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PROPOSITION DE STAGE EN COURS D'ETUDES

Référence : **DAAA-2025-45**
(à rappeler dans toute correspondance)

Lieu : Meudon

Département/Dir./Serv. : DAAA / MAPE

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DESCRIPTION DU STAGE

Thématique(s) : Développement de montage expérimentaux

Type de stage : ☒ Fin d'études bac+5 ☐ Master 2 ☐ Bac+2 à bac+4 ☐ Autres

Title: Super resolved temperature imaging using luminescent temperature sensitive particles

Subject: Understanding and predicting the transport of heat and chemical species in turbulent flows is crucial not only to study the formation and dispersion of pollutants in the atmosphere, for example the evolution of condensation trails or "contrails" in the wake of airplane engines, but also to improve the control of chemical reactors and the thermal management of electric and thermal propulsion systems. Yet an accurate description of turbulent transport remains difficult as many of the flows of interest involve a wide range of length scales preventing the use of Direct Numerical Simulations (DNS). To save computational effort, the smallest scales are not directly simulated and the transport due to sub-grid flow structures is modelled by additional equations. To develop and validate turbulence models, it is crucial to obtain temperature and velocity data in flow experiments with a resolution as high as the smallest scales in the flow.

To achieve high spatial resolution and probe the smallest structures, we advocate the use of sub-micron luminescent particles, seeded into the flow as an intricate web of micro-thermometers. Using super-resolution methods, the particles' positions can be localized with a sub-pixel resolution. This can be done by extracting the center of the particle image which size is limited by diffraction using a 2D Gaussian fit, which is positioned with a sub-pixel resolution. The use of super resolution in thermometry has so far been exclusive to the realm of optically trapped nanoparticles for biomedical applications. Here, we expand the horizon of this concept and leverage its potential for multi-point measurements in turbulent flows. Pushing the frontier further, we will strive for the third dimension, localizing the particle through triangulation from two views, akin to 3D particle tracking velocimetry concepts.

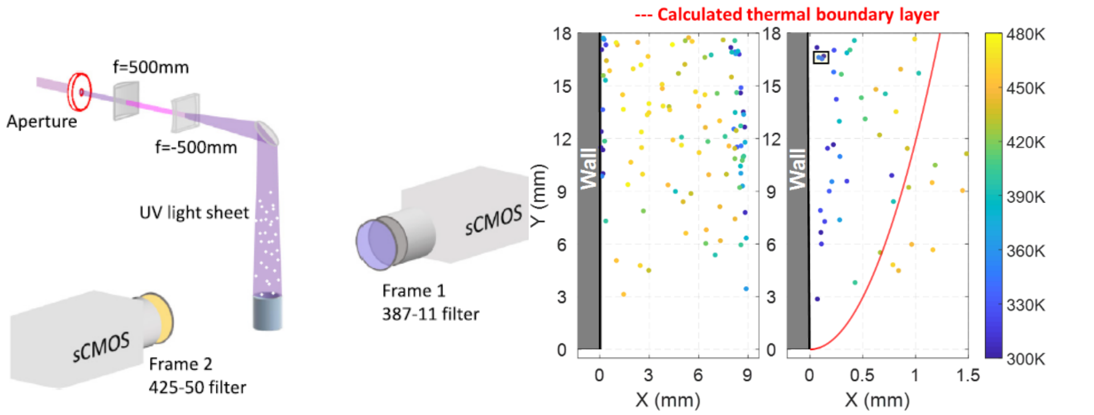

Figure 1 Experimental system for high resolution thermometry and obtained temperature measurements in a hot stream flowing past a cold plate using super-resolution localization [1]

In a recent study performed at the University of Magdeburg in Germany, we established the proof of concept of super-resolution temperature measurement using ZnO luminescent tracer particles in a laminar boundary layer [3]. Here the temperature is measured by exploiting the red shift of the ZnO luminescence emission spectrum with temperature using a two-color imaging system. Each point in Fig. 1b) corresponds to an independent temperature measurement positioned by 2D gaussian fits with an in-plane resolution better than 0.1 pixel, or 1 micron over a field of view wider than 10 mm. Thanks to this high resolution, the temperature profile in a 500-micron thin boundary layer could be measured and validated against theory.

In the project *SUPER resolution flow diagnostics for Scalar Transport And Dissipation (SUPERSTAD)* funded by the French National Science Foundation, the ANR, we propose to extend and apply this measurement concept based on submicron luminescent tracers to test and propose new sub-grid scalar models. As part of this project, we propose an internship project which can be followed by a fully funded PhD position on the topic.

More specifically, the intern will first set-up a similar measurement system at the ONERA research center in Meudon (Fig. 2). The system will be qualified with a simple test case which will be a plate with phosphor particle deposited on it to provide a repeatable particle distribution with all particles being at the same temperature. The temperature of the particle can be modified by heating up the plate.

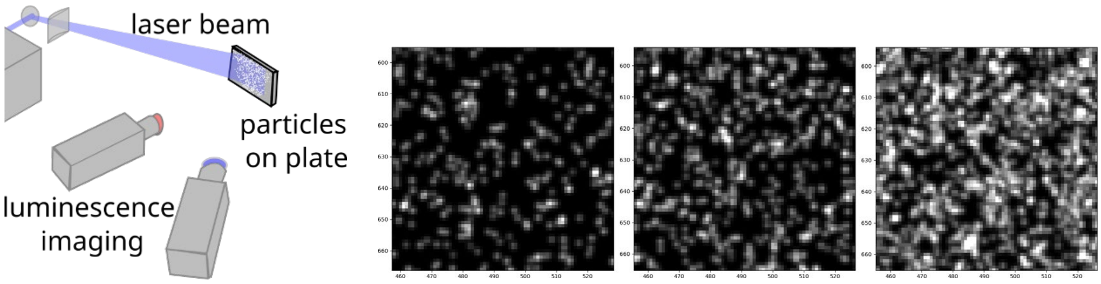

Figure 2: Experimental setup used in the internship. Example of particles images at different concentration

The obtained datasets will then be used to test and develop better algorithms in Python to treat the images formed by each particle on the plate, the goal being to properly isolate and evaluate the signals of each particles in the two images. The original algorithm is based on two dimensional gaussian fit, but there is scope to train Machine learning algorithms to be able to extract the thermometric parameters directly from the particle images.

Following the internship, there is a possibility for a fully funded PhD position for 3 years. The aim of the PhD will be to:

1) extend the subpixel localization approach to all three dimensions using stereoscopic imaging

2) measure velocity at the exact same point in space and time to obtain fully coupled scalar-velocity measurements.

3) Describe turbulent transport terms without filtering the smallest turbulent structures (10's of microns) in a reference turbulent flow: the round heated jet, to test and propose new sub-grid scalar models.

Bibliography:

[1] Xuan, G. et al. High spatial resolution fluid thermometry in boundary layers by macroscopic imaging of individual phosphor tracer particles. Experimental Thermal and Fluid Science (2023), 110977.

Est-il possible d'envisager un travail en binôme ? Non

Méthodes à mettre en oeuvre :

☐ Recherche théorique ☐ Travail de synthèse

☐ Recherche appliquée ☐ Travail de documentation

☒ Recherche expérimentale ☐ Participation à une réalisation

Possibilité de prolongation en thèse : Oui

Durée du stage : Minimum : 5 mois Maximum : 5 mois

Période souhaitée : Février - Juillet

PROFIL DU STAGIAIRE

Connaissances et niveau requis :	Ecoles ou établissements souhaités :
Mécanique des fluides. Master 2	Ecole d'ingénieur et ou Master 2