SYSTEM OF HIGH-VOLTAGE NANOSECOND GENERATORS FOR INJECTION-EXTRACTION KICKERS FOR FEL COMPLEX OF THE DUKE UNIVERSITY

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Abstract

A 1.2 Gev booster-synchrotron was created in order to increase the electron beam current in the main ring of the free electron laser SR FEL. The booster is planned to have 19 electron bunches at most, with the possibility of their pass-by in the SR FEL with a maximal frequency of 25 Hz.[1] Operation in the main ring is planned in a few regimes: 2, 4 and 8 bunches. The aim of this work is to inject the beam from the linear accelerator to the booster with minimal losses; to extract the beam in bunches from the booster and to inject it to the main ring of the SR FEL. This works considers a system of nanosecond generators of beam kick pulses on the injection and extraction kickers of the FEL booster as well as a kicker system to inject the beam into the main ring of the SR FEL. In the nanosecond generators, energy is switched to the load with the use of the Pseudo-Spark Switch (PSS, thyratrons with a cold cathode) of the TPI family. These PSS successfully compete with the traditional "hot thyratrons" and surpass them in jitter and rate of switching.

NANOSECOND GENERATORS FOR THE INJECTION AND EXTRACTION KICKERS OF THE BOOSTER SYNCHROTRON

Table 1: Below are given parameters of the injection generator

Pulse duration, ns	106
Maximal amplitude, kV	15
Pulse front time at the level of (0.1-0.9), ns	8
Pulse decay time at the level of (0.1-0.9), ns	8
Maximal pulse repetition rate , Hz	2
Output impedance, Ohm The output is two 50 Ohm cables, each powering its plate of the kicker.	25
Switch type	TPI1-1k/20
Type of the forming line	single
Voltage tuning range, kV	4 - 10

The function of energy storage in this generator is performed by a single cable forming line (FL). The key element for switching energy from the storage line to the load (plates of the kicker) is the pseudo-spark switch, PSS (or thyratron with a "cold" cathode) of the TPI-1-1k/20 type. The line is pre-charged from a DC power supply with a maximal output voltage of 15 kV and current of 1mA. The TPI is driven with a special driving unit – Thyratron Driver (TD).

The scheme of the generator is shown in Figure 1.

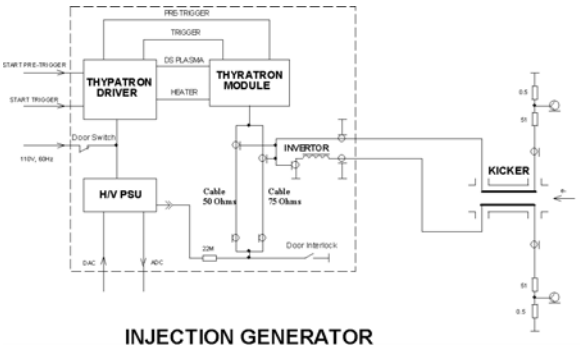

Figure 1: Generator for injection into the booster.

A rectangle pulse is formed in the following way.

When mains power is applied to the driving unit, voltage of no more than 7 V is applied to the TPI glow electrode (Figure 2).

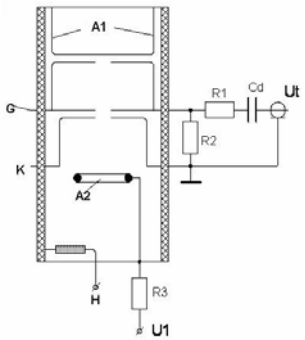

Figure 2: Arrangement of the TPI pseudo-spark switch.

At the same time, a direct voltage of the order of 700 V to 800 V is applied to the pre-ionization electrode, "A" (or the second anode), and in 1 to 2 minutes a current of 10 mA will arise between the second anode and thyratron cathode, which means that a stationary glow discharge is allowed in the cathode area and a plasma cloud, or "virtual plasma cathode", is formed. The latter becomes a source of secondary electrons for further ionization of the thyratron chamber.[2] In so doing, voltage across the pre-ionization electrode falls down to 100 V to 150 V and stays at this level till the arrival of a driving pulse. This regime is preparatory for the main operation of the pseudo-spark switch. All the mentioned processes run in the cathode area: between the second anode and the cathode. When a pulse with an amplitude of the order of 1 kV arrives to the pre-ionization electrode, charges of highest energy arise in the region of the main firing grid

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and density of the glow discharge current increases; the discharge goes to the region of superdense glow discharge. Then, 150 ns to 200 ns after the arrival of the pulse to the pre-ionization electrode, a pulse with an amplitude as high as 3 kV is applied to the main firing grid, “G”. The discharge burn goes to the main anode area, “A1”, and the switch operates with an almost momentary delay (20-40) ns and all energy from the forming line arrives to the load (the kicker plates). Oscillograms of pulses on the kicker plates are given below.The obtained minimal jitter of the operating pulse equals 400 ps (Figure 3).

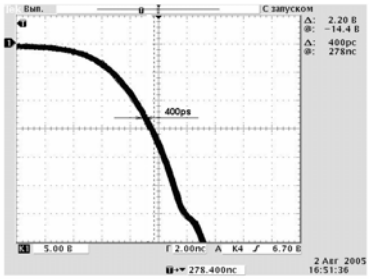

Figure 3: Oscillogram of the jitter of the injection generator pulse.

