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PERFORMANCE OF THE DIAMOND-II STORAGE RING COLLIMATORS

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Abstract

Particle losses in a storage ring are unavoidable and it is very important to capture them and protect the machine from any possible damage. For this purpose, 6 collimators have been introduced in the Diamond-II storage ring lattice. This paper describes the main layout of the collimators with their corresponding impact and performance.

INTRODUCTION

There are many sources of particle loss in storage rings. The lost particles may hit the vacuum chamber affecting the pressure profile or cause damage to diagnostic instruments or in-vacuum insertion devices. As such, it is essential to provide a means to collect them and ensure machine protection. In this paper, we present investigations into the performance of the collimators for the various loss mechanisms.

LAYOUT OF COLLIMATORS

Many different locations and numbers have been investigated for the collimators and finally a 6-collimator scheme has been selected for the Diamond-II storage ring [1, 2], 3 horizontal and 3 vertical. The general layout of the ring including the collimators is displayed in Fig. 1. The blue and red lines indicate which are the horizontal and vertical collimators respectively.

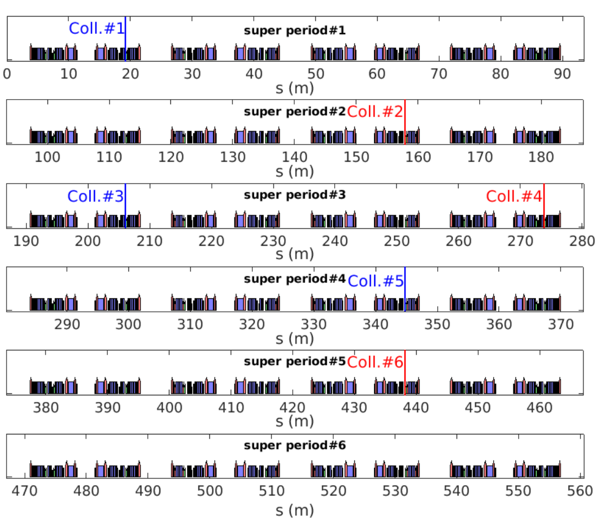

Figure 1: General layout of the collimators in the Diamond-II storage ring.

All the collimators are placed in the downstream half of the dispersion bumps following the mid-straights. Optics at this point are favourable for collimation as the dispersion and beta-functions are relatively large, meaning the oscillation amplitudes for both on and off-momentum particles will also be large. This location is also relatively free from engineering restrictions making it an obvious choice.

LATTICE PERFORMANCE

Inserting collimators into the ring will affect many accelerator parameters such as the dynamic and momentum apertures, injection efficiency (IE) and lifetime. A study of different values of horizontal and vertical collimator gaps has been carried out to determine the optimum compromise between machine protection and machine performance. All the plots in the lattice and collimator performance sections are the average over 20 seeds of errors and the ELEGANT [3] is employed for the calculations. The average dynamic aperture (DA) is displayed in Fig. 2. As expected, closing the collimator gaps leads to reduction in the DA. The top plot in Fig. 2 reveals that keeping the half gap of the vertical collimators (VGAP) at ±1.5 mm and closing the half gap of the horizontal collimators (HGAP) leads to shrinkage mainly in the horizontal DA, while keeping HGAP at = ±3.5 mm and closing VGAP results to more drastic situation with smaller DA in both planes (bottom plot).

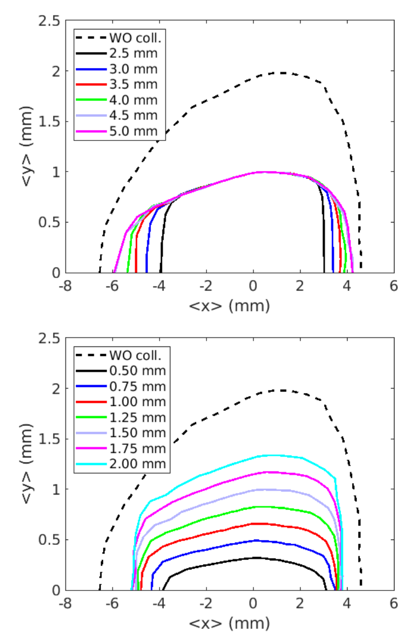

Figure 2: Mean dynamic aperture at the centre of the long straight section for various gaps of horizontal (top) and vertical (bottom) collimators. VGAP in the top plot is set to ±1.5 mm while HGAP in the bottom plot is kept at ±3.5 mm.

