Rydberg Exciton-Polaritons in a Magnetic Field

Emma Laird,[1,2] Francesca M. Marchetti,[3] Dmitry K. Efimkin,[1,2] Meera M. Parish[1,2] and Jesper Levinsen[1,2]

[1]*School of Physics and Astronomy, Monash University, Victoria 3800, Australia*

[2]*ARC Center of Excellence in Future Low-Energy Electronics and Technologies, Monash University, Victoria 3800, Australia*

[3]*Departamento de Física Teórica de la Materia Condensada & Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, Madrid 28049, Spain*

We theoretically investigate exciton-polaritons in a two-dimensional (2D) semiconductor heterostructure, where a static magnetic field is applied perpendicular to the plane. To explore the interplay between a magnetic field and a strong light-matter coupling, we employ a fully microscopic theory that explicitly incorporates electrons, holes and photons in a semiconductor microcavity. Furthermore, we exploit a mapping between the 2D harmonic oscillator and the 2D hydrogen atom that allows us to efficiently solve the problem numerically for the entire Rydberg series as well as for the ground-state exciton. In contrast to previous approaches, we can readily obtain the real-space exciton wave functions and we show how they shrink in size with increasing magnetic field, which mirrors their increasing interaction energy and oscillator strength. We compare our theory with recent experiments on exciton-polaritons in GaAs heterostructures in external magnetic fields and we find excellent agreement with the measured polariton energies. Crucially, we are able to capture the observed light-induced changes to the exciton in the regime of very strong light-matter coupling where a perturbative coupled oscillator description breaks down. Our work can guide future experimental efforts to engineer and control Rydberg excitons and exciton-polaritons in a range of 2D materials.