Impact of Incoherent Transverse Wakefield on Storage Ring Optics

P. Brunelle, L.S. Nadolski, R. Nagaoka
E = 2.75 GeV

Tunes = 18.176 / 10.234

ex = 4 nm.rad
Magnetic Structure

25 Insertion Devices

\[ \beta_x (m) \]

\[ \beta_z (m) \]

10 \( \eta_x(m) \)

0 20 40 60 80

s (m)

Medium straight section X 12
Short straight section X 8
Long straight section X 4
Variation of Injection Efficiency versus Tunes

Injection Efficiency (%)

ID configuration

Bare machine + WSV50 + HU80 + 1 U20 + 4 U20 + U18 + HU36 + HU640 Typical configuration

- nux = 18.155; nuz = 10.229
- nux = 18.150; nuz = 10.223
- nux = 18.140; nuz = 10.220
Variation of Beam Lifetime versus Tunes

Beam lifetime @ 430 mA (h)

ID configuration

- Bare machine
- + WSV50
- + HU80
- + 1 U20
- + 4 U20 + U18
- + HU36 + HU640
- Typical configuration

- nux = 18.155; nuz = 10.229
- nux = 18.150; nuz = 10.223
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Circular resistive-wall chamber
- no transverse wake is created
- due to the symmetry, as long as the driving beam stays on axis

Pioneering studies:
- A. Burov, V. Lebedev “Transverse Resistive Wall Impedance for Multi-Layer Flat Chambers”, EPAC 2002
For SOLEIL with vertically low gap chambers in most of the ring, the incoherent wake was evaluated to be non-negligible for both single and multibunch modes (R. Nagaoka, EPAC 2004)

Circulart resistive-wall chamber
• no transverse wake is created
• due to the symmetry, as long as the driving beam stays on axis

Non-circular resistive-wall chamber
• a transverse wake is created even if the driving beam stays on axis.
• Non-oscillating wakefields add up to build an extremely long range field.
• Its leading field component is “quadrupolar” type. Trailing particles are focused (defocused) "incoherently".
• Focusing strength depends linearly on the beam current and on the cross section geometry.

Pioneering studies:
- A. Burov, V. Lebedev “Transverse Resistive Wall Impedance for Multi-Layer Flat Chambers”, EPAC 2002
Vacuum Chamber Vertical Size Limitations

**Standard chambers**
X = 2 x 35 mm  
Z = 2 x 12.5 mm

**Long SS chambers**
X = 2 x 28 mm  
Z = 2 x 7 mm

**Medium SS chambers**
X = 2 x 23 mm  
Z = 2 x 5 mm

Length = 10.6 m  
Length = 5.6 m
Vacuum Chamber Vertical Size Limitations

**Standard chambers**
\[X = 2 \times 35 \text{ mm} \]
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**Medium SS chambers**
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**Short SS In vacuum U20 undulators**
\[X = 2 \times 52.5 \text{ mm} \]
\[Z = 2 \times 2.75 \text{ mm} \]

**Long SS Vertical Scraper**
\[X = 2 \times 35 \text{ mm} \]
\[Z = 2 \times 4.1 \text{ mm} \]

- **Length = 10.6 m**
- **Length = 5.6 m**
- **Length = 1.8 m**
- **Length = 0.082 m**
Incoherent Tune Shift versus Current for the Bare Machine

416 Bunch Filling Pattern (4/4)

Bunch current (mA) = 0.24  0.48  0.72  0.96  1.20
• Measure Response Matrix

(122 BPM, 57 H-correctors, 57 V-correctors)

• Adjust the Model to fit the Measured Response Matrix taking into account measured Dispersion, BPM noise, ...

• Use of the 163 quadrupoles of the machine and 24 virtual quadrupoles located at the middle of the straight sections

\[ \Delta v_x = + 0.0066 \]
\[ \Delta v_z = - 0.0068 \]
Main focusing effect comes from long and medium SS
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- Cryomodule n°1
  - In-vacuum undulator U24 + standard chamber

- Cryomodule n°2
  - In-vacuum undulator U18 + standard chamber
300 mA - Bare Machine – Virtual Quadrupole gradient

KL (m⁻¹)

