Modeling of the Photo-Mechanical Response of Liquid-Crystal Elastomers (LCEs)

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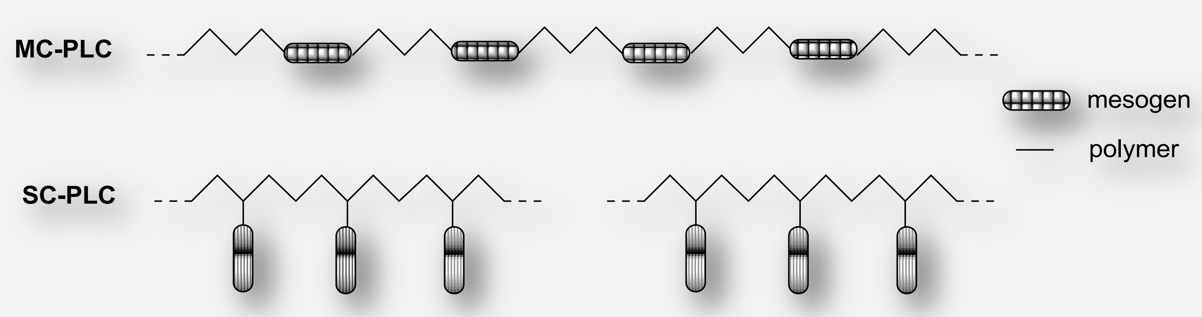
Liquid Crystal Elastomers

Liquid crystals can be described as fluids made of stiff molecules that show a long range orientational order. The simplest case is nematic, where the director **n** (the average ordering direction of the molecules) is uniform. Using long polymer chains and ordering them nematically, we obtain a polymeric liquid crystal (PLC).



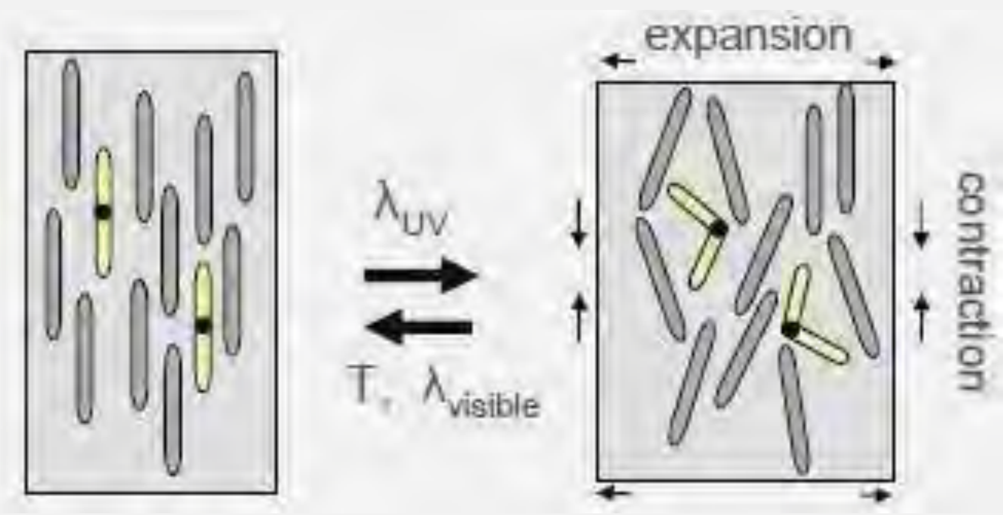
LCE are a particular kind of PLC [1]. Are rubber-like materials which react to external stimuli [2], depending on the orientation of the molecules, the absorption coefficient of the medium and the light intensity.

Photo-sensitive LCEs

The main focus of our work is on light driven liquid crystalline polymer actuators as a model system.

The idea is to use liquid crystal elastomer (LCE) that deforms when illuminated by a laser radiation. The photo-mechanical response of LCEs is due to a photo-sensitive dye, which change shape when absorbs part of the incident light, causing the deformation of the material.

These microscopic deformations can cause a macroscopic contraction or expansion of the material and this phenomenon can be used, for instance, to drive a small actuator with light.

