Ions, Atoms and Molecules in Intense Fields: From the Visible to FELs

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Upcoming 4th generation lights sources, so-called Free Electron Lasers (FEL), will provide, for the first time, intensities, coherence properties, short-time and pump-probe options in the VUV to X-ray regime comparable to those presently realized by intense, ultrashort laser pulses in the visible. At least three completely new fields of research are envisioned to open up in atomic and molecular physics. Those are (i) precision spectroscopy and ionization of all ions up to the highest charge states, (ii) quantum-state selective photoionization measurements on molecular ions and (iii) few-photon – few-electron processes on atoms, molecules and clusters. In the talk, they will be shortly highlighted and pioneer experiments under preparation at the DESY FEL will be briefly described. For the few-photon – few-electron processes, the transition from the multi-photon regime in the visible, realized by state-of-the-art optical lasers, to the VUV and X-ray few- to multi-photon area, accessible at the FELs, will be characterized in more detail with special emphasis on new possibilities to explore ultra-fast phenomena on the few femtosecond down to the attosecond time scale.