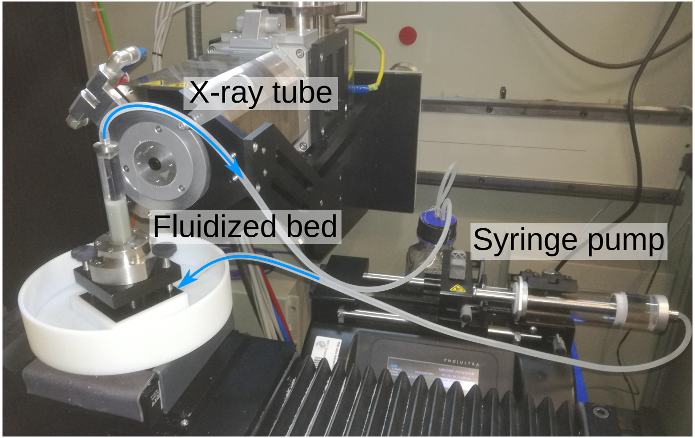
Experimental validation of X-DFA:
A suspension of sedimenting particles



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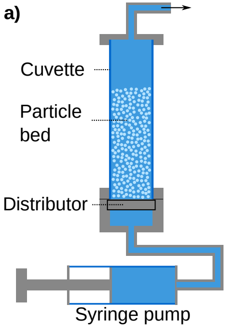
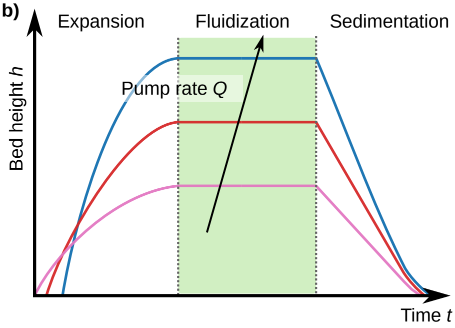
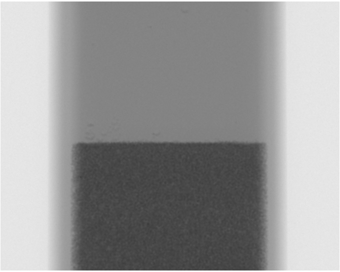
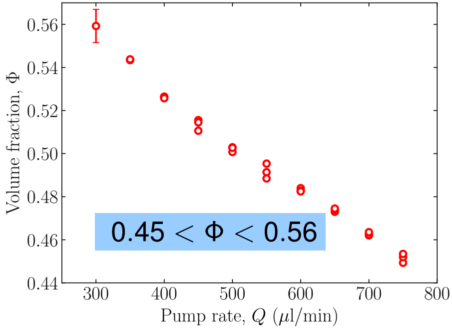


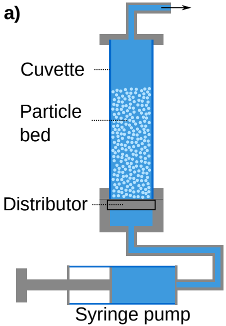


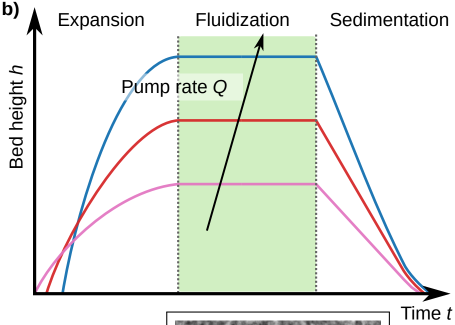
X-ray radiography



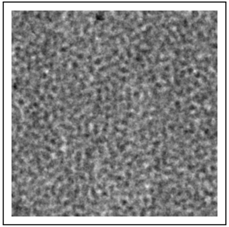


Experimental validation of X-DFA: A suspension of sedimenting particles





No reliable reference velocity!



