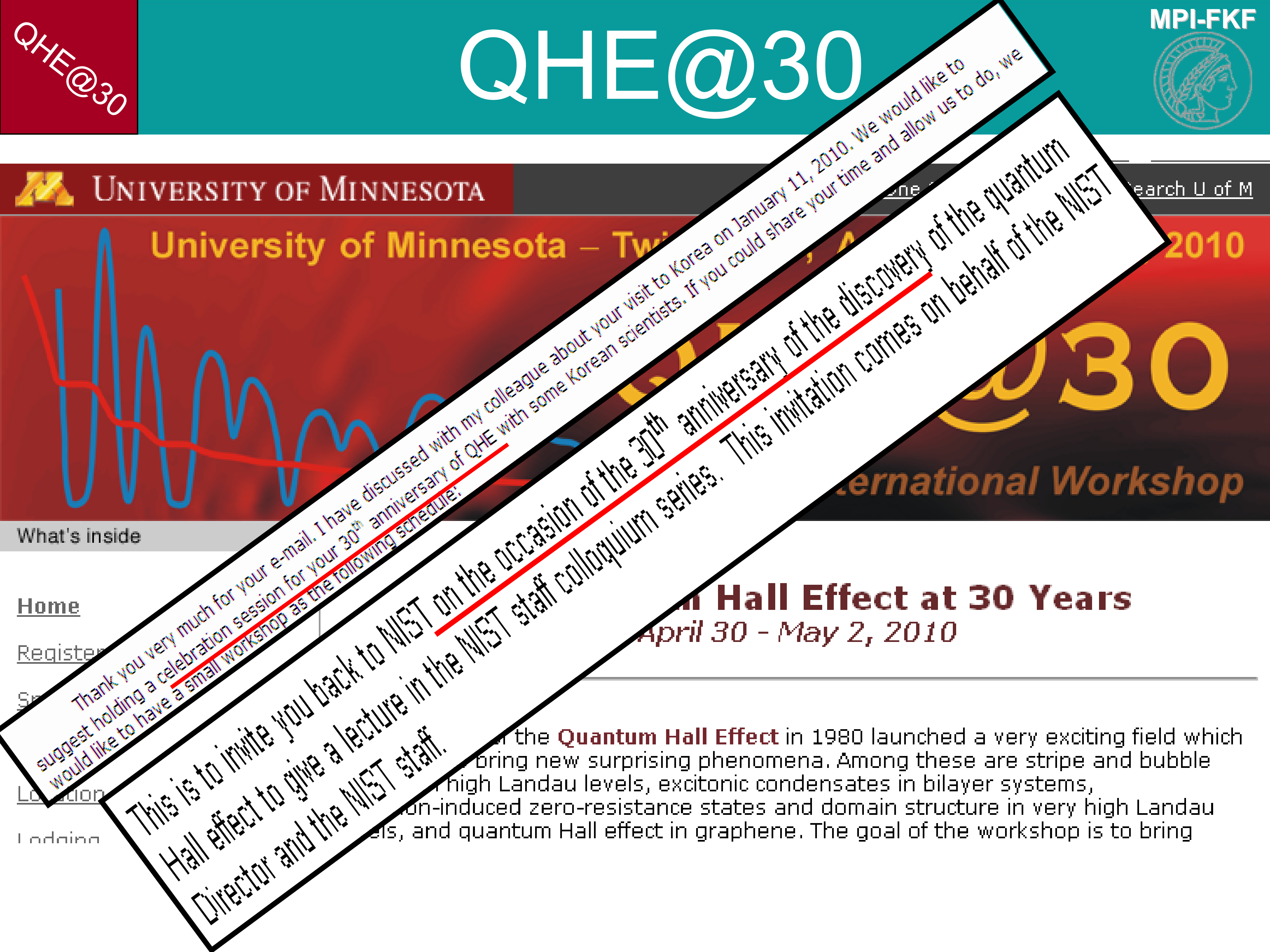
QHE@30



UNIVERSITY OF MINNESOTA

earch U of M

University of Minnesota – Twi

2010

@30

ernational Workshop

What's inside

Home

Registe

Lo ation

Lodging

Hall Effect at 30 Years

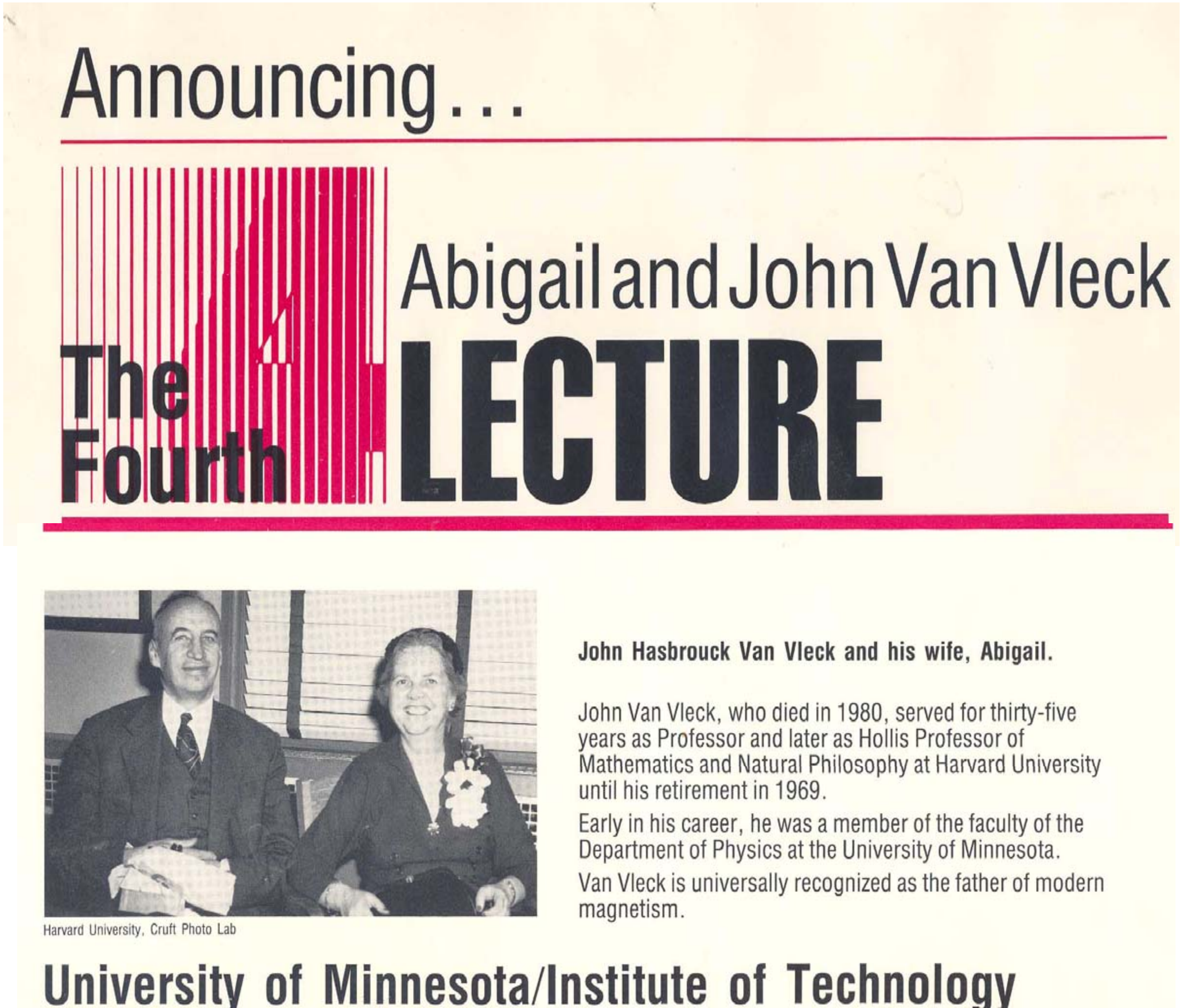
April 30 - May 2, 2010

the **Quantum Hall Effect** in 1980 launched a very exciting field which bring new surprising phenomena. Among these are stripe and bubble high Landau levels, excitonic condensates in bilayer systems, on-induced zero-resistance states and domain structure in very high Landau els, and quantum Hall effect in graphene. The goal of the workshop is to bring

Thank you very much for your e-mail. I have discussed with my colleague about your visit to Korea on January 11, 2010. We would like to suggest holding a celebration session for your 30th anniversary of QHE with some Korean scientists. If you could share your time and allow us to do, we would like to have a small workshop as the following schedule:

This is to invite you back to NIST on the occasion of the 30th anniversary of the discovery of the quantum Hall effect to give a lecture in the NIST staff colloquium series. This invitation comes on behalf of the NIST Director and the NIST staff.

24 years ago….



Announcing…

The Fourth

Abigail and John Van Vleck

LECTURE

Harvard University, Cruft Photo Lab

John Hasbrouck Van Vleck and his wife, Abigail.

John Van Vleck, who died in 1980, served for thirty-five years as Professor and later as Hollis Professor of Mathematics and Natural Philosophy at Harvard University until his retirement in 1969.

Early in his career, he was a member of the faculty of the Department of Physics at the University of Minnesota.

Van Vleck is universally recognized as the father of modern magnetism.

University of Minnesota/Institute of Technology

QHE@30

24 years ago….

MPI-FKF

Presenting . . .

Professor Klaus von Klitzing

Max-Planck-Institute for
Solid State Research, Stuttgart

October 15, 1986 4 p.m.

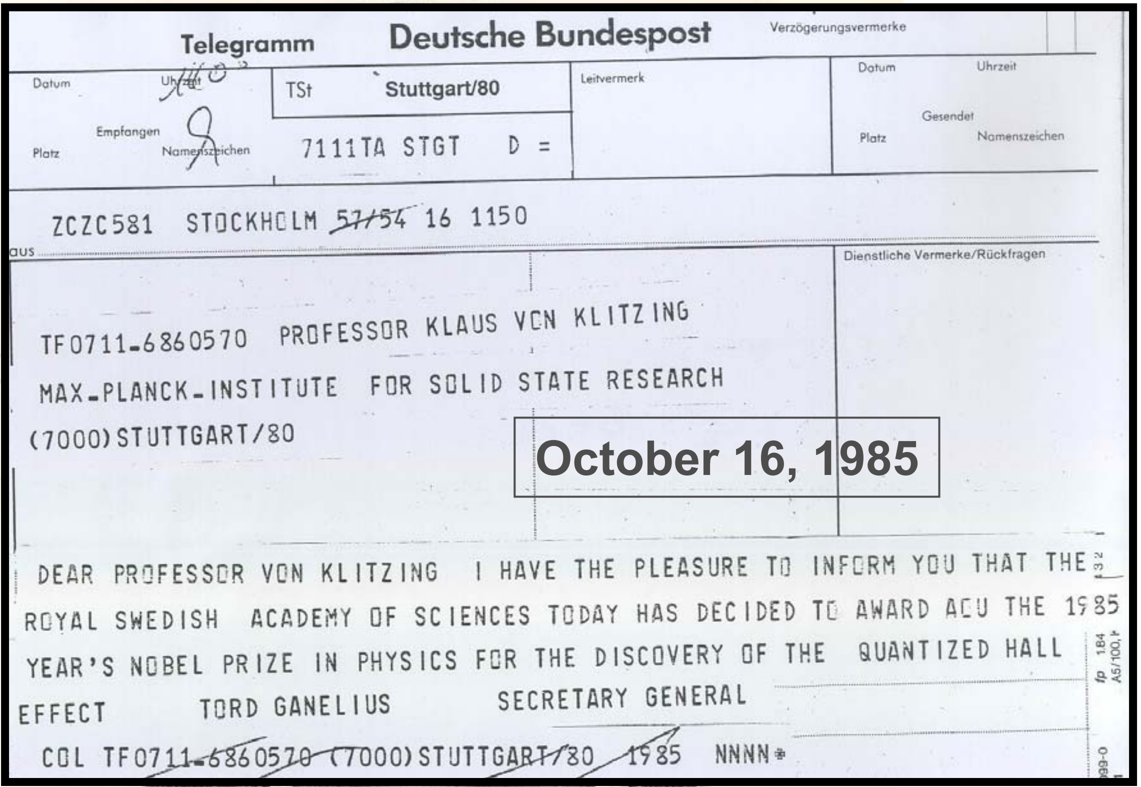
"Applications of the Quantum Hall Effect"

Coffman Theatre/Lecture Hall
Reception following the lecture
in the Campus Club

October 16, 1986 4 p.m.

"Basic Research on Microelectronic Devices"

Room 131, Tate Laboratory of Physics



Telegramm Deutsche Bundespost

Verzögerungsvermerke

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TSt Stuttgart/80

7111TA STGT D =

Leitvermerk

Datum Uhrzeit Gesendet Platz Namenszeichen

ZCZC581 STOCKHOLM ~~57/54~~ 16 1150

aus

Dienstliche Vermerke/Rückfragen

TF0711-6860570 PROFESSOR KLAUS VON KLITZING
MAX-PLANCK-INSTITUTE FOR SOLID STATE RESEARCH
(7000)STUTTGART/80

DEAR PROFESSOR VON KLITZING I HAVE THE PLEASURE TO INFORM YOU THAT THE ROYAL SWEDISH ACADEMY OF SCIENCES TODAY HAS DECIDED TO AWARD ACU THE 1985 YEAR'S NOBEL PRIZE IN PHYSICS FOR THE DISCOVERY OF THE QUANTIZED HALL EFFECT TORD GANELIUS SECRETARY GENERAL

COL TF0711-6860570 (7000)STUTTGART/80 1985 NNNN

October 16, 1985

Exactly one year after the announcement of the Nobel Prize for the QHE

2010: 25th anniversary of Nobel Prize for quantum Hall effect

QHE@30 + NP@25

ty of Minnesota –

One Stop | Directories | Search U of M

April 30 – May 02, 2010

E@30

nternational Workshop

ffect at 30 Years
y 2, 2010

980 launched a very exciting field which
. Among these are stripe and bubble
nsates in bilayer systems,
domain structure in very high Landau
he goal of the workshop is to bring

