Karlsruhe Institute of Technology

Status of the NbTi Wiggler and Experimental Program at ANKA

Axel Bernhard, for the KIT-CLIC collaboration

Laboratory for Applications of Synchrotron Radiation (LAS)

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Outline

Introduction

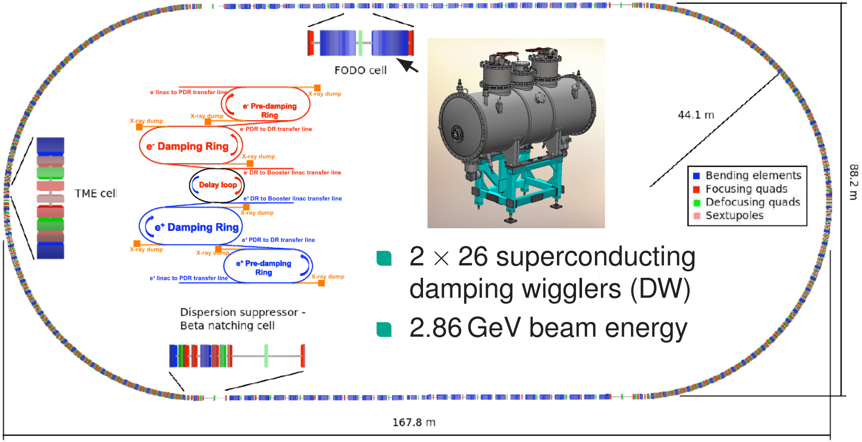
Design of the CLIC damping wiggler prototype

Results of the acceptance tests
- Cryostat performance
- Magnetic performance

Installation and further plans

Conclusion

Introduction — CLIC damping rings

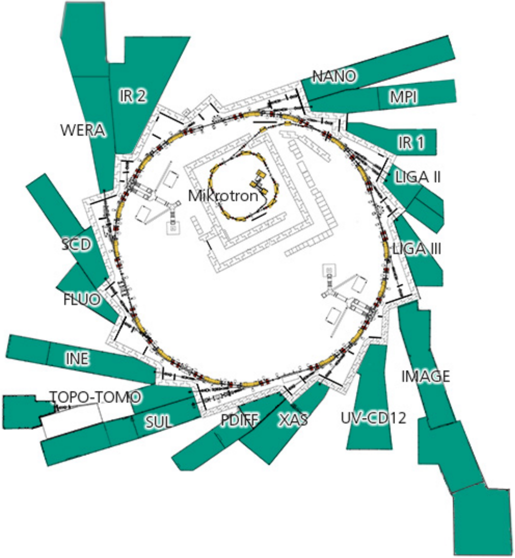


- 2 × 26 superconducting damping wigglers (DW)
- 2.86 GeV beam energy

Y. Papaphilippou et al. IPAC ’12; V. Syrovatin, priv. comm.

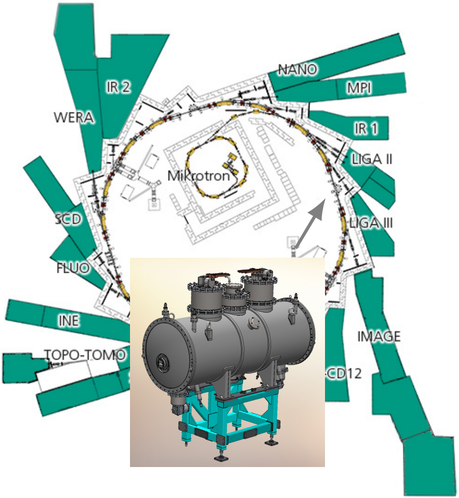
Introduction — ANKA

- Synchrotron radiation facility at KIT
- Normal user operation:
  - 2.5 GeV
  - 200 mA
- Special operation modes:
  - 1.3/1.6 GeV, low α_c
  - variable filling pattern



