Homework 1

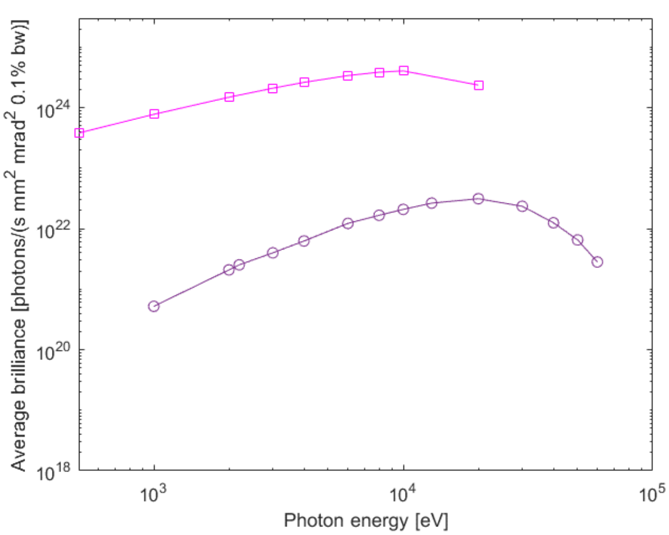
1.1 a) Using the definition for the dimensionless undulator parameter, derive the scaling law for K as a function of the undulator period in cm and magnetic field amplitude in T (i.e., derive $K = 0.9337 \frac{\lambda_u}{cm}\frac{B_0}{T}$).

b) Suppose you come across a proposal to use muons to produce undulator radiation instead of electrons. What can you say about the magnetic field to achieve the same K value for such a muonic undulator?

1.2 Certain undulators are designed so they can be transformed from a planar undulator to a helical undulator by moving the undulator magnets around. Assuming the undulator period and on-axis magnetic field amplitude are unchanged, what would happen to the FEL wavelength when the undulator polarization is switched from planar to helical?

1.3 Suppose we direct a powerful laser beam head-on against the electron beam and use it as a traveling electromagnetic undulator. Show that in the beam rest frame, the EM wavelength is shortened by 2γ. Derive an expression for the wavelength of the radiation that the electron beam emits in the lab frame (Hint: ignore the undulator K parameter of the EM wave).

1.4 The log-log plot of brilliance versus photon energy for the European X-ray FEL (pink) and the APS-U diffraction limited synchrotron light source (purple) show a peak at certain photon energies and then decrease rapidly (see below). Provide the reasons for this rapid roll-off in brilliance at these photon energies?



1.5 Show that the radiation time-bandwidth product, $\sigma_t\sigma_\omega \geq \frac{1}{2}$, can be rewritten in the form of pulse length in space ($c\sigma_t$) times the relative bandwidth, $\frac{\sigma_\omega}{\omega_0}$. What is the minimum value of the time-bandwidth product in this form?