

Laser-Induced Oxygen Formation from Carbon Dioxide

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Synopsis We report experiments on the direct observation of O₂ formation from CO₂ in strong laser fields. Our simulations and pump-probe measurements suggest that CO₂ undergoes bending motion during strong-field ionization which supports the O₂ formation.

O₂ production is one of the most important processes for life on the Earth, where oxygen molecules are mainly generated via the photosynthesis by green plants and algae from carbon dioxide and water [1]. Theoretical studies suggested the possibility of producing O₂ through the dissociation of a CO₂ molecule [2], and a recent experiment showed indirect evidences of O₂ formation straightly from CO₂ molecules after ultraviolet excitation through the detection of C⁺ (referring the creation of O₂ on the other side) [3]. However, so far, O₂ formation from CO₂ has not been directly observed.

In this submission, we report experiments on the direct observation of molecular oxygen formation from CO₂ in strong laser fields with a reaction microscope. In our experiments, strong laser pulses, with peak intensity on the order of 10¹⁴ W/cm² and pulse duration of 25 fs, were employed to doubly ionize CO₂ molecules and further induced molecular fragmentation. Except for the dominate C-O bond breakage process, the O₂ formation process ($\text{CO}_2 \rightarrow \text{C}^+ + \text{O}_2^+ + 2e^-$) was identified in the photo-ion-photo-ion coincidence distributions [Fig.1(a)]. Our accompanying quantum chemical simulations suggest that the bending motion during the strong-field interaction may trigger the O₂⁺ formation. To confirm the mechanism of bending motion-induced O₂ formation, we further performed pump-probe measurements using a Mach-Zehnder interferometer. Fourier analysis on the yields of O₂ formation process in pump-probe measurements contains clear frequency components of bending modes, as shown in Fig.1(b), which support the bending motion mechanism for the O₂ formation.

Our results may trigger experimental and theoretical investigations on further understanding of the O₂ production mechanism from CO₂ and optimizing the efficiency of the O₂ production with laser parameters. Moreover, our observation can also provide useful hints and new concepts for the studies on plane-

tary atmospheres.

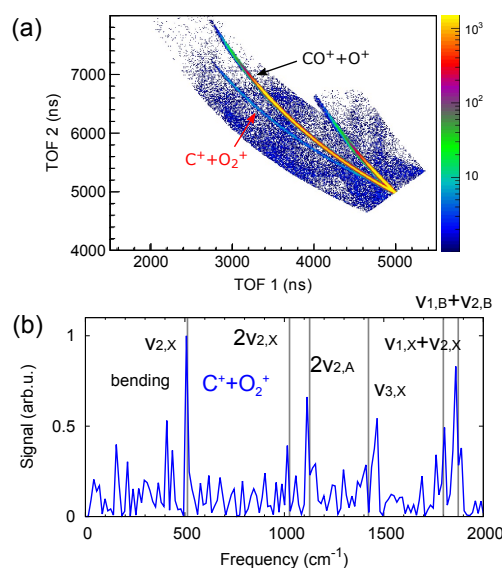


Figure 1. (a) Measured photo-ion-photo-ion coincidence distributions with selection conditions for the CO⁺+O⁺ channel and the C⁺+O₂⁺ channel. (b) Fourier transforms of the measured signal for the O₂ formation channel over the pump-probe delay, respectively. Vertical lines indicate the transition frequencies from NIST database [4], where ν_1 , ν_2 and ν_3 denote the frequencies of the symmetric stretching mode, the bending mode and the asymmetric stretching mode, respectively. The indexes X, A and B represent for the X, A and B states of CO₂⁺, respectively.

References

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