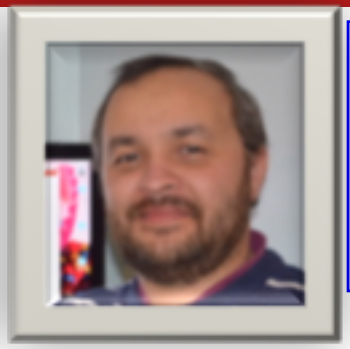
PHYS 3330: Modern Experimental Optics

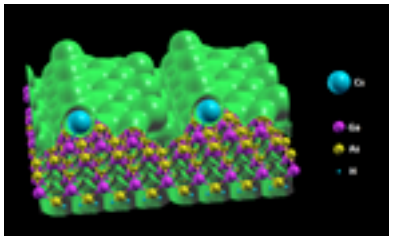


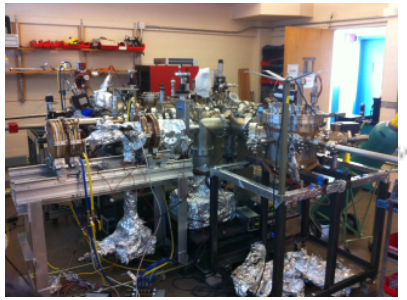
Jordan Moxon (TA)

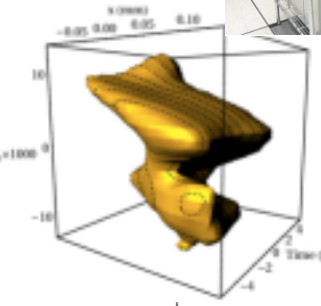
Professor Ivan Bazarov

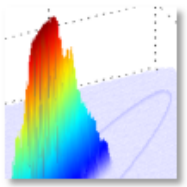
Physics Department / Cornell

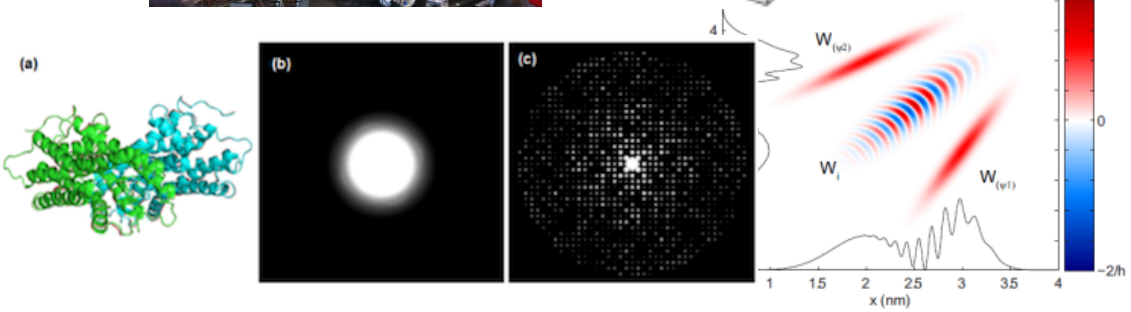
Research: Bright Electron Beams











Today's outline:

- **Course goals & logistics**
- **Light physics paradigms**
- **Experimental practices**
- **Integrity in research**

Course Goals

- ***Explore physics of light;***
- ***Acquire proper experimental skills;***
- ***Write scientific papers/reports.***

Logistics

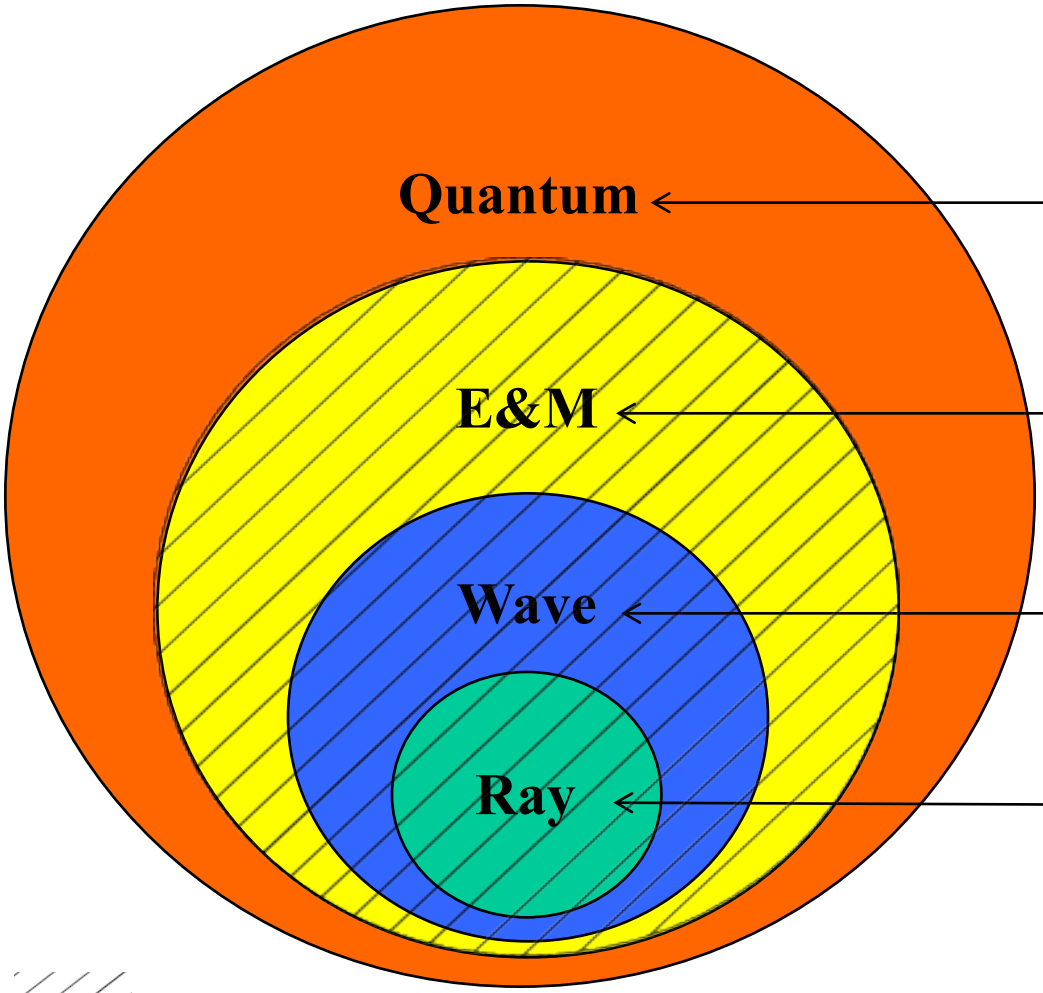
Course website: www.blackboard.cornell.edu
(schedule, lab policy, course docs, etc.)

