Großes Physikalisches Kolloquium an der Universität zu Köln

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Four-Dimensional Quantum Physics

It is well known that confinement on spatial dimensions smaller than the de Broglie wavelength leads to significant changes of the properties of e.g. an electronic system. Enabled by precise control over electromagnetic fields on a sub-femtosecond scale, we explore the physics emerging when light and matter become confined also in the fourth dimension – time. In a first set of experiments, we study the attosecond transport of electrons over atomic-scale tunneling junctions when biasing with phase-locked single cycles of near-infrared radiation. Femtojoule pulse energies are sufficient to reach a non-perturbative regime of current densities, aiming at novel quantum transport phenomena which might arise even at room temperature. A second area concerns the subcycle quantum physics of light itself. Reading out the nonlinear displacement of valence electrons in a semiconductor with few-femtosecond resolution, we can directly sample the vacuum fluctuations of the electric field. Their variance is proportional to the inverse space-time volume over which a probe pulse averages. This truly four-dimensional quantum confinement allows us to detect and manipulate signals derived from purely virtual excitations.