Riccardo Bartolini, DESY

I.FAST 2nd Annual Meeting, Trieste, 20.04.2023

Outline

- *Scope of WP7 and Task 7.2*

- *Ultra-low emittance rings*

  (limited) highlights of technical challenges

  and the IFAST activities in Task 7.2

- *Conclusions and ongoing work*

WP7: high brightness accelerators for light sources

- *Scope: WP7 pursues the R&D on new technical solutions for the design and construction of **accelerator-based light sources,** exceeding the performance of present machines. The research embraces both **storage ring based synchrotron light sources** and **free electron laser driven by Linacs.***
- *Fostering **networking** **activities** building on the previous EU networks funded within the ARIES and EuCARD2 projects (Task 7.2) Supporting **R&D and prototypes** on cutting edge technological aspects, critical in the construction of new, compact, and sustainable accelerators (Tasks 7.3-7.4-7.5) **– see next 3 talks***

WP7/Task 7.2: ultra low emittance ring

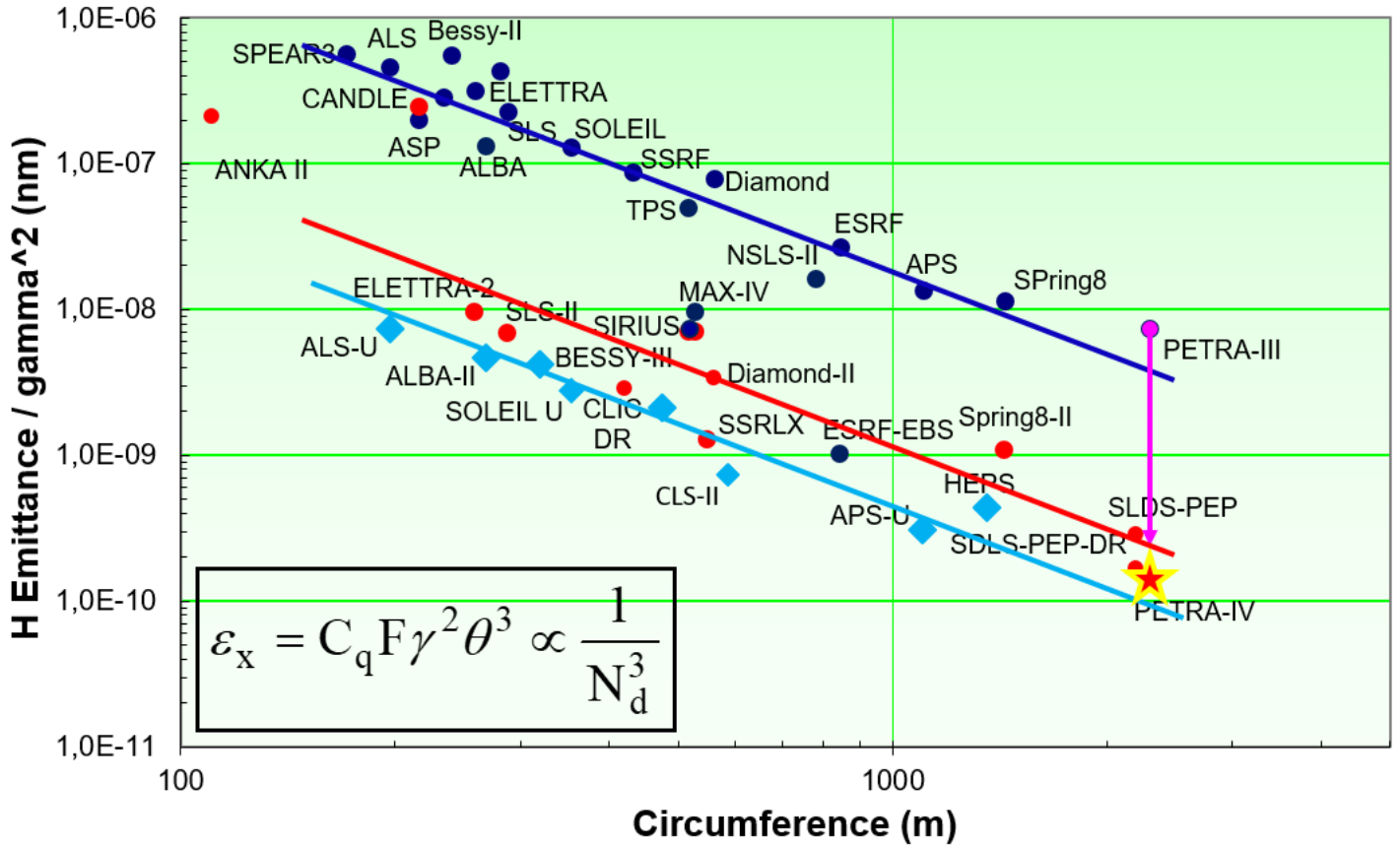
- *Organise general and topical workshops on the technology enabling the design and construction of future ultra-low emittance rings*
- *produce progress reports on the status of the R&D in the technology areas of relevance for ultra low emittance rings.*
- *support exchange of staff for visits and common experiments*

