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# Refractive index determination of dynamic droplets in a flow by analyzing light scattering signals with a machine learning approach

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**Abstract** – In this study, we present a new method for determining the refractive index of dynamic droplets in a spray using a machine learning approach, where the four light scattering signals from individual droplets were analyzed. These light scattering signals were generated by a Time-Shift-Time-of-Flight (TSTOF) system, known by some brand name SpraySpy. The spray was produced using a flat fan nozzle, and to vary the refractive index, a water-glycerin mixture with different mixing ratios was used. First, a machine learning model was developed to analyze the four light scattering signals. In addition, we explored whether the number of signals could be reduced while maintaining calculation precision.

## 1. Introduction

In spray characterization, determining the refractive index $m$ is just as crucial as measuring droplet size $d$ and velocity $v$. Dynamic droplets are droplets with a certain velocity within a flow or spray and exhibit varying trajectories. The measurement of individual static droplets, such as when a droplet is levitated acoustically or electromagnetically (Heinisch 2008), can be done by analyzing rainbow light scattering. However, determining the refractive index of individual dynamic droplets within a flow remains a significant challenge, as there are currently no commercial instruments capable of this measurement.

In 2011, a method was introduced as part of Schäfer's dissertation (Schäfer 2012) that enables the determination of the refractive index of transparent, individual dynamic droplets. This method was later patented by the Technical University of Darmstadt (Tropea et al. 2011), (Tropea et al. 2016) and published in (Schäfer et al. 2014), where initial experimental results validated its effectiveness. The proposed method is based on the analysis of light scattering signals generated by the Time-Shift method, which was first introduced by Semidetnov (1985) and Pavlovskii et al. (1991). A successful further development of this technique was achieved through several dissertations at the Technical University of Darmstadt by Damaschke (2003), Bakis (2010), Kretschmer (2011), Schäfer (2012), Rosenkranz (2016) and Li (2020).

The method for determining the refractive index of individual dynamic droplets, as described in (Schäfer 2012) (Tropea et al. 2011), (Tropea et al. 2016) and (Schäfer et al. 2014), is based on the signal processing of time-shift signals, focusing only on the peak positions of the signal. Due to technological constraints at the time, analyzing the signal shapes and other parameters was considered but could not be implemented.

## 2. Basic principle of TSTOF technique

The basic principle of the TS technique is illustrated schematically in Figure 1. It is based on the characterization of light scattered by individual droplets in a shaped light beam. A shaped light