

Introducing Background-Oriented Schlieren (BOS) to Cone Calorimetry

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INTRODUCTION

- Cone calorimetry provides key data on flammability, heat release, and material degradation.
- Convective heat and mass transport above the sample are critical but remain poorly resolved.
- Previous studies used:
 - Heat flux gauges / thermocouple rakes → indirect convective heat transfer.
 - PIV → first optical velocity-field measurements, but limited by access and seeding.
- Optical flow diagnostics in cone calorimetry are still in their infancy.
- This project initiates a systematic optical study starting with BOS, extending to PIV and related techniques.

OBJECTIVES

- Develop a non-intrusive, spatially resolved framework to study convection in cone calorimetry.
- Demonstrate BOS for visualization of buoyant thermal plumes above heated surfaces.
- Use an inert calcium silicate sample to isolate pure convection effects.
- Establish optical access and image quality required for future PIV and quantitative BOS.
- Lay the groundwork for a multi-technique optical approach (BOS + PIV + thermography).

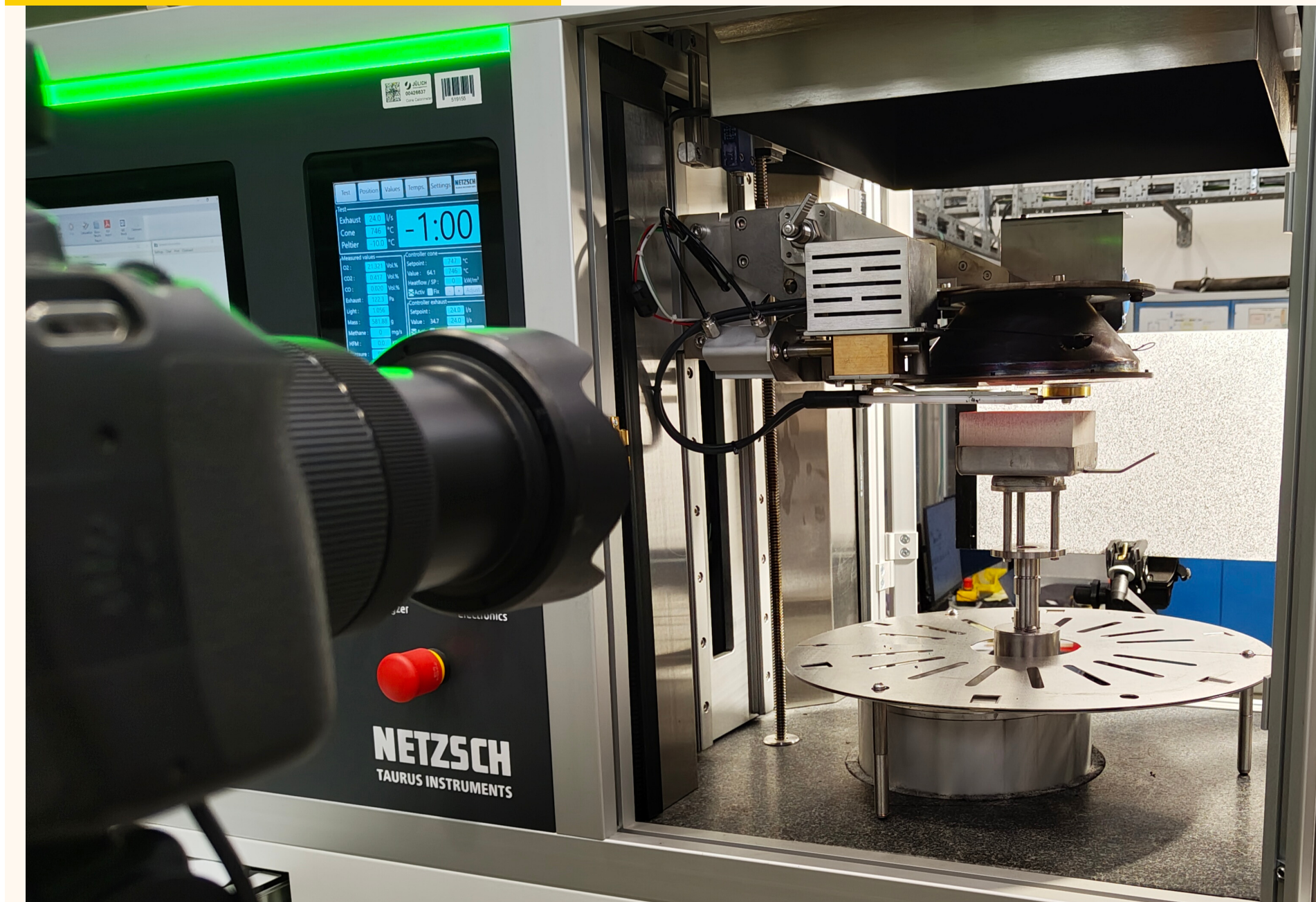
METHODS

- Standard **cone calorimeter** with optical side access.
- **Random dot background** positioned behind the sample for BOS imaging.
- Sample: inert **calcium silicate board**, exposed to an external heat flux of **50 kW/m²**.
- Distance between heater and sample: **50 mm** (increased for optical access).
- Cone door kept **open** to study ventilation effects.

Background-Oriented Schlieren (BOS) Principle

- Visualizes **refractive-index gradients** in air caused by temperature and density variations.
- Heating the sample produces a **buoyant plume** that refracts light and shifts the dot pattern.
- The **apparent displacements** between reference and heated images correspond to local density gradients ($\partial n/\partial x$, $\partial n/\partial y$).
- Image pairs analyzed in **PIVlab** (MATLAB cross-correlation) to compute displacement vectors and visualize the convective structure.

