EXPERIMENTAL INVESTIGATIONS OF HIGH ENTHALPY SUPERSONIC FLOWS FOR PLANETARY ATMOSPHERIC ENTRY APPLICATIONS

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The prediction of heat and mass transfers occurring during atmospheric entries is a fundamental and challenging step prior to Thermal Protection Systems (TPS) design and optimization. Significant advances are achieved through accurate modeling of the complex physical processes involved in radiative flows. The aim of this thesis is to produce experimental data to rely on the predictive capabilities of the theoretical models adopted in the tools developed at VKI for atmospheric entry applications. VKI Plasmatron and Microwave Plasma Torch facilities are employed to generate flow representative of atmospheric entry plasmas. Optical emission spectroscopy technique is applied to characterize plasma thermodynamic state and appropriate rebuilding methods are developed to cover different equilibrium situation detectable with atomic and molecular emission measurements. Comparison between measured quantities (temperature(s), density populations (Fig. 1) and computational predictions will allow an independent assessment of the thermodynamic state.

First investigations consist in evidencing situation close to Local Thermodynamic Equilibrium (LTE) in air and CO_2 plasma jets at different pressures. Macroscopic plasma parameters such as heavy particle translational temperature and electronic density are derived. LTE assumption is assessed measuring various internal temperatures such as excitation, rotational and vibrational. At high pressure, thermal and chemical equilibria are achieved. Conversely at low pressure, the atomic electronic level distribution reveals disagreement between Oxygen and Carbon excitation temperature in CO_2 plasma that is currently explained by the influence of recombination processes.

Further investigations consist in examining strong departure to LTE in supersonic plasma jets (Fig. 2). Electronic temperature and density influenced by alternatives compression and expansion zones within the jets leads to various equilibrium situations that involve non Boltzmann distributions of vibrational states of diatomic molecular species. Appropriate diagnostic based on spectra fitting method is used to characterize the departure from equilibrium.

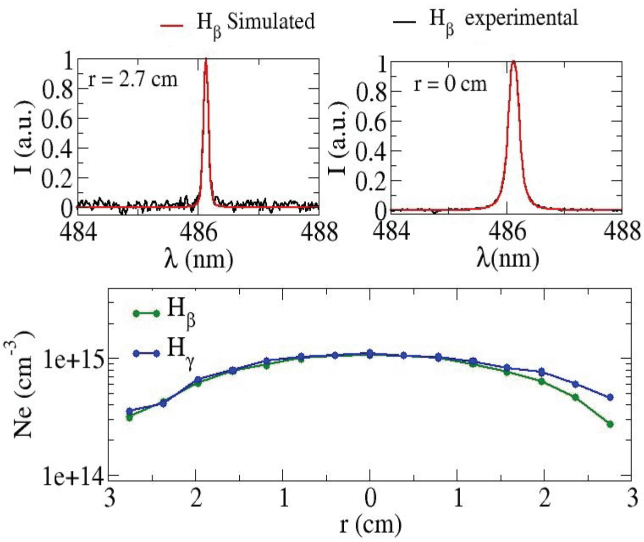

Figure 1 : Electronic density measurement from Stark broadening of hydrogen lines in air plasma seeded with a small amount of water

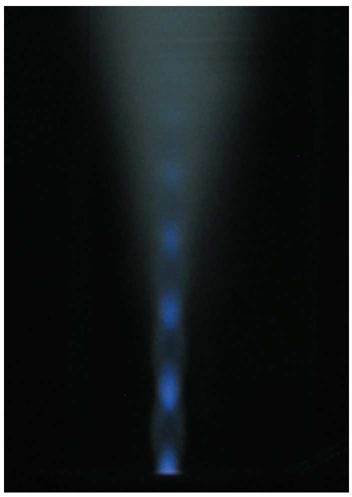

Figure 2 : Supersonic CO_2 plasma jet