

Progress on Development of Optical Tomography as a Plasma Diagnostic

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I. Abstract

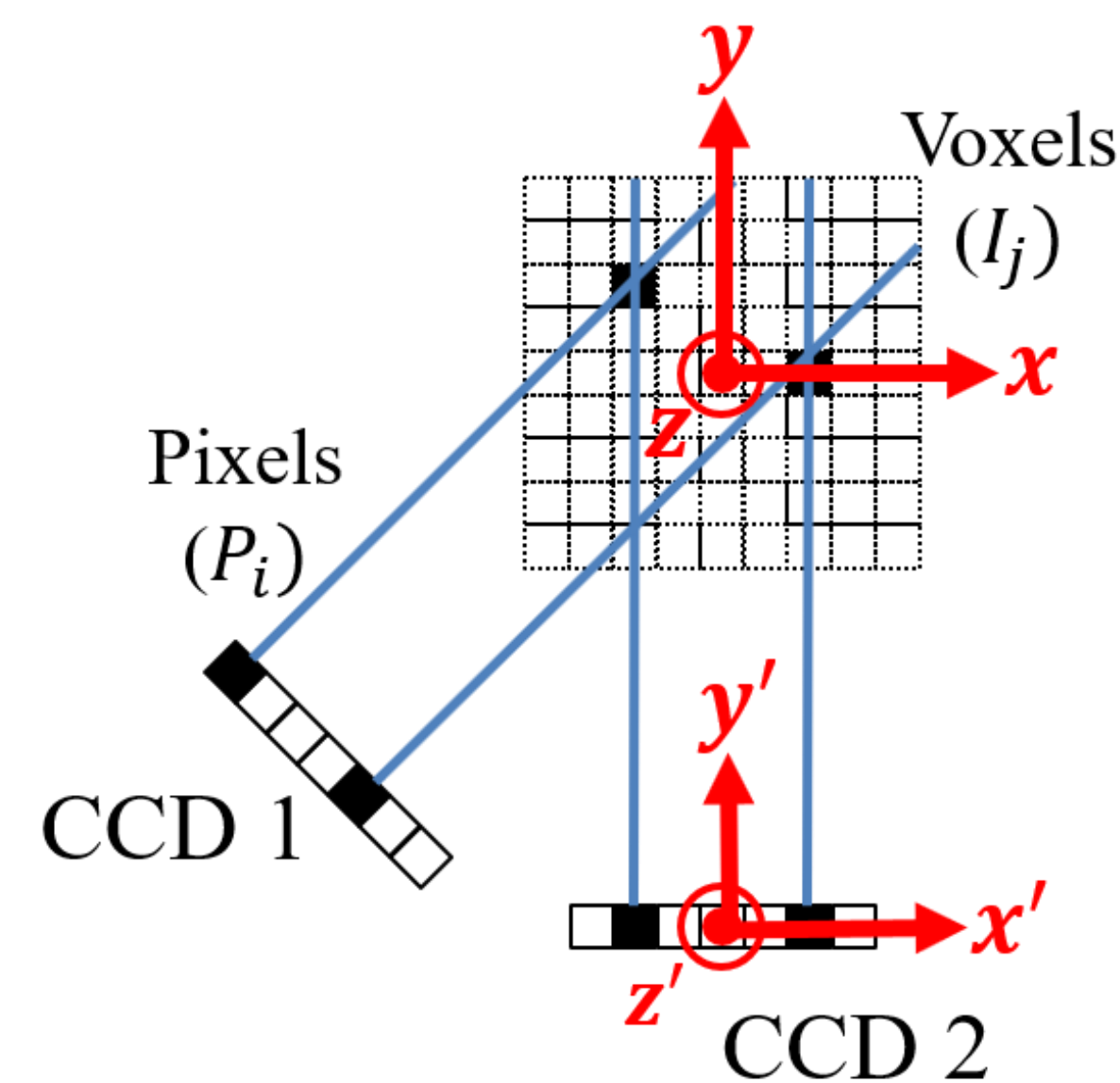
Well-controlled idealized plasmas have been investigated in 2D fashion, but spatially complex structures require a technique that can provide a more complete 3D picture. To address this need a plasma tomographic optical imaging capability has been developed at Sandia. Experimental measurements of the 3D optical emission of a helium nanosecond pulsed atmospheric pressure plasma jet are presented.