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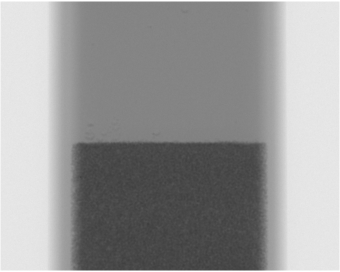
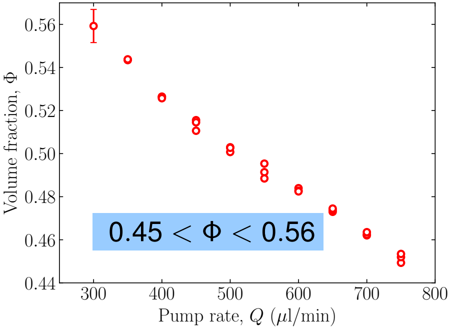
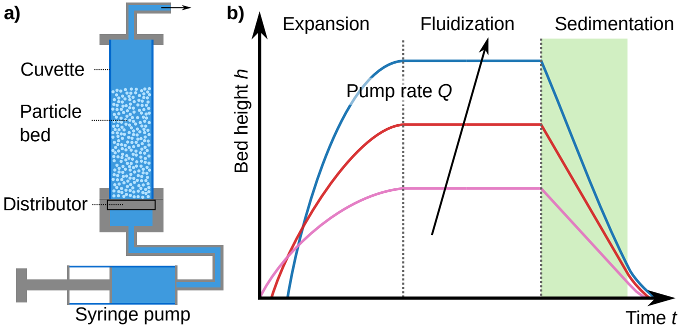
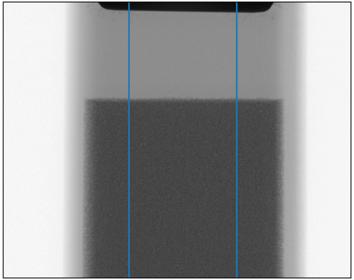




Experimental validation of X-DFA: A suspension of sedimenting particles

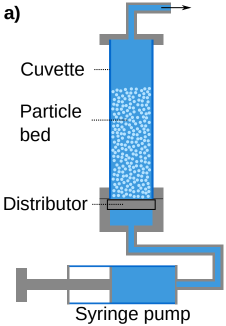


X-ray radiography

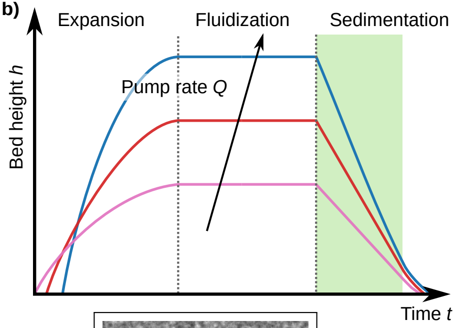


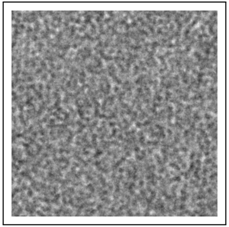
Experimental validation of X-DFA: A suspension of sedimenting particles

a)



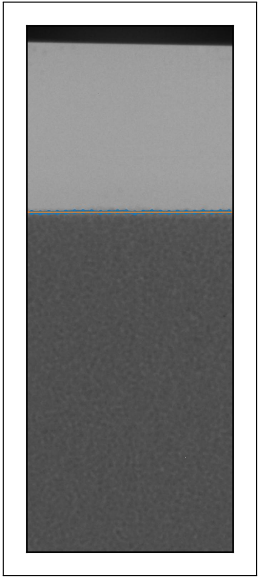
b)



