Physikalisches Kolloquium

Universität Konstanz

Di 29.11.16
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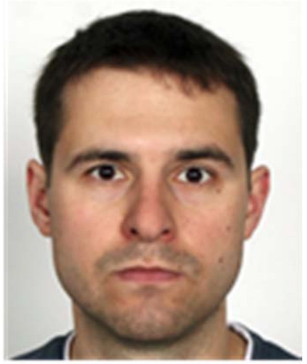

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Quantum dynamics with ultrashort broadband pulses of light

Progress in generation of extreme broadband pulses with very small durations (down to hundreds of attoseconds) and controlled shape is one of the fascinating and dynamic research areas in modern ultrafast photonics. In this talk I address from the theory perspective the issue of how such pulses can be applied to probe and control quantum states of both light and matter. Firstly, I will discuss the time-resolved behavior of the photonic ground state and show that vacuum fluctuations of its electric field can be directly detected using the linear electro-optic effect. I will sketch the main aspects of a general paraxial theory of electro-optic sampling of quantum fields developed for this purpose. Our calculations and the corresponding experimental results demonstrate that nonlinear mixing of a femtosecond near-infrared probe pulse with the multi-terahertz vacuum field in a thin electro-optic crystal leads to an increase of the signal variance with respect to the shot noise level. Moreover, with another femtosecond pump pulse interacting with the vacuum in an additional nonlinear optical crystal, we can modify the ground state of the field that leads to the generation of a pulsed squeezed vacuum state. Our findings shall pave the way for a new approach to quantum optics operating with an extreme, subcycle time resolution.

Then I will turn my attention to ultrafast control of the quantum-mechanical tunneling by phase-stabilized light pulses. When the pulse duration is sufficiently reduced, the tunneling process starts to be influenced by the energy gain as the electron moves in the classically forbidden region. We argue that this regime of non-adiabatic tunneling is realizable for experimentally available nanocontacts and light pulses. In a certain range of parameters, a decrease of the pulse duration leads to a drastic increase of the tunneling probability. Taking realistic waveforms and nanostructure configurations and utilizing a time-dependent quasiclassical approach, I will demonstrate that the preferred direction of the electron transport through the nanogap can be controlled by changing the carrier-envelope phase of the pulse.

Finally, I will consider the case when the pulse duration is so short that it becomes smaller than the characteristic time scales of the driven quantum system determined by the inverse energies of involved quantum transitions. In this case, the pulse action can be reduced to a quantum map between states of the driven system at a single appropriately chosen time moment during the pulse. This approach is used to control charge, spin, and valley degrees of freedom in semiconductor double quantum dots, semiconductor and graphene quantum rings. I will discuss ultrafast generation and elimination of currents. Schemes for spatial localization of spin and/or charge and its maintenance in time by tailored pulse trains will be also treated in the talk.