Texts: P3330 Lab Manual (required)
Hecht, Optics (optional)
Saleh & Teich, Fundamentals of Photonics (optional)

Labs: Mon/Wed 1:25-4:25PM Clark 405
1st lab this Monday

Grade: 75% lab reports & performance
10% qiuzzes + attendance
15% two final quizzes (thy & exp)

Physics of light



quantum optics: photons, entanglement

E&M optics: polarization, non-linear effects

scalar wave optics: interference, coherence, diffraction

geometric optics: lenses, ray tracing, imaging

this course – except no nonlinear optics

Postulates* of optics

**from Latin "a request, demand": a self-evident proposition*

Postulate = Essence of a Nature's Law, everything else follows from it

Ray Optics: Fermat's Principle for rays

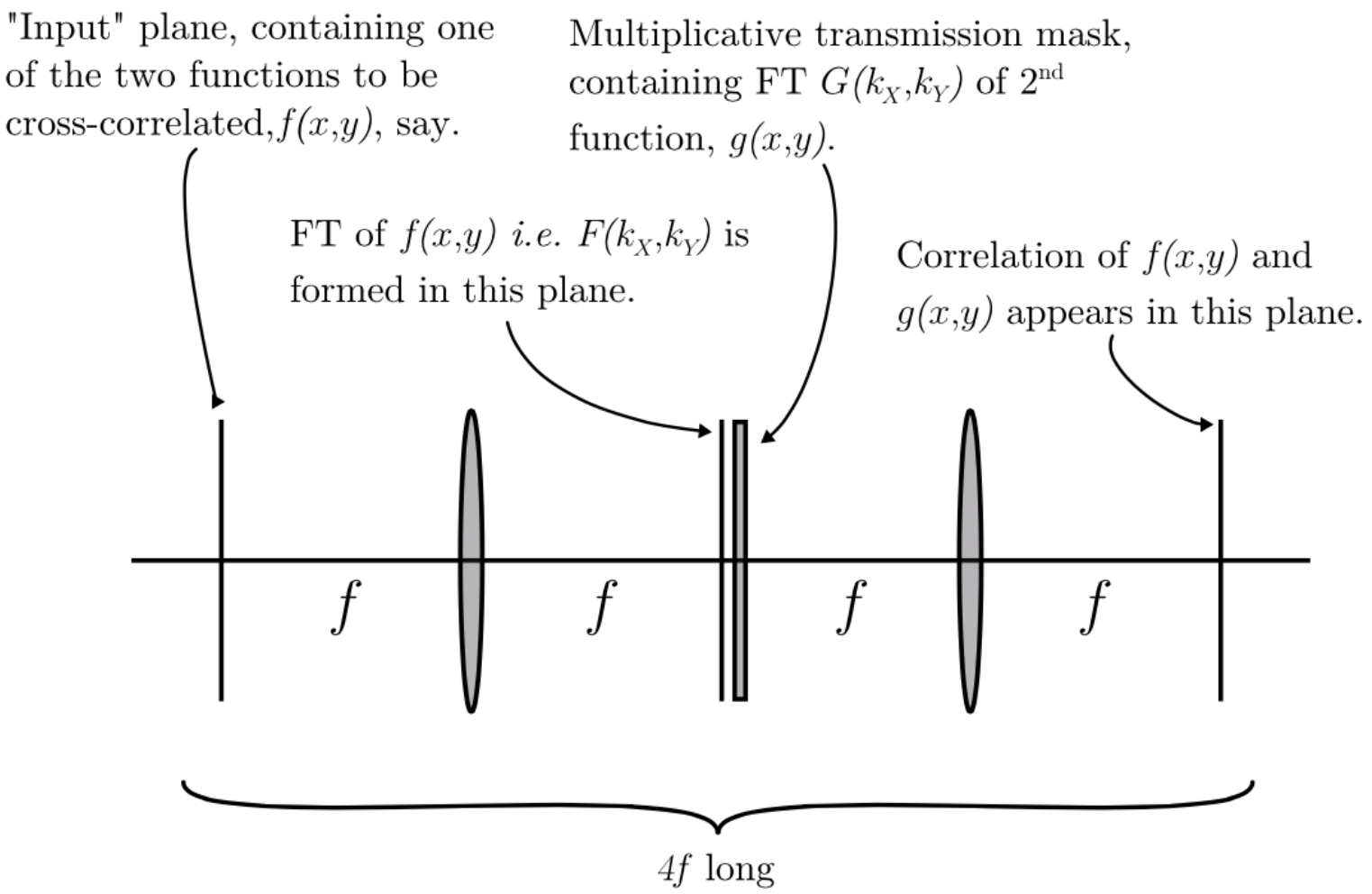
Wave Optics: scalar wave equation a.k.a. Helmholtz equation

E&M Optics: vector fields satisfy Maxwell equations

Quantum Optics: quantum electrodynamics (QED)

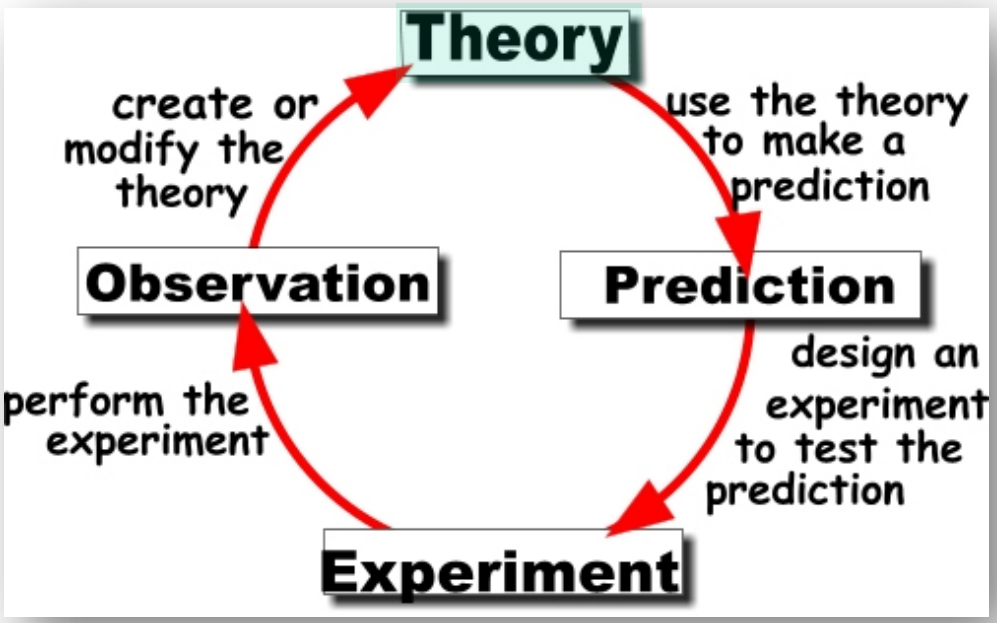
We'll be introducing concepts as needed for the lab.

