Plasma-Density Imaging – 2-Dimensional, - Second-Harmonic, Dispersion Interferometer

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ABSTRACT

Plasma-density interferometers are typically -

- robustly mounted, two-arm, high-maintenance devices

A **Second-Harmonic, Dispersion Interferometer** measures Df using 2w common-path beams

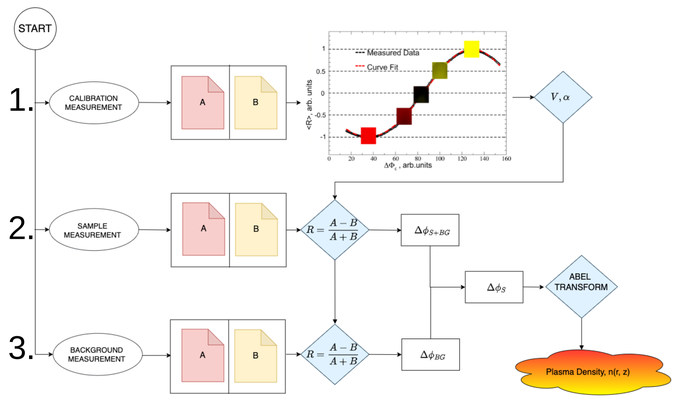
The 1-D SHDI uses CW (Nd:YAG, or CO_2) lasers [1]
A pulsed, high-intensity laser provides for large-area 2-D time-resolved imaging [2, 3]

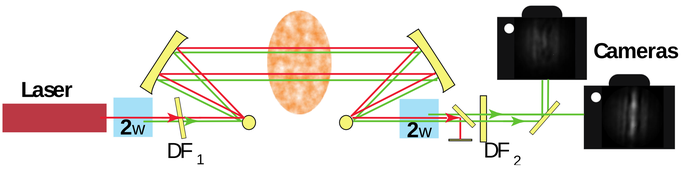
- 0.01-radian sensitivity, 0.1-mm resolution, 1-ns sampling, 10^5 Hz

The 2-D SHDI is being characterized on pulsed-gas jets/plasma jets

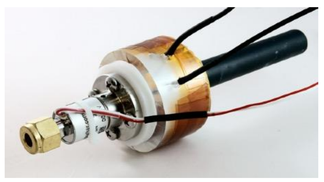
- 2 x 3 cm, 50-us, n·dl ~ 10^{16} cm^{-2}

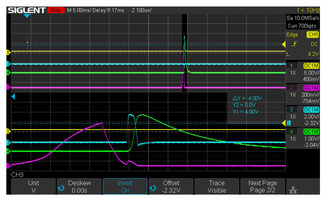
DATA AQUISITION





PLASMA SOURCE

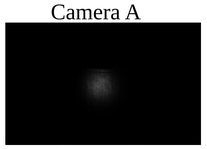




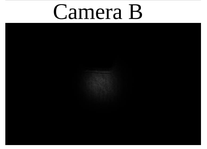
Parker Series 9 Valve - 2A, 500 us
N_{gas} ~ 10^{17} cm^{-3}
3-D printed insulator
Brass/SS electrodes
1-3 kV, 50 us, 500J square pulse
N_{plasma} ~ 10^{16} cm^{-3}