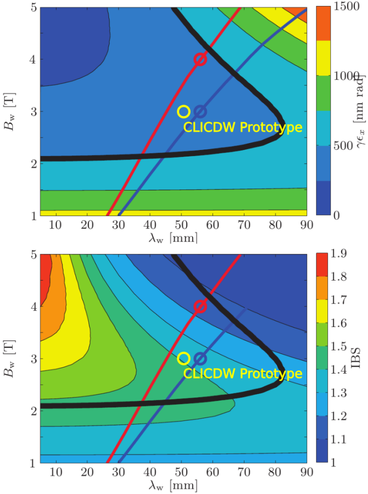
Introduction — CLIC-ANKA collaboration

- Wiggler parameters identified interesting for both CLIC DW and as light source for ANKA
- Wiggler developed and manufactured by the Budker Institute for Nuclear Physics (BINP), Novosibirsk
- Wiggler operated at ANKA:
  - Light source for IMAGE beamline producing hard X-rays
  - Long-term reliability test for CLIC DW



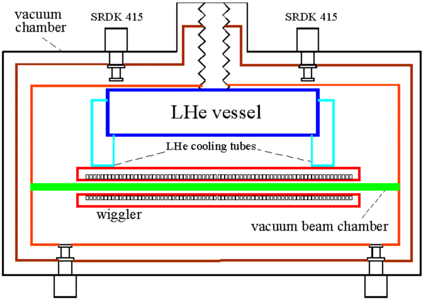
Design of the CLICDW prototype: Design parameters

Basic magn. design	
Period λ_W	51 mm
Magn. gap	18 mm
Flux density B_{y0}	3 T
Main poles	68
Matching poles	1/4, 3/4
Winding geometry	horizontal
Radiation (2.5 GeV, 200 mA)	
K	14
Power	13 kW
ϵ_{crit}	12 keV
SC technology	
Wire	Nb-Ti
Wire diameter (bare)	0.85 mm
SC:Cu ratio	1.1:1
Filaments	312



F. Antoniou; D. Schoerling et al, PRSTAB 15 (2012)

CLICDW Design: Conduction cooling



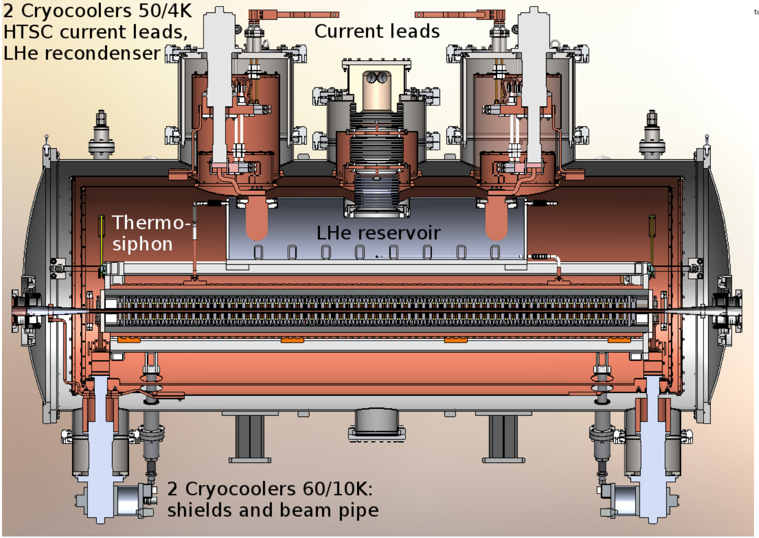
N. Mezentsev et al, *Final Design Report on CLIC damping wiggler test device*

Figure: Schematic cryogenic concept

Conduction cooling

- non-standard for sc wigglers
- minimized magnetic gap
- no pressure increase on beam pipe during quench
- easy heat extraction from beam pipe
- facilitates modular cryostat design

