Publications for Hartmut Häffner

(April 13, 2010)

Review articles

3. H. Häffner, *Quantum computing with trapped ions*, Journal of the Indian Institute of Science 89, No.3 (2009) in 'Quantum Computation—Current trends and implementations', Eds. V. Natarajan and A. Kumar.

2. H. Häffner, C. F. Roos, R. Blatt, *Quantum computing with trapped ions*, Physics Reports **469**, 155-203 (2008).

1. Günther Werth, Hartmut Häffner and Wolfgang Quint, *Continuous Stern-Gerlach effect on atomic ions*, Advances in Atomic, Molecular and Optical Physics, **48**, pages 191-217, B. Bederson (editor), Academic Press (2002).

Articles in refereed journals

45. T. Monz, K. Kim, A. S. Villar, P. Schindler, M. Chwalla, M. Riebe, C. F. Roos, H. Häffner, W. Hänsel M. Hennrich and R. Blatt, *Realization of Universal Ion-Trap Quantum Computation with Decoherence-Free Qubits*, Phys. Rev. Lett. **103**, 200503 (2009).

44. N. Daniilidis, T. Lee, R. Clark, S. Narayanan, H. Häffner, *Wiring up trapped ions to study aspects of quantum information*, J. Phys. B **42**, 144012 (2009).

43. V. Nebendahl, H. Häffner, C. F. Roos, *Optimal control of entangling operations for trapped-ion quantum computing*, Phys. Rev. A **79**, 012312 (2009).

42. K. Kim, C. F. Roos, L. Aolita, H. Häffner, V. Nebendahl, R. Blatt, *Geometric phase gate on an optical transition for ion trap quantum computation*, Phys. Rev. A **77**, 050303(R) (2008).

41. C. F. Roos, T. Monz, K. Kim, M. Riebe, H. Häffner, D. F. V. James, R. Blatt, *Nonlinear coupling of continuous variables at the single quantum level*, Phys. Rev. A **77**, 040302(R) (2008).

40. L. Aolita, K. Kim, J. Benhelm, C. F. Roos, H. Häffner, *High-fidelity ion-trap quantum computation with hyperfine clock states*, Phys. Rev A **76**, 040303 (2007).

39. L. Aolita, L. Davidovich, K. Kim, H. Häffner, *Universal quantum computation in decoherence-free subspaces with hot trapped ions*, Phys. Rev. A **75**, 052337 (2007).

38. M. Riebe, M. Chwalla, J. Benhelm, H. Häffner, W. Hänsel, C. F. Roos, R. Blatt, *Quantum teleportation with atoms: quantum process tomography*, New J. Phys. **9**, 211 (2007).

37. C. Wunderlich, T. Hannemann, T. Körber, H. Häffner, C. F. Roos, W. Hänsel, R. Blatt, F. Schmidt-Kaler, *Robust state preparation of a single trapped ion by adiabatic passage*, J. Mod. Opt. **54** 1541 (2007).

36. J. Korbicz, O. Gühne, M. Lewenstein, H. Häffner, C. F. Roos, R. Blatt, *Generalized spin-queezing inequalities in N-qubit systems*, Phys. Rev. A **74**, 052319 (2006).

35. M. Riebe, K. Kim, P. Schindler, T. Monz, P. O. Schmidt, T. Körber, W. Hänsel, H. Häffner, C. F. Roos, R. Blatt, *Process tomography of ion trap quantum gates*, Phys. Rev. Lett. **97**, 220407 (2006).

34. G. Werth, J. Alonso, T. Beier, K. Blaum, S. Djekic, H. Häffner, N. Hermanspahn, W. Quint, S. Stahl, J. Verdu, T. Valenzuela, M. Vogel, *Highly charged ions, quantum-electrodynamics, and the electron mass*, International Journal of Mass Spectrometry **251**, 152 (2006).

33. A. Browaeys, H. Häffner, C. M^{c}Kenzie, S. L. Rolston, K. Helmerson, W. D. Phillips, *Transport of atoms in a quantum conveyor belt*, Phys. Rev. A **72**, 053605 (2005).

32. M. Florescu, S. Scheel, H. Häffner, H. Lee, D. Strekalov, P. L. Knight, J. P. Dowling, *Singe photons on demand from 3D photonic band gap structures*, Europhys. Lett. **69**, 945 (2005).

