Multi-point single shot coherent Rayleigh Brillouin scattering for neutral gas flow characterization

Atulya Kumar[1], Stefan Karatodorov[1], Marios Kounalakis[1], Alexandros Gerakis[1]

1. *Luxembourg Institute of Science and Technology*

Single-shot coherent Rayleigh Brillouin scattering (CRBS) is a nonlinear optical diagnostic technique that enables the measurement of several thermodynamic parameters in a medium, such as temperature, number density and flow velocity vector. As CRBS does not rely on flow seeding or any specific gas chemistry, it offers to be a powerful tool for aerodynamic measurement and testing. CRBS has previously been used for velocimetry and gas remote sensing from a single point [1]. Here, we report on its extension to multiple points, providing spatial resolution on the measurements for enhanced flow characterization capabilities (see also Ref. [2]). We demonstrate multi-point velocimetry capabilities in different flow regimes: a) in the boundary layer of an airfoil in a sub-sonic custom-built open circuit wind tunnel; b) in a steady supersonic under-expanded jet. These experiments were performed with a custom-built frequency agile chirped laser system [3]. Our measurements highlight the capability of deploying single-shot CRBS in a low-speed open circuit wind tunnel facility to perform velocimetry at multiple locations simultaneously within the boundary layer created over an airfoil. The flow velocity component is measured over a pair of adjacent points (125 µm apart) scanned along the height of the airfoil (12 mm from the surface), as shown in Fig. 1a. The under-expanded jet flow experiments showcase the spatial resolution of the multipoint measurement by probing two distinct locations within the strong velocity gradients present in the flow (Fig. 1b). The flow velocity is quantified from the Doppler-shifted CRBS spectra observed in flow versus stagnant conditions allowing for the determination of the velocity components of interest and the direction of the shift gives insight into the flow direction with respect to the probe volume. Finally, the measurement results are validated qualitatively with imaging techniques such as schlieren/shadowgraphy and quantitatively with Pitot probe measurements and computational fluid dynamic simulations.

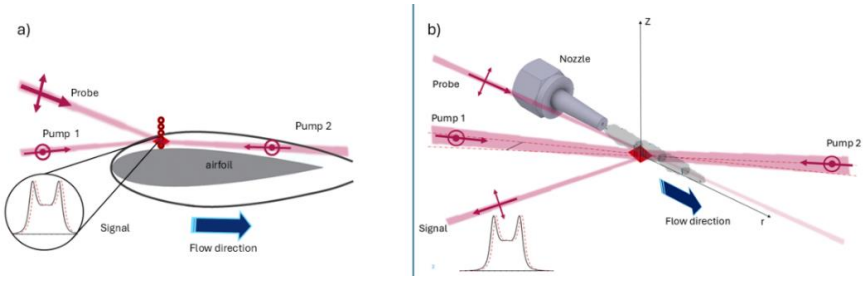

Figure 1. a) A scheme of the single shot CRBS used to characterize the boundary layer over an airfoil. b) A scheme of the two-point velocimetry setup in an under-expanded jet

1. Bak, J., Randolph, R. and Gerakis, A., Journal *of Physics D: Applied Physics*, *56*(7), p.074001 (2023).
2. Kumar, A.U., Karatodorov, S., Kounalakis, M., Covert, D.H. and Gerakis, A., in *AIAA SCITECH 2025 Forum* (2025), p. 0242.
3. Karatodorov, S., Kounalakis, M., Flores, G., Kumar, A., Vaishnav, A., Ramos, J., and Gerakis, A., arXiv:2503.17169.