Entanglement of excited atom-pair produced by the photo dissociation

Kouichi Hosaka1,* Yuko Nakanishi1, Kennichi Shiino1, Yutaro Torizuka1, Kazufumi Yachi1, Philipp. Schmidt2, Andre. Knie2, Kari. Jänkälä3, Arno. Ehresmann2, Takeshi Odagiri4, Masashi Kitajima1 and Noriyuki Kouchi1

1Tokyo Institute of Technology, Meguro-ku, Tokyo, 152-8551, Japan
2University of Kassel, Kassel, D-34132, Germany
3University of Oulu, Oulu, 3000 90014, Japan
4Sophia University, Chiyoda-ku, Tokyo, 102-8554, Japan

1 Introduction
A pair of H(2p) atoms produced in the photodissociation of H2[1] is potentially entangled [2,3].

\[ H_2(X^1Σ^-) → H_2(2p_\text{ex}) \rightarrow H(2p_\text{ex}) + H(2p_\text{ex}) \]

where \( γ_{\text{ex}} \) is the incident photon and \( γ_{2p} \) the Lyman–α photon. The subscripts of 0 and ±1 attached to 2p are the magnetic quantum numbers \( m \) with respect to the internuclear axis. The angular correlation function (ACF) of the Lyman-α photon-pair shows the features due to the entanglement in the H(2p) pair [2,3]. Recently we measured the ACF of the Lyman-α photon-pair in process (1) mediated by the linearly polarized light and found that there is a considerable difference in the variation magnitude between those experimental and theoretical ACFs [4].

To clarify the origin of the difference between the experimental and theoretical ACFs, the study on the isotope effect of the ACFs, that is, the comparison of the ACFs of H2, HD, and D2 is useful. Before measuring the ACFs, the precursor doubly excited states for the pair of H(2p) atoms was determined from the cross section curves of the H(2p) atom pair formation for D2[5] and HD[6], and an unexpected isotope effect on the cross section of 2p pair formation was found in the photoexcitation of H2, D2 and HD.

2 Experiment
Linearly polarized light was introduced into a gas cell filled with hydrogen gas. The pair of Lyman-α photons emitted from the 2p atom pairs were detected in coincidence by two detectors. It was confirmed that the coincidence count rates were proportional to the target gas pressure in the present range, i.e., below ~2Pa. The procedure of obtaining the absolute values of the cross sections of the 2p+2p pair formation from the coincidence counts was described in reference [5].

3 Results and Discussion
In general, the heavier isotope substitution brings about the smaller oscillator strength of the neutral dissociation because of the following reasons. The potential energy curve and resonance width of a doubly excited state, which determines the rate of the autoionization, have no isotope effects. On the other hand, the relative velocity of two nuclei down the potential energy curve in D2 is \( \sqrt{2} \) of that in H2, thus D2 needs more time than H2 to reach the region of the internuclear distance where the autoionization does not occur. As a result, D2 should have lower probability of escaping from the autoionization than H2.

However in experiment [6], the ratio of the oscillator strengths of the 2p+2p pair formation from the Q2 \( ^1Π_u(1) \) state was determined that H2 : HD : D2 = 1 : 1.1 : 0.71. We compared the experimental ratio with that of the calculated survival probabilities of the Q2 \( ^1Π_u(1) \) state based on the semiclassical treatment for the decay dynamics of the Q2 \( ^1Π_u(1) \) state with using its potential energy and resonance width [7]. The survival probability means the probability that a doubly excited hydrogen molecule dissociates into a pair of neutral hydrogen atoms escaping from the autoionization. The ratio of the calculated survival probabilities is H2 : HD : D2 = 1 : 0.81 : 0.58, which are able to be compared with the ratio of the oscillator strengths of the 2p+2p pair formation mentioned above since the oscillator strength of the electronic excitation has just small isotope effect [5]. The experimental ratio, D2 / H2= 0.71, is in agreement with the calculated ratio, D2 / H2= 0.58. On the other hand, the experimental ratio, HD/ H2= 1.1, is remarkably larger than the calculated ratio, HD/ H2= 0.81.

References

* hosakak@chem.titech.ac.jp