Bose-Einstein condensation and topological photonics with plasmonic lattices

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Arrays of plasmonic nanoparticles, so-called plasmonic lattices, when combined with an emitter material (gain medium), provide a versatile platform for studies on light-matter interaction in the nanoscale, including collective coherent phenomena as well as topological photonics. We have experimentally realized a new type of condensate: a BEC of hybrids of surface plasmons and light in a nanoparticle array, with unique polarization and coherence properties [1-4]. We observe the BEC both in the weak [1] and strong [2-4] light-matter coupling regimes. The spatial and temporal coherence show a change from Gaussian/exponential to power law decay at the transition from polariton lasing to BEC [4]. In the lasing regime, we have observed bound states in continuum (BIC) modes with different topological charges [5,6]. By tuning the size of a hexagonal unit cell, we can realize lasing that shows transitions between states of topological charges zero, one, and two [6]. We found that the transitions are driven by losses, determined by the geometric structure of the modes of different topological charges. Recently, we have experimentally observed non-zero quantum metric and Berry curvature along the diagonals of the Brillouin zone of a square lattice of gold nanoparticles [7]. By a theoretical analysis, we show that the Berry curvature originates solely from non-Hermitian effects [8]. In this talk, an introduction to these topics, and a discussion of the key results will be given.

References:

[1] T. K. Hakala, A. J. Moilanen, A. I. Väkeväinen, R. Guo, J.-P. Martikainen, K. S. Daskalakis, H. T. Rekola, A. Julku, and P. Törmä, Nature Phys. **14**, 739 (2018).

[2] A. I. Väkeväinen, A. J. Moilanen, M. Necada, T. K. Hakala, and P. Törmä, Nature Commun. **11**, 3139 (2020).

[3] J. M. Taskinen, P. Kliuiev, A. J. Moilanen, and P. Törmä, Nano Lett. **21**, 5202 (2021).

[4] A. J. Moilanen, K. S. Daskalakis, J. M. Taskinen, and P. Törmä, Phys. Rev. Lett. **127**, 255301 (2021).

[5] R. Heilmann, G. Salerno, J. Cuerda, T. K. Hakala, and P. Törmä, ACS Photonics **9**, 224 (2022).

[6] G. Salerno, R. Heilmann, K. Arjas, K. Aronen, J.-P. Martikainen, and P. Törmä, Phys. Rev. Lett. **129**, 173901(2022).

[7] J. Cuerda, J. M. Taskinen, N. Källman, L. Grabitz, P. Törmä, arXiv:2305.13174 (2023).

[8] J. Cuerda, J. M. Taskinen, N. Källman, L. Grabitz, P. Törmä, arXiv:2305.12244 (2023).