II. Optical Tomography

- Cameras measure projections of the light intensity
- Each pixel intensity, P_i , is related to the intensity within a voxel, I_j , by

$$P_i = \sum_j W_{ij} I_j$$

- Where W_{ij} represents the contribution of the j th voxel to the i th pixel [1,2]

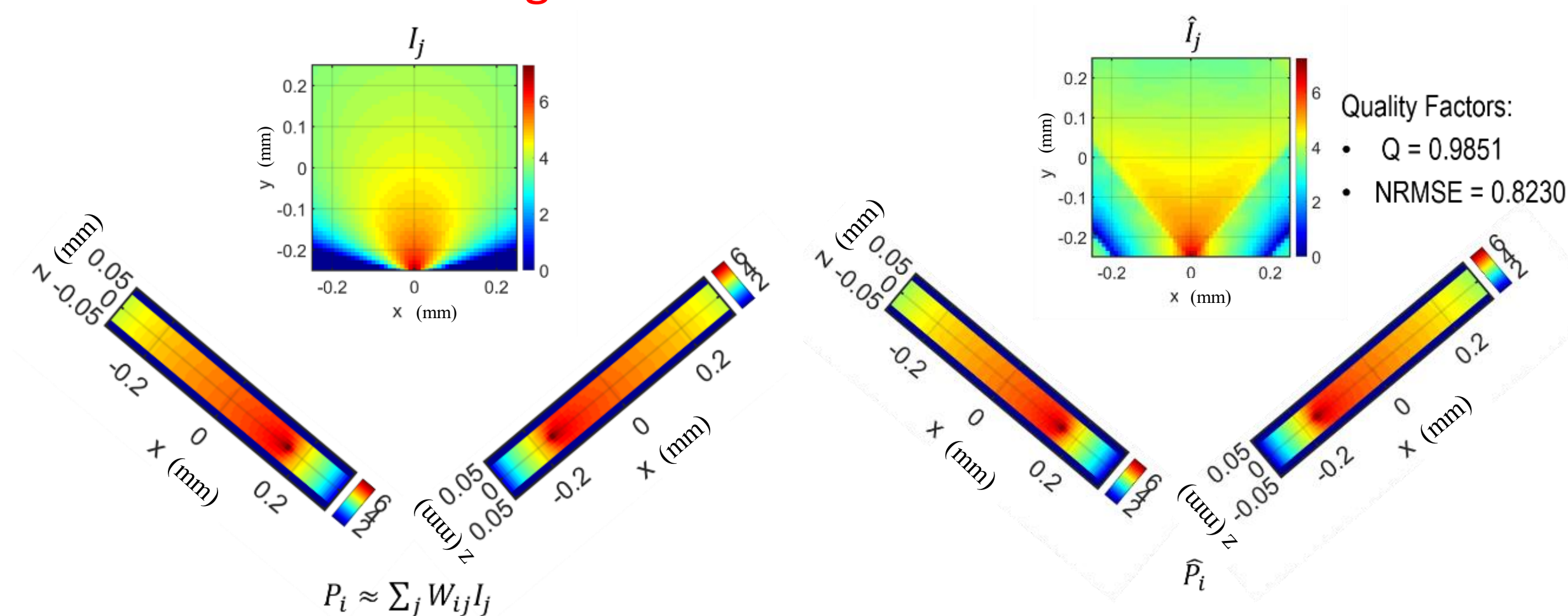


III. Simulated Tomographic Reconstructions

- Algebraic reconstruction techniques (ART) at iteration k estimate \hat{I}_j for known P_i and W_{ij}