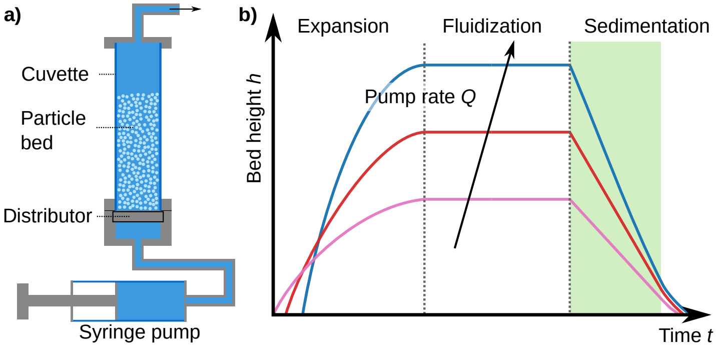


Comparison of $\langle v \rangle_{\mathrm{xdfa}}$ and $\langle v \rangle_{\mathrm{front}}$

X-ray radiography

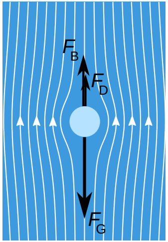


Liquid fluidized bed: Richardson-Zaki law



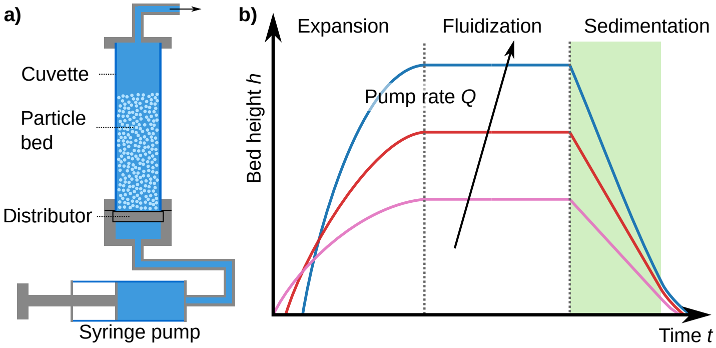
Gravitation Buoyancy Drag

$$F_G = F_B + F_D$$



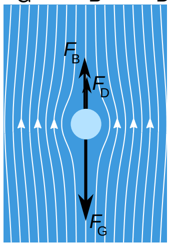
$$\frac{\langle v \rangle_{\text{fluid}}}{v_{\text{Stokes}}} = (1 - \Phi)^n$$

