Beam commissioning of the MAX IV Linac

Erik Mansten on behalf of the MAX IV linac team
MAX IV Laboratory @ Linac16

- Aleksandar Mitrovic
  - LLRF

- David Olsson
  - MOP10615, Commissioning status of the chopper system for the MAX IV injector

- Dionis Kumbaro
  - MOPLR019, High power RF commissioning

- Sara Thorin
  - TUP106013, First experimental results of T566 linearization in the MAX IV linac bunch compressors

- Erik Mansten
  - MOP106014, Relative bunch length measurements at the MAX IV linac
## MAX IV news

<table>
<thead>
<tr>
<th>Year</th>
<th>Linac building</th>
<th>Linac installation</th>
<th>Linac commissioning</th>
<th>Linac operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
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<td>2011</td>
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<td>2017</td>
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MAX IV

- 1.5 GeV ring – circumference 96 m
- 3 GeV ring – circumference 528 m
- Linac 250 m long
- 13 beamlines funded
- 26 beamlines in 2026
- Short Pulse Facility
R1 and R3 injection

- DC chopper
- Superposition of RF fields 100 MHz, 300 MHz and 700 MHz
- 500 MHz

Design parameters

<table>
<thead>
<tr>
<th></th>
<th>1.5 GeV/ 3 GeV</th>
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<tbody>
<tr>
<td>Injection</td>
<td>10 Hz</td>
</tr>
<tr>
<td>frequency</td>
<td></td>
</tr>
<tr>
<td>Charge</td>
<td>0.3-1 nC/shot</td>
</tr>
<tr>
<td>Emittance</td>
<td>10 mm mrad</td>
</tr>
<tr>
<td>Energy spread</td>
<td>&lt;0.2%</td>
</tr>
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</table>
The Chopper System

- The induced voltage at a BPM strip after two LINAC structures (W = 190 MeV). Here, one (left) and ten (right) ring buckets are filled.
R1 and R3 injection

Photo cathode
RF gun

Thermionic
RF gun

BC1 @ 260 MeV

Extraction
1.5 GeV

Extraction
3 GeV

BC2 @ 3 GeV

SPF
R3 and R1 injection - status

R3
- Top-up injection
- Up to 20mA/min inj rate
- 90% inj efficiency
- First light in BL

R1
- 9 turns
High brightness mode

Design parameters - SPF

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Energy</td>
<td>3 GeV</td>
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<tr>
<td>Injection frequency</td>
<td>100 Hz</td>
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<tr>
<td>Charge</td>
<td>100 pC</td>
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<tr>
<td>Bunch length</td>
<td>100 fs</td>
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<tr>
<td>Emittance</td>
<td>1 mm mrad</td>
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<tr>
<td>Energy spread</td>
<td>&lt;0.4%</td>
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</table>
Laser improvements for photo gun

- Beam more stable due to Relay imaging through laser beam transport
- Cross correlator for $3\omega$ pulse width measurements
- Pulse length increased from 1 ps to 6.4 ps by pulse stacking
Quad scan - emittance

Norm emittance improved $\sim 1.2$ mm mrad @ 100 pC

- Longer laser pulse
- Emittance compensation
- Good spot on cathode
Bunch compressors – double achromats

\[ \Delta z = R_{56} \left( \frac{\Delta E}{E} \right) + T_{566} \left( \frac{\Delta E}{E} \right)^2 \]

<table>
<thead>
<tr>
<th></th>
<th>BC1</th>
<th>BC2</th>
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<tbody>
<tr>
<td>(R_{56})</td>
<td>2.23 cm</td>
<td>2.89 mm</td>
</tr>
<tr>
<td>(T_{566})</td>
<td>8.05 cm</td>
<td>6.76 (\mu)m</td>
</tr>
</tbody>
</table>
Bunch compressor characterisation

Bunch compression

Off-crest acceleration

Sextupole magnets

YAG screen
Relative bunch length measurements

Bunch compression

Detector, BP @ 140 GHz

YAG screen

(a) Normalized Electron distribution

(b) Bunch spectrum

(c) Detector transfer function

(d) Detector frequency response

(e) Detector temporal response

(f) Detector bunch length dependency
Relative bunch length measurements

Bunch compression

Detector, BP @ 140 GHz

YAG screen

Phase scan

Detector bunch length dependency

of L01
Relative bunch length measurements

Bunch compression

Detector, BP @ 140 GHz

YAG screen

Phase scan

Bunchlength in \( \sigma \)

Erik Mansten - Poster
Conclusion

- Our own Spotify hit!
- Approved by
- R3, 90% inj efficiency, 20mA/min inj rate
- R1, 3 turns
- Double achromat bunch compressor - linearisation proven
- Relative bunch length measurements in BC1 (0.3 ps sigma est BL)
Outlook

- Emittance optimisation – higher field in RF cavity
- Relative bunch length measurements in BC2
- Absolute bunch length measurements BC2
- R1 commissioning
- FEL CDR application started

The science case for Swedish X-ray Lasers
- Collaboration between MAX IV Laboratory, the Lund Laser Centre, the Stockholm-Uppsala FEL Centre, and Uppsala University
- More than 40 proposals for science case
- http://www.llc.lu.se/sxlf
- http://frielektronlaser.se/activities/swedish_xfel.html