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Deep Strong Light-Matter Coupling in Landau-Polaritons

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Manipulation of light-matter interactions in the terahertz (THz) spectral range offers new opportunities for developing active photonic and optoelectronic devices. In particular, the strong- and ultra-strong-coupling regimes enable the formation of hybrid light-matter states whose properties can be engineered through cavity design and electronic structure control. Materials hosting relativistic quasiparticles are especially attractive in this context because their low effective masses can significantly enhance the coupling strength.

In this work, we investigate THz light-matter coupling in bulk $Hg_{0.85}Cd_{0.15}Te$, a narrow-gap semiconductor supporting three-dimensional Kane fermions. By integrating the material into a Fabry-Perot resonator and performing magneto-THz spectroscopy, we observe the formation of Landau polaritons over a broad range of magnetic fields and carrier densities. The exceptionally low cyclotron mass of Kane fermions enables coupling strengths that extend from the strong-coupling regime deep into the deep-strong-coupling regime, with a normalized coupling ratio exceeding 1.6. The hybridized polaritonic modes remain clearly observable up to and beyond room temperature, demonstrating the robustness of the phenomenon under technologically relevant operating conditions.

The experimental results are supported by a gauge-invariant microscopic theory that accurately reproduces the observed polariton dispersion and coupling behavior. Beyond the fundamental interest in extreme cavity quantum electrodynamics, our findings establish $Hg_{0.85}Cd_{0.15}Te$ as a promising platform for cavity-engineered THz functionalities. The demonstrated combination of giant coupling strength, tunability, and room-temperature operation opens prospects for next-generation THz photonic components, including tunable modulators, detectors, non-linear devices, and polaritonic architectures based on semiconductor materials with relativistic electronic spectra.

REFERENCES

[1] D. Yavorskiy, D. Hagenmuller, N. Charrouj, Y. Ivonyak, A. Kazakov, Y. Todorov, W. Knap, M. Bialek. arXiv:2604.28042 (2026).