Si MOSFET

Si MOSFET

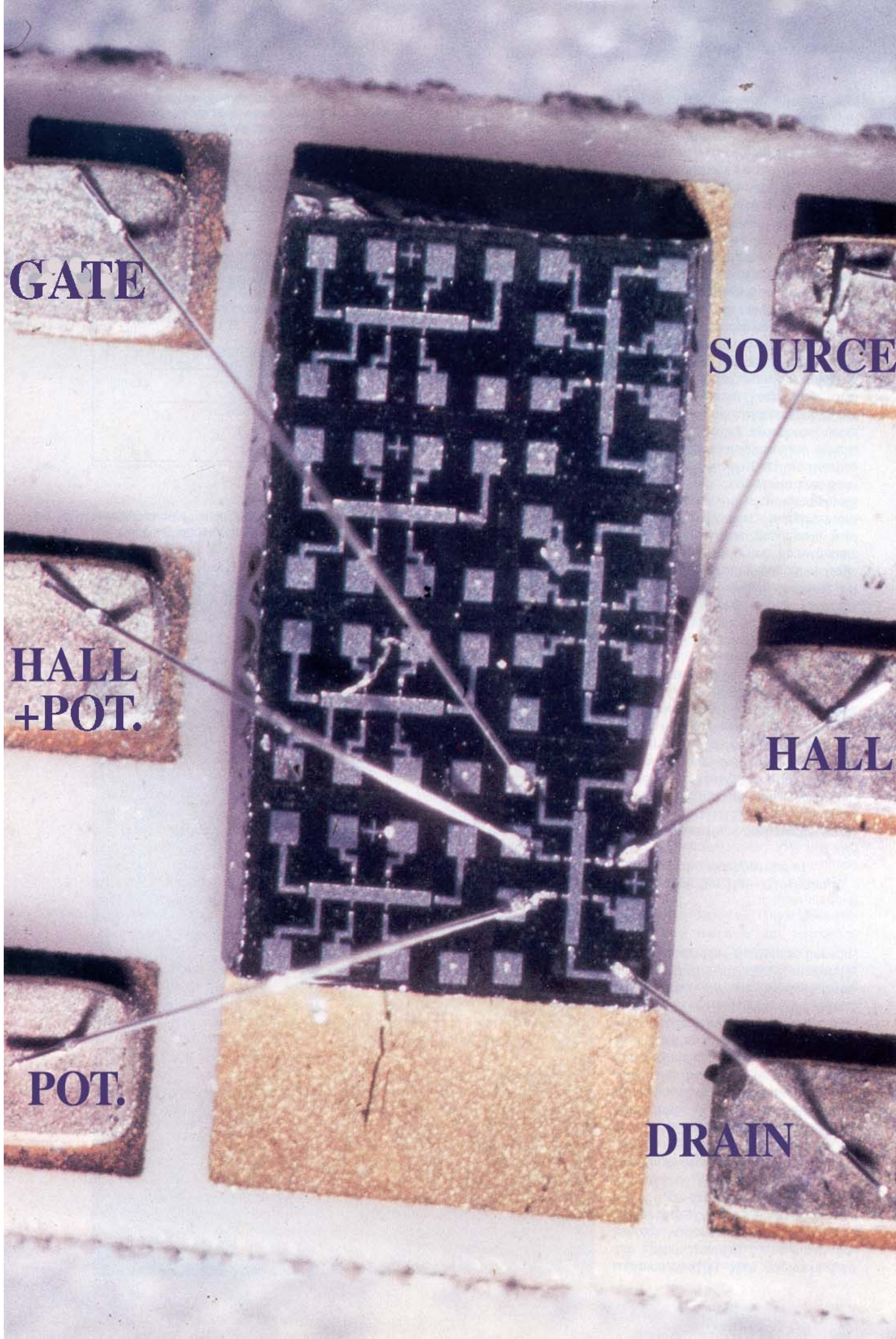
basic research on

such a device led

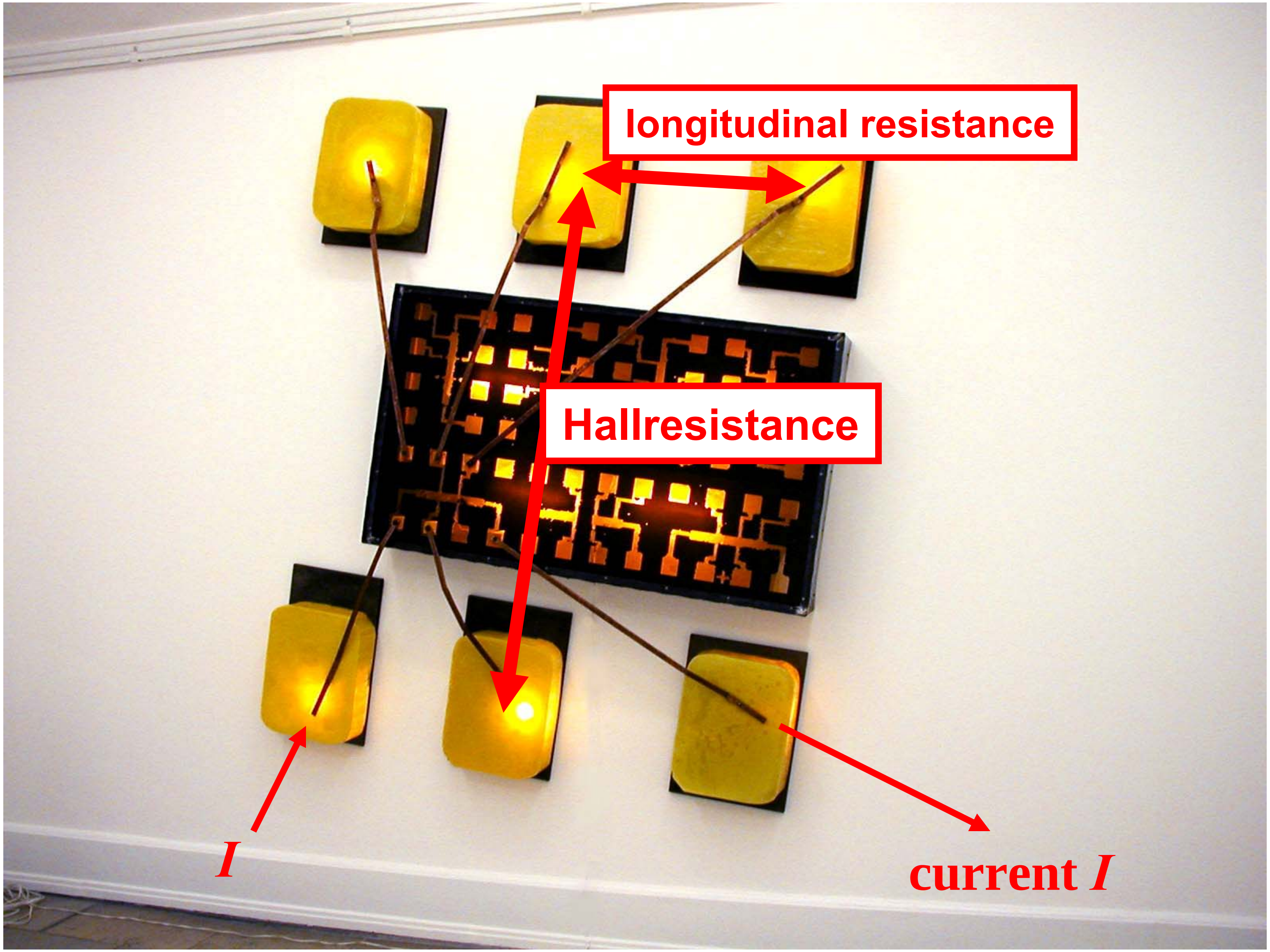
to the discovery

of the

Quantum Hall Effect

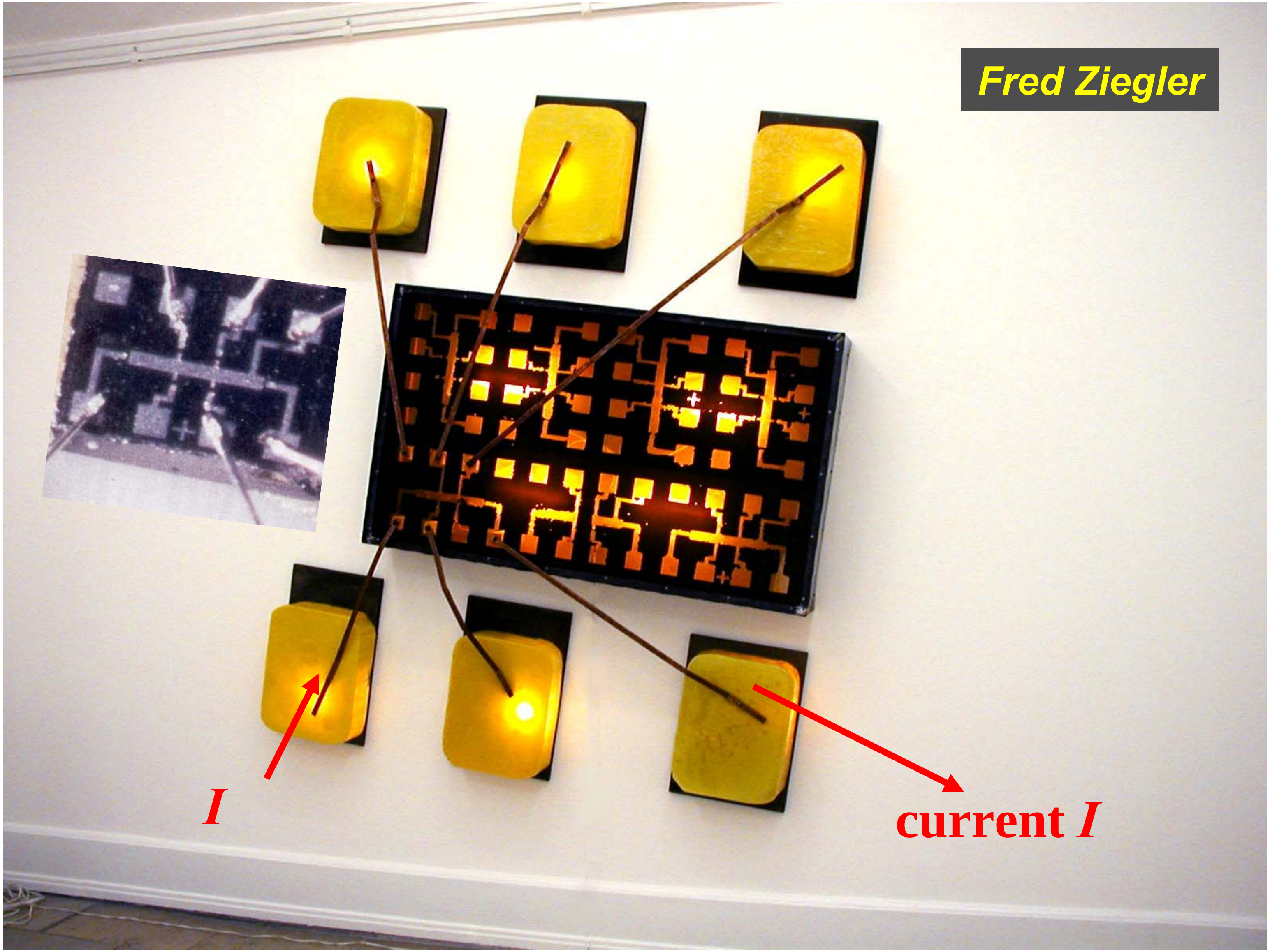


An artists impression of the original QHE device



Exhibitions in Germany and Switzerland

An Artists Impression of the Original QHE Device

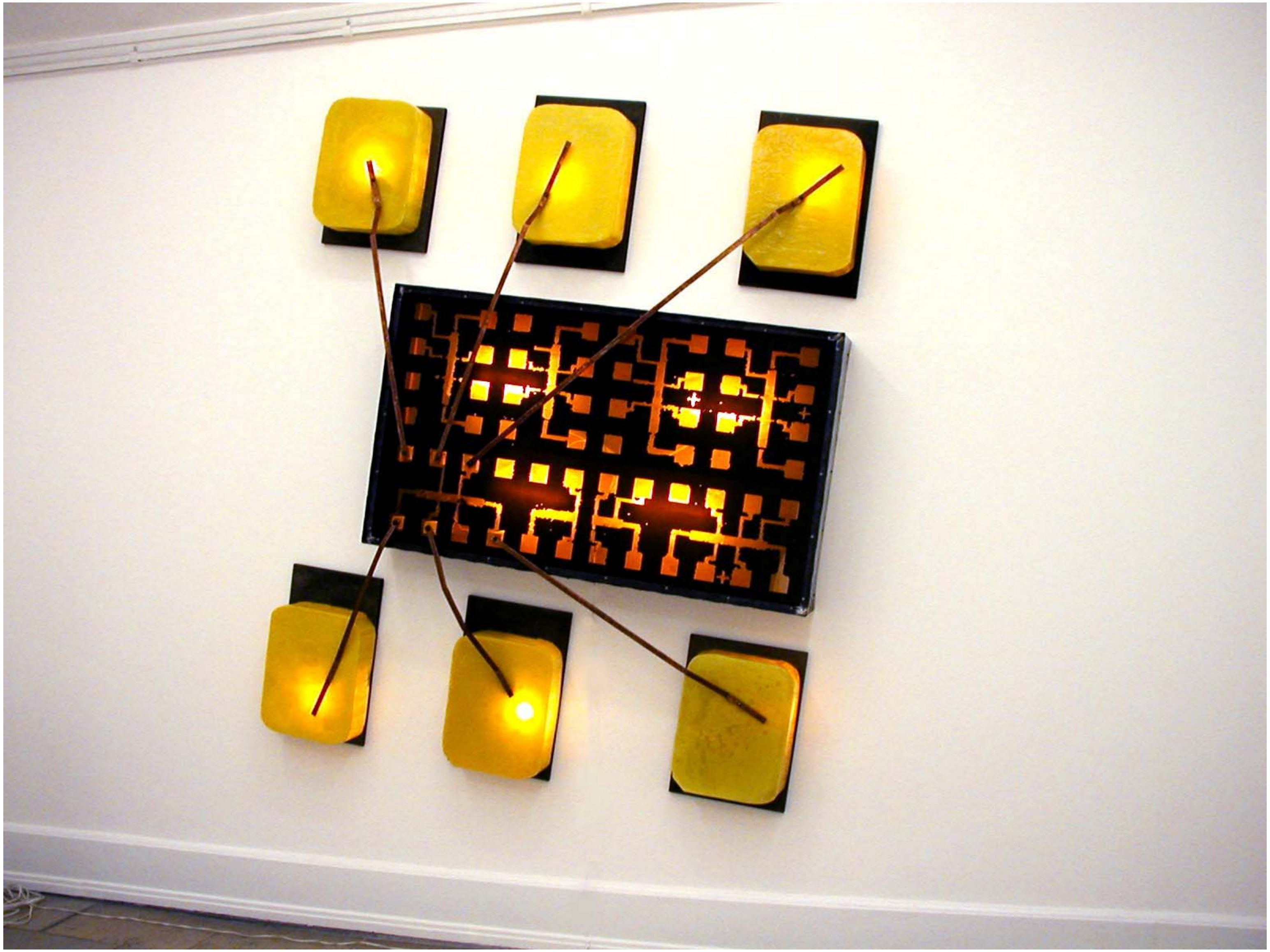


Exhibitions in Germany and Switzerland

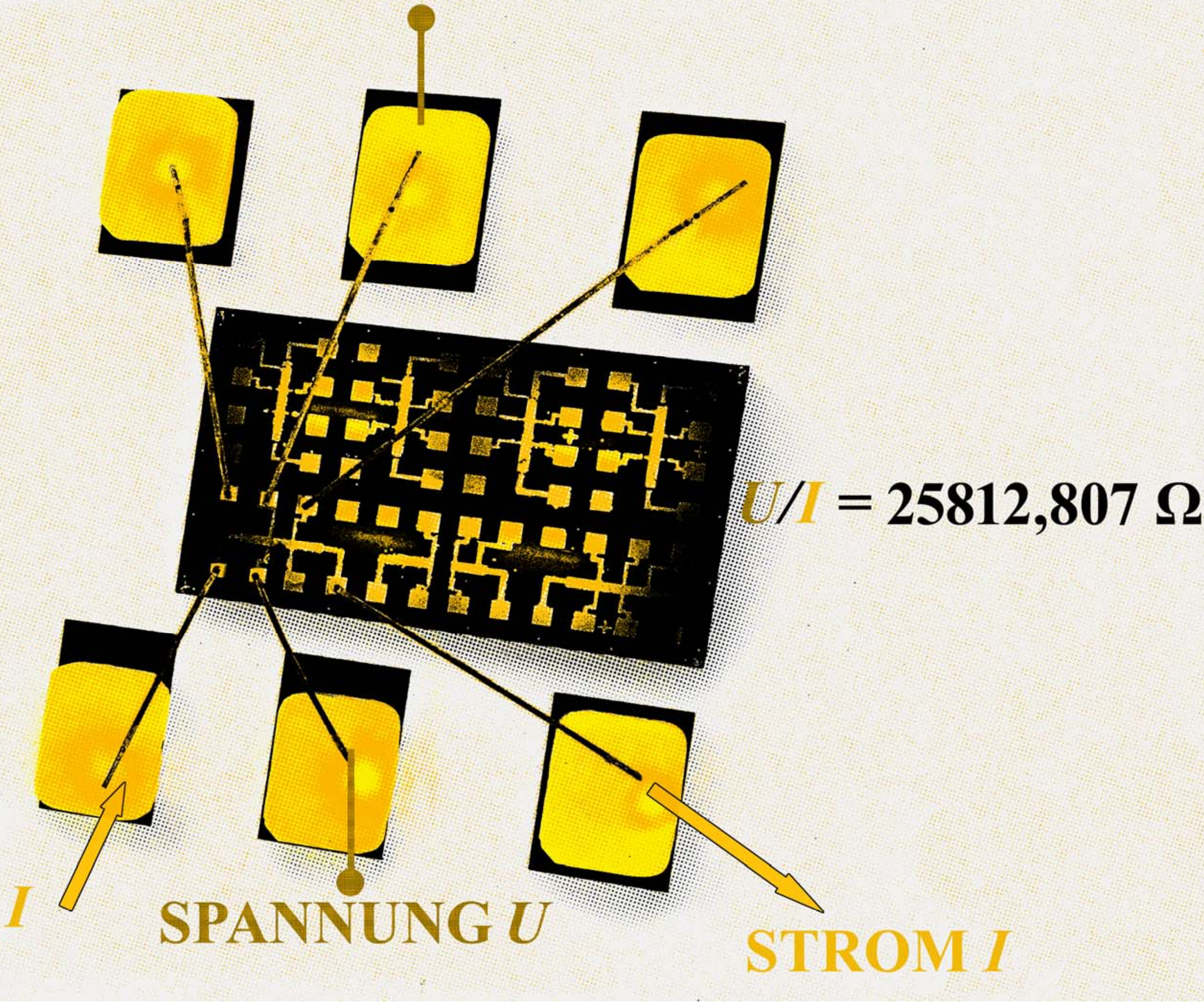
QHE@30

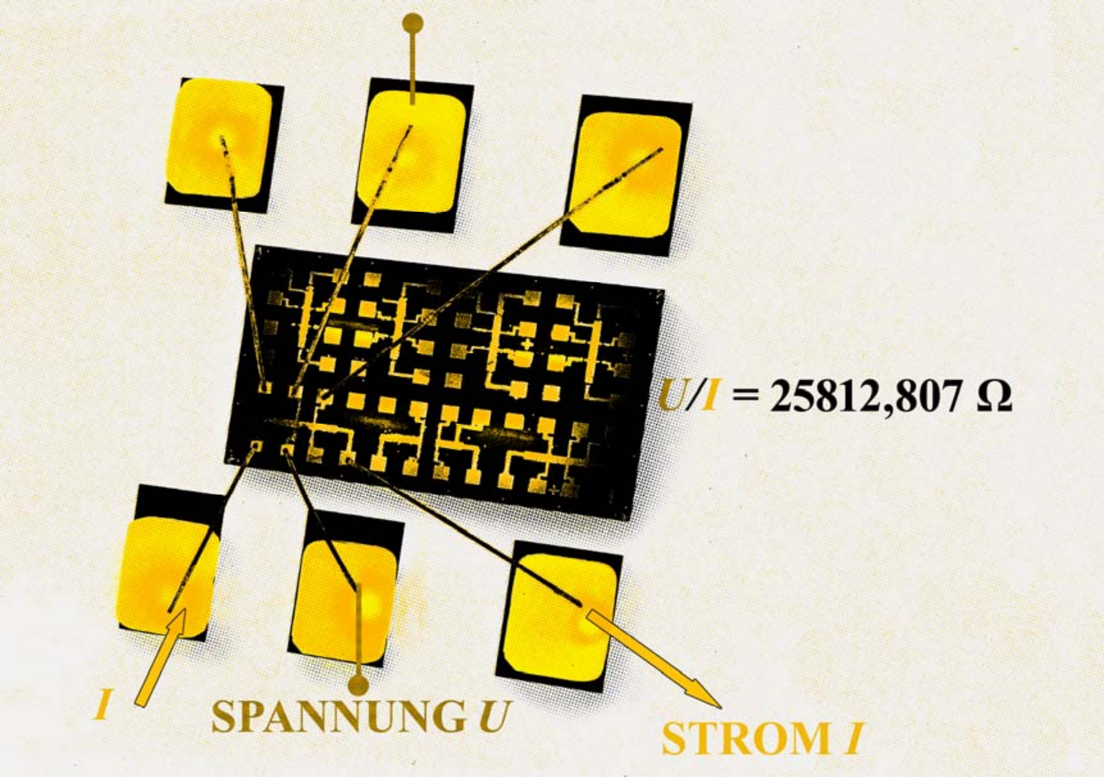
Quantum Hall Effect in the Museum

MPI-FKF



Exhibitions in Germany and Switzerland

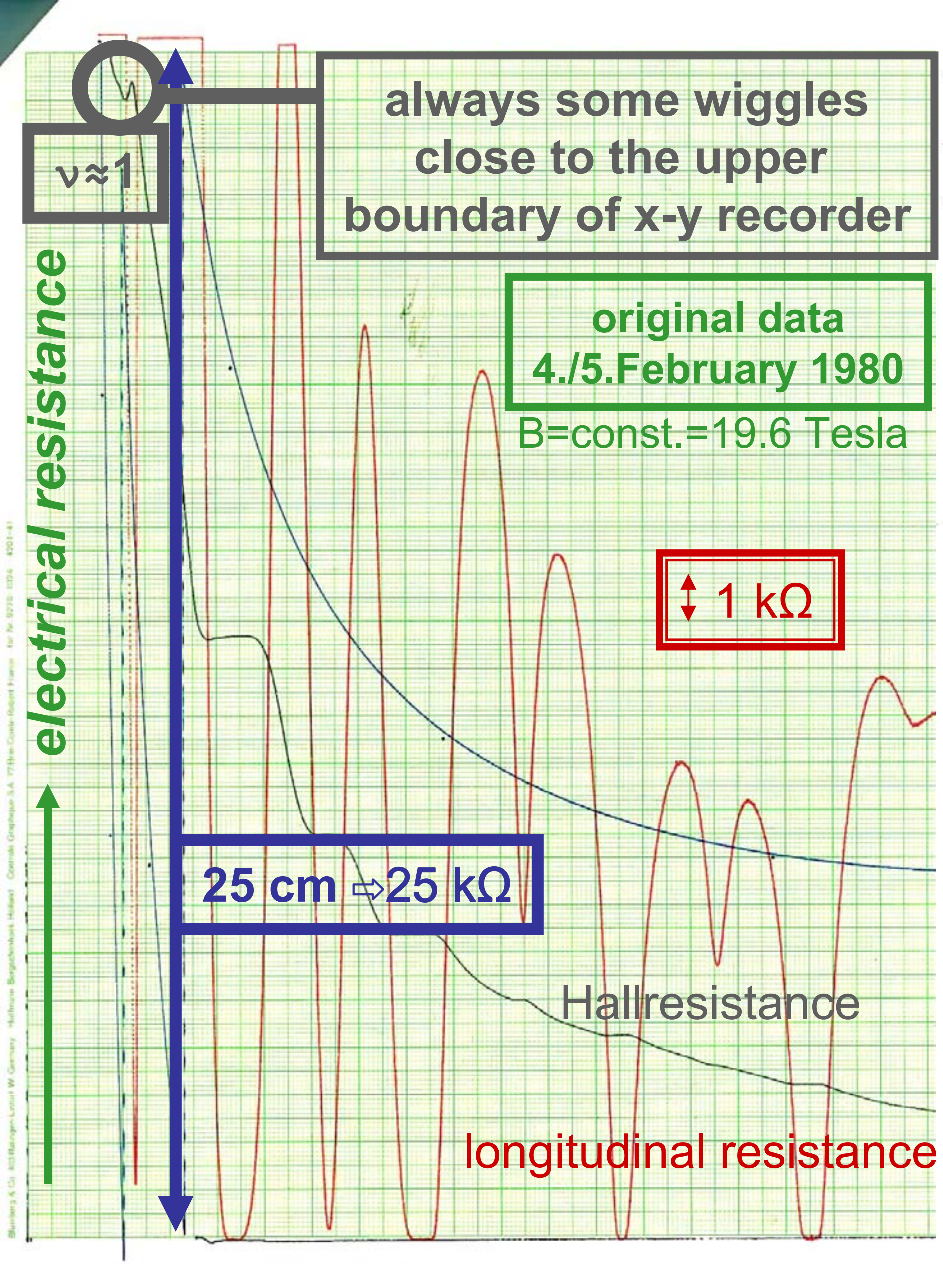

U/I = 25812,807 Ω
I
SPANNUNG U
STROM I



Another type of
LITHOGRAPGY

limited edition of 40 pieces ,
signed by K.v.K. and Fred Ziegler

Notes 4./5.2.1980



always some wiggles close to the upper boundary of x-y recorder

ν≈1

original data 4./5.February 1980

B=const.=19.6 Tesla

↕ 1 kΩ

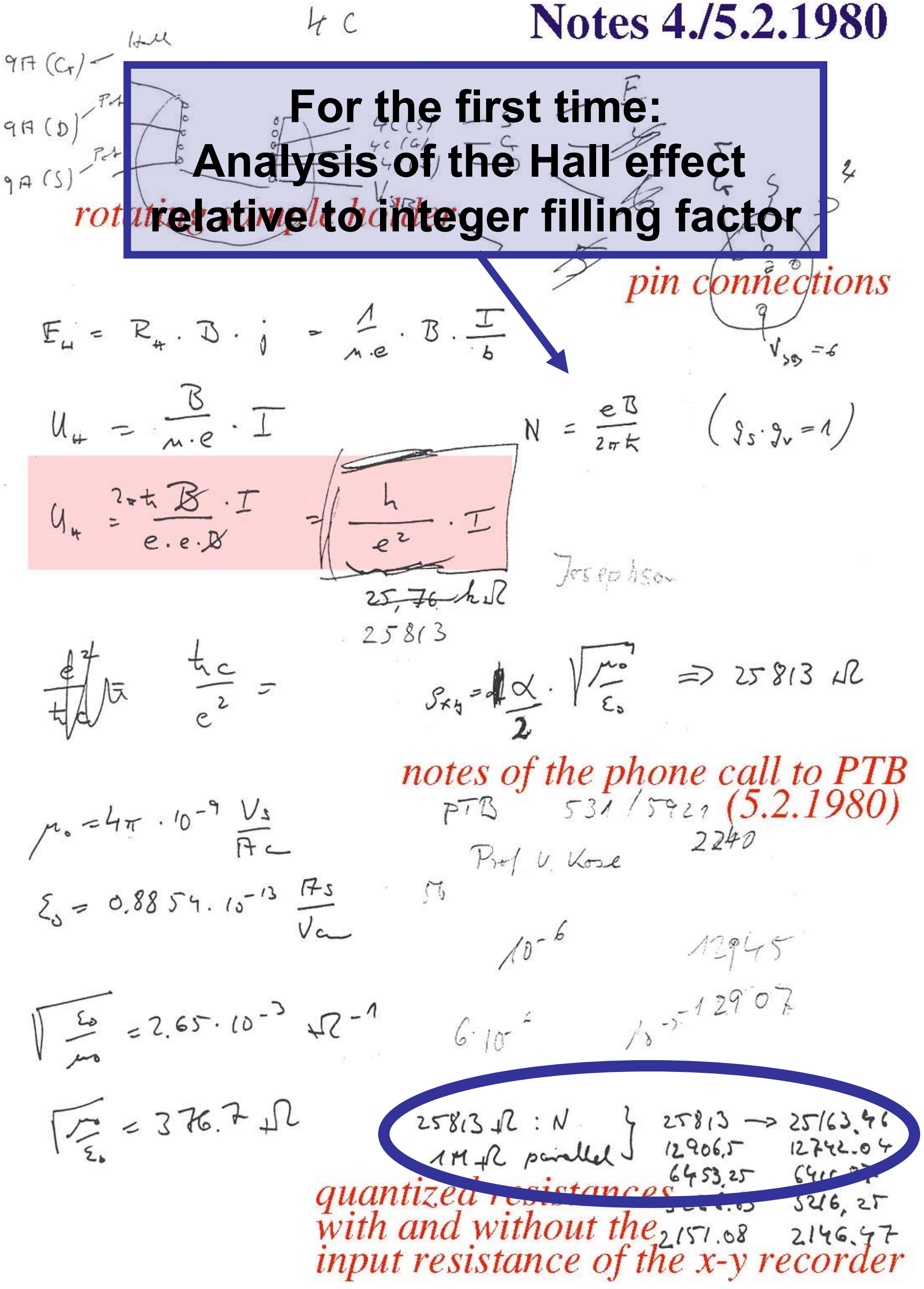
25 cm ⇨25 kΩ

Hallresistance

longitudinal resistance

electrical resistance

gate voltage



For the first time: Analysis of the Hall effect relative to integer filling factor

4 C

9A (G) ← Hall

9A (D) Pot

9A (S) Pot

4C (S)

4C (G)

rotating sample holder

pin connections

$V_{SD} = 6$

$E_H = R_H \cdot B \cdot j = \frac{1}{n \cdot e} \cdot B \cdot \frac{I}{b}$

$U_H = \frac{B}{n \cdot e} \cdot I$ $\qquad N = \frac{eB}{2\pi\hbar}$ $\quad (g_s \cdot g_v = 1)$

$U_H = \frac{2\pi\hbar \cancel{B}}{e \cdot e \cdot \cancel{B}} \cdot I = \frac{h}{e^2} \cdot I$

~~25,76 kΩ~~

25813

Josephson

$\frac{\hbar c}{e^2} =$ $\qquad \rho_{xy} = \frac{\alpha}{2} \cdot \sqrt{\frac{\mu_0}{\varepsilon_0}} \Rightarrow 25813\ \Omega$

notes of the phone call to PTB (5.2.1980)

PTB 531/5921

2240

Prof. v. Kose

$\mu_0 = 4\pi \cdot 10^{-9} \frac{Vs}{Acm}$

$\varepsilon_0 = 0.8854 \cdot 10^{-13} \frac{As}{Vcm}$

10^{-6}

12945

$\sqrt{\frac{\varepsilon_0}{\mu_0}} = 2.65 \cdot 10^{-3}\ \Omega^{-1}$

$6 \cdot 10^{-}$

