INJECTION AND EXTRACTION AT DAMPING RING OF AN ELECTRON-POSITRON INJECTION COMPLEX VEPP5

A. I. Butakov, B. I. Grishanov, F. V. Podgorny
Budker Institute of Nuclear Physics, Novosibirsk, 630090, Russia

Abstract

Engineering aspects of electron and positron injection, storage and extraction in a damping ring of an injection complex are described. Symmetrical strip-line type kickers are used in quasi-traveling wave mode. A generator of a pair of negative and positive polarity pulses bases on two double pulse forming network (DPFN). Both DPFN are charged up to 50 kV using a common pulse transformer. Every DPFN is commutated by single high-voltage hydrogen thyratron. One of the thyratrons has a floating cathode. Special design resistors are used as kicker terminators. Circuit wave resistance is 25 Ohm, pulses duration is 80 ns, and repetition rate is up to 50 Hz.

1. INTRODUCTION

An injection complex is designed in Budker Institute of Nuclear Physics in Novosibirsk in frame of a program of super high luminosity electron – positron facility VEPP-5 for energy up to 15 GEV construction [1]. High intensity bunches producing and forming is realized in two 10 cm linacs (electron and positron) and in a damping ring. Storage and cooling of the electron and positron bunches occurs in the damping ring in series cycles. At the end of each cycle the bunch is extracted.

Main parameters of the damping ring are shown in Table 1.

Table 1. Main parameters of the damping ring.

Energy	510 MeV
Circumference	27.40 m
Revolution frequency	10.94 MHz
Period of revolution	91.33 ns
Harmonic number	64
Injection repetition rate	50 Hz
Extraction repetition rate	1...4 Hz
Betatron tune: horizontal: vertical:	 4 .78 2 .86
Synchrotron tune	0.021

2. INJECTION AND EXTRACTION

One turn single bunch injection with pre-kick of a storage beam is used in the damping ring. One of two long strait sections with nearby bending magnets is occupied for installation of the kickers and a septum magnet for electrons. Another straight section is used for positrons. The same kickers are used for both the pre-kick and the extraction. Both the injection and the extraction are made in vertical direction by kicking in the horizontal plane in the same straight section. Lambertson type septum magnets are used in the damping ring.

Altogether two long strait sections with nearby bending magnets are occupied for injection and extraction. Accepted injection and extraction scheme proposes to use vertical DC Lambertson type septum magnet biased from an equilibrium orbit in the radial direction. Such scheme seems to be more economical in comparison with a vertical kick scheme because it does not demand of a bending magnet vertical aperture increase.

At the injection with the pre-kick both a storage bunch and a bunch to be injected are moving synchronously in the median plain at different sides of a septum magnet wall. The storage beam is shifted to the aperture border due to an influence of the pre-kicker. Both the pre-kicker and the kicker are installed middle in a distant of half betatron wavelength symmetrically relatively to the septum magnet. The storage beam returns to the equilibrium orbit without residual coherent oscillations practically after a blow by the kicker, residual coherent oscillations of an injected beam damp. This procedure is reiterated at 50 Hz repetition rate until a required particles number in the beam will be reached.

The same septum magnet is used as for the extraction also for the injection; the pre-kicker is used as a deflector. Just before the extraction pair pulse correctors fulfill a local distortion of the equilibrium orbit in the horizontal plane during about 25 ms to shift the storage and damping beam to the septum magnet wall. After the blow by the pre-kicker the beam moves along a new trajectory and gets to the septum magnet aperture.

3. KICKER

The damping ring kickers are executed as a symmetrical strip line pieces. Every one of the kickers is fed by a pair of an opposite polarity pulses. Because of the kickers are installed partially in the bending magnets ferrite type kickers could not be used.

Main parameters of the kickers are shown in Table 2.

Table. 2. Main parameters of the kickers

Plate length	110 cm
Wave resistance of each plate	50 Ohm
Working aperture: horizontal vertical	 3.0 cm 2.4 cm
Kick direction	radial
Plate feeding scheme	paraphase

Voltage on the kicker plates: counter-traveling wave mode accepted scheme*	 ± 60 kV ± 40 kV
Field nonuniformity in working aperture	≤ ± 10 %
Kick rise/fall time	≤ 80 ns
Kick instability	≤ ± 1 %
Bunch length (FWHM): at injection at extraction	 2.5 cm 1.0 cm
Injection frequency	50 Hz
Extraction frequency	1 ÷ 4 Hz

* Quasi-traveling wave mode is applied in the kickers.

