DEVELOPMENT OF FAST AND SUPER-FAST KICKER SYSTEM FOR SLS 2.0 INJECTION

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Abstract

Swiss Light Source plans a major upgrade to turn the existing Storage Ring (SR) into a modern diffraction limited light source called SLS 2.0. As part of this project, the injection system has to be upgraded as well in order to ensure reliable and efficient injection in the reduced beam aperture.

A 4 kicker bump and new thin septum will ensure the conventional injection in the SR. To further minimize the perturbation of the stored beam during injection two new schemes are in development: “Fast” and “Super-fast” one.

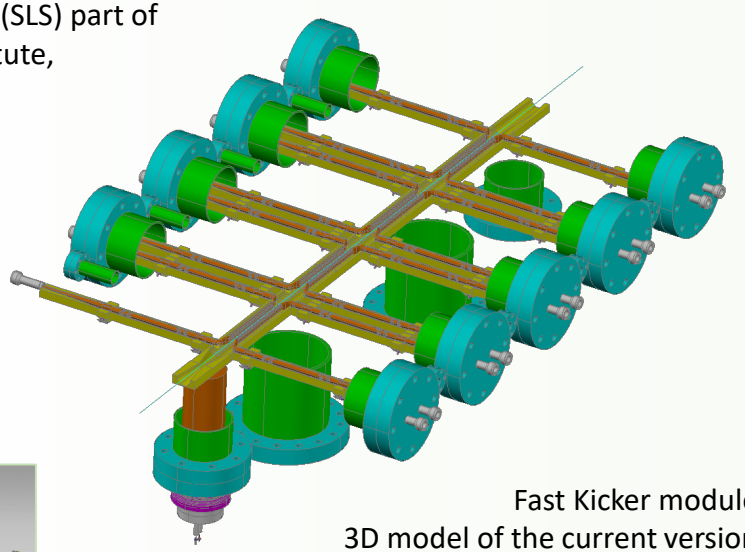
The “Fast” injection scheme should be able to ensure single-bunch off-axis top-up injection affecting only 10 to 20 SR bunches that are 2 ns apart.

The “Super fast” one should bring the perturbed bunches down to only one.

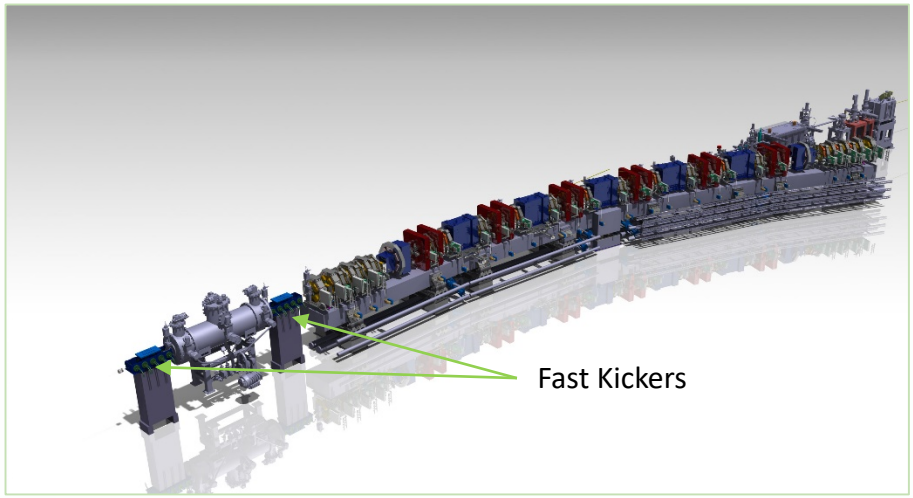
In “on-axis” mode it should be able to inject a top up bunch between two SR bunches with minimum disturbance of the adjacent ones. To do this a combination of special beam injection schemes and an extremely fast (ns) kicker system is required.

We will discuss the status of the development, the problems and the solutions for reaching such a challenging goal.