31. H. Häffner, W. Hänsel, C. F. Roos, J. Benhelm, D. Chek-al-kar, M. Chwalla, T. Körber, U. D. Rapol, M. Riebe, P. O. Schmidt, C. Becher, O. Gühne, W. Dür, R. Blatt, *Scalable multi-particle entanglement of trapped ions*, Nature **438**, 643 (2005).

30. H. Häffner, F. Schmidt-Kaler,W .Hänsel, C.F. Roos, T. Körber, M. Chwalla, M. Riebe, J. Benhelm, U. D. Rapol, C. Becher, R. Blatt, *Robust entanglement*, Appl. Phys. B **81**, 151 (2005).

29. A. Kreuter, C. Becher, G.P.T. Lancaster, A.B. Mundt, C. Russo, H. Häffner, C. Roos, W. Hänsel, F. Schmidt-Kaler, R. Blatt, M.S. Safronova, *New experimental and theoretical approach to the 3d 2D-level lifetimes of* $^{40}Ca^{+}$, Phys. Rev. A **71**, 032504 (2005).

28. M. Riebe, H. Häffner, C. F. Roos, W. Hänsel, J. Benhelm, G. P. T. Lancaster, T. W. Körber, C. Becher, F. Schmidt-Kaler, D. F. V. James, R. Blatt, *Deterministic quantum teleportation with atoms*, Nature **429**, 734 (2004).

27. C. F. Roos, M. Riebe, H. Häffner, W. Hänsel, J. Benhelm, G. P. T. Lancaster, C. Becher, F. Schmidt-Kaler, R. Blatt, *Control and Measurment of Three-Qubit Entangled States*, Science **304**, 1478 (2004).

26. C. F. Roos, G. P. T. Lancaster, M. Riebe, H. Häffner, W. Hänsel, S. Gulde, C. Becher, J. Eschner, F. Schmidt-Kaler, R. Blatt, *Bell States of Atoms with Ultralong Lifetimes and Their Tomographic State Analysis*, Phys. Rev. Lett. **92**, 220402 (2004).

25. A. Kreuter, C. Becher, G. P. T. Lancaster, A. B. Mundt, C. Russo, H. Häffner, C. Roos, J. Eschner, F. Schmidt-Kaler, and R. Blatt, *Spontaneous Emission Lifetime of a Single Trapped Ca^+ Ion in a High Finesse Cavity*, Phys. Rev. Lett. **92**, 203002 (2004).

24. F. Schmidt-Kaler, H. Häffner, S. Gulde, M. Riebe, G. Lancaster, J. Eschner, C. Becher and R. Blatt, *Quantized AC-Stark shifts and their use for multiparticle entanglement and quantum gates*, Europhys. Letters **65**, 587 - 593 (2004).

23. F. Schmidt-Kaler, H. Häffner, S. Gulde, M. Riebe, G. P. T. Lancaster, T. Deuschle, C. Becher, W. Hänsel, J. Eschner, C. F. Roos, R. Blatt, *How to realize a universal quantum gate with trapped ions*, Appl. Phys. B: Lasers and Optics (2003).

22. G.P.T. Lancaster, H. Häffner, M.A. Wilson, C. Becher, J. Eschner, F. Schmidt-Kaler, R. Blatt, *Doppler cooling a single Ca^+ ion with a violet extended-cavity diode laser*, Appl. Phys. B **76**, 805 (2003).

21. H. Häffner, S. Gulde, M. Riebe, G. Lancaster, C. Becher, J. Eschner, F. Schmidt-Kaler, and R. Blatt, *Precision measurement and compensation of optical Stark shifts for an ion-trap quantum processor*, Phys. Rev. Lett. **90**, 143602 (2003).

20. F. Schmidt-Kaler, H. Häffner, M. Riebe, S. Gulde, G. P. T. Lancaster, T. Deuschle, C. Becher, C. F. Roos, J. Eschner, R. Blatt, *Realization of the Cirac-Zoller controlled-NOT quantum gate*, Nature **422**, 408 (2003).

19. J. Verdú, T. Beier, S. Djekić, H. Häffner, H.-J. Kluge, W. Quint, T. Valenzuela, M. Vogel and G. Werth, *The magnetic moment anomaly of the electron bound in hydrogen-like oxygen $^{16}O^{7+}$*, J. Phys. B: At. Mol. Opt. Phys. **36**, 655 (2003).

