Welcome to the Non Linear Beam Dynamics Workshop

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Introduction to Non Linear magnet Lattices (1)

- The linear lattice is determined by a sequence of Bending Magnets and Quadrupole magnets. In a linear lattice, an electron makes a so-called betatron oscillation around a closed orbit. The frequency of this oscillation (tune) in both horizontal and vertical planes does not depend on the amplitude of the oscillation.

- Nevertheless because the deflection and focusing of the magnets scales inversely proportional to the electron energy (Maxwell equations) , both the closed orbit and the tunes depends on the electron energy. The tunes decrease with the electron energy (negative chromaticity). This has two detrimental consequences :

  - An energy spread in the beam drives a tune spread => reduced injection efficiency
  - The wakefield induced by such a beam into the ring chamber drives an instability which in most cases limits the stored current (head tail instability).

Introduction to Non Linear magnet Lattices (2)

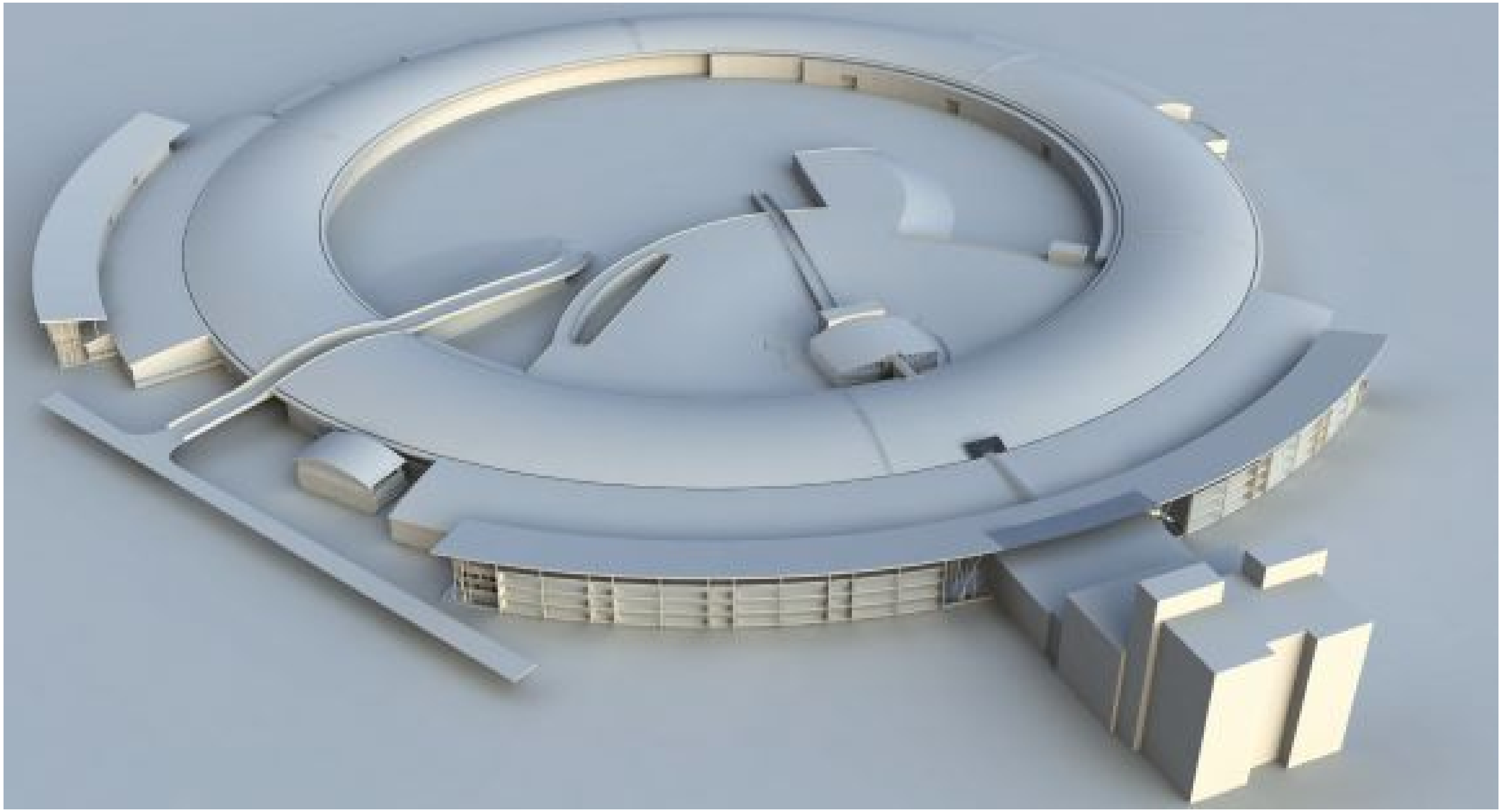
- It is mandatory for strongly focusing lattice to operate with **small positive chromaticity** in both horizontal and vertical planes. The remedy is to insert (chromatic) sextupole magnets at places where the energy dispersion is large (large closed orbit variation as a function of electron energy).
- (chromatic) sextupole generates additional difficulties such as a variation of the betatron amplitude as a function of the amplitude becoming unstable motion above some amplitude called **dynamic aperture**.
- The dynamic aperture can be re-enlarged by installing (compensation) sextupoles at places where the dispersion is zero or small.
- The full optimisation of a magnet lattice with such chromatic and compensation sextupoles is a difficult non linear topic still largely under debate within the community.
- This workshop deals with the following issues :
  - Methodology to optimize non-linear lattice
  - Comparison with experimental observations
  - Prediction of aperture, beam lifetime, injection efficiency, tune shift vs betatron amplitude …
  - Additional non linearity induced by Undulators and Wigglers magnets