DATA CAPTURE

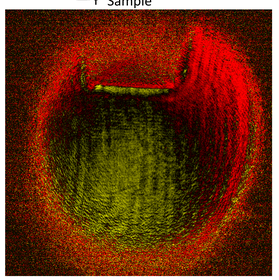
Camera A



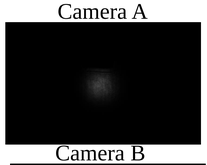
Camera B



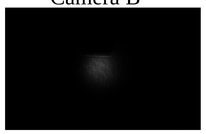
$\Delta\phi$ Sample



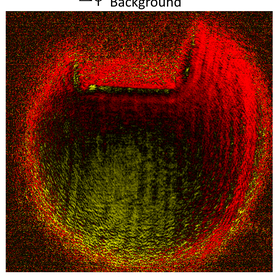
Camera A



Camera B



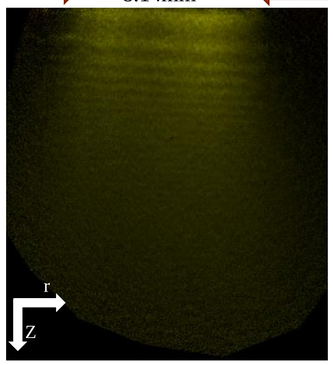
$\Delta\phi$ Background



$\Delta\phi$ Sample - $\Delta\phi$ Background

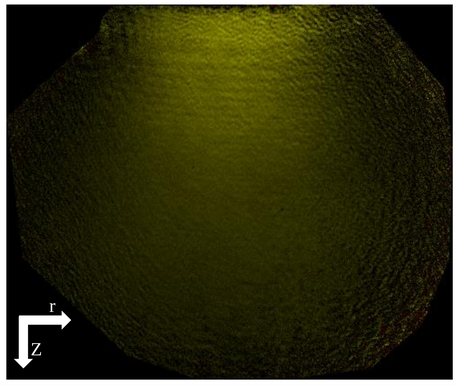
Rotated/cropped

8.14mm

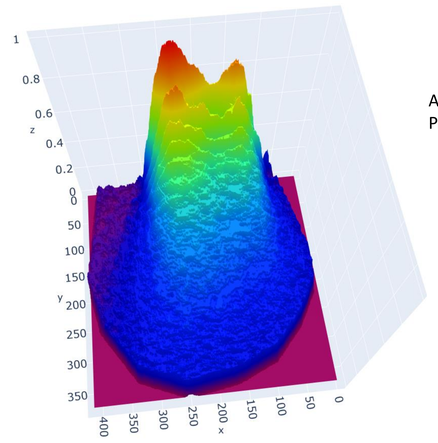


$$\Delta\phi(x,y) = 2.82\times10^{-13}\{\lambda_{532}-\lambda_{1064}\}\int_{-z_0}^{z_0} N_e(x,y,z)dz.$$

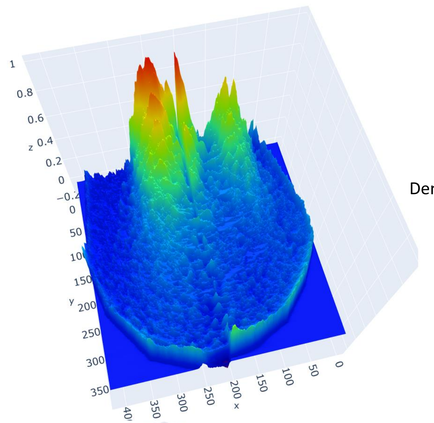
15.9mm



PyAbel TRANSFORMS

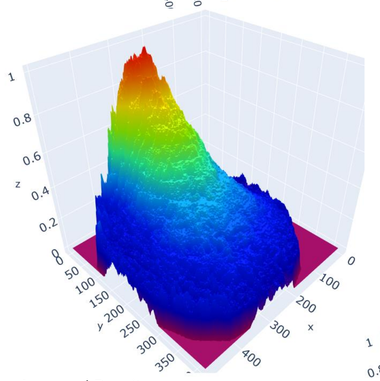


Averaged Density Projection

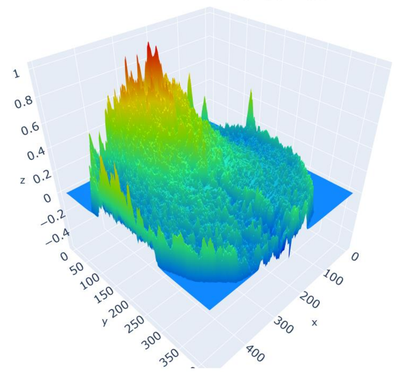


Density Profile

Peak Density:
$5*10^{16}$ cm^3



Averaged Density Projection

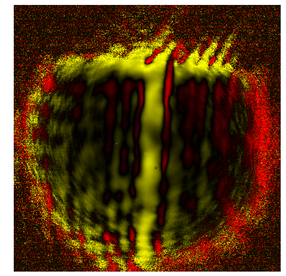


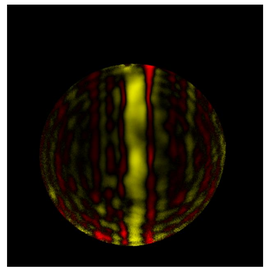
Density Profile

Peak Density:
$6*10^{16}$ cm^3

GAS JET IN AIR

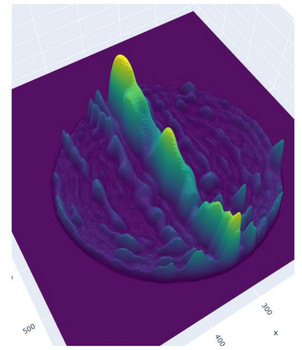
$\Delta\phi$





Gladstone-Dale Eqn.:

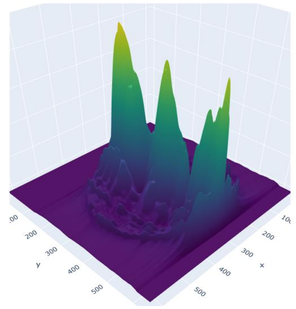
$$\bar{N} = \frac{\lambda}{4\pi L}\frac{N_0}{\Delta n_0}\Delta\phi$$



N(r, z) Projection

Density Profile N(x, y)

Peak Density:
1.18E19/cm^3



CONCLUSIONS

- Scalable for measurements on plasma, gas, fluids
- Simple design, with a single laser source and minimal optics
- Common path 2w beams eliminates noise
- Integrated S/W processing facilitates real-time data analysis
- Results are much easier to interpret compared to standard "fringe counting"
- Simple design
- Robustly stable
- Low-maintenance
- Low-cost
- US Patent #11,221,293

REFERENCES

1 Brandi, F., Wessel, F.J., Lohff, C., Duff, J.R., Haralson, Z.O., 2020, App.Optics 59, p.8486-8493.
2 Brandi, F. and Wessel, F.J., 2020, Optics Letters 45, p.4304.
3 Wessel, F. and Brandi, F. US Patent #11221293.

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We are seeking collaborators who will permit us to measure the plasma density on their experiments