A SLOW HALF-INTEGER RESONANCE BEAM EXTRACTION IN A PULSE STRETCHER RING PSR-2000

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Earlier [1], we have presented the design of the 3 GeV pulse stretcher ring with a slow beam extraction at the third-order resonance (Q_x =16/3). However, the enhancement in the operating energy of the stretcher up to 3 GeV leads to the reduction in the radiation damping time down to the value nearly equal to the beam extraction time, thereby diminishing the extraction efficiency for the particles with low betatron amplitudes. Therefore, as the energy increases, there arises the necessity of employing another scheme of slow beam extraction by means of the half-integer resonance which makes possible the extraction of particles with a zero betatron amplitude.

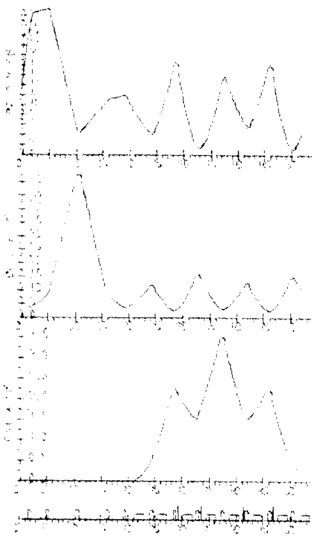

Fig.1. Amplitude and dispersion machine functions:

BETX, BETZ-radial and vertical betatron functions
FSIX -dispersion function
BM -bending magnet
QL -quadrupole lens

The PSR-2000 magnetic lattice provides for the frequency change to the operating point Q_x=5.5, Q_z=5.12. Figure 1 shows the amplitude and dispersion machine functions over one period of the stretcher in the vicinity of $Q_x \simeq 5.5$. The asymmetry of the function β_x on long straight sections is due to the chosen scheme of injection through reference orbit perturbation.

The layout of the magnet elements for the slow beam extraction is shown in Fig.2. The resonance harmonic of the quadrupole field is generated by pulsed quadrupole lenses LI1, LI2, LI3 and the separatrix value is set by the octupole lenses O1, O2. This scheme allows the beam extraction for both positive and negative detuning δ from the resonance ($\delta = Q_x$-5.5).

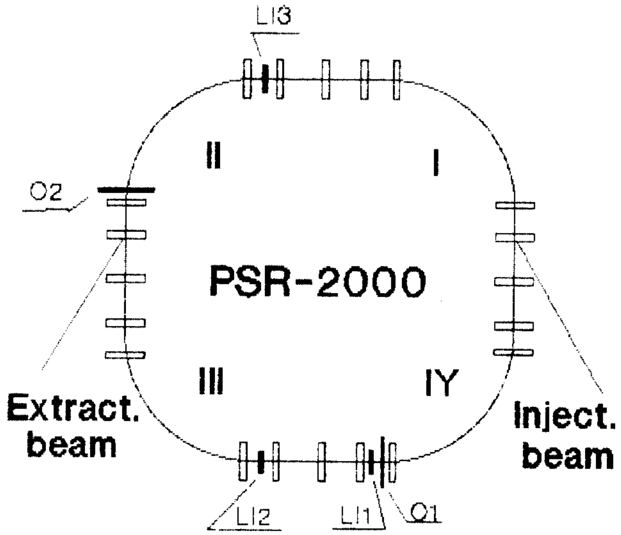

Fig.2. Layout of the extractor elements:

I,II,III.IV-focusing periods
LI1,LI2,LI3-pulse quadrupole lenses
O1,O2 -octupole lenses

The numerical estimates have shown that for the particle extraction at an optimum angle in the region of β_x = const for the initial detuning $\delta \simeq 3*10^{-2}$ in the range of the extracted beam amplitudes $0 < a < 13$ mm at a 4 cm distance from the septum, the "beam size" makes 1 cm.

On attaining the resonance by the use of one pulsed quadrupole lens (LI1 for $\delta < 0$ or LI2 for $\delta > 0$), the emittance of the extracted beam has been estimated to be $\varepsilon_x \sim 1.5$ mm*mrad. A ~ 0.15 mrad divergence of the extracted beam is due to the extraction angle variation with the decreasing betatron amplitude of the extracted particles.

The analytical treatment of the process of slow extraction, based on reduced equations of motion near the resonance, has indicated that the deviation of the particle extraction angle Θ can essentially be decreased by changing the amplitude and phase of the resonance quadrupole perturbation. For this purpose, one needs several (at least, two) pulsed quadrupole lenses with a particular law of their strength variation during extraction.

