# Reconfigurable dielectric metasurfaces via structural fluids

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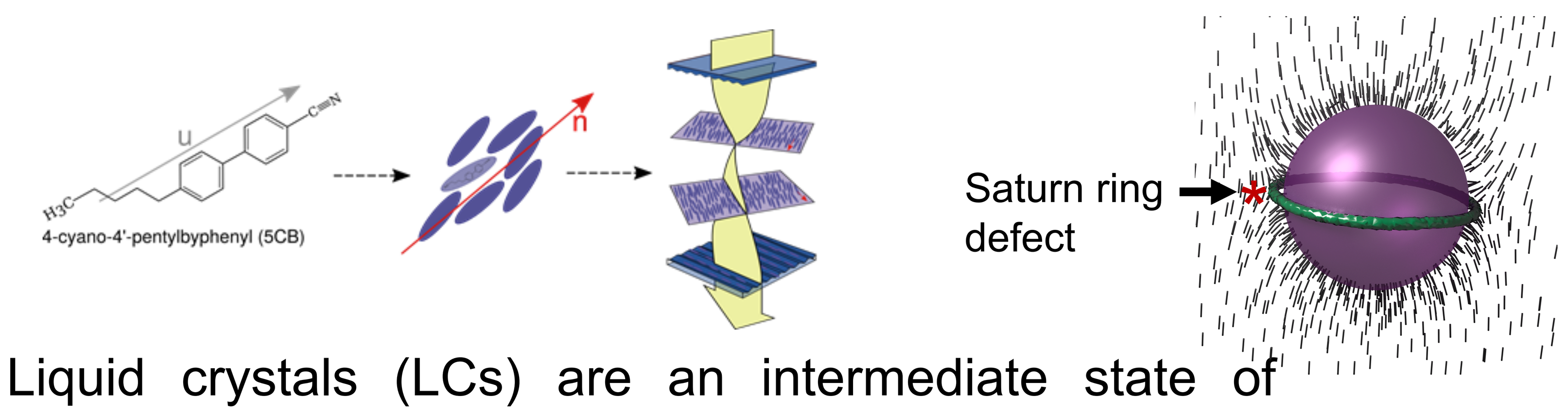
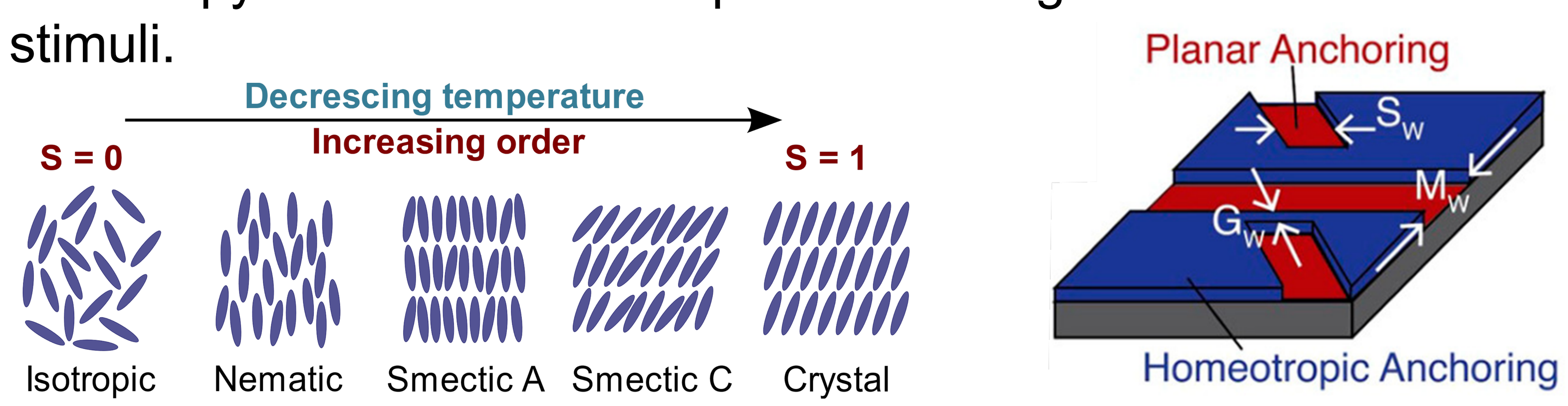
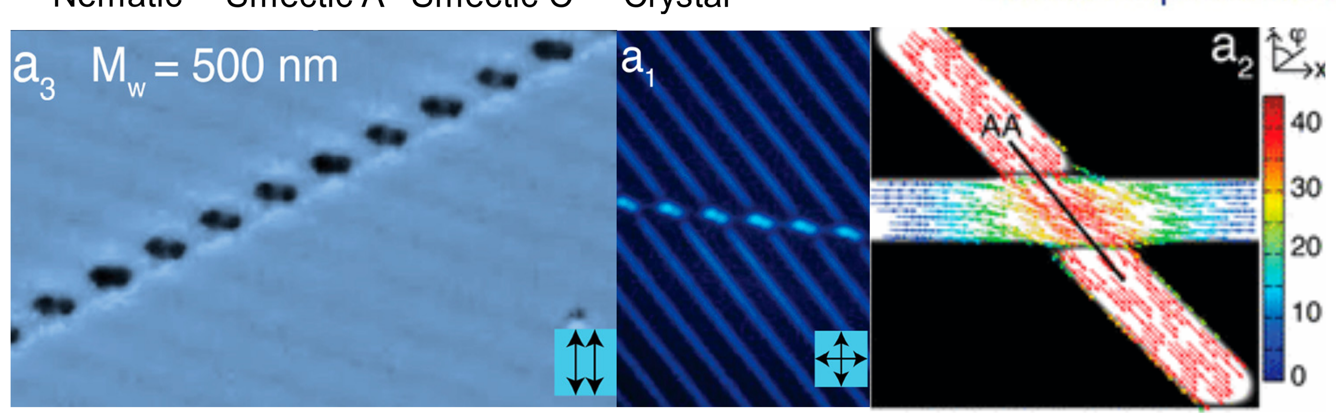
## Liquid crystal phenomenology




