Homework Problems III

1. Estimate the maximum emission into the fundamental mode by correctly choosing a.

2. Estimate the longitudinal displacement from the interaction of an electron with an N-period flat radiation pulse due to the ponderomotive effect. Show that the displacement is exactly that expected from the reduction of the longitudinal velocity from β to β^*. Estimate the longitudinal displacement due to the ponderomotive force for a Gaussian radiation pulse in terms of the relevant parameters (e.g., the peak value of a, the radiation wavelength, and the *rms* pulse length).

3. By computing the overlap integral for Gaussian distributions of unequal beam size, show the general formula for the luminosity of the Thomson collisions is

$$L = f \frac{N_e N_p}{2\pi \sqrt{\sigma_{ex}^2 + \sigma_{px}^2} \sqrt{\sigma_{ey}^2 + \sigma_{py}^2}}$$

By integrating Eqns. (3.8) over frequency, and taking the large photon beam limit ($\sigma_{ex} \ll \sigma_{px}$, $\sigma_{ex} \ll \sigma_{px}$) in the above formula, derive the angular power densities

$$\frac{dP_{par}}{d\Omega} = L \frac{(1+\beta_z) E_L}{(1-\beta_z \cos\theta)} \frac{d\sigma_{T,par}}{d\Omega}$$

$$\frac{dP_{perp}}{d\Omega} = L \frac{(1+\beta_z) E_L}{(1-\beta_z \cos\theta)} \frac{d\sigma_{T,perp}}{d\Omega}$$

where E_L is the low energy photon beam energy and σ_T is the Thomson cross section.

4. RF guns have demonstrated good performance over the years for low duty operation. ERL needs a high current CW source. For normal conducting (copper) RF structures CW operation poses a challenge of removing excessive heat due to wall losses. Estimate the highest accelerating gradient for a half-cell RF gun at 1.3 GHz assuming heat removal capacity of 0.5 kW/cm^2 and heat removal area of 200 cm^2. A typical value of geometric shunt impedance $R/Q = 200\ \Omega$ / cell, and copper structure at that frequency has intrinsic $Q_0 = 2 \times 10^4$. If one uses superconducting half-cell instead (e.g. $Q_0 \sim 10^9$), what would be the required refrigeration power to run at the gradient of 20 MV/m? (Tip: to remove 1 W of wall losses in cryogenic environment @ 4 °K requires ~ 400 W of refrigeration power).