Experimental Evidence for Wigner’s Tunneling Time

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Tunneling of a particle through a barrier is one of the counter-intuitive properties of quantum mechanical motion. Thanks to advances in laser technology and generation of electric fields comparable to those electrons experience in atoms, new opportunities to dynamically investigate this process have been developed. For example, in the so-called attoclock measurements \cite{1} the properties of the electron after tunneling are mapped on its emission direction after its interaction with the laser pulse.

In this work we investigate the first hundred attoseconds of the electron dynamics during strong field tunneling ionization.

We achieve a high sensitivity on the tunneling barrier thanks to two ameliorations to the attoclock principle. Using near-IR wavelength (1300 nm) we place firmly the ionization process in the tunneling regime and limit non-adiabatic effects. Furthermore, we compare the momentum distributions of two atomic species of slightly different atomic potentials (argon and krypton) being ionized under absolutely identical conditions.

Experimentally, using a reaction microscope, we apply coincident electron-ion detection in combination with a gas-target that contains a mixture of the two species and succeed in measuring the 3D electron-momentum distributions for both targets simultaneously. Theoretically, the time resolved description of tunneling in strong-field ionization is studied using the leading quantum mechanical Wigner treatment. A detailed analysis of the most probable photoelectron emission for Ar and Kr (Fig. 1) allows testing the theoretical models and a sensitive check of the electron initial conditions at the tunnel exit. The agreement between experiment and theory provides a clear evidence for a non-zero tunneling time delay and a non-vanishing longitudinal momentum at this point \cite{2}.

\begin{figure}[h]
\centering
\includegraphics[width=0.8\textwidth]{figure1.png}
\caption{The difference between the most probable photo-electron emission angle for argon and krypton: experiment and theories (with and without initial momentum and tunneling delay time)}
\end{figure}

References

\cite{1} P Eckle, A N Pfeiffer, C Cirelli, A Staudte, R Dörner, H G Muller, M Büttiker and U Keller, Science 322, 1525 (2008)