An Evaluation of Computational Imaging Techniques for Heterogeneous Inverse Scattering

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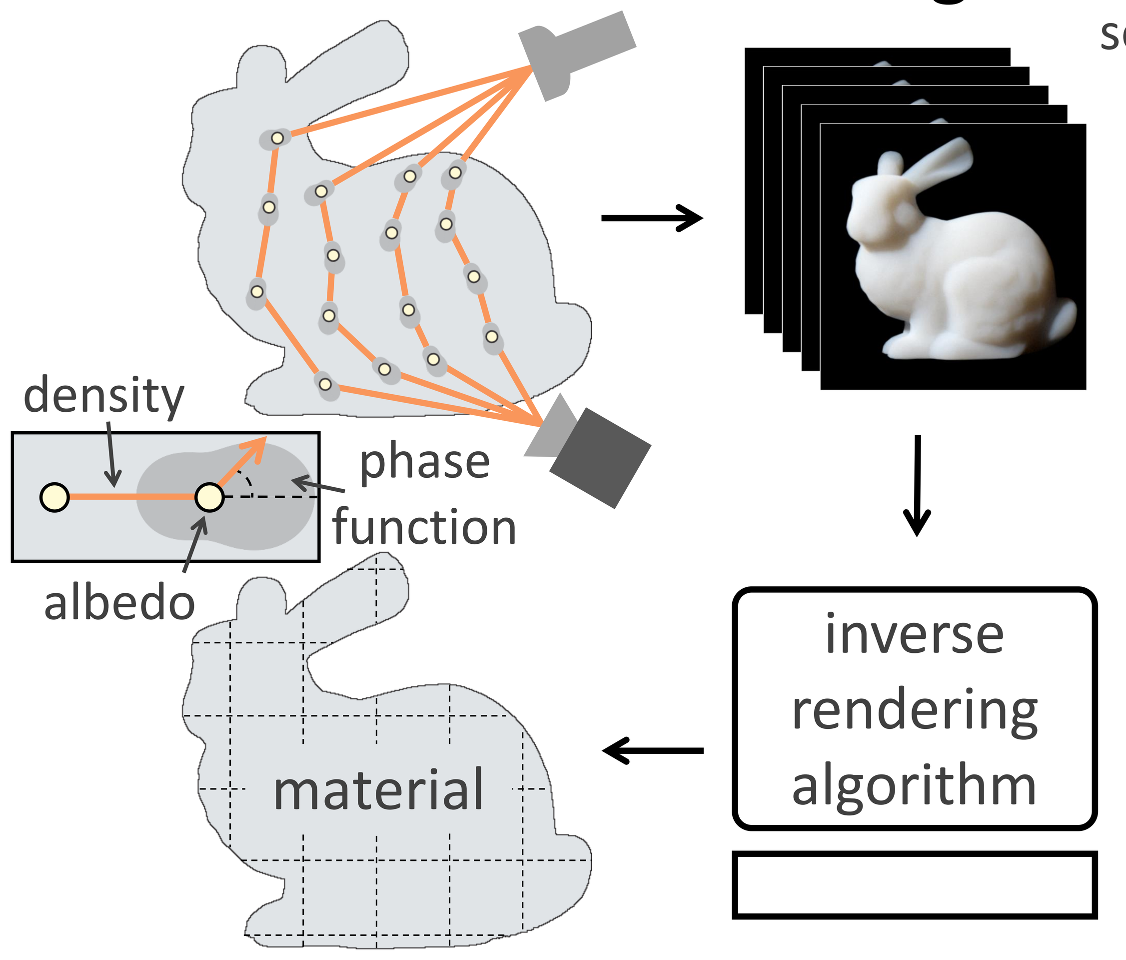
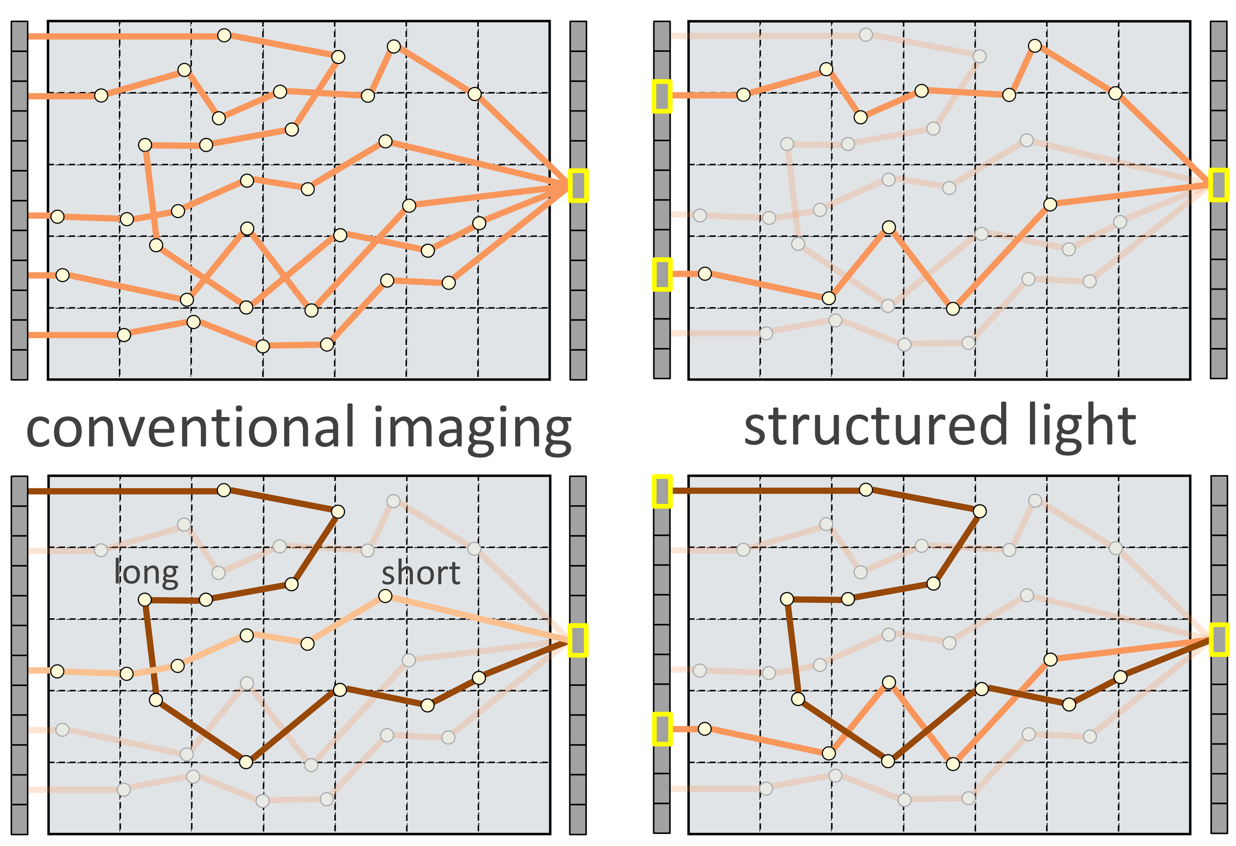
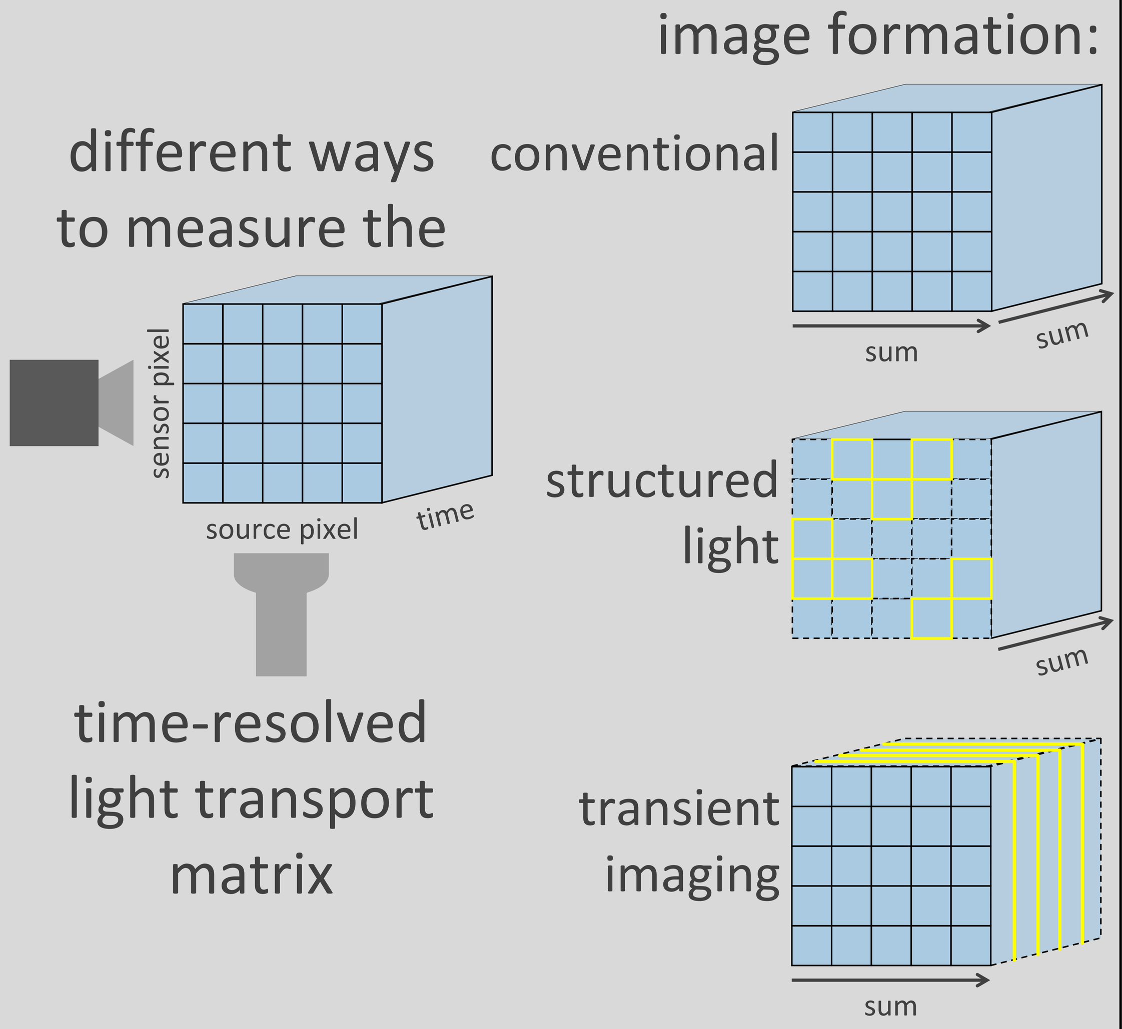
We do inverse scattering...



