Development of Self-Aligned Focusing Schlieren for Hypersonic Flow Visualization

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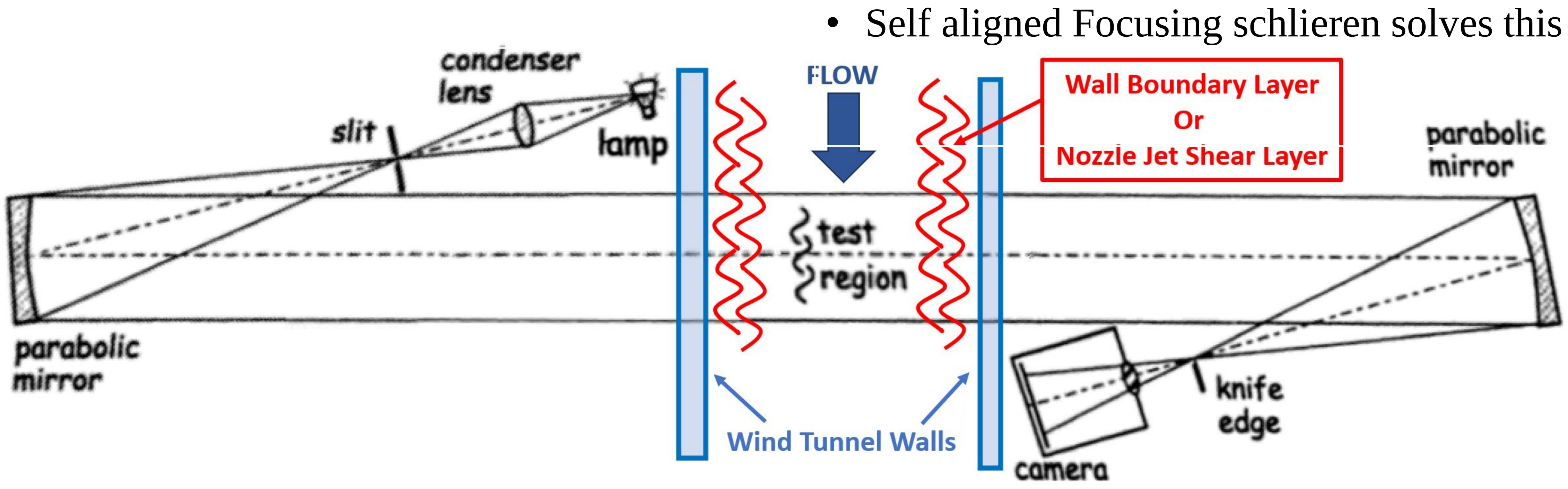
TECHNOLOGIES FOR THE NEXT GENERATION

Motivation

- There has been a recent surge in interest for high-speed aerodynamics
- Experimental aerodynamics are at the cornerstone of current research endeavors
- Schlieren flow visualization is a ubiquitous method to analyze aerodynamic phenomena. It enables direct, non-intrusive and high-speed density gradient visualization.

Current limitations

- Traditional schlieren is **path-integrated**. Undesirable density structures such as the tunnel wall boundary layer or jet are also resolved and may obscure the phenomenon of interest, often located at the tunnel centerline
- It is not possible to study many phenomena of interest occurring in a vehicle wake or along the centerline of a model with a large spanwise extent.
- Self aligned Focusing schlieren solves this limitation