Liquid crystals (LCs) are an intermediate state of matter with atypical mechanical and optical properties, which enable the amplification of molecular events up to the visible range.

The ordering is a consequence of the molecular anisotropy and can be manipulated through external stimuli.




a3: optical images of a pair of trapped PS colloidal particles at the distorted gap spaces (blue LC background decorated with black spots that represent the colloidal particles)

a1: dark and bright features along the stripes of the cell with the colloidal particles under crossed polarizers

a2: nematic orientation along the stripes, obtained from simulations

## Theoretical description

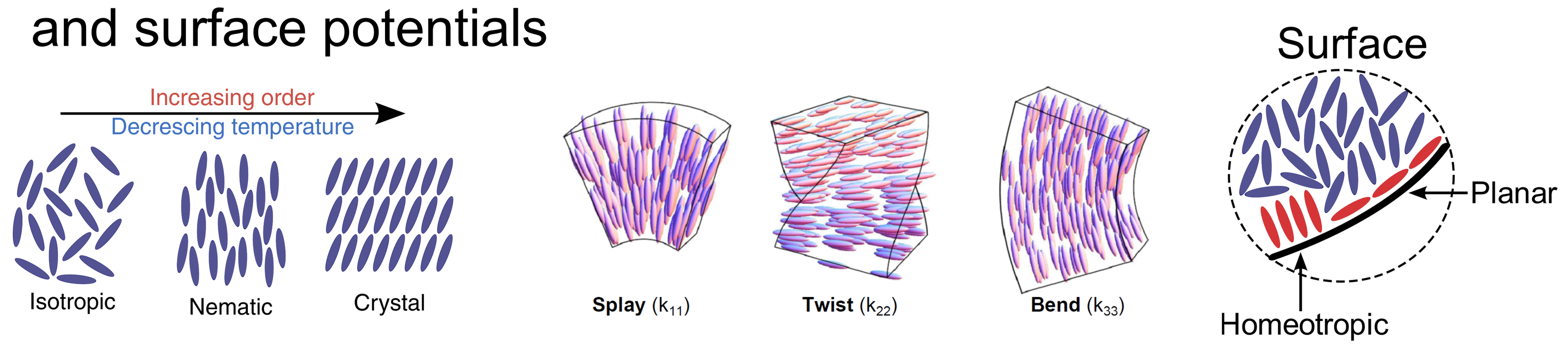
We characterize the degree of ordering in terms of the tensor order parameter **Q**, which contains all the information for an accurate thermodynamic description of the system.

