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Simultaneous Determination of Multiple Transport Properties from the Analysis of Non-Equilibrium Fluctuations by Shadowgraphy

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In numerous industrial and natural processes with fluid mixtures, heat, mass, and momentum transfer occur simultaneously. For the detailed description of such processes, thermal diffusivity, mass diffusivity, thermodiffusion coefficient, and kinematic viscosity have to be known at relevant conditions. These transport properties are often determined independently within different setups.

In the present contribution, we demonstrate the applicability of quantitative shadowgraphy for the determination of the named transport properties within a single experiment under steady state conditions. In a Soret experiment, the application of a macroscopic temperature gradient to a binary mixture leads not only to the formation of a concentration gradient, but also to intense hydrodynamic fluctuations that extend over the entire size of the system. The dynamics of these so-called non-equilibrium fluctuations (NEFs) is driven by diffusion of heat and mass as well as by viscous forces, confinement, and on Earth, buoyancy. To resolve the dynamics of those NEFs over a large spatial scale, a stack of images acquired in the near-field using a shadowgraph apparatus is analyzed with the so-called differential dynamic algorithm. The latter consists of a 2D fast Fourier-transform of all possible differences between images within the stack. The dynamic structure factor containing the information on the relaxation behavior of NEFs between few micrometers and few centimeters is calculated by performing an azimuthal average of the Fourier power spectra. From the mean lifetimes of NEFs arising from fluctuations in temperature, concentration, and velocity at different wavelengths, the thermal diffusivity, mutual diffusivity, thermodiffusion coefficient, and kinematic viscosity can be determined. For a test of the technique as well as of the optical setup installed at AOT-TP, first results are shown for reference systems, e.g., for mixtures consisting of 1,2,3,4-tetrahydronaphthalene and n-dodecane.