Beam-beam + Dynamic Aperture

ICFA Mini-Workshop
on Commissioning of SuperKEKB and e+e- Colliders

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Dynamic Aperture & Lifetime

Design Target of Lifetime: 600 sec

Design Lattice

With Beambeam

With BB + Re-Optimize (Sext/Oct)

Touschek Lifetime: 653.7 sec
Different Initial Condition

Touschek Lifetime: 512.2 sec

Touschek Lifetime: 72.6 sec

Touschek Lifetime: 604.7 sec

Design Target is achieved

Unrecovered

Working point \((\nu_x, \nu_y) = (0.53, 0.57)\)

We have to understand origin of aperture degradation
find method to cure transverse aperture
DA cured by Ideal Crab Waist

Initial amplitude vs Number of turns

- Ideal CW replaces map \( f_{BB} \) with \( f_{CW} (+\lambda) \cdot f_{BB} \cdot f_{CW} (-\lambda) \)

- \( f_{CW} \) is constructed by thin sextupole between thin phase rotator pair.

- \( f_{CW} (\lambda): (x,x',y,y',z,\delta) \rightarrow (x,x'+\lambda/2 \ y'^2, y-\lambda \ x \ y', y', z, \delta) \)
Past trial of CW on KEKB model

- Our past trial of CW on KEKB model lattice is failed because of degradation of aperture!

Questions

- Who is preventing dynamic aperture?
- What is operating condition of CW?

LER Model Optics for Crab Waist

- Insert thin sextupole pair into NIKKO and OHO section
- Transfer between crab waist sextupole pair is I'

Dynamic Aperture of LER Model Optics

- Tracking Condition: XY-Coupling 10%, RFSW ON

 Degradation by CW without BB

from 12th KEKB MAC (2007)
Simplified IR lattice model for study
- Remove solenoid, QC's offset & rotation, K0, SK0, SK1
- Control QC's multipoles Kn, SKn(n ≥ 2)
- Insert CW sextupole pair by using both thin sextupole and thin phase rotator into dispersion free section
- Fix betatron phase between CW sextupole and IP to (π + 2nπ, π/2 + 2mπ) (∀ n, m ∈ Z)
- Fix α_x & α_y at CW sextupole to 0
- Control β_x & β_y at CW sextupole
• Scan $\beta$-functions at CW sextupole

• CW works with ideal location, however, does not work with realistic location

• Aperture depends on $\frac{\beta_y}{\beta_x}$ ratio at CW sextupole

• This limit is caused by $K_2/2*(x^2-y^2)$ term.
• Location dependency test on simplified lattice without higher order multipoles

• Aperture depends with final focus quadrupoles between CW I-cell

• Aperture blocker WOULD be non-linear Maxwellian fringe of FF quadrupoles
CW operating condition study(4)

Trial of QC1 fringe correction by using octupoles (IP+Drift+QC1 in I-cell)

- CW improves aperture of worst cases
- CW limits aperture of best case
DA blocking multipole study (1)
Simplified IR + QC's Higher Order Multipole in Design (without CW)

- Good DA region disappears by adding QC's allowed multipoles in design
DA blocking multipole study (2)

Simplified IR + Non-allowed (K3, 7, 11, 15, 19) & Allowed (K5, K9, K13, 17, K21) in Design without CW

- Off-axis solenoid multipoles reduce aperture, but, is not critical
DA blocking multipole study (3)

Trial to correct K5 allowed multipoles

- Simplified IR + K5 (QCs Allowed in Design)
- K3 correctors are optimized (QC11, ECSP1419)
- K5 correctors are introduced into same place

- Aperture degraded by adding QC's K5 allowed multipole is improved by using K5 correctors
- Some correction parameter point exceeds 40σ
- Good parameter region looks like fragmented
Summary

- Beam-beam effect reduces dynamic aperture & Touschek lifetime
- DA degradation by BB effect COULD be cured by crab waist if I-cell of CW was linear
- Intrinsic non-linearity (Maxwellian fringe) blocks dynamic aperture of CW on our lattice
- Achieving 40\sigma aperture by using octupole correctors is difficult without QCs allowed multipole suppression
- Tuning K5 corrector on real machine WOULD be difficult because of fragmentation of good parameter region
Backup
CW location dependency without higher order multipoles

IP+Drift+QC1/2

IP+Drift+QC1

IP+Drift

With QC1 non-linear fringe

Without QC1 non-linear fringe