Towards a quantum platform using ultracold neutral molecules

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Due to their complex internal structures and strong long-range interactions, diatomic molecules are expected to be a promising platform for quantum simulations/computations [1,2]. An ideal quantum platform should be able 1. to manipulate every qubit with perfect freedom and 2. to entangle any sets of qubits in the system. The rotational states of the molecules trapped in an optical tweezer array form qubit states with long coherence time. And both global and local addressing of the qubits can be easily implemented by adjusting the trap depth or polarization of the individual tweezers.

To achieve the molecular quantum platform, the molecules should be prepared at ultracold temperatures. One way to cool the molecules is laser-cooling, the workhorse technique to cool the atoms. Despite the complicated internal structures of molecules, laser-cooling and magneto-optical traps of molecules have been demonstrated for several species including SrF, CaF, and YO, reaching temperatures down to 5 uK [3-7].

At Korea University, we aim to first laser-cool MgF molecules and trap them in an optical tweezer array. MgF has a favorable internal structures for laser-cooling. Moreover, its light mass and high transition frequency enable efficient cooling of the molecule via photon scattering. MgF has a large electric dipole moment of 3 Debye, which generates large interactions between the molecules. In this talk, the overall features of the molecular quantum platform are summarized, followed by the basic strategy and the current status of building one using MgF molecules.

References:

1. Lincoln D. Carr, David DeMille, Roman V Krems, and Jun Ye. Cold and ultracold molecules: science, technology and applications. *New Journal of Physics*, **11**, 055049 (2009).
2. John L Bohn, Ana Maria Rey, and Jun Ye. Cold molecules: Progress in quantum engineering of chemistry and quantum matter. *Science*, **357**, 1002-1010, (2017).
3. J. F. Barry, D. J. McCarron, E. B. Norrgard, M. H. Steinecker, and D. DeMille. Magneto-optical trapping of a diatomic molecule. *Nature*, **512**, 286-289 (2014).
4. Loic Anderegg, Benjamin L. Augenbraun, Eunmi Chae, Boerge Hemmerling, Nicholas R. Hutzler, Aakash Ravi, Alejandra Collopy, Jun Ye, Wolfgang Ketterle, and John M. Doyle. Radio Frequency Magneto-Optical Trapping of CaF with High Density. *Physical Review Letters*, **119**,103201 (2017).
5. S. Truppe, H. J. Williams, M. Hambach, L. Caldwell, N. J. Fitch, E. A. Hinds, B. E. Sauer, and M. R. Tarbutt. Molecules cooled below the Doppler limit. *Nature Physics*, **13**, 1173-1176, (2017).
6. Alejandra L. Collopy, Shiqian Ding, Yewei Wu, Ian A. Finneran, Loic Anderegg, Benjamin L. Augenbraun, John M. Doyle, and Jun Ye. 3D Magneto-Optical Trap of Yttrium Monoxide. *Physical Review Letters*, **121**, 213201, (2018).
7. Nathaniel B. Vilas, Christian Hallas, Loic Anderegg, Paige Robichaud, Andrew Winnicki, Debayan Mitra, and John M. Doyle. Magneto-optical trapping and sub-Doppler cooling of a polyatomic molecule. *Nature*, **606**, 70-74 (2022).