$$\mathbf{Q} = S\left(\mathbf{nn} - \frac{\delta}{3}\right)$$

The free energy is defined following a Landau-de Gennes form

$$F(\mathbf{Q}) = \int [f_{LdG}(A, U, \mathbf{Q}) + f_E(L_i, \mathbf{Q}, \nabla\mathbf{Q})]d^3x + \oint f_S(W, \mathbf{Q})d^2x$$

Each contribution accounts for thermal effects, deformation, and surface potentials




## COPSS-LC

Relaxation of the free energy functional allows us to explore equilibrium configurations.

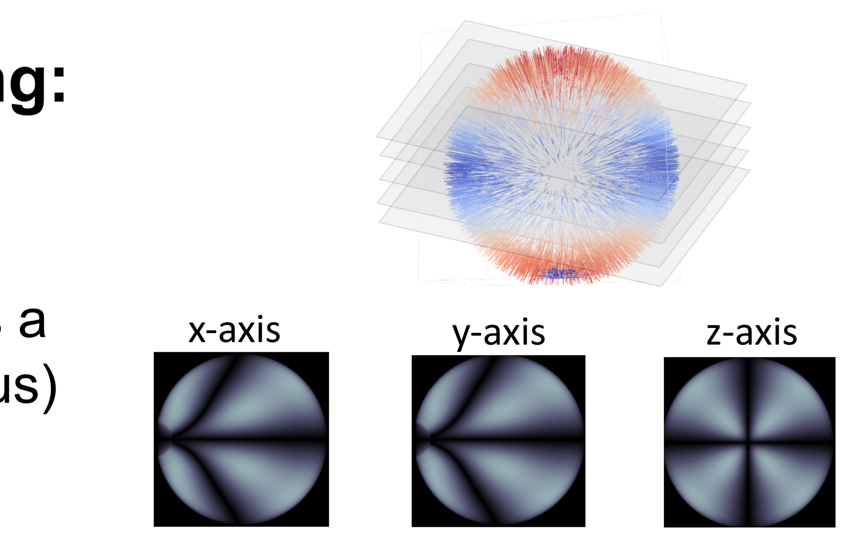
We currently use a Ginzburg-Landau relaxation: $\frac{\partial \mathbf{Q}}{\partial t} = -\frac{1}{\gamma}\left[\frac{\delta F}{\delta \mathbf{Q}}\right]^{ST}$

That can be reduced to a system of PDEs:

$$\gamma\frac{\partial Q_{ij}}{\partial t} = h_{ij} \qquad h_{ij}^{bulk} = \frac{\partial F}{\partial Q_{ij}} - \nabla\frac{\partial F}{\partial \nabla Q_{ij}} \qquad h_{ij}^{surf} = \nabla\frac{\partial F}{\partial \nabla Q_{ij}}\nu_i$$

