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NEW INJECTION SYSTEM OF SIBERIA-2 LIGHT SOURCE

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Abstract

The storage ring Siberia-2 is SR source of second generation with 2.5 GeV electron energy and circumference 124 m. The electron beam is injected into the storage ring at the energy 450 MeV. The Siberia-2 injection system was initially consisted of two high voltage rectangular pulses generators connected to a pre-inflector and an inflector which were provided by two in-vacuum strip line kickers of traveling wave (wave impedance 50 Ohm). The amplitude voltage was 21-32 kV with 20 ns pulse duration and 2-3 ns pulse front/fall. Recently the new injection generators were proposed. Injection system now includes two pulse generators with 1 μsec pulse duration and 10 kV voltage amplitude and the same kickers. A dynamics of the electron beam after injection moment is considered in the article. The possibility of effective injection with kickers pulse duration over 2 periods of revolution of the electron beam is shown. The results of the new injection system commissioning are also demonstrated.

INTRODUCTION

The project of the Light Source Siberia-2 was developed in Budker Institute of Nuclear Physics (BINP, Novosibirsk) in the 80s of the last century [1]. Historically, the first injection/extraction systems developed in BINP have used the generators of short HV rectangular pulses with short front/fall times because first accelerators had a small perimeter and as a consequence a small revolution period. As a rule, the generators had a wave impedance ρ=50 Ohm and fed the kickers (ρ=50 Ohm) in the traveling wave mode, where the impacts of deflecting forces of the electric and magnetic fields are equal for the relativistic electron beam.

Analogue system was developed and used in the Siberia-2 [2, 3]. The amplitude voltage was 22-32 kV (on the kicker) with 20 ns pulse duration and 2-3 ns pulse front/fall. The start of the ns generator pulses was realized with the ignition of spark gap of discharge devices and the amplitude and pulse duration were obtained by parameters of charge and length of form lines. The kickers were in-vacuum stripline-like parallel plates with a length of 530 mm.

Resent upgrade of injection system was forced due to degradation of main components of the generators.

The injection of electron beam from the booster Siberia-1 into Siberia-2 occurs on the energy 450 MeV. The scheme of the SR complex SIBERIA is shown on Fig. 1. Main facilities parameters are listed in Table 1, optical functions of the Siberia-2 are shown on Fig. 2.

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The injection system consists of two generators and two kickers called “prekicker” and “kicker” and septum-magnet between them, Fig. 2. The horizontal beta-function phase advance between every kickers and septum-magnet is $\pi/2$.

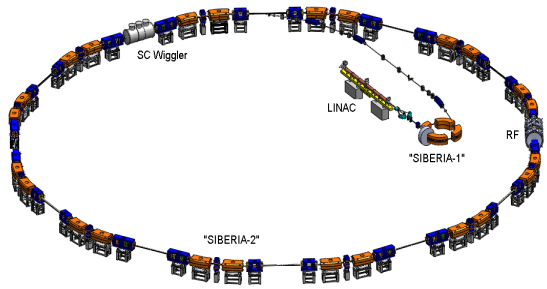

Figure 1: Layout of SR Source Siberia.

Table 1: Main Parameters of Storage Rings

	Siberia-1	Siberia-2
Ext./Inj. energy, MeV	450	
Circumference, m	8.68	124.128
Harmonic number	1	75
Nat. emittance, nm-rad	800	340
Energy spread	3.8e-4	6.2e-4
τ_x, τ_y, τ_s	7.5/7/3.4 msec	0.5/0.5/0.2 sec
σ_x/σ'_x mm/mrad	2.1/0.58	2.14/0.16

The using of two kickers with phase advance π is allowed to choose more flexible form and length of generators pulses since deflection of “prekicker” is compensated by “kicker” (if we neglect influence of sextupole lenses and suppose that pulses are equal).

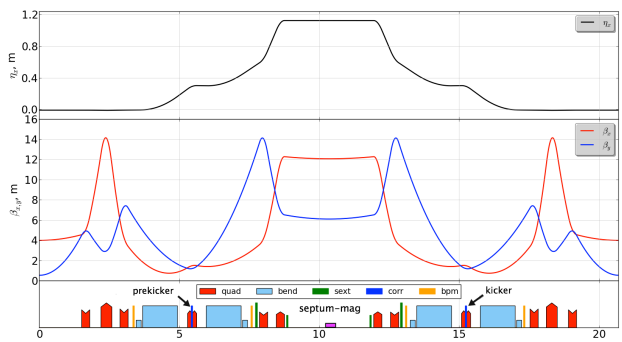

Figure 2: Siberia-2 optical functions.

