Circularly polarized lasing cavities using cellulose nanocrystals as polarization-selective reflectors

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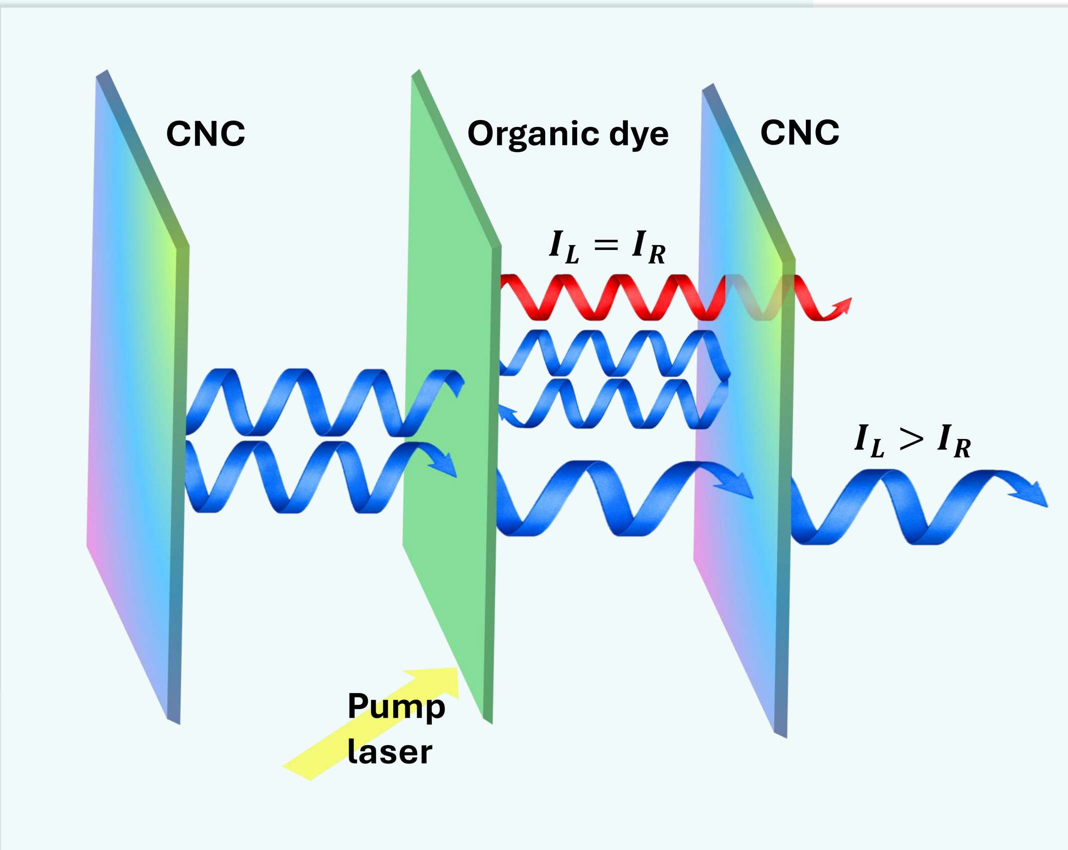
Introduction

Optical cavities are devices designed to confine and amplify light through multiple reflections between two mirrors and represent a key component in laser technology. The ability to produce cavities capable of emitting circularly polarized light (CPL) is particularly desirable for applications in photonics, displays and optical sensing. However, achieving this remains challenging, because the handedness of circularly polarized light is reversed upon each reflection.[1]

Cellulose nanocrystals (CNCs) are rod-shaped nanoparticles obtained by acid hydrolysis of cellulose. Being derived from renewable sources, they are a biocompatible and affordable material with many applications in materials science and biomedicine.[2] In aqueous suspension, CNC self-assemble into a chiral nematic phase, arranging into left-handed helical structures which tend to be retained after evaporation of the water solvent.[3] The resulting films exhibit preferential reflection of left CPL at a tunable wavelength, which makes them promising polarizing elements.[4] In this work, we propose to exploit this material for the manufacturing of CPL laser cavities.

