JUAS 2018 exam on synchrotron radiation (90 minutes)

Total number of points: 25 – Marks will not be renormalized to 20

The following constants will be used in the exercises

velocity of light	$c = 2.998 \cdot 10^8$ m/s
reduced Planck constant	$\hbar = h/2\pi = 1.05 \cdot 10^{-34}$ kg m^2/ s
vacuum dielectric constant	$\varepsilon_0 = 8.854 \cdot 10^{-12}$ F/m
electron rest energy	0.511 MeV
electron rest mass	$9.1 \cdot 10^{-31}$ kg
classical electron radius	$r_e = 1/(4\pi\varepsilon_0)\ e^2/(mc^2) = 2.81 \cdot 10^{-15}$ m

$$C_q = \frac{55}{32\sqrt{3}} \frac{\hbar}{mc} = 3.84\,.\,10^{-13}\ \text{m}$$

Ex. 1 (6 points)

A synchrotron light source with an electron beam of 2.5 GeV operates in the conditions of minimum emittance for a 10-cells DBA lattice (i.e. 20 equal bendings). The vertical (Y) emittance is defined by the coupling ratio $k = \varepsilon_y/\varepsilon_x$ of 10% (i.e. k = 0.1).

a) Compute the emittances of the ring (assuming $J_x \sim 1$) in both planes.
b) Assuming that the brightness is exclusively dictated by the electron beams and the dispersion is zero at the undulator, compute the increase in brightness if the coupling is reduced to k = 1%
c) At what wavelengths the finite beam size and divergence of the photons will change the results in b)?

Ex. 2 (7 points)

a) An electron flying through the space with the energy E passes the Earth. It is bent by the magnetic field of the Earth B_{Earth} = 3e-5 T and emits at this time a photon spectrum with a critical energy of λ_c = 600 nm (i.e. red light). What is the energy E of the electron.
b) The electron travels, in vacuum, along its bent trajectory of total length L = 1000 km. How much energy has the electron lost along this passage due to synchrotron radiation?

Ex. 3 (7 points)

A linear accelerator provides an electron beam of 200 MeV with very small transverse dimensions. At the end of the LINAC there is a permanent magnet undulator with period λ_u = 30 mm. The pole tip field B_r is 1 T. This undulator produces coherent radiation at λ = 300 nm at the fundamental harmonic (n=1). Using the relation

$$B = 2B_r \exp(-\pi \frac{g}{\lambda_u}) \text{ in Tesla}$$

a) Calculate the required gap of the undulator
b) How long is the undulator to obtain a bandwidth of $\Delta\lambda/\lambda$ = 5e-3?
c) Under what conditions does the emission spectrum become a broadband (dipole-like)?

Ex. 4 (5 points)

In order to design a modern storage ring for synchrotron radiation a very small beam emittance is required. Describe shortly the most important design criteria to fulfil these requirements and the concept of Multi Bend Achromat (MBA).