Experimental assessment of process intensification by increased transverse dispersion in 3D-printed logpile structures

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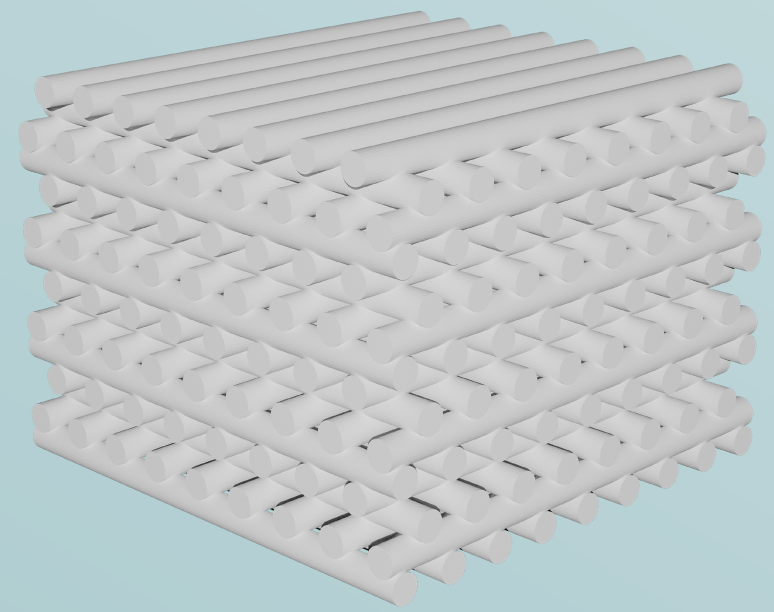
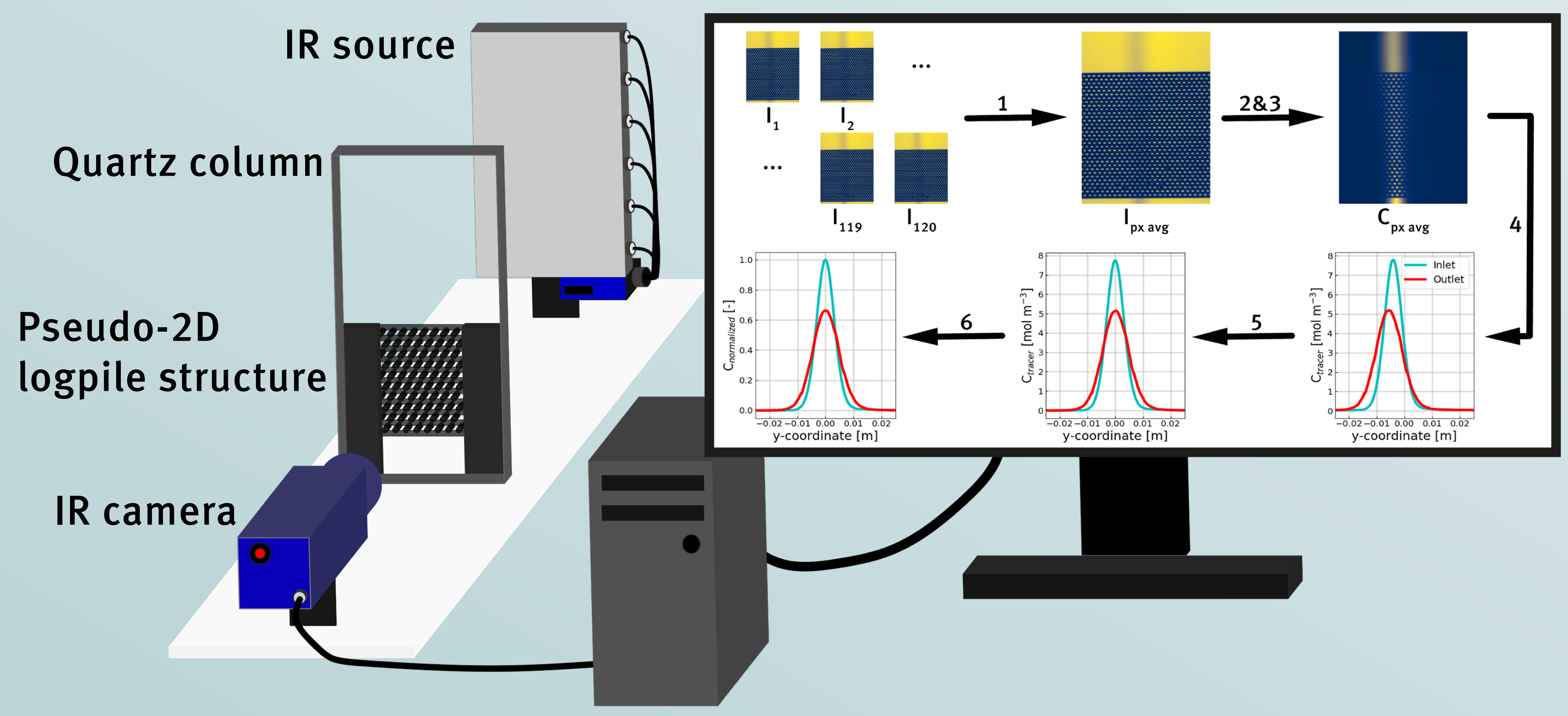
Logpile structures

