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A concept for lowering ANKA's emittance

A conceptual design keeping positions of the beamlines

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Abstract

A concept to reduce the emittance of the ANKA storage ring from actually circa $\varepsilon = 60\,\text{nm rad}$ *to less than* $\varepsilon = 10\,\text{nm rad}$ *has been developed. Given constrains like keeping the position of the beamlines have been met quite well.*

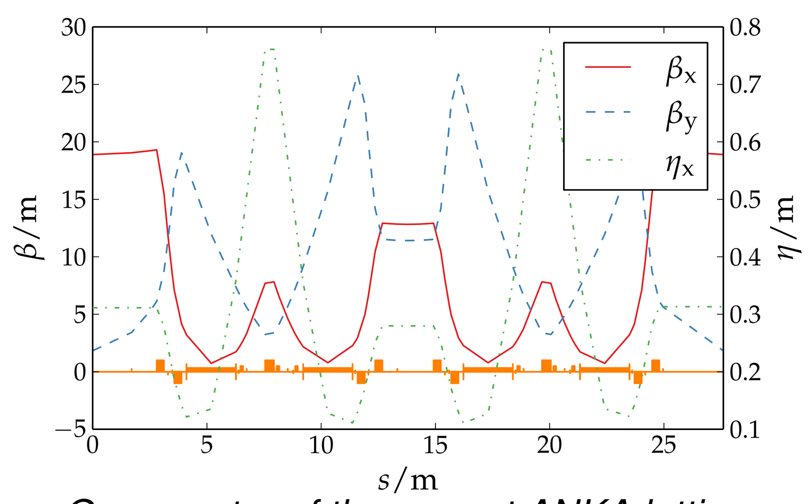
1. Motivation of this studies

Decreasing emittance to increase brightness. ANKA currently has got an emittance of about $\varepsilon = 60\,\text{nm rad}$. The goal was to reduce the emittance to $\varepsilon \leq 10\,\text{nm rad}$

1.1 Constrains:

- unchanged circumference
- unchanged dipoles' starting positions
- unchanged dipoles' mid-positions
- no shrinking of long straight sections (wigglers)
- no shrinking of short straight sections (rf and injection)

ANKA has got 5 quadrupole families and it was tried to stay with less than 10 families.



One quarter of the current ANKA lattice

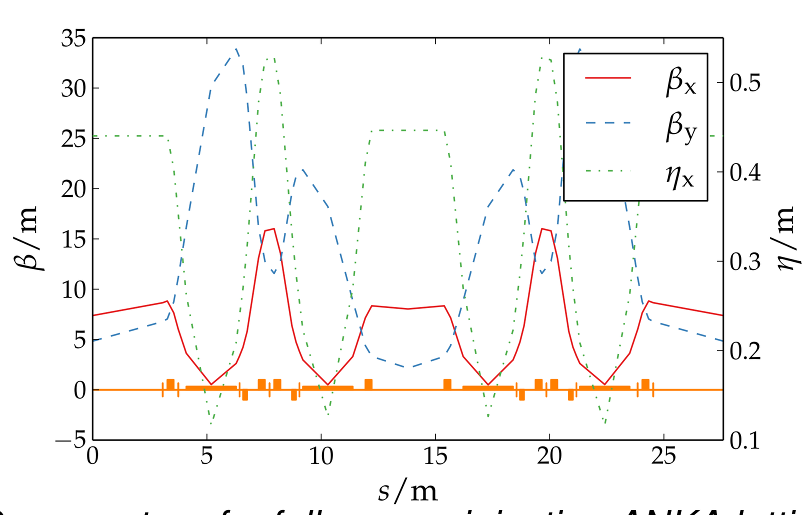
One can decrease emittance best by decreasing the bending radii and keeping dispersion low. [1]:

$$\varepsilon \sim \frac{\langle \mathcal{H}/\rho^3 \rangle}{\langle 1/\rho^2 \rangle}$$

$$\mathcal{H} = \beta D'^2 + 2\alpha D D' + \gamma D^2$$

2. Full energy injector concept

A concept for an alternative ANKA with different optimization goals, but a lesser emittance than the current one existed[2].



One quarter of a full energy injection ANKA lattice

This design has got the drawback of a higher dispersion in the long straight section where the insertion devices are placed. Already at $32.76\,\text{nm rad}$, but only optimized to $28.78\,\text{nm rad}$

3. Lattice creation approaches

- Split bending magnet into two to decrease deflection angle Θ due to $\varepsilon \sim \Theta^3$
- Increase quadrupole strengths
- Damping wigglers in straight sections are another option, though not that practical at ANKA

4. Optimization with *elegant*

With *elegant*[3] one can use *swarm*, *genetic* and *random-sample* algorithms for a global and *hybrid-simplex* for a local search. With these methods the lattices were optimized varying the quadrupole strength to minimize the dispersion and finally the emittance.