The mean momentum aperture (MA) for one super period is shown in Fig. 3 for various HGAPs and VGAPs. All momentum aperture curves overlap for the cases of high HGAPs and VGAPs, while a significant decrease in MA is

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found below ±2.5 mm HGAP and ±0.5 mm VGAP. The mean lifetime and mean injection efficiency (IE) as a function of the collimator half-gaps is plotted in Fig. 4. By closing the HGAP to less than ±3.5 mm, the total lifetime substantially reduces. Although the IE is still 100% for a HGAP of ±3.0 mm, a reasonable safety margin on top of ±3.0 mm is desirable. This is because the IE starts to drop at this gap and therefore ±3.5 mm for the HGAP could be an optimum number from the IE point of view. Based on the results, and to have a vertical DA not less than the 1 mm needed to ensure a safe injection and reasonable lifetime, a HGAP of ±3.5 mm and VGAP of ±1.5 mm has been selected as the nominal operating values to initiate investigation of collimator performance. For further details, please see Ref. [4].

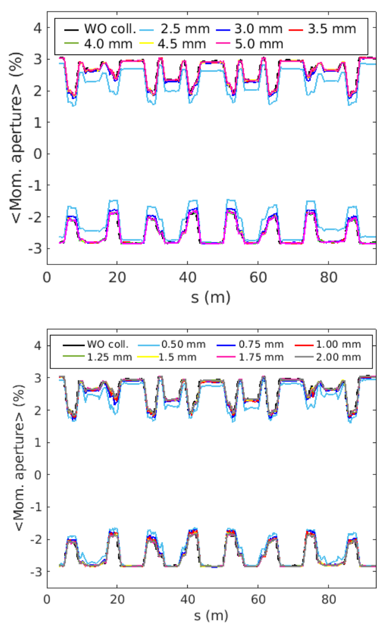

Figure 3: Mean momentum aperture in one super period for various gaps of horizontal (top) and vertical (bottom) collimators. VGAP in the top plot is set to ±1.5 mm while HGAP in the bottom plot is kept at ±3.5 mm.

COLLIMATION PERFORMANCE

To evaluate the performance of the collimators, four different loss mechanisms were considered. These are: RF switch-off, to cover RF trips or deliberate beam dumps, Touschek losses, gas scattering losses (both elastic and inelastic) and injection losses. Of these, the first two processes are expected to be dominant.

RF Off

The effectiveness of the collimators at collecting the lost particles due to turning the RF cavity off was found by tracking 1000 particles in a Gaussian distribution. The loss locations are recorded, and the fraction of particles collected by the collimators are extracted from the data. Figure 5 shows that the majority of the losses will be collected by the first vertical collimator in the ring. Blue and red dash lines represent the locations of the H/V collimators respectively. The reduction in beam energy and particle transmission during the tracking are plotted in Fig. 6.

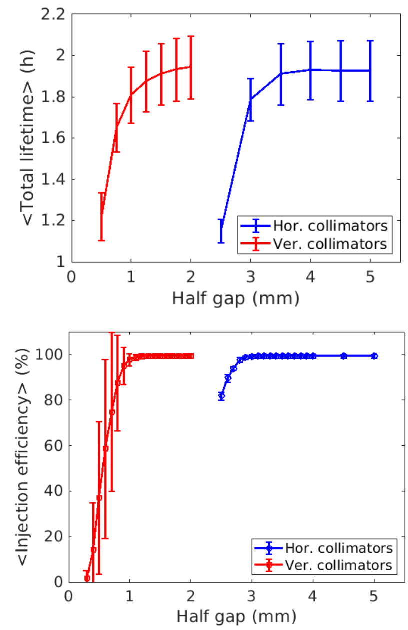

Figure 4: Mean lifetime (top), and mean IE (bottom) versus half gap of collimators. VGAP in the blue curve is set to ±1.5 mm while HGAP in the red curve is kept at ±3.5 mm.

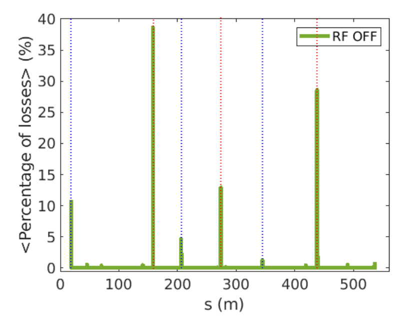

Figure 5: Mean percentage of particle losses due to RF off as a function of location in the ring.

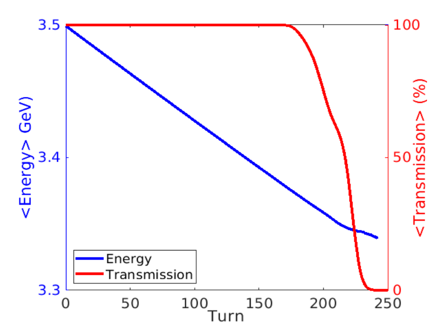

Figure 6: Reduction in beam energy and particle transmission during tracking with RF cavity off.