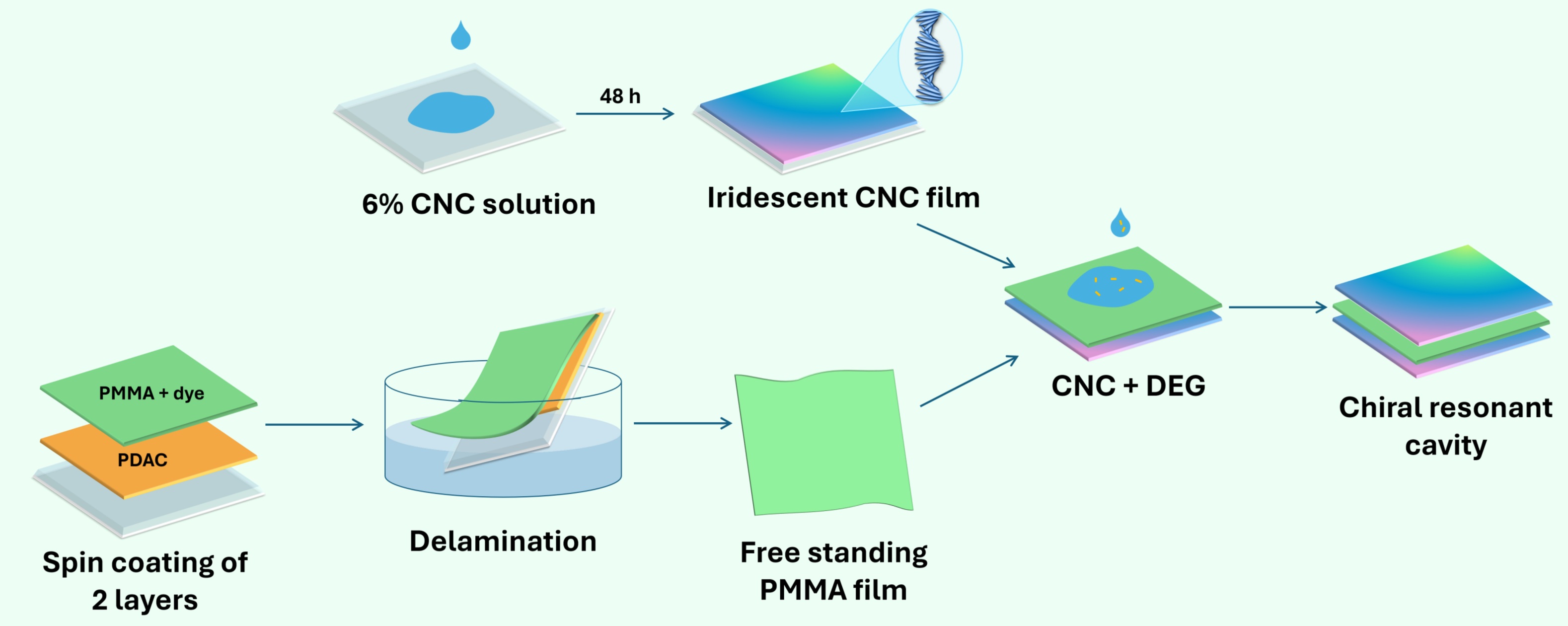
Key idea

A thin layer of a suitable emissive achiral organic dye is embedded between two CNC reflective films, whose reflection band is tuned to match the emission of the dye. Consequently, LCP light is reflected several times and amplified, while RCP light is transmitted.



