# Polarised light scattering in disordered media: a random matrix model

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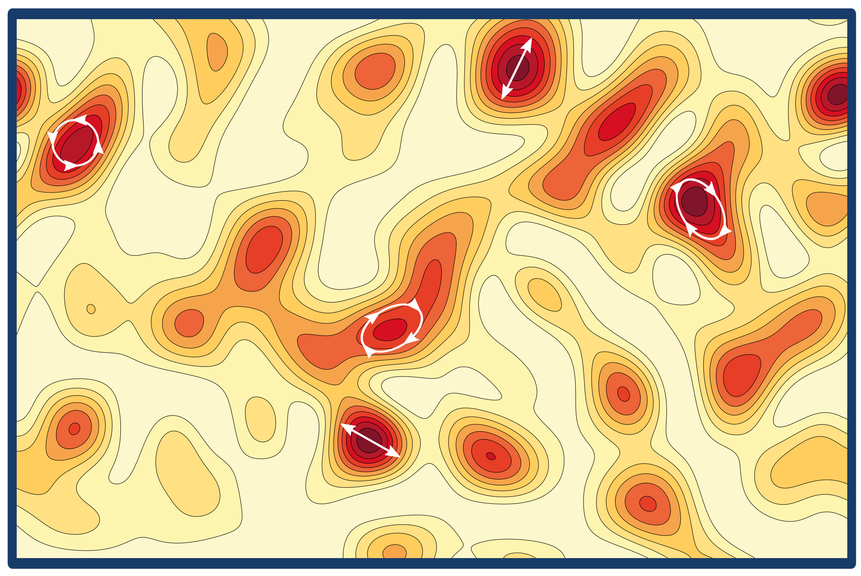
## Introduction

- Polarised light is a useful tool for analysing structural properties of materials, e.g. thin films and surfaces, biological tissue [1] and astronomical bodies.
- Multiple scattering in disordered media is detrimental to information transfer due to randomisation of phase, intenstiy and polarisation state [2].
- Knowledge of the scattering matrix and its statistical properties has enabled precise wavefront control and imaging through turbid media [3].
- We have developed a method for studying the statistics of physically constrained scattering matrices that incorporate polarisation properties of light.

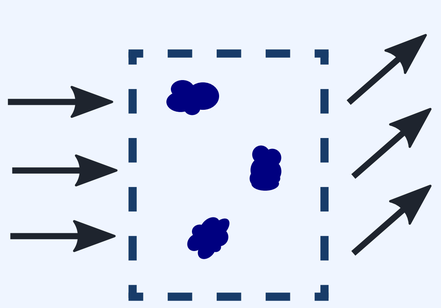


Randomly polarised speckles

## Model

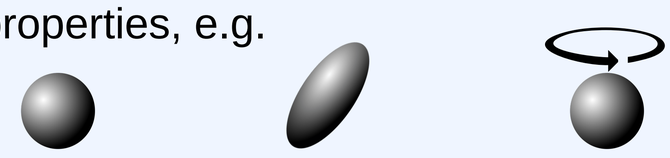
### ① Thin slab scattering

- Single scattering approximation.




$$\mathbf{E} = \sum_i \mathbf{E}_i$$

- Total field given by complex phasor sum.
- Particles may have different shapes, sizes, orientations and polarimetric properties, e.g.



Spheres Ellipsoids Chiral particles

### ② Random matrices

- Scattering matrix elements assumed to have joint Gaussian statistics.

$$p(\mathbf{z}) \sim e^{-\mathbf{z}^\dagger \Sigma^{-1} \mathbf{z}}$$

$$\mathbf{z} = (S_{11}, S_{12}, \dots S_{NN})$$

- Scattering matrix must be symmetrized so as to satisfy energy conservation + reciprocity [4].

$$\mathbf{S}^\dagger \mathbf{S} = \mathbf{I}$$

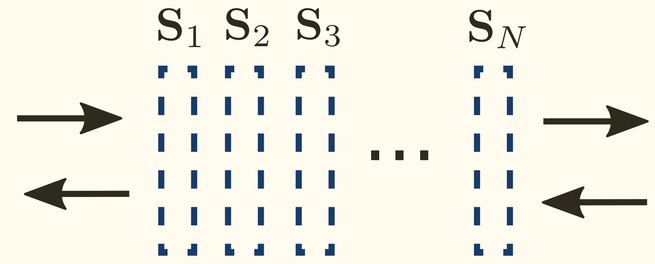
$$\mathbf{S} = \mathbf{K}\mathbf{S}^{\mathrm{T}}\mathbf{K}^{-1}$$

### ③ Matrix cascade

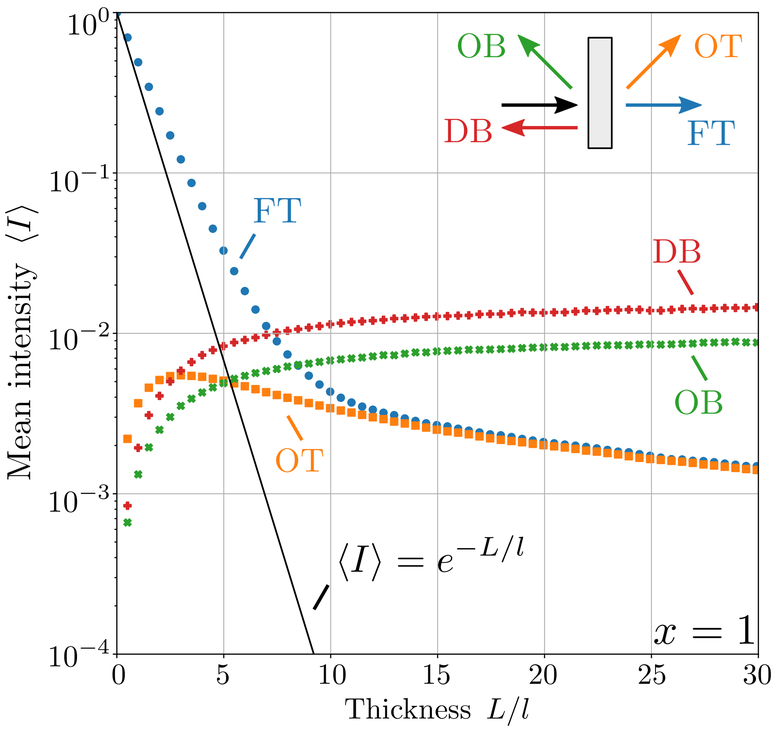
- Generated scattering matrix describes transmission and reflection by single thin slab.

