# THE DAMPING RING FOR NOVOSIBIRSK Φ- AND B-FACTORIES

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## Abstract

The Damping Ring is designed to provide the accumulation, cooling and extraction of electron and positron beams at energy of 510 MeV with the particle production rate $2 \times 10^{10}$ per second for injection into Φ-factory and (after additional acceleration) B-factory. The lattice consists of four symmetrical quadrants. The magnetic field polarity doesn't change by changing the particle sort. To provide a short bunch length ($\sigma \simeq 5\ mm$) two warm cavities of 800 kV total RF voltage are used. The single turn injection scheme with the orbit bump and horizontal kick is used. In this report the general parameters and features of the Damping Ring are presented. The state of the ring design and construction is discussed.

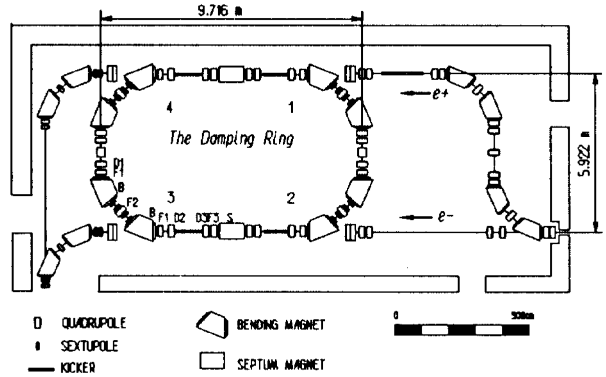


Figure 1: The Damping Ring layout

## 1 INTRODUCTION

The study and design of new generation electron-positron colliders with ultra high luminosity, Φ- and B-factories are carried out presently in Novosibirsk [1,2,3]. These new facilities will require a large intensity of injected beams. The new injection complex constructed now in BINP should solve this task. It will deliver electron and positron beams with the production rate $2 \times 10^{10}$ particles per second with energy of 510 Mev for injection into the Φ-factory and, with maximum energy of 8.5 Gev for injection into the B-factory. The injection complex includes the $e^-$ - $e^+$ linac at energy of 510 MeV [3], the Damping Ring of the same energy and main linear accelerator. After acceleration in the linac the electron and positron beams are accumulated alternately in the Damping Ring. They are cooled there due to SR damping, decreasing transverse and longitudinal sizes, and are extracted from the Damping Ring for injection into Φ-factory or the acceleration up to the maximum energy 8.5 GeV. A short description of the Damping Ring project for this program is presented in this report.

## 2 GENERAL PARAMETERS

The electron-positron linac produces short particle bunches with repetition frequency of 50 Hz. In the case of positrons a number of particles in each bunch is small, and many bunches have to be accumulated to achieve the required intensity. The electron and positron beams are injected in the ring by two different transfer lines. Polarity of ring magnets is not changed, so the electrons and positrons are injected in opposite directions at the opposite straight sections. The energy of accumulator is not changed at operation. The basic mode of operation includes an injection of 40 positron pulses in the same bucket, cooling them due to SR damping and extraction. One cycle duration is 1 s. It is possible to increase the extraction frequency up to 4 Hz. To decrease the horizontal betatron damping time the redistribution of horizontal and longitudinal dampings is provided by the use of bending magnets with field gradient (lattice with combined functions). It allows to reach the horizontal betatron damping time, which determines the injection efficiency, two times smaller than the injection period. At the gradient of bending magnets equal to 4 T/m the horizontal damping portion number is approximately equal to the longitudinal one, $G_h \simeq G_s \simeq 1.53$. The basic parameters of the Damping Ring are presented in Table 1. The disposition of the accumulator and transfer lines are shown in Figure 1.

## 3 LATTICE AND MAGNETS

The lattice of the Damping Ring is symmetrical relatively two axes passing through the centers of short and long straight sections and consists of four quadrants. Each quadrant includes the basic magnets and correctors with DC feeding and the group of pulsed magnets, which provide a beam extraction. One quadrant includes two bending magnets and seven quadrupoles. The lattice design