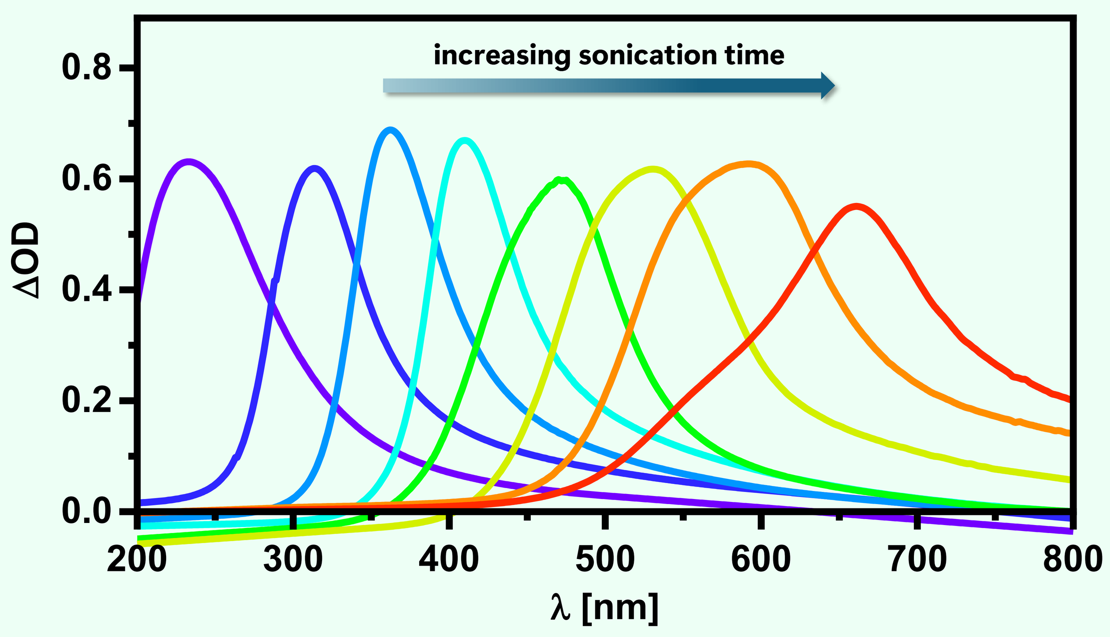
Preparation

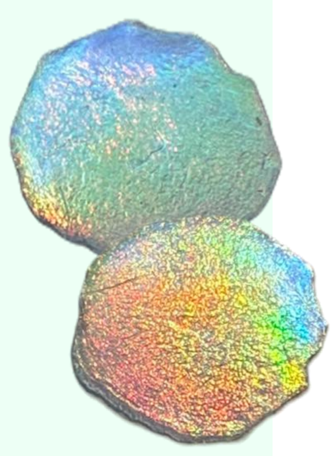
A sonicated CNC solution is evaporated to form a film. Next, a dye-doped PMMA film is spin-coated onto a water-soluble layer for delamination and transferred on top. A second CNC layer is evaporated from a sonicated CNC solution containing diethylene glycol (DEG) to ensure adhesion to PMMA.



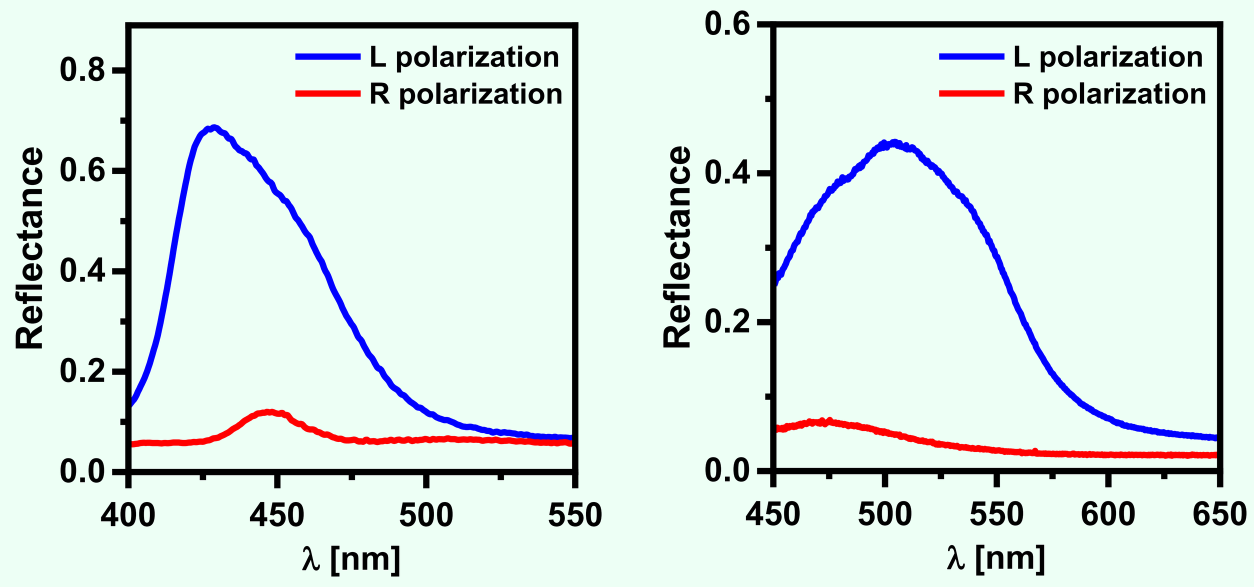
CNC film characterization

Increasing the sonication time produces a red-shift in the reflectance band of the CNC film. In this way, we can change the reflection band to match a desired spectral region.





Right- and left-handed reflectance spectra were also acquired to characterize the optical response of the material.

