On the measurement of multi components evaporating droplets by rainbow refractometry.

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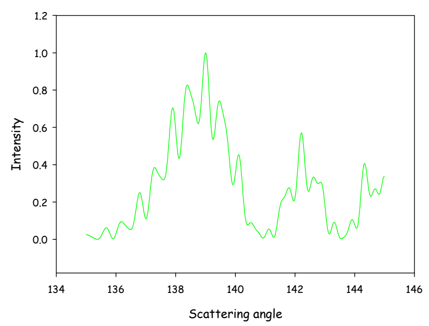
The understanding and the quantification of the evaporation of realistic sprays is a challenge, for example to control the behavior of plane engine or car engine. To reach this aim, the measurement of evaporation of multi component droplets must be carried out for individual droplet as well as for cloud of poly dispersed droplets.

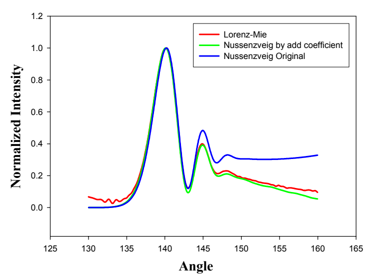
Several techniques are used to obtain information on the temperature of evaporating droplets. Infra red measurements give an information on the surface temperature. Laser Induced Fluorescence (LIF) give an information on the temperature inside of the droplet. Rainbow refractometry is sensitive to both the temperature and the composition of the droplets through refractive index dependence on these properties. The aim of the work that we purpose for this conference is a detailed numerical study of the sensitivity of rainbow refractometry to both temperature and composition gradients for two configurations: classical rainbow refractometry for individual droplet and global rainbow refractometry for poly dispersed cloud of droplets.

When working on individual droplets or on a line of identical droplets, the recorded scattered light in forward and backward is characterized by high frequency interference fringes between the different kind of rays (directly reflected ray, refracted rays, p times internally reflected rays). From these interference fringes an accurate information on the size and refractive index of the droplets could be extracted. The sensitivity of this information to gradients will be discussed in the framework of multilayered Lorenz-Mie predictions interpreted by the Nussenzveig theory.

When working on a cloud of polydispersed droplet, the recorded scattered light is characterized by only a low frequency evolution of the intensity from which information on the size distribution and an average refracted index could be extracted.



(a)



(b)

Figure 1 displays two exemplifying diagrams: figure 1a is the rainbow of an individual droplet (d = 75 µm, m = 1.33), figure 1b is the global rainbow for a cloud of droplet ($\bar{d} = 50\ \mu m, \sigma = 100, m = 1.33$).

INDIVIDUAL DROPLETS

The rainbow scattering pattern is a function of the particle size and refractive index.

In rainbow technique for individual droplets, the size information is often extracted from the forward scattering pattern which is assumed to be insensitive to the refractive index (value and gradient) and inhomogeneities, while the refractive index is extracted from the backward scattering at rainbow angle. We first quantify this procedure for the condition under study. Forward scattering (between 27° to 33°) and Backward scattering (from 135° to 145°) computed by Lorenz-Mie theory are interpreted in the framework of the Nussenzveig theory.

For homogeneous particle, the Nussenzveig theory is as accurate as Lorenz-Mie theory and as fast as Airy theory. We will show, that for homogeneous particle, the measurement accuracy, for particle of about 100 µm, is better than 0.01 µm for the size and 0.001 for the refractive index.

For no homogeneous particle, internal gradients are simulated according with an exponential law (see equation 1), and computed in the framework of Lorenz-Mie theory for multilayered sphere. This law used three parameters: the refractive index at the surface n_s of the droplet, the refractive index at the center n_c of the droplet and the coefficient b which controle the evolution from the center to the surface.

$$n = n_c + (n_s - n_c)\frac{e^{br} - 1}{e^b - 1} \qquad (1)$$

Figure 2 displays such refractive index laws for some values of b. More specifically we will discuss the behavior of forward scattering and rainbow scattering for a mixture of ethanol and acetone.

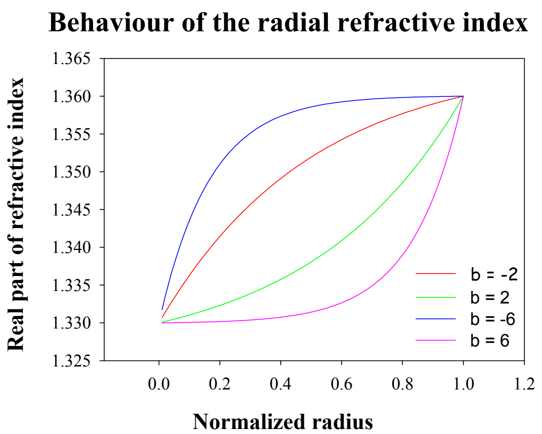


Figure 2: Example of refractive index gradients

Finally, the processing of real experimental signals will be carried out. Figure 3.is an example of a such experimental signals.

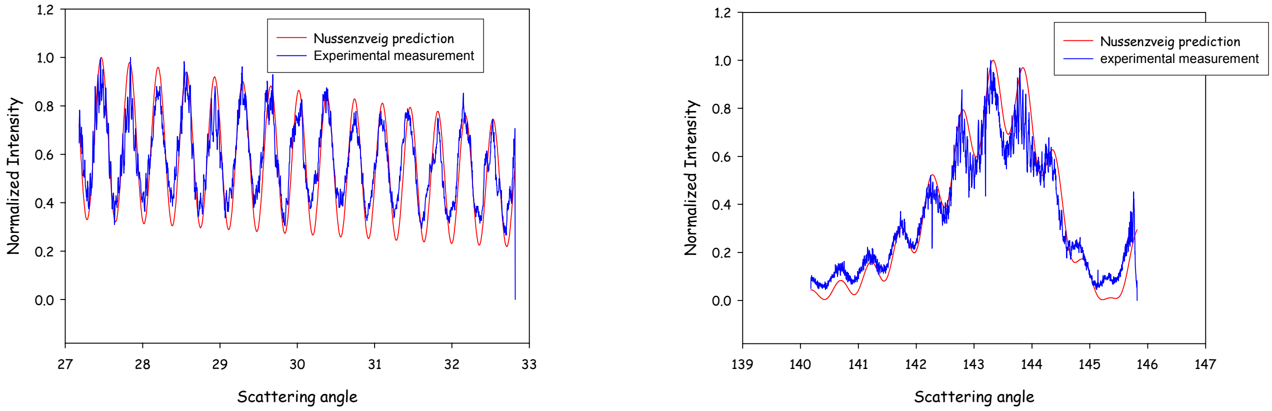


Figure 3: a couple of experimental rainbow signal, with the best fitting by Nussenzveig theory.

CLOUD OF DROPLETS

The same discussion as for the individual rainbow will be carried out for global rainbow refractometry. The sensitivity of the technique to refractive index gradient will be quantify and the possibility of identify such gradient will be discussed.