Strong field double ionization of H_2 : The phase space perspective

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Synopsis Composed of both sequential and nonsequential process, the double ionization probability of the H_2 molecule in strong laser pulses takes the form of a "knee" as a function of the intensity of the pulse. We identify the organizing structures that regulate the ionization process. Using finite-time Lyapunov maps, laminar plots, and periodic orbits, we derive reduced Hamiltonian models which help us inferring the classical mechanisms of sequential and nonsequential double ionization. Phase-space structures that regulate atomic double ionization are identified allowing verifiable predictions on the characteristic features of the "knee", a hallmark of the nonsequential process.

One of the most striking surprises of recent years in intense laser-matter interactions has come from multiple ionization by intense short laser pulses: Correlated (nonsequential) double ionization rates were found to be several orders of magnitude higher than the uncorrelated sequential mechanism allows. This discrepancy has made the characteristic "knee" shape in the double ionization yield versus intensity plot into one of the most dramatic manifestations of electron-electron correlation in nature. The precise mechanism that makes correlation so effective is far from settled. Different scenarios have been proposed to explain the mechanism behind ionization and have been confronted with experiments, the recollision scenario, in which the ionized electron is hurled back at the ion core by the laser, being in best accord with experiments.

The characteristic features of double ionization have been reproduced using classical trajectories and this success was ascribed to the paramount role of correlation. Indeed, entirely classical interactions turn out to be adequate to generate the strong two-electron correlation needed for double ionization.

We consider the double ionization of the molecule H_2 where the two nuclei are fixed. We complement [1] the well-known recollision scenario by identifying the organizing principles which explain the statistical properties of the classical trajectories such as ionization probabilities :

- Periodic orbits which organize the motion
- Identification of an inner and an outer electron
- Reduced Hamiltonians for each electron
- Finite time Lyapunov maps (see Fig. 1) and laminar plots
- Prediction of the maximum of nonsequential double ionization

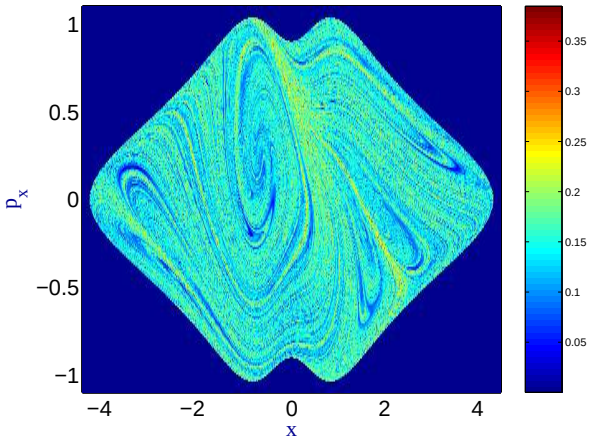

Fig. 2. Finite time Lyapunov map without the field at time $t = 50$ a.u. in the plane (x, p_x) with $y = 0$.

References

[1] F. Mauger, C. Chandre, and T. Uzer, Phys. Rev. Lett., to appear, 2009.

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