High-Intensity / Relativistic Optics

Problem set 2—The ponderomotive force

1. **Exercise:** Focusing a fraction of the JETI Laser pulse containing a power of 1 TW to a spot of 50 µm in diameter onto a solid surface, suffices to creates a plasma. The plasma will also be heated and consequently now tries to expand. The ponderomotive force of the beam, that mainly acts on the region of critical density, pushes the plasma back and causes a modification of the plasma density profile—abrupt changes of the density value corresponding to a spatial shift of the critical density value become observable.

   (a) How much pressure is exerted by the ponderomotive force and to which mass does this correspond?

   (b) How large a density jump can be supported by the light pressure when the ion and electron temperatures are assumed to be $\mathrm{k_B}T_\mathrm{i} = \mathrm{k_B}T_\mathrm{e} = 1\,\mathrm{keV}$?

2. **Exercise:** Self-focusing of a cylindrically symmetric laser pulse of frequency ω_L occurs when it propagates through an underdense plasma ($\omega_\mathrm{L} > \omega_\mathrm{p}$). In steady state, the beam's intensity profile and the density depression by the beam due to the ponderomotive force are related by a force balance. Prove the relation,

$$n = n_0 \exp\left\{-\frac{\epsilon_0\langle E^2\rangle}{2n_\mathrm{c}\mathrm{k_B}T}\right\} \equiv n_0 \mathrm{e}^{-\alpha(r)}\,,$$

   neglecting plasma heating ($\mathrm{k_B}T = \text{const.}$). The quantity $\alpha(0)$ is a measure of the relative importance of the ponderomotive pressure to the plasma pressure.