$1 \cdot 10^{-5}$ 12907

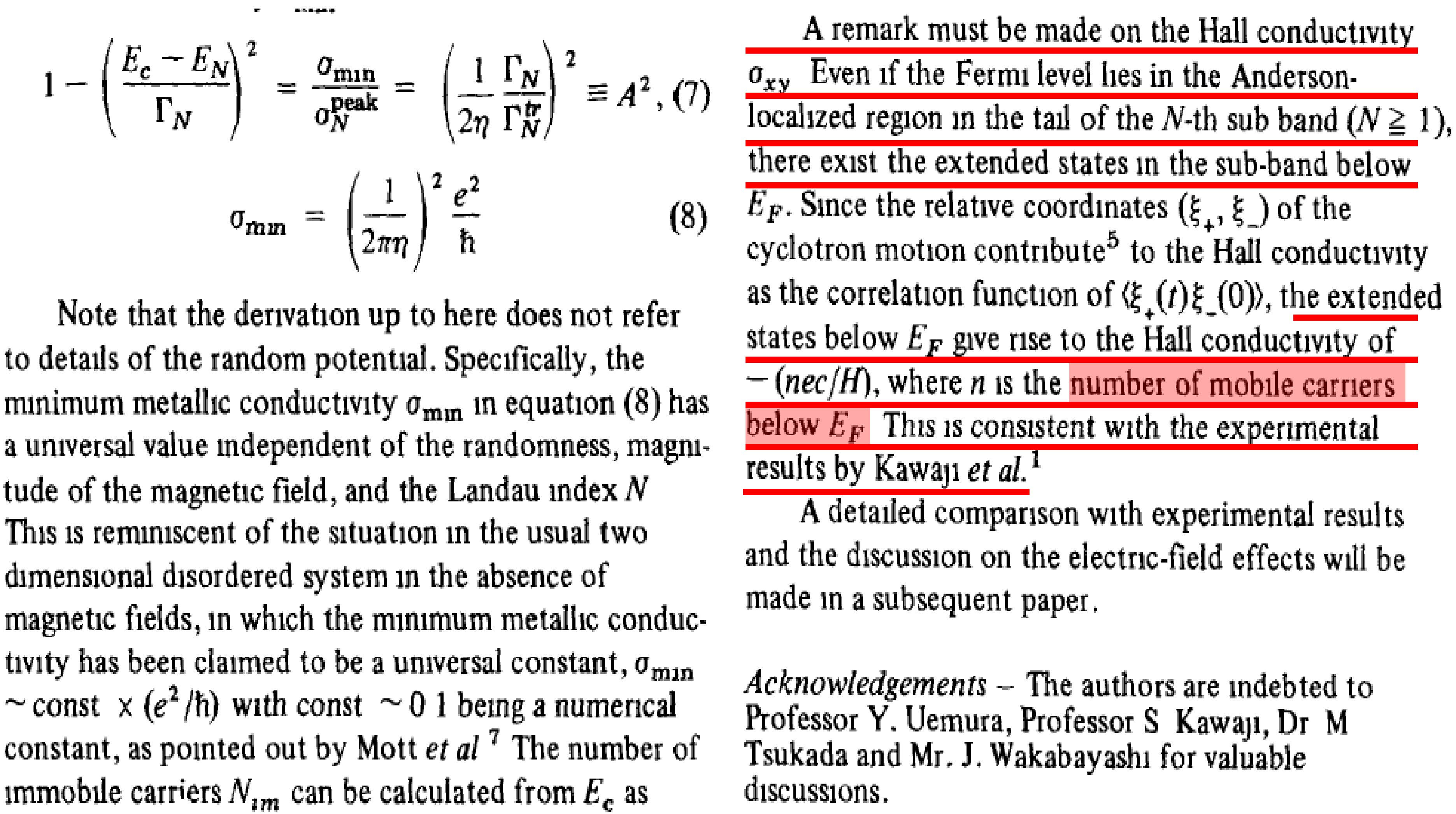
$\sqrt{\frac{\mu_0}{\varepsilon_0}} = 376.7\ \Omega$

25813 Ω : N
1MΩ parallel }

25813 →	25163.46
12906.5	12742.04
6453.25	64[illegible]
[illegible]	5216,25
2151.08	2146.47

quantized resistances with and without the input resistance of the x-y recorder

Misleading theoretical paper



$$1-\left(\frac{E_c-E_N}{\Gamma_N}\right)^2=\frac{\sigma_{\min}}{\sigma_N^{\mathrm{peak}}}=\left(\frac{1}{2\eta}\frac{\Gamma_N}{\Gamma_N^{tr}}\right)^2\equiv A^2, \quad (7)$$

$$\sigma_{\min}=\left(\frac{1}{2\pi\eta}\right)^2\frac{e^2}{\hbar} \quad (8)$$

Note that the derivation up to here does not refer to details of the random potential. Specifically, the minimum metallic conductivity $\sigma_{\min}$ in equation (8) has a universal value independent of the randomness, magnitude of the magnetic field, and the Landau index N This is reminiscent of the situation in the usual two dimensional disordered system in the absence of magnetic fields, in which the minimum metallic conductivity has been claimed to be a universal constant, $\sigma_{\min} \sim \mathrm{const} \times (e^2/\hbar)$ with const $\sim 0\ 1$ being a numerical constant, as pointed out by Mott *et al* [7] The number of immobile carriers N_{im} can be calculated from E_c as

A remark must be made on the Hall conductivity σ_{xy} Even if the Fermi level lies in the Anderson-localized region in the tail of the N-th sub band ($N \geqq 1$), there exist the extended states in the sub-band below E_F. Since the relative coordinates (ξ_+, ξ_-) of the cyclotron motion contribute[5] to the Hall conductivity as the correlation function of $\langle\xi_+(t)\xi_-(0)\rangle$, the extended states below E_F give rise to the Hall conductivity of $-(nec/H)$, where n is the number of mobile carriers below E_F This is consistent with the experimental results by Kawaji *et al.*[1]

A detailed comparison with experimental results and the discussion on the electric-field effects will be made in a subsequent paper.