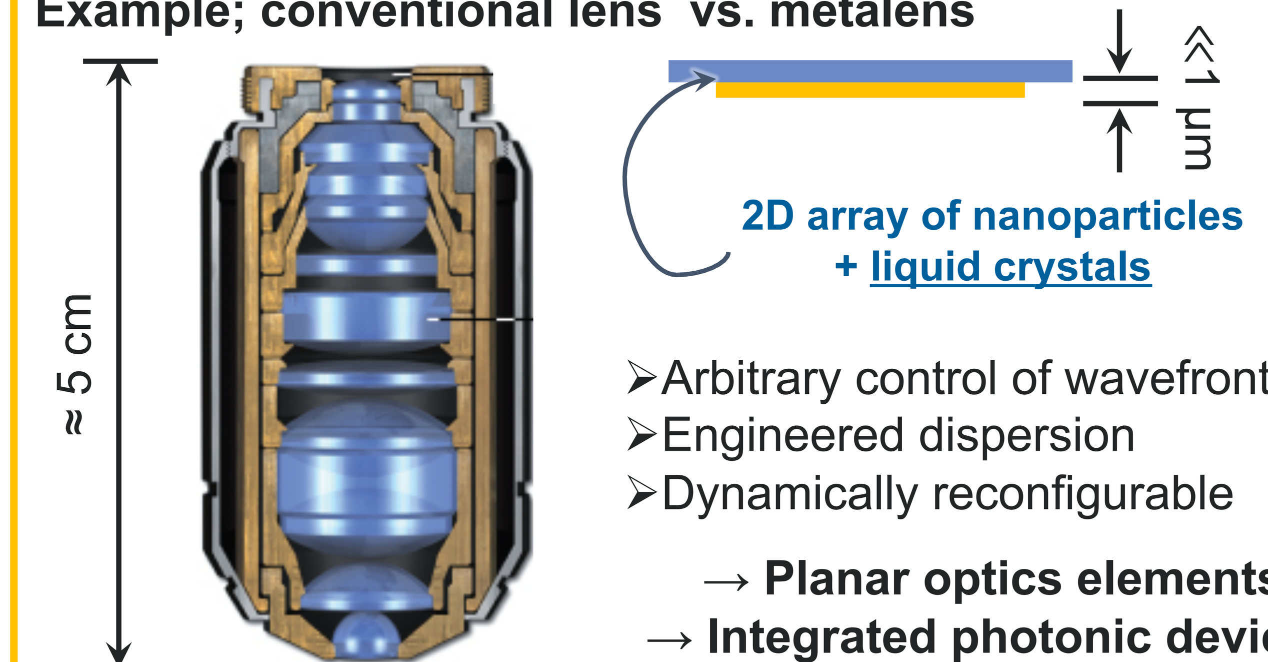
### Optical post-processing:

The transmission of the LC system is first calculated by approximating the material as a series of filters (Jones' calculus)




## Experimental; liquid crystal metasurfaces

**Example; conventional lens vs. metalens**



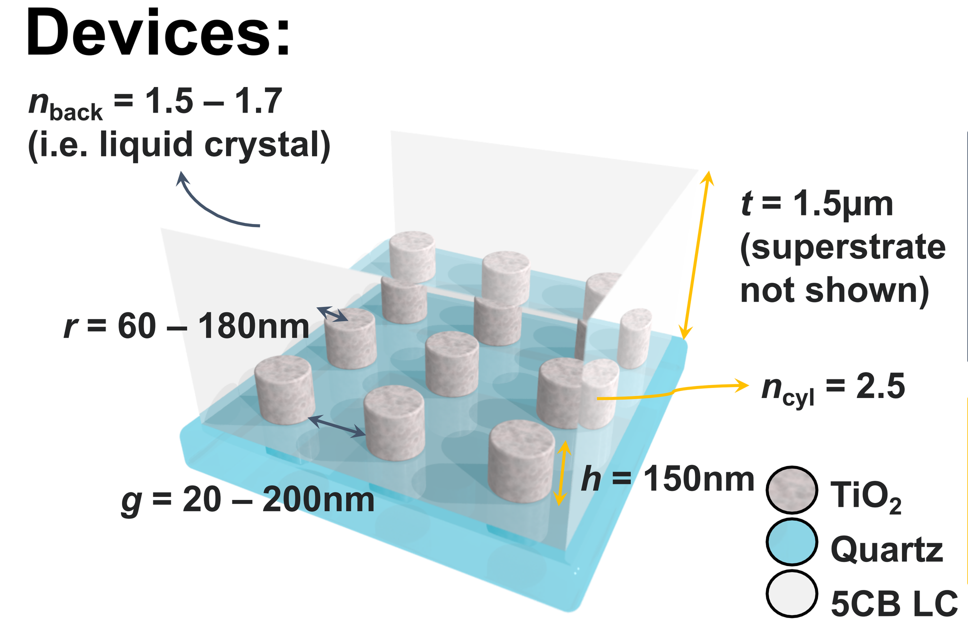

- Arbitrary control of wavefront
- Engineered dispersion
- Dynamically reconfigurable

