Status of DELTA: Light Source and Short-Pulse Facility
Shaukat Khan, Center for Synchrotron Radiation, TU Dortmund

ESLS, Grenoble November 25th 2014
Parameters and availability

Parameters
- circumference: 115.2 m
- beam energy: 1.5 GeV
- beam current: 130 mA multi-bunch
- beam current: 20 mA single bunch
- beam lifetime: ~14 h at 100 mA
- hor. emittance: ~15 nm rad
- bunch length: 40 ps rms

User operation: 2000 h/y (20 weeks/y)
Machine studies: 1000 h/y (10 weeks/y)
Parameters and availability

### Parameters
- **circumference**: 115.2 m
- **beam energy**: 1.5 GeV
- **beam current**: 130 mA multi-bunch
- **beam current**: 20 mA single bunch
- **beam lifetime**: ~14 h at 100 mA
- **hor. emittance**: ~15 nm rad
- **bunch length**: 40 ps rms
- **user operation**: 2000 h/y (20 weeks/y)
- **machine studies**: 1000 h/y (10 weeks/y)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>94.7%</td>
<td>90.8%</td>
<td>85.0%</td>
<td>99.0%</td>
<td>96.6%</td>
<td>97.0%</td>
<td>89.0%</td>
<td>96.4%</td>
<td>70.2%</td>
<td>98.0%</td>
<td>68.3%</td>
</tr>
</tbody>
</table>

**III. 2013**
- unexplained orbit motion
- large voltage fluctuations (defective "powerformer")
- short-circuit fault causing damage

---

[Diagram of DELTA, ESLS 2014]
Parameters and availability

**Parameters**
- circumference: 115.2 m
- beam energy: 1.5 GeV
- beam current: 130 mA multi-bunch
- beam current: 20 mA single bunch
- beam lifetime: ~14 h at 100 mA
- hor. emittance: ~15 nm rad
- bunch length: 40 ps rms

User operation: 2000 h/y (20 weeks/y)
Machine studies: 1000 h/y (10 weeks/y)

Beam lifetime at 100 mA 2005-2014
- has steadily improved
- no venting since 2012
- RF phase modulation
Alignment of the storage ring

(U. Berges, G. Dahlmann, T. Dybiona, B. Isbarn, B. Hippert, P. Kortmann, G. Pike**, H. Rast, G. Schmidt, T. Schulte-Eickhoff; **Faculty of Physics, TU Dortmund)

Vertical alignment completed in 2013
- improved stability, injection efficiency, radiation level

Horizontal alignment underway
- 180 reference panels for Taylor-Hobson spheres in place
- laser tracker with interferometric distance measurement
Superconducting wiggler
(W. Brembt, P. Hartmann, B. Hippert, S. Khan, V. Kniss, P. Kortmann, R. Molo, M. Paulus, D. Schirmer, G. Schmidt, C. Sternemann, M. Tolan)

Superconducting asymmetric wiggler
- is aging, no support from manufacturer
- request for funding underway
- no asymmetry option
- higher field \((5.3 \, T \rightarrow 7 \, T)\)
- more periods \((5 \rightarrow 10)\)
- less He consumption \((130 \, l/week \rightarrow \text{none})\)

Additional issues
- second RF cavity and solid-state RF amplifier
- modified storage ring lattice
- new vacuum chamber and absorber
- beamline modifications
- integration into control system
- radiation safety
**Stability**

(P. Hartmann, S. Khan, B. Riemann, G. Schünemann, P. Towalski, T. Weis)

**Fast orbit feedback installed and tested**

- frequency range 1 - 400 Hz
- 19 horizontal and 21 vertical correctors installed
- FPGA-based controllers and communication
- first results
Stability

(M. Höner, S. Khan, M. Sommer, C. Waldera)

Bunch-by-bunch feedback systems (installed 2011)

- damp longitudinal and transverse oscillations,
- used for accelerator studies and diagnostics
... instabilities, injection studies, beam loss monitor

example: longitudinal damping rates

result 0.41 ms\(^{-1}\)
expected 0.23 ms\(^{-1}\)
Facility for ultrashort VUV and THz pulses

Facility for ultrashort VUV and THz pulses

Coherent harmonic generation (CHG)

- laser-induced energy modulation within a bunch "slice"
- density modulation in a magnetic chicane
- coherent radiation at harmonics of the laser wavelength
  (so far 80 nm, goal 53 nm)

Coherent terahertz (THz) radiation

- short "dip" due to energy-dependent path length
- broadband coherent THz radiation
- narrowband coherent THz radiation from multiple dips

\[ \lambda_L = \lambda = \frac{\lambda_U}{2\gamma^2} \left( 1 + \frac{K^2}{2} + \gamma^2 \theta^2 \right) \]

\[ \Delta \lambda = \frac{\lambda_U}{2} \theta^2 \]
Facility for ultrashort VUV and THz pulses

