PHOTONIC FORCES

⊷ Ewold Verhagen

The Photonic Forces group studies light-matter interactions at the nanoscale, in particular the coupling between light and nanomechanical motion in optomechanical systems. We seek to understand how the behavior of light and sound in nanoscale devices is governed by fundamental principles such as spatiotemporal symmetries and quantum mechanics. We explore how suitable system design and control over light-matter interactions can induce unusual phenomena for photons and phonons such as nonreciprocity and topological states of sound and light. Using such insights, we challenge the conventional limits to nanophotonic and nanomechanical functionality, in application domains from quantum sensing and metrology to communication.

Highlights 2017-2022

- Demonstrated optical nonreciprocity in optomechanical systems, including magnet-free circulation and optomechanical birefringence [5].
- Demonstrated that strong pulsed, projective optical measurements of a mechanical resonator can be brought to the quantum regime [4].
- Observed topologically protected flow of light in silicon photonic crystals [3].
- Proposed and demonstrated effective magnetic fields for phonon transport in nanomechanical networks through radiation pressure control, and discovered gauge fields that control non-Hermitian dynamics [1,2].

Plans

The group's research in the next years comprises two synergetic main thrusts: On the one hand, we challenge the conventional limits of mechanical quantum metrology through strong, projective optomechanical measurements. We study how quantum squeezing and entanglement can be used to boost sensing performance, and develop high-resolution chip-based optomechanical sensors. On the other hand, we explore exotic states of light and sound that in metamaterials where temporal and spatial symmetries can be controlled through nanophotonic design and active radiation pressure control. This includes nonreciprocal behavior as well as non-Hermitian and nonlinear topological bosonic phases, with applications from sensing to communication.

Key research items

1. J. del Pino, J.J. Slim and E. Verhagen, *Non-Hermitian chiral phononics through optomechanically-induced squeezing*, Nature 606, 82 (2022)

2. J.P. Mathew, J. del Pino and E. Verhagen, *Synthetic gauge fields for phonon transport in a nano-optomechanical system*, Nature Nanotechnology 15, 198 (2020)

3. N. Parappurath, F. Alpeggiani, L. Kuipers and E. Verhagen, *Direct observation of topological edge states in silicon photonic crystals: Spin, dispersion, and chiral routing*, Science Advances 6, eaaw4137 (2020)

4. J.T. Muhonen, G.R. La Gala, R. Leijssen and E. Verhagen, *State preparation and tomography of a nanomechanical resonator with fast light pulses*, Physical Review Letters 123, 113601 (2019)

5. F. Ruesink, J.P. Mathew, M.-A. Miri, A. Alù and E. Verhagen, *Optical circulation in a multimode optomechanical resonator,* Nature Communications 9, 1798 (2018)

Nanoscale optomechanical system, where radiation pressure control fields induce nonreciprocal and topological states states of sound.