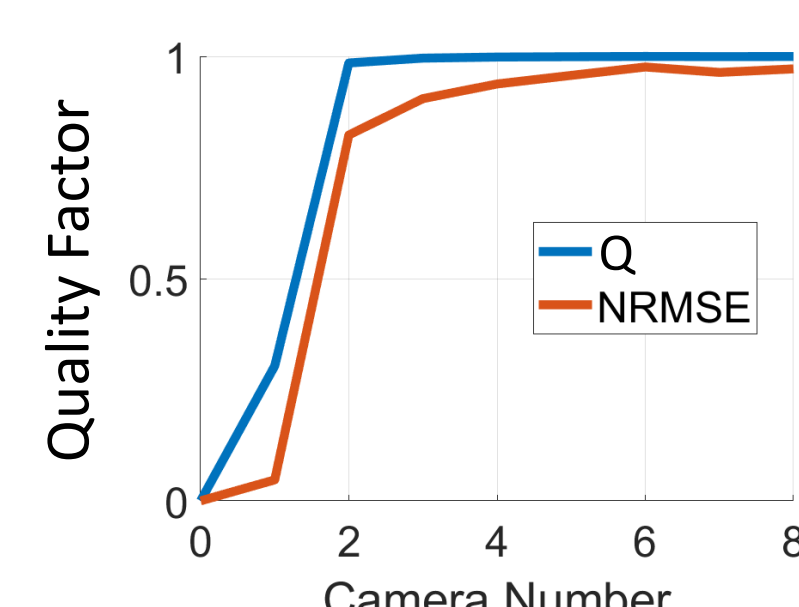
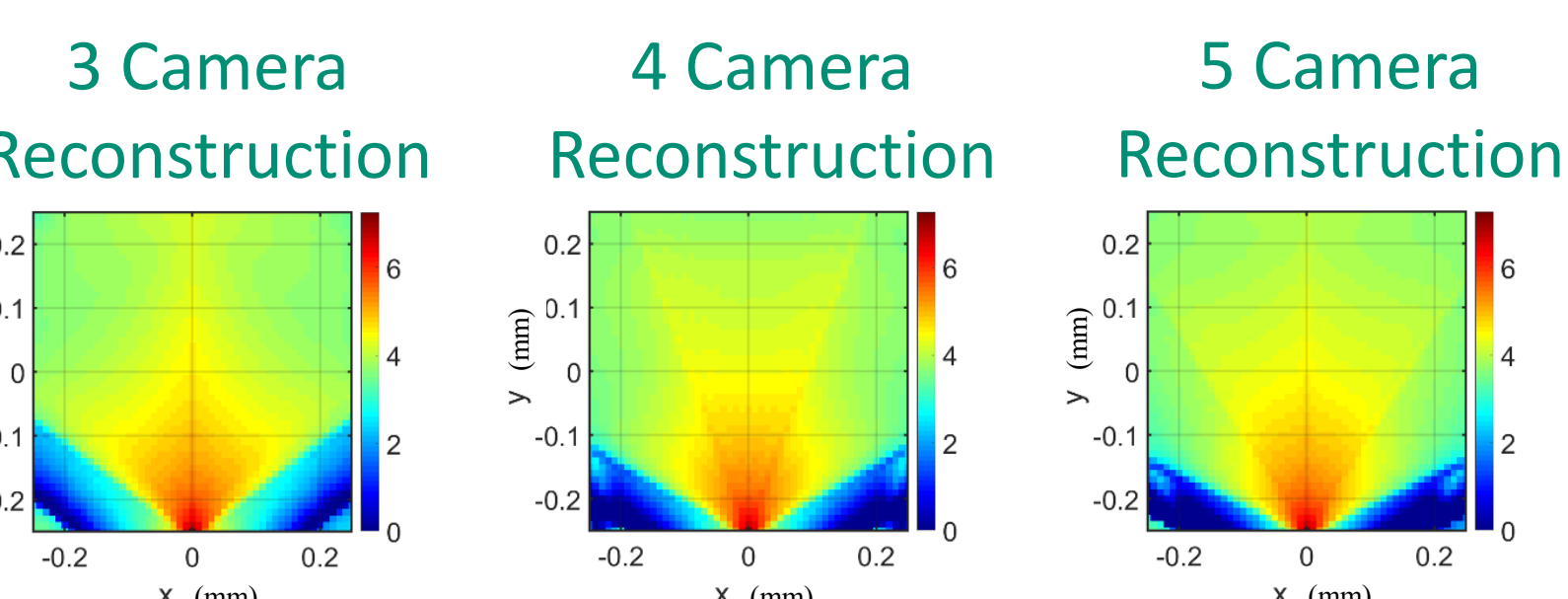
True 3D Test Image Slice