Liquid fluidized bed: Richardson-Zaki law

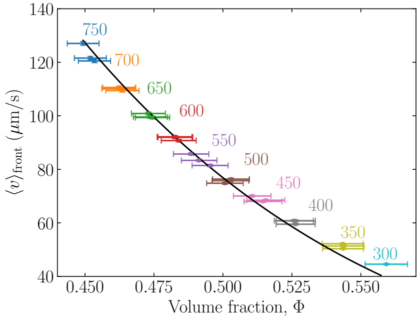


Gravitation Buoyancy Drag

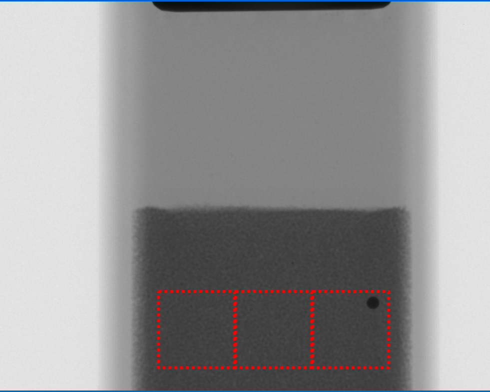
$$F_G = F_B + F_D$$

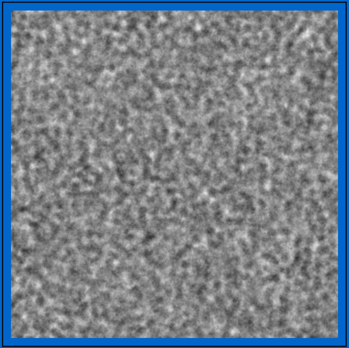


$$\frac{\langle v \rangle_{\text{front}}}{v_{\text{Stokes}}} = (1 - \Phi)^n$$

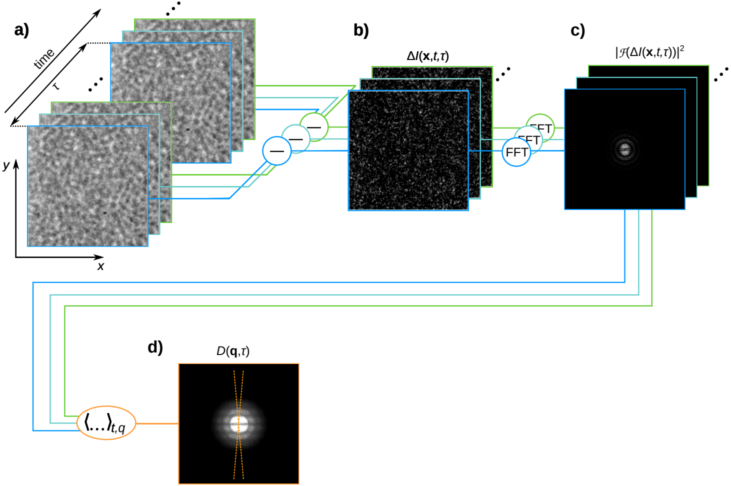


X-ray Digital Fourier Analysis of a suspension of sedimenting particles



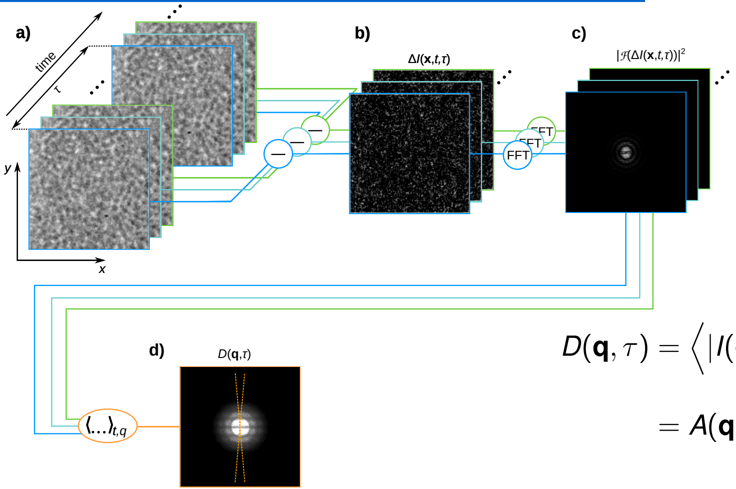


The image structure function $D(\mathbf{q}, \tau)$



In collaboration with Manuel Escobedo, University of Düsseldorf

The image structure function $D(\mathbf{q}, \tau)$



$$D(\mathbf{q}, \tau) = \left\langle |I(\mathbf{q}, t+\tau) - I(\mathbf{q}, t)|^2 \right\rangle_t$$

$$= A(\mathbf{q}) \left[1 - \frac{\langle I^*(\mathbf{q}, t) I(\mathbf{q}, t+\tau) \rangle_t}{\langle |I(\mathbf{q}, t)|^2 \rangle_t} \right] + B(\mathbf{q})$$

- $D(\mathbf{q}, \tau \to 0) = B(\mathbf{q})$
- $D(\mathbf{q}, \tau \to \infty) = A(\mathbf{q}) + B(\mathbf{q})$

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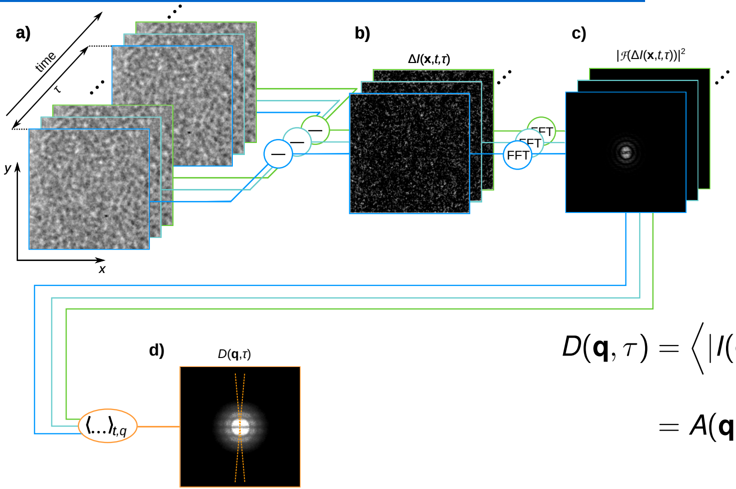
The image structure function $D(\mathbf{q}, \tau)$