- 5 focussing quadrupole families
- 4 defocussing quadrupole families
- quadrupole strength $K_{\max} \approx 12T/m$
- long straight section grows from 5.60 m to 6.36 m
- short straight section shrink from 2.24 m to 1.83 m, but still acceptable
- enough space for sextupoles and beam diagnostic
- emittance $\varepsilon = 7.97\,\text{nm rad}$
- for some beamlines one needs to investigate if they can operate with light from an different angle

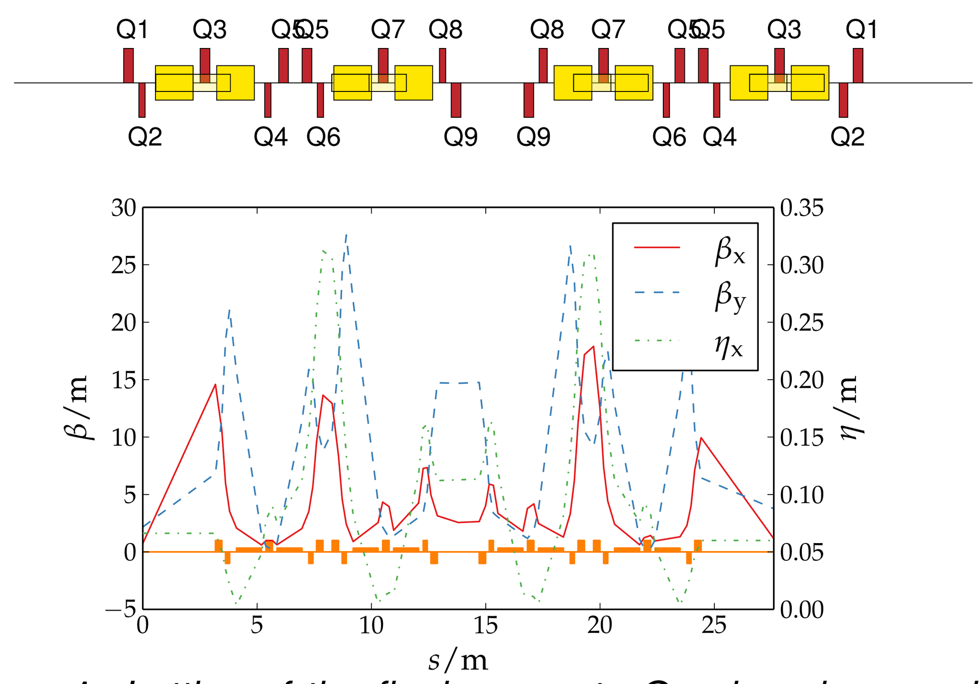


Figure 1: *Lattice of the final concept. Quadrupoles – red, bending magnets – yellow, original position of the bends with ports for the beamlines – transparent yellow*

- only linear effects were taken into account

Table 1: *Comparison of the emittance*

Design	Emittance (nm rad)	Damping time (hor.) (ms)
ANKA	60.70	2.10
Full energy	32.76	2.21
Full energy (opt.)	28.78	2.21
Final draft	7.97	2.70

Conclusion: It is possible to create linear optics for the ANKA storage ring so one can keep beamlines' positions and reduce the emittance to less than 10 nm rad.

5. Difficulties with wigglers in *elegant*

Try to shrink emittance with wigglers showed different behaviour of elegant's implementations. In elegant there are mainly three implementations of wiggler:

- wiggler implementation (WIGGLER)
- canonical wiggler (CWIGGLER)
- wiggler with generating functions (GFWIGGLER)

Compared to basic wiggler calculations with the canonical yield a lower horizontal tune, whereas that with the generating functions yield a slightly higher one.