Swiss Light Source (SLS) part of Paul Scherrer Institute, Switzerland



Fast Kicker module
3D model of the current version
(FastKicker_Model_Diff_100H_V5_1)

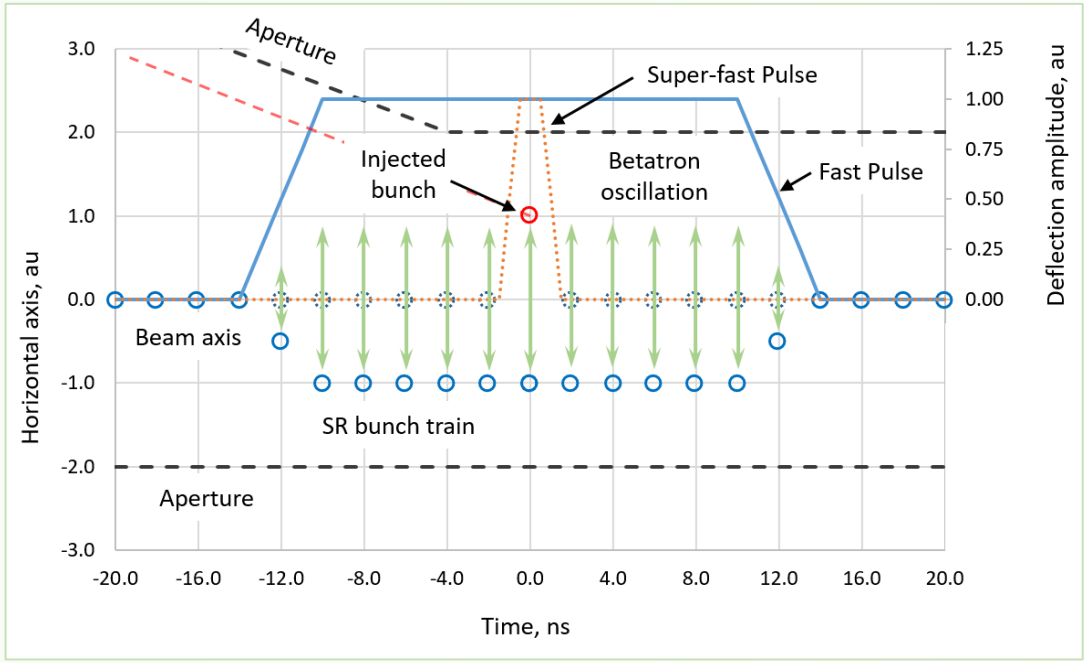


3D model of the upgraded SLS 2.0
electron storage ring starting with straight section 2

SLS 2.0 Advanced Injection Schemes

"Fast" injection scheme, aperture sharing

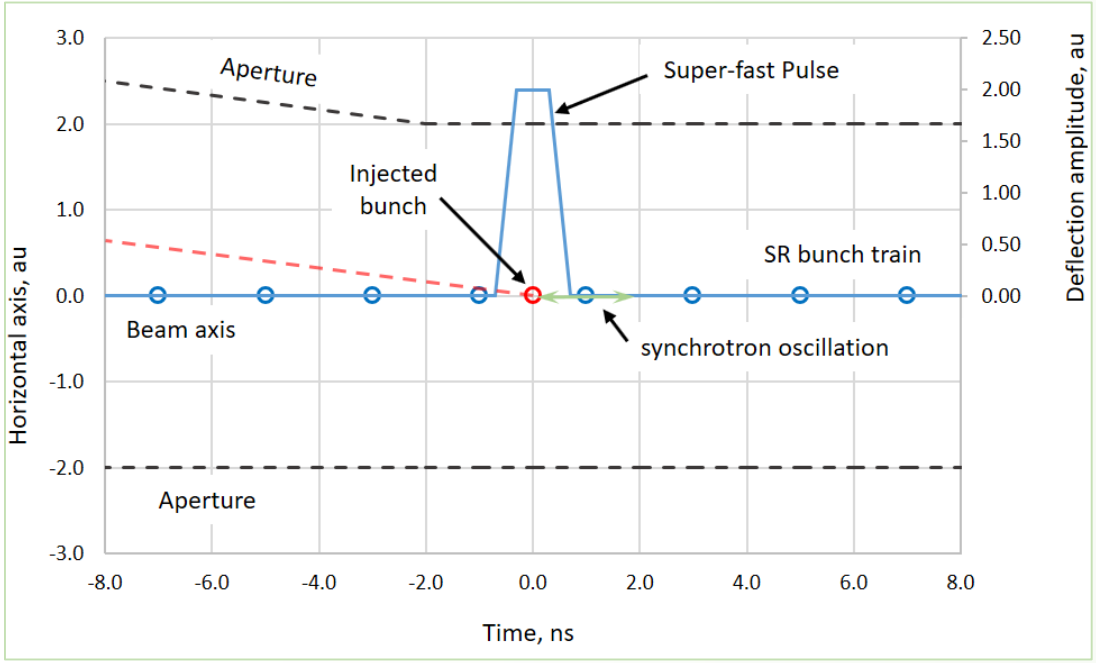
A portion of the stored beam (15 bunches in the illustration) and the *injected* bunch are deflected with a short kicker pulse (20..30 ns) to fit in the machine aperture. With decaying Betatron oscillation they come back on axis.



