Final Scientific Report

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The Oxford theory group has performed detailed studies of the process of adiabatic association of molecules via magnetic-field-tunable interactions in atomic Bose-Einstein condensates [1]. It has been observed that, in terms of the molecular association efficiency, the predictions of genuinely many-body calculations (based on the cumulant expansion of correlation functions) can be, to a large extent, recovered by a more practical approach, based on Landau-Zener theory. The basic idea behind this method is to first consider a single pair of atoms subjected to a linear sweep of the magnetic field strength across the zero-energy resonance. The probability for the association of such a pair of atoms to a molecule in this process can be calculated exactly and it depends on just a few physical parameters: the relative momentum of the colliding pair, the speed of the magnetic field sweep, the atomic mass and two parameters of the resonance enhanced scattering (the background scattering length and the resonance width). To extend this two-body description to the description of a gas of atoms, an incoherent pair-wise summation of all relevant transition probabilities is performed, a methodology routinely employed in studies of inelastic rate processes in collision physics. Recently, the pair-wise summation approach has been tailored to describe the association of molecules in a two-component Fermi gas, reaching full quantitative agreement in the regime of fast ramps with the available experimental data from the JILA and Rice groups [2].

During my stay in Oxford, in collaboration with Krzysztof Góral and Thorsten Köhler, I studied the dissociation of cold molecules [3], a reversal of the association process. This subject is important, both experimentally and theoretically, for several reasons. First, the dissociation of molecules by ramps of the magnetic field strength is necessary for their detection. Second, measurements of the dissociation spectra provide a very accurate method of determining the resonance widths [4]. Last but not least, the existing theoretical description of the cold molecule

dissociation, in terms of the two-channel approach, has been interpreted in a way implying that the state of the molecules produced coincides with the Feshbach resonance state belonging to the closed scattering channel [3].

We have developed a single-channel description of the dissociation process, which recovers the final result for the dissociation spectrum obtained in the two-channel model. It shows, however, that the Feshbach resonance state is irrelevant for the description of the dissociation process. Consequently, the molecules produced cannot be in this state, the fact supported by other experimental findings (e.g., measurements of the binding energies of the molecules).

On the more technical side, I performed calculations of the two-body propagator for a system of two ultra-cold atoms in a time-dependent external magnetic field. This propagator is an essential object for the determination of the dissociation energy spectrum. I wrote a numerical code and I tested it by comparing the results with analytic formulae, available in the asymptotic limit. This stage of work is already finished. Now in Warsaw I continue my research on this subject. Using my code I perform the calculations of the two-body propagator for the physically relevant range of parameters. The results, when completed, will be included in a joint publication.

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[4] S. Dörr, T. Volz, and G. Rempe, Phys. Rev. A **70**, 031601 (2004).