Abstract Submitted
for the MAR06 Meeting of
The American Physical Society

Optimal control of logical operations in the presence of decoherence: A two-spin model MATTHEW GRACE, CONSTANTIN BRIF, HERSCHEL RABITZ, Department of Chemistry, Princeton University, Princeton, NJ 08544, IAN WALMSLEY, Department of Physics, University of Oxford, Oxford OX1 3PU, UK, ROBERT KOSUT, SC Solutions, Inc., 1261 Oakmead Parkway, Sunnyvale, CA 94085, DANIEL LIDAR, Chemistry and Electrical Engineering Departments, University of Southern California, Los Angeles, CA 90089 — We study the feasibility of optimal control of logical operations in a simple model system composed of two interacting spins. In our model, one spin serves as a qubit and its evolution is controlled by a time-dependent external field. The other (uncontrolled) spin serves as an effective environment, coupling to which is a source of decoherence. The aim of control is to generate a target unitary operation for the qubit in the presence of the environmentally-induced decoherence. Given a target unitary operation G for the system, the fidelity of the actual transformation achieved is maximized with respect to the electric field $\epsilon(t)$ using two techniques, optimal control theory (OCT) and "pre-design" methods, which are well-developed in the field of nuclear magnetic resonance. The primary goal of this work is to illustrate the importance of OCT in designing logical operations, especially in the presence of environmental coupling, and the inadequacy of pre-designed gates in such situations.

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Date submitted: 07 Dec 2005 Electronic form version 1.4