A Brief History of the ESRF Storage Ring Lattice

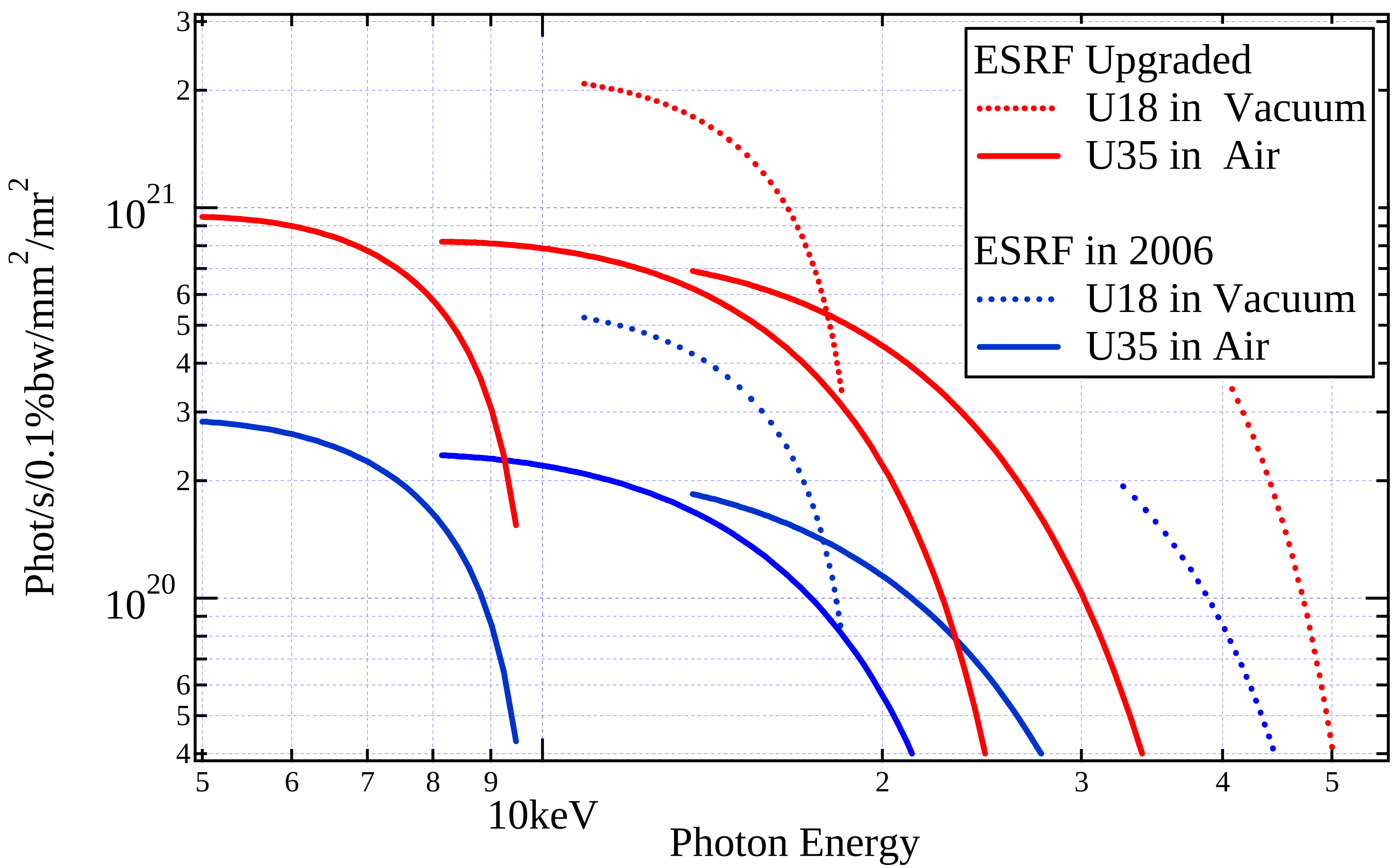
Double Bend Achromat
32 x 5 m straight sections
Perimeter : 844 m
Energy : 6 GeV

