AI-assisted real-time monitoring of particle mass concentration within droplets in suspension sprays

Walter Schäfer [1*], Tobias Jakobs [2] and Patrick Stegmann [3]

1. ai-quanton, Dr.-Werner-Freyberg-Str. 7, 69514 Laudenbach, Germany
2. ITC, KIT, 76344 Eggenstein-Leopoldshafen, Germany
3. UMD & NASA Goddard Space Flight Center, Greenbelt MD, USA

* info@ai-quanton.com

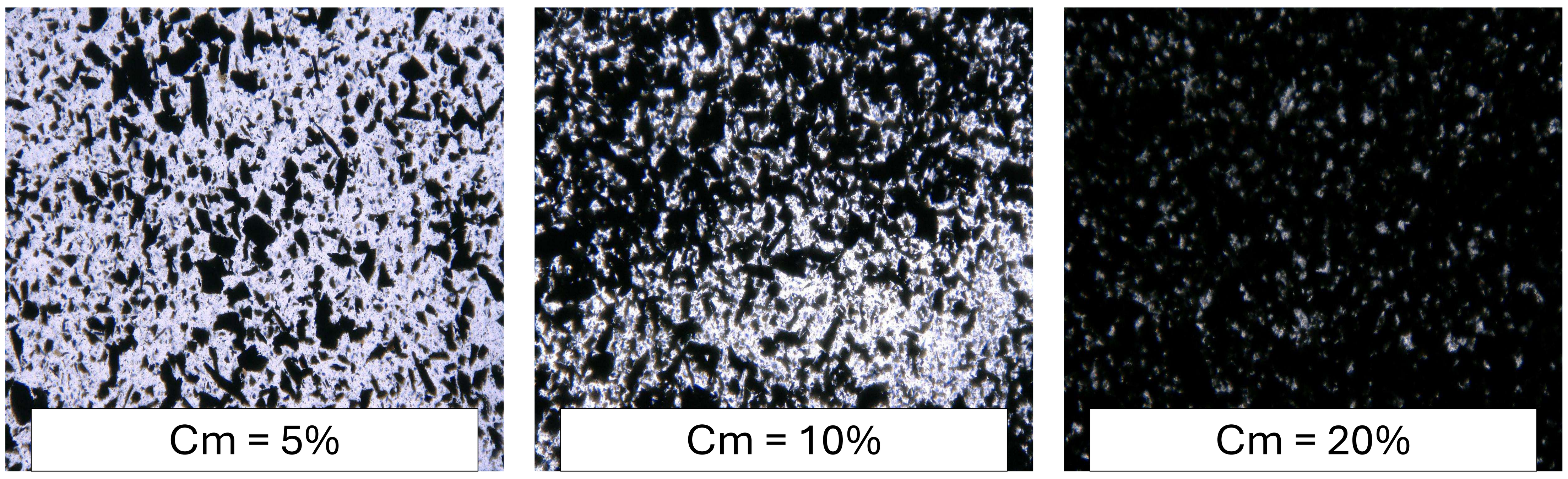

Figure 2: Images of suspension with different particle concentrations **Cm.**

We present a novel method for droplet and particle characterization based on the analysis of continuous light scattering signals from individual droplets or particles interacting with a shaped light beam. Four detectors collect scattered light at different angles, providing four distinct data streams associated with the droplet or particle flow. These signals are transformed into particle-tensor-AI **PTA** representations (see Fig. 1), which can be constructed in RGB images, with each color channel corresponding to a specific detector.

