# Hyperfine stark shifts of ground states of $^{87,85}$Rb

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**Synopsis** The hyperfine stark shifts of ground states of $^{87,85}$Rb are calculated by using relativistic configuration interaction plus core polarization (RCICP) approach, which agree with other theoretical and experimental results very well. The hyperfine Stark shift of $^{87}$Rb is larger than that of $^{85}$Rb.

The hyperfine stark shift is closely related to the difference of scalar polarizabilities between the hyperfine states with the same ($L$, $J$) but different $F$ quantum numbers. It is essential to evaluate the effect of blackbody radiation (BBR) shift, which are very important to determine the uncertainty of atomic clock. The hyperfine structure(hfs) transition of the ground state of $^{133}$Cs serves as a primary frequency standard for the current definition of a second. The similar hfs transition of Rb atom is also considered as secondary microwave frequency standard [1].

The polarizabilities of the ground states of Rb atom are calculated by using relativistic configuration interaction plus core polarization (RCICP) approach. After considering the hyperfine splittings, the energies and transition matrix elements of the hyperfine structure of $^{87,85}$Rb are computed. Then the scalar($\alpha_1$) and tensor($\alpha_1^T$) polarizabilities of the hyperfine ground states of $^{87,85}$Rb are determined.

Table 1 gives the differences of scalar and tensor polarizabilities of the hyperfine ground states of $^{87,85}$Rb. There are some results of the hyperfine Stark shifts of $^{87,85}$Rb [2-6] that are often reported as the Stark shift coefficients $k$, with units of (Hz/(V/m)$^2$. This is converted into a.u. by multiplying $0.4018778\times10^8$. The present hyperfine Stark shifts of $^{87,85}$Rb agree with the relativistic configuration interaction plus many-body perturbation (RCI+MBPT) [3], the relativistic linearized coupled cluster single-double with partial triple contributions (RLCCSDT) [4], and the perturbation theory [2] very well. These theoretical results are in good agreement with the experimental values by Mowat *et al*. [5] and Dallal *et al*. [6]. The hyperfine Stark shift of $^{87}$Rb is larger than that of $^{85}$Rb. The tensor polarizabilities of the hyperfine states do not exceed $10^{-4}$ a.u. in magnitude. The tensor polarizability of the $F = 1$ ground state of $^{87}$Rb is positive and that of the $F = 2$ ground state of $^{87}$Rb is negative. The difference of present tensor polarizabilities of $^{87}$Rb is more negative than the experimental value [6]. Similarly, the difference of tensor polarizabilities of $^{87}$Rb is also larger than that of $^{85}$Rb. It is predictable since $^{85}$Rb has the smaller hyperfine splittings than $^{87}$Rb.

**Table 1**. The differences of scalar and tensor dipole polarizabilities (in a.u.) of the hyperfine ground states of $^{87,85}$Rb. The notation $a[b]$ means $a\times10^b$.

| Method | $\alpha_1$ |
|---|---|
| $^{87}$Rb: $\alpha_1(F=2)-\alpha_1(F=1)$ | |
| Present RCICP | 0.995[−2] |
| RCI + MBPT [3] | 0.997(8)[−2] |
| RLCCSDT [4] | 0.997(3)[−2] |
| Perturbation theory [2] | 0.972[−2] |
| Expt. [5] | 0.99(24)[−2] |
| Expt. [6] | 0.9967(32)[−2] |
| $^{85}$Rb: $\alpha_1(F=3)-\alpha_1(F=2)$ | |
| Present RCICP | 4.486[−3] |
| Perturbation theory [2] | 4.311[−3] |
| Expt. [5] | 4.389(96)[−3] |
| $^{87}$Rb: $\alpha_1^T(F=2)-\alpha_1^T(F=1)$ | |
| Present RCICP | −1.0409[−4] |
| Expt. [6] | −0.8841(1045)[−4] |
| $^{85}$Rb: $\alpha_1^T(F=3)-\alpha_1^T(F=2)$ | |
| Present RCICP | −6.1115 [−5] |

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