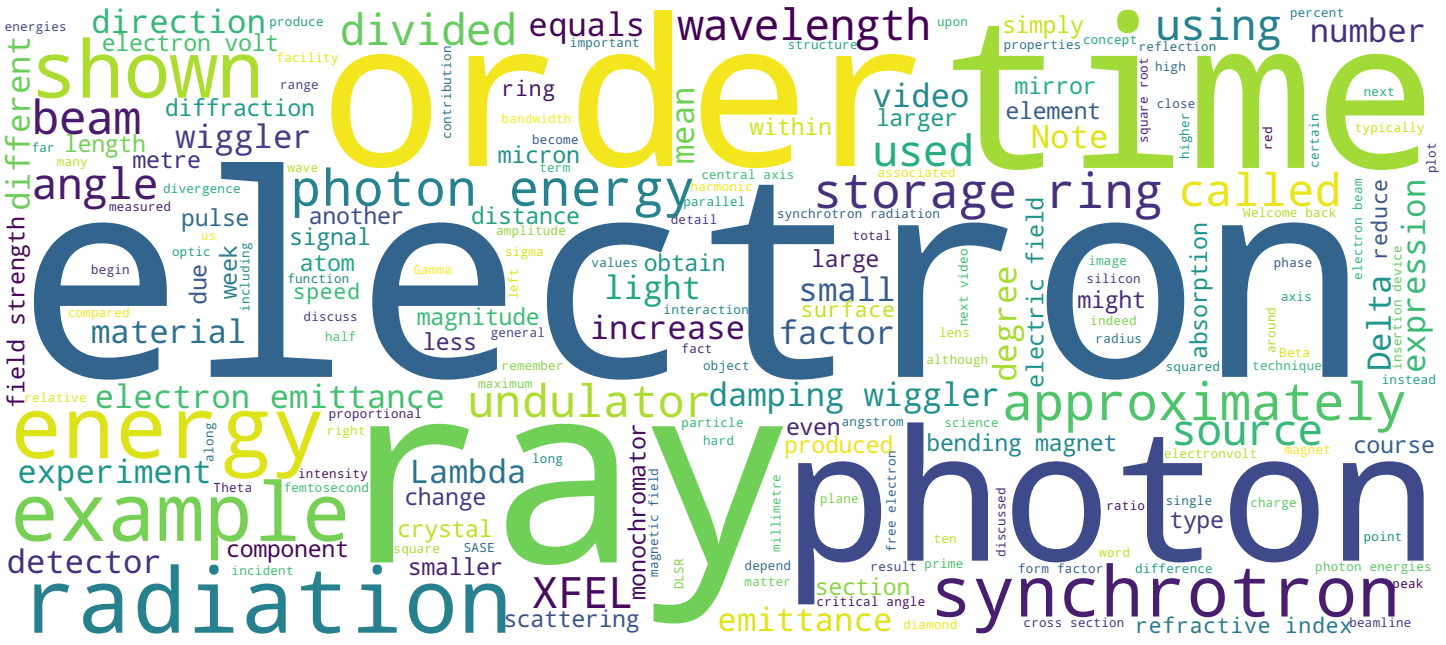


Search MOOC

Video

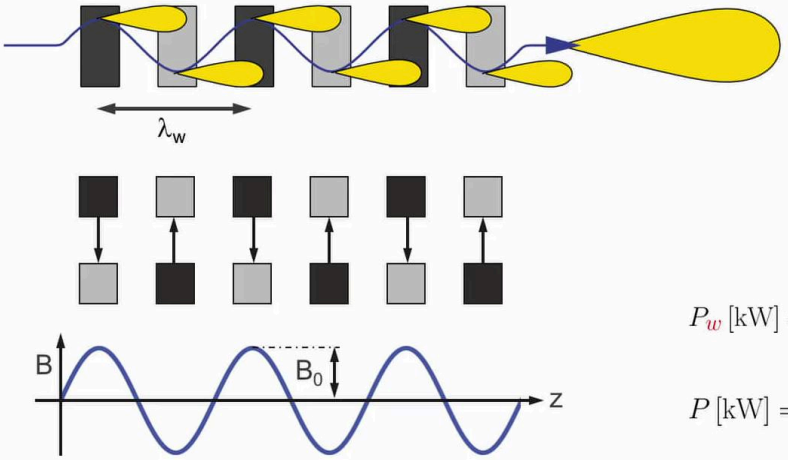
Welcome back. In this short video, we look at the type of insertion device called a wiggler and consider its uses in modern synchrotron facilities. A wiggler can be simply thought of as a bank of alternating, oppositely polarised dipole magnets.

Notes

Summary

0m 05s

Wigglers: a bank of bending magnets



- Wigglers
  - λ_w ~ 50 – 200 mm
  - K ~ 10 – 50
  - Broadband spectra
  - Opening angles
    - $\sigma_x' = K/\gamma \sim 5$ mrad
    - $\sigma_y' = 1/\gamma$

$$P_w\,[\mathrm{kW}] = 0.633\,\mathcal{E}^2\,[\mathrm{GeV}]\,B_0{}^2\,[\mathrm{T}]\,L\,[\mathrm{m}]\,I\,[\mathrm{A}]$$

c.f. BM power:

$$P\,[\mathrm{kW}] = 1.266\,\mathcal{E}^2\,[\mathrm{GeV}]\,B^2\,[\mathrm{T}]\,L\,[\mathrm{m}]\,I\,[\mathrm{A}]$$

This means that the electrons wiggle around the central axis, each wiggle caused by a dipole pair generating broadband bending-magnet-like radiation. The wigglers have the maximum deviation angles from the central axis that are substantially larger than the natural opening angle, one up on Gammer of the synchrotron radiation. The power emitted by wigglers is described by an equation which is essentially the same as that for bending magnets. The difference here is that for a bending magnet, the magnet field strength is normally constant along the length L of the arc. For a wiggler, the average field strength is half the maximum field strength, thus, we need to divide by two; and thereby obtain a pre-factor of 0.633 instead of 1.266.

