Multiphoton, Electron Collisions and BEC HPC Consortium

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In the area of electron collisions, research is focussed on electron collisions with complex atoms, collision induced multiple ionization of helium and positron scattering using parallelised *R*-Matrix and other techniques. The remaining problems are all in the theory of matter-laser interactions: laser-driven helium, laser-driven molecular hydrogen (H_2), *R*-Matrix-Floquet, laser-heating of clusters and laser interactions with Bose-Einstein condensates. All of these efforts involve large-scale time-dependent integrations of quantum mechanical few-and-many-body problems, with the aim of viewing the basic physics of laser-matter interactions in unprecedented detail.

The Multiphoton, Electron Collisions and BEC HPC Consortium has developed a number of highly successful massively-parallel codes in recent years. The most mature of these is the Belfast group's Helium code, which solves the 6-dimensional time-dependent helium-laser Schrödinger equation in its full generality. Thanks to the availability of adequate HPC resources in the UK, the Helium code has enabled the Belfast group to publish the first quantatively accurate helium double ionization cross-section calculations, the first correct predictions of angular-correlation of ejected electrons in double-ionization and the first demonstration of double-electron above threshold ionization (DATI).

DATI is a non-perturbative process in which intense fields violently eject the helium electrons in highly correlated 2-electron wavepackets. It is a process in which all degrees of freedom available to the system are simultaneously exercised and in which all terms of the helium-laser Schrödinger Equation are simultaneously exercised. It is a process of such intrinsic complexity that an accurate theoretical description requires the full sophistication of the Helium code and at present the full power of massively parallel computers.

The figure shows a quantum-mechanical state of helium prepared by a short intense laser pulse. The axes are the absolute value of each electron's momentum (k_1, k_2), which scales asymptomatically as the square root of electron kinetic energy. The circular arcs, satisfying the constraint $k_1^2 + k_2^2$ = constant, represent two-electron wavepackets of constant total kinetic energy. The arcs are separated in energy by a photon's energy, which is the signature of above threshold ionization.

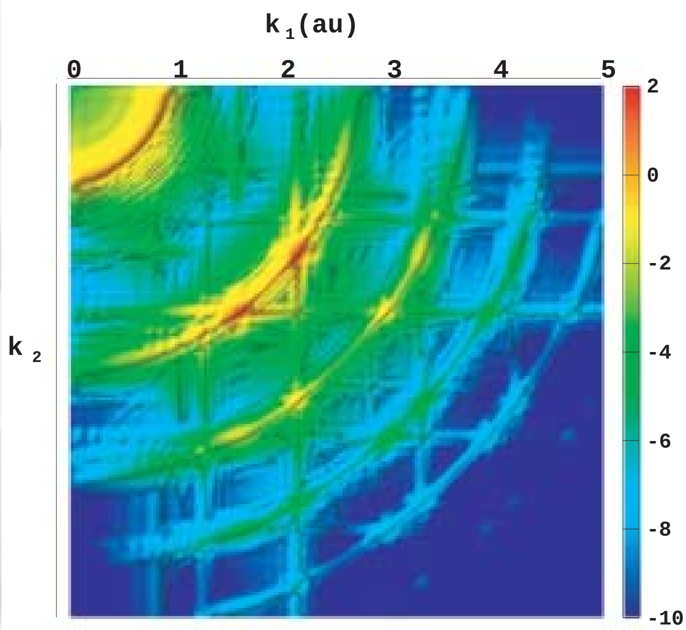

Figure 1 - Quantum-mechanical state of helium prepared by a short intense laser pulse.