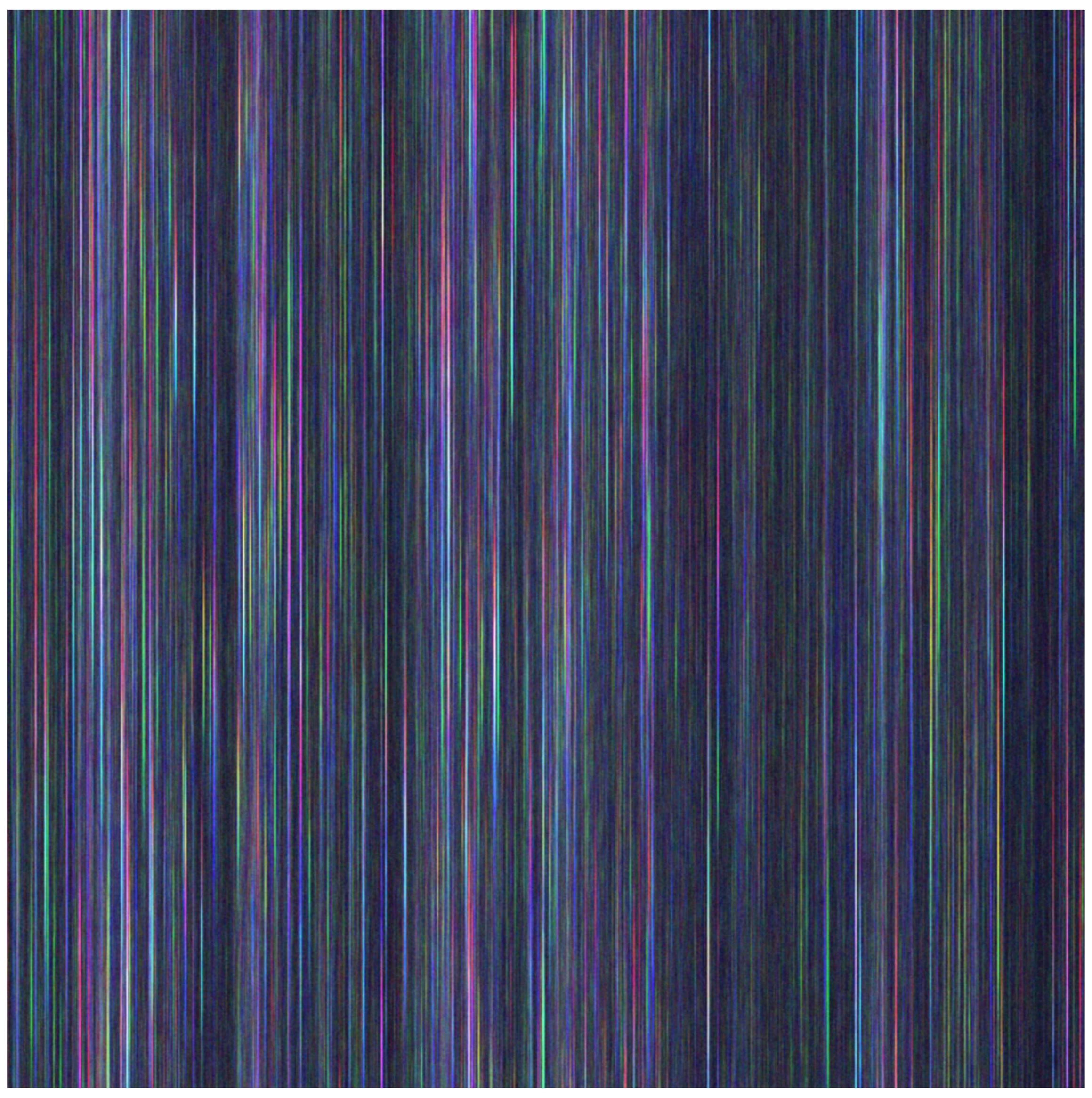

Figure 1: Example of a **PTA** with 3x1024x1024 dimension

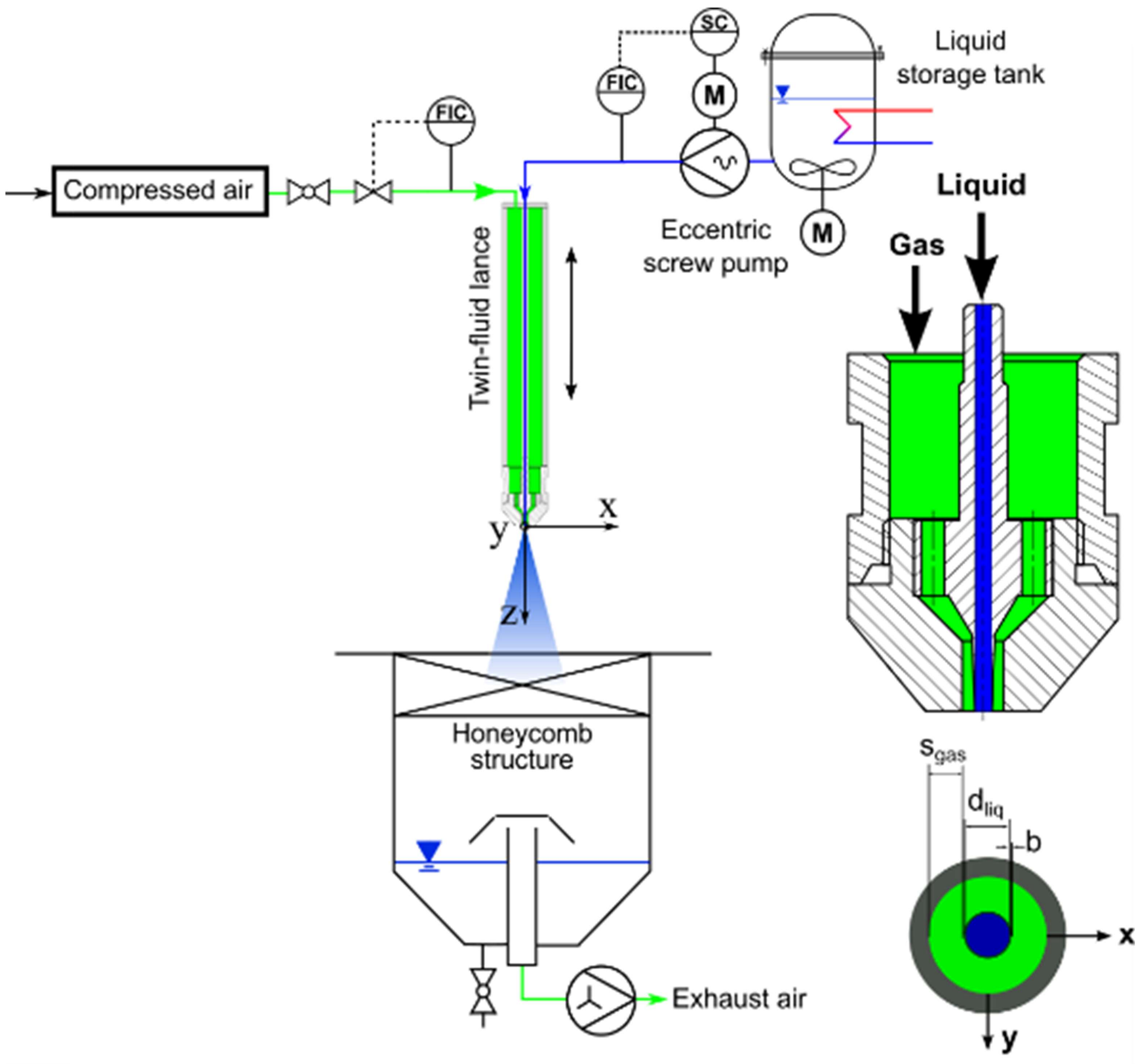

Figure 3: Atmospheric spray test rig (ATMO) with the applied twin-fluid nozzle

The suspension sprays were generated using a gas-assisted coaxial nozzle operated at constant atomization parameters $\dot{\mathrm{V}} = 7.5\,\mathrm{m^3/h}$ and $\dot{\mathrm{M}} = 12.56\,\mathrm{kg/h}$. Suspension slurry with three different particle concentrations $\mathbf{Cm} \in \{5\%, 10\%, 20\%\}$ were atomized. TSTOF measurement system is used to generate light scattering signals from dynamic suspension droplets by analyzing the interaction between a shaped light beam and a suspension droplet.

The predictive capability of **PTAs** was evaluated for determining the mass concentration of coal particles suspended in a coal–water slurry. All AI models were trained in classification mode, where **PTAs** were limited to dimensions of 3×256×256 with 8-bit resolution. With downsampling the temporal coverage of PTAs were extended approximately to **7ms**. To incorporate signals from all four detectors, multiple input combinations were tested, ranging from single-detector inputs (A) to three-detector groupings (B–C–D). Grayscale tensors, obtained by averaging detector signals, were also evaluated. In total, 168 configurations were analyzed. Training and testing were performed on an NVIDIA RTX GPU (**12GB** memory) using the TensorFlow framework. The classification task employed **CNNs** implemented in TensorFlow/Keras.