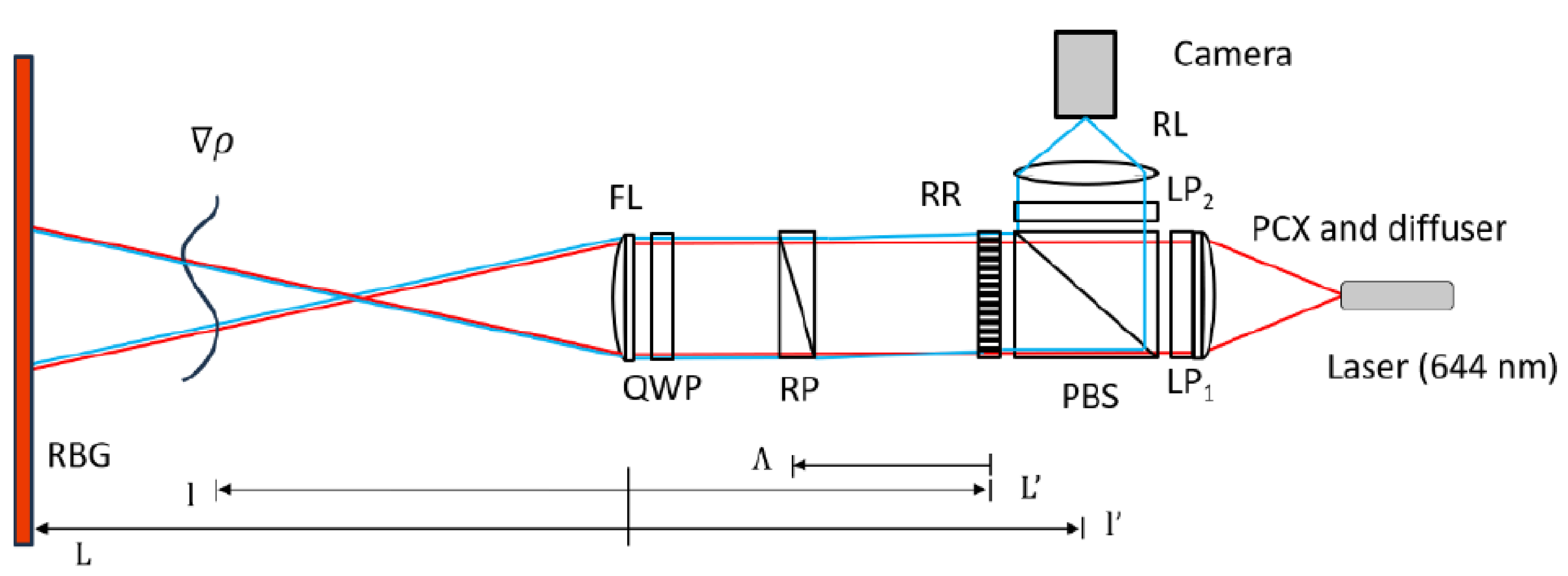


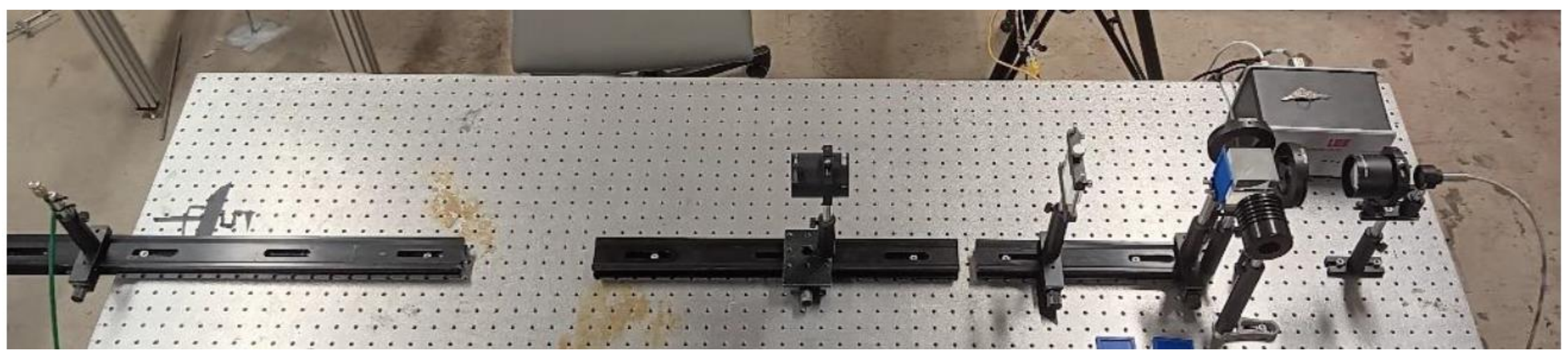
Objective: Develop Self Aligned Focusing Schlieren for use in FCAAP's PolySonic Wind Tunnel (PSWT)

How SAFS works

The light from a high-frequency laser is collimated by a plano-convex lens (PCX) and linearly polarized by a linear polarizer (LP) to pass through a polarizing beam splitter (PBS) and illuminate a Ronchi ruling (RR). The linearly polarized, backlit RR is projected by a field lens (FL) through a Rochon prism (RP) that allows the light to pass through with no deflection. The light then passes through a quarter wave plate (QWP) to convert it into a circular polarization state before encountering a density object ($\nabla\rho$) and a retroreflective background (RBG), which reverses the circular polarization direction. The light then returns to a linear polarization state perpendicular to its original state and passes through the RP, deflecting at the prescribed turning angle of the RP. The FL re-projects the image of the RR source from the RBG back on the face of the RR with a spatial offset defined by the RP angle and distance. On the return path, the light is turned 90◦ by the PBS and filtered by a second LP to allow only the light from the return path to pass through. A camera with an imaging relay lens (RL) is used to gather the light and resolve the image from the desired plane of focus.