Linear space invariant imaging

$$f(\mathbf{q}, \tau) = \frac{\langle \rho^*(\mathbf{q}, t)\rho(\mathbf{q}, t+\tau)\rangle_t}{\langle |\rho(\mathbf{q}, t)|^2\rangle_t}$$

Intermediate scattering function

$$D(\mathbf{q}, \tau) = \left\langle |I(\mathbf{q}, t+\tau) - I(\mathbf{q}, t)|^2 \right\rangle_t$$

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- $D(\mathbf{q}, \tau \to 0) = B(\mathbf{q})$
- $D(\mathbf{q}, \tau \to \infty) = A(\mathbf{q}) + B(\mathbf{q})$

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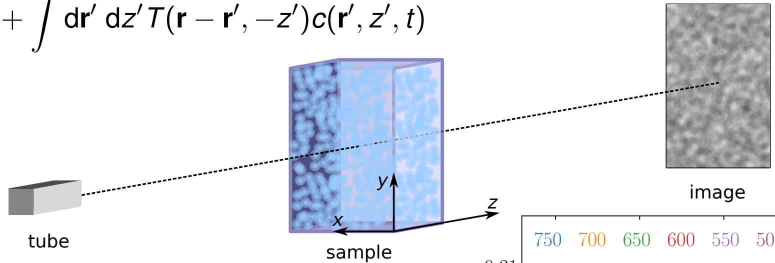
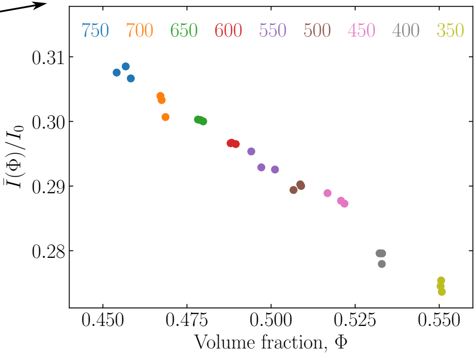
X-ray radiography: Linear space invariant?

$$I(\mathbf{r}, t) = I_0 + \int \mathrm{d}\mathbf{r}' \, \mathrm{d}z' \, T(\mathbf{r} - \mathbf{r}', -z') c(\mathbf{r}', z', t)$$

