REPORT DOCUMENTATION PAGE

Public Reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comment regarding this burden estimates or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188,) Washington, DC 20503.

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE December 6, 2002	3. REPORT TYPE AND DATES COVERED Technical Report

4. TITLE AND SUBTITLE quantum computing and the onset of quantum chaotic motion	5. FUNDING NUMBERS G DAAD 19-02-1-0086
6. AUTHOR(S) Giulio Casati	

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Centro di Cultura Scientifica A Volta Villa Olmo- Via Cantoni, 1 22100 COMO Italy	8. PERFORMING ORGANIZATION REPORT NUMBER GC1-2002

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U. S. Army Research Office P.O. Box 12211 Research Triangle Park, NC 27709-2211	10. SPONSORING / MONITORING AGENCY REPORT NUMBER 43379.4-PH-QC

11. SUPPLEMENTARY NOTES
     The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other documentation.

12 a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.	12 b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

-We have extended the theory for the statistical average of the fidelity to incorporate system-specific fluctuations. The volume of phase space that contributes to the average vanishes in the classical limit for times less than the Ehrenfest time. It is only after the Ehrenfest time that the average decay is representative for a typical initial condition.

- We have studied fidelity decay and growth of entanglement in the Jaynes-Cummings model under echo dynamics for coherent initial states. Theoretical predictions based on linear response theory and semiclassical considerations agree with numerical simulations.

We have shown that a quantum computer operating with a small number of qubits can simulate the important phenomenon of dynamical localization of classical chaos.

We are initiating an investigation on plasmon-assisted transfer of entanglement, motivated by a very recent experimental demonstration.

14. SUBJECT TERMS Classical and quantum fidelity	15. NUMBER OF PAGES 5
	16. PRICE CODE

17. SECURITY CLASSIFICATION OR REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION ON THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UL

GENERAL INSTRUCTIONS FOR COMPLETING SF 298

The Report Documentation Page (RDP) is used for announcing and cataloging reports. It is important that this information be consistent with the rest of the report, particularly the cover and title page. Instructions for filling in each block of the form follow. It is important to *stay within the lines* to meet *optical scanning requirements.*

Block 1. Agency Use Only (Leave blank)

Block 2. Report Date. Full publication date including day, month, and year, if available (e.g. 1 Jan 88). Must cite at least year.

Block 3. Type of Report and Dates Covered. State whether report is interim, final, etc. If applicable enter inclusive report dates (e.g. 10 Jun 87 - 30 Jun 88).

Block 4. Title and Subtitle. A title is taken from the part of the report that provides the most meaningful and complete information. When a report is prepared in more than one volume, repeat the primary title, and volume number, and include subtitle for the specific volume. On classified documents enter the title classification in parentheses.

Block 5. Funding Numbers. To include contract and grant numbers; may include program element number(s) project number(s), task number(s), and work unit number(s). Use the following labels:

  C - Contract   **PR** - Project
  G - Grant   **TA** - Task
  PE - Program   **WU** - Work Unit
     Element   Accession No.

Block 6. Author(s). Name(s) of person(s) responsible for writing the report, performing the research, or credited with the content of the report. If editor or compiler, this should follow the name(s).

Block 7. Performing Organization Name(s) and Address(es). Self-explanatory.

Block 8. Performing Organization Report Number. Enter the unique alphanumeric report number(s) assigned by the organization performing the report.

Block 9. Sponsoring/Monitoring Agency Name(s) and Address(es) Self-explanatory.

Block 10. Sponsoring/Monitoring Agency Report Number. (*if known*)

Block 11. Supplementary Notes. Enter information not included elsewhere such as; prepared in cooperation with....; Trans. of...; To be published in.... When a report is revised, include a statement whether the new report supersedes or supplements the older report.

Block 12a. Distribution/Availability Statement. Denotes public availability or limitations. Cite any availability to the public. Enter additional limitations or special markings in all capitals (e.g. NORFORN, REL, ITAR).

  DOD - See DoDD 4230.25, "Distribution Statements on Technical Documents."
  DOE - See authorities.
  NASA - See Handbook NHB 2200.2.
  NTIS - Leave blank.

Block 12b. Distribution Code.

  DOD - Leave Blank
  DOE - Enter DOE distribution categories from the Standard Distribution for unclassified Scientific and Technical Reports
  NASA - Leave Blank.
  NTIS - Leave Blank.

Block 13. Abstract. Include a brief (*Maximum 200 words*) factual summary of the most significant information contained in the report.

Block 14. Subject Terms. Keywords or phrases identifying major subject in the report.

Block 15. Number of Pages. Enter the total number of pages.

Block 16. Price Code. Enter appropriate price code (NTIS *only*).

Block 17. - 19. Security Classifications. Self-explanatory. Enter U.S. Security Regulations (i.e., UNCLASSIFIED). If form contains classified information, stamp classification on the top and bottom of the page.

Block 20. Limitation of Abstract. This block must be completed to assign a limitation to the abstract. Enter either UL (Unlimited) or SAR (same as report). An entry in this block is necessary if the abstract is to be limited. If blank, the abstract is assumed to be unlimited.

