22.67 2023 Principles of Plasma Diagnostics

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Pset 2: B-dot probes and plasma position

Firstly, consider time-resolved interferometry performed along a chord through a plasma.

1.1 Come up with a suitable "phantom" density profile, $\int n_e(t)dl = \langle n_e L\rangle$ to test your code. A simple Gaussian is a bit boring.
1.2 Calculate the signal from a homodyne Mach-Zehnder interferometer. Note where the signal exhibits phase ambiguity.
1.3 Consider a "quadrature" system, in which the probe beam is split and interfered with 1) a reference beam which is initially in phase with the probe and 2) a reference beam with is initially $\pi/2$ radians out of phase with the probe. By combining the information from these two signals, can you resolve all of the phase ambiguity?
1.4 Now consider a "triature" system where the probe is split into three beams and interfered with reference beams at 1) 0, 2) $\pi/3$, and 3) $2\pi/3$ radians out of phase. Has this helped? Should you keep going?
1.5 Now consider a temporally heterodyned interferometer, in which the probe and reference beams oscillate with different frequencies, ω_1 and ω_2. Try a range of beat frequencies $\omega_1 - \omega_2$ and consider how you would use the resulting intensity signal to infer the line integrated density - can you actually back out the signal you put in?
1.6 Consider briefly the hardware and cost limitations which might push you towards a simpler system, including the number of channels required and the speed of the digitizer.

Now consider a spatially heterodyned imaging interferometer.

2.1 Come up with a suitable "phantom" density profile, $n_e(x, y, z)$ to test your code. A simple Gaussian is still a bit boring. A phantom where the density goes to zero at the edge is probably easiest to work with.
2.2 Write code to produce synthetic interferograms from a spatially heterodyned interferometer. The probing frequency and the offset angle between the reference and probe beam should be freely adjustable.
2.3 For some reasonable probe frequency (based on the density you have chosen) generate synthetic interferograms for a range of offset angles, including $0°$.
2.4 What angle is required to resolve any phase ambiguity (closed interference fringes)? Is this angle special in some way? Relate it back to the properties of $n_e(x, y, z)$.

2.5 Outline how you would infer the line-integrated electron density $\langle n_e L(x,y) \rangle = \int n_e dz$ from your interferogram.