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Excitation of vibrationally-excited ultralong-range strontium Rydberg molecules in quantum gases

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Synopsis The photoexcitation rate for ultralong-range Rydberg molecules is sensitive to the initial spatial separation of the atoms from which they are formed. Here we explore the photoexcitation of different molecular vibrational states as a probe of spatial correlations in a cold atomic gas.

Rydberg dimer molecules comprise a ground-state atom bound to a Rydberg atom by scattering of the Rydberg electron [1]. The resulting molecular potential for a $5s31s^3S_1-5s^2^1S_0$ atom pair is shown in Fig. 1(a) together with the wavefunctions for the $v=0, 1, 2$ and 3 molecular vibrational levels. The $v=0$ wavefunction is strongly localized near the electron outer classical turning point whereas those for the $v=1, 2$, and 3 states extend to smaller internuclear separations. Since photoexcitation of a particular molecular level requires an atom pair with the appropriate initial separation, R , this suggests that measurements of the formation rates for different vibrational levels can be used to probe spatial correlations in a cold gas over a broad length scale.

Here we compare results for molecule formation in a cold ($T \sim 1 \mu\text{K}$) gas of spin-polarized ^{87}Sr , for which quantum statistics are expected to reduce the pair correlation function $g^{(2)}(R)$ at small R due to Pauli exclusion (antibunching), with results for an unpolarized sample which provides a good approximation to a gas of uncorrelated particles. Figure 1(b) shows the results of theoretical predictions for the excitation of the $v=0, 1$, and 2 states in both polarized and unpolarized samples. As seen in Fig. 1(b), the calculations predict a reduction in the production of the $v=1$ and, to a lesser extent, the $v=2$ excited states, relative to the ground $v=0$ state, in the polarized sample, a manifestation of Pauli exclusion affecting the Franck-Condon factor for vibrational states that extend to small R . Figure 1(b) also includes the results of experimental measurements which are seen to be in good accord with the theoretical predictions. The data thus demonstrate that measurements of Rydberg

molecule formation can provide, even for a single value of n , a probe of spatial correlations over a sizable range of internuclear separations.

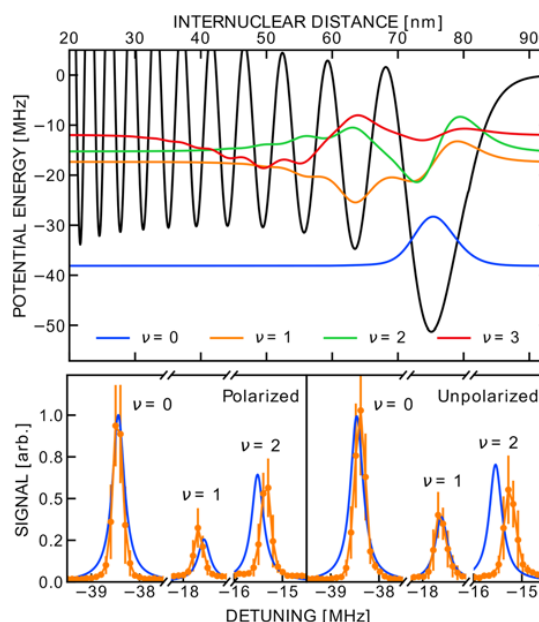


Figure 1. (top) Molecular potential for a $5s31s^3S_1-5s^2^1S_0$ atom pair together with the $v=0, 1, 2$ and 3 vibrational wavefunctions. (bottom) Calculated (---) and measured (o) $v=0, 1$, and 2 excitation features for polarized, and unpolarized, $T \sim 1 \mu\text{K}$ ^{87}Sr gases (see text). The experimental and theoretical $v=0$ features are normalized to each other.

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References

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