MOPAB109

A Lattice for PETRA IV Based on the Combination of Different Arc Cell Designs.

Joachim Keil*, Ilya Agapov, Reinhard Brinkmann
Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

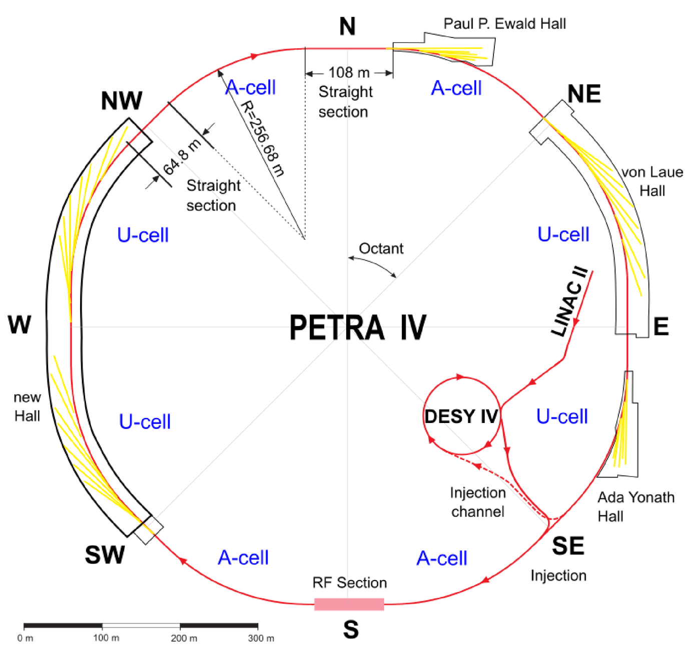
* joachim.keil@desy.de

Introduction

The 6 GeV synchrotron light source PETRA III at DESY is in user operation since 2009. In 2016 investigations of upgrading PETRA III into a diffraction-limited storage ring at 10 keV have been started. The ambitious goal is to achieve an emittance in the range of 10-30 pm·rad. For the conceptual design report (CDR) of PETRA IV a lattice based on hybrid multi-bend achromats (HMBA) has been chosen. It consists of eight arcs connected by eight long straight sections whereas each arc consists of eight HMBA cells. While this lattice variant has an advantage in terms of simplicity of magnet and girder design it is challenging in regards of multipole strengths and beam dynamic properties. However, only a part of all eight arcs will be used for undulator beamlines. This offers the possibility to choose a more relaxed optics design in the arcs without undulators while preserving the ultra-low emittance. In addition, the use of reverse bends in the undulator cells allows smaller beta functions at the undulators for an increased brilliance. The design and the beam dynamic properties of this combi lattice are discussed in this paper and compared to the lattice based on HMBA cells.

PETRA IV : Parameters and Layout

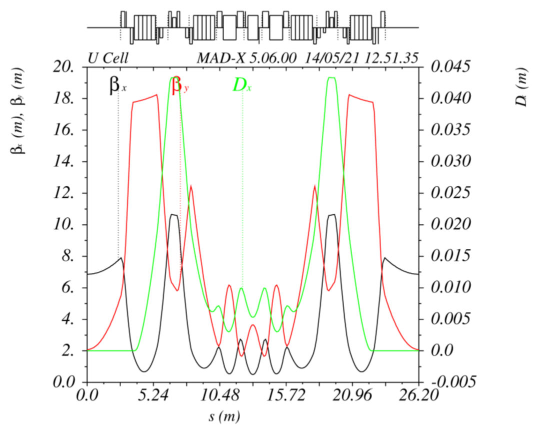
- Upgrade of the PETRA III to a diffraction limited storage ring at 10 keV
- Energy 6 GeV, emittance 10-30 pm·rad (with closed gaps of undulators a factor of 2 smaller)
- Using hybrid multi-bend achromats based on the ESRF-EBS design
- Brightness mode: 200 mA in 1920 bunches, Timing mode: 80 mA in 80 bunches
- 500 MHz RF-system, voltage 8 MV, 3rd harmonic RF system for bunch lengthening
- Eight arcs with 45° total bending angle; each arc consists of 8 HMBA cells
- 8 long & short straight sections (108 m and 65 m)
- For some straight sections installation of 10 m long undulators is foreseen



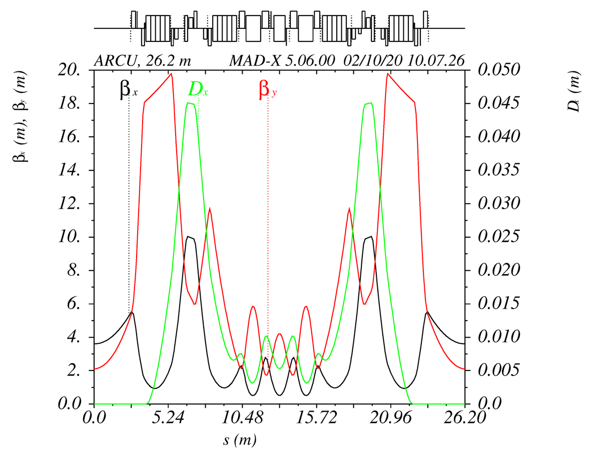
Layout of PETRA IV. The positions of undulator cells (U-cell) and relaxed cells (A-cell) for the combi lattice arcs are marked in blue. The pure HMBA lattice is using U-cells for all arcs.

