Characterization of LNH_3 Spray and Light Scattering from Single LNH_3 Droplets

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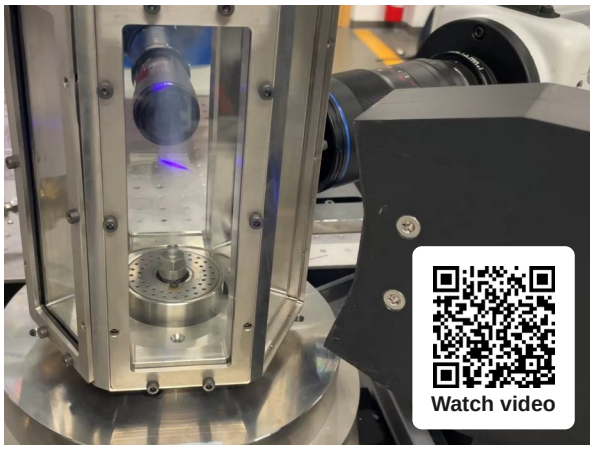

Figure 1: Experimental setup with the combustion chamber in the center and a measurement probe on the right.

1 Motivation

Optical droplet characterization in dense sprays is a particular challenge for all methods based on **forward scattering**, including laser diffraction, phase-Doppler and imaging techniques. The causes are the strong attenuation of light by absorption in the spray and multiple scattering, which superimposes on and distorts the scattered light relevant for the evaluation. In addition, optical access is often limited, which restricts forward-scattering methods further or makes them impossible.

Such dense sprays with limited optical access occur in particular in **combustion research**, for example in closed combustion chambers in which the spray is generated and ignited. The droplets exist only briefly after leaving the nozzle. In ammonia sprays (LNH_3 spray), the droplets can also contain **gas inclusions**.

2 Measurement principle

To overcome the limitations of forward-scattering methods and to detect droplets with gas inclusions, this work uses the **backscattering**-based measurement technique **TSTOF** [1]. It captures second-order light scattering: the detected signal passes through the droplet twice and therefore also carries information about its internal structure. TSTOF records four light-scattering signals per droplet, from which droplet velocity and size can be determined redundantly.

$$I(x,y,z) = \frac{2P_0}{\pi w_x(z)\, w_y(z)} \mathrm{Exp}\left\{-\frac{2x^2}{w_x^2(z)} - \frac{2y^2}{w_y^2(z)}\right\} \xRightarrow{y\to\infty,\ z\to 0} I(x) = I_0\, \mathrm{Exp}\left\{-\frac{2x^2}{w_{x0}^2}\right\} \xRightarrow{v = x/t} S(t) = \sum_{p}^{\{0,1,2,1,\ldots\}} S_p \left\{-\frac{2(t-t_p)^2}{\sigma^2}\right\}$$

Intensity distribution of the Gaussian beam | Profile along the flight direction in the focus | Time signal as a sum of Gaussian peaks

3 Morphology of ammonia breakup

Figure 2: Morphology of ammonia breakup at the exit of borosilicate nozzles (D = 100 µm) with varied geometry and superheat. **Left:** transition regime for a short channel (L/D = 2.5) and high superheat (R = 13); characteristic bursting of the liquid jet directly at the nozzle exit. **Center:** detail of the droplet zone downstream; secondary breakup of droplets formed primarily by Rayleigh–Taylor instabilities, caused by internal bubble formation and flash evaporation. **Right:** fully developed flash-boiling spray for an extended channel (L/D = 10) and moderate superheat (R = 8).

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[1] W. Schäfer, *Time-Shift Technique for Particle Characterization in Sprays*. Ph.D. dissertation, Technische Universität Darmstadt, Germany, 2012; book edition: Berlin, Germany, 2013, ISBN 979-8161309988. https://amzn.eu/d/08dPYjDf

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