# Dipole-Dipole Interaction Strength and Dipole Blockade Radius using Förster Resonances in Rb Atoms

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Dipole blockade [1] is a phenomenon, where due to dipole-dipole (DD) interaction between Rydberg atoms the simultaneous excitation of two/multiple Rydberg atoms in a "blockade sphere" [2] is suppressed. Our aim is to find the best experimental parameters necessary to achieve dipole blockade radius of $R_b \approx 50\mu m$, which will be later measured experimentally. We are especially interested in the resonant $1/R^{-3}$ type DD interaction, which happens in the presence of Förster resonances, e.g. the $58d_{3/2} + 58d_{3/2} \to 60p_{1/2} + 56f_{5/2}$ transition in $^{87}Rb$ [3], leading to $R_b = 10\mu m$, or $81s_{1/2} + 84s_{1/2} \to 81p_{1/2} + 83p_{1/2}$ transition [4], which allows for $R_b = 22\mu m$ to be achieved for the experimentally accessible excitation laser Rabi frequency of $6MHz$. With our purpose in mind, we calculate the magnitude of $C_6$ coefficients for specific Förster transitions in $^{87}Rb$ of the form $n_a d_{3/2,5/2} + n_b d_{3/2,5/2} \to n_\alpha l_\alpha j_\alpha + n_\beta l_\beta j_\beta$. The two atoms are initially in the $d_{3/2,5/2}$ states, while the $l$ and $j$ numbers of the final states can take different values. The principal quantum numbers $n_a$ and $n_b$ of the initial states can differ by $\pm 1, \pm 2, \pm 3$, etc., while those of the final states can be the same or different. A large $C_6$ coefficient is associated with a minimum in the absolute value of the Förster defect $\delta_k$, which we plot as a function of the principle quantum number $n_a$ for the transitions descibed above. We found that in all cases under study, the "$\delta_k$ vs $n_a$" curves show diverging behavior and no minimum of the absolute value of $\delta_k$ is observed. An

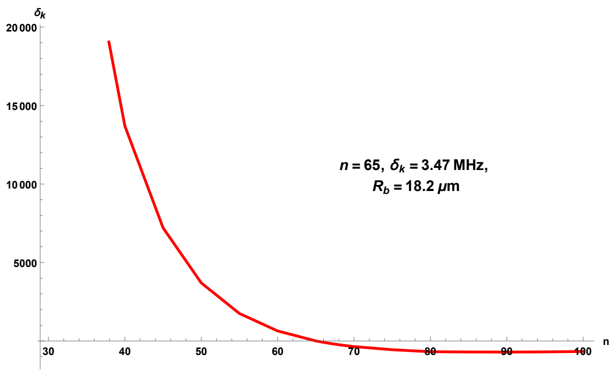


FIG. 1: Förster defect vs principal quantum number when atoms are initially in the $p_{1/2}$ states, where $n_b = n_a + 20$ and $n_\beta = n_\alpha + 19$.

interesting case when the initial principal quantum numbers of the two atoms differ by a significant amount, is studied experimentally in [5], e.g. $60p + 80p \to 59d + 78d$. Here we extend the study of Förster defect vs principal quantum number for transitions $n_a p_{1/2,3/2} + n_b p_{1/2,3/2} \to n_\alpha l_\alpha j_\alpha + n_\beta l_\beta j_\beta$. All obtained curves are crossing the "$\delta_k = 0$" line in the vicinity of $n_a = 60$, besides the one for $np_{1/2} + (n+20)p_{1/2} \to (n-1)d_{3/2} + (n+18)d_{3/2}$ transition, shown in FIG. 1. The minimum occurs at $n_a = 65$, corresponding to $\delta_k = 3.47MHz$, $C_6 = -219000GHz\mu m^6$, and giving a blockade radius of $R_b = 18.21\mu m$. We are curently studying similar transitions within the $d$ states manifold, looking for the cases which will give the maximum possible $R_b$.

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