Coherent harmonic generation (CHG)
- laser-induced energy modulation within a bunch "slice"
- density modulation in a magnetic chicane
- coherent radiation at harmonics of the laser wavelength
  (so far 80 nm, goal 53 nm)

Coherent terahertz (THz) radiation
- short "dip" due to energy-dependent path length
- broadband coherent THz radiation
- narrowband coherent THz radiation from multiple dips
Facility for ultrashort VUV and THz pulses

Coherent harmonic generation (CHG)

- laser-induced energy modulation within a bunch "slice"
- density modulation in a magnetic chicane
- coherent radiation at harmonics of the laser wavelength
  (so far 80 nm, goal 53 nm)
Facility for ultrashort VUV and THz pulses

**Coherent harmonic generation (CHG)**

- laser-induced energy modulation within a bunch "slice"
- density modulation in a magnetic chicane
- coherent radiation at harmonics of the laser wavelength (so far 80 nm, goal 53 nm)
Facility for ultrashort VUV and THz pulses

Coherence of CHG radiation

- Young's double-slit experiment
- double-slit experiment with delay
- Michelson interferometer
- single-shot speckle measurements
Facility for ultrashort VUV and THz pulses

Coherence of CHG radiation

- Young's double-slit experiment
- double-slit experiment with delay
- Michelson interferometer
- single-shot speckle measurements

200 nm CHG spectral width 3 nm

200 nm undulator with 10-nm filter
Facility for ultrashort VUV and THz pulses

Coherence of CHG radiation

- Young's double-slit experiment
- double-slit experiment with delay
- Michelson interferometer
- single-shot speckle measurements

200 nm CHG spectral width 3 nm

200 nm undulator with 10-nm filter

C. Gutt et al.,
Coherence Workshop,
Chicago (2014)
SNI Conference,
Bonn (2014)
Facility for ultrashort VUV and THz pulses

**RF-phase modulation**
- suppresses coupled-bunch instabilities
- improves the beam lifetime

**RF-phase modulation and CHG**
- synchronize modulation with laser pulses
- phase scans (i) electronic delay
  (ii) frequency mismatch (beating)
- CHG and THz signal out of phase*
- CHG and THz signal enhanced*

* depending on modulation amplitude and frequency, and on RF power (synchrotron frequency).
Facility for ultrashort VUV and THz pulses

Generation of broadband and narrowband THz radiation

- slow (InSb) and fast (YBCO) bolometers
- FT-IR spectrometer with Si bolometer
- coherent THz radiation observed over 19 turns
- tunable narrowband spectra from 1 THz to 5.5 THz

C. Evain et al., PRST-AB 13 (2010), 090703

YBCO detector from IMS-KIT

cooperation with Univ. Lille/France and KIT Karlsruhe

YBCO detector collaboration with Univ. Lille/France and KIT Karlsruhe

C. Evain et al., PRST-AB 13 (2010), 090703

talk by Carsten Mai tomorrow 09:55
Echo-enabled harmonic generation at DELTA

Supported by Helmholtz ARD initiative (FZ Jülich)

- modulators: 2 short undulators
- radiator: present U250 undulator
- requires longer straight section
- modified storage ring optics
- additional undulator for "slicing"

Echo-enabled harmonic generation at DELTA

Supported by Helmholtz ARD initiative (FZ Jülich)

- modulators: 2 short undulators
- radiator: present U250 undulator
- requires longer straight section
- modified storage ring optics
- additional undulator for "slicing"

- storage ring lattice finalized
- two undulators ordered

7+2 electromagnetic periods
period length 200 mm
gap 40 mm
magnetic field 0.62 T
External activities

**DESY Hamburg:** FEL seeding (HGHG, EEHG)

**KIT Karlsruhe:** THz radiation, feedback

**HZB Berlin:** RF for BERLinPro and BESSY VSR

Accelerator physics in the bachelor and master curriculum

**Bachelor, master, PhD theses**

**One-semester course on instruments of modern physics**
- 2 hrs lecture
- 1 hr exercises

**Two-semester accelerator course**
- 2 hrs lecture
- 1 hr exercises
- 1 hr seminar
- 2 field trips
  (Berlin, Hamburg, Mainz...)
Acknowledgements

- Rektorat of TU Dortmund, Faculty of Physics, MEC, Kuratorium
- Users: FZ Jülich, ISAS e.V., Univ. Siegen and Bergische Univ. Wuppertal
- Tax payer: DFG, BMBF, MIWF NRW
- colleagues at DESY, FZJ, GSI, HZB, KIT and many others
- colleagues at DELTA: machine, beamlines, workshops, administration