Simplified illustration of "Fast" injection scheme with aperture sharing (off-axis injection)

"Super-fast" injection scheme, on-axis

A very short kicker pulse (<2 ns) puts the injected bunch on-axis *without significantly disturbing* the adjacent stored bunches. With decaying Synchrotron oscillation the injected bunch joins a stored one.



Simplified illustration of "Super-fast" on-axis injection scheme

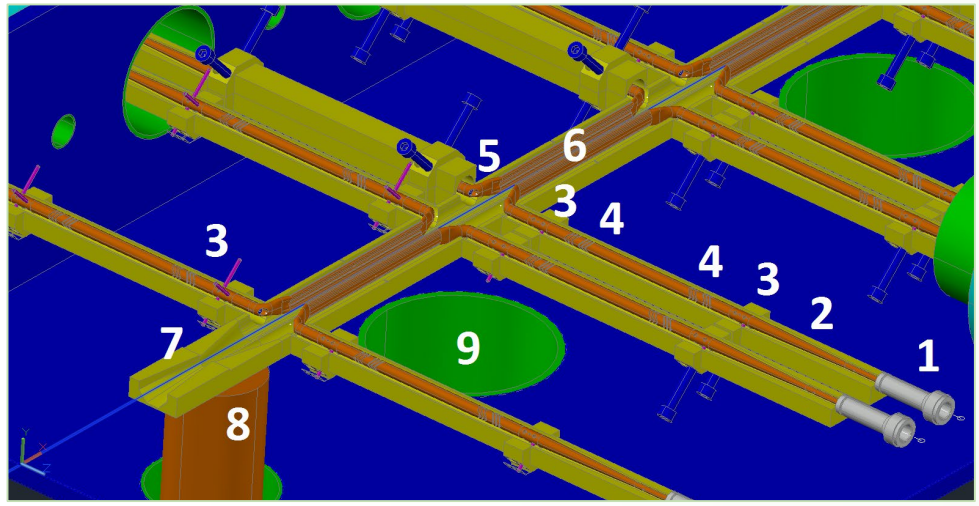
SLS 2.0 Fast Kicker requirements and construction

Given and machine related

Parameter	Fast	Super-fast
Beam momentum	2.7 GeV/c	
SR bunch spacing	2 ns	
Injection repetition rate	3 Hz	
Injection type	Horizontal	
Number of defl. SR bunches (off-axis)	<15	1
Number of defl. SR bunches (on-axis)	NA	0
Deflection angle (off-axis)	>0.35 mrad	
Deflection angle (on-axis)	NA	1.0 mrad
Horizontal aperture on axis	±5 mm	
Active kicker length	800 mm	

Derived and chosen kicker parameters

Parameter	Fast	Super-fast
Deflection type	Electromagnetic (TEM)	
Kicker type	Stripline (vacuum)	
Kicker section length	100 mm	
Number of sections	8	
Maximum deflection	0.5 mrad	1.0 mrad
Magnetic field	2.8 mT	5.7 mT
Electric field	0.9 MV/m	1.7 MV/m
Electrode voltage	±4.3 kV	±8.5 kV
Electrode current	±85 A	±170 A
Excitation pulse length	<30 ns	~1 ns
Odd / Even el. impedance	2x 50.0 Ω / 2x 56.0 Ω	



Current version 3D CAD model

(1) Broad bandwidth vacuum feedthrough for exciting/terminating the kickers

(2) Gradual diameter change of the coaxial transmission line to adapt the dimensions of the standard N-type connector to the feeding transmission lines