Pure HMBA Lattice

High β_x cell in undulator arcs (U-cell)



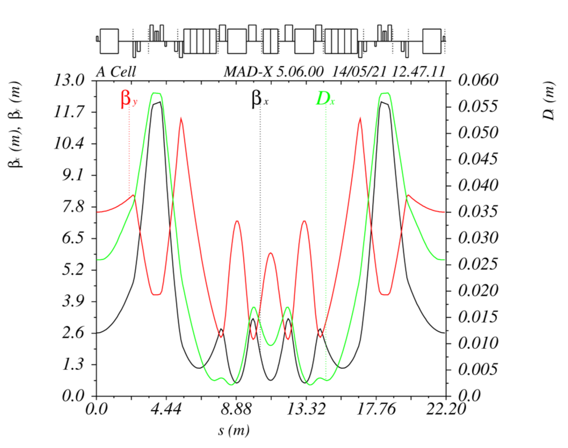
Low β_x cell in undulator arcs (alternative U-cell)



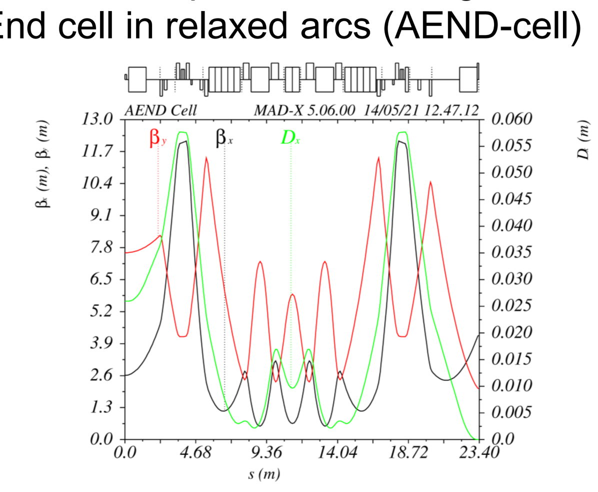
- Lattice of PETRA IV is using HMBA cells in all eight 45°-arcs → pure HMBA lattice
- For the Conceptual Design Report (CDR) a HMBA with high β_x at the IDs was chosen
- Cell length is 26.2 m cell and bending angle 5.625° → small dispersion peak of 43 mm
- Phase advance of U-cell is μ_x = 2+3/8, μ_y = 1-1/8; 8 cells → almost a 4th order achromat
- Alternative U-cell design: HMBA with low β_x at the ID center using reverse bends
- Reverse bends in alternative U-cell design are realized by shifting two quadrupoles near dispersion peak by a few mm
- Alternative HMBA design has higher brilliance; problem of BBA of shifted quadrupoles is under investigation

Combi Lattice

Cell in relaxed arcs (A-cell)



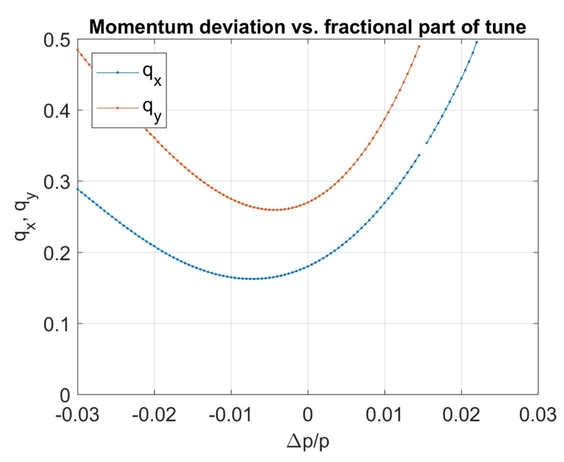
For dispersion matching:
End cell in relaxed arcs (AEND-cell)