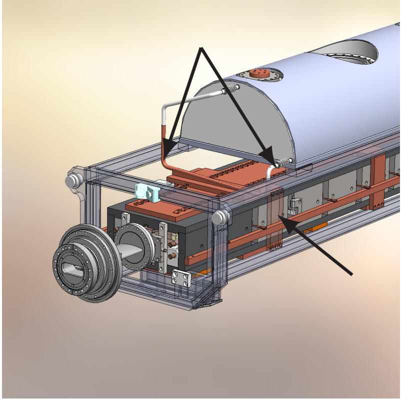
CLICDW Design: Cryostat Overview

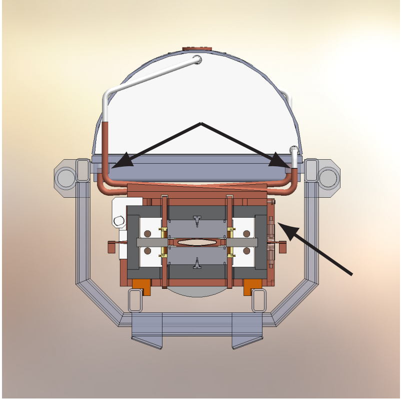


N. Mezentsev et al., *Final Design Report on CLIC damping wiggler test device*

CLICDW Design: Magnet cooling

- Top coil cooled through thermosiphon pipes at both ends
- Bottom coil connected to top coil via Cu heat links.

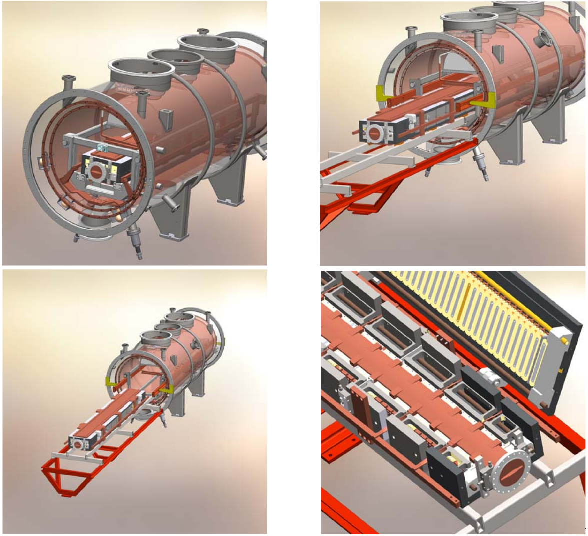




Figures: V. Syrovatin, priv. comm.

CLICDW Design: Modular cryostat

- ANKA:
  test of different coils and beam pipes
- CLIC-DR:
  repair / maintenance



Figures: N. Mezentsev et al.: *Final Design Report on CLIC damping wiggler test device*

Factory and Site Accpetance Test Results

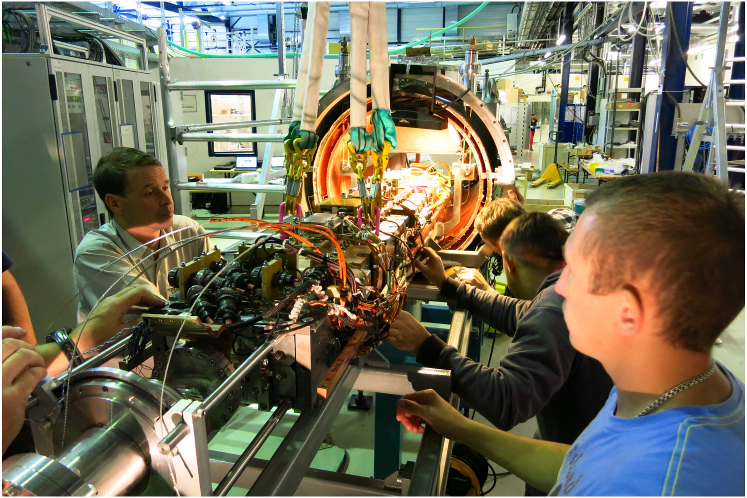
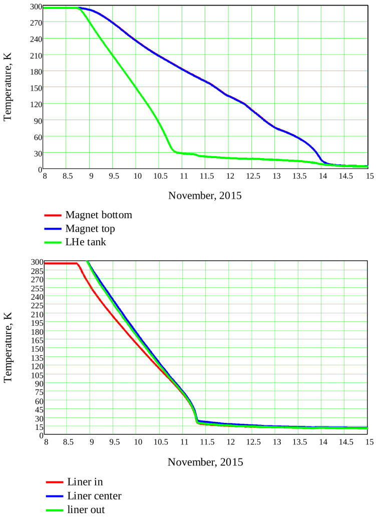


