Fundamentals of attosecond science

A L'Huillier

Department of Physics, Lund University, Lund, SE-22 100, Sweden

Extreme Ultraviolet light sources based on high-order harmonic generation (HHG) in gases are now used in many areas of science. The radiation consists of a train of extremely short light bursts, in the attosecond range, allowing for outstanding temporal resolution. HHG has opened the field of attosecond science, capturing ultrafast electron dynamics in matter [1]. This presentation will give a short historical perspective on this field of research.

The HHG efficiency depends both on the response of a single atom to a strong laser field and, as in any coherent nonlinear optical process, on the phase matching between the waves emitted by individual atoms in a macroscopic medium. An introduction to the physics of HHG will be given, covering both aspects of the process. The importance of phase matching is illustrated in Figure 1, showing the conversion efficiency of the 23rd harmonic in argon [2]. A good conversion efficiency can be obtained both with a long medium, low pressure and a short medium, high pressure, allowing for versatile setups. The implications of geometrical scaling [3] and wavelength scaling [4] will be discussed.

The short pulse duration and broad bandwidth of attosecond pulses allow the study of photoionization dynamics using laser-assisted photoionization. We will describe in particular the interferometric technique RABBIT (reconstruction of attosecond beating by two-photon transition) method [5], which has been used first for the measurement and characterization of attosecond pulses, then for the determination of photoionization time delays in atoms and molecules [6].

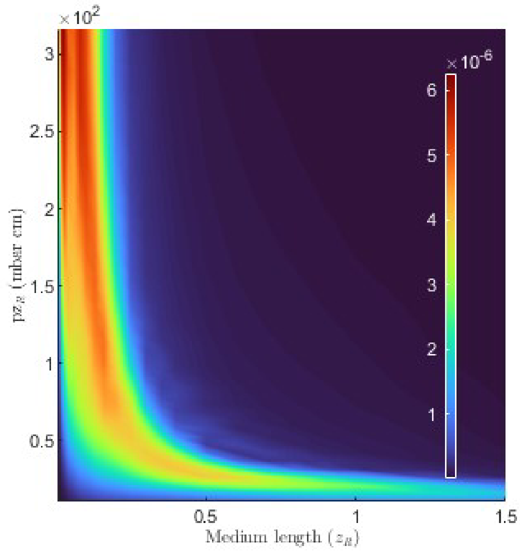

Figure 1. Conversion efficiency of the 23rd harmonic of 800 nm radiation generated in argon at an intensity of 2.5 x10^{14} W/cm^2. z_R denotes the Rayleigh length. Adapted from [1].

References

[1] F. Krausz and M. Ivanov, Rev. Mod. Phys. 81, 163 (2009)
[2] R. Weissenbilder R et al arXiv:2202.08202 (2022)
[3] C. M. Heyl et al., J. Phys. B, 50, 013001 (2017)
[4] B. Sheehy et al., Phys. Rev. Lett. 83, 5270 (1999); T. Popmintchev et al., Science 336, 1287 (2012)
[5] P.-M. Paul et al., Science 292, 1689 (2001)
[6] K. Klünder et al., Phys. Rev. Lett. 106, 143002 (2011)