- Flexible design
- High catalyst holdup
- Favorable transport properties?



Experimental quantification of transverse dispersion

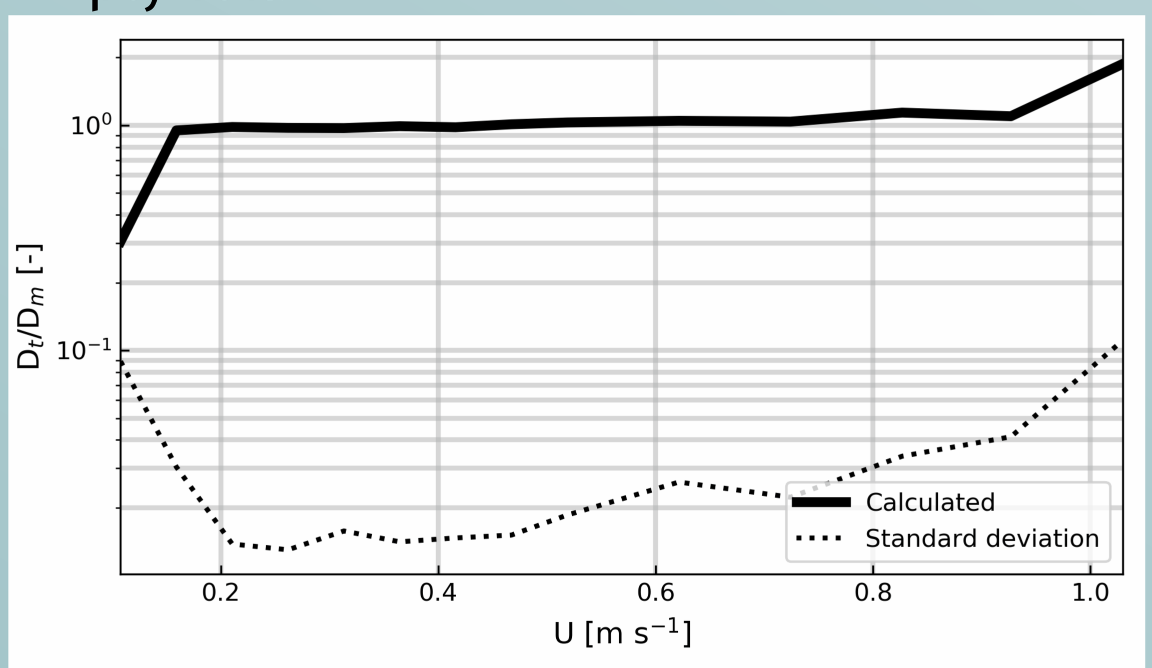
Novel non-invasive infrared transmission technique