Acknowledgements – The authors are indebted to Professor Y. Uemura, Professor S Kawaji, Dr M Tsukada and Mr. J. Wakabayashi for valuable discussions.

QHE reseach before 1980

Theory of Hall Effect

J. PHYS. SOC. JAPAN 39 (1975) 279-288

Theory of Hall Effect in a Two-Dimensional Electron System

Tsuneya ANDO,* Yukio MATSUMOTO and Yasutada UEMURA

Department of Physics, University of Tokyo, Bunkyo-ku, Tokyo 113

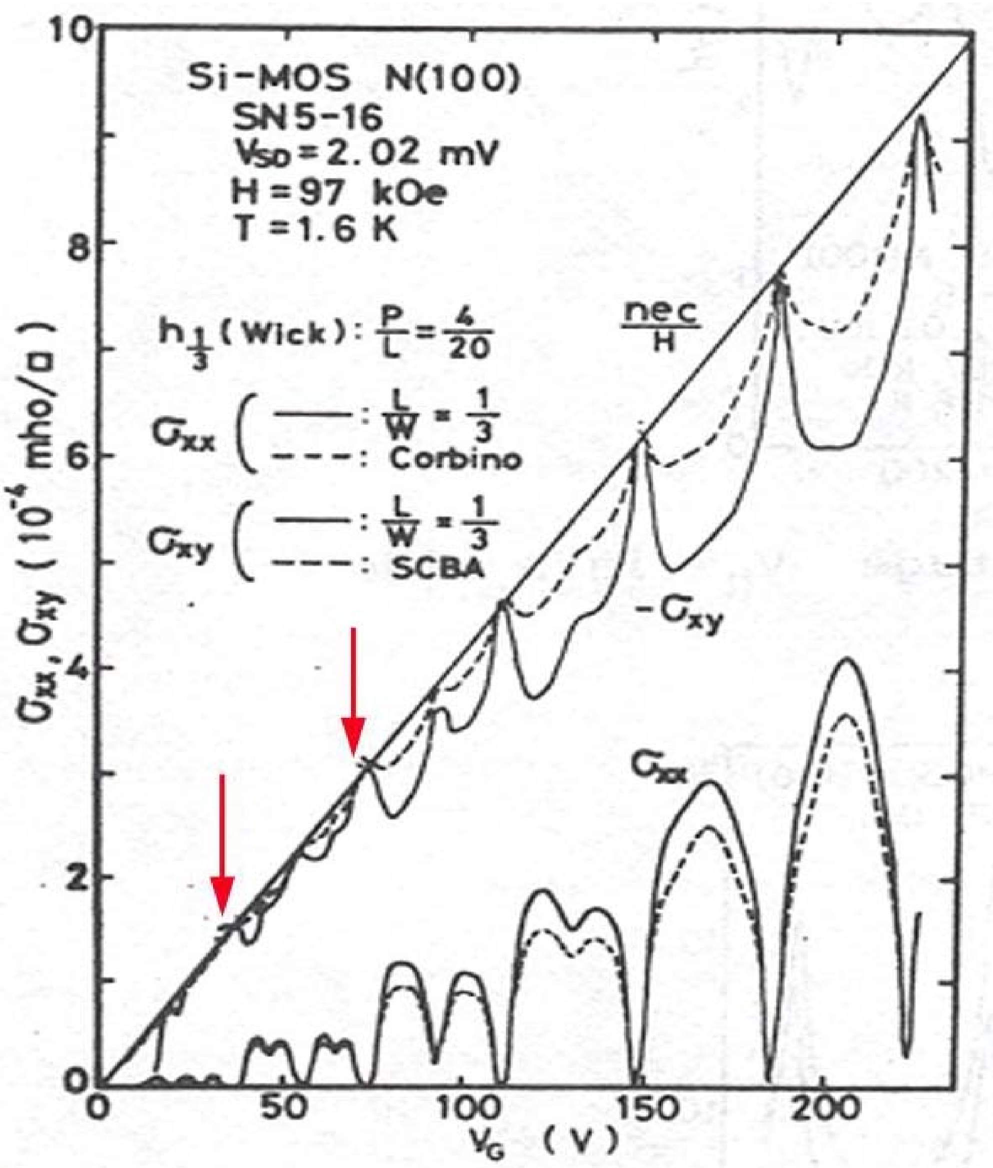
(Received February 14, 1975)

classical Hall effect

$$
\begin{aligned}
\sigma_{XY} &= -\frac{nec}{H} + \Delta\sigma_{XY}^{(1)}, \\
&= -\frac{e^2}{\pi^2\hbar}\int\left(-\frac{\partial f}{\partial E}\right)\mathrm{d}E\left\{\frac{\pi}{2}\left[N+1-\frac{1}{\pi}\,\mathrm{Im}\ln X_N\right]\right. \\
&\quad -2\pi l^2\sum_{\mu}\int \mathrm{d}Z\, N_i^{(\mu)}(Z)\sum_{m}\left|\left(Nm\left|\,l\frac{\partial v^{(\mu)}(Z)}{\partial x}\right|Nm+1\right)\right|^2 \\
&\quad \times[v_{Nm}^{(\mu)}(Z)-v_{Nm+1}^{(\mu)}(Z)]^{-1}\left[v_{Nm}^{(\mu)}(Z)\,\mathrm{Im}\frac{1}{X_N-v_{Nm}^{(\mu)}(Z)}\,\mathrm{Re}\frac{1}{X_N-v_{Nm+1}^{(\mu)}(Z)}\right. \\
&\quad \left.\left.+v_{Nm+1}^{(\mu)}(Z)\,\mathrm{Re}\frac{1}{X_N-v_{Nm}^{(\mu)}(Z)}\,\mathrm{Im}\frac{1}{X_N-v_{Nm+1}^{(\mu)}(Z)}\right]\right\}. \qquad (4.4)
\end{aligned}
$$

EP2DS Conference Berchtesgaden (September 19-22, 1977)

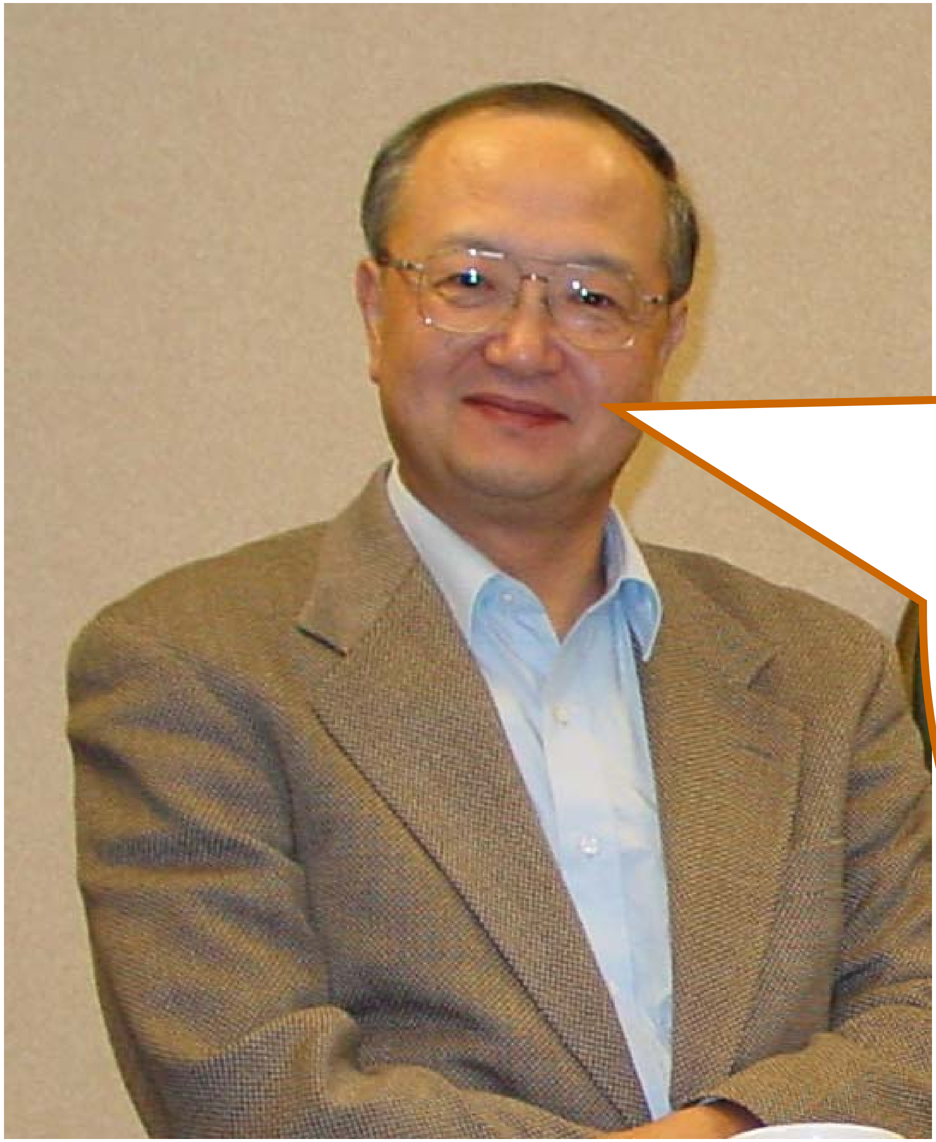
(Experiments by S.Kawaji)



Hallconductivity σ_{xy} always smaller than classical value?!
Scattering?
Localization?

Fig.11 σ_{xx} and σ_{xy} in a wide sample. Broken line in σ_{xx} is measured in a Corbino disk. Broken line in σ_{xy} is calculated by the SCBA theory.

Tsuneya ANDO, Univ. of Tokyo

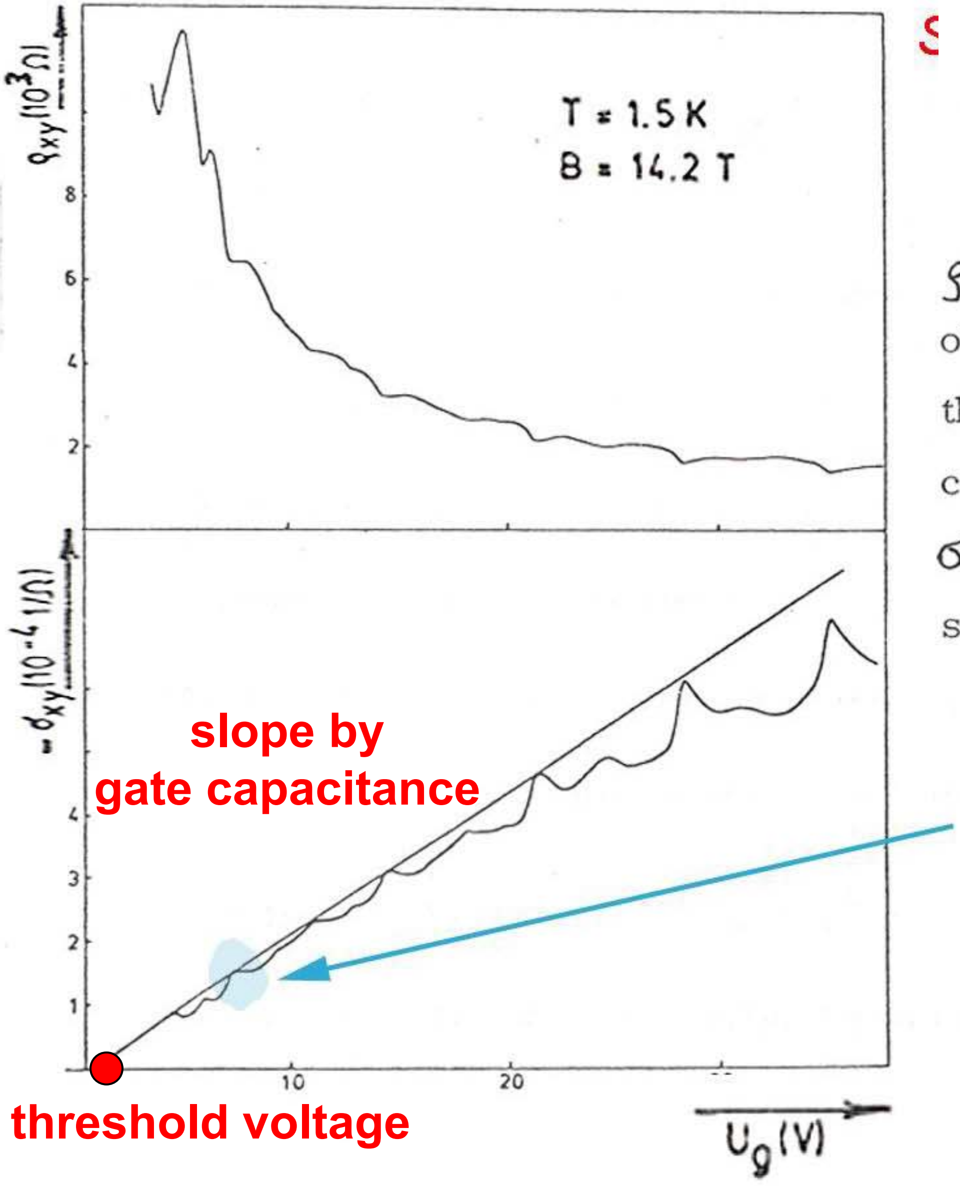


T. Ando:

You should not
believe in theory.
at all, if it is not
confirmed by
experiments.

T. Ando,
Osaka, 5.11.87

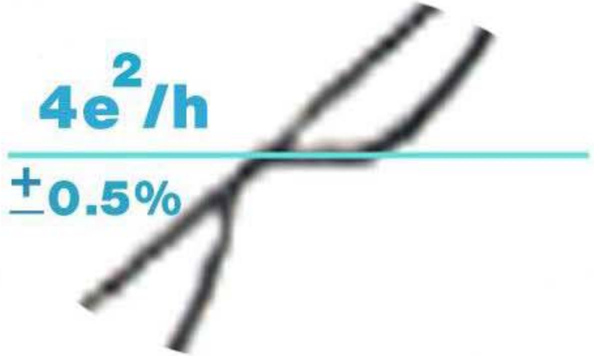
EP2DS-2, Berchtesgaden (Sept.19-22, 1977)
Th. Englert and K.v.K., Surface Science 73, 70 (1978)



slope by gate capacitance

threshold voltage

ρ_{xy} as a function of the gate voltage obtained from the Hall voltage. In the lower part the calculated σ_{xy}-curve is plotted. The relation $\sigma_{xy} = -\frac{ne}{B}$ is indicated by the straight line.