- Installation of IDs is foreseen for half of all 45°-arcs
- Combi lattice: Use in four arcs (North + South) a relaxed cell design (A-cell) and use in other four arcs (East + West) HMBA cells for the installation of undulators (U-cell)
- Relaxed cell design similar to HMBA but without ID straights
- A-cell length is shorter with larger dispersion peak and weaker sextupoles
- First & last cell have a different design for dispersion matching to the straights (AEND-cell)
- Phase advance of A-cell is μ_x = 1+7/9, μ_y = 1-3/9; 45°-arc (= 9 cells) is a 4th order achromat
- Use the phase advances of the eight straight sections to minimize the off-momentum beta-beating

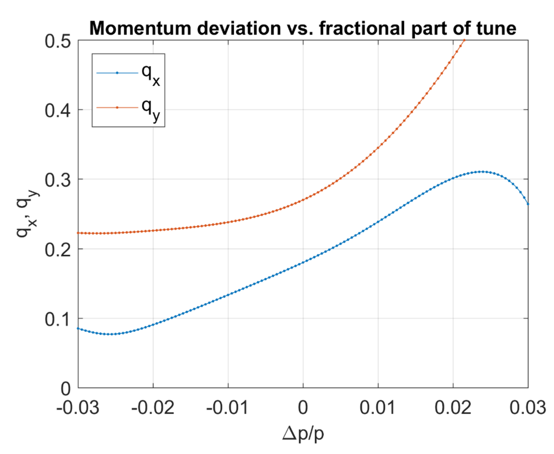
Tune Shift with Momentum Deviation

Pure HMBA lattice



- Large 2nd order chromaticity is dominating
- Crossing of $2Q_y$ resonance at δ=1.5% and $2Q_x$ at δ=2.2%

Combi lattice

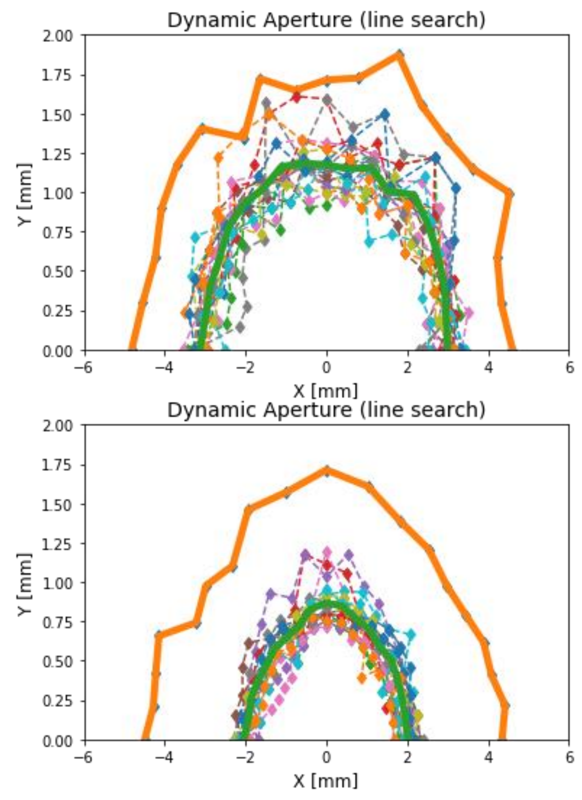


- Phases of straight sections optimized to reduce off-momentum beta-beating
- 2nd order chromaticity substantial reduced
- Only crossing of $2Q_y$ resonance at δ=2.1%

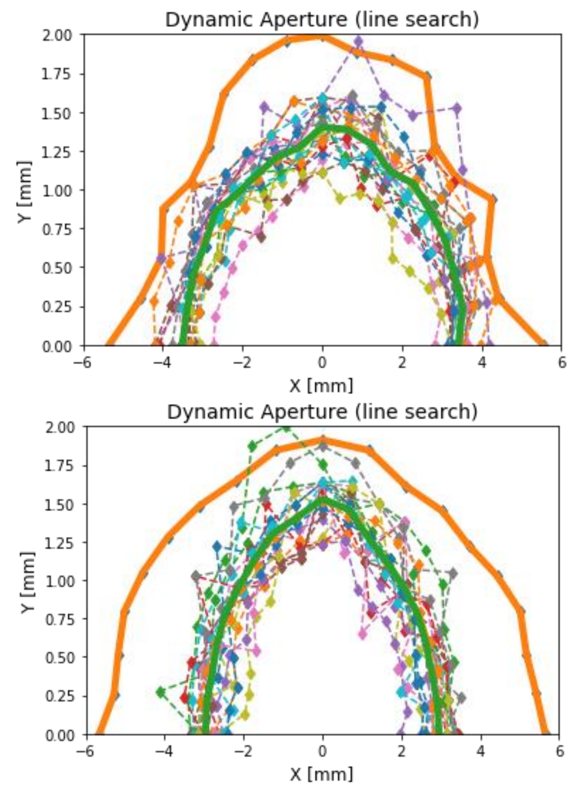
Dynamic Aperture

- Dynamic aperture with and without errors (orange line); β_x=21.7, β_y=3.7m
- Plotted for the pure HMBA lattice (left) and for the combi lattice (right)
- Alignment errors (magnets and BPMs) of 30 µm (RMS), 3σ cutoff, 20 error seeds