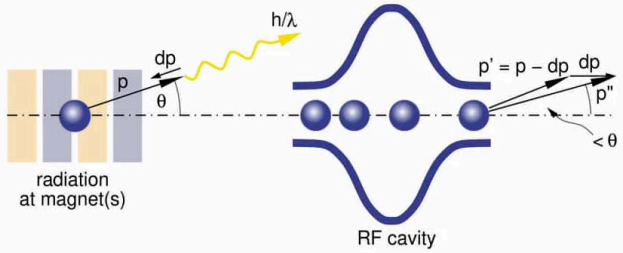
Notes

Summary

0m 23s

Damping wigglers

- Remember: radiation damping



$$\epsilon_W = \epsilon_0 \frac{U_0}{U_0 + U_W}$$

- e.g. DW100 @ NSLS II (3 GeV)
  - λ_W = 100 mm
  - B_0 = 1.8 T
  - K = 16.81
  - Critical photon energy = 10.77 keV
  - L = 7 m
  - P = 64.6 kW
  - 8 devices, P_{tot} = 517 kW
  - ε_0 = 2 nm rad
  - ε_W = 0.55 nm rad
- Thermal management of damping wigglers!

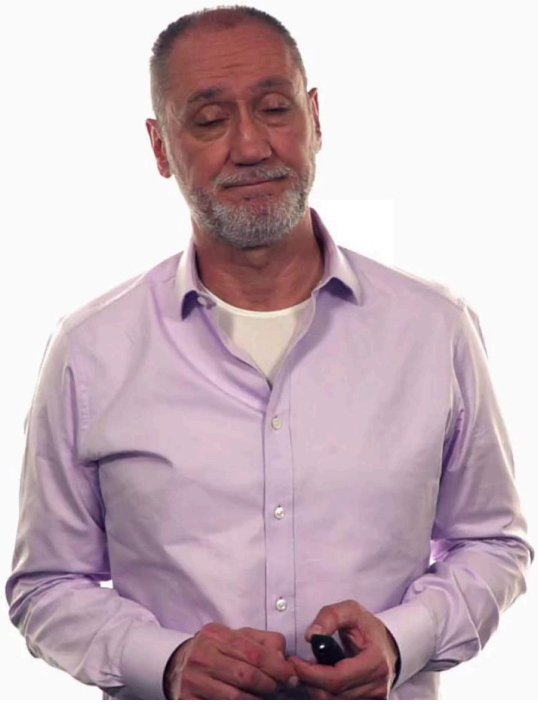
Damping wigglers are installed at some facilities, perhaps most notably at NSLS2 in Brookhaven in order to improve the performance of the storage ring by decreasing the electron emittance. Last week, we discussed the concept of radiation damping, the loss in momentum due to the emission of a photon at an angle theta from the central axis is regained within the RF cavity, but added vectorially parallel to the RF cavity access, thus reducing the divergence. The more radiative power any component in the ring has, the more it will contribute to reducing the emittance via radiation damping. Damping wigglers are expressly installed to produce many kilowatts of radiative power and reduce the electron admittance by a significant factor. Let us consider the example of the DW100 damping wiggler at NSLS2. Eight such wigglers are installed and one can easily calculate using the equation just shown before, that they emit a total power of 517kW of x-rays; approximately three times more than produced by the rest of the ring. This reduces the emittance by approximately a factor of four compared to the same machine without the eight damping wigglers. But 500kW of x-ray power is the thing of space wars and, as such, thermal management of the dissipated power is not at all trivial.

Notes

Summary

1m 25s

Damping wigglers



- Advantages
  - Easy implementation
  - Useful for high-photon-energy BLs
    - Especially fast hard x-ray spectroscopy
- Disadvantages
  - High power output
    - Thermal management
    - Facility power consumption
  - Practical limits to reduction in emittance
  - Space otherwise available for undulators
- Other approach to reducing emittance?
  - Minimize quantum excitation
  - DLSRs

Damping wigglers advantageous insofar that they are easy to implement and are useful for high photon energy beamlines, especially those which scan the photon energy very quickly in order to perform time-resolved chemical kinetics, for example. Now, on the other hand, their very high power output demands extremely careful thermal management strategies and, of course, associated as well with this is a substantial increase in the total power consumption of the facility as a whole, including the need to install more RF supplies. This all sets a practical lower limit to the reduction in emittance. As we have just seen, installing eight damping wigglers at NSLS2 – not a cheap venture, increases the power consumption of the facility by a factor of four for a decrease in emittance, also, only by a similar factor. Now, although one can use damping wigglers for interesting high-energy experiments, the space they occupy might be used otherwise, for undulators and experiments that might profit better from these latter devices. One can therefore make the argument that if the raise on debt of damping wigglers is to reduce the electron emittance, other approaches, especially the use of multibent acrobats at DSLRs, might be more profitable. In the next video, we take a closer look at the jewels in the storage ring crown, namely, the high-brilliance insertion devices called undulators.

Notes

Summary

3m 10s