Because of the injected beam has a small length and single bunch operation mode is chosen for the damping ring both the rise time and the fall time of the kick almost could achieved the circulating period is equal of about 90 ns. As it follows from the Table 2, it is necessary to feed ± 60 kV to the kicker in the counter-traveling wave. (It should be remarked that a matched operating mode or the same as the traveling wave mode they name a regime when voltage V, current I and wave resistance ρ are connected with expression: $I = V/\rho$.) As it was mentioned above it is possible to work at rather long rise and fall time of the kick due to the small bunch duration. It allows choosing the regime, which we call quasi-traveling wave mode. At that the kicker feeding voltage could be reduced sufficiently.

In our case every plate of the kicker has wave resistance of about 50 Ohm, is fed by 25-Ohm generator and loaded by 25-Ohm terminator. As a result, 50-Ohm kicker plates turns out to be put into a brake of a matched 25-Ohm circuit. Relatively small reflections only arise here since a wave traveling time through the kicker is match less than the pulse rise/fall time and the wave resistances of the kicker exceeds one of the circuit two times only. The strip could be considered as a not great additional inductance where is excited a current equal to a traveling wave current of the generator:

$$Ig = Vtr / \rho g \text{, where}$$

Vtr – the traveling wave voltage,

ρg – the wave resistance of the generator and the terminator.

This magnitude exceeds a current value corresponding to the matching mode operation at the voltage Vtr.

An influence of both an electric and a magnetic field components of the kicker to the beam are summarized for the counter wave and subtracted for an accompanying wave. The influences of the both components are equal for relativistic particles. In our case the beam is deflected 1.5 times more strongly in comparison with the counter-traveling mode at equal voltage due to two times more current. That is why ± 40 kV should be enough in the accepted feeding scheme of the kickers. That reduces requirements to the generators very sufficiently. Capacitors Ccor are installed in parallel to inputs and outputs of the kickers to improve transient processes.

Constructively a vacuum chamber is an essential design part of the kicker. Elements of a damping ring magnetic structure are accomplishing after final welding of the ring vacuum chamber. Kicker plates cross section was chosen as a result of a working aperture field simulation. The field distribution in the kicker aperture is shown on the Figure 1. The kicker plates are fastened at their ends to ceramic feedthrough inner conductors. Flexible elements are made provision at the fasten places for thermic efforts reduction which could appear at a heating the construction.

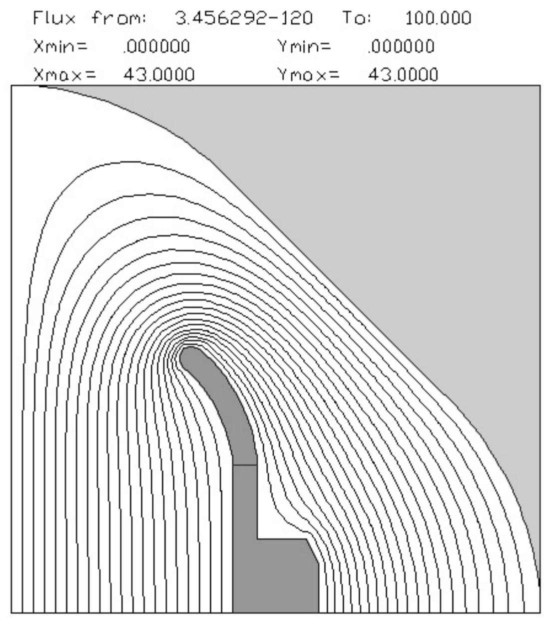

Figure 1. Field distribution in the kicker aperture.

4. GENERATOR

The kicker feeding generator is executed as a linear modulator based on double pulse forming network (DPFN) Blumline type. It is well known DPFN consists of two identical pulse forming networks PFN. Let us name them PFN1 and PFN2. High voltage hydrogen thyratrons are used as switchboards. Every generator includes a charging unit and two pulsers: pulser F1 and pulser F2, which produce the pair of opposite polarity pulses to feed single kicker.

Figure 2 shows the kicker feeding scheme. Main parameters of the generator are shown in the Table 3.

Table 3. Main parameters of the generator

Charging voltage, max	50 kV
Output pulse voltage, max	40 kV
Load resistance	25 Ohm
Pulse duration (FWHM)	80 ns
Pulse rise/fall time	≤ 70 ns
Jitter	≤ 5 ns
Repetition rate, max	50 Hz

