Interferometric Diagnostic of Plasma Rotational Flux

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Plasma Rotation: Myth or Reality?

An unsettled question

- Indirect experimental evidence suggests existence of plasma rotation in the current sheath of the plasma focus[1]

- Occasionally, there are 'dramatic' observations which strongly indicate presence of plasma rotation. An example is from Lebedev Institute[2] where a conical copper foil kept on the anode got 'twisted'.
- **Convincing direct evidence is missing.**
- Theoretically, a relaxed state with strong Hall Effect is expected to possess rotation of the order which is believed to exist in the plasma focus current sheath.
- A microscopic mechanism which can generate rotation even in a rotationally symmetric plasma has been proposed earlier[3]

1. S.K.H. Auluck, IEEE Trans. Plasma. Sciences, vol.25, p.37, 1997.
2. V. Ya. Nikulin, Private Communication
3. S.K.H. Auluck, Physics of Plasmas, vol 9, p. 4488, 2002.

Why is rotation important?

- A shifted-Maxwellian velocity distribution has a positive gradient →can cause particle acceleration by inverse Landau damping.
- Rotating plasma would give rise to rotating ions.
- Since the relaxed state arises only in magnetized plasma, the dense plasma shock is not expected to have rotation: only the current carrying sheath is expected to have rotation.
- Mixing of a rotating relaxed plasma containing fast ions and a non-rotating dense plasma in front triggered by shock reflection from the axis gives a plausible neutron production mechanism

Proposed Direct Diagnostics for Plasma Rotational Flux

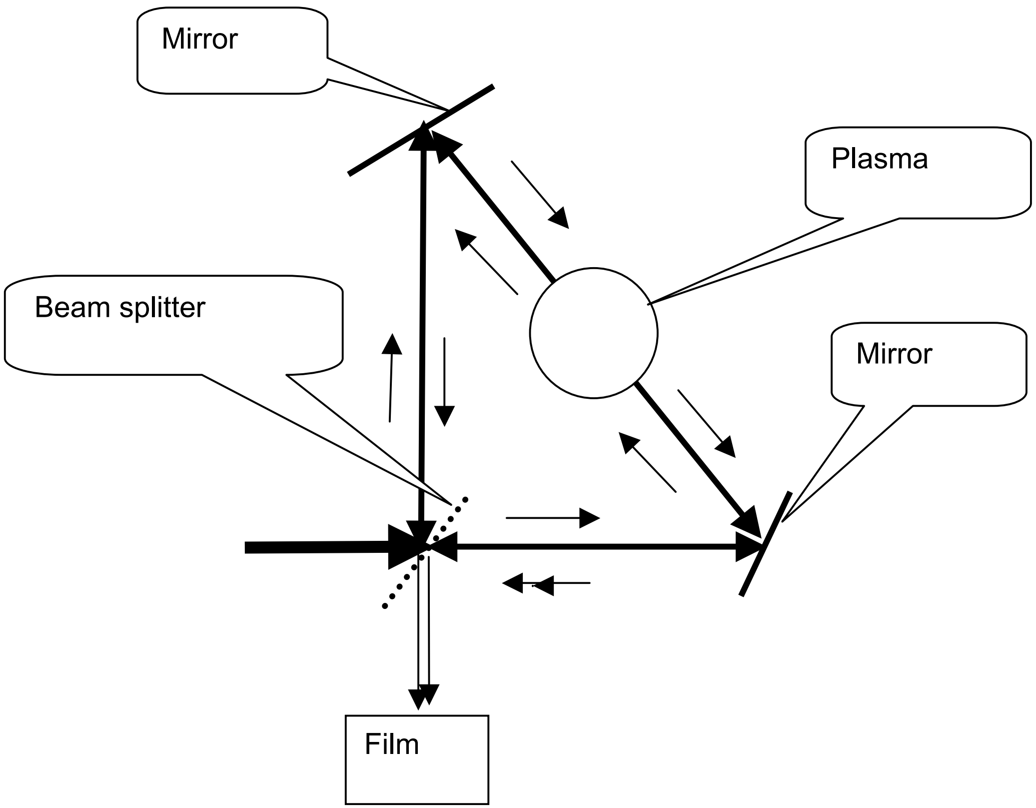


Fig.2

- Nanosecond laser pulses traverse the plasma in opposite directions at the same instant.
- Plasma sees them as Doppler-shifted with opposite sign
- They recombine at the film at the same time

Phase Difference

A static phase object would give zero fringe-shift

$$\Delta\Phi \approx \frac{2}{cn_c}\int\left(\vec{k}\cdot n\vec{v}\right)ds$$

If the pulses traverse the plasma at the same instant

n_c : critical density; $n\vec{v}$: plasma flux

c : velocity of light; s : chord length

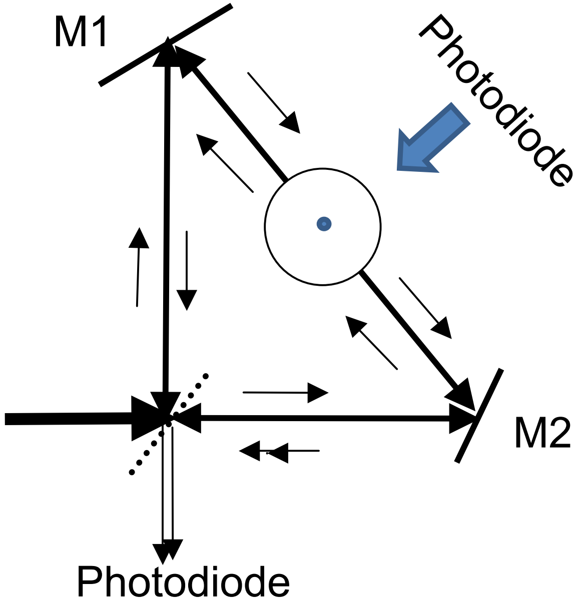
$$\Delta\Phi \approx \frac{2\pi\Delta t}{\lambda n_c}\int\frac{\partial n}{\partial t}ds$$

If the pulses traverse the plasma after a time Δt

In both cases, a different kind of detail will be revealed about plasma dynamics

Practical Issues

- The coincidence of the two pulses at the axis of the anode and at the film has to be achieved to a great precision
- A cylindrical scattering object can be kept on the axis. Two photodiodes, one at 90° to the beam axis and another at the location of the film would see both pulses together.



- Mirrors M1 and M2 must be adjusted using appropriate positioners so that spatial and temporal overlap of the two pulses is achieved at both locations.

Discussion

- Turbulent regions in ~ 100 eV plasma may have electron drift velocities ~ 0.01-0.1c, density ~10^{17} -10^{18} cm^{-3}.

- With Nd-YAG laser, fringe shifts from a tenth of a fringe to a few fringes may be reasonably expected.

- With time-shifted pulses, new information on unstable modes of the plasma may be obtained.

Conclusion

- A variant of conventional interferometry sensitive to azimuthal electron flux is discussed.
- This is achievable in several laboratories for example ICDMP, Lebedev Institute etc.

- New information on turbulent electron velocity fields and unstable MHD modes could become accessible with this diagnostic.

Thank you for your kind attention!