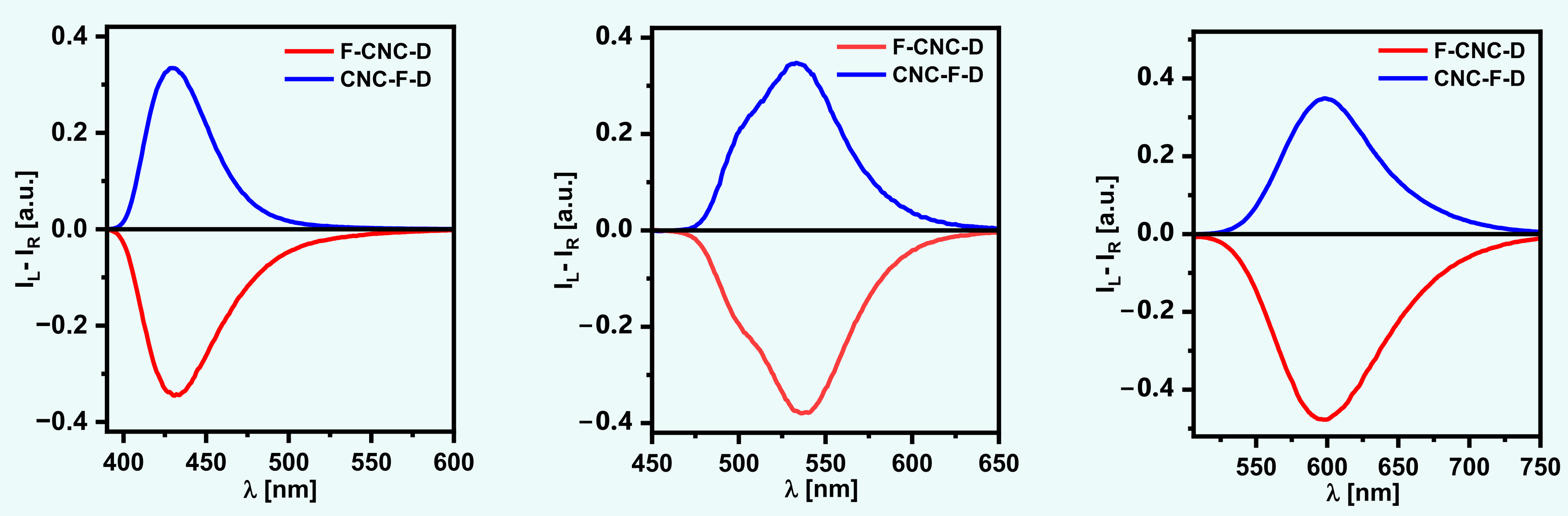


Bilayer characterization

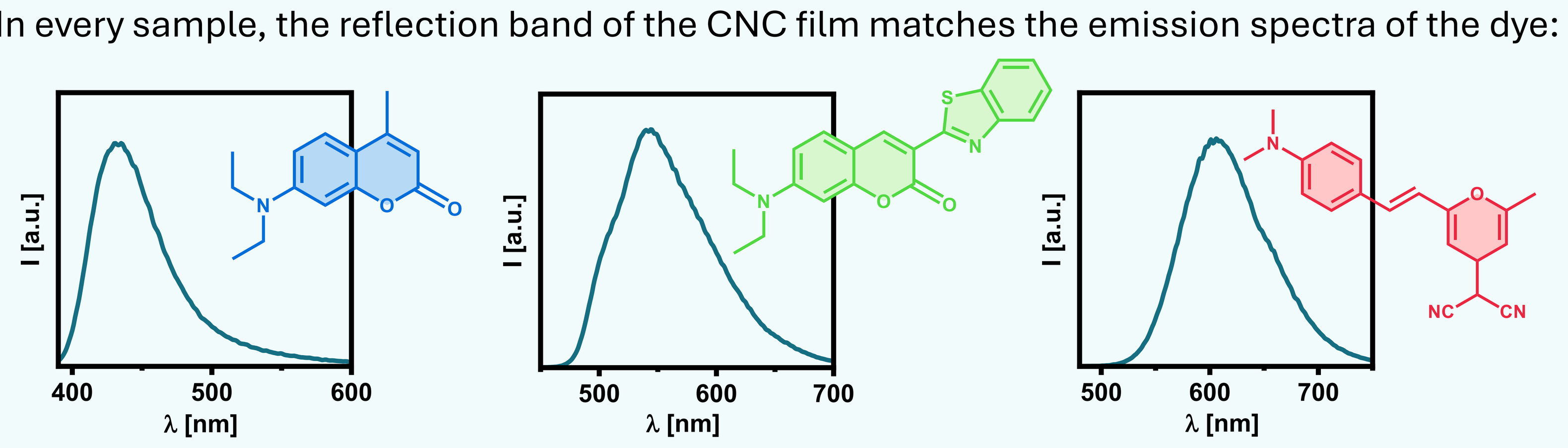
A bilayer system consisting of a CNC film and a dye-doped PMMA layer was assembled, and CPL emission was measured in two configurations.

fluorophore – CNC – detector
Part of the left polarized light is reflected away from the detector.

CNC – fluorophore – detector
Part of the left polarized light is reflected back to the detector.



In every sample, the reflection band of the CNC film matches the emission spectra of the dye:



Conclusions and Outlook

In this work, drying conditions of CNC films were optimized, yielding significant improvements in their optical properties, as confirmed by spectroscopic characterization. Furthermore, CNC-PMMA bilayers were successfully fabricated and characterized, demonstrating their suitability as functional components for resonant cavities. We were able to deposit a second layer of CNCs, obtaining the first prototype of the device. Ongoing efforts are focused on optimizing the fabrication condition of cavities in order to improve the overall performance of the cavity.

References

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