Pure HMBA lattice



Combi lattice



U-cell (high β_x)

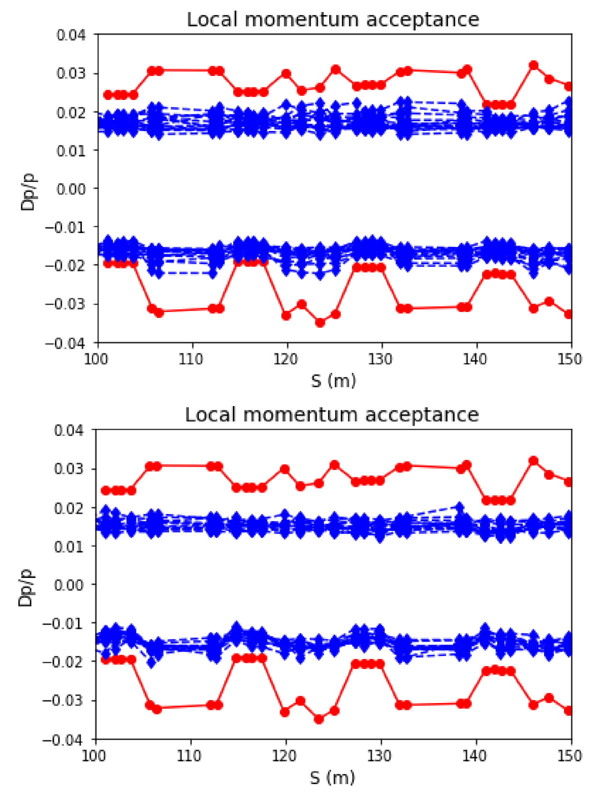
U-cell (low β_x)

- Dynamic aperture of combi lattice is larger compared to the pure HMBA lattice for both U-cell variants

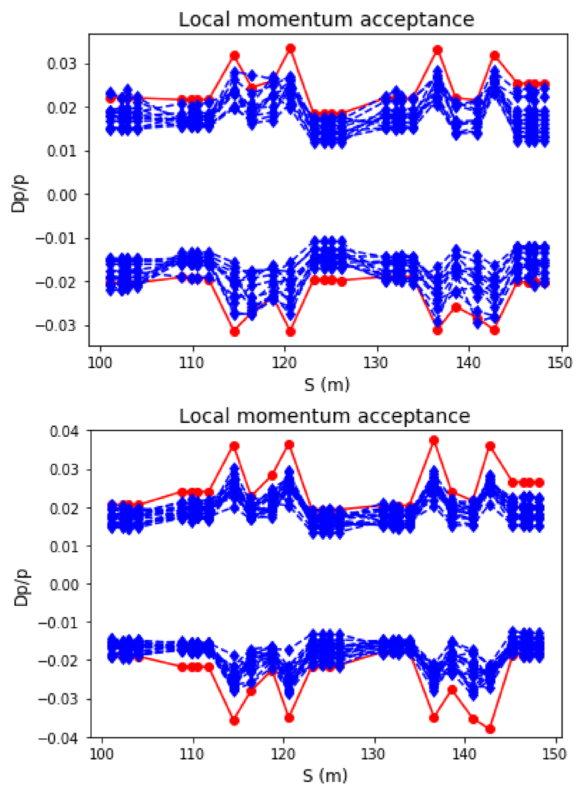
Local Momentum Acceptance

- Local momentum acceptance with (blue) and without errors (red)
- Plotted for the pure HMBA lattice for U-cells (left) and for the combi lattice for A-cells (right)
- Alignment errors (magnets and BPMs) of 30 µm (RMS), 3σ cutoff, 20 error seeds

Pure HMBA lattice



Combi lattice



U-cell (high β_x)

U-cell (low β_x)

- LMA with errors of pure HMBA lattice is limited by crossing of half integer resonances
- Larger LMA with (blue) and without errors (red) compared to pure HMBA lattice
- Touschek lifetime: low beta cell: 1.77 h pure HMBA → 2.11 h combi lattice
  high beta cell: 1.68 h pure HMBA → 2.60 h combi lattice

Conclusion

The combi lattice provides more dynamic aperture and a larger local momentum acceptance compared to the pure HMBA lattice. It has also the advantage, that the sextupole strengths are lower and more parameters are available to optimize the non-linear dynamics. It has only a marginal higher emittance compared to the pure HMBA lattice. Because of the superior performance of the combi lattice it has been chosen as the baseline lattice for the TDR of PETRA IV.