18. F. Schmidt-Kaler, S. Gulde, M. Riebe, T. Deuschle, A. Kreuter, G. Lancaster, C. Becher, J. Eschner, H. Häffner and R. Blatt, *The coherence of qubits based on single Ca^+ ions*, J. Phys. B: At. Mol. Opt. Phys. **36**, 623 (2003).

17. H. Häffner, T. Beier, S. Djekić, N. Hermanspahn, H.-J. Kluge, W. Quint, S. Stahl, J. Verdú, T. Valenzuela, G. Werth, *Double Penning trap technique for precise g factor determinations in highly charged ions*, Eur. Phys. J. D **22**, 163 (2003).

16. Stephan Gulde, Mark Riebe, Gavin P. T. Lancaster, Christoph Becher, Jürgen Eschner, Hartmut Häffner, Ferdinand Schmidt-Kaler, Isaac L. Chuang, Rainer Blatt, *Implementation of the Deutsch-Jozsa algorithm on an ion-trap quantum computer*, Nature **421**, 48 (2003).

15. Thomas Beier, H.-Jrgen Kluge, Wolfgang Quint, Hartmut Häffner, Günther Werth, *Mass of the Electron from the Electronic g Factor in Hydrogenlike Carbon – the Influence of Other Fundamental Parameters*, Hyperfine interactions **146–147**, 53 (2003).

14. J. Hecker Denschlag, J. E. Simsarian, H. Häffner, C. M^{c}Kenzie, A. Browaeys, D. Cho, K. Helmerson, S. L. Rolston, and W. D. Phillips, *A Bose-Einstein condensate in an optical lattice*, J. Phys. B **35**, 3095 (2002).

13. J. Verdú, T. Beier, S. Djekic, H. Häffner, H.-J. Kluge, W. Quint, T. Valenzuela and G. Werth, *Measurement of the g_j factor of a bound electron in hydrogen-like Oxygen $^{16}O^{7+}$*, Can. J. Phys **80** (11): 1233-1240(2002).

12. C. M^{c}Kenzie, J. Hecker Denschlag, H. Häffner, A. Browaeys, L. E. E. de Araujo, F. K. Fatemi, K. M. Jones, J. E. Simsarian, D. Cho, A. Simoni, E. Tiesinga, P. S. Julienne, K. Helmerson, P. D. Lett, S. L. Rolston, and W. D. Phillips, *Photoassociation of Sodium in a Bose-Einstein Condensate*, Phys. Rev. Lett. **88**, 120403 (2002).

11. T. Beier, H. Häffner, N. Hermanspahn, S. Djekić, H.-J. Kluge, W. Quint, S. Stahl, T. Valenzuela, J. Verdú and G. Werth, *The measurement of the electronic g factor in hydrogenlike ions - a promising tool for determining fundamental and nuclear constants*, Europ. Phys. J. A **15**,41(2002).

10. T. Beier, H. Häffner, N. Hermanspahn, S. Karshenboim, H.-J. Kluge, W. Quint, S. Stahl, J. Verdú, and G. Werth, *A new determination of the electron's mass*, Phys. Rev. Lett. **88**, 011603 (2002).

9. W. Quint, J. Dilling, S. Djekić, H. Häffner, N. Hermanspahn, H.-J. Kluge, G. Marx, R. Moore, D. Rodriguez, J. Schnfelder, G. Sikler, T. Valenzuela, J. Verdú, C. Weber, G. Werth, *HITRAP: A Facility for Experiments with Trapped Highly Charged Ions*, Hyperfine Interactions **132**(1/4), 453 (2001).

8. G. Werth, H. Häffner, H.-J. Kluge, W. Quint, T. Valenzuela, J. Verdú, *A Possible New Value for the Electron Mass from g-Factor Measurements on Hydrogen-Like Ions*, Hyperfine Interactions **132**(1/4), 209 (2001).

7. W. K. Hensinger, H. Häffner, A. Browaeys, N. R. Heckenberg, K. Helmerson, C. M^{c}Kenzie, G. J. Milburn, W. D. Phillips, S. L. Rolston, H. Rubinsztein-Dunlop & B. Upcroft, *Dynamical tunnelling of ultracold atoms*, Nature **412**, 52 (2001).