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THE INJECTION SCHEME

The trajectories of injected and stored particles are shown in Fig. 3. We can estimate the angles for "prekicker" and "kicker" taking into account the centers of mass displacements of stored and injection beams on the azimuth of septum - 13 and 27.4 mm correspondently. Also taking into account the fact that after "kicker" both beams will have equal amplitudes of remain angles we obtain that "prekicker" and "kicker" have to provide angle kicks as much as 3 and 4.7 mrad respectively. For estimation we used simple expression:

$$x' = \frac{x_{disp}}{\sqrt{\beta_s \beta_k} \sin\mu}, \qquad (1)$$

where β_s, β_k– beta-functions on azimuth kicker and septum, μ - phase advance between kicker and septum.

Note, that from the very beginning of Siberia-2 operation the amplitude functions of electron beam transport channel and Siberia-2 storage ring were made mismatched. The reason was to obtain a minimum loss of the injected beam when moving through the aperture of Siberia-2 septum. Theoretical calculations gave a injection efficiency till 96% for the old scheme injection [4]. Transverse dimensions of the injected electron beam have great beats while driving along the ring due to the large mismatch of amplitude functions, Fig. 3. Septum-magnet is placed at a distance 20 mm from the closed orbit.

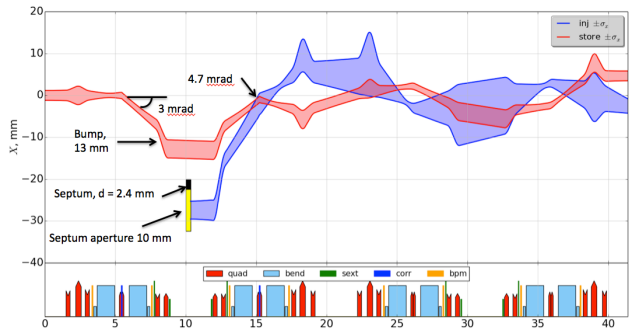

Figure 3: Trajectories of injected and stored beams in the moment injection, with sextupole influence.

Injected and stored beams have remaining horizontal oscillations with angle amplitudes equal ~ 1.7 mrad but with opposite signs after the "kicker". The oscillations disappear due to radiation damping without losses of particles. However, the picture will be more complicated in case when pulse duration of the deflecting fields is longer than revolution period equal to 414 ns.

THE NEW GENERATORS

After some investigation and experiments we had chosen the new type of pulse generators based on resonance circuit and the thyratrons TPI1-10k/50 [5] as switches. The main feature of the new system is that the particle beams are deflected only by magnetic field instead of electromagnetic field of travelling wave. To obtain required deflection angle the pulse current amplitude should be in the range I = 0.7 - 1.3 kA on the each plate of kicker in accordance with magnetic field calculation. Should be note that we use the same kickers with wave impedance equals to 50 Ohm, but instead of 50 Ohm matching resistance on the edge of plate we use a shorting jumper, Fig. 4. In that case short transport cables with wave impedance 50 Ohm and kicker will represent inductance for the generator as a load.

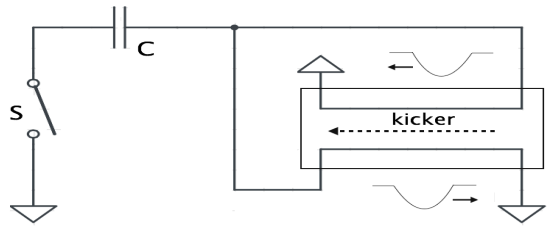

Figure 4: Simplified scheme of the new generator.

Initially a prototype of generator with 160 ns duration of half-sine pulse was made. To minimize the connecting cable inductivity we have localized the prototype of generator close to the kicker in accelerator hall. After successful testing of the prototype on the real beam we have ordered the generators from industry with almost the same parameters.

During testing the new industrial generators we have confronted with technical problems, which forced us to increase the pulse duration till 1 μsec [5]. It means that injected and stored beams will be inflected in electromagnetic field over two period of revolution.

THE INJECTION SIMULATION WITH LONG PULSE

Simulation of the injection process was carried out by Ocelot program, which already used for beam dynamics simulation of Siberia-2 [6]. Digital oscillogram of the current pulse on the kicker is used for tracking simulation. Form and length of the pulses on the both kickers are very similar and one is shown in Fig.5.

