Gas flows in microsystems find nowadays more and more industrials applications in numerous fields such as aerospace engineering, vacuum systems or MEMS. In such fluidic microsystems, shrinking down the dimensions leads to an increase of the Knudsen number, \( Kn = \frac{\lambda}{L_c} \), ratio of the mean free path \( \lambda \) over a characteristic length \( L_c \) of the microsystem. The Knudsen number encountered in classic microsystems is frequently between \( 10^{-3} \) and \( 10^{-1} \), which is the typical range of the well-known slip flow regime [1]. In this moderate rarefied regime, the classical continuum physics are no longer valid but it is well established that the standard Navier-Stokes and energy equations can be used if accompanied by the appropriate velocity-slip and temperature-jump boundary conditions.

In the past ten years, a number of theoretical and numerical studies, taking into account rarefaction effects have been aimed at modeling gas flow and heat transfer, but there is still a crucial lack of experimental data in this field.

Even if the theory of gas hydrodynamics in the slip flow regime is now supported by smart experiments [2-4], most of these data are only related to micro-flowrates measurements. The experimental analysis of the velocity and the temperature distributions even in simple geometrical configurations remains an issue because it cannot be easily done by conventional methods due to the small size scale involved. At small scale, one of the most common techniques is the use of thermocouples [5, 6] or resistance temperature detectors (RTDs) [7] which are inserted along the inside wall of the microchannels. Infrared thermography has also already been applied in some works but this technique is limited to surface temperature measurement [8-9]. Laser Induced Fluorescence (LIF) thermometry has also been widely used [10-13]. If all these techniques have already been applied at microscale for liquid flows, very few of them have been used for gas flows.

Providing accurate experimental data on temperature distribution in gas microflows is a challenge for the next years [21], which would allow a real discussion on the validity of velocity slip and temperature jump boundary conditions, as well as on the limits of applicability of slip flow theory, in terms of degree of rarefaction. It is then necessary to develop techniques to be able to measure fluid temperatures at small scales and to design original fluidic microsystems involving gas flow and heat transfer.

The objective of the project is to build a specific experimental setup based on molecular tagging. As far as we know, MTV technique has been used once to measure temperature by Hu [15] but in a liquid application and with millimetric dimensions. In our research group, this technique is currently being developed to measure velocity fields. The principle is based on luminescence phenomenon [16]: the flow is seeded with fluorescent or phosphorescent molecules which emit light when they are activated by photons. Typically, a slice of flow is tagged by a laser. A comparison between the initial tagged line and the distorted line detected a short time later allows determining the displacement of the tagged slice and the velocity profile. The setup is shown in Figure 1 and an example of velocity profile extraction is illustrated in Figure 2.

For temperature measurement, we will exploit the properties of the phosphorescence lifetime dependence on the temperature. The first step will be to implement the technique for gas and to compare the experimental data to results obtained with others techniques. Then, the validity of simplifying assumptions used in analytical models and numerical simulations will be discussed. New developments with improved accuracy could also been proposed.
The microfluidics research group of the Institut Clément Ader (ICA) at INSA Toulouse has an internationally recognized experience in experimental analysis of gas microflows [2, 3, 14]. It has already designed original experimental setups and provided accurate data on the hydrodynamics of gas microflows (Figure 3). It also develops numerical tools for accurate modeling of thermally generated gas microflows [22, 23].
The PhD project will be co-supervised by Prof. Stéphane Colin and Dr. Christine Barrot. Stéphane Colin is the editor and author of several textbooks in microfluidics [17, 18]. The candidate will benefit from the experience gained within the GASMEMS European Network, coordinated by Stéphane Colin (see details at http://www.gasmems.eu). This Initial Training Network offers training to young researchers in the field of rarefied Gas Flows in Micro Electro Mechanical Systems. In the framework of the proposed project, an international collaboration is foreseen with the following universities from the GASMEMS Network: the University of Limerick-Ireland (Dr. Newport) for complementary experimental approaches (μ-interferometry), the University of Bologna-Italy (Pr. Morini) for the expertise in the development of heat transfer models at microscale, the University of Karlsruhe-Germany (Pr. Brandner) for the fabrication of the experimental micro-devices including pressure and temperature sensors and the polytechnic University of Milano-Italy for molecular simulation by the Direct Monte Carlo Simulation method. Our research team has already active collaborations with joint publications with these research groups.