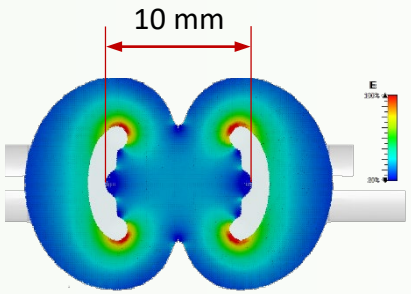
(3) Ceramic studs, spring supports and fine tread M5 bolts to fix the radial position of the middle conductor in the transmission line shell and the vertical blades position. Small amount of dielectric material ensures small electrical discontinuity in the support region

(4) Flexible section to cope with mechanical stress produced by blades' positon adjustment

(5) Blade-to-coaxial line transition

(6) Self-supporting blades to avoid ceramic spacers near the beam axis

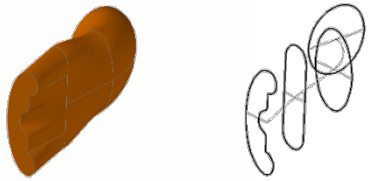
SLS 2.0 Fast Kicker – Electrical and Beam Characteristics



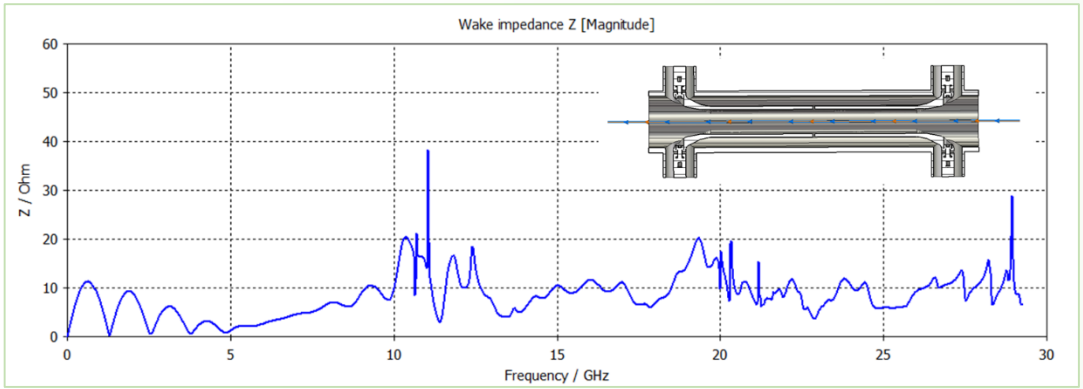
Kicker blades' cross section

The transition from the stripline structure to the feeding coaxial transmission lines is carefully designed to minimize impedance mismatch. This part of the geometry defines as well the amplitude of the beam-induced pulses.

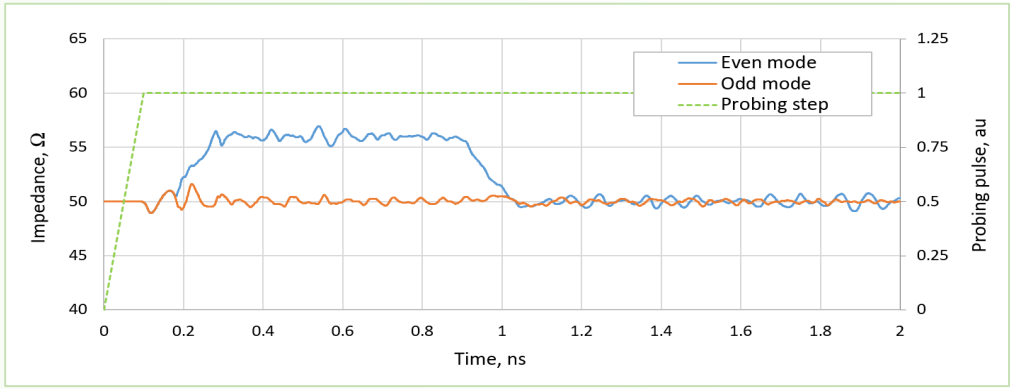
The kicker electrodes were optimized to provide the necessary field and electrical impedance maximizing the clear aperture on axis. Care was taken to avoid excessive surface electric field.