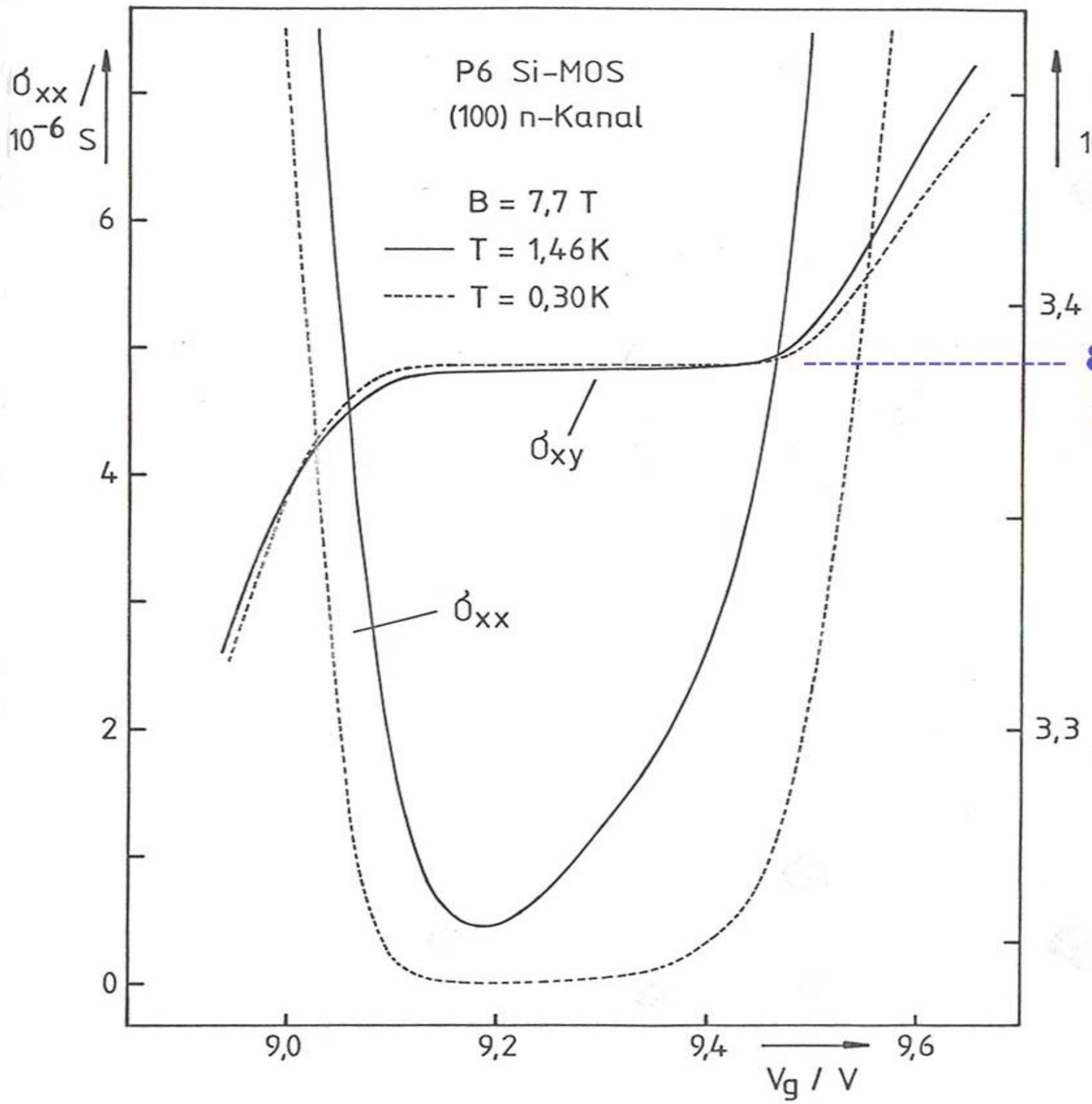


QHE@30

Diploma Thesis GÜNTHER EBERT

(Würzburg, August 1979)

MPI-FKF

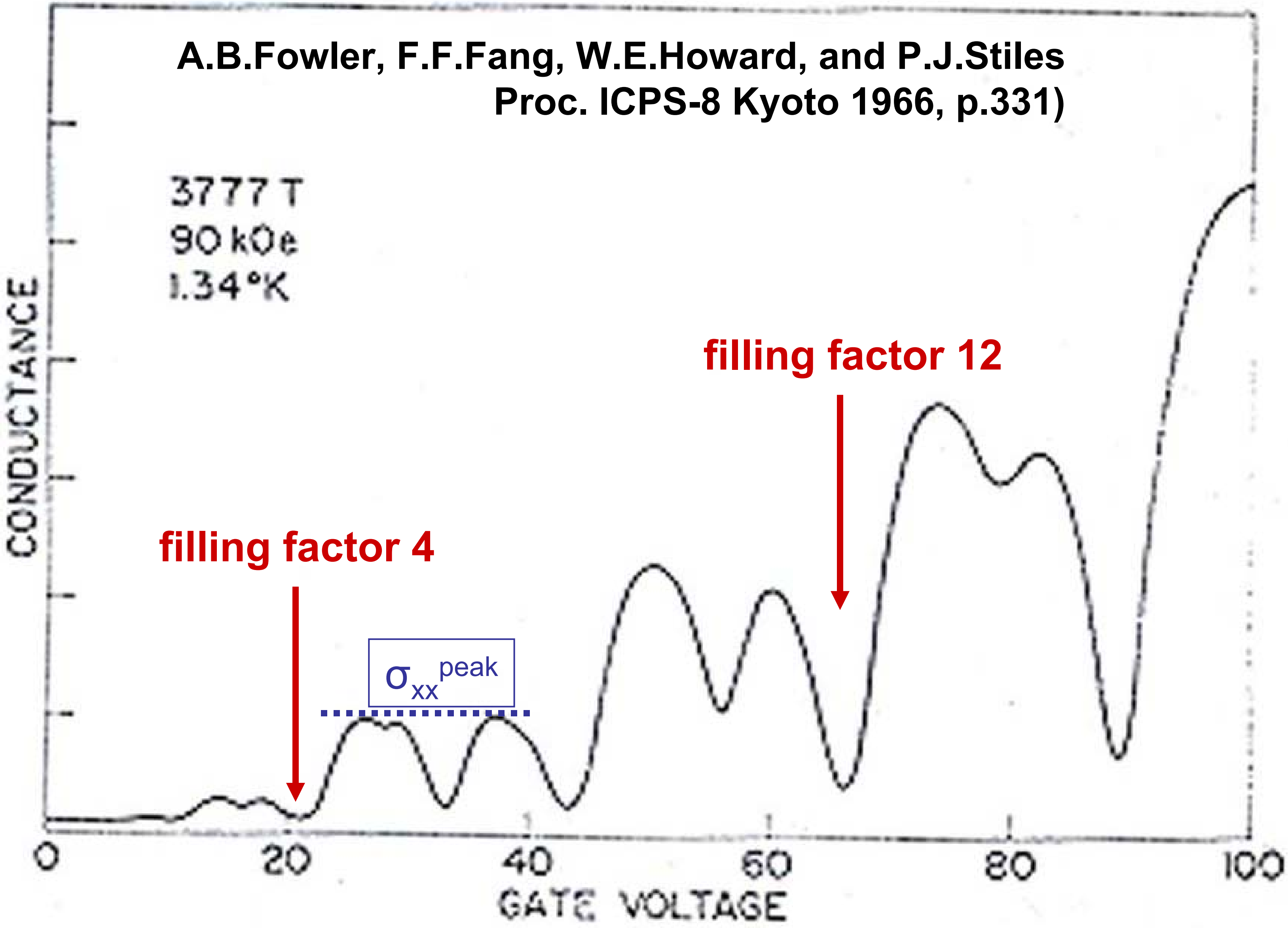


8.74 e^2/h

instead of

8.00 e^2/h

First Magnetotransport Experiments on Si-Fieldeffect Transistors (Corbino Device)



A.B.Fowler, F.F.Fang, W.E.Howard, and P.J.Stiles
Proc. ICPS-8 Kyoto 1966, p.331)

filling factor 4

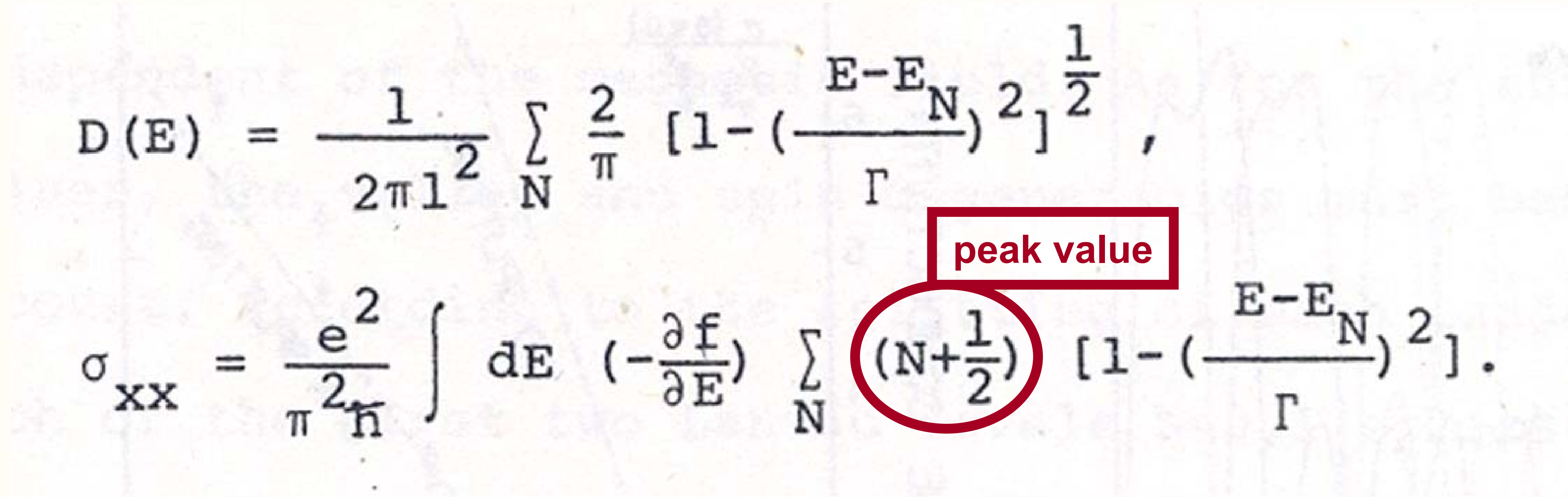
filling factor 12

Self Consistent Born Approximation

Theory:

T. Ando, Y. Matsumoto, Y. Uemura

(Proc. ICPS-11 Warszawa 1972, p.294)



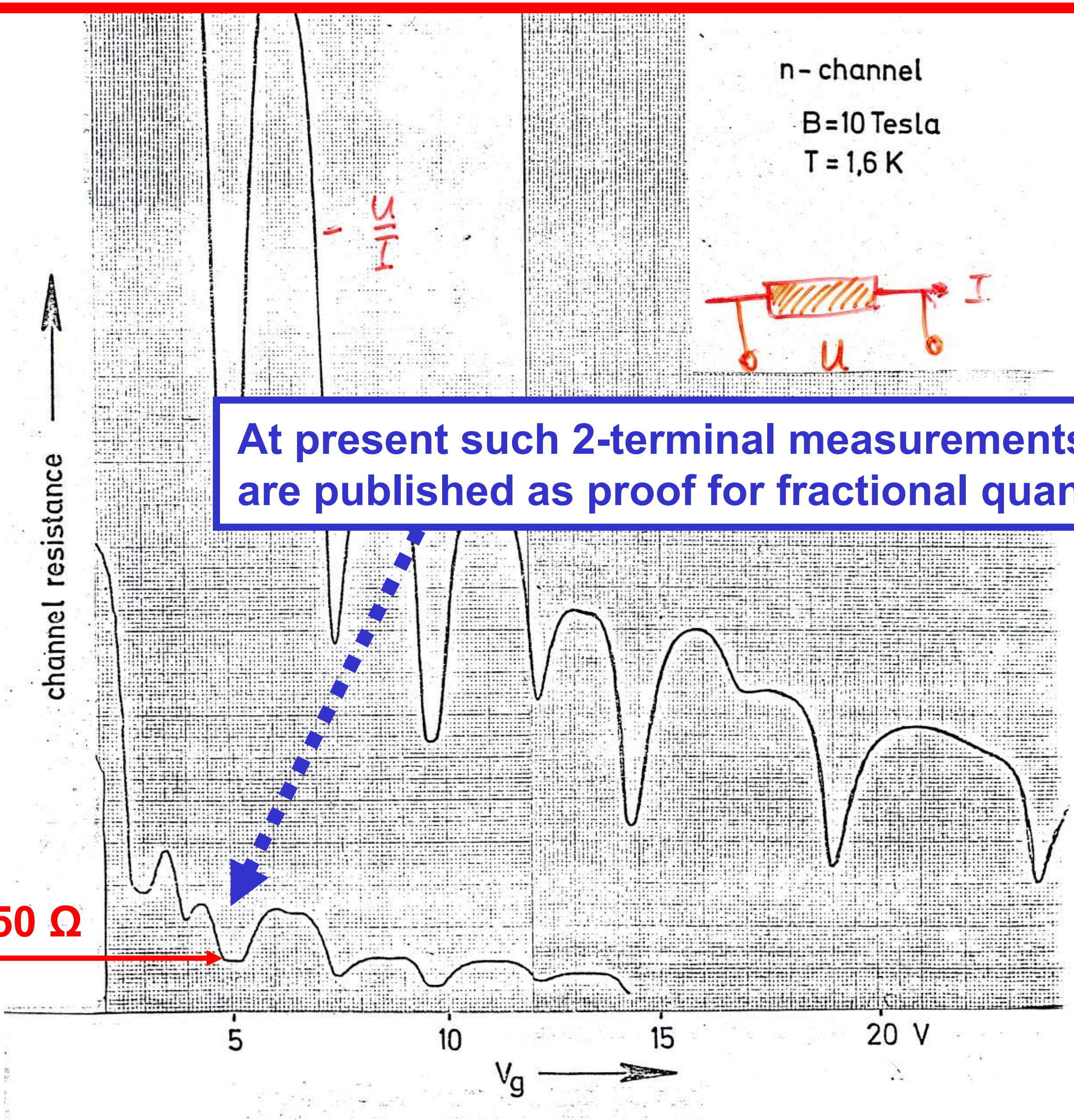
$$D(E) = \frac{1}{2\pi l^2} \sum_N \frac{2}{\pi} \left[1-\left(\frac{E-E_N}{\Gamma}\right)^2\right]^{\frac{1}{2}} ,$$

$$\sigma_{xx} = \frac{e^2}{\pi^2 \hbar} \int dE \left(-\frac{\partial f}{\partial E}\right) \sum_N \overset{\text{peak value}}{\boxed{\left(N+\frac{1}{2}\right)}} \left[1-\left(\frac{E-E_N}{\Gamma}\right)^2\right] .$$

$$\boxed{\sigma_{xx} \sim D(E)^2}$$

28.11.1973

The very first experiment which showed quantized Hall resistance

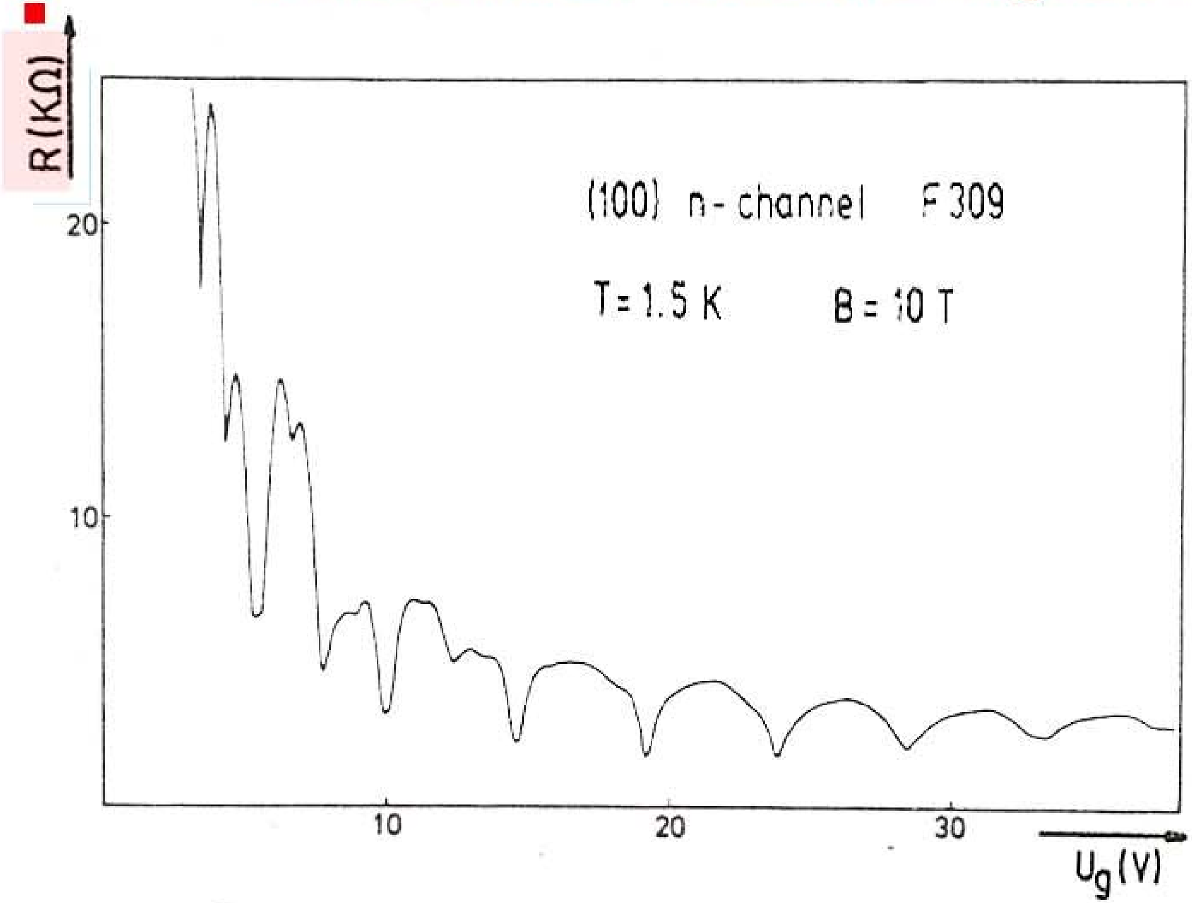


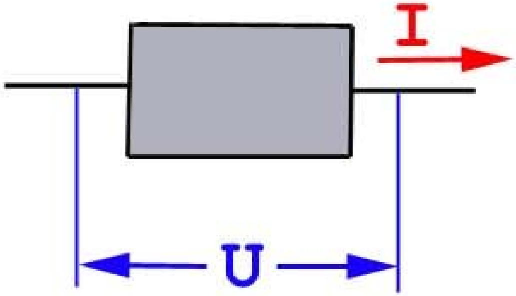
At present such 2-terminal measurements on graphene are published as proof for fractional quantum Hall effect

$h/4e^2 \approx 6450\ \Omega$

?