- ***Novel injection schemes** (PSI, SOLEIL). Fast switches for fast pulsers and fast kickers or stripline. Strong involvement with industrial partners*
- ***Advanced magnet concepts** (CERN, KYMA) develop permanent magnet (PM) dipole and quadrupole for green facilities for space saving and sustainability.*
- ***RF and diagnostics** for beam control of ultra-low emittance rings (INFN) to develop feedback systems, orbit stability, harmonic cavities, diagnostics for ultra-small beam size.*
- ***Vacuum systems in small apertures** (DLS, SOLEIL, CERN): feasible ultra-vacuum systems based on small radius pipes, NEG coating and new surface treatments.*
- ***Experimental tests** (KIT, CERN) on the major technical challenges: impedance; NEG characterization (@SOLEIL, DLS, KIT); injection; beam based alignment of complex combined function magnets*

Courtesy A. Mochihaschi (KIT)

Relevance of objectives and impact: the landscape of 3rd and 4th generation light sources

- *The WP7 in Task 7.2 will continue to foster and disseminate the latest development in accelerator technology of ultra low emittance rings serving a large and ever growing community in EU (and worldwide)*



Recent changes:

Korea-4GLS:
58 pm, 4 GeV, 800 m
Spring8-II new design
50 pm, 6 GeV, 1436 m

DW based H6BA
SDLS-PEP – 16 pm at 5 GeV
PETRA IV – 20 pm at 6 GeV

Workshop on Low-Emittance Lattice design (June 22, ALBA)

Design challenges and solutions were reviewed at the 3RD LEL workshop (ALBA) ~60 participants

https://indico.cells.es/event/1072/

3rd Workshop on Low Emittance Lattice Design - LEL 2022

Jun 26 – 29, 2022
ALBA
Europe/Madrid timezone

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- Overview
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- Committees
- Group Picture

Secretariat

dperez@cells.es

The **3rd Workshop on Low Emittance Lattice Design - LEL 2022** will be held from the 26th to the 29th of June 2022, hosted by the ALBA Laboratory, Cerdanyola del Vallès (Barcelona), Spain.

The workshop is organised by ALBA and supported by the iFAST project. It is the third one in a series of workshops on this topic.

The goal of this series of LEL workshops is to bring together experts from the scientific community working on low emittance lattice designs for high brightness light sources and colliders.

The workshop will focus on the following topics:
- LEL Design concepts
- LEL design Tools / non-linear optimisation Tools / analysis Tools
- LEL Error sensitivity / Alignment strategies / Correction schemes
- LEL Collective effects
- LEL Injection / design of injector chain