Reconstruction with 2 Cameras



$$\hat{P}_i = \sum_j W_{ij} \hat{I}_j^k$$

$$I_j^{k+1} = I_j^k \left(\frac{P_i}{\sum_j W_{ij} I_j^k} \right)^{\mu W_{ij}}$$

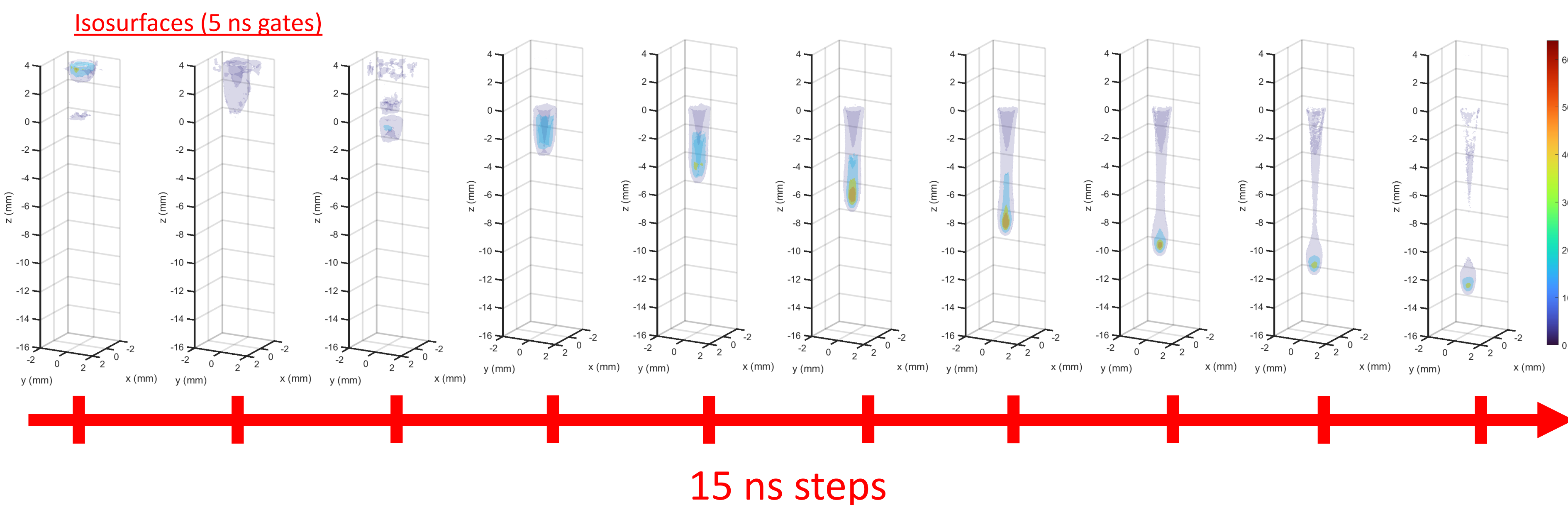
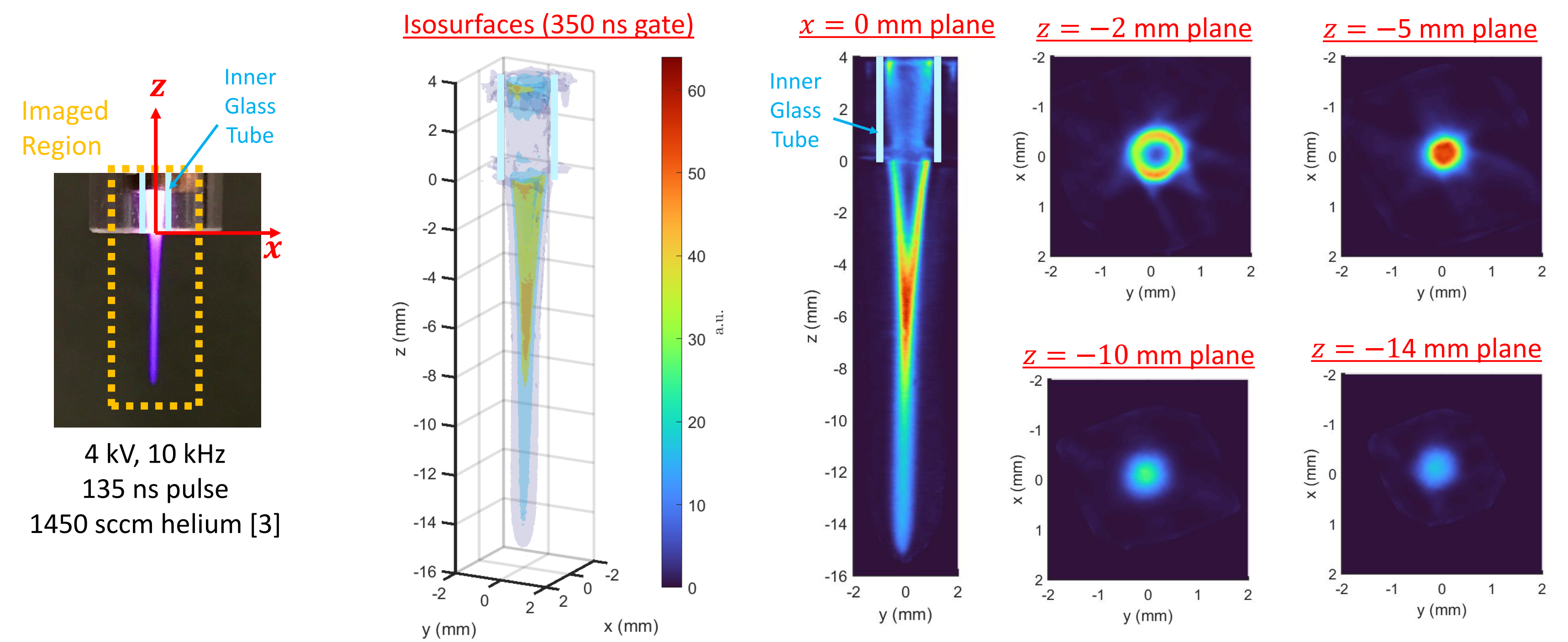


$$Q = \frac{\sum_j I_j \hat{I}_j}{\sqrt{\sum_j I_j^2 \sum_j \hat{I}_j^2}}$$

$$\text{NRMSE} = 1 - \sqrt{\frac{\sum_j (\hat{I}_j - I_j)^2}{\sum_j I_j^2}}$$

IV. Atmospheric Pressure Plasma Jet Tomographic Reconstructions

- Four intensified cameras and eight viewing angles give 3D and temporal information
- Calibration targets co-register cameras, 3D spatial resolution is 20 μm , 1 hour for reconstruction



V. Conclusions

Optical tomography is promising for investigation of fully 4D plasma structures and behaviors found in streamer, arcs, cathode spots, anode spots, ionization waves, magnetic field interactions, etc. Advanced modeling in 4D is needed for comparison.

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References:

- [1] C. Atkinson and J. Soria, *Exp. Fluids* **47**, 2009
- [2] B. Z. Bentz, A. V. Chavan, D. Lin, E. H. Tsai, and K. J. Webb, *Appl. Opt.*, **55**(2), 2016.
- [3] M. Mirzace, M. S. Simeni, and P. J. Bruggeman, *Phys. Plasmas*, **27**(12), 2020.