

Quantum Computing with Switchable Dipoles

Robin Côté¹, Susanne Yelin¹, Elena Kuznetsova¹, and K. Kirby²

¹ *Physics Department, University of Connecticut, 2152 Hillside Road, Storrs, CT 06269*

² *ITAMP, Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138*

Quantum computing, one of the most rapidly developing areas in physics, has significant potential to outperform classical computing [1], by using quantum superposition in which the fundamental piece of information, called a *qubit*, consists of a superposition of quantum states, denoted $|0\rangle$ and $|1\rangle$. In order to implement quantum logic operations it is essential to address these quantum states coherently. A key challenge in all approaches proposed as possible platforms is to identify *strong* and *controllable* interactions that would allow for the creation of fast quantum operations with minimal decoherence.

Polar molecules present a promising new platform for quantum computation [2], because they incorporate the prime advantage of both neutral atoms and trapped ions [3], i.e., long coherence times and strong interactions, respectively [4]. Here we explore the possibility of switching “on” and “off” the strong interactions between polar molecules by taking advantage of the fact that the magnitude (and sign) of a molecular dipole moment can change depending on the state of the molecule. By exciting the molecule between a state that exhibits a strong dipole moment and a state with a dipole moment of zero, the interactions can be effectively turned on and off, thus helping to simplify phase gates and minimize decoherence.

The generic setup to obtain a phase gate, or universal two-qubit operation, is described in Fig. 1. We will discuss different schemes for quantum gates using real molecules: CO, LiH, etc. These are polar molecules being experimentally studied at ultracold temperatures. It should be noted that our scheme could be integrated into condensed matter physics architectures, using, for example, molecule-chips or microtraps connected to superconducting wires [4]. In a recent article [4], the experimental implementation of quantum information processing using superconducting stripline resonators has been studied in detail; our approach based on dipolar switching can be readily adapted to this architecture.

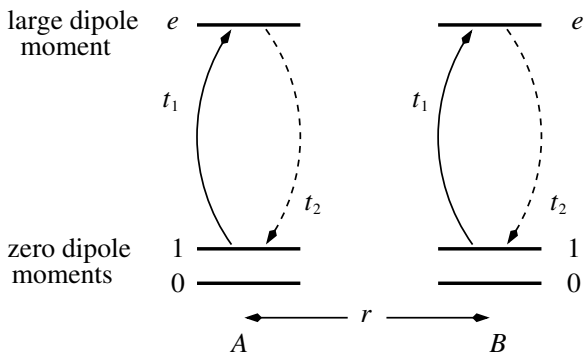


Figure 1: Phase gate: two molecules A and B separated by r are prepared in a superposition of states $|0\rangle$ and $|1\rangle$. At $t_1 = 0$, we excite $|1\rangle$ of both into $|e\rangle$: both interact via dipole-dipole interactions, and acquire a phase ϕ . At time $t_2 = \tau$ such that $\phi = \pi$, we stimulate both $|e\rangle$ back to $|1\rangle$.

References

- [1] http://qist.lanl.gov/qcomp_map.shtml.
- [2] D. DeMille, Phys. Rev. Lett. **88**, 067901 (2002).
- [3] S.F. Yelin, K. Kirby, and R. Côté, Phys. Rev. A **74**, 050301(R) (2006).
- [4] A. André *et al.*, Nature Physics **2**, 636 (2006). R. Côté, *ibid.*, 583.