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Ultrafast nano-optics: accessing structure, function, and dynamics of matter on its natural length and time scales

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Structure, function, and dynamics of matter are the result of an intricate interplay of its elementary excitations defined on femtosecond time and mesoscopic nanometer length scales. This gives rise to often complex phase behavior in soft matter as well as quantum phases in correlated electron materials with competing atomic scale short-range as well as mesoscopic nanoscale interactions. I will discuss our developments and applications of new nano-optical spectroscopies to study those interactions providing microscopic insight into otherwise difficult to probe processes in soft- and correlated matter. Our approach is based on the combination of plasmonic and optical antenna concepts with ultrafast and shaped laser pulses to achieve precise control of an optical excitation on the nanometer-femtosecond scale. I will introduce the enabling principles based on new regimes of near-field light-matter interaction in terms of impedance matching and optical antenna control of a quantum excitation