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Optomechanical polarization effects in a chiral metasurface

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Polarization is a key attribute of light, having great relevance in science and technology. Most of all, chirality-carrying polarization states – i.e., elliptical and circular polarization states – are of extreme importance in connection to biology, where the enantiomeric molecules have different biological roles, and can be detected by optical means. However, the manipulation of light polarization classically relies on components such as waveplates, which are bulky and hardly integrable. In this view, metamaterials and metasurfaces are showing great potentials since they allow to manipulate light amplitude, phase and polarization in unprecedented ways [1].
In this work we show that a dielectric membrane, patterned with chiral (L-shaped) holes, can dynamically transform light polarization. The operation principle is as follows: the patterned membrane (detail in Fig. 1b) converts linear impinging light polarization into a prescribed polarization state (Fig. 1a), thanks to metasurface optical resonances (antenna-like resonant mode dictated by the L-hole shape; here optimized for operation at a wavelength of 1550 nm). If the membrane is forced to oscillate in its fundamental drum-like mode (vibrometric measurement in Fig. 1c), the polarization state of the reflected light can be modulated in a non-trivial way on the Poincaré sphere, as illustrated in Fig. 1d. This behavior, that originates from the optical interaction of the free-standing metasurface membrane with the underlying substrate, can in principle be engineered to span a-priori prescribed paths on the Poincaré sphere, thus further expanding the operation illustrated in Fig. 1d (where each colored line indicates the polarization modulation at a fixed wavelength).
In addition to this mechano-optic effect, we discovered that the reverse, opto-mechanic effect also takes place: the polarization state of input light affects the mechanical eigenfrequency. We measured the transduction of the membrane while varying the input light polarization state, observing the effect reported in Fig. 1e: the mechanical resonance frequency depends on light polarization. Notice that, when represented on the flattened Poincaré sphere, the effect reveals a precise chirality (Fig. 1f). Among the possible mechanisms responsible for this behavior, we identified that a thermomechanic effective spring constant softening is the most plausible candidate, as supported by the strong correlation between the mechanical resonance frequency shift and the photonic intracavity energy density (Fig. 1g).
We believe that the reported effects are proving principles that may pave the ground towards innovative polarization state generators and detectors.

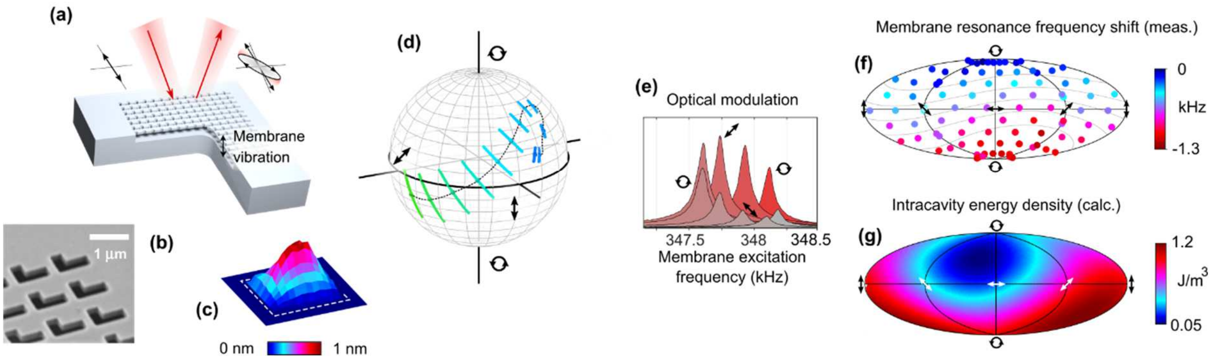

Figure 1. Concept and data illustrating optomechanical effects in a chiral metasurface.

References

[1] M. Hentschel, M. Schäferling, X. Duan, H. Giessen, N. Liu, "Chiral Plasmonics", *Sci. Adv.* **2017**, *3*, e1602735.