- Design started by the European Synchrotron Radiation Project in 1984 under the leadership of S. Tazzari (Green Book)
- Re-visited and optimised by A. Ropert, J. Laclare and L. Farvacque in 1986 (Red Book)
- Commissioned in 1992 with emittance of 7 nm at 6 GeV
- The Lattice has since been modified several times
  - Distributed dispersion => Emittance of 3.8 nm
  - Vertical beta tuned to 2.5 m in all ID straight to allow for small ID gap.
  - ID straight Section Length 5 m-> 6 m
  - One more family of chromatic sextupoles

ESRF Upgrade



Brilliance


ESRF Upgraded
U18 in Vacuum
U35 in Air
ESRF in 2006
U18 in Vacuum
U35 in Air
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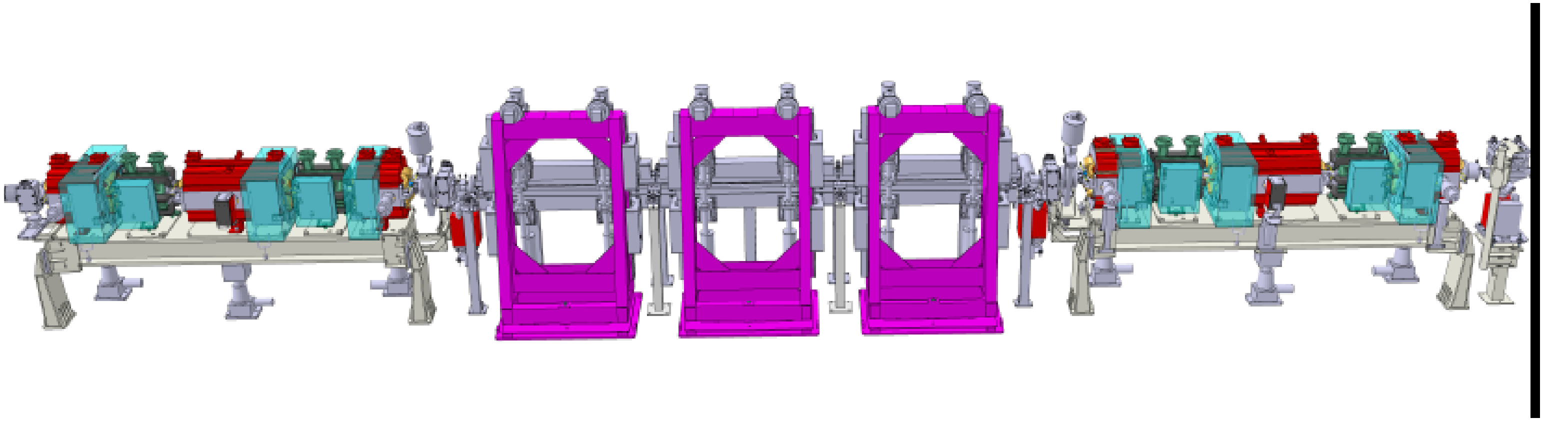
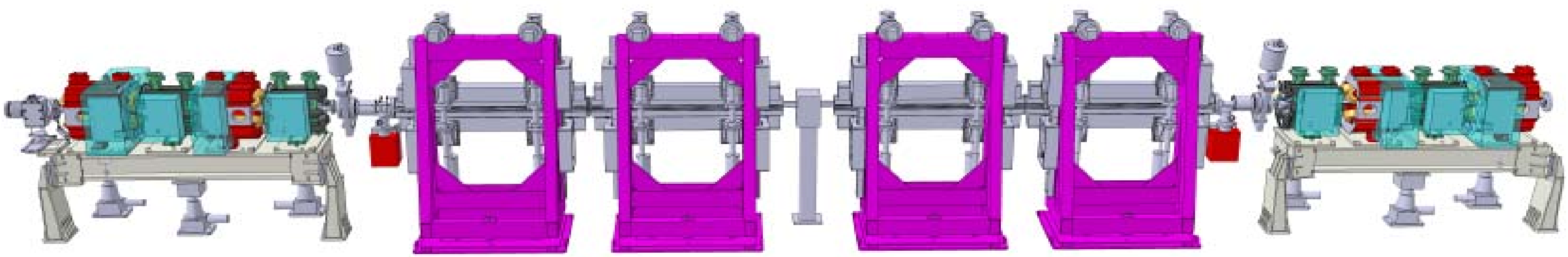
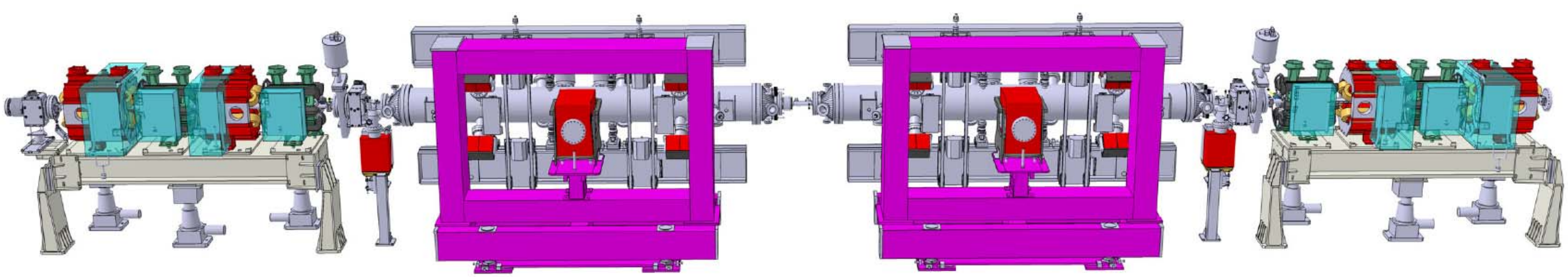
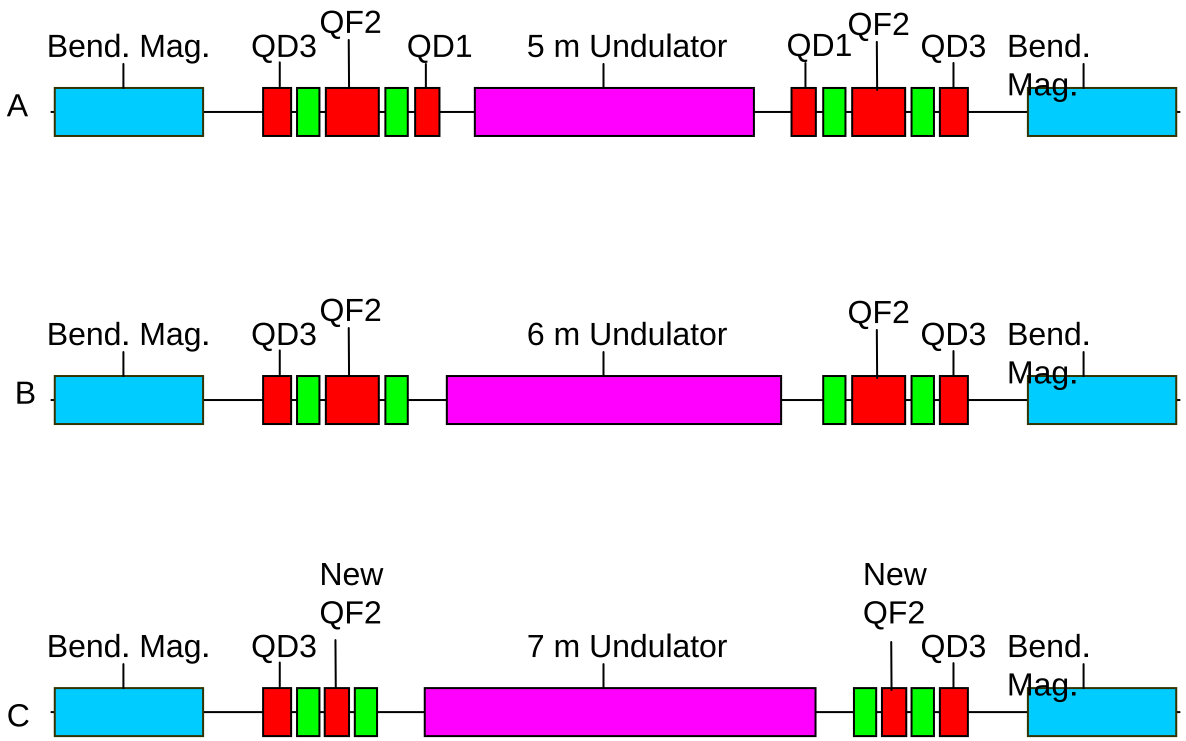
Photon Energy