Six watch points have been placed next to the collimators and one at the centre of the long straight section (LSS) to record variation of the beam parameters. Due to the presence of synchrotron radiation in the simulation, the beam energy reduces to around 3.35 GeV before the

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particles are lost. The deviation of the beam centroid from the nominal orbit is displayed in Fig. 7, showing that the centre of the beam is offset by around 3 mm horizontally and 1.5 mm vertically when it is lost.

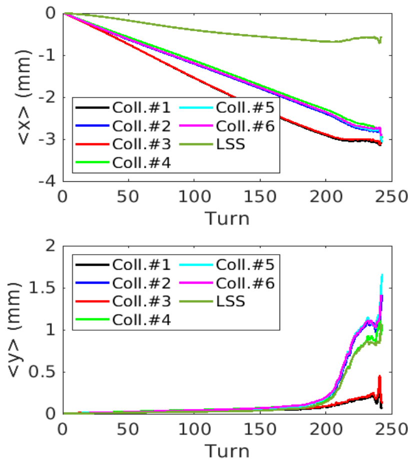

Figure 7: Variation of the beam amplitude during tracking through the ring with RF cavity off, horizontal (top), vertical (bottom).

Touschek Effect

For the Touschek losses, the loss points are found by tracking particles at different scattering locations around the ring, gradually increasing the momentum deviation of the particles until they are lost on an aperture. The ELEGANT [3] code based on Monte Carlo method is employed for this purpose. Figure 8 shows the loss locations.

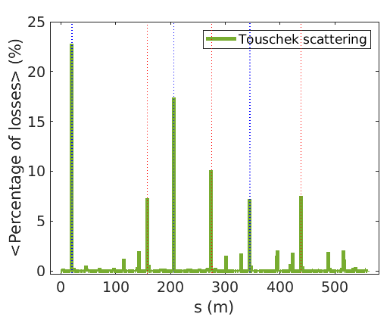

Figure 8: Location of losses due to the Touschek effect.

Gas Scattering

The "elastic_scattering" and "inelastic_scattering" commands in ELEGANT [3] are employed to compute the particle loss distributions due to these gas scattering processes. The results are shown in Fig. 9 and reveal that the collection of lost particles is not very efficient by the collimators. However, due to the long lifetime, these two scattering processes are less relevant compared with the other ones.

Injection

In the case of injection losses, the injection efficiency is expected to approach 100% for the selected collimation scheme. As such, the effectiveness of the collimators was assessed by deliberately mis-steering the injected beam for the single bunch aperture sharing injection [5] and recording where particles were lost. The degree of mis-steering was adjusted in order to give injection efficiencies in the range 65%-75%. The results from both planes are shown in Fig. 10 where the losses for all different mis-steerings are added together. It is found that the septum blade will expectedly catch some electrons for mis-steered beams and remaining losses are all caught by the collimators. The vertical collimators are found to be very effective in collecting all losses for vertically mis-steered beams.

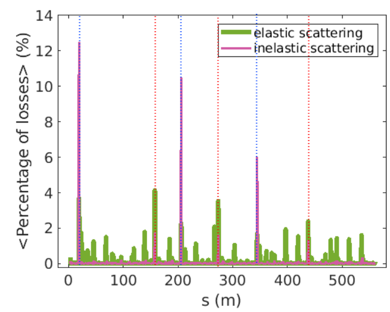

Figure 9: Location of losses due to elastic and in-elastic scattering effects.

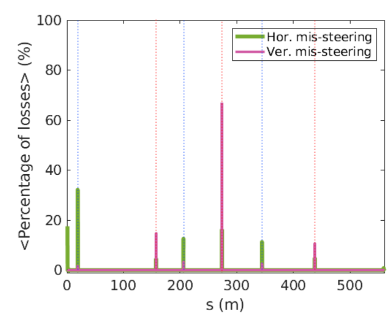

Figure 10: Location of losses during injection with mis-steered beams.

SUMMARY AND CONCLUSION

A collimation scheme using six collimators is introduced for the Diamond storage ring upgrade to capture the particles lost due to different loss mechanisms. The half gaps of the horizontal and vertical collimators are set to ±3.5 mm and ±1.5 mm based on their impacts on nonlinear beam dynamic aspects. Table 1 provides a summary of the collimator efficiency.

Table 1: Percentage of Lost Particles Captured by the Collimators, HGAP = ±3.5 mm, VGAP = ±1.5 mm

Loss mechanism	All collimators (%)
RF switch-off	96.0 ± 5.0
Touschek scatter	68.8 ± 3.6
Elastic gas scatter	21.4 ± 0.4
Inelastic gas scatter	34.5 ± 0.3
Injection, hor. mis-steer	81.4 ± 16.6
Injection, ver. mis-steer	99.9 ± 0.2

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