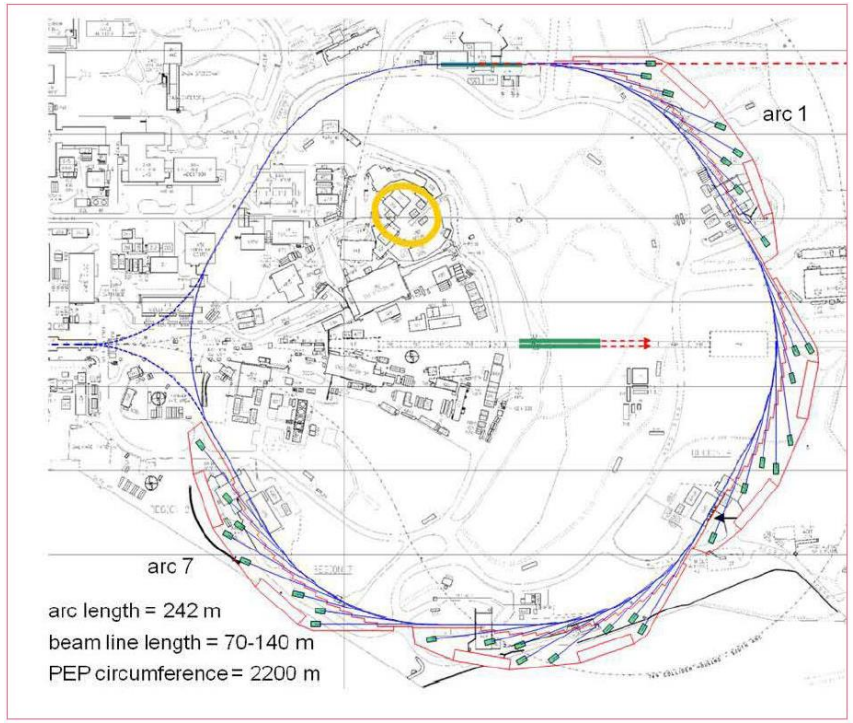
The 3rd LEL Design workshop is a face-to-face meeting, no option to attend the sessions on-line.

