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Extremely high-intensity laser interactions with fundamental quantum systems

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The field of laser-matter interaction traditionally deals with the response of atoms, molecules, and plasmas to an external light wave. However, the sustained technological progress is opening up the possibility of employing intense laser radiation to trigger or substantially influence physical processes beyond atomic-physics energy scales. Available optical laser intensities exceeding 1022 W/cm2 can push the fundamental light-electron interaction to the extreme limit where radiation-reaction effects dominate the electron dynamics, can shed light on the structure of the quantum vacuum, and can trigger the creation of particles such as electrons, muons, and pions and their corresponding antiparticles. Also, novel sources of intense coherent high-energy photons and laser-based particle colliders can pave the way to nuclear quantum optics and may even allow for the potential discovery of new particles beyond the standard model. These are the main topics of this talk, which is devoted to a review of recent investigations on high-energy processes within the realm of relativistic quantum dynamics, quantum electrodynamics, and to a smaller degree nuclear and particle physics, occurring in extremely intense laser fields.

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