Photodissociation of sympathetically crystallized CaH$^+$

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Synopsis

We demonstrated photodissociation of sympathetically crystallized CaH$^+$ toward rovibrational spectroscopy by UV-UV or IR-UV double resonance. The photodissociation of CaH$^+$ was successfully confirmed at $\lambda = 283$-$287$ nm.

Rovibrational precision spectroscopy on sympathetically crystallized molecular ions is expected to be an important tool for discussions of fundamental physical constants stability [1]. Especially, some precision measurements of vibrational transitions in homonuclear diatomic molecules or diatomic hydrides have been proposed toward time variation detection of proton-electron mass ratio $\beta (= m_p / m_e)$ [2] [3]. The vibrational transition of $X^1\Sigma(v,N) = (0,0) \rightarrow (1,0)$ in CaH$^+$ is one of the candidates. Recently, sympathetic cooling and spectroscopic studies of CaH$^+$ have been demonstrated by several research groups [4] [5].

We have constructed a cryogenic linear Paul trap for rotational cooling of Coulomb crystallized CaH$^+$ ions [4] [6]. Now we are trying to observe the laser induced fluorescence (LIF) from internally cooled CaH$^+$. Unfortunately, the transition wavelength to observe the LIF has not been experimentally determined yet. Therefore, as an alternative plan, we started a photodissociation experiment in order to determine the rovibrational constants. Here, we report on the photodissociation experiment of sympathetically crystallized CaH$^+$ ions toward rovibrational spectroscopy.

In Fig. (a-1), we show an observed LIF image from a laser cooled Ca$^+$ crystal. As we demonstrated before, CaH$^+$ ions can be generated by a laser induced chemical reaction of Ca$^+$(2P$_{1/2}$) + H$_2$ $\rightarrow$ CaH$^+$ + H. As shown in Fig. (a-2), generated CaH$^+$ ions are sympathetically crystalized in a Ca$^+$ crystal. The ion numbers of Ca$^+$ and CaH$^+$ are determined by comparing LIF image with simulation images obtained by molecular dynamics simulations [4]. In the photodissociation experiment, we irradiated a UV pulsed laser beam ($\lambda = 283$-$287$ nm) to a mixed Coulomb crystal. Theoretical calculation predicted that the photodissociation via the excited state of 1$^1$T in CaH$^+$ could occur [7]. As shown in Fig. (a-2) and (a-3), we successfully observed the photodissociation of sympathetically crystallized CaH$^+$. Fig. (b) shows a decay curve of the number of CaH$^+$ as a function of the laser irradiation time. A dissociation rate was determined to be $\gamma = 2.3(0.5) \times 10^{-2}$ s$^{-1}$ using a least-square fitting of a single exponential function to the data in Fig. b.

In our poster presentation, we will present the detail of the experiments and discuss our next plan for rovibrational spectroscopy.

**Figure a.** CCD images of mixed species Coulomb crystals during CaH$^+$ generation and photodissociation. The ion numbers of Ca$^+$ in (a-1) and CaH$^+$ in (a-2) are 450 and 64, respectively.

**Figure b.** A plot of the ion number of CaH$^+$ as a function of the laser irradiation time.

References


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