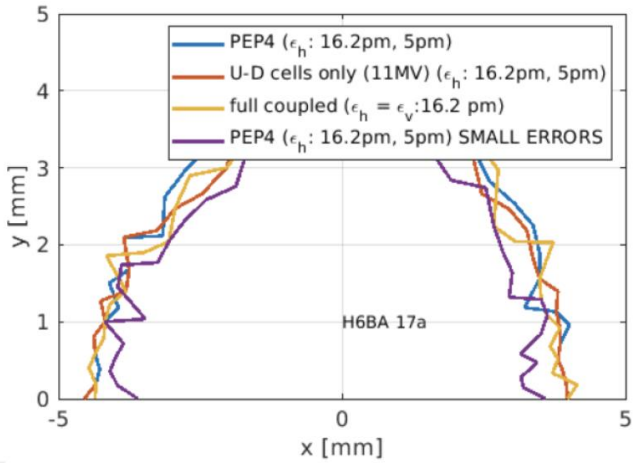
ALBA

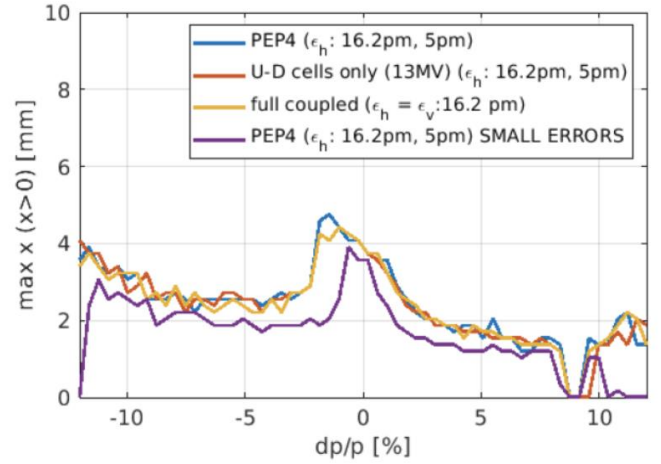
iFAST

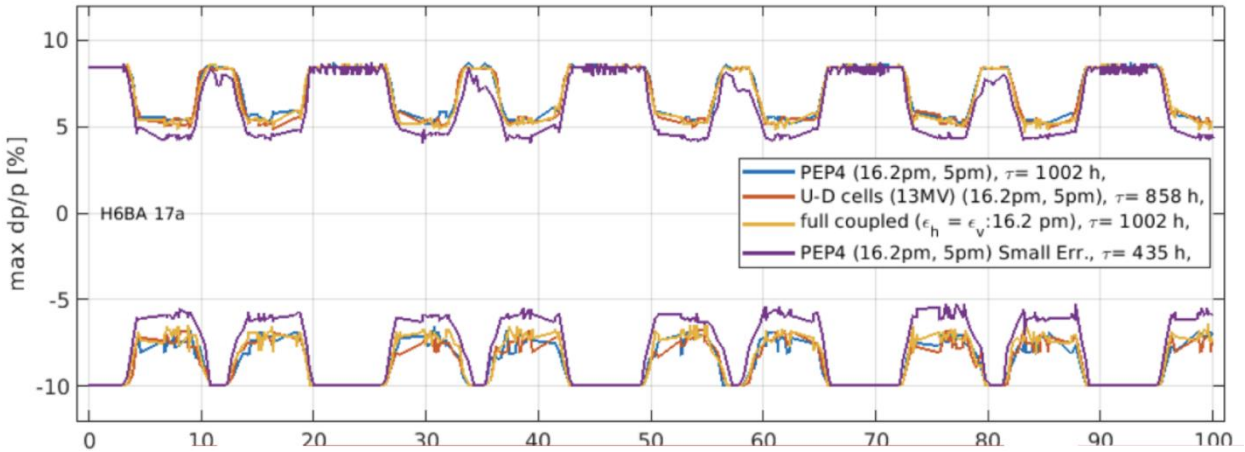
New lattice variants were presented

H6BA lattice in the PEP tunnel ε_x = 16pm @ 5 GeV (P. Raimondi) with damping wigglers









Courtesy P. Raimondi, S. Liuzzo

The momentum aperture is of the order of ±8%
The Touschek lifetime is of the order of 500hrs.
The drop in performances due to errors is very moderate, given the very moderate detunings

Technical challenges: injection systems

Injection schemes in ultra-low emittance rings face two main problems

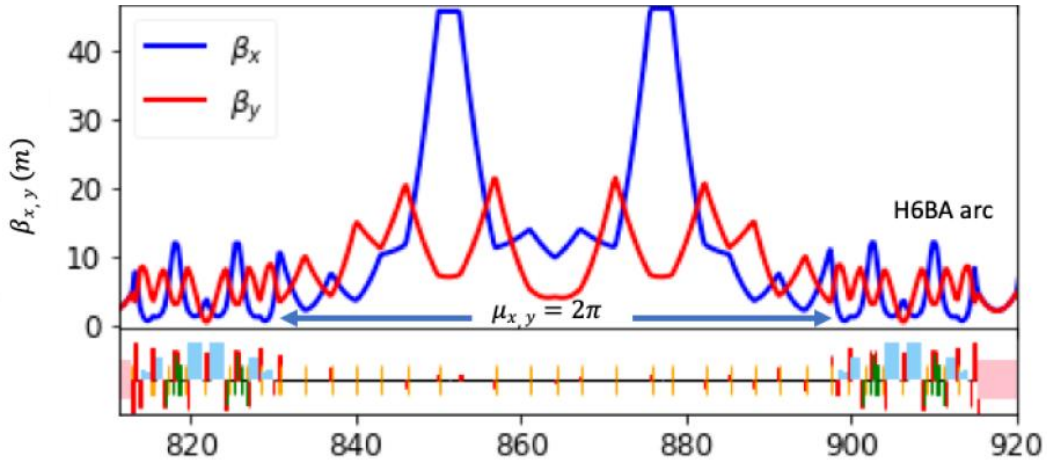
- many rings have **very small dynamics apertures** and must use **on-axis injection**)
  e.g. swap out injection at the APS-U: kick in – on axis – only the required bunches in the train (inevitably kick off the stored depleted bunch)

