Atomic entanglement studied by the two-photon fluorescence emitted from excited neutral dissociation fragments

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The ionization-free photodissociation of the doubly excited (also called super-excited) Q states in Hydrogen leads to an entangled pair of excited atomic fragments which will decay into their ground states while each atom emits a fluorescence photon. The angular correlation of this fluorescence is a fingerprint of the entanglement of the atom pair.

We investigate these entangled atom pairs utilizing the coincident detection of the two emitted photons from the two fragments after excitation of H_2 with an energy of 33.6eV and subsequent dissociation. The verification and the determination of the recently found extraordinary high scattering cross section [1] for entangled atom pairs is intended.

In a preparatory experiment, the dispersed fluorescence spectrum of molecular hydrogen after excitation with the mentioned 33.66eV in the range of 110nm to 210nm has been recorded in order to determine the amount of fluorescence lines in comparison to the expected Lyman-α-line (see fig. 1). The spectrum shows the prominent Lyman-α fluorescence line at 121.6 nm with a number of unresolved fluorescence transitions beneath, leading to the expectation of numerous false coincidences during the measurement.

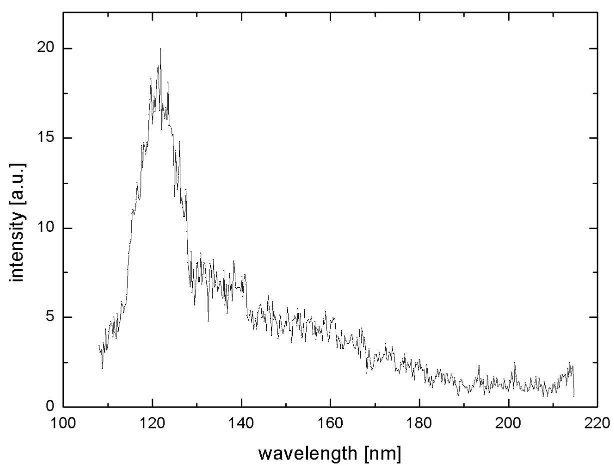

Fig. 1: Fluorescence intensity spectrum of Hydrogen after excitation with synchrotron radiation of 33.66eV. The prominent peak at 121.6nm is the Lyman-α fluorescence line, beneath are numerous unresolved fluorescence lines.

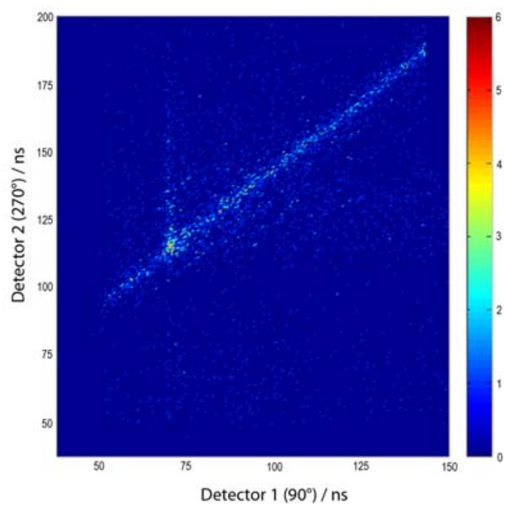

Fig. 2: Coincidence map of Lyman-α fluorescence transitions of entangled hydrogen atoms. The map shows the occurrences of events in dependence of the time they have been recorded at.

An exemplary coincidence map for the recorded data is shown in figure 2. The axes of the map are given in nanoseconds with an arbitrary offset. The color indicates the amount of events recorded at the according times on each of the detectors.

Figure 3 shows preliminary results for the lifetime measurements of the Lyman-α transitions and exponential decay fit functions for several gas pressure values in the target cell. The lifetimes of the H(2s) states, measured by the time of their decay with emission of a Lyman-α photon, are apparently in dependence of the target pressure as claimed in [2].

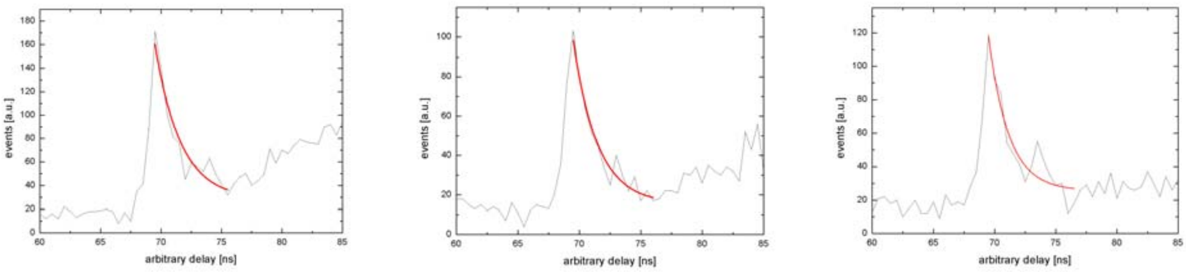

Fig. 3: Lifetime measurements for the H(2p) states of entangled hydrogen atom pairs at a target pressure of 400mPa, 200mPa and 100mPa (from right to left). The decay of the H(2p)-State is depicted with the red exponential decay curve in each plot. The lifetimes, taken from the exponential decay, turn out to be 2.11ns ± 0.59ns, 1.98ns ± 0.35ns and 1.65ns ± 0.41ns and therefore are in dependence of the target pressure.

The conclusion from this dependency is that the lifetimes of excited entangled atom pairs are shorter than the ones of single excited H atoms. With higher pressures, collisions between the atoms become more and more likely, leading to a disturbance of the entanglement and thus to a longer average lifetime.

However, the data have inadequate statistics and are to be regarded preliminary. The measurements, now with the additional knowledge on appropriate parameters, will be done again with a more refined experimental setup.

References

[1] Tanabe et al, Phys. Rev. Lett. **103**, 173002 (2009)
[2] Tanabe et al, Phys. Rev. A **82**, 040101(R) (2010)