Figure: The magnet assembly is slided into the cryostat

Test results: Cryostat performance

- Cryogen-free cool-down procedure with N_2 heat tubes and condensation of He gas
- Magnet reaches LHe temperature within 5 days
- In closed-cycle operation with release valve closed the magnet reaches 3.1 K (reduced helium boiling temperature due to underpressure)
- Modulatity and "easy" access to magnet and beam pipe successfully demonstrated

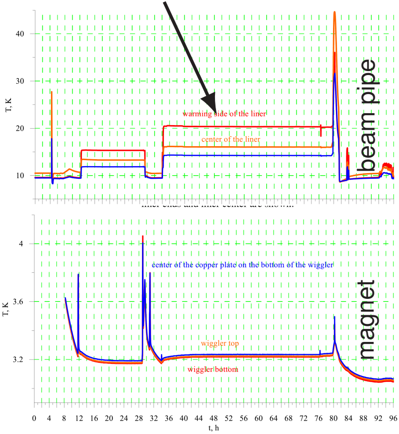


N. Mezentsev et al., CLICDW SAT report

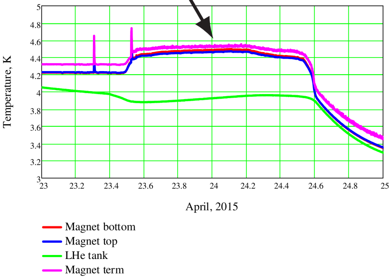
Test results: Cryostat performance II

Performance under heat load to beam pipe

- 20 W heat load to exit part of the beam pipe, 40 h, magnet charged

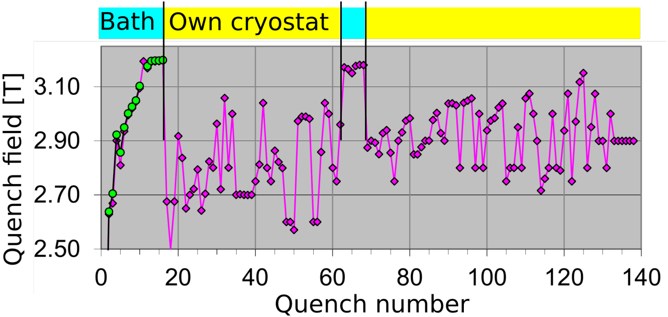


- beam pipe temperature stabilized at 80 K, 24 h, magnet charged



N. Mezentsev et al., CLICDW FAT report

Test results: Magnet performance I



N. Mezentsev et al., CLICDW SAT report

Bath test

- Training: 16 quenches
- 3.2 T stable after 11 quenches

Own cryostat

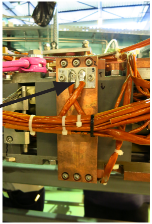
- Up to 3.1 T reached during ramp
- but no stable operation above 2.6 T (holding quenches occurring after minutes to hours)

Test results: Magnet performance II

Holding quenches: Magnet modifications

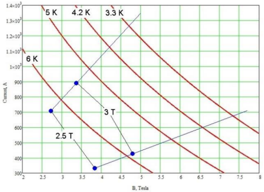
Measures taken

- suspicious coils exchanged
- all splices ($\sim$ 300) thermally connected to heat sinks
- magnet design modified:
  - gap decreased to 17 mm
  - period increased to 51.4 mm, Cu-foils as additional heat sinks inserted



Result

- 2.95 T stable at 3.1 K to 4.5 K

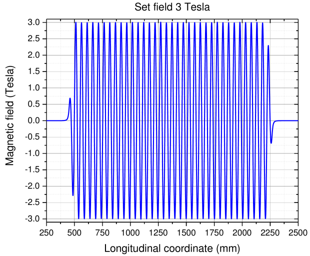


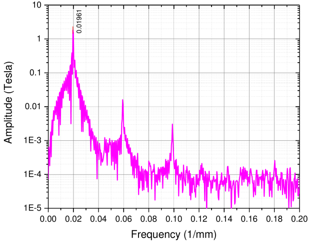
Load lines of inner and outer coil section

Test results: Magnet Performance III

Hall probe scans

- Hall probe scans with array of 5 probes
- at 7 field levels 0 T to 2.95 T
- peak-to-peak variation $< \pm 1\,\%$
- roll-off $< 0.3\,\%$
- however, mutual calibration and alignment not sufficient to determine local multipoles



