Resonance energies and linewidths of Rydberg excitons in Cu_2O quantum wells

N. Scheuler[1,*], P. Rommel[1], J. Main[1], P. A. Belov[2]
[1]*Institute for Theoretical Physics 1, University of Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany.*
[2]*Institute for Physics, University of Rostock, Albert-Einstein-Straße 23-24, 18059 Rostock, Germany.*
**e-mail: st166772@stud.uni-stuttgart.de*

Rydberg excitons, similar to Rydberg atoms in solid-state systems, can attain significant sizes, reaching up to micrometer scale for principal quantum numbers up to n=25, particularly in materials like cuprous oxide [1]. The creation of quantum well-like structures within the crystal induces quantum confinement effects, enabling the investigation of a transition from three-dimensional to two-dimensional excitons. Narrow quantum well widths result in distinct Rydberg series separated by various scattering thresholds, leading to electron-hole resonances with finite lifetimes above the lowest threshold. Employing the stabilization method to analyze the parametric dependencies of the real-valued eigenvalues of the original three-dimensional Schrödinger equation, we compute resonance energies and linewidths for Rydberg excitons in quantum wells, where perturbative treatments are not feasible. Comparing the positions and finite linewidths of resonances above the third threshold with the complex resonance energies obtained through the complex-coordinate-rotation technique reveals an excellent agreement, validating both methods for intermediate sizes of quantum well-like structures and, consequently, for arbitrary widths.

Fig. 1. Stabilization diagram, density of states, and complex resonance energies for cuprous oxide Rydberg excitons in a quantum well with width L = 8nm.

References

[1] T. Kazimierczuk, D. Fröhlich, S. Scheel, H. Stolz, and M. Bayer, Giant Rydberg excitons in the copper oxide Cu_2O, Nature 514, 343 (2014).

[2] N. Scheuler, P. Rommel, J. Main, P. A. Belov, Resonance energies and linewidths of Rydberg excitons in Cu_2O quantum wells, Phys. Rev. B 109, 165440 (2024).

Acknowledgements

This work was supported by Deutsche Forschungsgemeinschaft (DFG).