Dissertation Thomas Englert 27.10.77



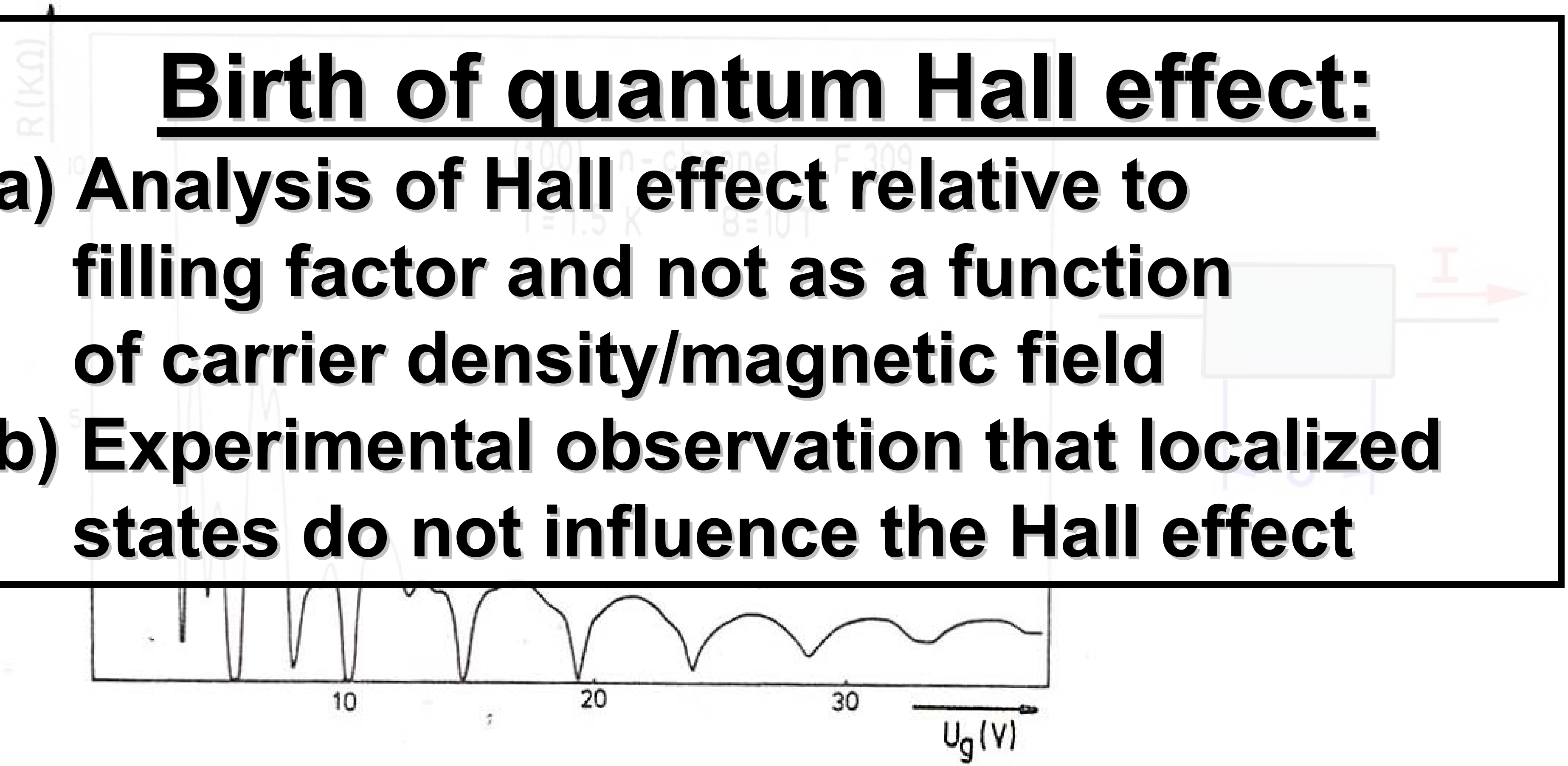


POTENTIAL MEASUREMENTS INCLUDING CURRENT CONTACTS

Birth of quantum Hall effect:

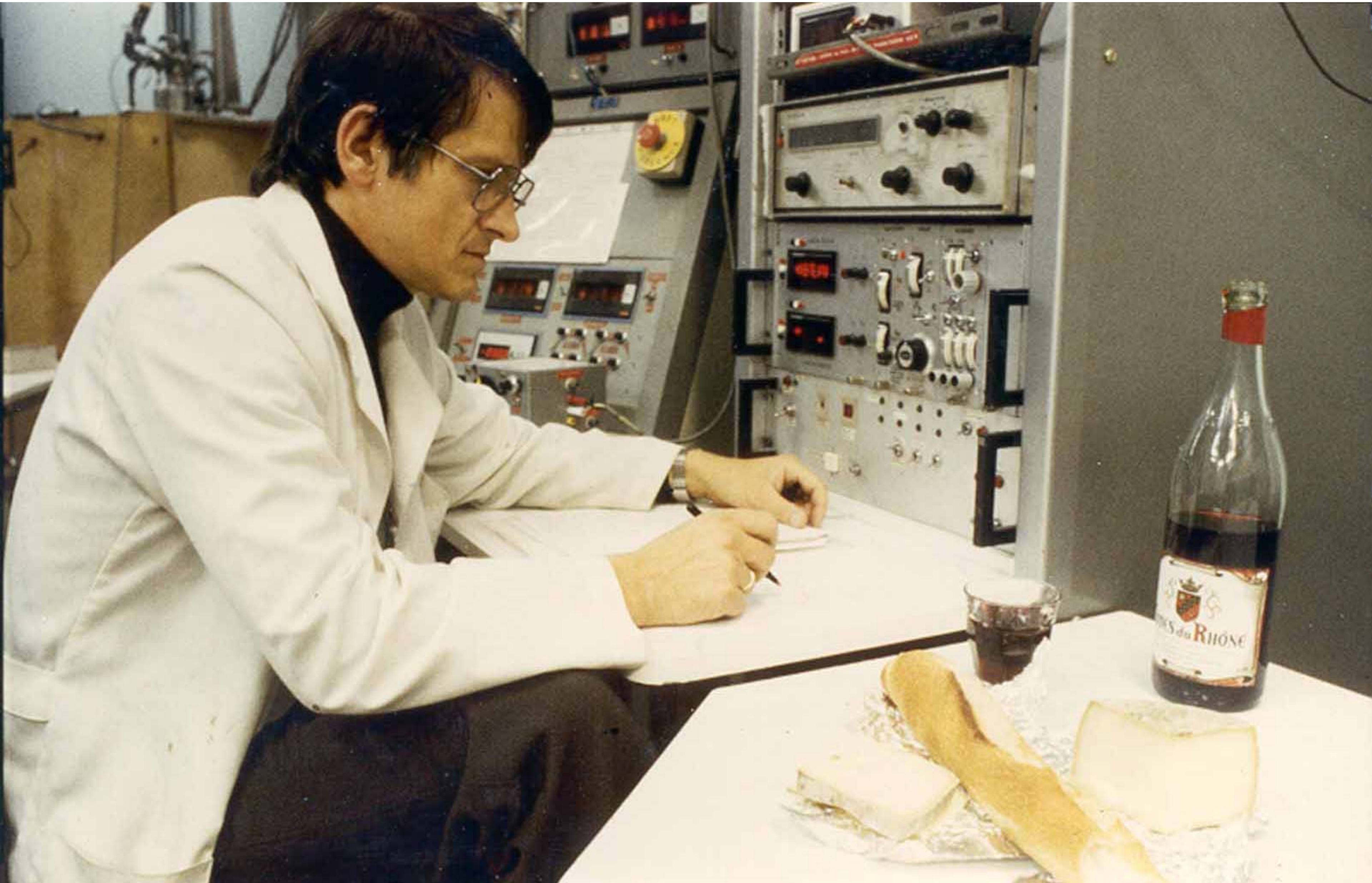
a) Analysis of Hall effect relative to filling factor and not as a function of carrier density/magnetic field

b) Experimental observation that localized states do not influence the Hall effect

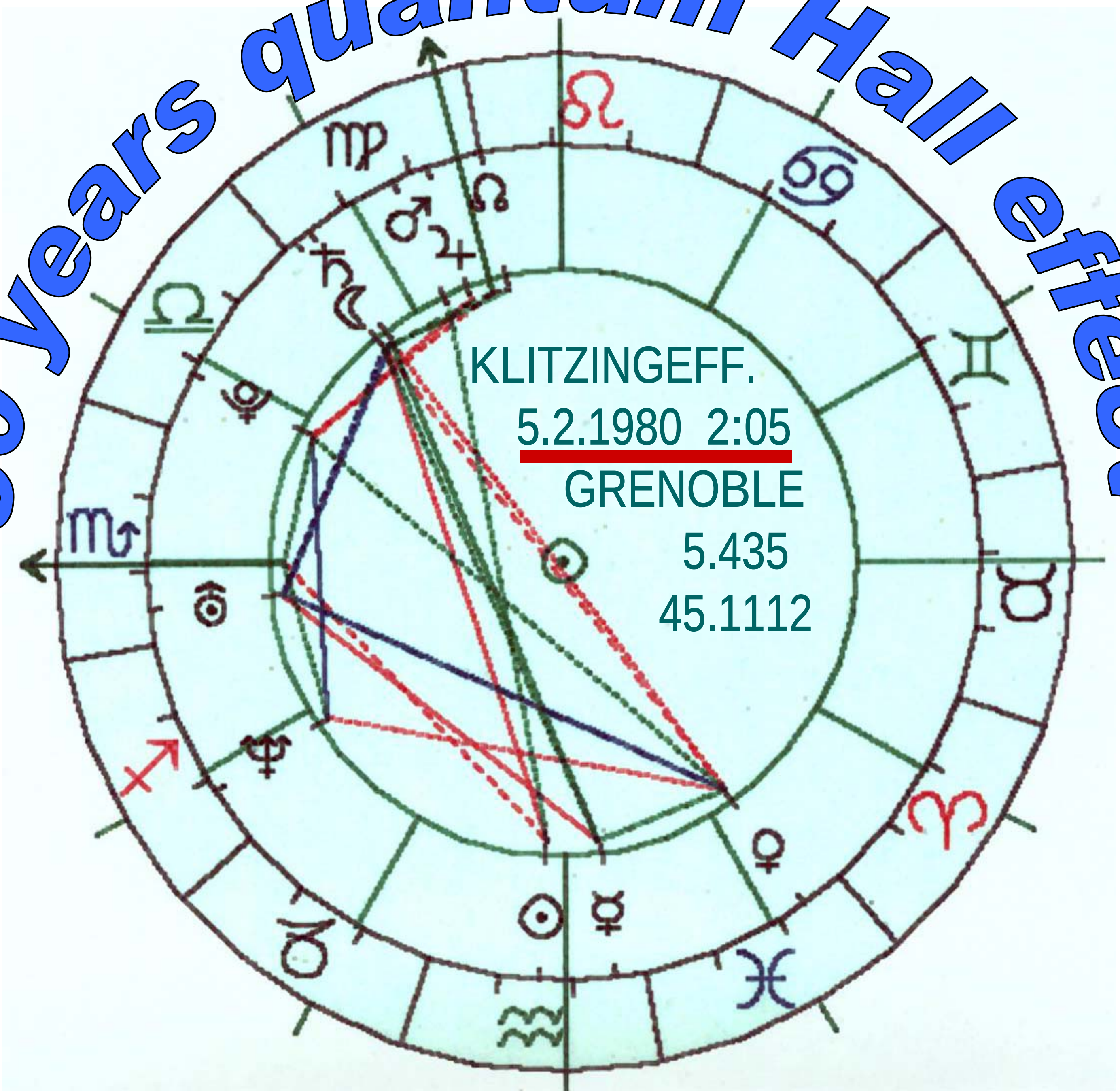


POTENTIAL MEASUREMENTS
WITH POTENTIAL PROBES

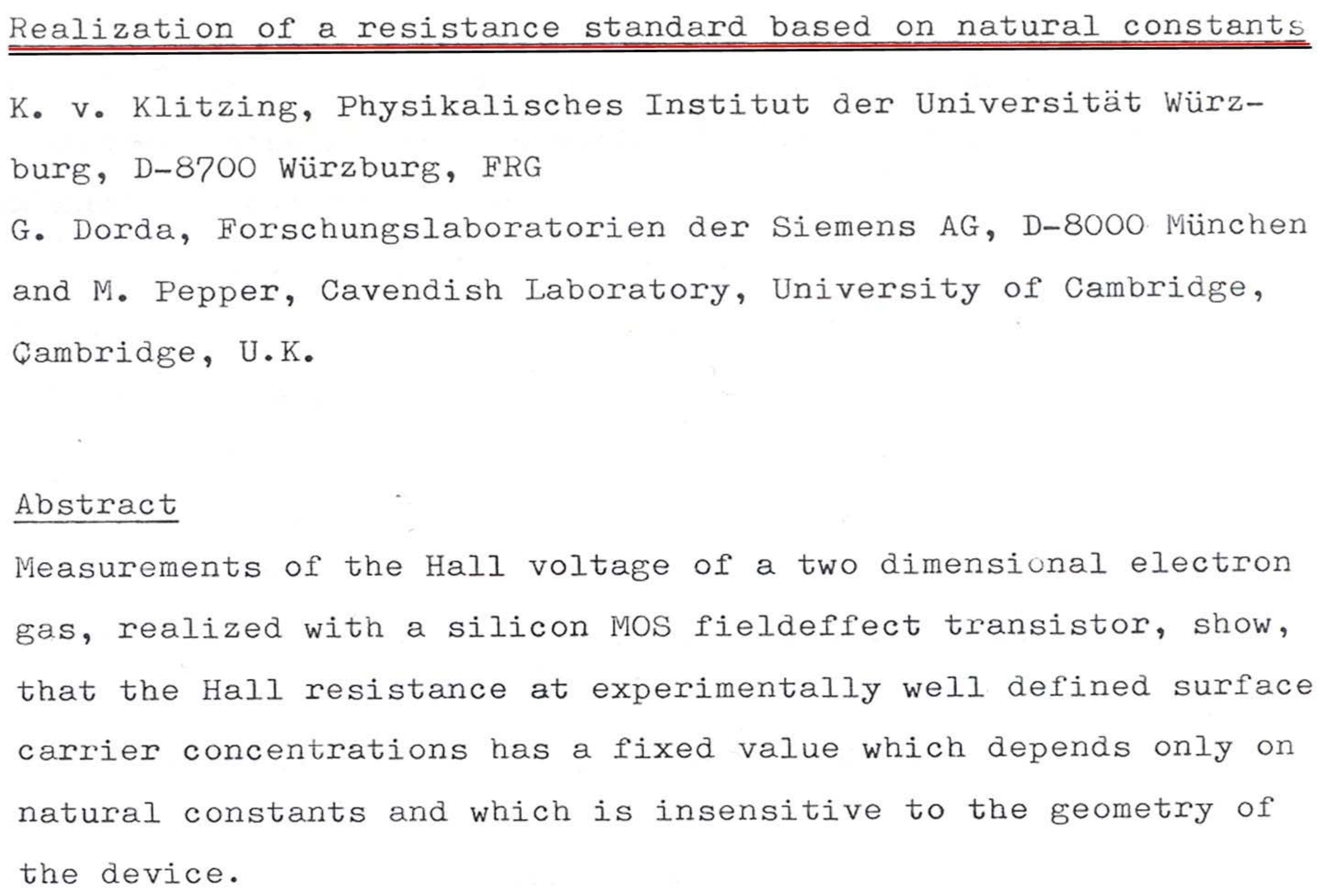
Reconstruction of the moment of the discovery of the QHE on 5.2.1980 at 2 a.m in Grenoble (photo from 1985)



30 years quantum Hall effect



First Version of the “NOBEL” Publication (2 month after discovery)



Realization of a resistance standard based on natural constants

K. v. Klitzing, Physikalisches Institut der Universität Würzburg, D-8700 Würzburg, FRG
G. Dorda, Forschungslaboratorien der Siemens AG, D-8000 München
and M. Pepper, Cavendish Laboratory, University of Cambridge,
Cambridge, U.K.