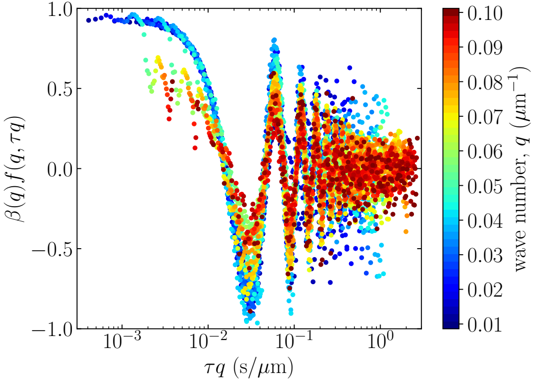


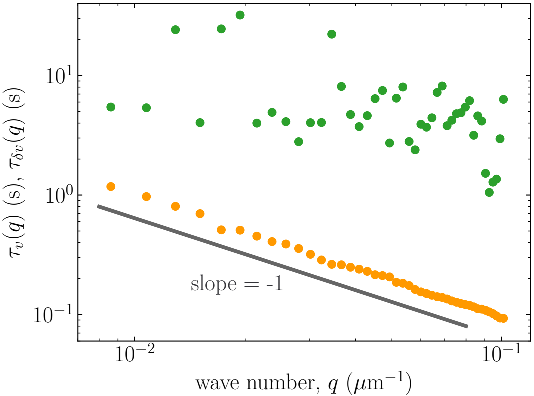


X-DFA for a suspension of sedimenting particles

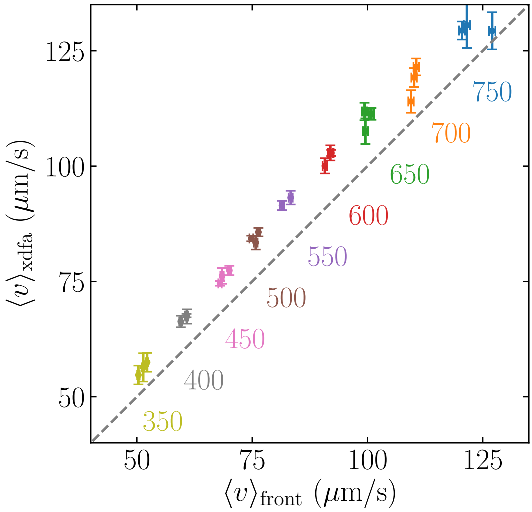
$$f(q,\tau) = \cos(q\langle v_s\rangle\tau)\exp\left(-\frac{1}{2}q^2\delta v^2\tau^2\right)$$

$$\langle v_s\rangle = \langle \Delta r\rangle/\tau_\nu, \langle \delta v\rangle = \langle \delta r\rangle/\tau_{\delta\nu}$$



