

Magneto-optical Kerr effect in pump-probe setups

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We develop a general theoretical framework for computing the time-resolved magneto-optical Kerr effect in ultrafast pump-probe setups, formulated within the Dynamical Projective Operatorial Approach (DPOA) [1-3] and its application to the generalized linear-response theory for pumped systems [4]. Furthermore, we exploit this formalism to express the post-pump optical conductivity — and consequently the Kerr rotation — in terms of the time-evolved single-particle density matrix (SPDM), providing a transparent and computationally efficient description of photo-excited multi-band systems. This extension, in addition to its lower computational cost, has the advantage of allowing the inclusion of phenomenological damping. We illustrate the formalism using both (i) a two-band tight-binding model, which captures the essential physics of ultrafast spin-charge dynamics and the Kerr rotation, and (ii) weakly spin-polarized germanium, as a realistic playground with a complex band structure. The results demonstrate that, by exploiting DPOA and/or its SPDM extension, one can reliably reproduce both the short-time features under the pump-pulse envelope and the long-time dynamics after excitation, offering a versatile framework for analyzing time-resolved magneto-optical Kerr effect experiments in complex materials. Moreover, this analysis clearly shows that the Kerr rotation can be used to deduce experimentally the relevant n-photon resonances for a given specific material [5].

References:

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