E.g. *Fastest* Fourier Transform



$100M supercomputer vs. 2x$20 lenses:
same speed to compute the Fourier Transform/correlation!

Scientific Method – the Vehicle of Science



output → ***Scientific Theory***
"building blocks of science"

Q: Why do science?

- **A tool for well-being (pragmatic view)**
- **Quest for knowledge (has an intrinsic value)**

Scientific Experiment

- Must be **verifiable**, **repeatable**
  Q: can all knowledge be reduced to repeatable/verifiable?

- Must account for **errors** (**uncertainties**)
  - both **statistical** (e.g Higgs boson: ~100 counts)
  - and **systematic** (e.g. 2011 faster-than-light neutrinos)

- In this course, your record/writing of the experiments will be in the form of **logbook** and lab **reports**

Logbook (or lab notebook)

- **Essential** scientific tool! (graphed, labeled, page #'s)
- Each to maintain **his/her own record**/data/etc. (even if working in pairs)

History note: dead-reckoning to reconstruct ship's path using a ship log. A book with such records = logbook or captain's log. Only the captain had access to it. Messing with it = capital offense! Watch a video on the historical context of logbooks https://youtu.be/Bd_oMOkHf74

- Keeps track of all original data, "**your scientific path**" (don't erase anything! may find it useful later)
- Should be **dated**, with useful **sketches**, and reasonably **tidy**

Lab reports (papers/publications)

- You will produce **6 lab reports**
- **Essential** skill to develop! (most of the grade)
- Both the **format** and **breakdown** must follow the guidelines
  - Refer to the Lab Manual for the paper's breakdown (p.6)
  - All raw data must be preserved (in logbook), initialed by the TA. In case of a question, logbook is used to prove a point.
- (pdf)LaTeX (best to steer away from MS Word!)

Integrity in research/lab

- We are **subjective** beings in search of **objective** knowledge.

- **Basic rules** for responsible conduct of research:

NO

Fabrication → **proper book-keeping** (logbook, computer data)

Falsification → **experimental verification** (error propagation, full disclosure)

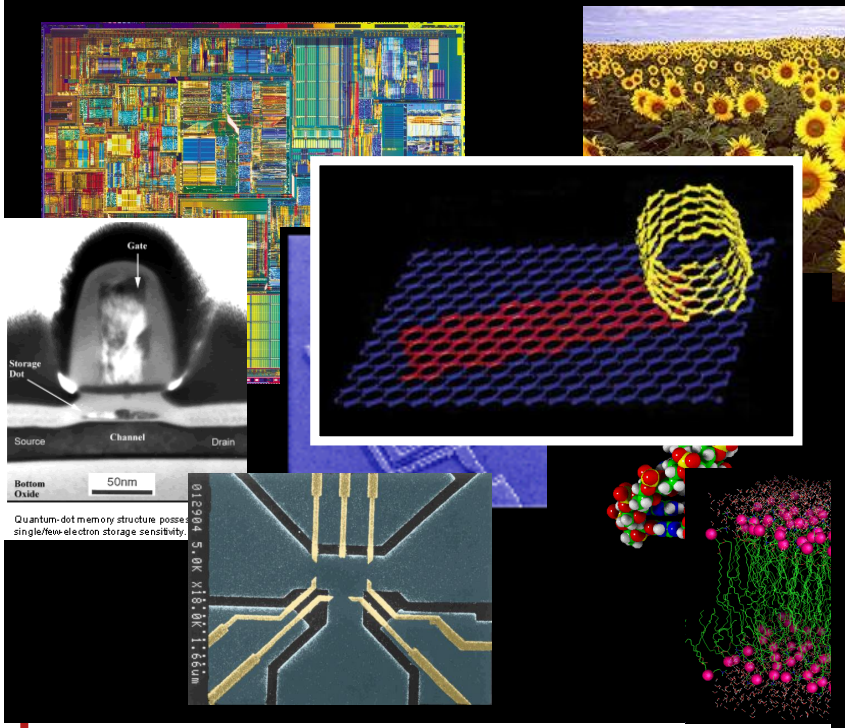
Plagiarism → **proper attribution**: do not pretend that ideas and work of others to be your own

misconduct

responsible conduct of research

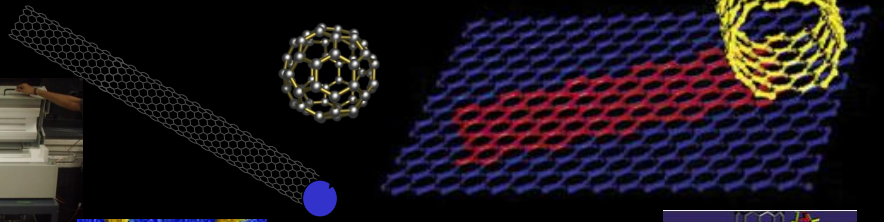
The Perfect Storm: The Rise and Fall of Hendrik Schon

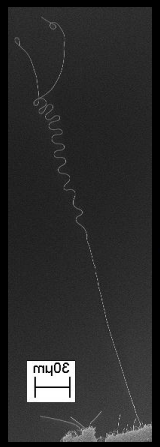
Two Nanotechnologies

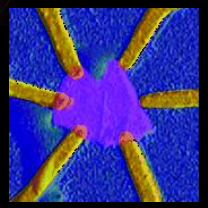


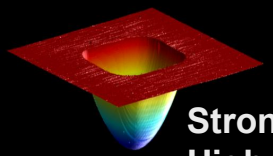
Lucent Technologies
Bell Labs Innovations

