Complete Quantum Coherent Control of Ultracold Molecular Collisions

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Coherent control of scattering events relies on tuning the values of scattering properties (such as collision cross sections) via quantum interferences, induced by prior preparation of coherent superpositions of molecular states [1]. This method has the advantage of being a field-free control method for ultracold collisions rather than being reliant, as other methods are, on the use of external electromagnetic fields.
Two factors limit the extent of coherent control of state-to-state integral cross-sections: the partial wave expansion and the contributions of satellite terms. The former is a problem for coherent control because partial waves are independent and thus do not interfere with one another. The latter are uncontrollable contributions due to the absence of interferences owing to symmetry requirements (i.e. energy conservation, angular momentum projection conservation, etc).

We demonstrate that these two issues can be solved for ultracold thermoneutral (elastic) collisions [2], leading to dramatic control. In this case, only the s-wave is involved before and after the scattering. Furthermore, the satellite contributions are negligible due to the Wigner threshold laws. Then, complete control is achieved with the possibility of complete destructive interference. We develop an analytical model for the control parameters and illustrate the complete control of spin-exchange transitions in O_2-O_2 scattering. An extended range of control over 9 orders of magnitudes is observed for the integral cross-sections, and over 17 orders of magnitude for branching ratios.

[1] J. Nyman and G. M. Day, *CrystEngComm*, **17**, 5154-5165 (2015).
[2] J. Nyman and G. M. Day, *Phys. Chem. Chem. Phys.*, **18**, 31132-31143 (2016).