input to round-table discussion

message from Pascal Elleaume

list of open questions

some references on wiggler dynamics

discussions with H. Braun, M. Korostelev, E. Levichev, P. Vobly

Frank Zimmermann
Wiggle 2005, Frascati

Message from P. Elleaume (ESRF) to Wiggle2005 audience

wiggler technology:

- **well understood and mature**
- achievable field and period strongly related to technology & magnetic gap.
- recommend starting from **planar permanent magnet wiggler** type technology
- formulas exist which describe field, period and gap that can be reached.
- if one absolutely needs very short period, one should try to build the wiggler in **sections with vertical refocusing in between** (doublet or triplet) to maintain low vertical beta
- **superconducting devices** are option for high field & shorter periods but more expensive and more delicate

beam dynamics:

(1) **field errors due to non ideal and slightly displaced permanent magnets**.
These can be taken care by magnetic shimming and while they are an issue in Synchrotron Light Sources where the gap of the wigglers is changed continually, they **should not be an issue in a damping ring** where the field is static.

(2) **focusing effects and non linear focusing terms proportional to the inverse of the square of the electron energy**. If the wiggler horizontal pole width is large enough (which has cost impact), then the effect is purely vertical and it can be precisely computed analytically and introduced efficiently in tracking codes. If the pole width is narrow (to save cost) , some additional horizontal deflection and focusing take place when electrons travel close to the edge of the pole. Such effects have been seen on one wiggler at SPEAR (see a paper by Safranek et al. in EPAC 2000).

In general, rather optimistic that heavily wiggler dominated damping rings can be built and operated safely. **I believe that some difficulties may arise if one tries to shrink the period to the very minimum.**

still there may be some open questions:

for given peak wiggler field and gap, what is **minimum acceptable period**, in view of nonlinear dynamics, electron cloud, impedance, SR power removal,…?

SR power handling – need the wiggler be optimized for this (longer period!)?

thermal stability of permanent magnets; **machine protection**; absorber design

what determines the **minimum gap height**?

can we achieve sufficient **orbit control** inside long wiggler sections? COD tolerance due to various effect (dynamic aperture, SR fan, emittance)?

which is the **dominant nonlinear effect of the wiggler**? **correction of nonlinear wiggler effects**? can we **model** (and correct) **wiggler nonlinearities by standard multi (e.g. 8-) poles**? do wiggler effects or sextupoles determine **dynamic aperture**?

shaping of pole pieces for horizontal focusing? use of **'magic fingers'**?

… and more open questions:

effect of **radiation energy loss** on **wiggler nonlinear dynamics** (increasing ‘wiggle’ amplitude, increasing strength of nonlinear fields, loss of symmetry,…)

importance of **path length effects**?

limits on the **maximum length of a wiggler section**?

should □ be **matched to natural □ of wiggler**? $\square_{nat} \square (\sqrt{2}...2)\square$

is there an **optimum ratio $L_w/\square$**?

can we produce lower emittance operating with **undulators rather than wigglers**?

limits to the **semi-classical treatment of wiggler synchrotron radiation**?

use **coherent radiation** to damp instabilities? & wiggler CSR effects

electron-cloud countermeasures as part of the wiggler design

some literature on wiggler beam dynamics (incomplete)

L. Smith, 'Effects of Wigglers and Undulators on Beam Dynamics', 13th HEACC Novosibirsk (1986).

E. Forest, K. Ohmi, 'Symplectic Integration for Complex Wigglers,' KEK 92-14 (1992)

W. Decking et al., 'Treatment of Wiggler and Undulator Field Errors in Tracking Codes,' PAC05 Dallas (1995).

A. Wolski, 'Symplectic Integrators for Nonlinear Wiggler Fields,' LCC-0062 (2001).

J. Safranek et al., 'Nonlinear Dynamics in the SPEAR Wiggler,' PRST-AB 5, 010701 (2002)

M. Venturini, A. Wolski, A. Dragt, 'Wigglers and Single-Particle Dynamics in the NLC Damping Rings,' PAC2003 Portland (2003).

M. Venturini, 'Effect of Wiggler Insertions on the Single-Particle Dynamics of the NLC Main Damping Ring', LBNL-53264 (2003)

M. Preger, 'The wiggler transfer matrix,' DAFNE L-34 (2003)

F. Meot, A. Verdier, 'Effect of the Undulator in IR4 on the LHC Beam' LHC Project Note 343 (2004).

A. Wolski, M. Venturini, S. Marks, 'Dynamic Aperture Studies for the NLC Main Damping Rings', EPAC'04 Lucerne (2004).

V. Kiselev, E. Levichev, P. Piminov, 'Effect of the Dipole Wigglers on Dynamic Aperture of VEPP-4M Collider (2004).

E.B. Levichev, P.A. Piminov, 'Symplectic Integrator for Particle Tracking in Complex Magnetic Field' (2004)

E. Levichev, P. Piminov, 'Wiggler Influence to the ALBA Parameters' (2005).