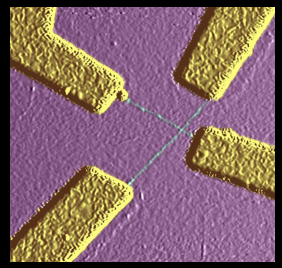
Nano Carbon

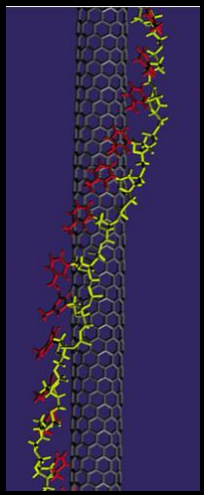












Strongest mat'l in world
Higher mobility than Si
Truly molecular scale

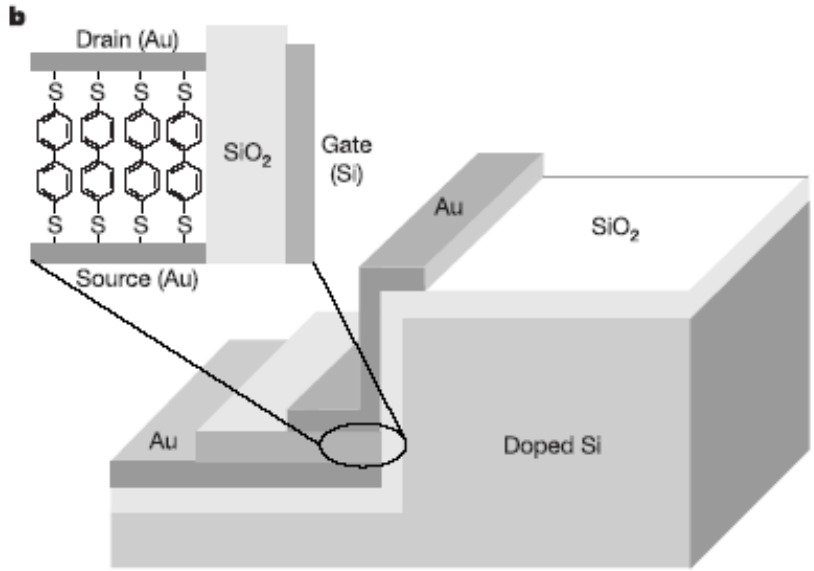
Slides courtesy Profs. Paul McEwen and David Muller

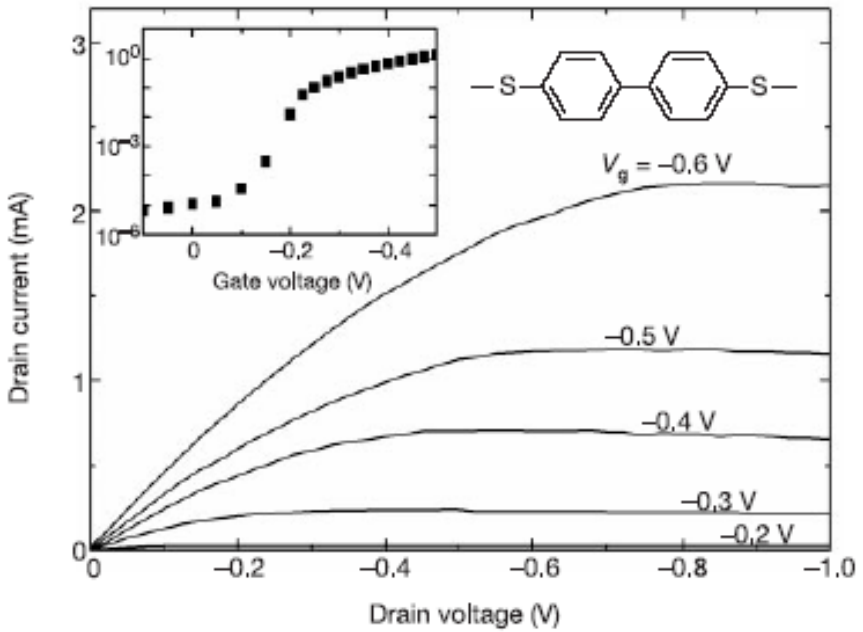
Self-assembled monolayer organic field-effect transistors

Nature **413**, 713 (2001).

Jan Hendrik Schön, Hong Meng & Zhenan Bao

Bell Laboratories, Lucent Technologies, Mountain Avenue, Murray Hill, New Jersey 07974, USA





Gate Modulation ~ 10^5

P-Channel g ~ 10 mA/V

Figure 2 Transistor characteristics of a 4,4′-biphenyldithiol (molecule **2**) SAMFET at room temperature. The inset shows the transfer characteristics, that is, drain current at $V_d = -1$ V as a function of V_g.

A Single-Molecule Transistor

BBC NEWS WORLD EDITION

You are in: Science/Nature

News Front Page

Thursday, 18 October, 2001, 14:03 GMT 15:03 UK

Tiny transistor breaks new limits

Bell Labs scientists usher in new era of molecular-scale electronics

FOR RELEASE WEDNESDAY OCTOBER 17, 2001

Tiny organic transistors may lead to less expensive and more powerful chips

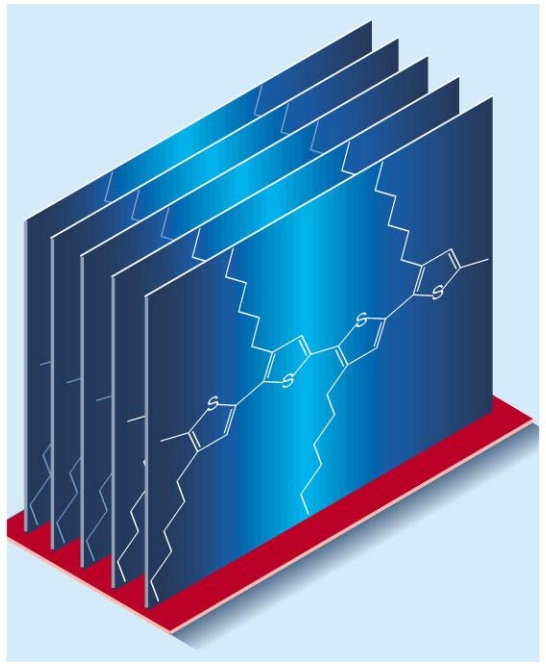
"The molecular-scale transistors that we have developed may very well serve as the historical 'bookend' to the transistor legacy started by Bell Labs in 1947," Federico Capasso, physical research vice president at Bell Labs.