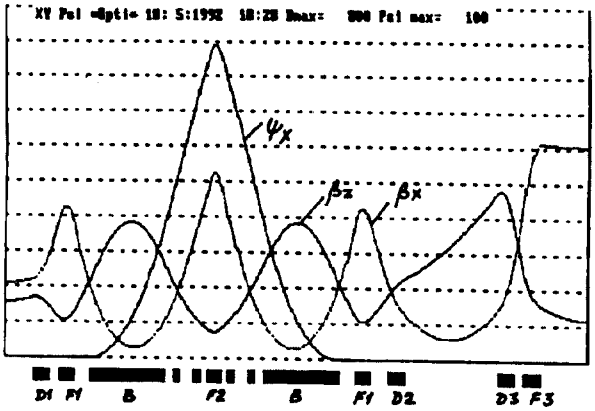


Figure 2: Betatron and dispersion functions

provides the zero dispersion function in the straight sections and the horizontal betatron phase advance between two kickers equal to $\pi$. The betatron and dispersion functions of one quadrant are shown in Figure 2. The parameters of the Damping Ring magnets are given in Table 2. Two families of sextupoles for the vertical and horizontal chromaticity correction are used. They are placed symmetrically between bending magnets. Each family includes eight sextupoles.

## 4 RF SYSTEM

The RF-system is designed to solve the next tasks: 1) capture of the electron and positron bunches coming from the linac; 2) compensation of the energy loss caused synchrotron radiation (5.3 keV/turn); 3) formation of the short bunches for injection in the $\Phi$-factory and the main linac.

The RF frequency has been chosen equal to 700 MHz, what corresponds to the 64-th harmonic of a revolution frequency. To obtain the short length of bunches ($\sigma$ =5 mm) the RF-system with high voltage has to be used. For longitudinal coupling impedance of the vacuum chamber $(Z_n/n) \simeq 1\ Ohm$ and for the given bunch length the calculation determines the required RF voltage of 800 kV. In this case the longitudinal acceptance of the accumulator dE/E is equal to 2.3%, what provides a sufficient bucket height to capture the linac pulses. The energy spread of injected positrons has been designed equal to ± 0.01. The energy spread of incoming electrons is smaller. Two warm cavities should provide the required RF-voltage. The parameters of the RF-system are given in Table 3.

## 5 INJECTION AND EXTRACTION

There are two identical injection and extraction systems for the two sorts of particles. A vertical 20° Lambertson type septum with a constant magnetic field and two kickers with horizontal kick are used for the injection. Both kickers are placed symmetrically relatively to the center of long straight section. The first kicker pushes the accumulated bunch to the septum magnet edge. At the same time the linac bunch appears on the other side of the sep-

Table 1: The Damping ring parameters

| | |
|---|---|
| Energy (MeV) | 510 |
| Circumference (m) | 27.401 |
| Number of particles | $2 \times 10^{10}$ |
| Beam current (mA) | 35.5 |
| RF frequency (MHz) | 700 |
| injection frequency (Hz) | 50 |
| extraction frequency (Hz) | 1–4 |
| Energy loss/turn (keV) | 5.3 |
| Momentum compaction | 0.028 |
| Horizontal tune $\nu_x$ | 4.78 |
| Vertical tune $\nu_z$ | 2.86 |
| Synchrotron tune $\nu_s$ | .021 |
| Horizontal chromaticity $S_x$ | –7.66 |
| Vertical chromaticity $S_z$ | –4.94 |
| Horizontal damping time (ms) | 11.3 |
| Vertical damping time (ms) | 17.5 |
| Longitudinal damping time (ms) | 11.9 |
| Horizontal r.m.s. acceptance (mrad cm) | 10 |
| Vertical r.m.s. acceptance (mrad cm) | 4 |
| Input beam parameters: | |
| Horizontal r.m.s. emittance (mrad cm) | 1.5 |
| Vertical r.m.s. emittance (mrad cm) | 1.5 |
| Energy spread | 0.01 |
| Output beam parameters: | |
| Horizontal r.m.s. emittance ($\mu$rad cm) | 2.3 |
| Vertical r.m.s. emittance ($\mu$rad cm) | 0.5 |
| Energy spread | 0.0007 |
| Bunch length (cm) | 0.5 |

Table 2: Parameters of magnets

| Bending magnet | |
|---|---|
| Number | 8 |
| Field strength* (T) | 1.52 |
| Field gradient (T/m) | 4.0 |
| Magnetic length (m) | 0.88 |
| Gap height* (mm) | 36 |

| Quadrupoles | number | Insc. radius mm | Gradient (T/m) | Length m |
|---|---|---|---|---|
| F1 | 8 | 30 | 22.67 | 0.18 |
| D1 | 4 | 30 | -10.88 | 0.18 |
| F2 | 4 | 30 | 20.31 | 0.18 |
| D2 | 4 | 40 | -5.64 | 0.20 |
| F3 | 4 | 40 | 14.17 | 0.20 |
| D3 | 4 | 40 | -15.13 | 0.20 |