Fig.3 shows the behaviour of the angle of extraction for the case when the strength of LI1 linearly grows, and that of LI3 linearly decreases down to zero in the process of extraction. In this case, the Θ value was found to be 0.04 mrad. As seen from Fig.4, with a quadratic lens LI3 strength variation by the law $F = F_0*(1-0.8*t-0.2*t^2)$, Θ changes by 0.0026 mrad, and this gives grounds to expect an essentially reduced emittance of the extracted beam with a uniform extraction conserved.

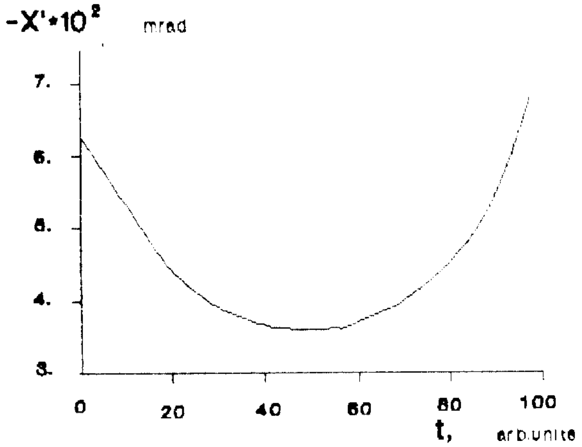

Fig.3. The angle of particle entrance X'_s to the septum (X_s=40 mm) versus time t for a linear dependence of the LI3 lens strength on the beam extraction time.

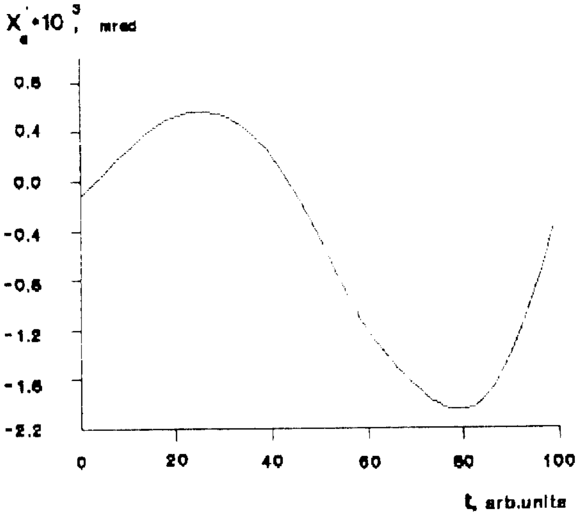

Fig.4. The angle of particle entrance X'_s to the septum (X_s=40 mm) versus time t for a quadratic dependence of the LI3 lens strength on the beam extraction time.

The simulation of the achromatic slow extraction with taking into account synchrotron oscillations has been performed using the DeCA program [2]. Fig.5 shows the phase maps of the beam at the septum input for $\delta \sim 3*10^{-2}$, $0 < a < 13$ mm, $E/E=10^{-3}$. It is evident from the figure that with the suggested scheme of extraction one can obtain the extracted beam emittance to be $\varepsilon_x \sim 0.2$ mm*mrad.

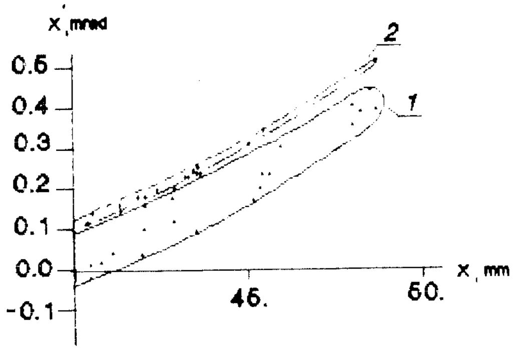

Fig.5 Phase map of the beam at the septum input;

X-particle coordinate

X'-angle of entrance

1-without compensation of the angle of deviation

2-with a compensated angle of deviation

References

1. V.F.Boldyshev et al., Proc. of the IEEE Particle Accelerator Conference, Washington, DC, March 16-19,1987, v.2, pp.883-886
2. P.I.Gladkikh, A.Yu.Zelinsky, M.A.Strelkov "DeCA Application program package. Version 1.1. User guide. A physical model" preprint KhFTI 89-44. Moscow, TsNIIAI pub.,1989.