Commissioning of the infrared undulator

Part I: Electron beam transport

Oliver Grimm, 30 October 2007

...for the infrared undulator team.
Some results from magnetic tuning

Goal

Reduction and flattening of field integrals over full operation range 0 to 435 A

Means

6 power supplies, 40 variable resistors, 80 switches
<table>
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<th>$I_{\text{main}}$ (A)</th>
<th>Left period (A)</th>
<th>Right period (A)</th>
<th>N 1 (A)</th>
<th>N 22 (A)</th>
<th>N 2 (A)</th>
<th>N 21 (A)</th>
<th>Int.1 (G·cm)</th>
<th>Int.2 (kG·cm²)</th>
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</tbody>
</table>

![Graph](image-url)
First field integral

\[ \Theta = \frac{ec}{E} I_1 \]

0.2 mrad
@ 700 MeV

Second field integral

\[ x = \frac{ec}{E} I_2 \]

0.4 mm
@ 700 MeV

Reproducibility

Degaussing
Long term temperature effects

-ΔB

Int.1 (G*cm), -Int.2 (G*cm²)*10^3

Current 435 A

Time after turn-on (hours)

Magnetic field (T)

longterm10.435
longterm11.435
Reference probe, scaled

1.1331
1.1332
1.1333
1.1334
1.1335
1.1336
1.1337
1.1338

1.1332
1.1333
1.1334
1.1335
1.1336
1.1337
1.1338

2 4 6 8 10 12 14 16
IR undulator first harmonic wavelength

- **FEL wavelength (nm)**
  - Energy (MeV)
  - Wavelength of first harmonic on-axis (μm)

- **Magnetic field (T)**
  - Pole pair 3
  - Pole pair 7
  - Pole pair 11

- **Main coil current (A)**
  - Main coil excitation current (A)

- **K value**
  - Main coil current (A)

Graphs showing the relationship between energy, wavelength, magnetic field, and current for different pole pairs.
DDD panels
Effect of IR undulator on orbit

Measurements at 700 MeV, no orbit correction

\[ \Delta x = \frac{ec}{E} I_2 \]

\[ I_2: \text{2nd field integral} \]
Required steerer currents to fix orbit

BPMs in front of and after undulator (3EXP and 9EXP) kept at zero reading by orbit feedback. Undulator correctors as prescribed from tuning.
Coil measurements

<table>
<thead>
<tr>
<th>Pole pair</th>
<th>1</th>
<th>2</th>
<th>21</th>
<th>22</th>
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</thead>
<tbody>
<tr>
<td>Combined resistance (Ω)</td>
<td>1.06</td>
<td>1.05</td>
<td>1.11</td>
<td>1.07</td>
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<td>Voltage at 1 A (V)</td>
<td>1.07</td>
<td>1.06</td>
<td></td>
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<tr>
<td>Resistance top coil (Ω)</td>
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<td>0.55</td>
<td>0.55</td>
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<tr>
<td>Resistance bottom coil (Ω)</td>
<td>0.55</td>
<td>0.56</td>
<td>0.53</td>
<td>0.52</td>
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</table>

Total voltage U6P3EXP @ -1 A: -15.22 V  
U6P12EXP @ -1 A: -20.96 V  
@ +1 A: +22.12 V

Resistance of 1st corrector coil ≈ 9 mΩ,  
2nd corrector coil ≈ 15 mΩ,  
main coils ≈ 30 mΩ.

Same fluctuations as measured at JINR.
Reversing all correctors helps...
Beam displacement studies

-3 -2 -1 0 1 2 3 4
-6 -5 -4 -3 -2 -1 0 1 2 3 4

Wanted offset (mm)
Measured offset (mm)

TTF2.DIAG/BPM/3EXP/X
TTF2.DIAG/BPM/9EXP/X

OTR chamber 12EXP indeed horizontal offset by $\approx 6$ mm

35 mm inner diameter beam pipe

... but after BPM 9EXP
Horizontally centred

Horizontally moved by ≈10 mm
...if undulator would be tilted with respect to BPM zero?

Beam moved horizontally to +10 mm on BPM 3EXP and -2.5 mm on BPM 9EXP. All correctors reversed.

Field integrals valid for on-axis beam transport
Temperatures

Sensors at undulator

Sensors at cooling tower
Reproducibility after reversing current

Initial at 200 A

-435 A -> 200 A

+435 A -> 0 A -> 200 A
Conclusions / Outlook

- Electron beam transported without losses to dump at all undulator settings (using orbit feedback, not yet tried in long-pulse mode)
- Discrepancy between expected and measured orbit displacement → critical if this would strongly affect the radiation properties - not seen (yet?)

- Correct aperture problem and strong beam steering effect
  → Again measure/realign EXP section
- Establish fully parasitic operation and/or final protection system ("laser" safety)
- Study radiation properties and dependence on undulator settings

- Use it as source and beam diagnostics tool