RESONANT NANOPHOTONICS

⊶ Femius Koenderink

We develop resonant optical metasurface and nano-antenna motifs for controlling light-matter interaction, and for realizing new types of information processing and sensing schemes. Key concepts are precise spatial and spectral control of local density of optical states to manipulate emission, amplification, non-linear conversion and inelastic scattering (SERS/molecular optomechanics) of light, and also full control and measurement of far field information encoded in vector, amplitude and phase properties of light. Societal impact domains include solid-state lighting, wafer metrology, SERS/IR and chiral spectroscopy, and energy-efficient information processing.

Highlights

- We observed that optical bound states in the continuum that have no symmetry protection are nonetheless protected by far-field polarization topology [2].

- We developed plasmonic-photonic resonators with tunable high-Q resonances yet record confinement (Q/V ~ ($\lambda^3/10^6$)), and demonstrated their use for sideband-resolved molecular optomechanics [4].

- Our high-NA, fully polarimetrically and phase-resolved single nano-object radiation microscopy enables from foundational to applied research, including on singular light generated by plasmonic-photonic resonators, metasurface mathematical operations, and diffraction-based super-resolution [3].

- We disseminate know-how as Open Source code, e.g., for unbiased Bayesian-inference based photon-by-photon analysis of single-emitter intermittency photophysics [5], and for light-matter engineering design relevant for LEDs, PV, and enantioselective microscopy.

Plans

On the crossroads of metasurfaces, wavefront-shaping, and computational imaging we will impact two main research arenas: metrology and imaging in complex systems (e.g. wafer metrology) with linear and nonlinear nanophotonics, and metaphotonics for information processing. Here we envision stacks of reconfigurable, nonlinear and trainable metaphotonics to process and classify analog data encoded in 2D wavefronts, and that can ultimately interface 2D to in-plane optoelectronics. Regarding light-matter interaction, we will develop photonic reservoir engineering (generalized spatial, spectral and vector LDOS control) for coherent molecular optomechanics, nonlinear light generation, and chiral nanophotonics.

Key research items

1. A.F. Koenderink, *Single-Photon Nano-Antennas (Perspective)*, ACS Photonics 4, 710–722, (2017) [most read ACS Photonics paper in 2017]

2. H.M. Doeleman, F. Monticone, W. den Hollander, A. Alù and A.F. Koenderink, Experimental Observation of a Polarization Vortex at an Optical Bound State in the Continuum, Nature Photonics 12, 397–401, (2018) [winner 2019 thesis award]

3. R. Röhrich, C. Hoekmeijer, C.I. Osorio and A.F. Koenderink, *Quantitative Single Nano-Antenna Far Fields through Interferometric and Polarimetric k-Space Microscopy*, Light: Science and Applications 7, 65, (2018) [nucleus of ARCNL-ASML collaboration]

4. I. Shlesinger, I.M. Palstra and A.F. Koenderink, *Integrated Sideband-Resolved SERS with a Dimer on a Nanobeam Hybrid*, Phys. Rev. Lett. 130, 016901 (2022/2023)

5. I.M. Palstra and A.F. Koenderink, *A Python Toolbox for Unbiased Statistical Analysis of Fluorescence Intermittency of Multi-Level Emitters*, J. Phys. Chem. C 125, 12050–12060, (2021) - Open Code project (DOI: 10.5281/zenodo.4557226).

Two concepts for hybrid plasmonic-photonic resonators – lithographic (left), and based on the nanocube-on-mirror geometry, in a Fabry-Perot microcavity (right).