* — at the central orbit

Table 3: RF parameters

| | |
|---|---|
| RF frequency (MHz) | 700 |
| Harmonic number | 64 |
| Total voltage (kV) | 800 |
| Synchrotron tune $\nu_s$ | .021 |
| RF power (kW) | 70 |
| Energy loss/turn (keV) | 5.3 |
| Energy acceptance dE/E | 0.023 |
| Number of cavities | 2 |
| Quality factor | 21000 |
| Beam current (mA) | 35.5 |

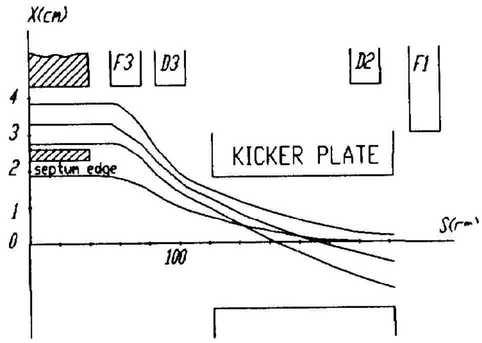

Figure 3: Beam layout at the injection

tum edge, which makes the linac bunch travel parallel to the accumulated bunch. The betatron oscillations are canceled by a kicker downstream of the injection septum, so the accumulated bunch follows again the central orbit, a new bunch has small betatron oscillations. The horizontal betatron phase advance between kickers is equal to $\pi$.The injection is repeated after approximately double damping time of the horizontal betatron oscillation. After several injections an extraction takes a place, using the same septum magnet. A pair of pulse correctors displaces a closed orbit to the edge of the septum magnet and the fast kicker extracts the bunch from the Damping Ring. Then new injection again takes a place. Each kicker consists of two 110 cm length plates, each of them provides a 60 kV pulse. The expected full rise and fall times are equal to 80 ns, what is less than a revolution period. The injection and extraction kick instabilities are less than 1%. The beam layout at the injection is shown in Figure 3 .

## 6 BEAM TRANSFER LINE FROM LINAC TO DAMPING RING

To transfer the electron and positron beams from linac to the Damping Ring two different transfer lines are used (see Figure 1). After the linac the positron bunch has rather large energy spread, so to have an effective injection one should decrease it. Taking into account a small bunch length the transformation in the longitudinal phase space have been suggested for use before injection. In this case

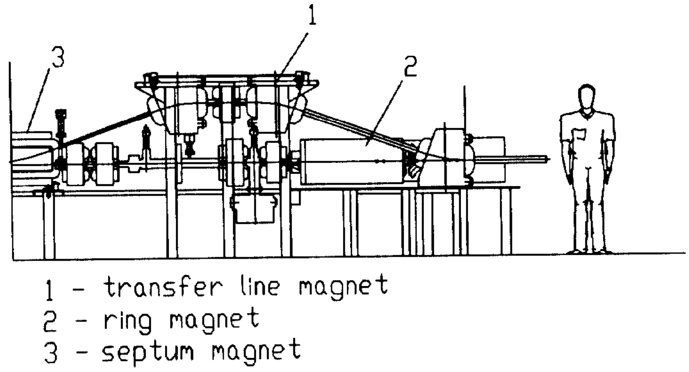

Figure 4: Beam transfer to the Damping Ring

during movement in a specially designed beam line the bunch length increases due to energy spread, what produces the energy modulation along the bunch length. The downstream linac type accelerator section is used to cancel this modulation that decreases the initial energy spread of the bunch.It is possible to vary the energy modulation of the bunch length over a wide range. Specially designed three 20° vertical magnets together with the septum magnet produce the achromatic beam transfer from the transfer line to the Ring (see figure 4. To separate the electron and positron beams an input dipole magnet is used. For a change of particle sort from positrons to electrons it has to be switched off.

## 7 STATUS

At present time the design of magnets and cavities of the Damping Ring is finished, the prototypes of magnets are in the production. By the end of this year the construction of the building for the Damping Ring housing has to be finished.

### References


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[3] N.S.Dikansky et al., "Novosibirsk B – factory: Status and perspectives" XV-th International Conference on High Energy Accelerators, Hamburg, Germany, July 1992.