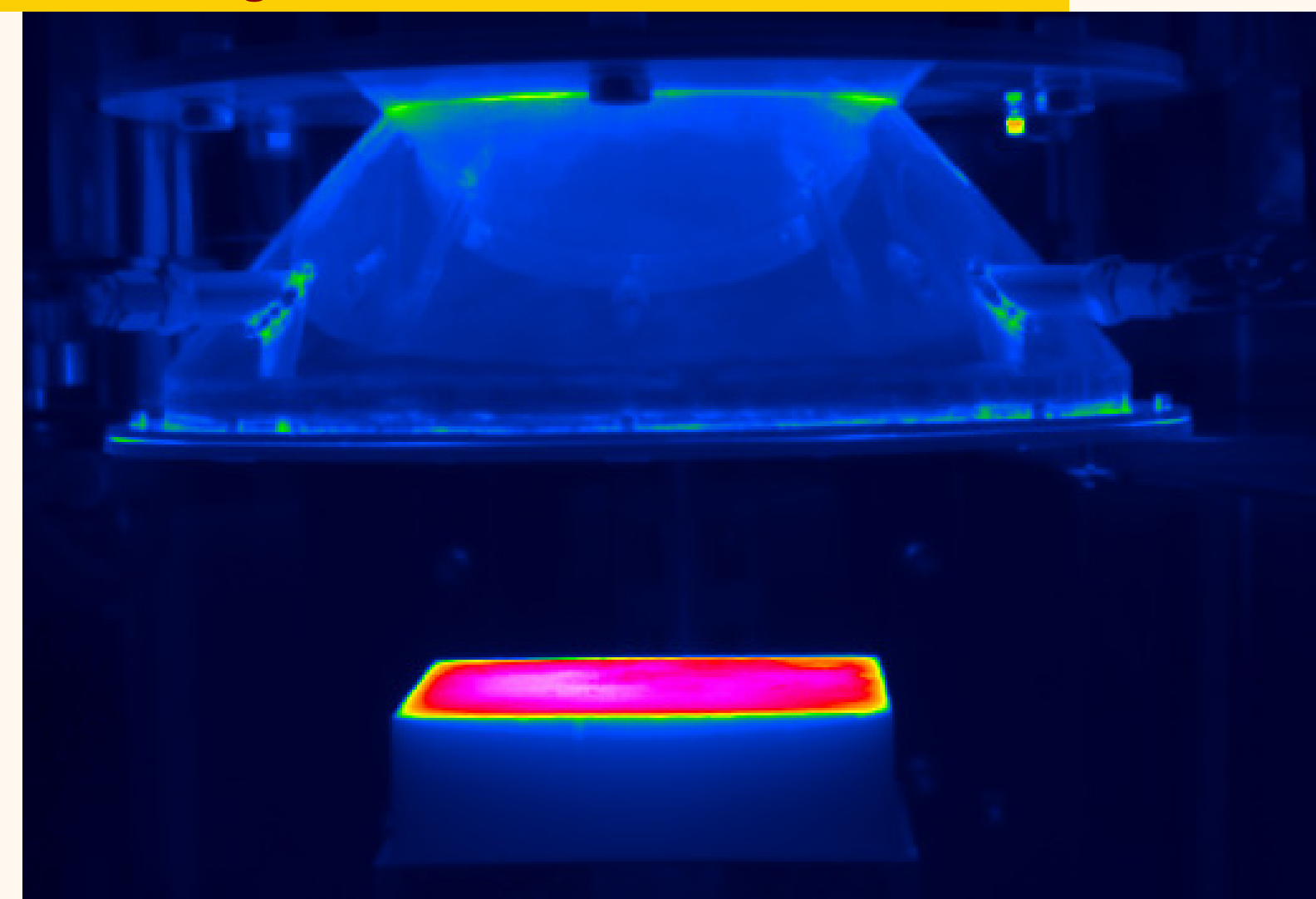
Measurement setup



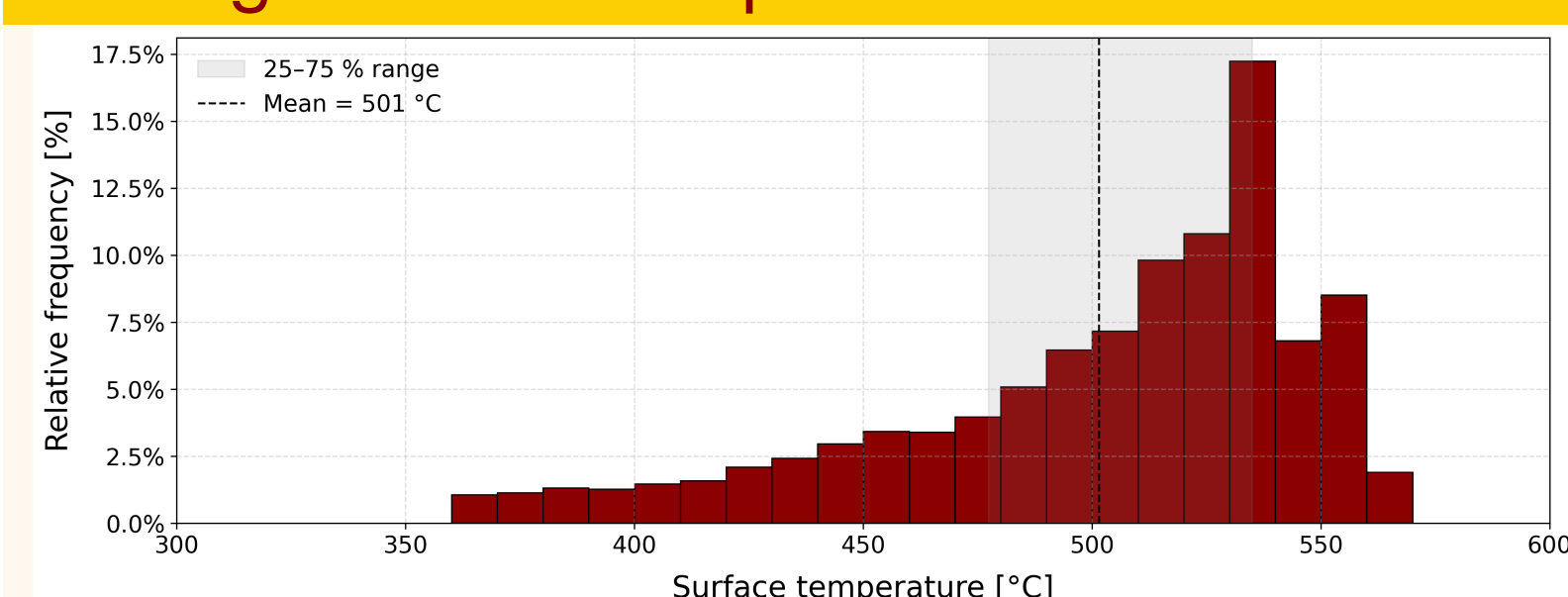
RESULTS

Irradiation uniformity check

IR-Image of calcium silicate block



Histogramm of Temperature Data on CaSi-Block



- Verified heating uniformity at 50 mm heater–sample distance.
- Confirms homogeneous irradiation and valid boundary conditions for BOS.