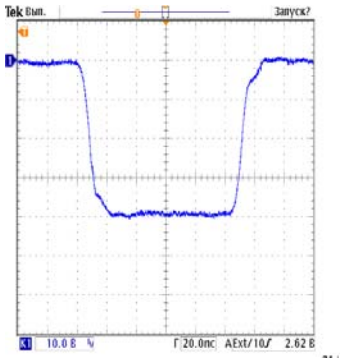

Figure 4: Panoramic oscillogram of a pulse on the injection kicker.

Table 2: Below are given parameters of the extraction generator

Pulse half-amplitude duration, ns	10
Maximal amplitude, kV	22
Front duration at the level of (0.1-0.9), ns	10
Fall duration at the level of (0.1-0.9), ns	10
Maximal pulse repetition rate, Hz	25
Output impedance, Ohm	50
Switch type	TPI1-1k/20
Type of the frming line	Blumlein
Voltage tuning range, kV	4 -20

Unlike the injection generator, the PFN by the Blumlein scheme is used in the extraction generator as the storage line. The minimal front obtained at TPI-1-1k/20 was of the order of 9 ns to 10 ns. Since the beam size at extraction is certainly less than 1 ns, the bell-shaped pulse is quite admissible especially because the extraction pulse jitter is ±200 ps. Fig. 5 and 6 show an oscillogram of a summed-up pulse (positive and negative) between both plates of the extraction kicker. The pulse amplitude turned out to be 28.6 kV and the residual amplitude of the kick of neighboring separatrices was no more than 40%.

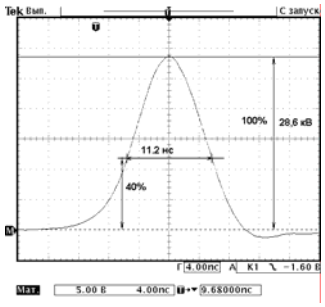

Figure 5: Oscillogram of a summed-up pulse on the extraction kicker with a 50 Ohm load.

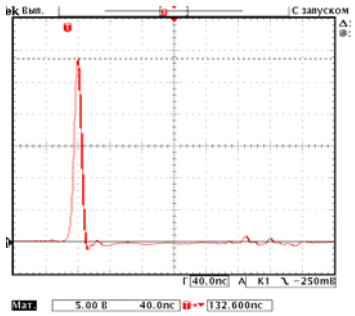

Figure 6: Panoramic oscillogram of a pulse on the extraction kicker.

Figure 7 shows (in a corrected scale) a diagram of pulse shape variation as a function of charge voltage tuning. TPI driving parameters (the glow, firing, and pre-ionization) were not changed. It can be seen that the pulse shape is quite admissible in the charge voltage range of (5-25) kV.

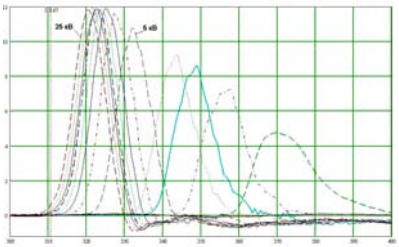

Figure 7. Diagram of the modified pulse amplitude on the injection kicker, charge voltage across the injection generator PFN varying in the range of 350 V to 25 kV.

GENERATORS FOR PARTICLE INJECTION INTO THE MAIN RING OF THE SR FEL

Table 3: Parameters of the generator for injection for the kickers of the ring

Charge voltage PFN (Blumlein), kV	30
Output voltage (kicker pulse amplitude), kV	30
TPI maximal current (at 30 kV)	4.8 kA
Output resistance, Ohm	12.5
Pulse duration (double path over each PFN section), ns	50
Front duration at the level of 0.1-0.9	30
Fall duration 0.1-0.9	30
Jitter (pick-to-pick), ns	<1

This design applies one pseudo-spark switch, TPI1-10к/25, to power both plates of each of the kickers. The pseudo-spark switch works at maximal current as high as 5 kA and maximal anode voltage as high as 30 kV. Such a design offers the following advantages:

1. No jitter between the kicker plates.
2. Only one TPI driver is required.
3. Each generator to power the corresponding kicker is designed as a separate module and is compactly arranged in a special cabinet.

Figure. 8 and 9 show oscillograms of pulses on both plates of one of the FEL injection kickers, the charge voltage being 28 kV at most. One of the pulses in the oscillogram has been inverted with Tektronix TDS-3052 in the measurement circuit (to simplify superposition).

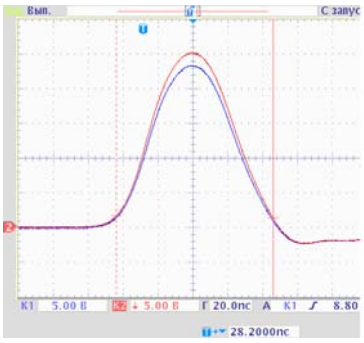

Figure 8: A pulse on injection kicker (20 ns/div).

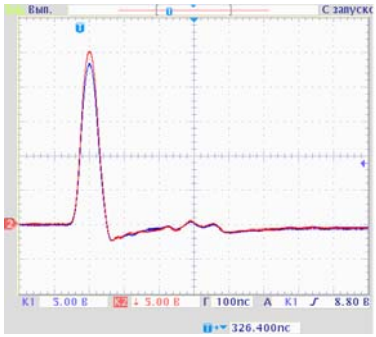

Figure 9: A pulse on injection kicker (100 ns/div).

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[2]Ryazan State Radioengineering Academy, 59/1 Gagarin str., 391000 Ryazan, Russia[3]G.I. Budker Nuclear Physics Institute SB RAS, 630090, Novosibirsk, Russia2002 International Power Modulator Conference, Los-Angeles (June – July 2002).20th ISDEIV (Tour, France, June-July 2002).