Laser-Induced Oxygen Formation from Carbon Dioxide

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Synopsis We report experiments on the direct observation of O_2 formation from CO_2 in strong laser fields. Our simulations and pump-probe measurements suggest that CO_2 undergos bending motion during strong-field ionization which supports the O2 formation.

O_2 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 O_2 through the dissociation of a CO_2 molecule [2], and a recent experiment showed indirect evidences of O_2 formation straightly from CO_2 molecules after ultraviolet excitation through the detection of C^+ (referring the creation of O2 on the other side) [3]. However, so far, O_2 formation from CO_2 has not been directly observed.

In this submission, we report experiments on the direct observation of molecular oxygen formation from CO_2 in strong laser fields with a reaction microscope. In our experiments, strong laser pulses, with peak intensity on the order of 10^{14} W/cm^2 and pulse duration of 25 fs, were employed to doubly ionize CO_2 molecules and further induced molecular fragmentation. Except for the dominate C-O bond breakage process, the O_2 formation process ($CO_2 \rightarrow C^+ + O_2^+ + 2e$) 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 O_2^+ formation. To confirm the mechanism of bending motion-induced O_2 formation, we further performed pump-probe measurements using a Mach-Zehnder interferometer. Fourier analysis on the yields of O_2 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 O_2 formation.

Our results may trigger experimental and theoretical investigations on further understanding of the O_2 production mechanism from CO_2 and optimizing the efficiency of the O_2 production with laser parameters. Moreover, our observation can also provide useful hints and new concepts for the studies on planetary atmospheres.

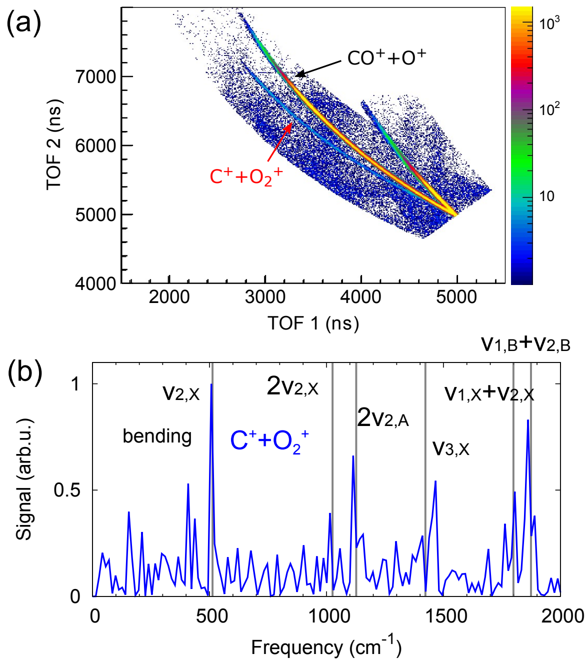

Figure 1. (a) Measured photo-ion-photo-ion coincidence distributions with selection conditions for the $CO^+ + O^+$ channel and the $C^+ + O_2^+$ channel. (b) Fourier transforms of the measured signal for the O_2 formation channel over the pump-probe delay, respectively. Vertical lines indicate the transition 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 CO_2^+ , respectively.

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References

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