→ **Planar optics elements**

→ **Integrated photonic devices**

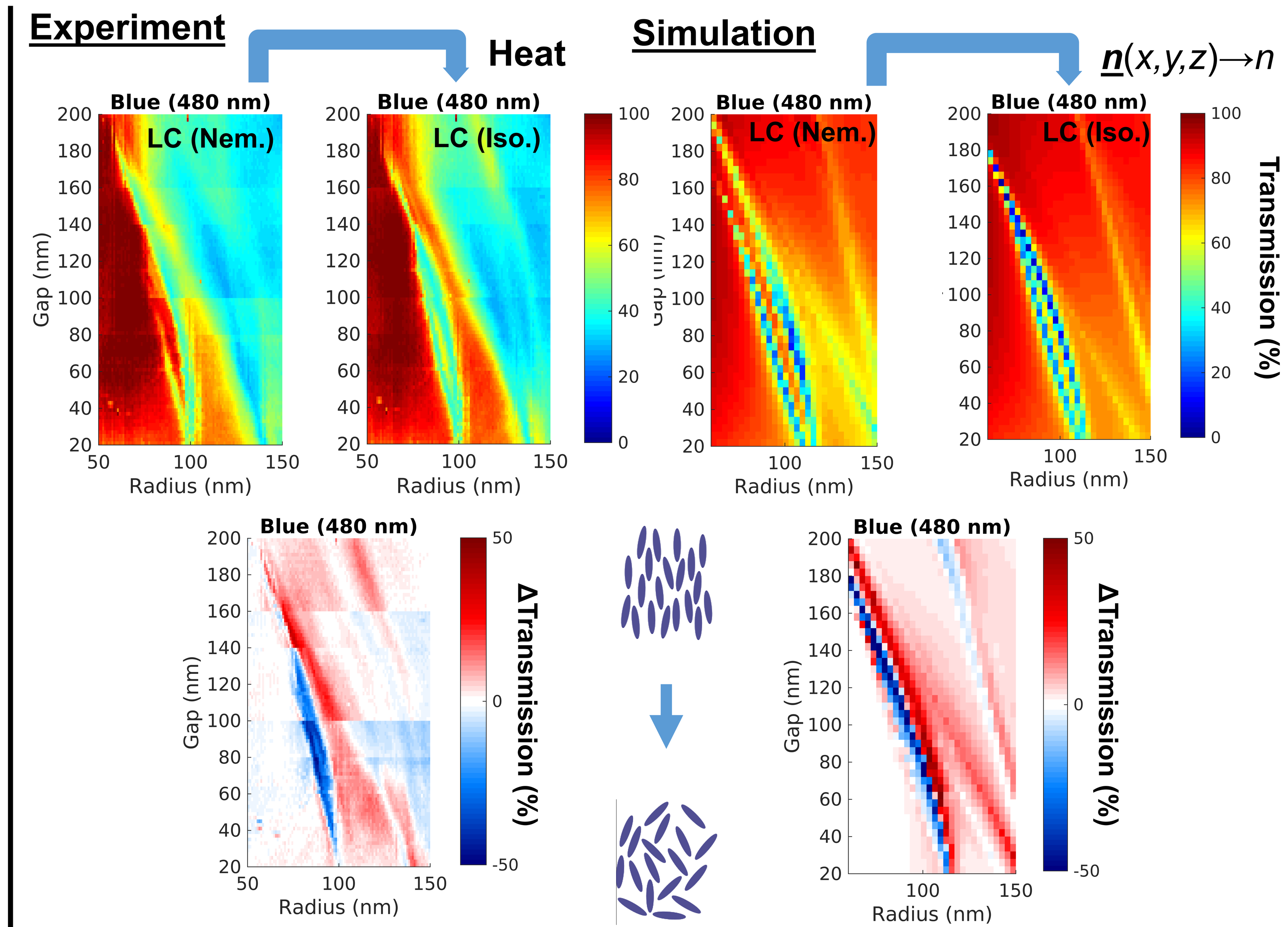
Metasurfaces—arrays of optically resonant nanoparticles—exhibit optical properties highly sensitive to the local director field of the surrounding liquid crystals, i.e. $\underline{\mathbf{n}}(x,y,z)$.

