Motivation and Goals

Analysis of highly resolved gas flow fields in interstices

- Measurement of highly resolved (ms, 100µm) gas velocity and turbulence data for validation in numerical and experimental partner projects
- Direct optical measurement of flow fields in the gas phase of packed beds
  - Avoid limitations of similarity theory used for results of refractive index matching for liquids
  - But optical distortion for transparent bulk particles
- Solution: reconstruction with ray tracing simulation
- Adaptation of ray tracing to PIV
- Introduction of specific physics to existing numerical models

Challenges

- Adaptation of ray tracing for PIV
- Reproduction of exact experimental set-up in simulations
- Optimization of PIV lighting in interstices and calibration procedures
- Numerical optimization for best results
- Effective Monte-Carlo sampling strategies for ray tracing

Results

Inlet conditions and bed height independent flow

- PIV Measurements of the empty bulk reactor
  - Particle Reynolds number range from 200 to 500
  - Symmetric inlet flow (Fig. 5)
- PIV Measurements in different bed heights
  - Symmetric flow above the bed
  - Bed height independent flow field can be assumed from layer 17 to 21 where the inlet independent bed height is reached (Fig. 6)
- Flow fields above odd layers of spheres as validation data will be provided for C6

Simulation

- Robust and automatic reconstruction reconstruction
  - Removal of artifact by using ray differentials as weighting of ray samples
- End-to-end simulation of PIV setup allows for rapid testing of experimental setups and reconstruction methodologies
  - Example: stereoscopic setup to reduce or remove regions where optical distortion is too high for reconstruction (Fig. 8)
- Ray tracing applied to radiative heat transfer in cooperation with B3
  - More details on dedicated poster

Method

- Particle Image Velocimetry (PIV) in transparent packed bed based on reference configuration
  - 40mm N BK7 spheres in body centred cubic packing
  - 3x3 spheres in the first layer
  - Up to 21 layers Design of inlet conditions by honeycombs and packing material to reach symmetrical flow conditions
- Image acquisition adapted to the requirements of the ray tracing based correction
  - Calibration
  - Reference images based on a purpose-made target
  - Particle field images

Ray tracing based correction

- PIV surface measurements
  - Correction of particle fields behind two spheres in different bed heights for particle Reynolds numbers from 200 to 500 (Fig. 7)
  - Corrected flow field matches the freeboard flow
  - No significant change applied to regions without distortion due to correction method
  - Perspective allows also to correct highly distorted regions (rim region)

Future Work

- Flow velocity fields in the interstices accessible without ray tracing with high spatial resolution
- Influence of the perspective to increase the reconstructed area
- Tomographic PIV with ray-tracing correction as additional concept for access inside the packed bed
- 10x10 bcc packing of 10mm spheres as second reference configuration
- Investigating still persisting artefacts in the light field reconstruction
- Extension of reconstruction method to anisotropic light field
- Investigation of different camera models and setups using the end-to-end simulation
- Automatic correction of minor displacement errors between real world geometry and simulated ones using a numerical optimization

Current Collaborations

- Exchange of geometry and inlet conditions of the test rig for numerical simulations. First simulations were carried out.
- Heat Simulations based on Monte Carlo raytracing
- Exchange of geometry and inlet conditions of the test rig for numerical simulations. Cooperation on configuration related errors.
- MRI in similar reference configuration for liquid flow simulation
- Heat simulation in a packed bed