6. H. Häffner, T. Beier, N. Hermanspahn H.-J. Kluge, W. Quint, S. Stahl, J. Verdú, and G. Werth, *High-Accuracy Measurement of the Magnetic Moment Anomaly of the Electron Bound in Hydrogenlike Carbon*, Phys. Rev. Lett. **85**, 5308 (2000).

5. Thomas Beier, Ingvar Lindgren, Hans Persson, Sten Salomonson, Per Sunnergren, Hartmut Häffner, Nikolaus Hermanspahn, *g_j factor of an electron bound in a hydrogenlike ion*, Phys. Rev. A **62**, 032510 (2000).

4. H. Häffner, N. Hermanspahn, P. Indelicato, H.-J. Kluge, E. Lindroth, V. Natarajan, W. Quint, S. Stahl, J. Verdú, and G. Werth, *Testing Atomic Structure Theories with High-Accuracy Mass Measurements on Highly Charged Ions*, Hyperfine Interactions **127**, 271 (2000).

3. N. Hermanspahn, H. Häffner, H.-J. Kluge, S. Stahl, W. Quint, J. Verdú, and G. Werth, *Observation of the Continuous Stern-Gerlach Effect on an Electron Bound in an Atomic Ion*, Phys. Rev. Lett. **84**, 427 (2000).

2. M. Diederich, H. Häffner, N. Hermanspahn, M. Immel, H.-J. Kluge, R. Ley, R.Mann, W. Quint, S. Stahl, J.Verdú and G. Werth, *The g-factor of the Electron Bound in Hydrogen-like Ions*, Physica Scripta **T80**, 437 (1999).

1. M. Diederich, H. Häffner, N. Hermanspahn, M. Immel, H.-J. Kluge, R. Ley, R. Mann, S. Stahl, W. Quint, and G. Werth, *Observing a single hydrogen-like ion in a Penning trap at $T = 4$ K*, Hyperfine Interactions **115**, 185 (1998).

Contributions to books

3. H. Häffner, W. Hänsel, C. F. Roos, P. O. Schmidt, M. Riebe, M. Chwalla, D. Chek-al-kar, J. Benhelm, U. D. Rapol, T. Körber, C. Becher, O. Gühne, W. Dür, R. Blatt, *Quantum Computing with Trapped Ions*, Controllable Quantum States, Eds.: J. Nitta, H. Nakano, World Scientific (2008).

2. H. Häffner, M. Riebe, F. Schmidt-Kaler, W. Hänsel, C. F. Roos, M. Chwalla, J. Benhelm, T. W. Körber, C. Becher, D.F.V. James, R. Blatt, *Controlling three atomic qubits*, Physical Realizations of Quantum Computing, Eds.: M. Nakahara, S. Kanemitsu, M.M. Salomaa, S. Takagi, World Scientific (2006).

1. G. Werth, H. Häffner, N. Hermanspahn H.-J. Kluge, W. Quint, S. Stahl, J. Verdú, *The g Factor of Hydrogenic Ions: A Test of Bound State QED*, The Hydrogen Atom: Precision Physics of Simple Atomic Systems, Eds.: S. G. Karshenboim, F. S. Pavone, G. F. Bassani, M. Inguscio, and T. W. Häsch, Springer-Verlag (2000).

Edited books

1. Atomic Physics 20, AIP conference proceedings **869**, Melville, New York, 2006, Eds.: R. Blatt, H. Häffner, C. F. Roos.

Proceedings and not refereed articles

9. O. Gühne, H. Häffner, *Tomografie eines Quantenzustands – Verschränkung und Reinheit*, e & i Elektrotechnik und Informationstechnik **124** 5, 131 (2007).

8. H. Häffner, F. Schmidt-Kaler, W. Hänsel, C. F. Roos, P. O. Schmidt, M. Riebe, M. Chwalla, D. Chek-al-kar, J. Benhelm, U. D. Rapol, T. Körber, C. Becher, R. Blatt, *Long lived entangled states*, proceedings of the ISQM-Tokyo 2005, Foundations of Quantum Mechanics in the Light of New Technology, Eds.: S. Ishioka, K. Fujikawa, World Scientific, Singapore (2006).