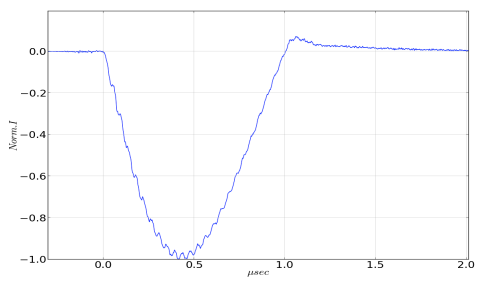

Figure 5: Digital oscillogram of the current pulse on the kicker.

We simulated injection process in horizontal phase space taking into account influence of sextupole lenses. There are not any limitations for vertical phase space and movement in this phase space was not considered. The simulations have shown that highest injection efficiency is obtained if kicks for "kicker" and "prekicker" are about 4.7 and 3 mrad, respectively.

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The horizontal phase trajectory for first 4 turns of injected beam is shown in Fig. 6. As we can see injected beam has high emittance and even mismatched optics of transport channel does not allow to fit $\pm 3(\sigma_x,\sigma_{x'})$ of the beam into septum aperture. On the next turns the injected beam will be cut by septum. Thus all particles outside of the acceptance of the ring will be lost. Simulation was taking into account of energy spread also. Thus simulations shown that long pulse duration does not decrease the injection efficiency which can be reached 96% that is the same as was obtained in [4].

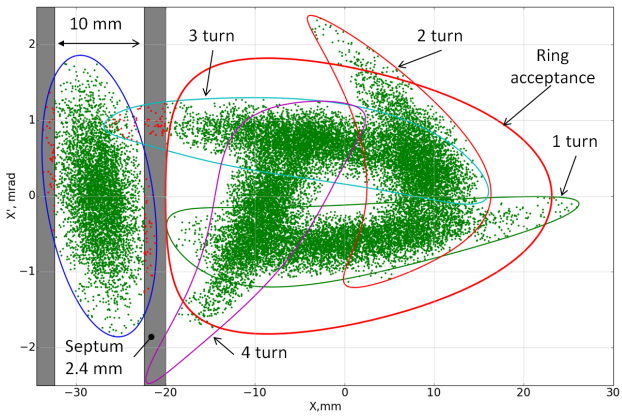

Figure 6: Phase trajectory of injected beams on the septum magnet azimuth. Ellipse and particles distribution are $\pm 3(\sigma_x,\sigma_{x'})$.

Influence of the long pulse on the stored beam is not so obvious because during the injection process the number of bunches revolved in the ring is increased and different initial conditions are possible for the different bunches.

We had simulated the influence of the long pulse for every of 75 bunches on the ring during 7 turns and the phase trajectory one of these bunches is presented in Fig. 7. Every of the 75 bunches does not go beyond of the ring acceptance.

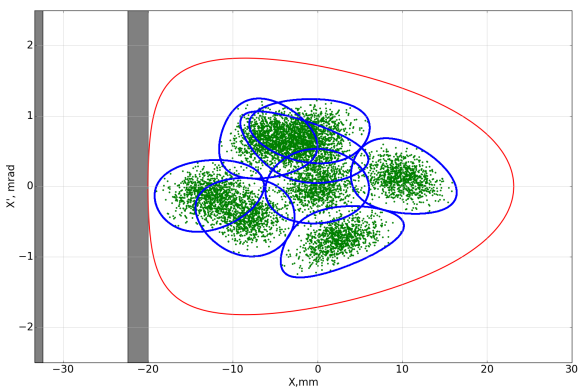

Figure 7: Phase trajectory of one stored bunch on the septum magnet azimuth during 7 turns.

These positive results of the simulation allowed us to install new generators with pulse duration 1 μsec.

RESULTS OF OVER ONE YEAR OPERATION

At the moment the new generators with pulse duration 1 μsec is in operation about 2 years and the ones have shown high reliability and efficiency. After short period experimental operation on the ring when was uncovered and eliminated some minor defects the generators works without any maintenance over one year.

There is one question that was not considered properly yet. It is a change of transverse impedance of vacuum chamber because in-vacuum plates in the kickers have not matching resistance. Nevertheless we see no effect on the injection process at least till 170 mA of stored current, Fig. 8a. And a maximum of one-shot injection efficiency is about 70%, Fig. 8b as the same as with old generators.

Figure 8: Current and injection efficiency with new generators.

ACKNOWLEDGMENT

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