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# Coherent Control of Decoherence

M. P. A. Branderhorst[1], P. Londero[1], P. Wasylczyk[1], I. A. Walmsley[1],

C. Brif[2], H. Rabitz[2] and R. L. Kosut[3]

[1]*Clarendon Laboratory, University of Oxford, Oxford, OX1 3PU, UK*

[2]*Department of Chemistry, Princeton University, Princeton, New Jersey 08544*

[3]*SC Solutions, Sunnyvale, CA, USA*

branderhorst@physics.ox.ac.uk

Coherent control of quantum systems uses the constructive or destructive interference between pathways to manipulate the evolution of the system. The success of any coherent manipulation of the dynamics depends on maintaining the quantum phase relationships between the different parts of the system. The inevitable interaction of any real system with its environment will corrupt the unitary evolution and prevent the coherent control from reaching its objective.

We have studied the possibility of using the principles of coherent control itself to counteract decoherence. The objective of the coherent control scheme was to manipulate the interferences on such a way that the system became less sensitive to its environment. We used iterative adaptive control to achieve the objective of maintaining the purity of an initial wavepacket by adjusting the shape of the wavepacket to reduce its coupling to the environment. In order to accomplish this we needed to identify a `decoherence surrogate', which is a measurable quantity whose value could be estimated rapidly in an experiment and which would serve as a reasonable measure of the decoherence of the state.

We used diatomic potassium molecules at high temperature to test these concepts. The vibrational and rotational degrees of freedom provided an experimental model of system-environment interaction. The coupling between the two degrees of freedom makes a decoherence-free subspace not possible, we look instead for a decoherence-resistant subspace. A shaped femtosecond laser pulse created a vibrational wavepacket in the excited electronic state. The wavepacket dephased due to the coupling to many thermally distributed rotational levels. The controls consisted of spectrally shaping the broadband laser field in phase and amplitude. The decoherence surrogate to run the iterative adaptive scheme was the spatial localization of the wavepacket. The outcome of the experiment was the clearly observable presence of interference in a region where there was no interference before the experiment.

The diatomic molecules also provided a suitable model to test the concepts of quantum process tomography for a many-dimensional system. We completely characterized the rotationally induced decoherence process, using a novel approach featuring convex optimization. Quantum process tomography is very hard because of the large number of free variables the estimation problem. We showed that the size of the estimation problem can be significantly reduced by using prior knowledge of the process, which is available in most real systems.