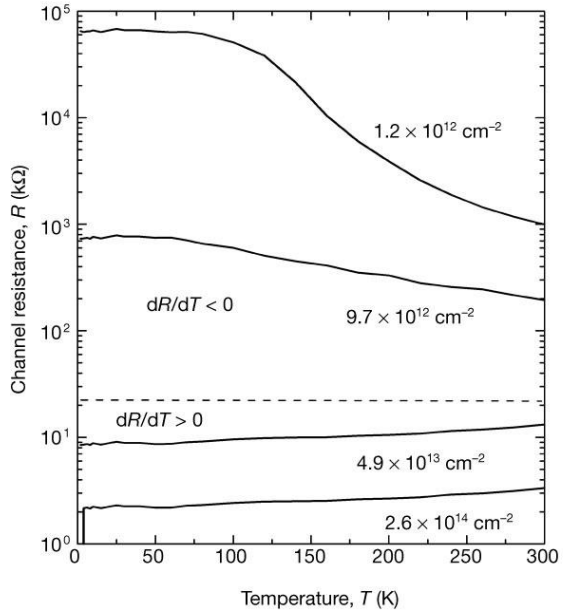
Superconducting Plastic

Gate-induced superconductivity in a solution-processed organic polymer film

J. H. Schön[1], A. Dodabalapur[1], Z. Bao[1], Ch. Kloc[1], O. Schenker[2] & B. Batlogg[1,3]

Nature **410**, 189-192 (8 March 2001)

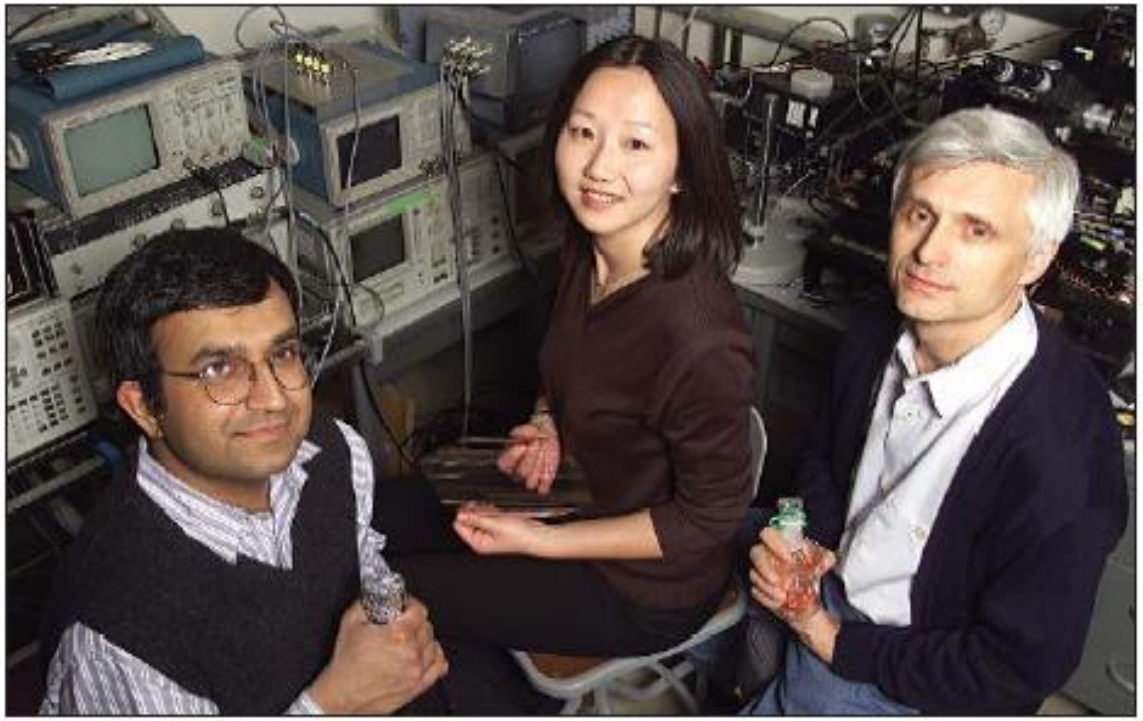




First Electrically-Pumped Organic Laser

First electrically powered organic laser may lead to more widespread use of lasers for various applications

FOR RELEASE FRIDAY JULY 28, 2000



Team effort. Bell Labs colleagues such as Ananth Dodabalapur, Zhenan Bao, and Christian Kloc were among Schön's many collaborators.

"Magic Hands"

Braunschweig Prize

- 1 Paper every 8 days in 2001!
- With 25 coauthors
- 6 patent filings
- numerous international awards

Science Magazine:

BREAKTHROUGH OF THE YEAR

In 2001, scientists assembled molecules into basic circuits, raising hopes for a new world of nanoelectronics

Molecules Get Wired

Outstanding Young Investigator Award

Jan Hendrik Schön
Bell Laboratories, Lucent Technologies

Talk Presentation
Molecular Materials for Electronic Devices
Wednesday, April 3, 12:05 p.m.
Salon 7, Marriott Hotel

