron charge can be adjusted by changing the grid bias (voltage) as shown in Fig. 7.

Figure 8 shows the pulse shape according to the grid bias. The pulse widens and the change increases as the grid bias is reduced. This is mainly due to the pulse tail and the triode space charge effect. The parallel capacitance of the

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cathode to ground may also widen the pulse because of integration.

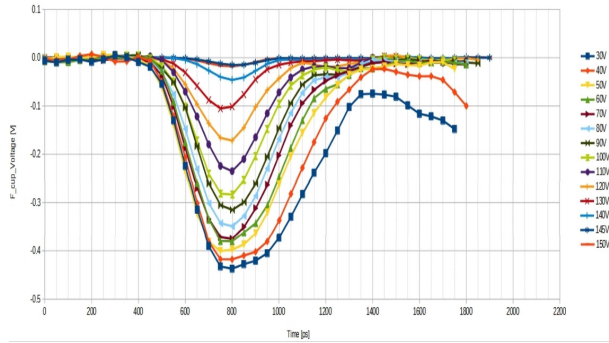


Figure 8: Faraday-cup voltage vs. time for different grid voltages ($V_{bias2} = V_{grid}$). Time base = 20 ps/div.

Figure 9 (pink trace) shows the measurement realized using the last BBPs after the accelerating structures at the end of the Linac. It confirms the presence of a single bunch without satellites with sub-harmonic pre-buncher enabled. Figure 10 shows similar result also without satellites and with the sub-harmonic pre-buncher disabled.

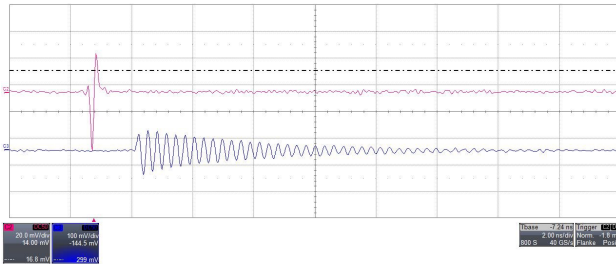


Figure 9: Waveform from beam pick-up after the accelerating structures showing no satellites. Sub-harmonic pre-buncher enabled. Time base = 2 ns/div.

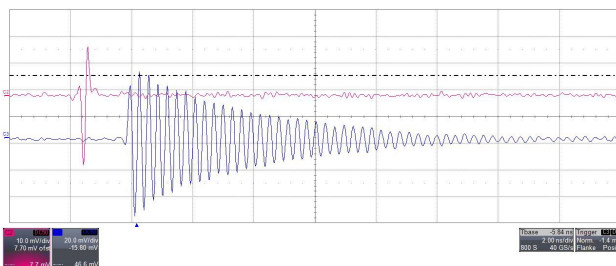


Figure 10: Waveform from beam pick-up after the accelerating structures showing no satellites. Sub-harmonic pre-buncher disabled. Time base = 2 ns/div.

A successful installation of the new pulser (see Fig. 11) happened beginning of 2025 during the preparation for the start-up of the SLS 2.0 accelerator complex. Most of the field tests were done in this period. The SLS 2.0 start-up was smooth, and the new gun driver has been since then in continuous operation.

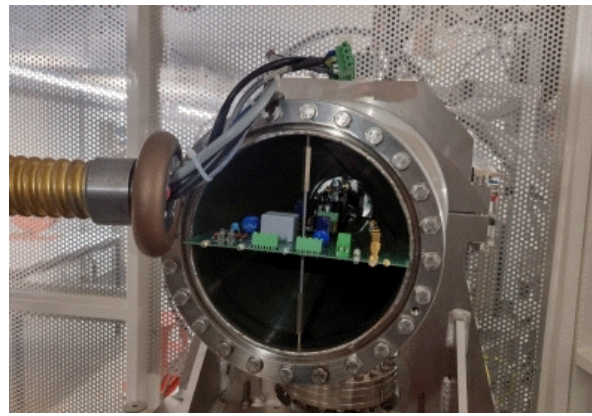


Figure 11: Installation of the new pulser in SLS 2.0 Linac.

CONCLUSION

In this work, we presented the new fast pulser developed for the thermionic gun of the SLS 2.0 Linac.

We have shown that the excitation of the cathode gun by an ultra-short pulse is feasible.

We have also confirmed that it is possible to send the generated short electron bunch directly to the 3 GHz travelling wave accelerating structures without sub-harmonic pre-bunching. This unveils new possibilities for simpler and smaller Linac designs.

The Linac can easily be tuned so that a single bunch with complete absence of satellites is present at the end of the accelerating structures.

ACKNOWLEDGMENTS

We would like to acknowledge the PSI Center for Accelerator Science and Engineering and the High Frequency Section for their financial support for this project.

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