Increasing the Undulator length



Some Lattice issues in relation with the ESRF Upgrade

- How many 7 m straight sections can be accommodated before the lifetime and the injection efficiency are reduced ?

- Is it mandatory to place the 7 m straight periodically along the ring circumference (2 x 180, 3 x 120 or 4 x 90 degrees,…) ?

New Storage Rings

Recently Commissioned

- CLS (Canada)
- Soleil (France)
- Diamond (UK)
- Australian LS

Under Construction

- ALBA
- Petra III
- SSRF
- NSLS II
- MAX IV
- ….

- Implement many small gap undulators and operate in top-up mode.
  - Touchek lifetime must be closely controlled as it defines the beam losses
    - Safety issue
    - Frequency of injection into the ring.
  - The aperture must be large enough with all Undulators in Operation.

A Few Questions

- How many sextupole families ? How to optimize the current in the sextupole families ?

- Undulator technology is under progress : cryogenic in-vacuum undulators are almost there with 30 % field increase. Superconducting technology is under development .
  - How many small periods undulator can be tolerated ?
  - What are the constraints on the undulator field?

- Why is the observed energy acceptance lower than the design values ?

- How well does the modeling reflects the measurements (lifetime, aperture,…) ?

My (personal view) of an Ideal Lattice for a Light Source …

- The smallest emittance
- Large number of Undulators
- Compact
- Low beta functions everywhere
- Large dynamic aperture
  - Large intrabeam scattering (Touschek) Lifetime
  - Full Injection efficiency