Ausgabe 1/2002

Dr. Jan Hendrik Schön erhielt Otto-Klung-Weberbank-Preis für Physik 2001

Nobelpreisverdächtig

veritas iustitia libertas

ZEITUNG DER FREIEN UNIVERSITÄT BERLIN

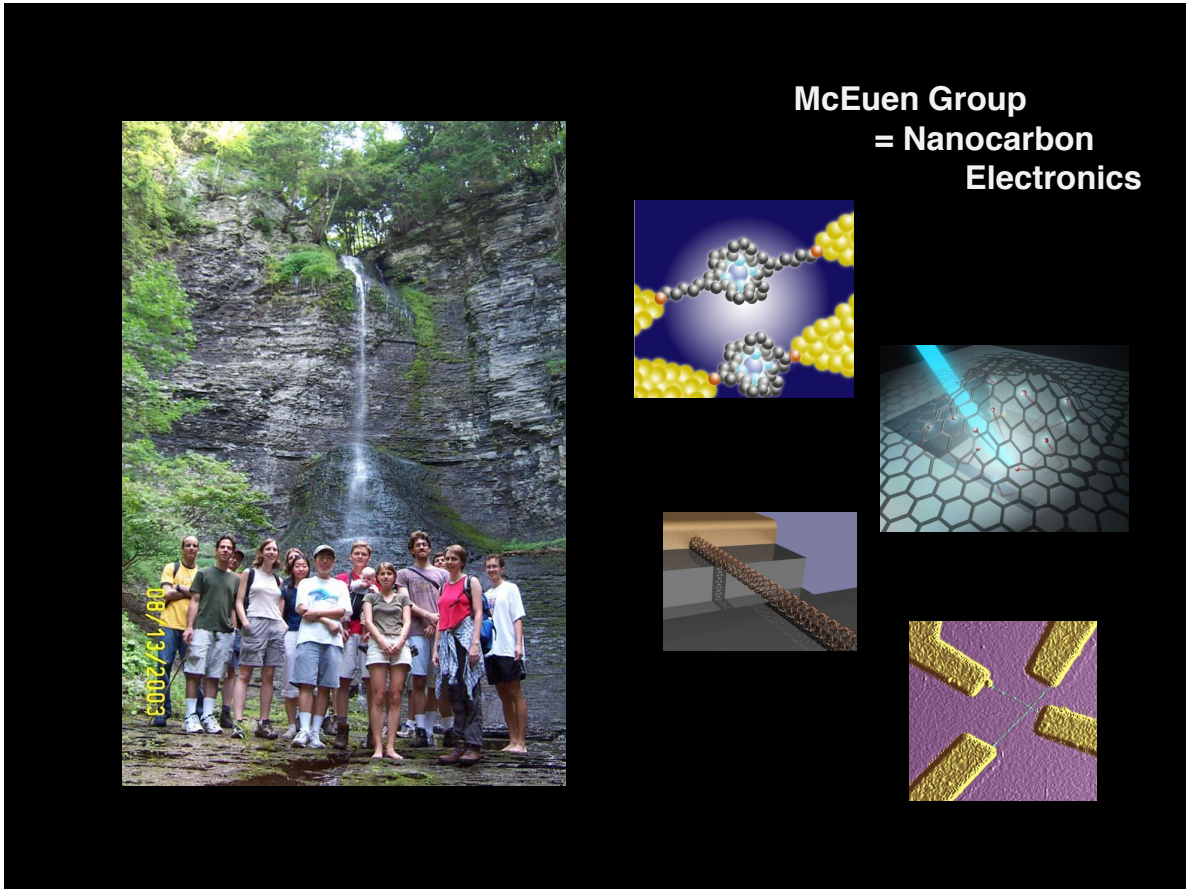
INHALT

Er ist jung und auf dem besten Wege, eines Tages Nobelpreisträger zu werden. Der 31-jährige deutsche Physiker Dr. Jan Hendrik Schön ist mit dem Otto-Klung-Weberbank-Preis für Physik ausgezeichnet worden. Auf Vorschlag der Auswahlkommission am Fachbereich Physik der Freien Universität erhielt Schön, der seit drei Jahren in Amerika forscht, den mit 50.000 DM dotierten Preis für seine „richtungweisenden Arbeiten über organische Halbleiter und zur Supraleitung".

Preisverleihung im Harnack-Haus; (v.l.n.r.) Prof. Dr. Dr. h.c. Günter Kaindl (Vorsitzender der Auswahlkommission Physik der Otto-Klung-Stiftung), Dr. Christian Grün (Mitinhaber und Sprecher der persönlich haftenden Gesellschafter der Weberbank Privatbankiers KGaA und Geschäftsführer der Fördergesellschaft der Weberbank gGmbH), Kanzler a. D. Kurt Hammer (Vorstandsmitglied der Otto-Klung-Stiftung), Dr. Jan Hendrik Schön (Otto-Klung-Weberbank-Preisträger 2001), Prof. Dr. Horst Störmer, Columbia University/N.Y. (Nobelpreis für Physik 1998 und Otto-Klung-Preis 1985), Michael Graf Strasoldo (Geschäftsführer der Fördergesellschaft der Weberbank gGmbH).

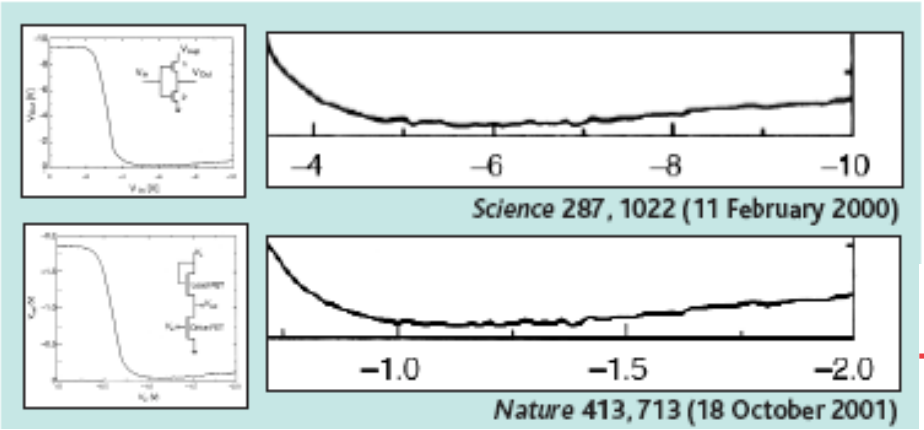
Repeatable/verifiable?

- Meanwhile here at Cornell: trouble reproducing Schon's results by the local nanocarbon experts…
- "**What are we doing wrong?!**"



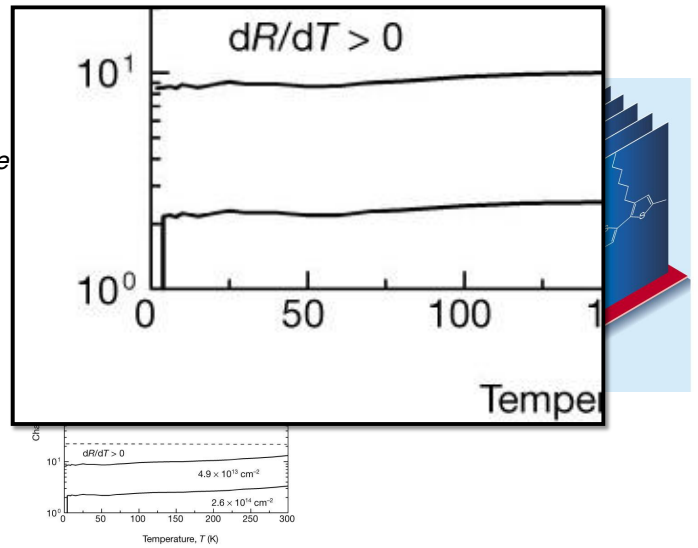
Falsification?

Duplicate Noise in Different Papers



Superconducting Plastic

Nature



Duplicate Curves

Perylene: A promising organic field-effect transistor material

J. H. Schön,[a] Ch. Kloc, and B. Batlogg
Bell Laboratories, Lucent Technologies, 600 Mountain Avenue, P.O. Box 636, Murray Hill, New Jersey 07974-0636

Fig. 1. Drain current of an ambipola α-6T FET at room temperature as function of positive drain-source V bias for different gate-source volt ages V_g. At high gate voltage, th electron current dominates, where as hole conduction becomes noti cable at low gate and high source drain voltages.