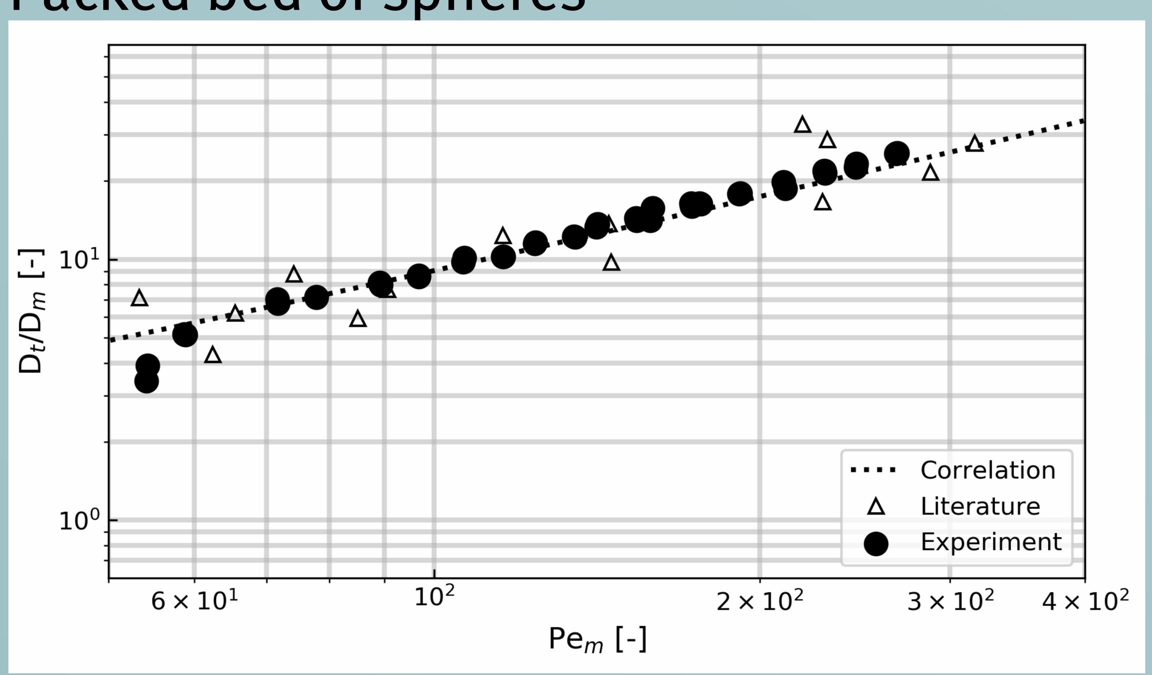
1. Element-wise averaging
2. Convert intensity to absorbance
3. Convert absorbance to concentration
4. Extract inlet and outlet
5. Peak centering and baseline correction
6. Peak normalization

