Correction of Beam Deflection Effects in Interferometry for Near-critical Density Plasma Diagnostics

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Laser interferometry is widely used for laser-plasma diagnostics because it is non-invasive and delivers excellent spatial and temporal resolution. However, near-critical density plasmas pose a unique challenge for interferometric diagnostics. In this density regime, steep density gradients bend the interferometer's probe beam to follow a refracted, curved path through the plasma. As a result, the phase is accumulated along this bent trajectory rather than a straight line, leading to distortions in the reconstructed plasma density profile. This refraction effect is rarely taken into account when retrieving plasma densities using interferometry.

For laser pulse compression using a plasma [1], a very high density plasma in the near-critical regime is required and its accurate diagnostics is needed. Hence, it is necessary to develop a correction method that can reduce the interferometer errors caused by the beam deflection.

Now we are working on the laser pulse compression experiment and developing diagnostic methods for near-critical plasmas, which includes the correction method to retrieve accurate plasma density profiles from the distorted interferometric data. To verify its effectiveness, we conducted Hamiltonian ray-tracing simulations for UV probes traversing a plasma with a peak density of 2.0×10^{21} cm^{-3}. In this case, beam deflection induced a 12% error before correction in the reconstructed density. Our correction algorithm, which iteratively compares the measured phase with ray-tracing predictions, successfully reduced the error to 0.38% after 9 iterations, leading to a very good result.

We also conducted experiments, including diagnostics of the near-critical density plasma with a UV interferometer. The plasma had a density range of 10^{20}~10^{21} cm^{-3}. Using our correction method, we successfully recovered the plasma density, reducing the measurement error to 0.9 % from the distorted result of 9.9 % error.

Both in experiments and simulations, we demonstrated that our correction algorithm can accurately recover the true plasma density by taking account of the probe beam deflection. Moreover, our method is simple and easy to apply to any interferometric results from near-critical density plasma. Detailed results will be shown in this presentation.

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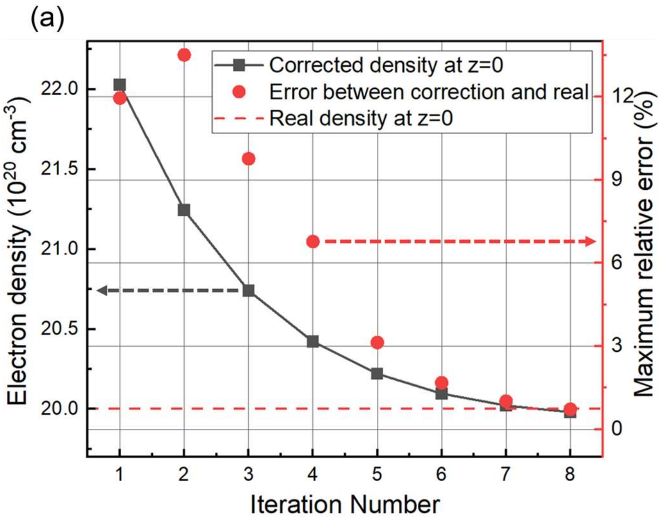
References

[1] Hur, M.S., Ersfeld, B., Lee, H. *et al*. Nat. Photon. **17**, 1074–1079 (2023).



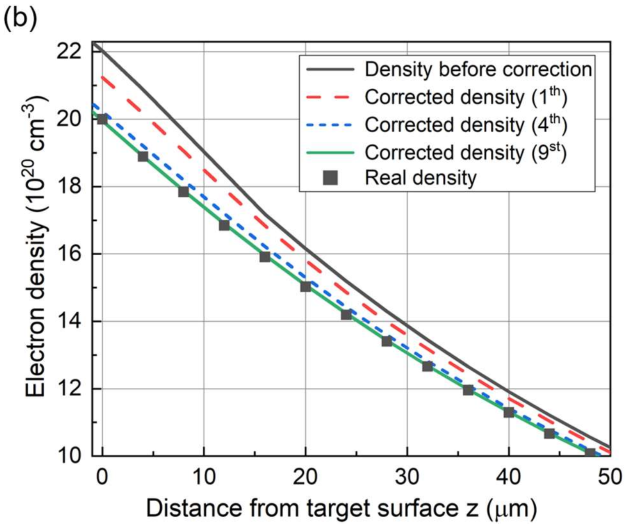


Figure 1. (a) Iterative correction algorithm result for the exponential decaying from 2.0×10^{21} cm^{-3} peak density, and (b) plasma density distribution in space. The graphs show that the deflection leads to a significant error in density measurement in this case. The initial 12% error between the density before correction and real density was reduced to 0.38% by the correction algorithm.