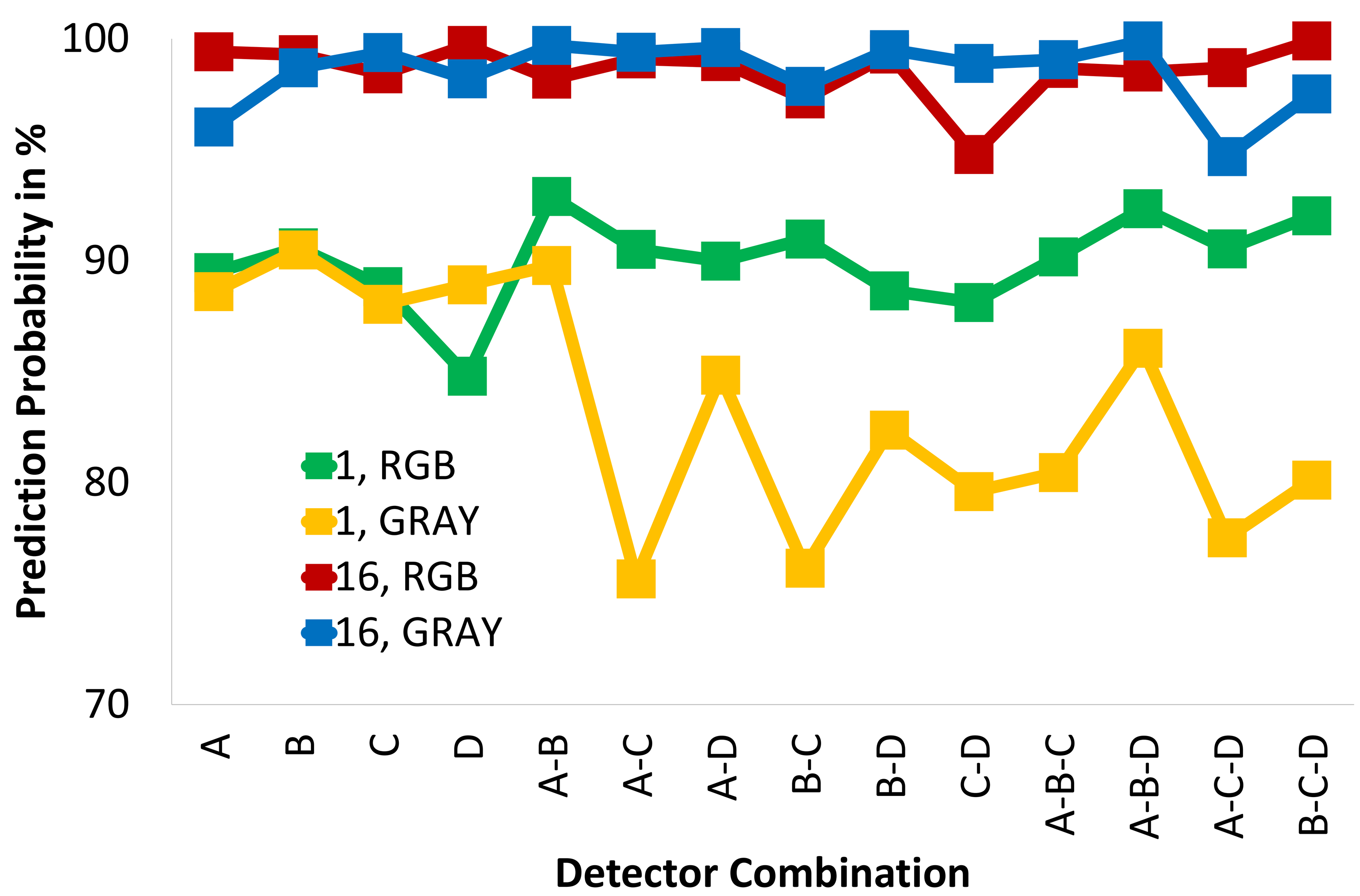

Figure 4: Prediction error of **PTA**-based classification of mass concentration **Cm** for different detect combinations.

The use of **PTAs** in combination with AI opens new diagnostic possibilities for investigating complex sprays and particle-laden flows. Potential applications include determining droplet size and velocity distributions, estimating refractive indices of multicomponent liquids, quantifying solid loading in suspension sprays, monitoring pigment distribution in paint sprays, and enabling real-time diagnostics in industrial atomization and coating processes.