Injection and Top-Up experience at SOLEIL

A. Loulergue
and Source & engineering division

Topical Workshop on Injection and Injection systems

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Outline

- Top-Up overview at SOLEIL
- Residual bump corrections from pulsed elements
- Conclusion
Different filling patterns

Top-Up operated since 2009
Different filling patterns

Good flat shape linac pulse
100 bunches / 300 ns

3 Hz booster power supplies
ramped up and down over 10 s

10 s
Top-Up operation survey

Before injection sequence checks:

- Machine PSS
- Machine interlock
- Injector status

As well as the last injection

Efficiencies

Manage the different ring filling patterns
Top-Up operation survey

Uniform 500 mA

Hybrid 445 + 5 mA

Filling current control quarter to quarter
Refill the lowest one
Top-Up operation

Typically 2 mA every 3 mn
Current stability below ±0.2 %
Top-Up operation

Current stability below ±0.2 %

Constant thermal load on beam-line optics
Mirror alignment, thermal optical bumps, ...

Constant thermal load on accelerator equipments.
Reduction of thermal drift on BPM electronics.

Only way to reach sub micron stability level
But Not suitable for all user needs (long integration time, image scanning, ...)

Gating signal:

Very significant improvement for the data quality recorded at the SMIS IR-beamline. This results in an increase of the S/N of the spectra by a factor between 12 and 15!
Users Top-Up operation over 6 days

450 mA hybrid mode

- 12-14 hrs
- 80 %
- 90-95 % LPM
- 70-80% SPM

User times
Top-up efficiency and MTBF

When the stored current drops below 0.5 mA from the nominal value
Ring injection layout

Inserted in free 12m long section

Kicker layout

Kickers:
Half sine wave
7 µs (6 turns)
120 mT

Thin Septum:
Full sine wave
120 µs
400 mT
In vacuum Eddy current septum
3 mm thick
20 mm from axe

Thick Septum:
Half sine wave
3.3 ms
1 T
Thin Septum H & V residual bump

Initial: Half sine wave, no shielding

Step 1: Change the pulse profile from an half sine to a full sine wave
Gain = a factor of 2

Step 2: Adapt a shield screen over the complet SR inner chamber including the pumping outlet
Magnetic alloy: SuperImphy of 0.5 mm thickness
Gain = a factor of 100

=> Residual stray field reduced from 400 μTm to ~2 μTm (Mag. Meas.)
=> Residual orbits ~ cancelled
Thick Septum H & V residual bump

2009 Bump reduced by means od µ-metal and grounded upstream Eddy current.

A last pass in 2015 grounding downstream the Eddy current.

\[ \beta_x = 14 \text{ m} @ \text{BPM (long straight)} \]
\[ \sigma_x = 320 \mu\text{m} @ 4 \text{ nm.rad} \]
20 \mu m => ~6% of \( \sigma_x \) => Below 10%

\[ \beta_z = 12 \text{ m} @ \text{BPM (long straigth)} \]
\[ \sigma_z = 20 \mu\text{m} @ K=1\% \]
5 \mu m => ~25% of \( \sigma_z \) => Still larger than 10%
Kicker pulse profile investigation

Beam Based turn by turn data analysis:

Get the differential \((x,x', z,z')\) induced by the 4 kickers at each turn on a set of BPMs

Fit the differential kickers profiles in both planes

Repeat with different timing (circulating beam vs kicker) to sample the pulse profile measurements
Kicker pulse profile investigation

Without any BPMs in between the kickers, it is not possible to distinguish the 4 kickers, there is only 2 unknowns per plane:

==> Fit the mean profile of K1 K2 and K3 K4

Exemple of different mis-matching kicker pulse:
Voltage
Timing
duration
Kicker pulse profile investigation

Exemple of kickers matching process by step

*Ring filled with 1 quarter*

*Kicker pulse duration over 6 turns*

Voltage correction

Timing correction

Need duration correction

=> Pulser modification
Kicker pulse profile investigation

Optimization based on:
- Saturating self
- Parallel capacitor

2007 optimization
- 30 µrad residual kicker deviation
- 0.5% from max deviation
- Factor 2 to 3 gain

2009 optimization
- 10 µrad residual kicker deviation
- 0.2% from max deviation
Kicker pulse profile investigation

$\beta_x = 14 \text{ m} @ \text{BPM (long straight)}$

$\sigma_x = 320 \text{ µm} @ 3.7 \text{ nm}$

$70 \text{ µm rms} \Rightarrow \sim 20\% \text{ of } \sigma_x \Rightarrow \text{Still larger than 10\%}$

$\beta_z = 12 \text{ m} @ \text{BPM (long straight)}$

$\sigma_z = 20 \text{ µm} @ K=1\%$

$40 \text{ µm rms} \Rightarrow \sim 200\% \text{ of } \sigma_z$

$\Rightarrow \text{Very large !}$
Kicker pulse profile investigation

The perturbation times appear to be much larger than the kicker pulse....
## H & V residual bump

**Summarized**

Bumps measured at BPM with $\beta_x = 14$ m and $\beta_x = 12$ m

Target = 10 % beam size (with 1% coupling) !

<table>
<thead>
<tr>
<th>Plane</th>
<th>H</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Target</strong></td>
<td>~30 µm</td>
<td>~2 µm</td>
</tr>
<tr>
<td>Thin septum</td>
<td>~0</td>
<td>~0</td>
</tr>
<tr>
<td>Thick septum</td>
<td>20 µm</td>
<td>5 µm</td>
</tr>
<tr>
<td>Kickers</td>
<td>100 µm</td>
<td>50 µm</td>
</tr>
</tbody>
</table>

To reduce it further:
- Need a NLK
- Need feedforward/feedback?
Conclusion

Top-Up operation :

➢ Fully operated since 2009 in all filling pattern modes
➢ Since 2011, the Top-Up efficiency is about 99.5 %
➢ Provides a good beam stability (constant thermal load)
➢ Pre-injection signal gating provided to the beamlines (long integration times)

Residuals Orbits / Oscillations

➢ We have still about 20% in Hor. and 200% in Vert. plane beam size perturbations
➢ Beamlines presently don't complain from these perturbations
➢ A NLK (à la BESSY) is under construction in the frame of SOLEIL / MAXIV collaboration. Installation is planned in 2018.
➢ A feedforward (feedback?) will be necessary, at least in the vertical plane, to reduce these oscillations toward 10% beam size : under investigation
Thank you for your attention