7. C. Becher, J. Benhelm, D. Chek-al-kar, M. Chwalla, W. Dür, O. Gühne, H. Häffner, W. Hänsel, T. Körber, A. Kreuter, G.P.T. Lancaster, T. Monz, E. S. Phillips, U. D. Rapol, M. Riebe, C. F. Roos, C. Russo, F. Schmidt-Kaler, R. Blatt, *Entanglement of trapped ions*, proceedings of the ICOLS 2005, Laser Spectroscopy, Eds.: A. Ferguson, E. Riis, E. A. Hinds, World Scientific, Singapore (2005).

6. H. Häffner, M. Riebe, F. Schmidt-Kaler, W. Hänsel, C. F. Roos, M. Chwalla, J. Benhelm, T. Körber, C. Becher, D.F.V. James, R. Blatt, *Teleportation with*

Atoms, proceedings of the ICAP 2004, Atomic Physics 19, AIP conference proceedings **770**, Eds.: L. Marcassa, K. Helmerson, V. Bagnato, Melville, New York (2005).

5. R. Blatt, H. Häffner, C. F. Roos, C. Becher, F. Schmidt-Kaler, *Quantum information processing in ion traps I*, proceedings of the Summer School Les Houches 2003, Quantum Entanglement and Information Processing, Session LXXIX 79, Eds.: J.M. Raimond, J. Dalibard, D. Estève, Elsevier Science, Amsterdam (2004).

4. R. Blatt, H. Häffner, C.F. Roos, C. Becher, and F. Schmidt-Kaler, *Ion Trap Quantum Computing with Ca^+ Ions*, Quant. Inf. Proc. 3, Nos. 1-5, (2004).

3. S. Gulde, H. Häffner, M. Riebe, G. Lancaster, A. Mundt, A. Kreuter, C. Russo, C. Becher, J. Eschner, F. Schmidt-Kaler, I. L. Chuang, R. Blatt, *Quantum information processing and cavity QED experiments with trapped Ca^+ ions*, proceedings of the ICAP 2002, Atomic Physics 18, Eds.: D. Prichard, W. Ketterle and R. Heller, World Scientific, New Jersey (2003).

2. W. K. Hensinger, H. Häffner, A. Browaeys, N. R. Heckenberg, K. Helmerson, C. M^{c}Kenzie, G. J. Milburn, W. D. Phillips, S. L. Rolston, H. Rubinsztein-Dunlop & B. Upcroft, *Cold atoms in an amplitude modulated optical lattice – dynamical tunnelling*, proceedings of the ICOLS 2001, Laser Spectroscopy, Eds. V. Vuletic, S. Chu, A. J. Kerman, and Cheng Chin, World Scientific, Singapore, (2001).

1. M. Diederich, H. Häffner, N. Hermanspahn, M. Immel, H.-J. Kluge, R. Ley, R. Mann, W. Quint, S. Stahl, and G. Werth, *The g-factor of hydrogen-like ions*, Atomic Physics 16, Eds.: W.E. Baylis and G.W.F. Drake, , proceedings of the ICAP 1998, Springer, Berlin (1999).

Invited seminars, talks and colloquia

39. *Quantum information with trapped ions—real thought experiments*, colloquium, University of Reno, Feb 5 2010.

38. *Wiring up trapped ions*, Condensed Matter Physics Seminar, UC Los Angeles, Dec 9 2009.

37. *Wiring up trapped ions for quantum information*, seminar, Electrical Engineering and Computer Sciences, UC Berkeley, Oct 2 2009.

36. *Quantum information with trapped ions—real thought experiments*, colloquium, University of Toronto, Sep 24 2009.

35. *Quantum information with trapped ions*, colloquium, University of Freiburg, Jul 3 2009.

34. *Quantum computation with trapped ions*, invited talk, CLEO/IQEC Baltimore, June 5 2009.

33. *Quantum computation with trapped ions*, Habilitation colloquium, University of Innsbruck, May 19 2009.

32. *Wiring up trapped ions for quantum information* (invited talk, QIon09, Workshop on Quantum Information and Quantum Dynamics in Ion Traps, Tel Aviv, May 4 2009.

31. *Quantum computation with trapped ions*, ALS/CXRO seminar, Lawrence Berkeley National Laboratory, Apr 15 2009.

30. *Quantum computation with trapped ions*, colloquium, School of Natural Sciences, UC Merced, Apr 3 2009.

