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Absence of entanglement effect on the decay dynamics of H($2p$) pairs produced by VUV photodissociation of H_2

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Synopsis The effects of entanglement on the spontaneous decay of a pair of H($2p$) previously observed by Tanabe *et al.* (*Phys. Rev. A* **82**, 040101 (2010)) could not be reproduced despite careful determination of emission times with respect to the synchrotron bunch.

The entanglement of a pair of H(2p) generated by VUV photodissociation of H_2 along the Q_2 $^1\Pi_u$ doubly excited state has been discussed in a series of publications [1, 2, 3]. In an attempt to reproduce the effects attributed to entanglement, namely the shortening of the apparent lifetime and the stronger modulation of the angular distribution at lower pressure, we have studied this reaction at the DESIRS beamline of the SOLEIL Synchrotron facility operating in single-bunch mode.

In the present experiment, the synchrotron beam is injected into an interaction cell filled with H_2 between 2×10^{-4} and 10^{-2} mbar. On either side of the cell, a CsI-coated multichannel plate assembly located behind a 1 mm-thick MgF_2 window detects Lyman-α photons emitted by H($2p$) at time t_1 and t_2. The synchrotron clock signal t_0, and the photon arrival times t_1 and t_2 are recorded by a multichannel TDC (120 ps binwidth) receiving the triple coincidence signal as a common stop. This setup differs from that used by Tanabe *et al* [2] who had only access to $t_2 - t_1$. It also allows us to measure the emission time of the first incoming photon $t_<$ and that of the second photon $t_>$ independently.

The histogram of $t_1 - t_0$, $t_2 - t_0$ (Fig.1(a)), can be fitted by an exponential function giving lifetimes $\tau_1 = 1.65(5)$ ns and $\tau_2 = 1.57(5)$ ns respectively, both compatible with the lifetime of an isolated H($2p$) atom. The histogram of $t_< - t_0$ and $t_> - t_0$ (Fig.1(b)) gives the temporal distribution for the first and second photon, respectively. Those follow the functional dependence discussed by Sanjo and Plaja [4]. All fits are consistent with a single decay time affecting photon emission. We have systematically varied the experimental conditions, i.e. the pressure of H_2, the incoming photon energy and polarization, the latter giving access to the angular distribution of the emitted photons.

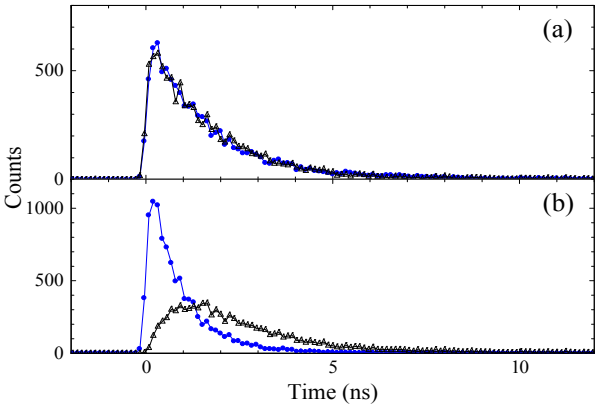

Figure 1. Time spectrum recorded at 3×10^{-3} mbar - (a) detector 1 (dots) and 2 (triangles), (b) first (dots) and second photon detected (triangles).

The invariability of the decay time throughout the measurements, determined to be identical to the natural lifetime of the $2p$ state, rules out any modification of the decay rate due to entanglement of the atom pair and its possible decoherence upon collision with surrounding molecules. Superradiance or concerted emission [5] is not expected since the atoms are ~90 μm apart at the time of their radiative decay. A similar conclusion was reached independently by Nakanishi *et al* [6] who attributed earlier findings to a flaw of the experiment.

References

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