Validation

Empty column

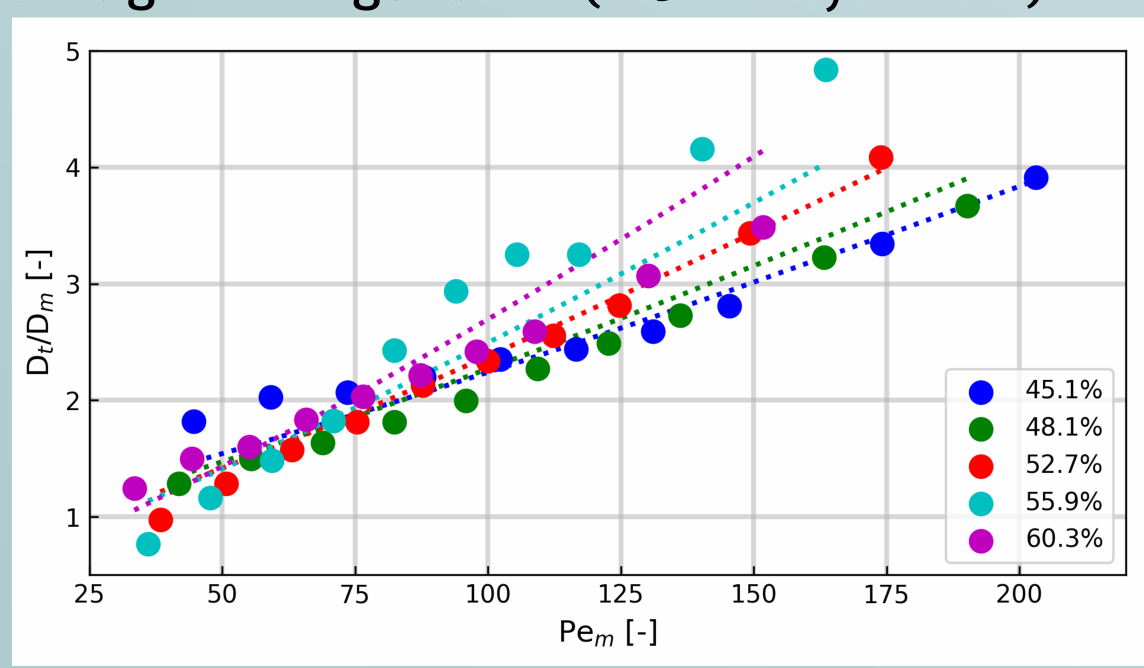


Packed bed of spheres

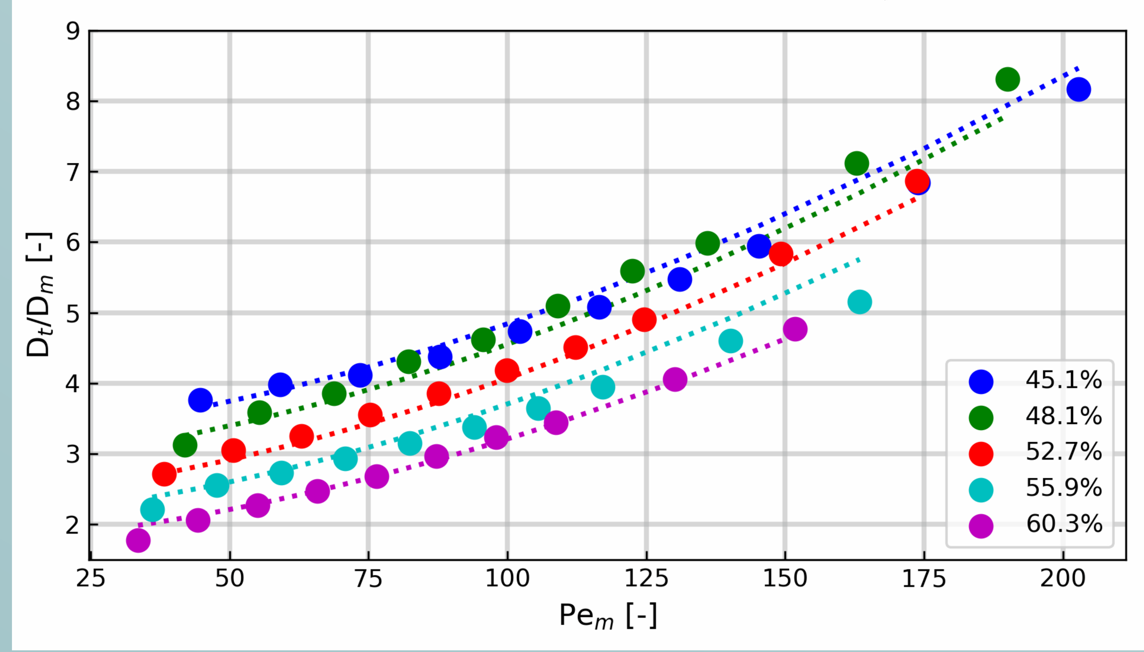


Key results

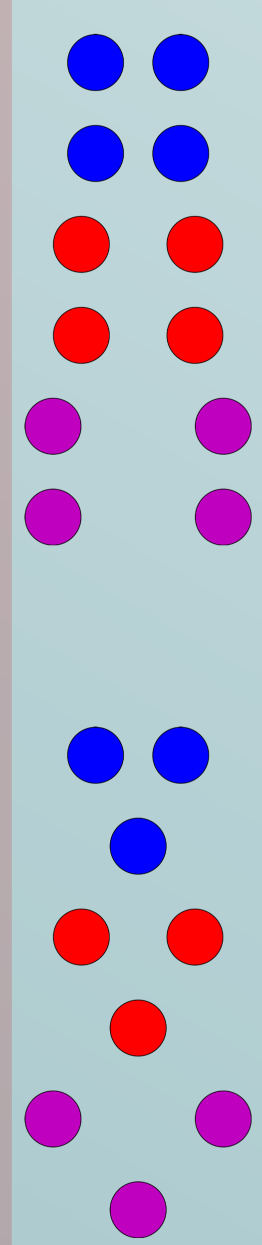
Straight configuration (1.5mm cylinders)



Staggered configuration (1.5mm cylinders)



Porosity visualisation



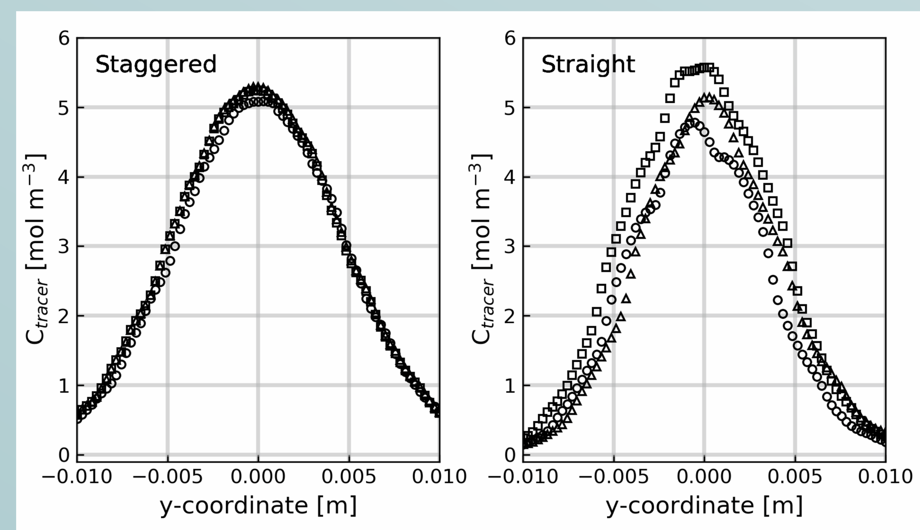
Transverse dispersion can be correlated to structure's properties, for straight configuration:

$$\frac{D_t}{D_m} = 0.769\left(\frac{1-\epsilon}{\epsilon}\right)^{1.31} + 0.0262\epsilon^{2.04}Pe_m^{1.19}$$

and for staggered configuration:

$$\frac{D_t}{D_m} = 2.64\frac{1-\epsilon}{\epsilon} + 0.00631\left(\frac{1-\epsilon}{\epsilon}\right)^{2.65}\left(\frac{d_h}{d}Pe_m\right)^{1.67}$$

The staggered correlation has a low MAPE of 3.74%, but the straight correlation has a fairly high MAPE of 9.26%. This can partially be explained by the poor reproducibility:



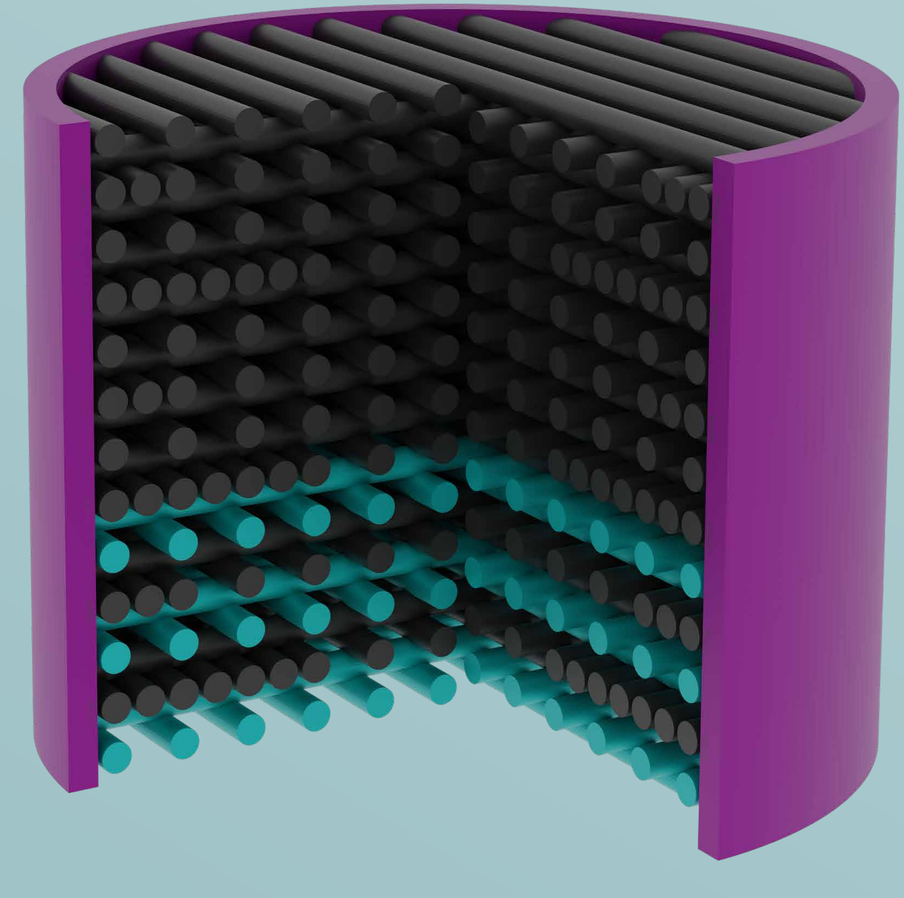
Full paper:

Conclusions

- Novel experimental method is validated for accurate determination of the transverse dispersion coefficient.
- Staggered 3D-printed logpile structures allow for tuning of transverse dispersion coefficient by changing of geometrical parameters.
- While tuning is possible, high transverse dispersion values cannot be achieved. This limits the process intensification potential of these structures.
- Correlations do not yet offer fundamental insights.

Next steps

- Modelling the flow through these structures (in OpenFOAM) to get better understanding of the operating trade-offs.
- Designing new structures with baffle-like internals which can better realize the process intensification potential.
- Experimental testing of these novel structures in reaction systems with strong heat effects.
- Conceptualizing further enabling developments for 3D-printing in process intensification: co-printing of multiple catalysts or sorbents and printing of entire reactors.



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