29. *Atomic, Molecular and Optical Physics at Berkeley*, talk, Open House for admitted prospective graduate students, UC Berkeley, Apr 2 2009.

28. *Wiring up ion traps for quantum information*, talk, "nano" seminar, BNNI, Berkeley, Jan 23 2009.

27. *Ion trap quantum computing*, lecture, ETH Zürich, Switzerland, Dec 08 2008.

26. *Wiring up trapped ions*, talk, summer school on "Modern Applications of Trapped Ions", Les Houches, France, May 22 2008.

25. *Perspectives of quantum information processing with trapped ions*, seminar talk at UC Berkeley, CA, USA, Feb 12 2008.

24. *Quantum computation with trapped ions*, colloquium at UC Berkeley, CA, USA, Feb 11 2008.

23. *Quantenphysik mit Ionen*, Universität Kaiserslautern, Nov 12 2007.

22. *Quantum computing with trapped ions*, IBM T.J. Watson Research Center, Yorktown Heights, NY, USA, Oct 10 2007.

21. *Experimental quantum information*, tutorial, Informal Quantum Information Gathering, Innsbruck, Mar 13 2007.

20. *Perspectives of ion trap quantum computing*, seminar for quantum information Singapore, Singapore, Feb 7 2007.

19. *Error correction, fault tolerance, threshold: experimental perspectives*, talk, 7th European QIPC Workshop Quantum Information Processing and Communication, London, UK, Oct 13 2006.

18. *Ein Modell eines Quantencomputers*, talk on experimental quantum computing for the general public, International Lübeck symposium for health care in Europe, Hannover, Germany, Sep 4 2006.

17. *Quantum computation with trapped ions*, talk, Conference on Quantum Information and Quantum Control II, Toronto, Canada, Aug 8 – 11 2006.

16. *Das IQOQI*, Übersichtsvortrag über die Aktivitäten des Instituts für Quantenoptik und Quanteninformation in Innsbruck, Konsulententag der Austrian Business Agency, Innsbruck, Austria, Mar 26 2006.

15. *Coupling trapped ions via transmission lines for quantum computing*, talk, DPG-Tagung Frankfurt, Germany, Mar 12 2006.

14. *Quantum computation with trapped ions*, talk, International Symposium on Mesoscopic Superconductivity and Spintronics 2006, Tokyo, Japan, Feb 27 – Mar 3 2006.

13. *Quantum information processing with trapped ions*, talk, GDEST EU-US workshop on quantum information, Munich , Germany, Dec 8 2005.

12. *Quantum information processing with trapped ions*, colloquium, Cuervanaca, Mexico, Nov 30 2005.

11. Lectures series together with Christian Roos on *Ion trap quantum information processing*, International Summer School on Quantum Information, Dresden, Germany, Aug 29 – Sep 30 2005.

10. *Quantum computation with trapped ions*, talk, ISQM 2005, Tokyo , Japan, Aug 24 2005.

9. *Quantum computation with trapped ions*, talk, Quantum Optics VI, Krynica , Poland, June 13–18 2005.

8. *Teleportation with atoms*, talk, ICAP 2004, Rio de Janeiro, Brazil, July 25–30 2004.

7. *Quantum information processing with trapped ions*, seminar, Poznan University of Technology, Poznan, Poland, June 18 2004.

6. *Using entanglement as a resource for teleportation of atomic states*, talk, symposium "Entanglement, Information & Noise", Krzyzowa, Poland, June 14–20 2004.

5. *Quantum computation with trapped ions – Teleportation with atoms*, talk, workshop "Are the DiVincenzo Criteria fulfilled in 2004?", Kinki University, Osaka, Japan, May 7–8 2004.

4. *Quantum computation with trapped ions*, talk, The 2004 "LATSIS Symposium", Lausanne, March 1–3 2004.

3. *Dynamical Tunneling of Cold Atoms*, talk, WE-Heraeus-seminar "Chaos and Quantum Transport", Bad Honnef, 23–27 March 2003.

2. *Dynamical Tunneling of Cold Atoms*, seminar "Quantum Dynamics", Max-Planck-Institut fr Physik komplexer Systeme, Dresden, July 17 2002.

1. *Precision measurement of the g-factor of the electron bound in Hydrogen-like Carbon* , Chalmers University of Technology, Göteborg, Dec 15 1999.