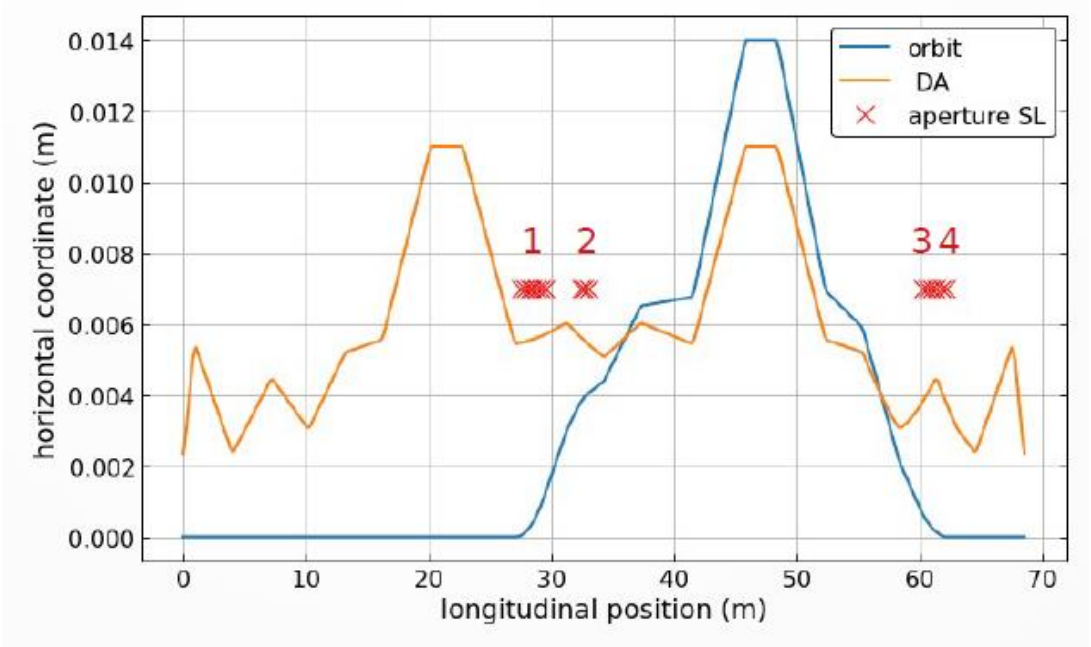
- even if DA aperture is sufficient for **off-axis injection** we should avoid **injection transient during top-up**: residual oscillation from a non-closed orbit bump will affect only the bunches disturbed by the injection bump

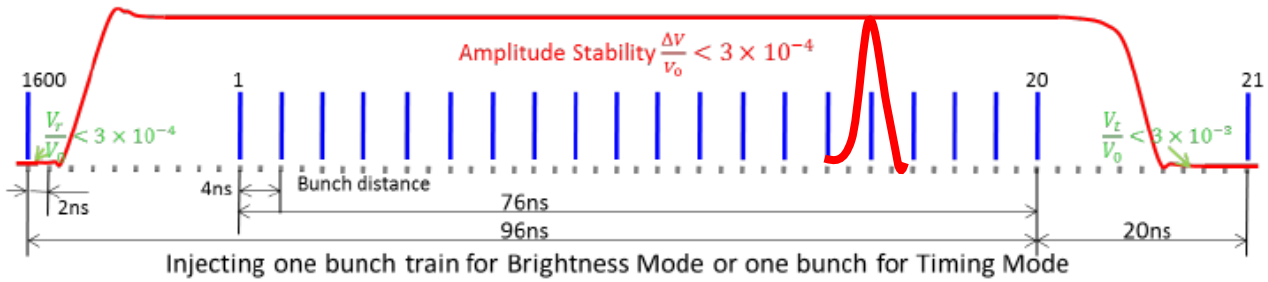
Development of high voltage ultra short pulsers and stripline kickers are required to address these issues