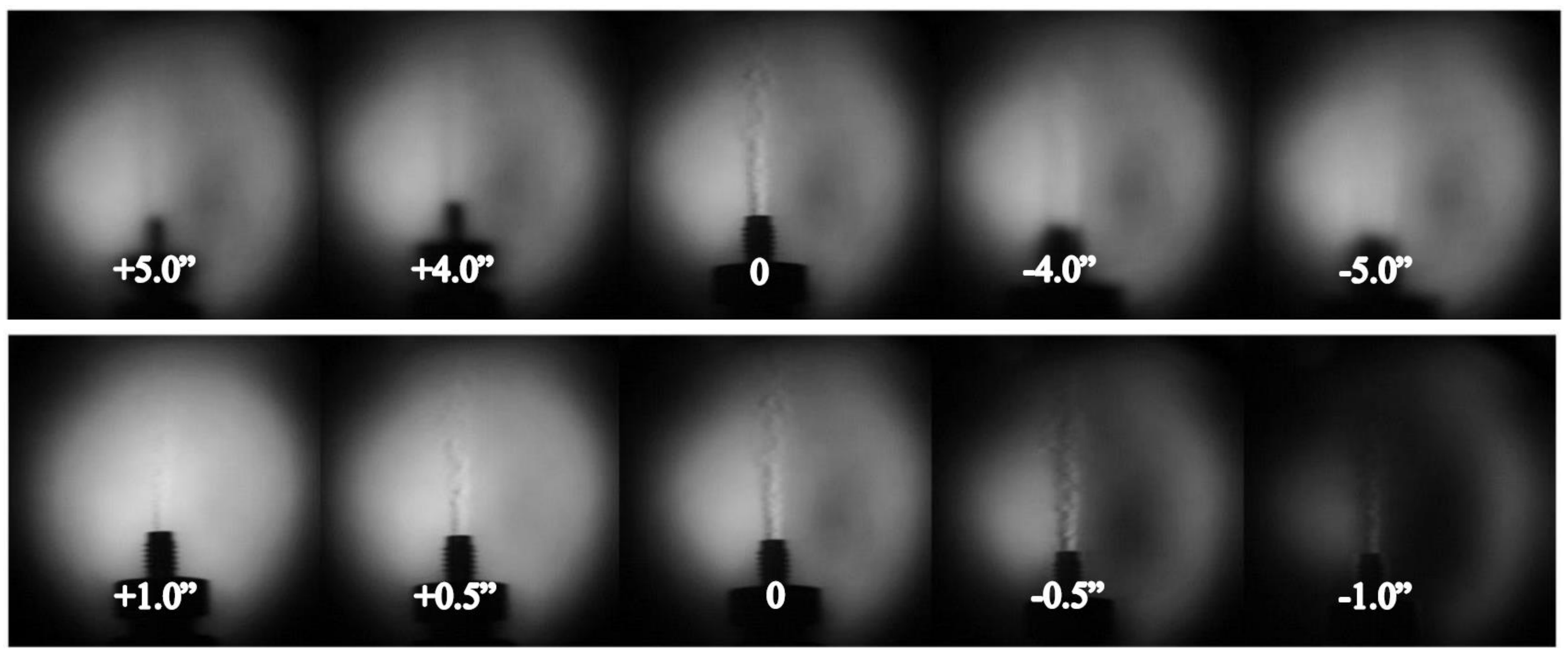
f (mm)	L' (mm)	l (mm)	l' (mm)	L (mm)	Λ (mm)
400	536	955	636	1605	262





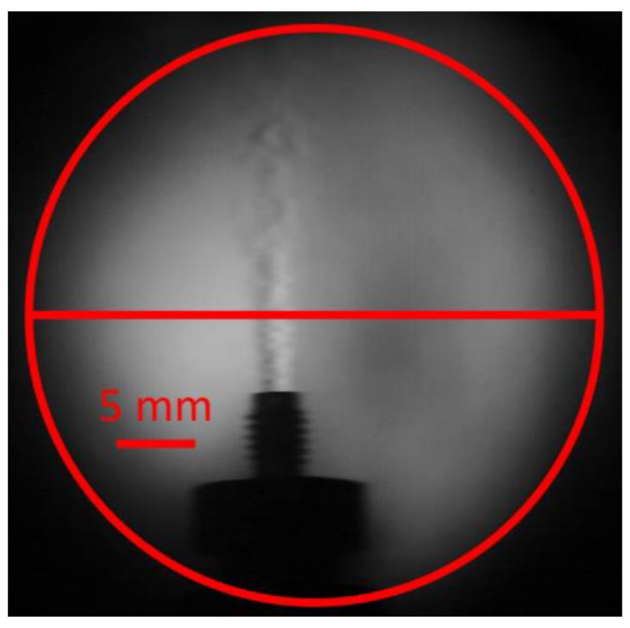
Results

- ✓ **Depth of Focus:** The focusing aspect of the SAFS setup is evident as the jet structures are blurred at distances od ±4" from the plane of focus. This is sufficient for the PSWT since the test section is 12"
- ✓ **Sensitivity:** Good sensitivity is achieved as small axial movements of the RP on the order of 1" away from the ideal 50% cutoff complete one light – dark cycle.
- ✓ **Field of view:** Resulting image has a diameter of 37.5 mm



Future Work

- Explore alternative setups that maximize depth of focus and field of view. There is a trade off between these figure of merits.
- Design a compact cage system for ease of implementation.
- This new capability will make FCAAP's PI more competitive in grant applications.



Conclusion: Self-Aligned Focusing Schlieren has been successfully implemented for use at FCAAP's PolySonic Wind Tunnel