Determination of transport properties of fluids by optical methods

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There is a considerable interest in the development of optical methods for the characterization of the often simultaneous occurrence of heat and mass transfer in multicomponent fluids. When liquid mixtures are subjected to a temperature gradient, there is not only heat conduction but also a diffusive mass flux caused by the Soret effect until a steady state is reached. In this steady state, the so-called thermodiffusion is counterbalanced by the Fick diffusion, and a concentration gradient is established on top of the temperature gradient. In addition, these gradients are accompanied by strong non-equilibrium fluctuations, which extend over the entire dimensions of the system.

In this workshop we will discuss some fundamentals of equilibrium and non-equilibrium thermodynamics, in particular how concentration gradients are formed due to the Soret effect. At first we will pay attention to the analysis of fluctuations at macroscopic thermodynamic equilibrium for the determination of the Fick diffusion coefficient and the thermal diffusivity. Then, starting with the extended diffusion equation, we will derive solutions for the concentration field under common experimental geometries and introduce modern optical techniques for the measurement of the Fick diffusion, thermodiffusion and Soret coefficients. Prominent examples for such methods are photon correlation spectroscopy, optical beam deflection and thermal diffusion forced Rayleigh scattering. Finally, we will present optical techniques that are based on the analysis of nonequilibrium fluctuations for the determination of the thermal diffusivity, Fick diffusion, thermodiffusion and Soret coefficients as well as the kinematic viscosity. Some of the methods will be demonstrated in live during the workshop.

Because of the recent growing interest on ternary mixtures, we will also discuss the limits of single-wavelength optical methods. Due to the additional degree of freedom, these optical methods cannot provide sufficient information for the determination of all transport properties in ternaries. By adding an additional laser wavelength for detection, also ternary mixtures become experimentally accessible. Such “two-color detection” schemes are, e.g., employed in microgravity measurements on ternary mixtures within the DCMIX project aboard the International Space Station and in the NeufDix microgravity project for the investigation of giant nonequilibrium fluctuations. Towards the end of our workshop, we will explain the ideas behind such “two-color detection” schemes and develop an understanding for the fundamental limitations of such methods, which result mainly from ill-conditioned contrast factor matrices.