STATUS REPORT ON ELECTRON-POSITRON STORAGE RING VEPP-3

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(presented by G. N. Kulipanov)

In the report presented at the last Conference in Erevan, the storage ring design and its expected operating regimes were described in detail. The assembly of the storage ring magnetic system was reported as completed and that tracing with 1 MeV protons had been performed.

The present status of the storage ring VEPP-3 is described below.

The manufacture and adjustment of the main structural elements of the storage ring complex is completed. The injector synchrotron B-4 is now in operation. By May of 1970 the electron beam was injected into VEPP-3. The synchrotron was operated mostly at the energy of 250 MeV. The deflected current is 200 mA or about $3 \cdot 10^{10}$ electrons per pulse. The beam current limitation takes place over the first several turns after injection. It is due to the excitation of some parasitic oscillations. The work on increasing the accelerated beam current is carried on. Now the synchrotron is completely prepared for operation at an energy of 450 MeV.

There are two RF cavities in the storage ring VEPP-3. The RF cavity N 1 with a peak voltage of 10 kV is tuned to 4 MHz (the first order harmonic of the revolution frequency). The RF cavity N 2 is designed for 750 kV peak and 76 MHz (the 19th order harmonic). At present an RF voltage of 650 kV is obtained. That is sufficient for the acceleration of electrons up to the energy of 2.5 GeV.

The storing technique actually applied is a little different than was proposed earlier. Then it consisted of the successive filling of the 19 separatrices and the subsequent recapture into one separatrix. The electrons are stored at the first order harmonic. The injection instant is synchronized with the RF voltage phase so that the injected particles are displaced with respect to the synchronous phase. The injected bunch is short so, by the time of the following injection, the electrons captured before have had enough time for damping of the phase oscillations, therefore the stacking does not result in the excitation of the betatron oscillations in the stored beam. Such a storing technique is to be applied for positrons stacking.

The measured betatron oscillation frequencies are in good agreement with those expected from magnetic measurements. The betatron frequencies are readily controlled by the correction windings. Resonances of the fourth order and higher are crossed by the beam practically without any loss. The third-order resonances result in an appreciable beam loss. The guide field non-linearity is determined by means of betatron frequency measurements. The values are as follows :

$$\frac{\partial \nu_x}{\partial r} = 7 \cdot 10^{-2}\ \mathrm{cm}^{-1},\ \frac{\partial \nu_z}{\partial r} < 10^{-3}\ \mathrm{cm}^{-1}$$

$$\frac{\partial \nu_x}{\partial a^2} \approx \frac{\partial \nu_z}{\partial a^2} = 10^{-3}\ \mathrm{cm}^{-2}$$

The non-linearity may be eliminated or introduced at will making use of the correction windings.

The distortions of the design orbit do not allow yet the use of the entire storage ring admittance so the beam lifetime at the energy of 250 MeV and at small current value is $\tau \sim 700$ sec. The average pressure in the storage ring vacuum chamber (the distributed vacuum pumps turned-off) is $P \sim 1.5 \cdot 10^{-8}$ torr. The measured value of the beam height is $2\sigma_z = 1.1$ mm, and the beam width is $2\sigma_x = 1.2$ mm at the energy of 250 MeV.

Till now, we did not observe any instability resulting from the excitation of the coherent betatron oscillations up to a beam current of 100 mA. The incoherent effects leading to the increase of the transverse beam size were the only ones observed (an increase by a factor of 1.5 at a current of 100 mA). It is thought that this effect arises from the increase in the effective pressure due to the accumulation of ions inside the beam region. The same reason may account for the lifetime decrease with current ($\tau = 120$ sec at $I \sim 100$ mA).

The current dependence of the bunch length was studied at the following values of operating parameters :

$$E = 260\ \mathrm{MeV}\ ;\ V = 4\ \mathrm{kV}\ ;\ q = 1.$$

The bunch length varied from 70 cm to 130 cm in the current range of 0 - 100 mA. The beam lengthening practically vanished if the beam height was increased by a factor of 3. The effect observed is likely to result from the multiple scattering in the bunch.

The stacking of the current in the range of 100 mA was possible only under the condition that the RF cavity N 2 was used as a passive system to suppress the coherent phase oscillations (instability threshold about 50 μA). The tunable parasitic cavity (94th order harmonic) installed in the N 2 cavity was also used for this purpose. The influence of the voltage induced by the beam in the cavity N 2 became observable at times, as the beam could spontaneously split into 2 to 7 bunches at the current of 100 mA.

Thus the preliminary results of operating the electron beam prove the possibility of storing currents in the region of 100 mA at an energy of 260 MeV.

At the beginning of the year 1971 the storage ring magnets were connected to the main power supply allowing a top electron energy of 2.0 GeV to be reached in the storage ring. The energy augmentation was performed without any correction of the orbit. To keep the betatron frequencies unchanged one had to alter somewhat the ratio between the magnet current over the ring and the excitation currents for the quadrupole lenses in the straight section on account of the differences in degree of saturation.

At present the lenses of the collision straight section are connected to separate power supplies. With the structure of the straight section available and with equal quadrupole strengths, the β function value at the collision point is about 2.3 m in both directions.

A higher storage ring luminosity can be obtained by making low beta values at the collision point by varying the strengths of the quadrupole lenses. The retention of the unit transfer matrices of the straight section proves possible, leaving the motion in the circular parts of the storage ring unchanged. However, in this case the increase of the beam envelope undulations over the straight section length diminishes the storage ring admittance. That is inadmissible for the positron stacking in VEPP-3. Because of this, we have accepted the variant of low-beta operation in which the straight section is retuned with the stored beams present, by means of varying the quadrupole strengths. Some reserve of the vacuum chamber aperture and operation at an energy less than the maximum value allows retuning without any beam loss.

The complicated character of lens current dependence on time needed to keep the unit transfer matrix of the straight section requires that the quadrupole lens excitation currents must be controlled by a computer.

Such a retuning of the straight section yields $\beta_x = 25 - 200$ cm and $\beta_z = 25$ cm at the collision point and gives a 10 - 12 fold increase of luminosity at an energy of 2.5 GeV. The retuning of the straight section magnetic system without the beam is now mastered.

We shall start experiments after having reached the luminosity of $L = 10^{29}$ cm^{-2} sec^{-1}. At the energy of 2.5 GeV, a positron current of $I^+ = 1$ mA and an electron current of $I^- = 30$ mA would be enough. The experimental equipment is already manufactured and installed in the collision section. Unfortunately the positron program is still behind schedule. We hope this part of work will be performed in the near future.

DISCUSSION

W.K.H. PANOFSKY : What is the configuration of your positron conversion system ?

G.N. KULIPANOV : Our conversion system consists of two pulsed bending magnets with operating field 120 kG and with a focusing length 30 cm.

W.K.H. PANOFSKY : What is the expected conversion efficiency ?

G.N. KULIPANOV : We hope to get a conversion efficiency of the order of $I^+/I^- = 2 \times 10^{-4}$ for the positron beam accepted in the storage ring.

P. MARIN : What will be the free space in VEPP-3 with the low-beta insertion ?

G.N. KULIPANOV : The length of the free space in the straight section is 3 m.