Abstract

Measurements of the Hall voltage of a two dimensional electron gas, realized with a silicon MOS fieldeffect transistor, show, that the Hall resistance at experimentally well defined surface carrier concentrations has a fixed value which depends only on natural constants and which is insensitive to the geometry of the device.

UNIVERSITY OF CAMBRIDGE
DEPARTMENT OF PHYSICS

Telephone : 0223-66477
Telex 81292

CAVENDISH LABORATORY
MADINGLEY ROAD
CAMBRIDGE CB3 0HE

6th November 1979

Dr. K. von Klitzing,
Max-Planck-Institut,
Hochfeld-Magnetlabor.
C.N.R.S.,
Grenoble 25, Avenue des Martyrs,
Grenoble Cedex,
France.

Dear Karl,

I hope that the chips have arrived safely and I'd be grateful if you could confirm this. I'm also preparing some more chips with different processing conditions.

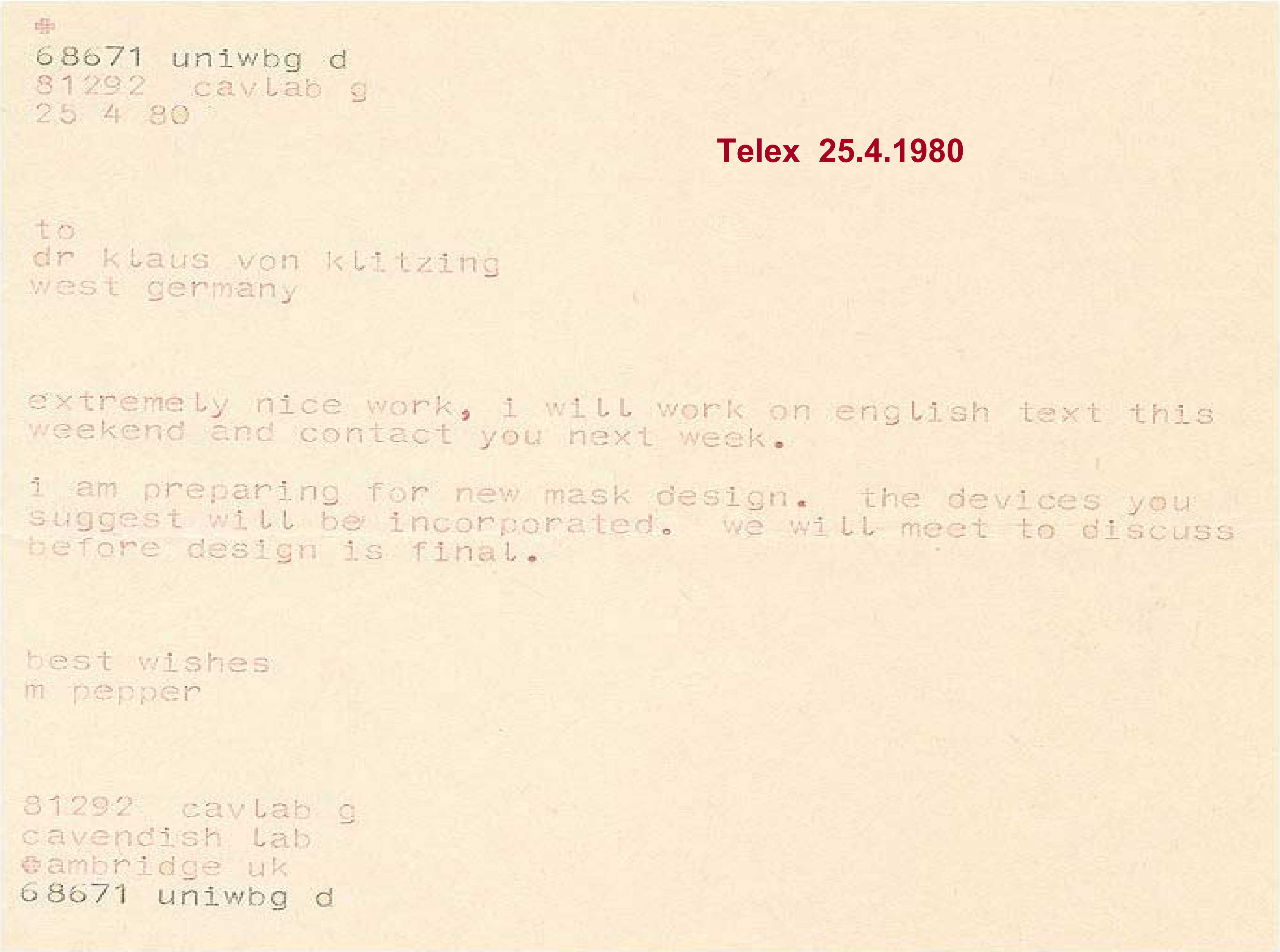
As I'm sure you appreciate the preparation of special samples is a very expensive and time consuming business. I fund this work with grants from agencies within the U.K. and abroad, as a consequence I have to document and fully report all the obtained results. Thus, the samples are not gifts but are part of a collaborative venture and all results obtained using them must be written up as joint publications with due acknowledgements to the funding agencies. I hope that this is agreeable

Klaus v. Klitzing
AM PHYSIKALISCHEN INSTITUT
DER UNIVERSITÄT WÜRZBURG

8700 WÜRZBURG, 22. 4. 1980
Röntgenring 8
Fernsprecher (09 31) 31 585.
Telex 068671 Uni

Dear Mike!

Enclosed the draft of a paper which should be published as soon as possible (perhaps Phys. Rev. Letters) I hope that you agree with the physical content and it would be helpful if you could improve the english text. (I have finished the experiments last weekend and had no time to „polish" the text I am in hurry because the postoffice in the University closes in five minutes.



68671 uniwbg d
81292 cavlab g
25 4 80

Telex 25.4.1980

to
dr klaus von klitzing
west germany

extremely nice work, i will work on english text this weekend and contact you next week.

i am preparing for new mask design. the devices you suggest will be incorporated. we will meet to discuss before design is final.

best wishes
m pepper

81292 cavlab g
cavendish lab
cambridge uk
68671 uniwbg d

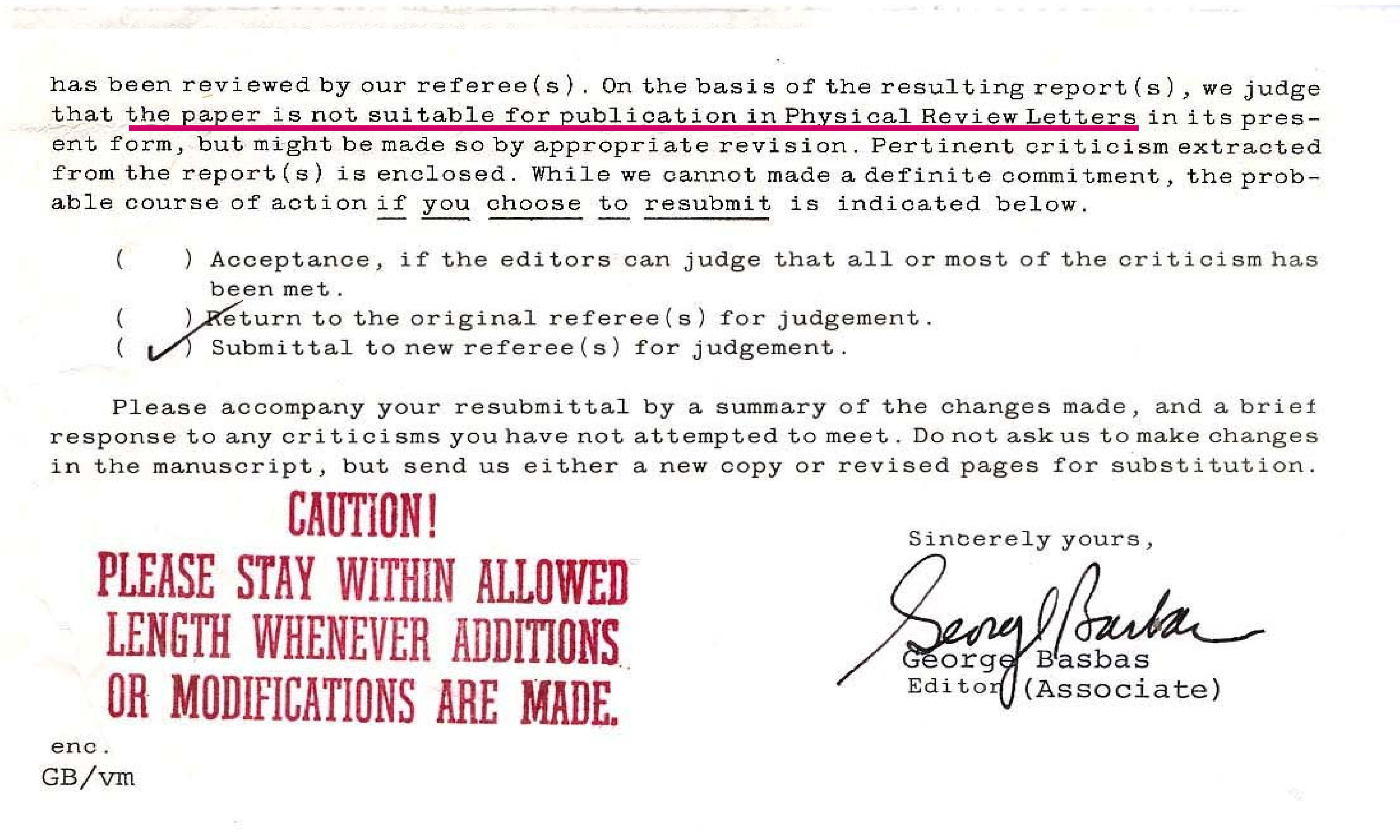
Physics in High Magnetic Fields

Hakone, Japan, 10.-13.9.1980

Kubo: ***Tomorrow, everything will be clear***

Mt. Fuji

Answer from PRL Editor



has been reviewed by our referee(s). On the basis of the resulting report(s), we judge that the paper is not suitable for publication in Physical Review Letters in its present form, but might be made so by appropriate revision. Pertinent criticism extracted from the report(s) is enclosed. While we cannot made a definite commitment, the probable course of action if you choose to resubmit is indicated below.

- ( ) Acceptance, if the editors can judge that all or most of the criticism has been met.
- ( ) Return to the original referee(s) for judgement.
- (✓) Submittal to new referee(s) for judgement.

Please accompany your resubmittal by a summary of the changes made, and a brief response to any criticisms you have not attempted to meet. Do not ask us to make changes in the manuscript, but send us either a new copy or revised pages for substitution.

CAUTION!

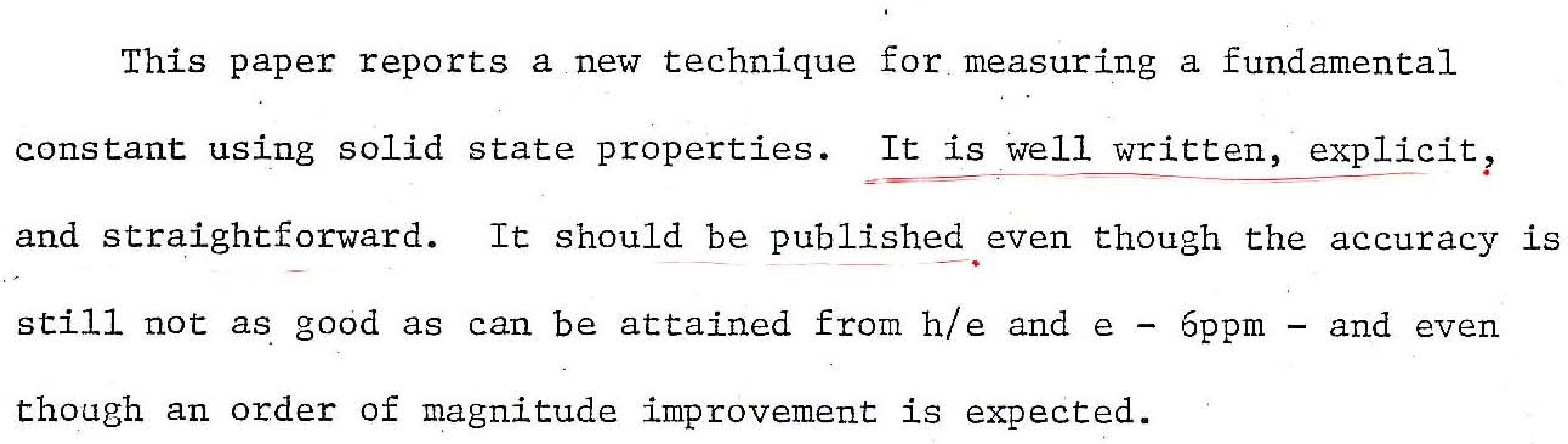
PLEASE STAY WITHIN ALLOWED LENGTH WHENEVER ADDITIONS OR MODIFICATIONS ARE MADE.

Sincerely yours,

George Basbas
Editor (Associate)

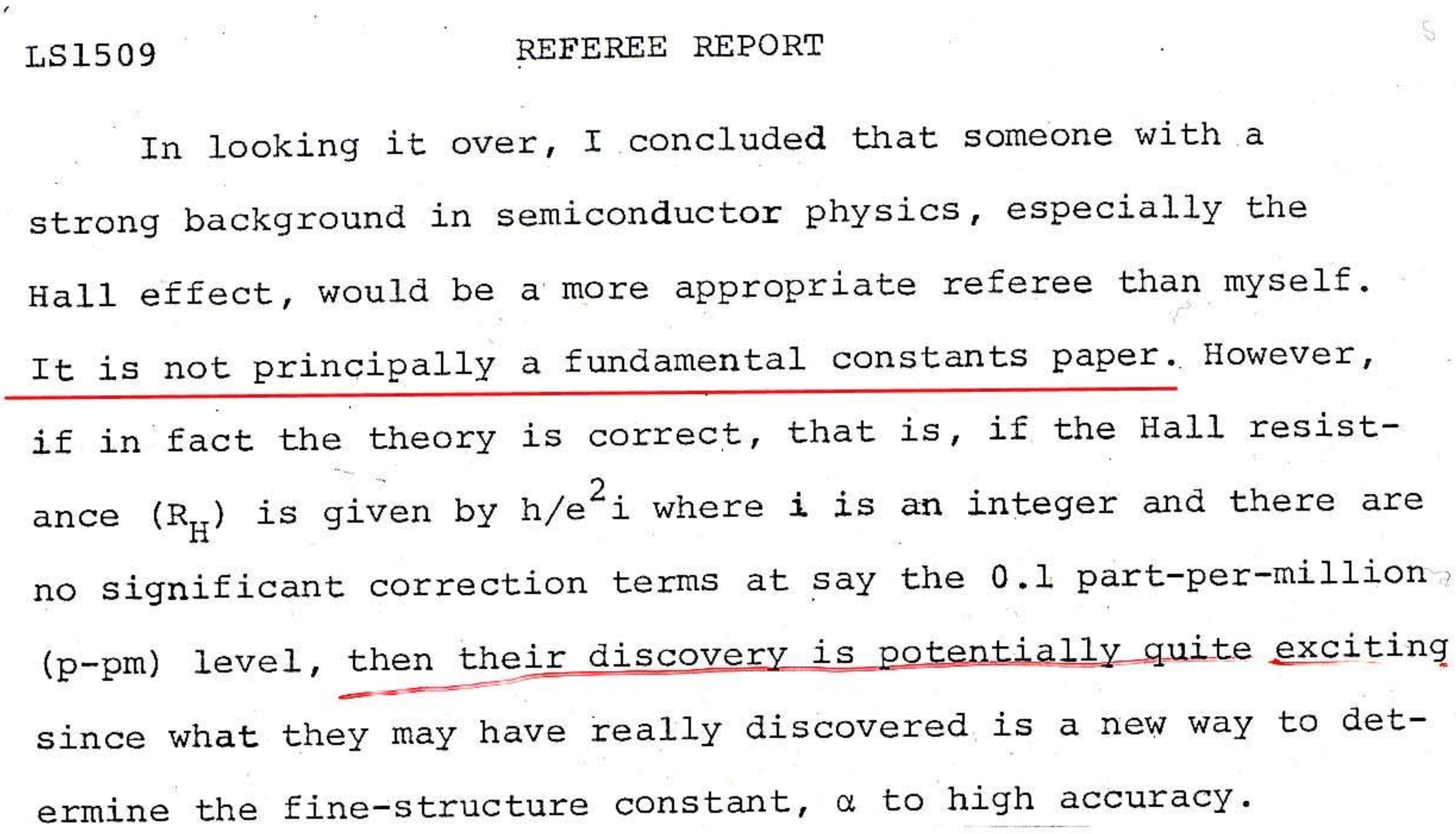
enc.
GB/vm

Referee report



This paper reports a new technique for measuring a fundamental constant using solid state properties. It is well written, explicit, and straightforward. It should be published even though the accuracy is still not as good as can be attained from h/e and e - 6ppm - and even though an order of magnitude improvement is expected.

