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Frequency standard in THz-region using molecular ions

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The atomic transition frequencies in the optical and microwave regions have been measured with the uncertainties of 10^{-18} and 10^{-16}, respectively. The vibrational transition frequencies of homonuclear diatomic molecular ions are also expected to be measured with the uncertainties of 10^{-18} in the infrared or optical region, which is useful for the detection of the variation in the proton-to-electron mass ratio [1]. It is useful to establish the frequency standard also in the THz region (0.1-10 THz), for example, for the chemical analysis of materials.

We propose the precise measurement of the X^1S (J,F) = (0,1/2)-(1,1/2) transition frequencies of QH^+(Q: even isotope of group II atoms)[2] and RH^+ (R: rare gas atoms) [3] molecular ions, which are listed in Table 1 (J: rotational state, F: hyperfine state).

	Transition frequency (THz)	DC Stark shift (/(V/cm)^2)
$^{40}CaH^+$	0.282	5.8×10^{-11}
$^{24}MgH^+$	0.382	1.2×10^{-11}
$^{202}HgH^+$	0.390	8.8×10^{-13}
$^{40}ArH^+$	0.616	5.6×10^{-13}
$^{20}NeH^+$	1.039	7.1×10^{-13}
$^{4}HeH^+$	2.010	5.7×10^{-14}

Table.1 Transition frequencies and fractional DC Stark shift of the $X(J,F)$ = (0,1/2)-(1/1/2) transition frequencies

These transition frequencies are free from the electric quadrupole shift, and the blackbody radiation shift with the surrounding temperature of 300 K is lower than 2×10^{-16}. There is a quadratic Zeeman shift can be suppressed to lower than 10^{-15} keeping the magnetic field lower than 0.5 mG. The attainable accuracy is limited mainly by the Stark shift induced by the trap electric field, which is expected to be lower than 0.03 V/cm. Seeing the coefficients of the fractional DC Stark shift listed in Table 1, the attainable accuracies of the $^{40}CaH^+$ and $^{24}MgH^+$ transition frequencies are of the order of 10^{-14}. The measurement uncertainty lower than 10^{-15} is possible for the $^{202}HgH^+$, $^{40}ArH^+$, $^{20}NeH^+$, and $^{4}HeH^+$ transition frequency.

The rotational transition is monitored by quantum logical method [4]. It is also possible to observe the fluorescence from the (v,J,F) = (0,1,1/2)-(1,0,1/2) cycling transition, where v is the vibrational state [3]. For example, the cycling rate is 560 /s with $^{20}NeH^+$, and the fluorescence is observed when the blackbody radiation is suppressed using a cryogenic chamber (temperature < 10 K).

References

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