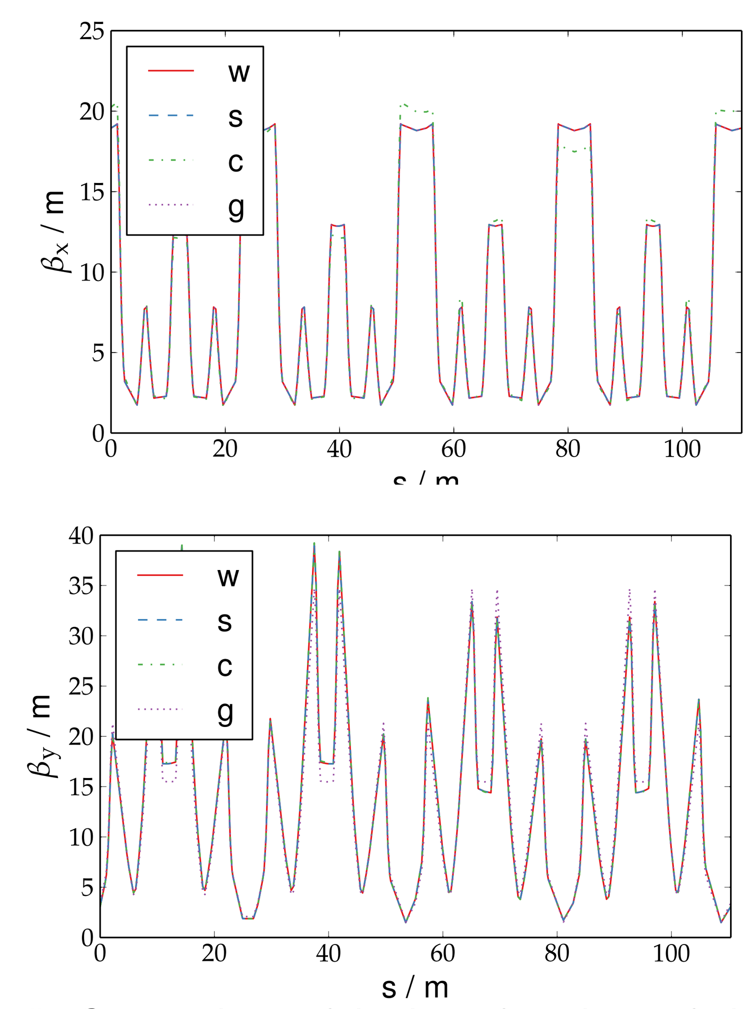


Figure 2: *Comparison of the beta functions of elegant's wiggler implementations at* ANKA *with a* CLIC *wiggler:* Wiggler *(red),* Canonical Wiggler with option SINUSOIDAL=1*(blue),* Canonical Wiggler *(green),* Generating Functions *(violet)*

Simple transferline:

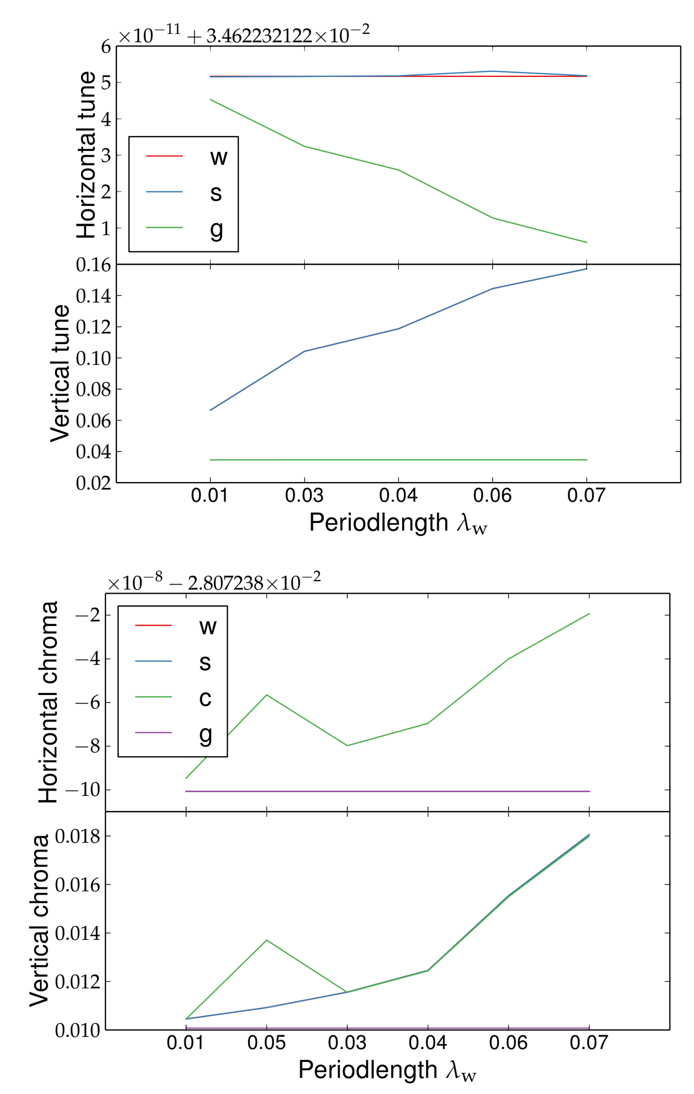


Figure 3: *Comparison of the tunes and chromaticities of elegant's wiggler implementations against the wiggler's period length*

- Canonical implementation: much stronger effects in fig 3, but the same tendency as the generating function's one
- Where do the differences come from
- How to avoid these issues
- If not avoidable: which implementation to choose

References

[1] H. Wiedemann. *Frontiers of Particle Beams*, vol. 296 of *Lecture Notes in Physics*, chap. Low emittance storage ring design, 390–439. Springer Berlin Heidelberg (1988).

[2] E. Huttel, et al. In *Proceedings of PAC09*, 1147–1149. Particle Accelerator Conference, Vancouver, BC, Canada (2009).

[3] M. Borland. elegant: A Flexible SDDS-Compliant Code for Accelerator Simulation (2000).