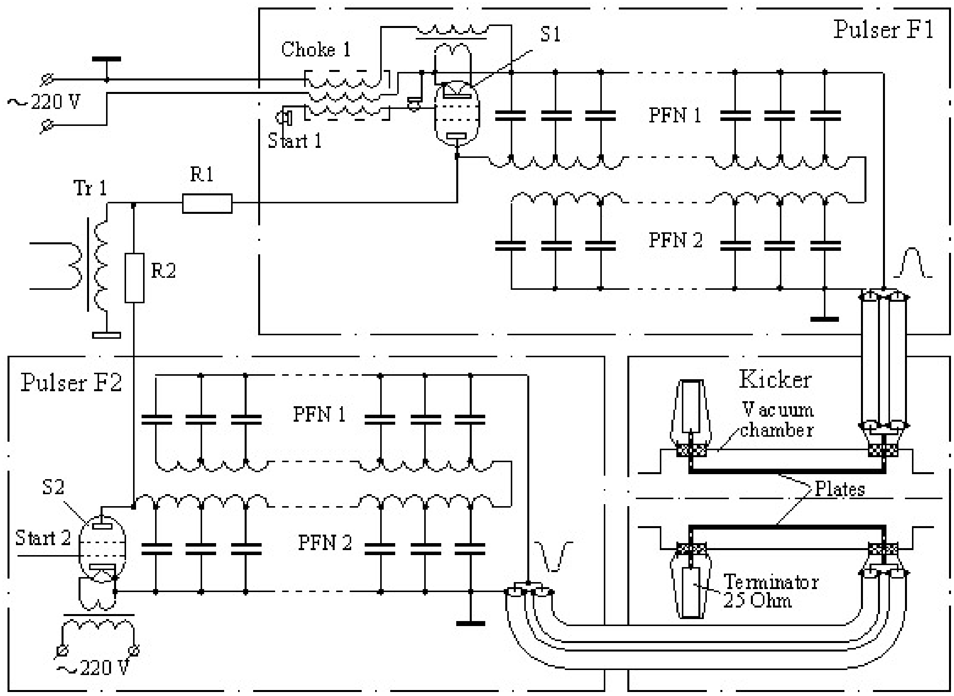

Figure 2. The kicker feeding scheme.

A charging of the both pulser DPFN is fulfilled through a common transformer TR1 and charging resistors R1 and R2. A positive polarity high voltage appears on a secondary winding by discharge of a previously charged capacitor to the transformer input over thyristor during approximately 1 ms.

A positive polarity pulse is formed in the pulser F1. The thyratron S1 has a floating cathode because of it connected just to the pulser output point. A filament feeding and a drive pulse feed to the thyratron S1 through Choke1. The thyratron S2 has a grounded cathode. It is faired by coming of a drive pulse and short-circuits PFN2 input. As a result a negative polarity pulse is formed on the pulser F2 output.

Matching water-cooling terminators are made using special low inductance resistors that are manufactured from thin stainless still rings. The neighboring rings are join zigzag. Each terminator dissipates of about 500 Watts [3].

Output pulse oscillogram is shown on Figure 3. Scale is 80 ns/division. Each pulse is fed from the generator to the kicker input through two parallel coaxial cables of 50 Ohm wave resistance and 24 mm diameter of polyethylene. To improve an electrical strength of the cables they are filled with gas SF6 under overpressure up to 5 atmospheres.

5. CONCLUSION

At present time all the kickers are manufactured, tested and made ready for installation to the damping ring. Feed-throw ceramic insulators were manufactured by industry in Novosibirsk (Russia). Someone of them was tested at negative DC voltage up to –100 kV successfully without breakdowns. At the voltage of –100 kV a leak current (together with a corona current) do not exceeded 1 mkA. A terminator prototype is made and tested; a complete set of the terminators is under production in the BINP workshop.

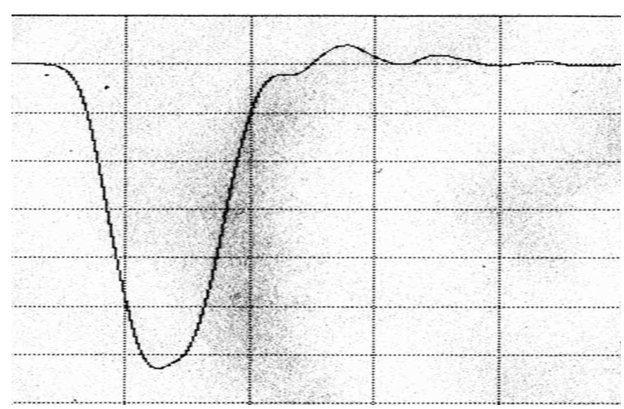

Figure 3. Output pulse oscillogram.

6. REFERENCES

[1] Physical project VEPP-5. BINP SB RAS. 1995.
[2] B.I. Grishanov, F.V. Podgorny, J. Ruemmler, V.D. Shiltsev. "Very fast kicker with high repetition rate for accelerator applications", NIM A 396 (1997) 28-34.
[3] High pulse and average power low-induction load. B.I. Grishanov, F. V. Podgorny. HEACC-2001.