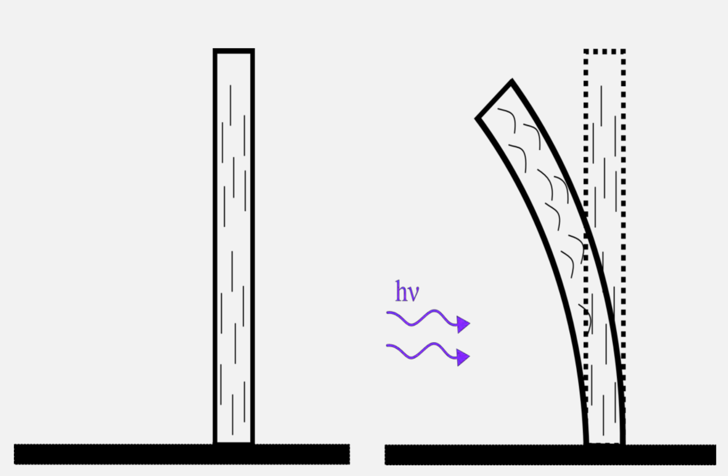


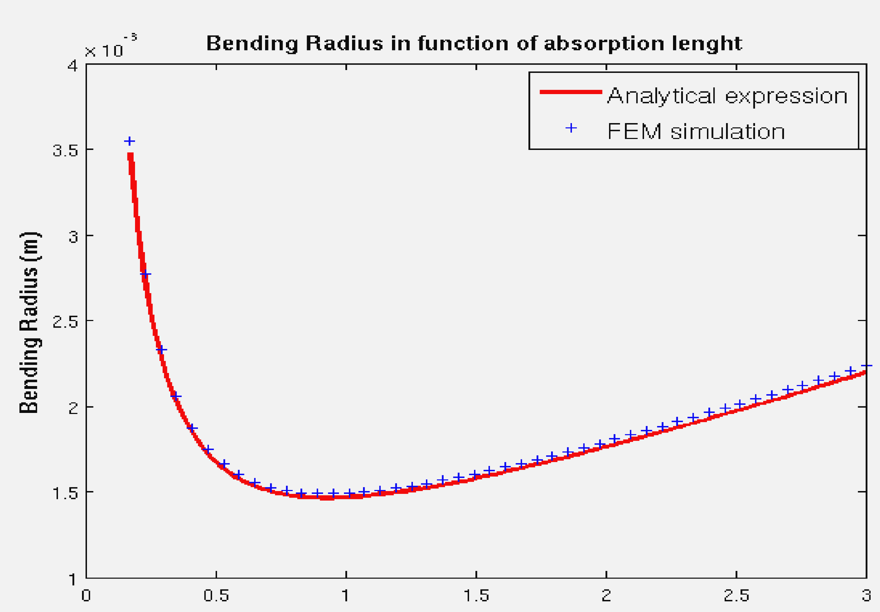
Modeling

We modeled (stationary and time dependent) the macroscopic deformation of a two-dimensional photo-sensitive LCE cantilever in response to light excitation. Incoming light was modeled by a plane wave and the resulting deformation is a function of molecular alignment, absorption coefficient and light intensity. We also compared our results with a simplified analytical model assuming the Beer-Lambert's law of absorption [3].

$$I = I_0 \times e^{\frac{-x\varphi}{d}} \qquad \varepsilon(x) = \varphi P_{\parallel} I(x) cos^2\Theta + \varphi P_{\perp} I(x) sin^2\Theta$$

The Comsol RF package was used to solve the electromagnetic problem of the light scattering and absorption by the object. The resulting material deformation was then evaluated using the Comsol SM package by introducing an equation that expresses the strain in the material as a function of the retrieved light intensity.

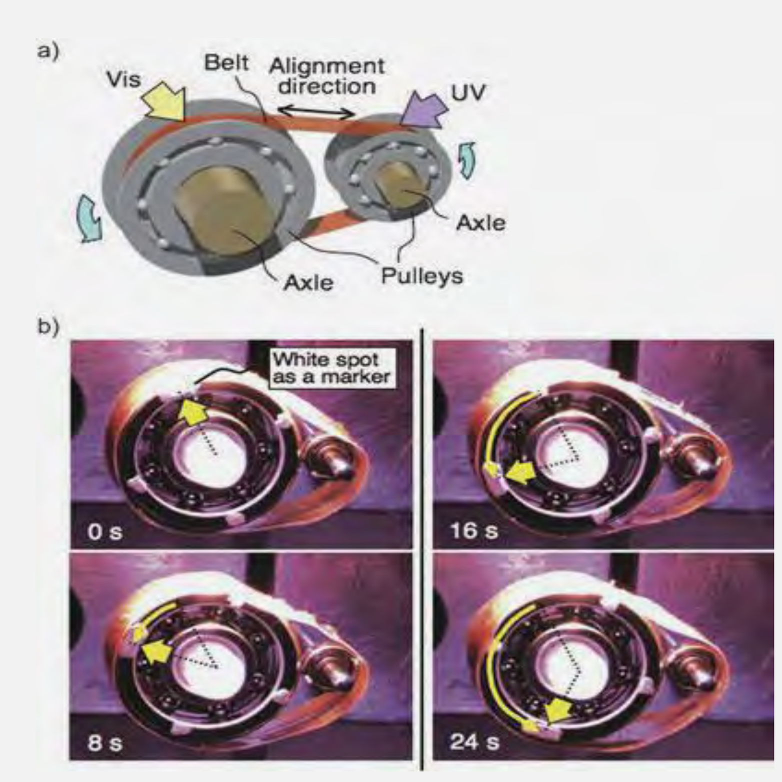




Applications

Liquid-crystal elastomers (LCEs) are very interesting materials and show a high potential in a wide range of applications, from microfluidics components [4] to artificial muscles [5].

By solving exactly the electromagnetic problem, our finite-element model completes the theoretical models known so far on the deformation of LCE-based materials. It can be easily applied to more complex geometries and may find use in a near future in the design of actuators for lab-on-a-chip devices [6] or in the implementation of soft motors [7].



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