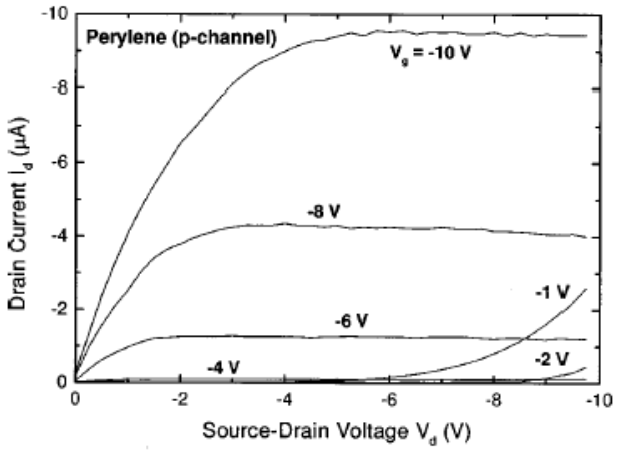


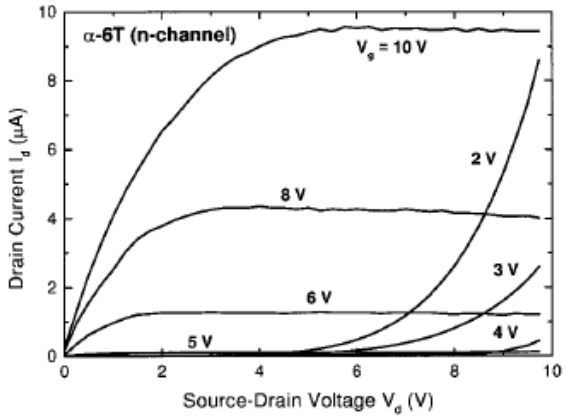
FIG. 2. Drain current characteristics of a perylene field-effect t operated in the *p*-channel mode at room temperature.

Duplicate Curves

A Light-Emitting Field-Effect Transistor

J. H. Schön,* A. Dodabalapur,* Ch. Kloc, B. Batlogg

Fig. 1. Drain current of an ambipolar α-6T FET at room temperature as a function of positive drain-source V_d bias for different gate-source voltages V_g. At high gate voltage, the electron current dominates, whereas hole conduction becomes noticable at low gate and high source-drain voltages.



SCIENCE VOL 290 3 NOVEMBER 2000

Independent Commission: May 2002

Physics Today:

Bell Labs Convenes Committee to Investigate Questions of Scientific Misconduct

Is there an innocent explanation for the appearance of similar figures in different publications?

- External Panel of scientists examine all papers
- Interviews all coauthors
- Off limits: Patents, Management responsibility

Science:

RESEARCH INTEGRITY

Pioneering Physics Papers Under Suspicion for Data Manipulation

Bell Labs launches inquiry into allegations of data duplication

Results of inquiry into the validity of certain physics research papers from Bell Labs

Sep 2002

Independent committee finds one researcher committed scientific misconduct, clears the 19 other authors investigated

http://publish.aps.org/reports/

- Only Schön made devices
- No coauthors ever witnessed an experiment
- No laboratory records were kept
- Original data (if it existed)
  was deleted from the computers

Nearly every rule of scientific documentation violated.

All Papers retracted

25. Reck-Peterson, S. L., Novick, P. J. & Mooseker, M. S. The tail of a yeast class V myosin, myo2p, functions as a localization domain. *Mol. Biol. Cell* 10, 1001–1017 (1999).
26. Gomes de Mesquita, D. S., van den Hazel, H. B., Bouwman, J. & Woldringh, C. L. Characterization of new vacuolar segregation mutants, isolated by screening for loss of proteinase B self-activation. *Eur. J. Cell Biol.* 71, 237–247 (1996).
27. Hill, K. L., Catlett, N. L. & Weisman, L. S. Actin and myosin function in directed vacuole movement during cell division in *Saccharomyces cerevisiae*. *J. Cell Biol.* 135, 1535–1549 (1996).
28. Catlett, N. L. & Weisman, L. S. The terminal tail region of a yeast myosin-V mediates its attachment to vacuole membranes and sites of polarized growth. *Proc. Natl Acad. Sci. USA* 95, 14799–14804 (1998).
29. Catlett, N. L. & Weisman, L. S. Divide and multiply: organelle partitioning in yeast. *Curr. Opin. Cell Biol.* 12, 509–516 (2000).

Acknowledgements We thank M. Cantwell for helping with the isolation of the *vac17-1* mutant. We thank T. Monniger and the University of Iowa Central Microscopy Research Facility for guidance in the use of the confocal microscope. We thank R. Cohen, J. Donelson, R. Piper, P. Rubenstein, J. Shaw and M. Stamnes for discussions. This work was supported by grants from the National Institutes of Health and the National Science Foundation (to L.S.W.).

Competing interests statement The authors declare that they have no competing financial interests.

Correspondence and requests for materials should be addressed to L.S.W. (e-mail: lois-weisman@uiowa.edu).

retractions

Superconductivity in $CaCuO_2$ as a result of field-effect doping

J. H. Schön, M. Dorget, F. C. Beuran, X. Z. Zu, E. Arushanov, C. Deville Cavellin & M. Laguës

Nature 414, 434–436 (2001).

This manuscript was, in part, the subject of an independent investigation[1] conducted at the behest of Bell Laboratories, Lucent Technologies. The independent committee reviewed concerns related to the validity of data associated with the device measurements described in the paper.

J.H.S.: As a result of the committee's findings[1], I am issuing a retraction of the paper. I note nevertheless that this paper may also contain some legitimate ideas and contributions.

M.D., X.Z.Z., E.A. and C.D.C.: In the light of the recent findings of the investigation[1] committee chaired by Professor Beasley, we would like to warn readers about the validity of the field-effect doping data presented in this paper and issue a retraction of this article. Our laboratory specializes in the synthesis, by molecular beam epitaxy, of copper oxide thin films. In May 2001, we initiated a collaboration with J.H.S., in which our role was limited to the synthesis of a thin-film sample of $CaCuO_2$. We can certify the quality (composition and structure) of the sample, and we are ready to prepare such samples for other serious scientific teams who want to try to reproduce these results.

