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Investigation and Optimization of Transverse Beam Dynamics in HESR@FAIR for Experiments with Highly-Charged Heavy Ions*

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Introduction

The High-Energy Storage Ring (HESR) was primarily designed for experiments with stored and cooled antiprotons. But it also appeared to be most suitable facility to maintain a wide range of experiments with high-energy stored heavy-ion beams. In this study the transverse nonlinear beam dynamics for heavy ions in the HESR were investigated.

Beam optics optimization for heavy ion experiments

Within PHELIX project at FAIR@GSI an appropriate place for an experiment, where laser and ion beams are overlapped, has to be found. Available free space and flexible optics are important factors in search for the right location. As an optimal solution a place in the straight section in between two quadrupole triplets is proposed. To maximize the brightness of the ion beam in the above-mentioned location (which is crucial for the experiment) we have to minimize a beam profile as much as possible. For this purpose with the help of MIRKO code an algorithm for decreasing the beam transverse profile was developed.

The technique of variation the quadrupole magnets strengths along the ring allowed to locally decrease the β_x-function in the place of beams interaction. As a result, in modified ring optics in the location of interaction the β_x-function was reduced to the value of 3.1 m, which is 7 times less than in standard optics. Optics variation didn't require any change of the designed quadrupoles parameters.

The emittance of a transferred (from the CR to the HESR) beam is about $\epsilon_{x,y}$ = 0.5 mm mrad and the momentum spread about $7 \cdot 10^{-4}$ [1]. Thus one can calculate the size of the beam. The following results are obtained: the horizontal and the vertical beam widths after changing the optics equal to 1.2 mm and 1.5 mm correspondingly.

With the existing set of sextupoles the chromaticities ξ_x = -14.35 and ξ_y = -13.71 can be corrected up to 0.

Frequency map analysis

Frequency map analysis for both ring optics has been performed. The field errors of dipole and quadrupole magnets [2] were included. An ordinary tracking was used to define the dynamic aperture (DA). From the DA plot for modified optics (see figure 1): A_x = 3.1 mm, A_y = 15.0 mm. The emittances which correspond to the dynamic aperture are ϵ_x = 0.7 mm mrad and ϵ_y = 17.8 mm mrad. For standard optics we have ϵ_x = 11.2 mm mrad and ϵ_y = 13.3 mm mrad. One can see that the horizontal DA decreased significantly (from 11.2 mm mrad to 0.7 mm mrad). The betatron tunes are: Q_x = 7.94, Q_y = 7.62 for modified and Q_x = 7.62 Q_y = 7.62 for standard optics. Further investigation and analysis are needed in order to find out and possibly eliminate the causes of DA shrinking.

A revised Fourier technique [3] with data windowing was used in order to obtain a frequency map with a diffusion coefficient (see figure 2).

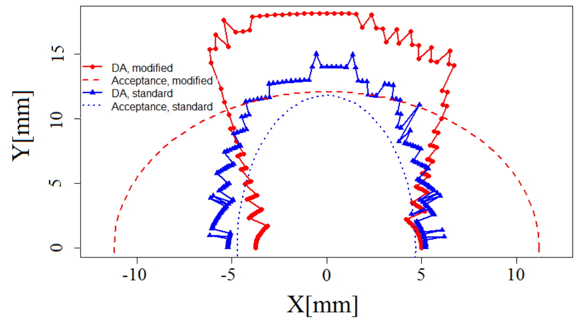

Figure 1: Calculated dynamic aperture for modified (β_x = 13.7 m, β_y = 12.6 m) and standard optics (β_x = 2.4 m, β_y = 11.9 m) for Δp/p = 0.

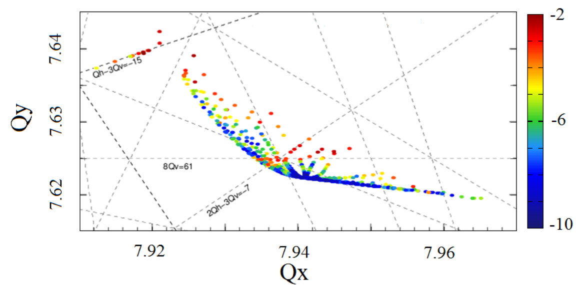

Figure 2: Frequency diagram for modified optics

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