Fast kickers reduce the number of bunches perturbed during injection

Example: Injection in PETRA IV



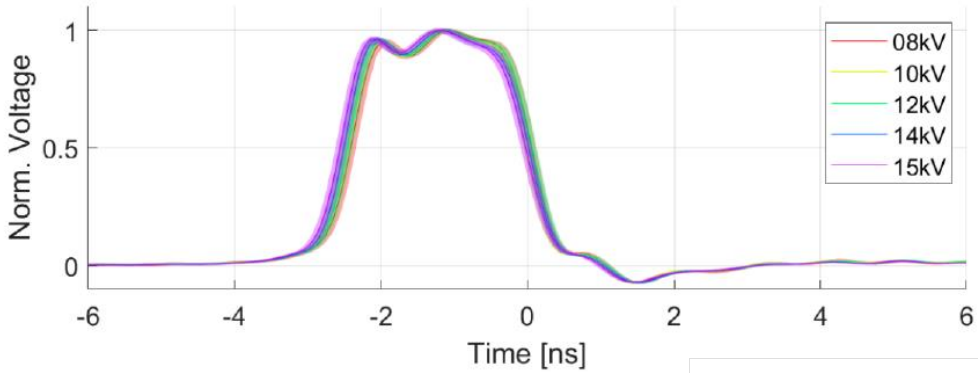


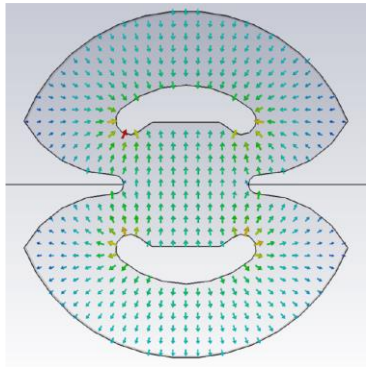


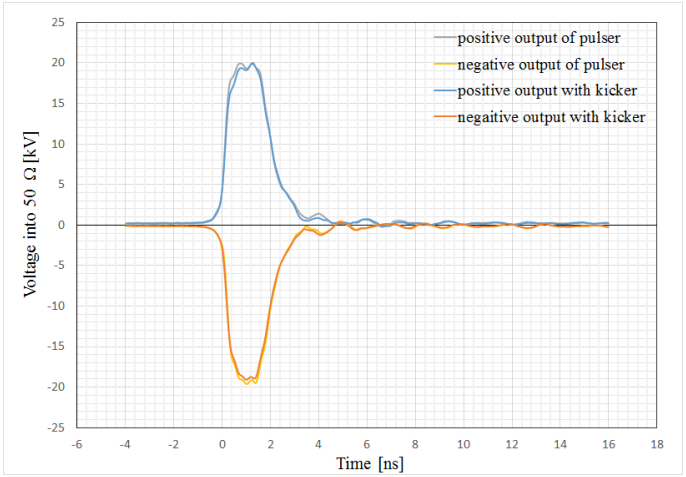
A total of 10 stripline kickers are required to reach the orbit bump necessary for off-axis injection at ~7 mm off-centre
15 kV – ~4 ns pulsers