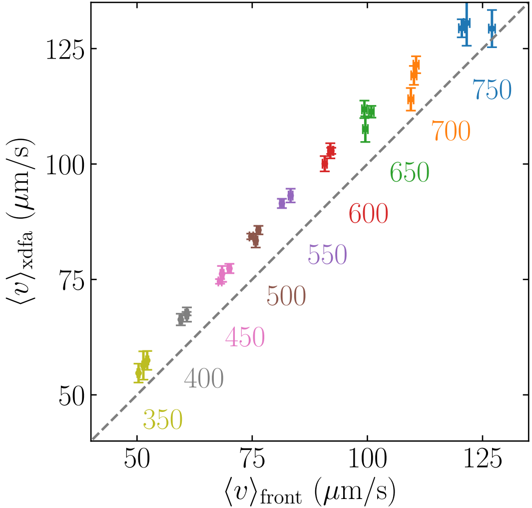


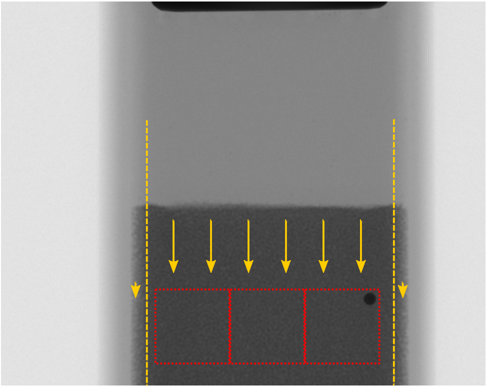
Front tracking vs. X-DFA



$\langle v \rangle_{\mathrm{xdfa}} > \langle v \rangle_{\mathrm{front}}$ by 9.4%

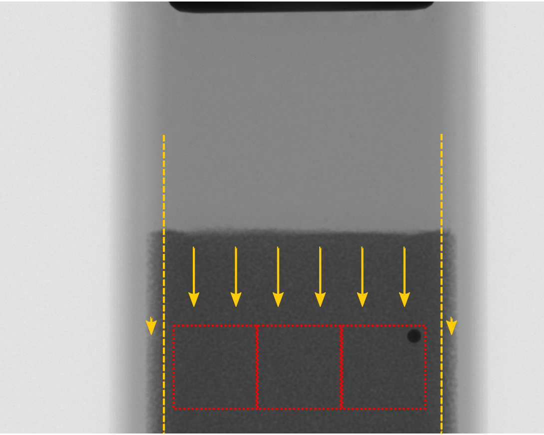
Front tracking vs. X-DFA





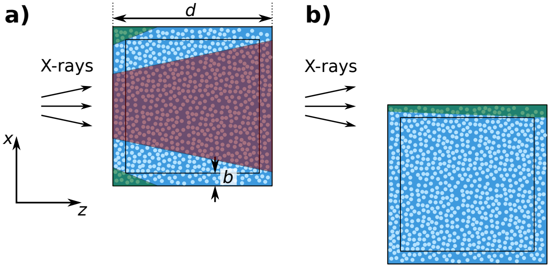
$\langle v \rangle_{\mathrm{xdfa}} > \langle v \rangle_{\mathrm{front}}$ by 9.4%

Estimate width of boundary layer



$\langle v \rangle_{\text{xdfa}} > \langle v \rangle_{\text{front}}$ by 9.4%

$\langle v \rangle_{\text{xdfa}}$ takes two layers into account
$\langle v \rangle_{\text{front}}$ takes four layers into account

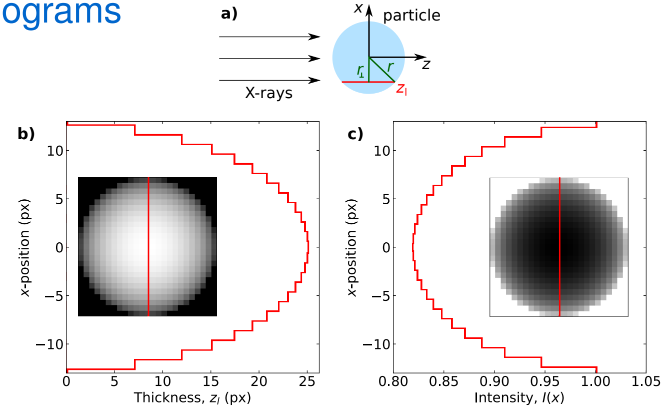


Estimation:
Boundary velocity = 0
Else = const.
$\rightarrow b \approx 3$ particle diameters

Thank you for your attention!

Backup slides

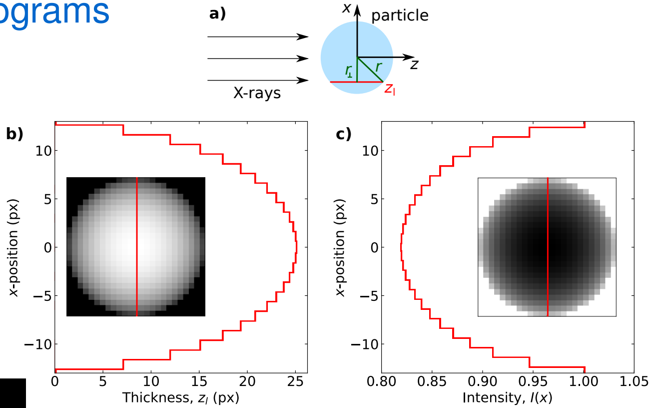
Synthetic radiograms

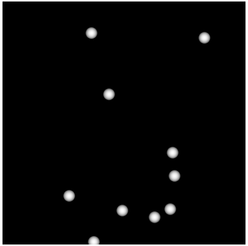


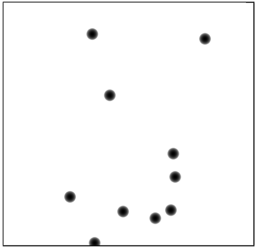
Beer-Lambert

$$I(z_l) = I_0 \exp(-\mu z)$$

Synthetic radiograms







Beer-Lambert

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Linear space invariant imaging

Image correlation function

$$g(\mathbf{q}, \tau) = \frac{\langle I^*(\mathbf{q}, t) I(\mathbf{q}, t+\tau) \rangle_t}{\langle |I(\mathbf{q}, t)|^2 \rangle_t}$$