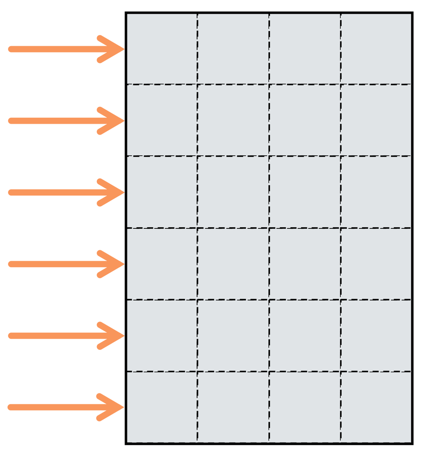
...using computational imaging



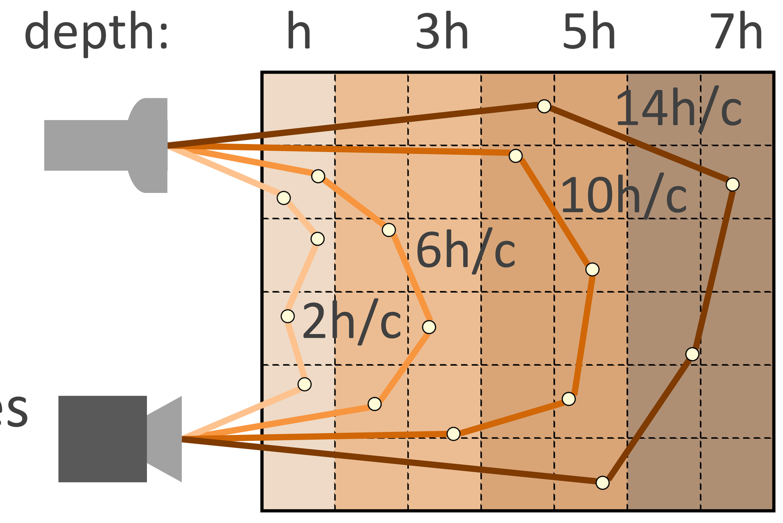


What kind of imaging to use?