M.L. and F.C.B.: We comment here as researchers at Wintici SA, a technology company. The synthesis of the $CaCuO_2$ sample reported in the paper was undertaken in collaboration with researchers from ESPCI, and we can vouch for its quality. But in the light of the committee's findings[1], we wish to issue a retraction of the paper. We note nevertheless that this paper may also contain some legitimate ideas and contributions. □

1. Beasley, M. R., Datta, S., Kogelnik, H., Kroemer, H. & Monroe, D. Report of the Investigation Committee on the Possibility of Scientific Misconduct in the Work of Hendrik Schön and Coauthors. ⟨http://publish.aps.org/reports/⟩ (doi:10.1103/aps.reports.lucent) (Lucent Technologies/American Physical Society, September 2002).

Superconductivity in single crystals of the fullerene C_{70}

J. H. Schön, Ch. Kloc, T. Siegrist, M. Steigerwald, C. Svensson & B. Batlogg

Nature 413, 831–833 (2001).

This manuscript was, in part, the subject of an independent investigation[1] conducted at the behest of Bell Laboratories, Lucent Technologies. The independent committee reviewed concerns related to the validity of data associated with the device measurements described in the paper. As a result of the committee's findings, we are issuing a retraction of the paper. We note nevertheless that this paper may also contain some legitimate ideas and contributions. □

1. Beasley, M. R., Datta, S., Kogelnik, H., Kroemer, H. & Monroe, D. Report of the Investigation Committee on the Possibility of Scientific Misconduct in the Work of Hendrik Schön and Coauthors. ⟨http://publish.aps.org/reports/⟩ (doi:10.1103/aps.reports.lucent) (Lucent Technologies/American Physical Society, September 2002).

Self-assembled monolayer organic field-effect transistors

Jan Hendrik Schön, Hong Meng & Zhenan Bao

Nature 413, 713–716 (2001); correction *Nature* 414, 470 (2001).

This manuscript was, in part, the subject of an independent investigation[1] conducted at the behest of Bell Laboratories, Lucent Technologies. The independent committee reviewed concerns related to the validity of data associated with the device measurements described in the paper. As a result of the committee's findings, we are issuing a retraction of the paper. We note nevertheless that this paper may also contain some legitimate ideas and contributions. □

1. Beasley, M. R., Datta, S., Kogelnik, H., Kroemer, H. & Monroe, D. Report of the Investigation Committee on the Possibility of Scientific Misconduct in the Work of Hendrik Schön and Coauthors. ⟨http://publish.aps.org/reports/⟩ (doi:10.1103/aps.reports.lucent) (Lucent Technologies/American Physical Society, September 2002).

Gate-induced superconductivity in a solution-processed organic polymer film

J. H. Schön, A. Dodabalapur, Z. Bao, Ch. Kloc, O. Schenker & B. Batlogg

Nature 410, 189–192 (2001).

This manuscript was, in part, the subject of an independent investigation[1] conducted at the behest of Bell Laboratories, Lucent Technologies. The independent committee reviewed concerns related to the validity of data associated with the device measurements described in the paper. As a result of the committee's findings, we are issuing a retraction of the paper. We note nevertheless that this paper may also contain some legitimate ideas and contributions. □

1. Beasley, M. R., Datta, S., Kogelnik, H., Kroemer, H. & Monroe, D. Report of the Investigation Committee on the Possibility of Scientific Misconduct in the Work of Hendrik Schön and Coauthors. ⟨http://publish.aps.org/reports/⟩ (doi:10.1103/aps.reports.lucent) (Lucent Technologies/American Physical Society, September 2002).

VOLUME 89, NUMBER 28 PHYSICAL REVIEW LETTERS 31 DECEMBER 2002

Retraction: Universal Crossover from Band to Hopping Conduction in Molecular Organic Semiconductors [Phys. Rev. Lett. 86, 3843 (2001)]

Jan Hendrik Schön, Christian Kloc, and Bertram Batlogg

(Received 18 December 2002; published 27 December 2002)

DOI: 10.1103/PhysRevLett.89.289902 PACS numbers: 72.80.Le, 71.38.–k, 72.20.Fr, 99.10.+g

On 25 September 2002, Bell Laboratories, Lucent Technologies, announced the findings of an independent committee it formed to investigate the validity of certain research reported from 1998 to 2002 by teams of Bell Labs and other scientists. In its report [1], the committee concludes that "based on the preponderance of the evidence, Hendrik Schön committed scientific misconduct as defined by the falsification or fabrication of data, such that the research is not accurately represented in the research record."

The above-mentioned manuscript was not reviewed by the committee and therefore did not appear in their report. Nevertheless, all of the authors of the Letter with the exception of J. H. Schön have agreed to a complete retraction of the paper.

[1] http://dx.doi.org/10.1103/APS.Reports.Lucent

All coauthors agreed (except by Hendrik Schon)

The Star-Ledger

Ex-Lucent scientist is stripped of his degree

Betrayed brain trust by fabricating data

Saturday, June 12, 2004

By KEVIN COUGHLIN
Star-Ledger Staff

Two years ago, he left Bell Labs in disgrace amid a fraud scandal that shocked the scientific world.

Now, Jan Hendrik Schön has been stripped of his doctoral degree and asked to return his diploma to his German alma mater.

The University of Konstanz revoked Schön's 1998 physics degree after reviewing his role in "the biggest data fabrication scandal in physics in the last 50 years," professor Wolfgang Dieterich said yesterday. Schön has a month to appeal.

Once the Boy Wonder of physics, touted for the Nobel Prize, Schön, 34, has left a very different legacy.

BOOKS & ARTS

Keeping up scientific standards

A journalistic account of the case of data manipulation by physicist Jan Hendrik Schön is rich in detail but draws the wrong conclusions about the self-correcting processes of science, argues **Martin Blume**.

Plastic Fantastic: How the Biggest Fraud in Physics Shook the Scientific World
by Eugenie Samuel Reich
Palgrave Macmillan: 2009.
272 pp. £15.99, $26.95

Jan Hendrik Schön first came to New Jersey's Bell Laboratories from his doctoral work at the University of Konstanz, Germany, as an intern in 1997. A year later he became a postdoc and staff member. Over the next few years he published apparently groundbreaking research in materials science. His results appeared in major research journals, and his co-authors and supervisors included highly respected researchers. Scientists worldwide tried to replicate his findings — but were unable to do so. Mounting complaints about

The Dark Secret of Hendrik Schon
BBC Documentary
The Science Channel

Links/references/acknowledgements

https://en.wikipedia.org/wiki/Fourier_optics#/media/File:4F_Correlator.svg

http://tomatosphere.org/teachers/guide/images/scientific-method.jpg