I-FAST supports the PULPOKS workshop

Examples: tests of pulsers for PETRA IV and HEPS
15 kV/20 kV in <4 ns 0-to-0



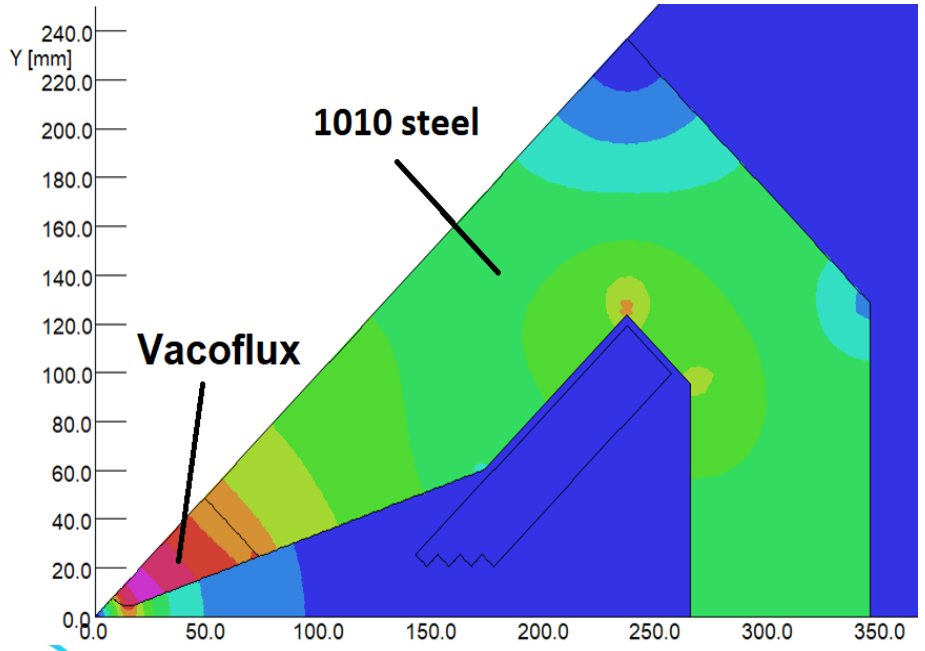




Resistive magnets are still the workhorse of rings

While PM based solution have become popular for sustainability (and stability) reasons, resistive magnets are very challenging in many cases and are being optimised also for power consumption reduction

Cross section of PQA 115 T/m (1.6 kW)



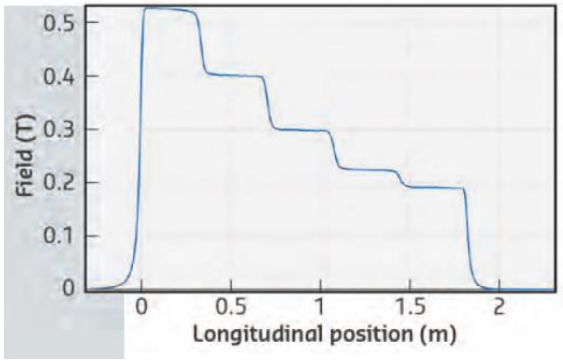
Vanadium permendur pole tips are used to achieve large gradients reducing saturation effects
but: expensive material

Coil cross section and cables optimization combined to reduce power consumptions
but: impact on allowed ΔT is complex (especially in presence of nearby PM)

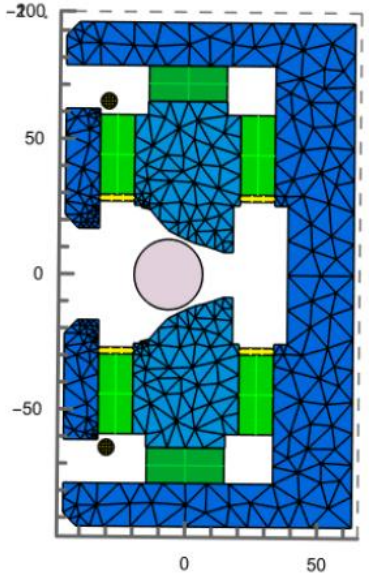
Magnets based on permanent magnets

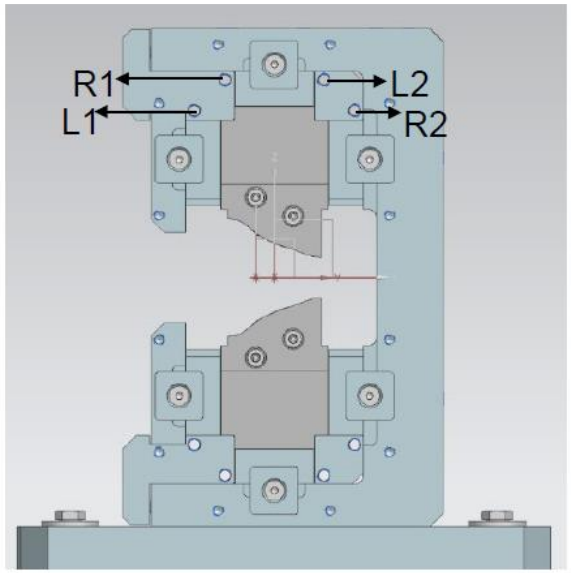
PM based longitudinal gradient dipoles pioneered by the ESRF are extensively used and further developed (e.g. longitudinal and transverse gradient dipole)

ESRF Longitudinal gradient dipole: 0.17- 0.67 T field (PM)
5 modules of 357 mm each



Cross section of DLQs: 0.3 T 11 T/m





The use of PM dipoles for PETRA IV will save **~1.6 MW**

Sustainability is key. Collaboration with WP11: Task 3 and Task 1: Critical Materials and Life Cycle Management: The Example of Rare Earths (DESY, 6-8 February 2023)

Workshops on magnet technology

These topics will be the focus of two upcoming workshop:

Mini-workshop on resistive magnets for ultra low emittance rings (DESY 1st-2nd June)
https://indico.desy.de/event/39184/

Investigate challenges and recent trends in the design, construction and operation of resistive magnets for ultra low emittance rings

Workshop on permanent magnet based magnets for ultra low emittance rings (Trieste, 14-15th November 2023)

Recent trends in the design, construction and operation of PM based magnets
Joint LEAPS/I-FAST workshop

Summary of activities in Task 7.2

- *Regular meetings scheduled for Task. 7.2 chaired by A. Mochihashi (KIT)*

Three workshops already organized:

- *10th-11th May 2021 (DESY/Virtual): Miniworkshop on girders and alignment (Virtual / DESY) ~80 participants https://indico.desy.de/event/30022/*
- *25th-29th April 2022 (KIT): Beam diagnostics and dynamics in low emittance rings ~80 participants https://indico.scc.kit.edu/event/2592/overview*
- *26th-29th June 2022 (ALBA): 3rd workshop on low emittance ring design ~60 participants https://indico.cells.es/event/1072/*

Workshop support and preparation:

- *26th-29th April 2023 (DESY): support for the Pulse POwer for Kicker System (PulPOKS)*
- *1st-2nd June 2023 (DESY): Resistive magnets sustainable solutions*
- *October 2023 (University of Saloniki, TBC) : 9th general workshop ultra low emittance rings*
- *14-15th November 2023 (Trieste): Permanent magnet based solution for low emittance rings (joint with LEAPS)*

Next topical workshops identified on injection/boosters (TBD) and feedback systems (KIT/SOLEIL + tests)

Courtesy A. Mochihaschi (KIT)

WP7 Task 7.2: milestones and deliverables

D7.1	Final report on the development of high brightness electron beams for light sources	7.1	UOXF	R	PU	48
D7.2	Report on enabling technology for ultralow emittance ring	7.2	KIT	R	PU	45
D7.3	Longitudinally variable bend prototype fabrication	7.3	CERN	DEM	PU	40
D7.4	Mechanical realization and low power RF test of the two RF guns	7.4	INFN	DEM	PU	38
D7.5	Construction of the XLS accelerating structure pre-prototype.	7.5	ELETTRA-ST	DEM	PU	24
D7.6	Construction of the XLS accelerating structure full prototype.	7.5	ELETTRA-ST	DEM	PU	36

MS25	General workshop on Task7.2 activity summary	7.2	42	Indico page
MS26	Magnet specifications based on optics calculations for ELETTRA. Magnetic and mechanical design including fabrication drawings	7.3	24	Report
MS27	Prototype acceptance tests	7.3	46	Report
MS28	Electromagnetic and mechanical design of the two guns	7.4	24	Report
MS29	High-power test stand setup and final results of the high-power tests	7.4	46	Report
MS30	Construction and RF tests of CompactLight accelerating structure prototype	7.5	21	Prototype in operation

Tasks	Description	Year 1												Year 2												Year 3												Year 4													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
WP7	High Brightness Accelerators for light sources																																																			
7,1	Coordination and communication																																																D			
7,2	Enabling technologies for ultra-low emittance rings																																										M			D						
7,3	Variable Dipole for the upgrade of the ELETTRA storage ring																							M																	D						M			
7,4	Very high gradient RF Guns operating in the C-band RF technology																							M															D						M			
7,5	CompactLight Prototype Accelerating Structures																					M		D												D												

Other tasks covered in next talks by A. Poyet, D. Alesini, and P. M. Sanchez)

Conclusions and perspectives

After the pioneering of MAX IV (2016) and the successful operation of ESRF-EBS (2020)

the field is moving from conceptual and technical design study to project implementation

APS shut down 3 weeks ago, HEPS is under construction

SLS-II, ELETTRA 2.0, and Diamond II are funded

Many TDR/CDR programmes are also funded (PETRA IV, SOLEIL-II, ALBA-II, ..)

WP7 Task 7.2 will continue to foster interactions in the community of ultralow emittance rings in the coming years

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Thanks A. Mochihaschi (KIT) and Y. Papaphilippou (CERN)
Thank you for your attention!

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