$$\mathbf{S} = \begin{pmatrix} \mathbf{r} & \mathbf{t}' \\ \mathbf{t} & \mathbf{r}' \end{pmatrix}$$

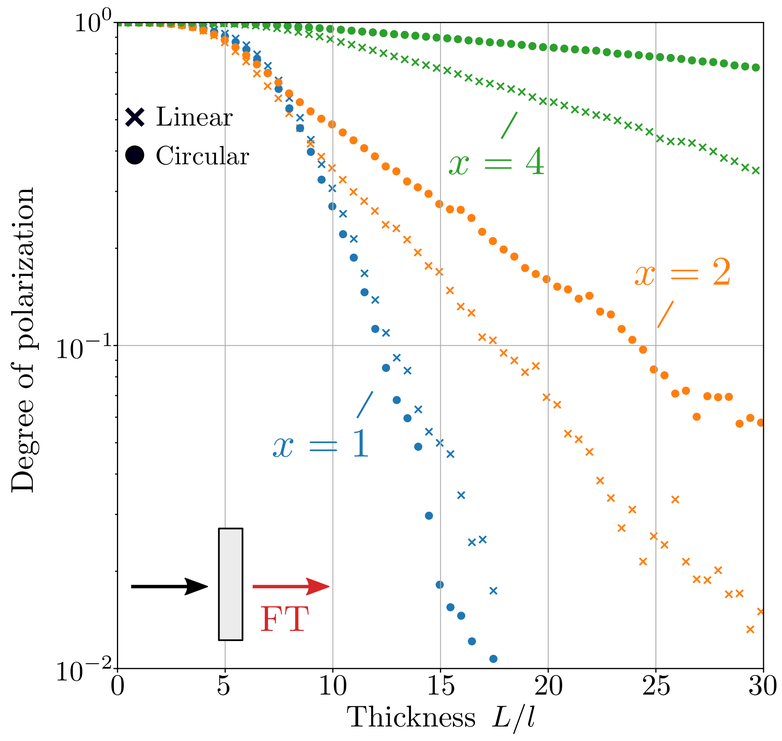
- Slabs can be cascaded to model thick, multiple scattering media.



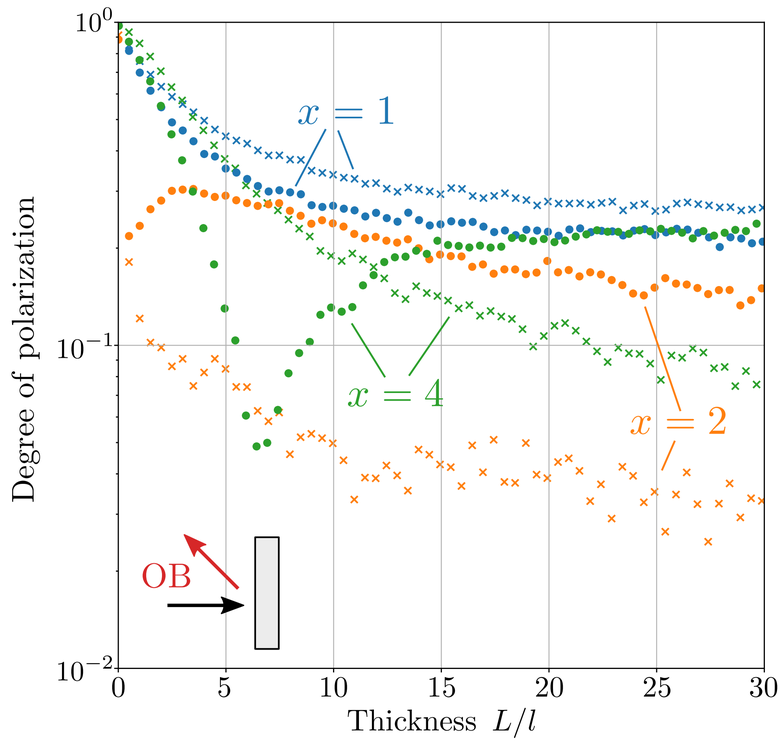

## Results




- Mean intensity in different scattering directions.
- As thickness increases, light tends to scatter more in reflection than in transmission.




- DoP in forward transmission.
- Decay rate depends on particle size and incident polarization state.




- DoP in oblique backscattering.
- DoP dips to a minimum for large particles and circularly polarized incident light.

## References

[1] Tuchin, V. V., Journal of Biomedical Optics 21(7), 071114 (2016)
[2] Byrnes, N. et al., New Journal of Physics 22, 083023 (2020)
[3] Katz, O. et al., Nature Photonics 8, 784–790 (2014)
[4] Byrnes, N. et al., Physical Review Research 3, 013129 (2021)

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