Correction of Nonlinear Coupling Resonances in the SPring-8 Storage Ring

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Contents

• Introduction
  – Injection Beam Loss
  – Touschek Lifetime
• Coupling Resonance Excited by Insertion Device
• Correction of Coupling Resonance by Skew Octupole magnet
• Summary
Injection beam oscillating in horizontal direction with a large amplitude.

Converted to vertical oscillation.

Nonlinear Coupling

Lost at narrowest vertical aperture.

By closing v. scraper, Injection efficiency decreasing.
Touschek scattered particle at dispersive section starts to oscillate horizontally with a large amplitude. Converted to vertical oscillation. Lost at narrowest vertical aperture.

Nonlinear Coupling

Measured Touschek Lifetime

- V. Scraper open
- V. Scraper +/-1mm

By closing v. scraper, Touschek lifetime decreasing.

Momentum acceptance

1mA / bunch

3.2 %

2.8 %
**ID Induced Coupling Resonance**

- ID07 (**out-vacuum**) has a peculiar magnetic field distribution and generates strong skew octupole field.
- As closing the ID gap, injection efficiency and lifetime are reduced by the effect of ID magnetic field.

*Injection efficiency vs. ID07 gap w/ v. scraper +/-1mm (gap 2mm)*

- **ID07 magnet array**
  - Composed of 4 arrays.
  - Period of side arrays is twice of center ones.

*Generate v field*

*Generate h field*

*By T. Tanaka*
Beam Oscillation Measurement by Turn-by-Turn BPM

- Measured beam oscillation kicked by injection bump to give an initial amplitude $x_0$ as injection beam.

**Beam oscillation w/ ID07 gap open @ $x_0=-10$mm**

**Beam oscillation w/ ID07 min. gap @ $x_0=-10$mm**
Mode Analysis from Turn-by-Turn Measurement

• By closing ID07 gap, skew octupole resonance is excited in vertical oscillation.
Coupling Resonance Induced by ID07

• By closing ID07 gap, resonance is excited exponentially near minimum ID gap.
Skew Octupole Magnets at SPring-8 SR

- 4 skew octupole magnets (SkOCT) are installed adjacent to ID07 to correct the ID induced coupling resonance.
Coupling Correction by SkOCT’s

- The SkOCT’s suppress the coupling resonance excited by ID07.

Peak amplitude vs. SkOCT
w/ scraper gap 2mm
w/ ID07 min. gap
Suppression of Vertical Oscillation by SkOCT

• Measured beam oscillation w/ and w/o coupling correction by SkOCT.

Beam oscillation w/o SkOCT correction @ $x_0=-10\text{mm}$

Beam oscillation w/ SkOCT correction @ $x_0=-10\text{mm}$
Correction of Skew Octupole Coupling Resonance

- Peak amplitude of skew octupole coupling resonance is suppressed by exciting SkOCT.

**Beam spectrum w/ \( x_0 = -10 \text{mm} \) w/o SkOCT correction**

**Skew Octupole Resonance**
\[ 3\nu_x - \nu_y = \text{int.} \]

**Beam spectrum w/ \( x_0 = -10 \text{mm} \) w/ SkOCT correction**

**Graphs**
- \( \nu_x, -2\nu_x + \nu_y \)
- \( 2\nu_x \)
- \( \nu_y, 3\nu_x \)

**Graphs**
- \( \nu_x, 2\nu_x \)
- \( \nu_y \)
Effect of SkOCT Coupling Correction

- Injection efficiency and Touschek lifetime are improved by the correction of the coupling resonance by the SkOCT magnets.
Study for Correction by Skew Sextupole Magnets

- Study for the correction of the coupling resonance by the skew sextupole (SkSX) magnets is in progress.
- For a single particle motion with a sudden momentum change like Touschek effect, optimizing the strength of the nearest skew sextupole coupling resonance ($2\nu_x - \nu_y = 63$) reduces vertical oscillation amplitude.

![Calculated max. amplitude of vertical oscillation after Touschek scattering](chart1.png)

![Spectrum of vertical oscillation w/ momentum deviation +2%](chart2.png)
Summary

- The peculiar insertion device (ID07 @ SPring-8) excites strong **skew octupole coupling resonance**.
- The excitation is suppressed by the **skew octupole magnets** installed adjacent to ID07.
- Study of the correction of nonlinear coupling resonance by the skew sextupole magnets is in progress.