22.67 2023 Principles of Plasma Diagnostics

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Pset 4: Proton imaging

Write a code produce synthetic proton images, given a specified electric and magnetic field distribution.

1. Implement a code to calculate the deflection vector **ff** from a given 2D map of E and B. You can assume that the fields do not vary in the direction of probing, so that dl is a scaling factor. Keep the proton energy W as a free parameter.
2. Assume that a grid is placed just before the target plasma, at a distance l from the source, and the source is a point source which radiates isotropically in 4 pi. You can assume the grid holes are infinitesimally thin. Effectively each grid hole represents a single proton at a set angle which will undergo a single deflection **ff** at the target plasma, and then continue L to the detector. Make the mesh relatively fine (at least 100 x100, much more than in a real experiment) so that there is good spatial resolution.
3. Come up with a reasonable model for the Biermann-battery generated magnetic fields in a laser-driven plasma bubble. You might consider the model in Fox, W., Bhattacharjee, A. & Germaschewski, K. "Fast Magnetic Reconnection in Laser-Produced Plasma Bubble" Physical Review Letters 106, 1–4 (2011).
   All we really need is some thin region where the fields are non zero in an annulus. For the electric field, assume some non-zero radial electric field in the same region (this isn't correct, but it will do).
4. For some reasonable field strengths and probing proton energies, show the proton images where either the electric or magnetic fields dominate, for both single bubbles and two bubble reconnection events (here consider simply summing the magnetic and electric fields from two adjacent bubbles).
5. Show also images where the protons probe from either side, that is for the bubbles either focusing or defocusing the protons (hint - changing the proton charge is the same as flipping the probing direction).
6. Explore some different regimes of μ to show the small deflection and caustic regimes. For a given experimental geometry (l, L and plasma parameters all fixed), how can we change μ, and hence whether we get caustics? What can we change about the grid to avoid caustics?