Strong field double ionization: insights from nonlinear dynamics

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One of the most striking surprises of recent years in laser-matter interactions has come from multiple ionization by intense short laser pulses. Multiple ionization of atoms and molecules is usually treated as a rapid sequence of isolated events. However, in the early 90's, experiments using intense laser pulses found double ionization yields which departed from these predictions by several orders of magnitude. It has made the knee shape in the double ionization probability versus intensity curve one of the most dramatic manifestation of electron-electron correlation in nature.

It turns out that entirely classical interactions are adequate to generate the strong two-electron correlation needed for double ionization: numerical simulations succeed to reproduce qualitatively the knee shape observed experimentally. The central question is how two electrons leave the nucleus under the influence of a short and intense laser pulse? The precise mechanism that makes electron-electron correlation so effective follows the recollision scenario: An ionized electron, after picking up energy from the field, is hurled back at the ion core upon reversal of the field and dislodges the second electron.

In this talk, I will revisit the recollision mechanism, a keystone of strong-field physics, using a nonlinear dynamics perspective. I will show that this recollision scenario has to be complemented by the dynamical picture of the inner electron. Using this global picture of the dynamics, we were able to derive verifiable predictions on the characteristic features of the "knee", a hallmark of the nonsequential process.

Many questions remain unanswered regarding strong-field double ionization, and one that is still completely open concerns polarization. The stakes are high when it comes to understanding the influence of polarization since it is well known that the emission of harmonics is strongly dependent on the ellipticity of the driving field. A common wisdom is that the recollision scenario is suppressed with circular polarization (CP) since an ionized electron tends to spiral out from the core. The matter would rest there if it were not for conflicting experimental evidence: In some experiments using CP fields, the double ionization yields follow the sequential mechanism whereas in others these yields are clearly several orders of magnitude higher than expected. The question we resolve here is: Are recollisions possible in pure CP fields or does one have to rely on a small residual ellipticity? We explain these seemingly contradictory findings and show that, contrary to common belief, recollision can be the dominant mechanism leading to enhanced double ionization yields in CP fields.

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