Long SS  Medium SS  Short SS
$\Delta \nu_x = +0.0058\ (+0.0066) \quad \Delta \nu_z = -0.0038\ (-0.0068)$
Adjustment using the 163 quadrupoles of the machine
Adjustment when adding 24 virtual quadrupoles
Comparison 300 mA / 500 mA - Bare Machine – β-beating

\[ \Delta \nu_x = +0.0108 \] for 500 mA

\[ \Delta \nu_z = -0.0094 \] for 500 mA

\[ \Delta \nu_x = +0.0066 \] for 300 mA

\[ \Delta \nu_z = -0.0068 \] for 300 mA
Comparison 300 mA / 500 mA
Bare Machine – Virtual Quadrupole gradient

KL (m^-1)
Comparison 300 mA / 500 mA
Bare Machine – Virtual Quadrupole gradient

\[ y = 1.5575x - 6E-05 \]
300 mA – 6 x In-vacuum Undulators are closed at 5.5 mm gap
Quadrupole gradient variation

"In-vacuum Undulators are closed"
"Bare Machine"
300 mA – 6 x In-vacuum Undulators are closed at 5.5 mm gap

Tune variation

Total tune variation when In-vacuum Undulators are closed

\[ \Delta v_x = +0.0203, \Delta v_z = +0.0094 \]

Total tune variation for the Bare Machine

\[ \Delta v_x = +0.0066, \Delta v_z = -0.0068 \]
18 mA – 6 x In-vacuum Undulators are closed at 5.5 mm gap

Magnetic contribution measured at low current

"In-vacuum Undulators are closed @ 300 mA"
"Magnetic contribution @ 18 mA"
**Total tune variation when In-vacuum Undulators are closed @ 300 mA**

\[ \Delta \nu_x = +0.0203, \Delta \nu_z = +0.0094 \]

**Tune variation due to Magnetic contribution @ 18 mA**

\[ \Delta \nu_x = +0.0079, \Delta \nu_z = +0.0172 \]
Total tune variation when In-vacuum Undulators are closed

\[ \Delta \nu_x = +0.0203, \Delta \nu_z = +0.0094 \]

Tune variation due to Magnetic contribution

\[ \Delta \nu_x = +0.0079, \Delta \nu_z = +0.0172 \]

Tune variation due to Wakefield Effect

\[ \Delta \nu_x = +0.0058, \Delta \nu_z = -0.0010 \]

Total tune variation for the Bare Machine

\[ \Delta \nu_x = +0.0066, \Delta \nu_z = -0.0068 \]

Optical functions in short SS: \(<\beta_x> = 14.3 \text{ m}, <\beta_z> = 2.4 \text{ m}\)
300 mA – 6 x In-vacuum Undulators are closed at 5.5 mm gap

Incoherent Transverse Wakefield Effect

In vacuum U20 undulators

\( X = 2 \times 52.5 \text{ mm} \)
\( Z = 2 \times 2.75 \text{ mm} \)

Length = 1.8 m

Long SS chambers

\( X = 2 \times 28 \text{ mm} \)
\( Z = 2 \times 7 \text{ mm} \)

Length = 10.6 m

Medium SS chambers

\( X = 2 \times 23 \text{ mm} \)
\( Z = 2 \times 5 \text{ mm} \)

Length = 5.6 m

Incoherent \( \Delta \nu_x = +0.0058 \)
Total length = 10.8 m
\( <\beta_x> = 14.3 \text{ m} \)
\( G \times L = 0.046 \text{ T} \)
\( G = 0.0043 \text{ T/m} \)

Incoherent \( \Delta \nu_x = +0.0066 \)
Total length = 71.6 m
\( <\beta_x> = 5.8 \text{ m} \)
\( G \times L = 0.130 \text{ T} \)
\( G = 0.0018 \text{ T/m} \)
• At SOLEIL, the non circular low gap chambers generate large incoherent tune shifts as predicted by calculations.
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• The incoherent transverse wakefield contribution of low gap in-vacuum undulators is not negligible in terms of focusing strength. At SOLEIL, the effect is amplified by the $\beta_x$ high value.

• For machines of the future, the effect will be amplified by smaller vertical apertures.
At SOLEIL, the $\beta$-beat does not affect so much the beam lifetime and the injection efficiency
• At SOLEIL, the β-beat does not affect so much the beam lifetime and the injection efficiency

→ The optics is restored on the model only at low current, for the bare lattice.
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However, tune variations affect beam lifetime and injection efficiency when undulators gaps are varying.
At SOLEIL, the $\beta$-beat does not affect so much the beam lifetime and the injection efficiency

$\rightarrow$ The optics is restored on the model only at low current, for the bare lattice.

However, tune variations affect beam lifetime and injection efficiency when undulators gaps are varying

$\rightarrow$ Tunes are kept fixed thanks to a global feedback
Thank you for your attention