Linear space invariant imaging

Image correlation function

$$g(\mathbf{q},\tau) = \frac{\langle I^*(\mathbf{q},t)I(\mathbf{q},t+\tau)\rangle_t}{\langle |I(\mathbf{q},t)|^2\rangle_t}$$

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$$f(\mathbf{q},\tau) = \frac{\langle \rho^*(\mathbf{q},t)\rho(\mathbf{q},t+\tau)\rangle_t}{\langle |\rho(\mathbf{q},t)|^2\rangle_t}$$

Linear space-invariant imaging:

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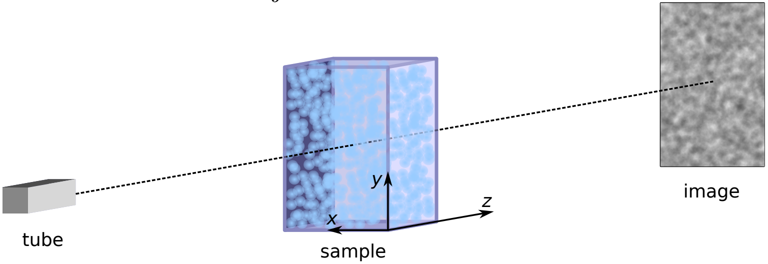
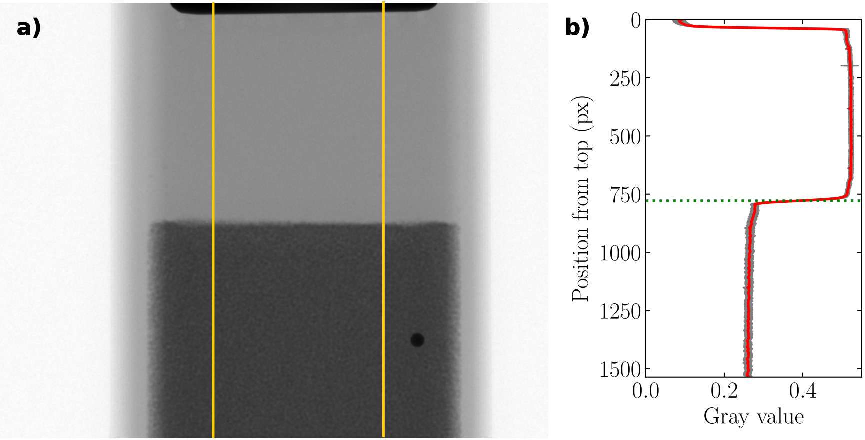
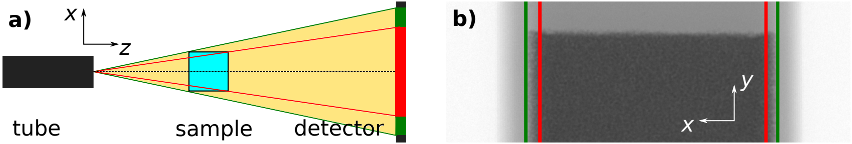
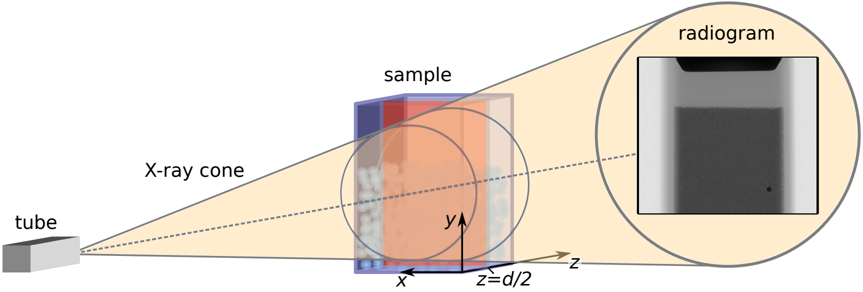


Tracking of particle front



Tracking of particle front





Tracking of particle front