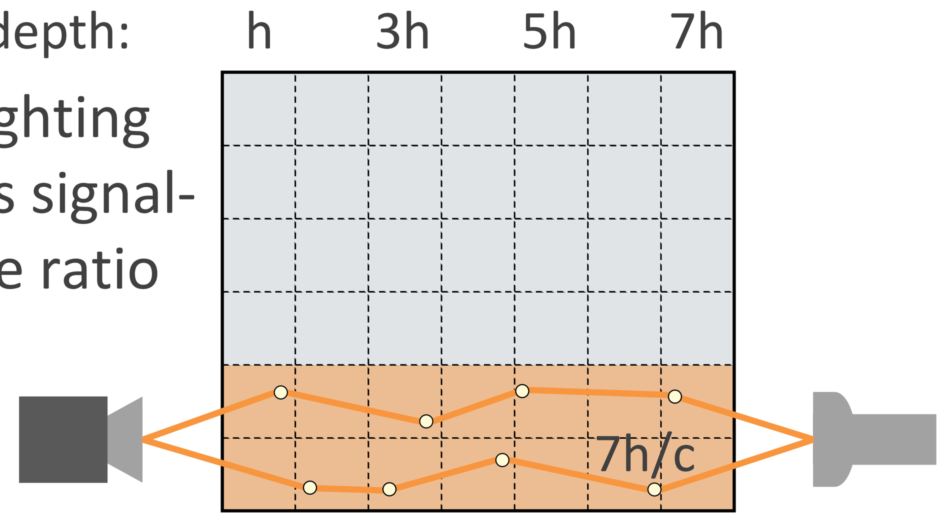
high-frequency illumination reduces local ambiguities



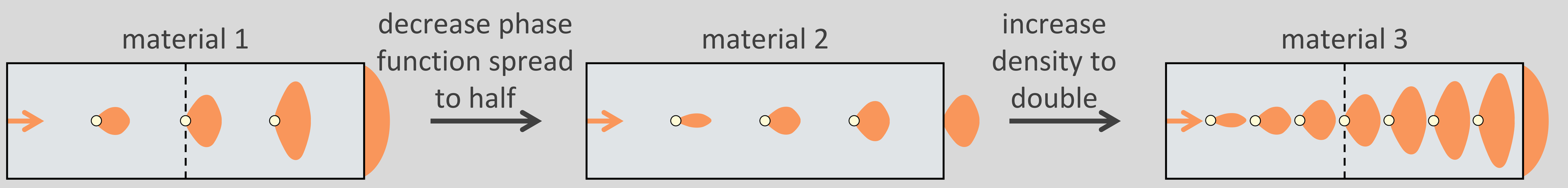
front-lighting and transient reduces non-local ambiguities



back-lighting increases signal-to-noise ratio

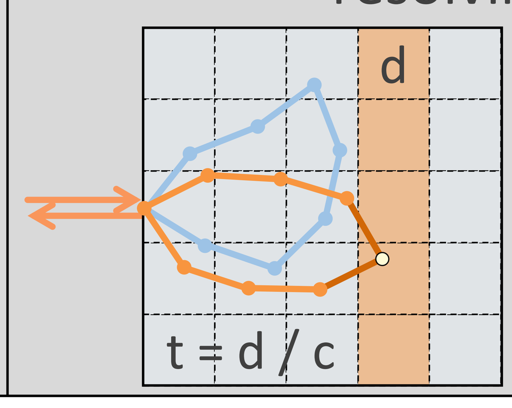


local similarity relations



- high-frequency input increases number of bounces before outputs look identical
- local similarity relations hold for both steady-state and transient imaging

resolving non-local ambiguities



only depend on layers before depth d

$$I_t = Q + f(m_d) \cdot R$$

linear function of material at depth d

- uniquely infer volume layer-by-layer

Appearance matching optimization

$\min_{m(x)} \|$  $- \text{image}(m) \|^2$

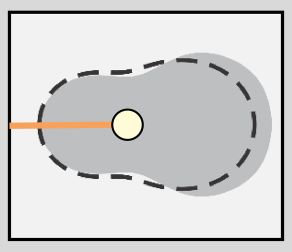
challenging optimization problem:

- high-dimensional (10^5 unknowns)
- very nonlinear ("image" function)

stochastic gradient descent

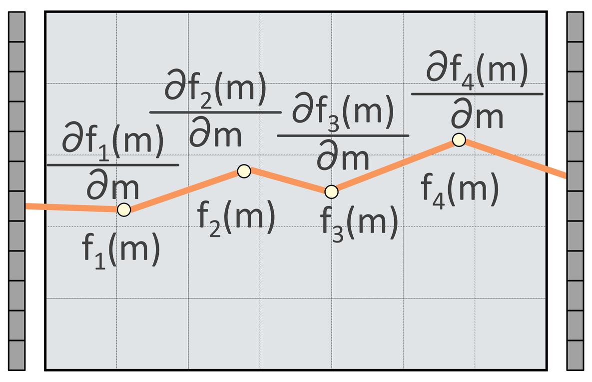
while (not converged)
update m using $\frac{\partial \widetilde{loss}(m)}{\partial m}$

$\frac{\partial \widetilde{image}(m)}{\partial m}$



material $m+\partial m$

Monte Carlo gradient rendering



$\sum_{paths} f_{path}(m) \rightarrow \text{image}(m)$

$\sum_{paths} \frac{\partial f_{path}(m)}{\partial m} \rightarrow \frac{\partial \text{image}(m)}{\partial m}$

computation-noise trade-off:

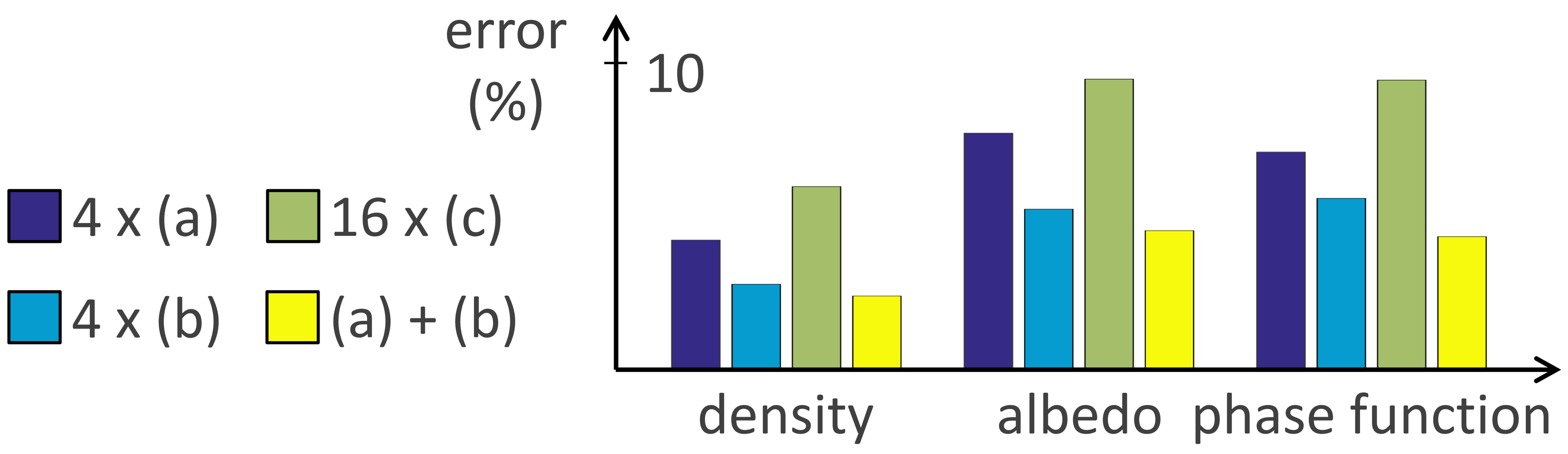
10^6 paths 3 hours, 10^2 paths 10 secs

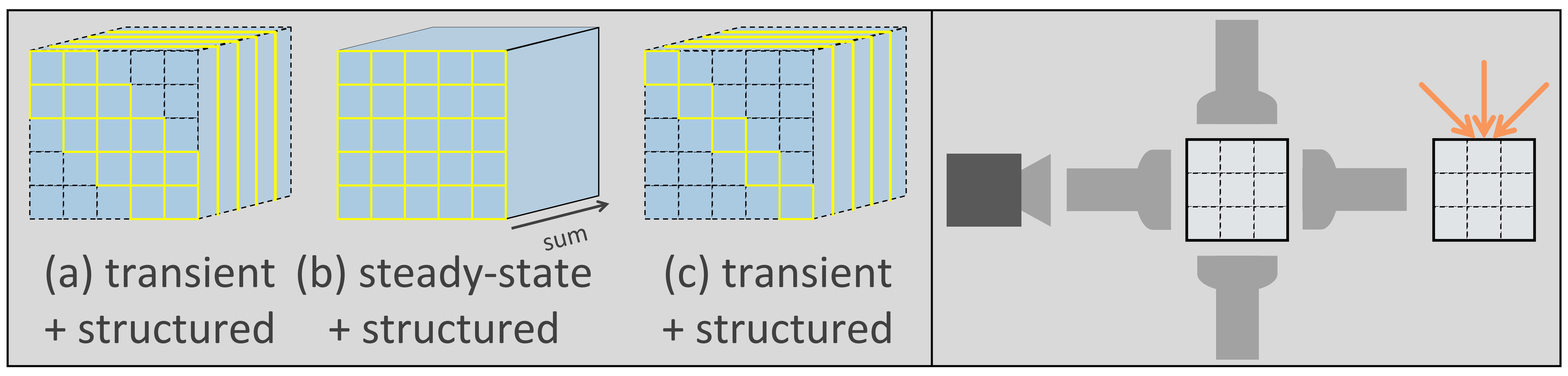
algorithm sketch

while (not converged)
- randomly sample a photon path
- compute path-segment terms
  - radiance throughput when rendering images
  - throughput gradient when rendering gradients
- aggregate terms into whole path contribution
- update image estimate

- physically accurate (accounts for all scattering)
- generally applicable (all above imaging types)
- scalable (highly parallelizable)

Empirical evaluation of imaging types

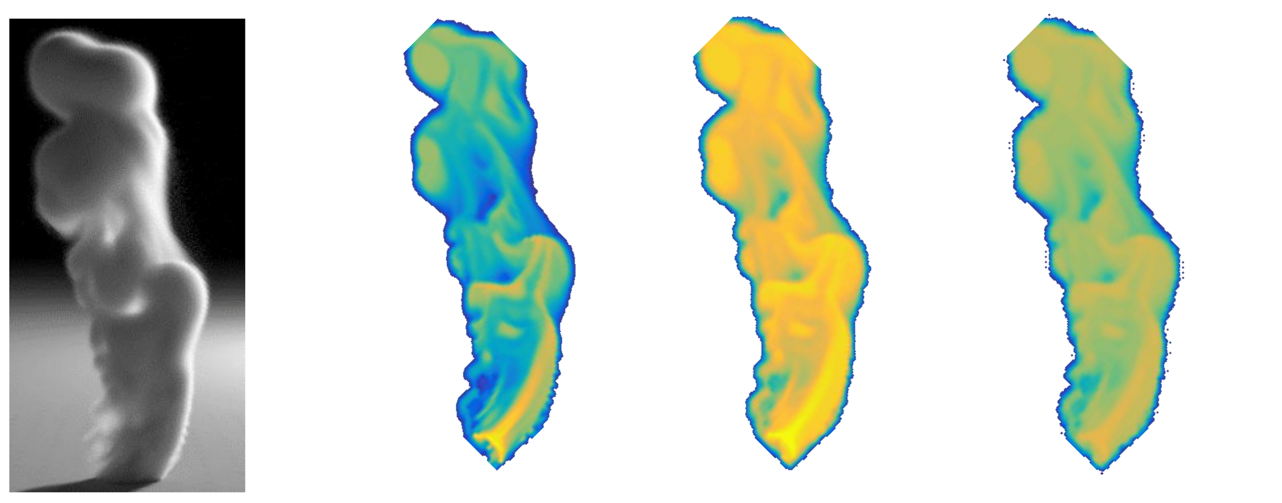




(a) transient + structured (b) steady-state + structured (c) transient + structured

Large-scale inverse scattering simulation

- 10^4 cores
- 10^6 images
- 10^5 unknowns



smoke volume density albedo phase function

Code online soon!

try with your own imaging configurations

http://vision.seas.harvard.edu/inverse_transient