1. Papers:

a)
Marko Znidaric and Tomaz Prosen,
'Fidelity and Purity Decay in Weakly Coupled Composite Systems'
submitted to J. Phys. A: Matematical and General
http://arxiv.org/abs/quant-ph/0209145

Tomaz Prosen, Thomas H Seligman and Marko Znidaric,
'Evolution of entanglement under echo dynamics'
preprint. Submitted to Phys. Rev. Lett.

G. Benenti, G. Casati, S. Montangero and D.L. Shepelyansky: "Dynamical Localization
simulated on a few qubits quantum computer". Submitted to Phys. Rev. Lett.
http://arxiv.org/abs/quant-ph/0210052

P.G.Silvestrov, J. Tworzydlo, C.W.J.Beenakker
Hypersensitivity to perturbations of quantum-chaotic wave-packet dynamics
http://arxiv.org/abs/nlin.CD/0207002
submitted to Phys.Rev.Lett.

d)
P.G. Silvestrov:
"Hypersensitivity to perturbations of quantum-chaotic wave-packet dynamics",
Institute for Nuclear Theory Program on "Chaos and Interactions: from Nuclei
to Quantum Dots'", University of Washington, Seattle, USA, 17 July, 2002.

I. Adagideli:
"The Loschmidt echo: The quantum/classical competition",
Institute for Nuclear Theory Program on "Chaos and Interactions: from Nuclei
to Quantum Dots'", University of Washington, Seattle, USA, 17 July, 2002.

G. Casati
"Quantum computers and quantum chaos"
Institute for Nuclear Theory Program on "Chaos and Interactions: from Nuclei
to Quantum Dots'", University of Washington, Seattle, USA, 17 July, 2002.

2. Scientific personnel:
Giulio Casati
Carlo Beenakker
Tomaz Prozen
Philippe Jacquod
Giuliano Benenti
Italo Guarneri

4-We have examined the role of system-specific fluctuations in the context of
the "Loschmidt echo'", which measures the sensitivity to perturbation of
quantum chaotic dynamics. The overlap squared of two wave packets evolving
under slightly different Hamiltonians is shown to have a double-exponential
initial decay in the main part of phase space. The decay rate is the

self-averaging Lyapunov exponent. The average decay is single exponential
with a different decay rate. The volume of phase space that contributes to
the average decay vanishes in the classical limit for times less than the
Ehrenfest time. It is only after the Ehrenfest time that the average decay is
representative for a typical initial condition.

-We have studied stability of time evolution as characterized by the fidelity, and the
decay of purity, of a reduced density matrix of a weakly coupled composite system, say a
qubit array and the environment, or two parts of a qubit array.
First, we have proved a nontrivial inequality between the fidelity,the novel quantity
which we named `reduced fidelity', and the purity. Reduced fidelity is defined as
fidelity between reduced (environment traced) density matrices of uncoupled versus weakly
coupled systems. Second, we have expressed fidelity and purity decay of
composite systems (in the linar response regime of fidelity and purity close to one) in
terms of time autocorrelation functions of the perturbation in each of the subsystems.
The general conclusion was that enhanced chaoticity of central systems and/or
environmental hamiltonian, as characterized by stronger correlation decay, increases all
the three stability/entanglement measures. The theoretical predictions have been tested
in a system of two coupled kicked tops. This work has been written up [new reference 1,
see below] and submitted for publication.

-    We have studied fidelity and purity decay (or growth ofentanglement) in the Jaynes-
Cummings model (coupled harmonic oscillator and spin, e.g. atom in one mode of EM field)
under the echo dynamics. We have derived explicit formulas for the case of regular
classical dynamics and coherent initial states, which indicate that purity decays with
classical, i.e. hbar-independent rate. Numerical results confirm theoretical predictions
[new reference 2, see below].

-    We have also made a progress in general semiclassical understanding of quantum
fidelity decay in classically integrable systems, for the special and important case of
'ergodic' perturbation with vanishing time-average (which may often happen due to
discrete symmetries).
This work is in progress and will be written up shortly.

We have studied the quantum dynamical localization for a dynamical model-the sawtooth
map- using an algorithm that we have previously developed.
This algorithm has some specific advantages with respect to similar algorithms for the
simulation of other dynamical systems, for instance the kicked rotator. There are no
extra work space qubits, namely all the qubits are used to simulate the dynamics of the
system. This implies that less than 40 qubits would be sufficient to make simulations
inaccessible to present day supercomputers. We note that this figure has to be compared
with the more than 1000 qubits required to the Shor's algorithm to outperform classical
computations. We have also shown that in our model, dynamical localization
should be observed already with 6 qubits.

<u>**MEMORANDUM OF TRANSMITTAL**</u>

U.S. Army Research Office
ATTN: AMSRL-RO-BI (TR)
P.O. Box 12211
Research Triangle Park, NC 27709-2211

☐ Reprint (Orig + 2 copies)   ☐ Technical Report (Orig + 2 copies)

☐ Manuscript (1 copy)   ☐ Final Progress Report (Orig + 2 copies)

                                      ☐ Related Materials, Abstracts, Theses (1 copy)

CONTRACT/GRANT NUMBER:

REPORT TITLE:

is forwarded for your information.

SUBMITTED FOR PUBLICATION TO (applicable only if report is manuscript):

                         Sincerely,