Phase proper orthogonal decomposition for analysis of spatio-temporal modal dynamics in a co-axial jet

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Local energy transfer in the fashion suggested by Richardson, i.e., that energy is passed from large to small scales through interactions between scales of similar sizes, forms the basis for the cascade picture of the classical picture of turbulence [1], that is hypothesized to result in turbulence equilibrium [2]. The local energy transfer hypothesis appears to be valid to a good approximation in some turbulent flows [3], while there is also evidence that non-local interactions exist in other stationary turbulent flows [4] [5].

To gain more insight into the actual underlying processes of inter-scale energy exchange, we have established an experimental setup to generate stationary and non-stationary turbulent jet flows, see Figure 1 [6] [7]. Seeding micron-sized (air-filled) bubbles into the flow and illuminating them using high-power LEDs, four high-speed high-resolution cameras are used to record and reconstruct the flow field using Particle Tracking Velocimetry (PTV).

To be able to analyze these processes of energy exchange between scales, we have developed a *Phase Proper Orthogonal Decomposition (Phase POD) that can be used to analyze the spatio-temporal modal dynamics in both stationary and non-stationary turbulent flows.* In a non-stationary lid-driven cavity flow simulation[8]., we found clear evidence of non-local energy transfer coupled to the non-stationarity in the analyzed flow.

In the current study, the stationary jet will be investigated for different velocity ratios between the inner jet flow and the outer (concentric) jet flow and analyzed using

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the new Phase POD method. The four-dimensional Phase POD modes will be visualized, and the local and non-local energy transfer results will be shown corresponding to different velocity ratios of the inner jet and the outer jet.

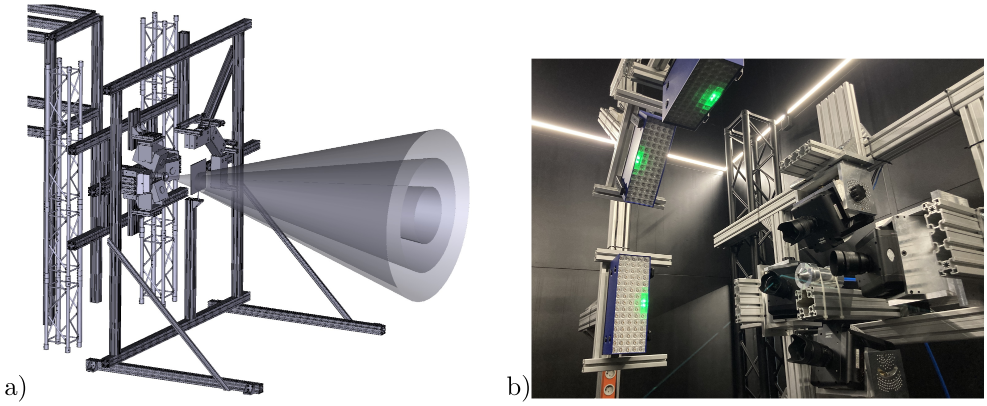

Figure 1: The experimental setup.