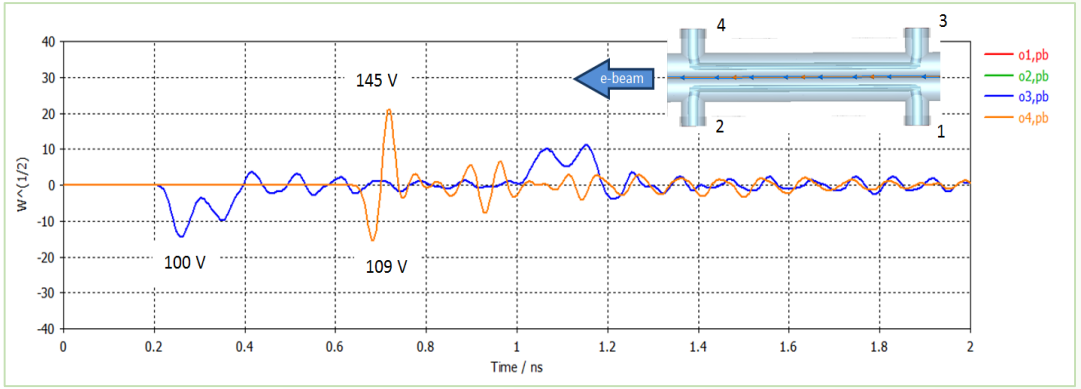
Blade-to-transmission line transition



Longitudinal beam impedance of single kicker section (Version Diff_100H_V5.1). The wake loss factor is 0.11 V/pC.



Simulated time domain reflectometry of the even and odd mode of one kicker section. The 100 ps probing step waveform is shown as well.



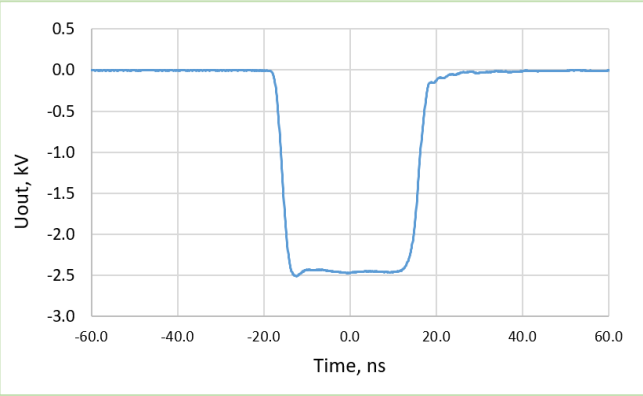
Beam induced pulses at excitation and termination ports of single kicker section – bunch charge 1 nC, bunch sigma 3.5 mm.

Pulse generation

“Fast” pulse generator

A low stray inductance Marx type generator is designed to produce 20..30 ns 5 kV pulses necessary for the “Fast” injection scheme. 5-stage prototype is built to demonstrating the fast rise and fall capability of the GaN JFET based design.

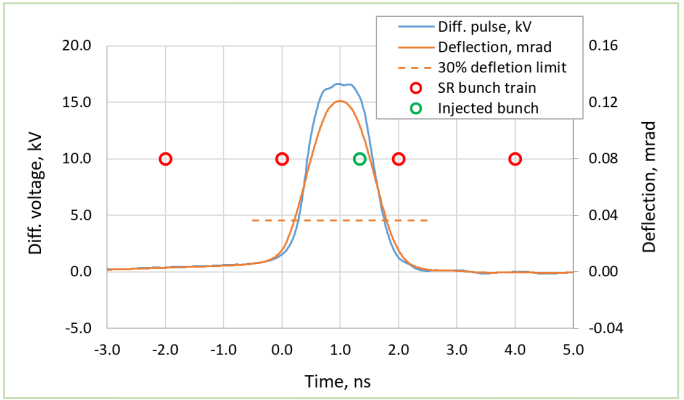
We hope to have the full 10-stage version soon.



Output pulse waveform of 5-stage prototype GaN JFET based Marx generator.

“Super-fast” superfast

A ±10 kV positive-negative prototype pulse generator pair was acquired from FID GmbH. It is capable of producing the required ~1.5 ns pulses that should allow injection of a single bunch (**green circle**) between two SR bunches (**red circles**) with small disturbance of the adjacent ones. The dashed line shows the 30% limit.



Differential voltage pulse waveform of FID GmbH pulse generator and the numerically calculated one kicker section deflection in the moving electron bunch frame.

Conclusion

The development of the SLS 2.0 advanced “Fast” and “Super-fast” injection schemes is *challenging and is still associated with significant risk*. Despite the technical difficulties the project is advancing and no *uncircumventable obstacles have been identified.*