BOS visualization of the buoyant plume

- Visualization of refractive-index gradients above the heated calcium silicate surface, captured using Background-Oriented Schlieren (BOS).
- The overlay combines the optical image and BOS displacement field, highlighting buoyant flow structures in the near-surface region.
- The observed pattern reveals coherent upward motion along the central plume axis and lateral entrainment near the edges.

BOS Image Pair: Reference vs. Heated Flow

Reference frame (no heating)

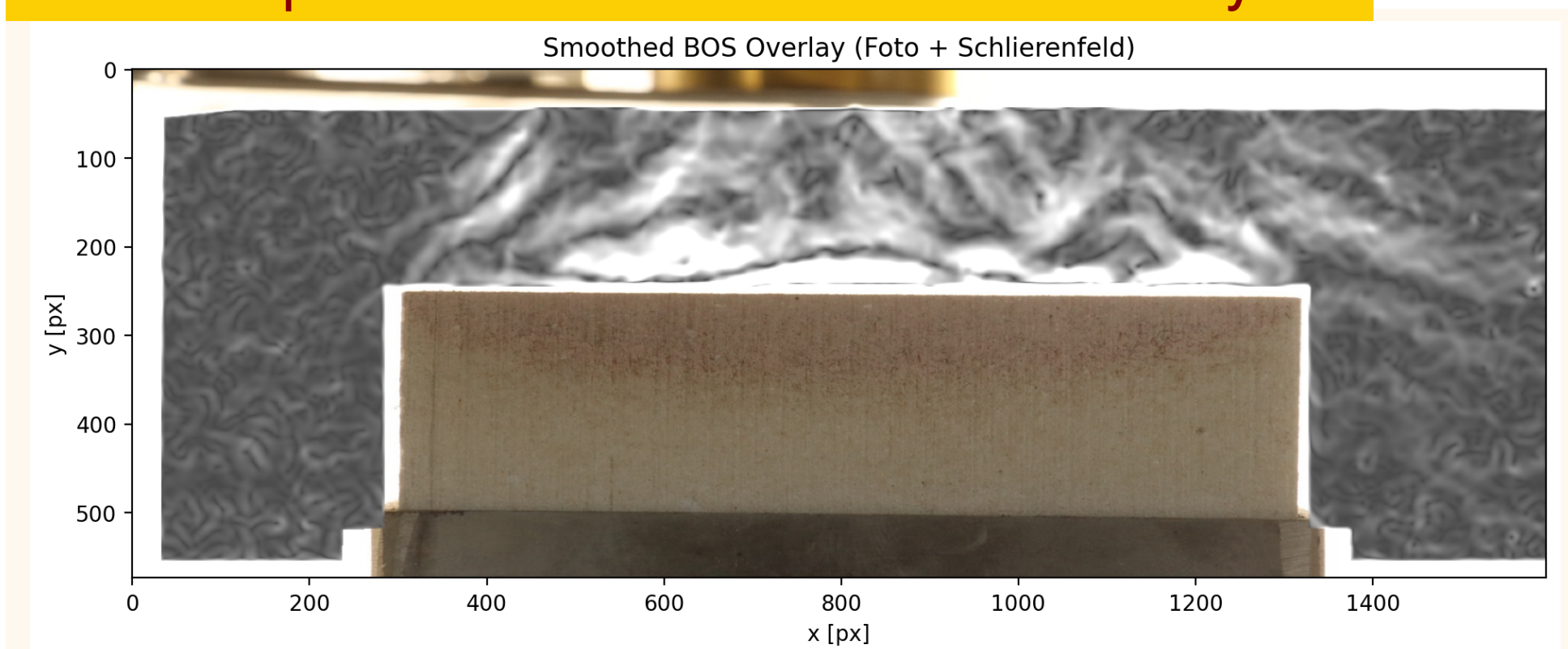


Heated sample (50 kW/m²)



- Reference and heated images captured under identical setup.
- Dot-pattern distortion indicates refractive-index change above the heated surface.

BOS displacement field from PIVlab analysis



DISCUSSION

- BOS successfully visualized refractive-index gradients above the heated calcium-silicate surface. layer in a cone calorimeter.
- The gradients correspond to the buoyant plume structure expected for convective heat transfer.
- Results confirm that BOS can resolve the near-surface convective layer in a cone calorimeter.
- Minor artefacts from optical turbulence suggest improvements in illumination and image averaging.
- Provides a foundation for quantitative BOS calibration and future comparison with PIV velocity fields.

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