Ultrashort laser pulses: a new toolbox for ultracold quantum gases

Dr. Juliette Simonet

Institute for Quantum Physics, Universität Hamburg

Ultrashort laser pulses provide new pathways to manipulate and probe atomic quantum gases on femtosecond timescales. In particular, the strong light field of such pulses enables controlled and instantaneous photoionization of ultracold gases [1].
Above the two-photon ionization threshold of 87Rb, strong-field ionization triggers the formation of an ultracold plasma. While the initial thermal energy of the ions can be neglected, the electrons carrying the excess energy undergo rapid cooling on picosecond timescales [2].
Below the ionization threshold, we report the excitation of Rydberg states within a single femtosecond laser pulse. Due to the large bandwidth of the femtosecond laser, the Rydberg blockade is bypassed, resulting in the formation of dense Rydberg gases.
By combining state-of-the-art techniques from ultrashort laser pulses and ultracold atomic gases, we have developed a novel detection unit, consisting of a high-resolution ion microscope and a velocity map imaging spectrometer [3]. It will allow the simultaneous measurement of the spatial distribution of ions with a simulated spatial resolution of 100 nm and the momentum distribution of electrons with a relative resolution of 10 % over six orders of magnitude. Such a coincidence detection unit is an essential step towards the investigation of hybrid atom-ion quantum systems [4].

References

[1] P. Wessels et al., Communications Physics 1, 32 (2018)
[2] T. Kroker et al., Nature Communications 12, 596 (2021)
[3] M. Drescher et al., European Patent Application EP 4 303 907 A1 (2024)
[4] L. Oghittu et al., Physical Review Research 6, 023024 (2024)