### Devices:

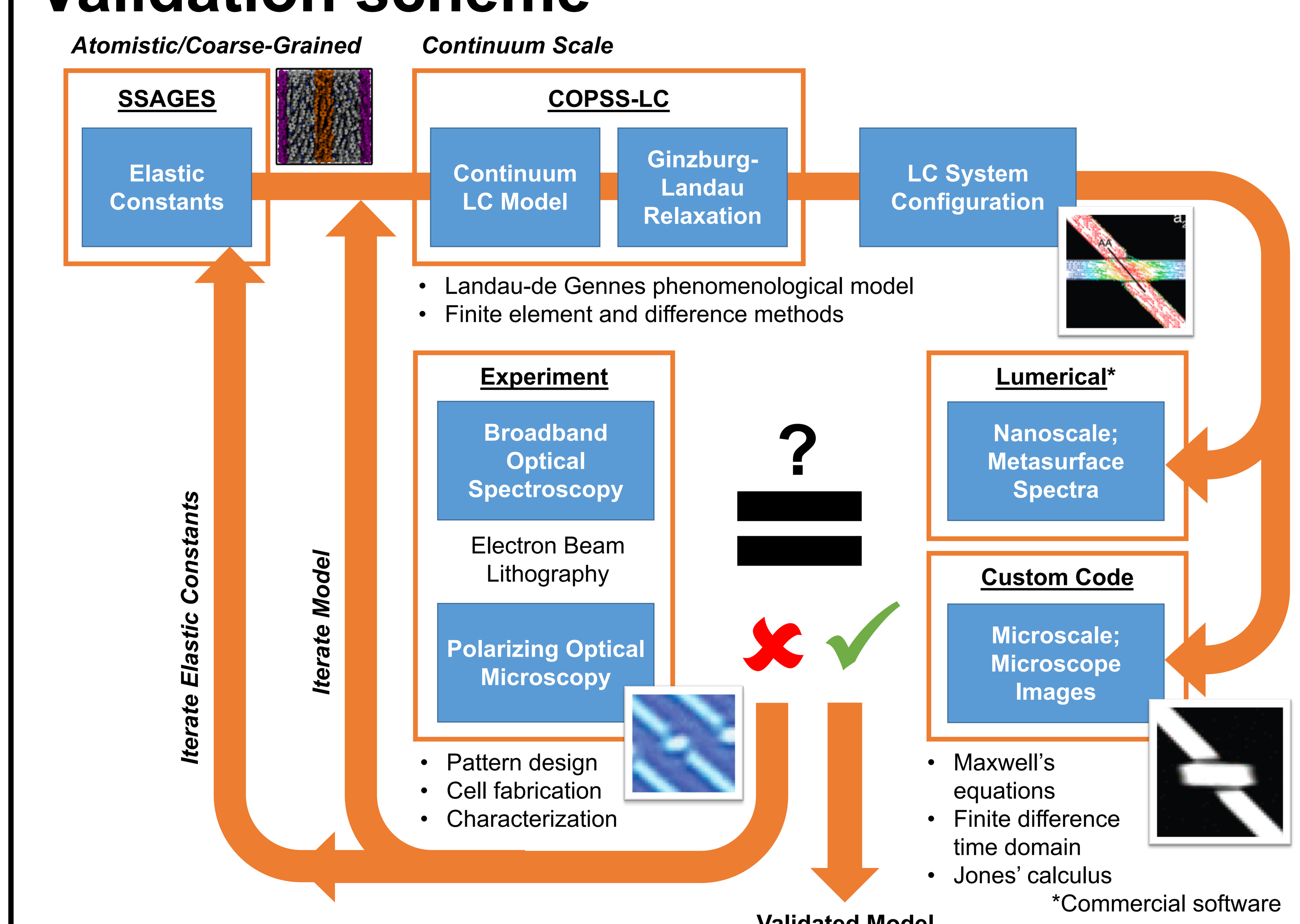



**Variable parameters:**
Cylinder radius, $r$
Cylinder-to-cylinder gap, $g$
Background index, $n_{back}$
Wavelength, $\lambda$

**Fixed parameters:**
Cylinder height, $h$
Cell thickness, $t$
Cylinder index, $n_{cyl}$




## Validation scheme




## Acknowledgements

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(2) Ravnik, M. and Zumer, S. Liquid Crystals **36**, 1201- 1214 (2009).
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