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Characterizing the electronic structure of quantum defects in semiconductors using time-resolved spectroscopy

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Wide-bandgap semiconductors like diamond and silicon carbide (SiC) are a leading solid-state platform for quantum technologies because they can host optically active point defects ("color centers") whose electronic structure enables optical spin initialization and readout schemes, as well as robust operation across a broad range of environments. Nowadays often called "quantum defects", these color centers have found widespread use cases such as quantum sensing and computing. Among them, the nitrogen-vacancy (NV) center in diamond is the most well-established system that is already utilized by several companies and startups for quantum-technology applications.

The particular spin-optical properties of quantum defects are defined by specific *intrinsic* relaxation channels occurring after photoexcitation that enable methods such as optically detected magnetic resonance (ODMR). In actual devices, defects do not exist in isolation but can interact with the host material and other defects through processes like photoionization and tunneling. These *extrinsic* dynamics lead to intricate interactions that alter important defect parameters such as their charge state.

I will give an overview on how we use time-resolved spectroscopy techniques to characterize bulk ensembles of quantum defects with respect to their intrinsic and extrinsic photodynamics. We use transient absorption (TA) spectroscopy to characterize intrinsic photodynamics by probing localized electronic transitions of the defect and time-resolved Terahertz (THz) spectroscopy as an all-optical probe for charge carrier dynamics in the electronic bands of the host [1]. Examples include quantum defects in diamond, SiC and hexagonal boron nitride [2-4].

References

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