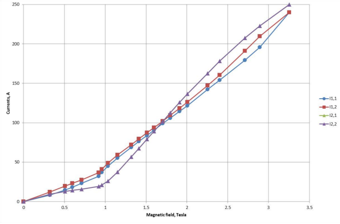


Test results: Magnet Performance IV

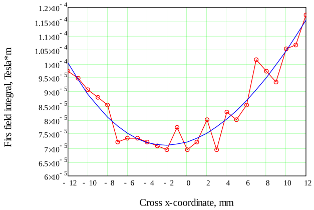
Field integrals

- field integral measurements with stretched wire with DC current
- coil currents adjusted for zero 1st and 2nd field integral
  - $I_1 \leq 5 \times 10^{-5}\,\mathrm{T\,m}$
  - $I_2 \leq 5 \times 10^{-5}\,\mathrm{T\,m^2}$
- field integrals as function of transverse position *x*: integrated multipoles
  - int. quad.: $1 \times 10^{-3}\,\mathrm{T}$
  - int. sext.: $2.5 \times 10^{-1}\,\mathrm{T\,m^{-1}}$

Currents for zero field integrals

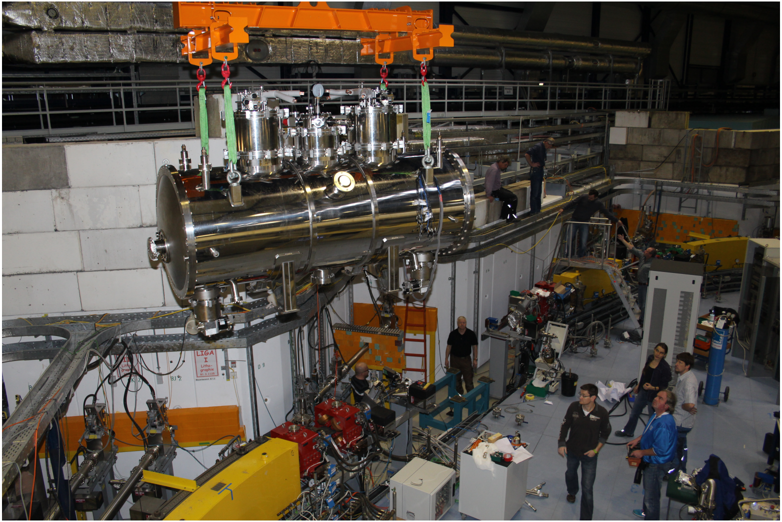


Integrated multipoles



N. Mezentsev et al., CLICDW SAT report

Installation and further plans



2015 Dec. 9th: The wiggler on its way into the ANKA storage ring

Plans for commissioning

- Commissioning and final acceptance test with beam is foreseen for 2016 Feb. 1-12
- Planned test and measurements:
  - beam orbit and tune as a function of the wiggler field, refine orbit correction tables, establish tune correction if necessary
  - orbit stability at low wiggler field
  - tune as a function of local vertical orbit bumps, identify median plane, decide on alignment correction, iterate step 1
  - chromaticity as a function of the wiggler field
  - check maximum stable field with full electron beam current
  - simulate CLIC-DR operation conditions with additional heat load to beam pipe

Further plans: Advanced experiments

In upcoming machine development shifts an advanced experimental program in close collaboration with CERN is envisaged, including

- SR-based beam-size / emittance measurements
- grow-damp measurements (damping time changes)
- emittance coupling vertical/horizontal
- low α_c at 1.3 GeV
  - bunch structure, CSR bursting patterns
  - multibunch effects
- further ideas and suggestions wecome!

Conclusions

- The Nb-Ti CLIC damping wiggler prototype with
  - conduction cooling
  - modular design

  has passed Factory and Site Acceptance Tests and is installed in the ANKA storage ring
- cryogenic system: performance outstanding
- magnet:
  - design modification/parameter relaxation necessary to reach specified field
  - issue of “holding quenches” still not understood and remaining subject to investigation
- wiggler ready for commissioning and final acceptance test with beam
- we are looking forward to the further experimental program with the wiggler at ANKA

Thank you for your attention!