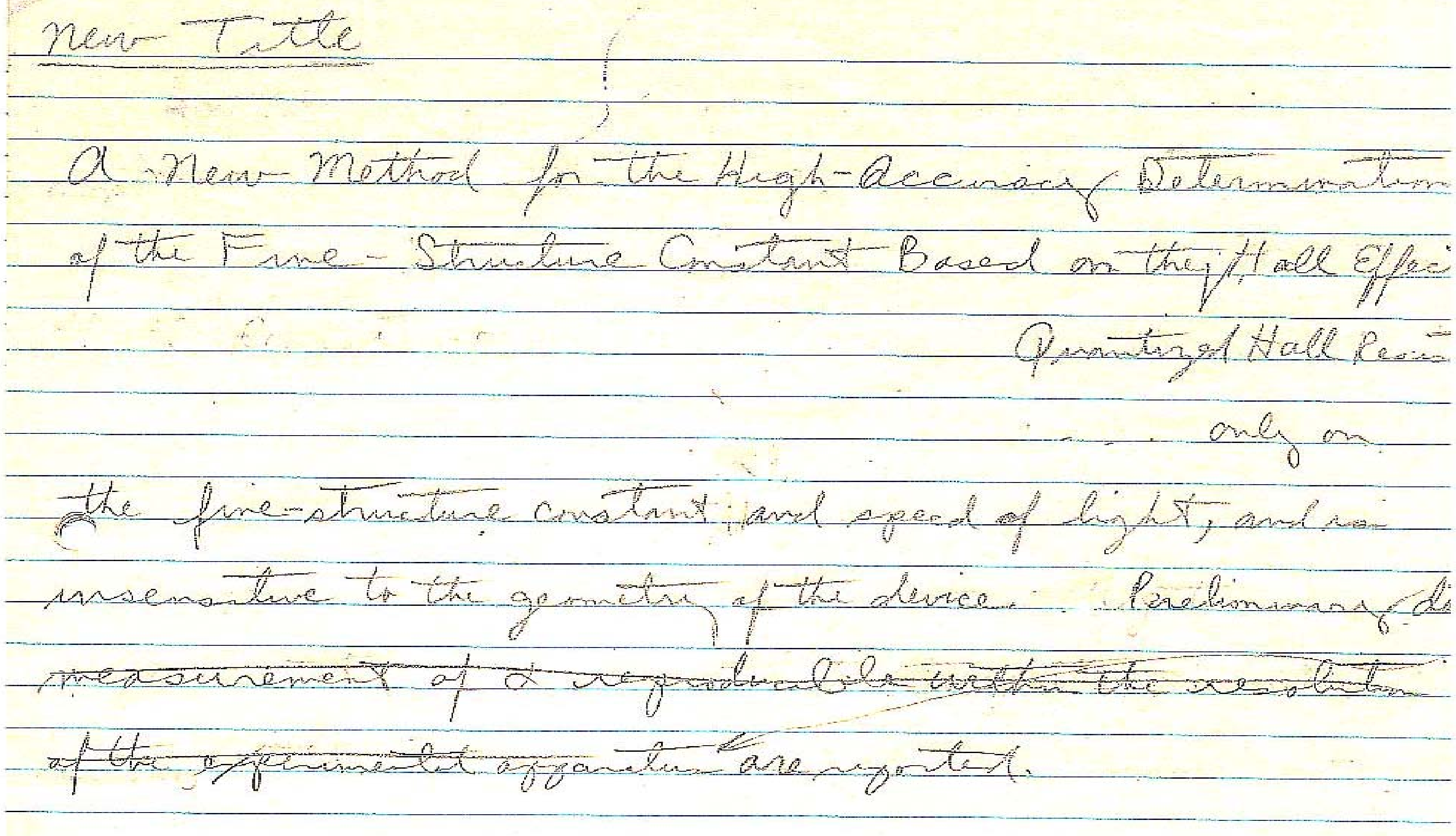
Referee report from Berry Taylor (NBS)



LS1509 REFEREE REPORT

In looking it over, I concluded that someone with a strong background in semiconductor physics, especially the Hall effect, would be a more appropriate referee than myself. It is not principally a fundamental constants paper. However, if in fact the theory is correct, that is, if the Hall resistance (R_H) is given by $h/e^2 i$ where i is an integer and there are no significant correction terms at say the 0.1 part-per-million (p-pm) level, then their discovery is potentially quite exciting since what they may have really discovered is a new way to determine the fine-structure constant, α to high accuracy.

Result of discussions on 27.6.1980 with Dr. E.R.Cohen and referee Dr. B.N.Taylor (NBS/NIST) about the submitted QHE paper



new Title

A New Method for the High-Accuracy Determination of the Fine-Structure Constant Based on the Hall Effec

Quantized Hall Resi

only on

the fine-structure constant and speed of light, and is insensitive to the geometry of the device. Preliminary di

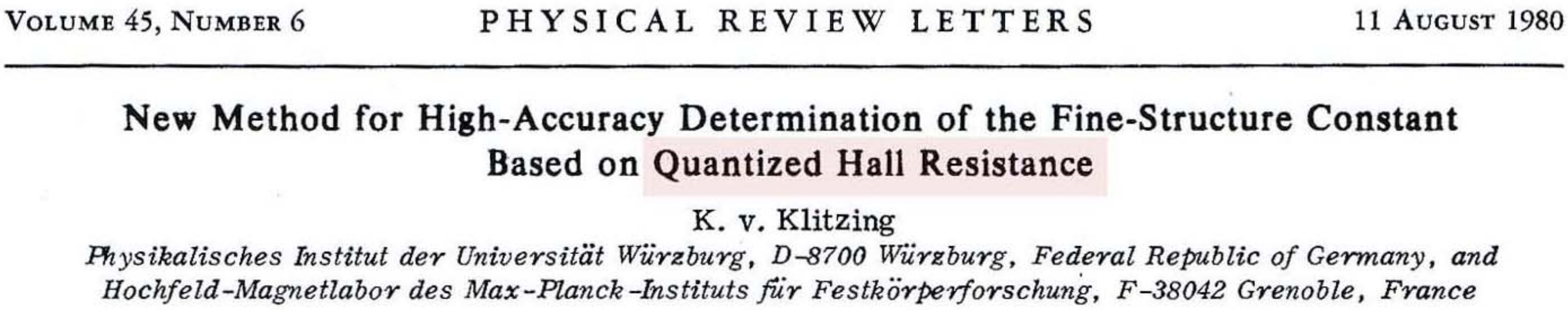
~~measurement of α reproducible within the resolution of the experimental apparatus~~ are reported.

QHE@30

First Publication about the QUANTUM HALL EFFECT

MPI-FKF

11 August 1980



Volume 45, Number 6 PHYSICAL REVIEW LETTERS 11 August 1980

New Method for High-Accuracy Determination of the Fine-Structure Constant Based on Quantized Hall Resistance

K. v. Klitzing

Physikalisches Institut der Universität Würzburg, D-8700 Würzburg, Federal Republic of Germany, and Hochfeld-Magnetlabor des Max-Planck-Instituts für Festkörperforschung, F-38042 Grenoble, France

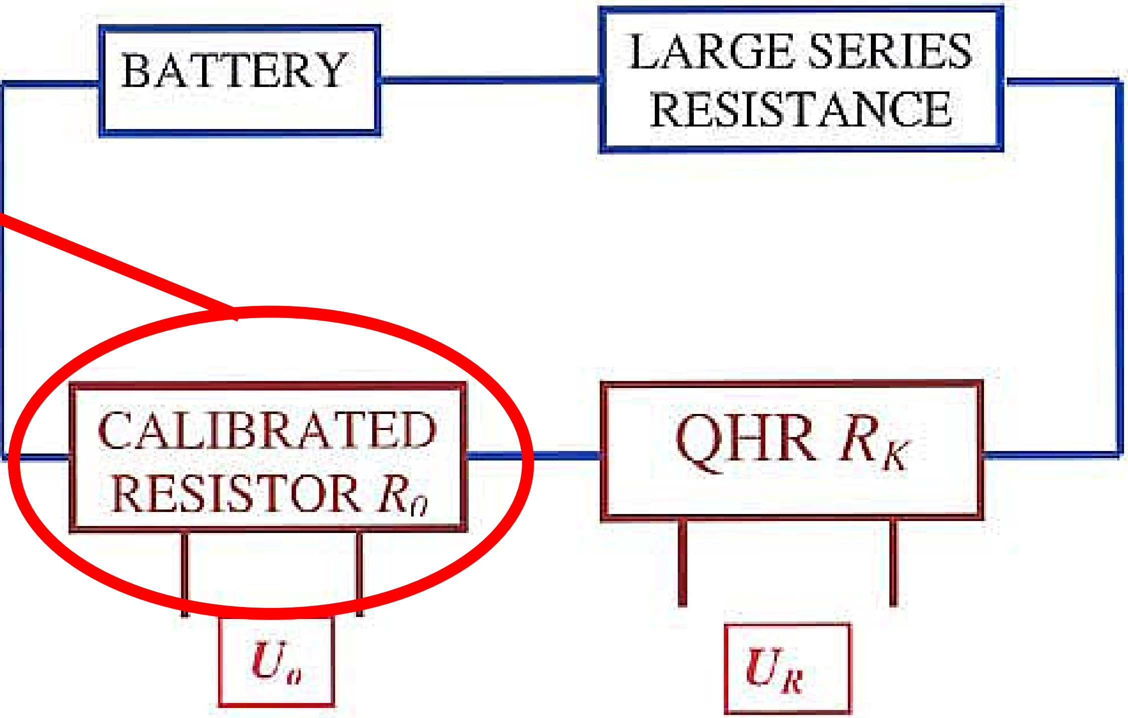
and

Measurements with a voltmeter with higher resolution and a calibrated standard resistor with a vanishing temperature coefficient at T=25°C yield a value of $h/4e^2 = 6453{,}17 \pm 0{,}02\ \Omega$ corresponding to a fine-structure constant $\alpha^{-1} = 137{,}0353 \pm 0{,}0004\ \Omega$

Experimental Determination of the Quantized Hall Resistance $R_K = h/e^2$

main problem

R=9999,69 Ω at 20°C



$$R_K = R_0 \cdot U_R / U_0$$

{+ current switch,

thermal power reduction,

temperature control...}

12.4.80

Würzburg, 12.4.1980

MP 9/4

8.4
4.45
10 ≙ 50 V

3 – Source
2 – Drain
1 – Hall
4 – Gate
5 } – Pot
6 } – (H)

T = 19°C

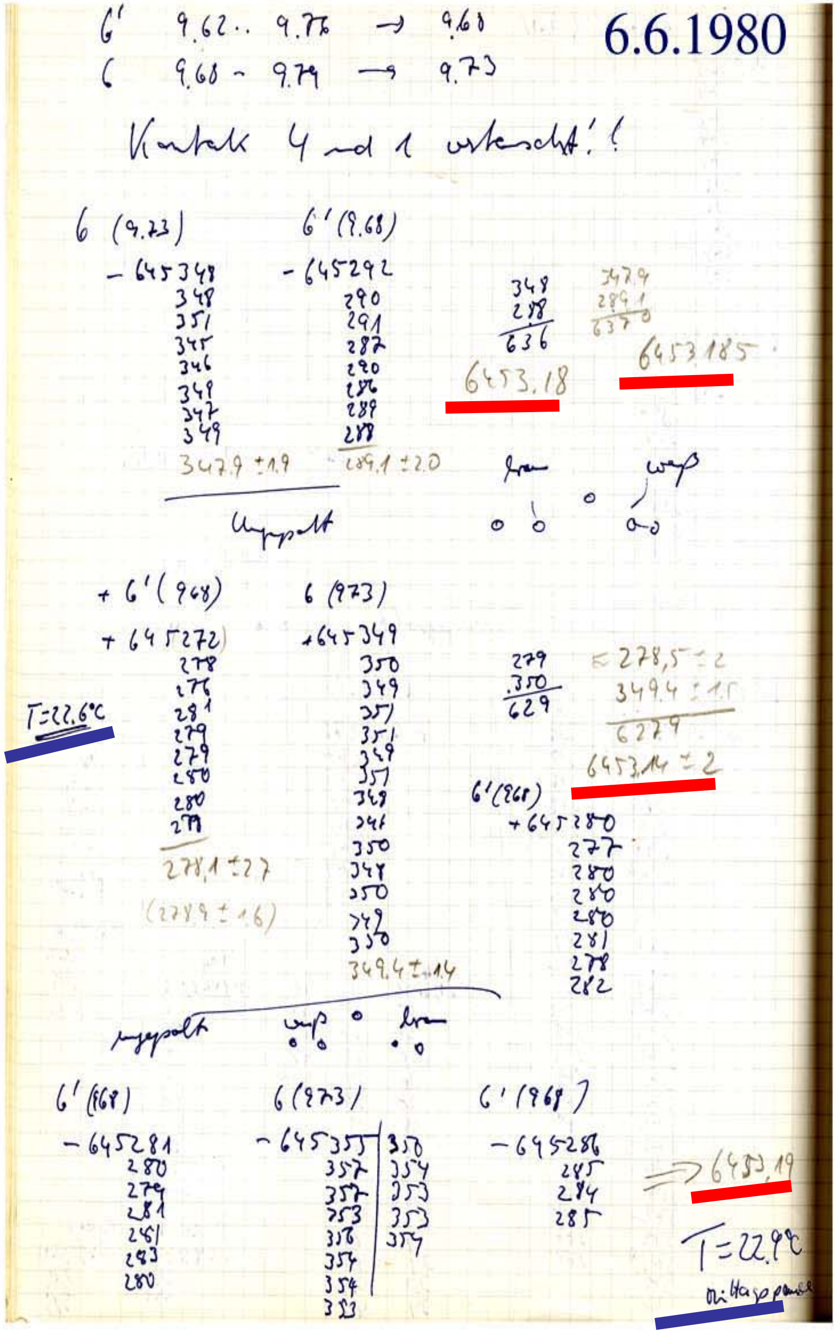
β = 4,311
T = 424

	Upp					
8.2	+ 1590	− 1580	− 45583	45580	− 15441	14329
8.25	1114	1084	25596	45593	15368	14260
8.30	632	608	45610	45607	15298	14192
8.35	149	118	45624	45621	15259	14172
8.40	56	48	45626	45624	15252	14174
8.45	263	308	45620	45619	15155	14064
8.50	825	945	45606	45607	14857	13771
8.55	1365	1538	45593	45595	14576	13464

9 1250

29 426

Typical pages from my workbook for high precision measurements of the QHE



6.6.1980

6' 9.62.. 9.76 → 9.68
6 9.68 - 9.79 → 9.73

Kontakt 4 und 1 vertauscht!!

6 (9.73)	6' (9.68)
-645348	-645292
348	290
351	291
345	287
346	290
349	286
347	289
349	288
347.9 ±1.9	289.1 ±2.0

348
288
636

347.9
289.1
637.0

6453.18

6453.185

braun ○ weiß

Umgepolt

+ 6' (968)	6 (973)
+ 645272	+645349
278	350
276	349
281	351
279	351
279	349
280	351
280	348
279	346
278,1 ±2.7	350
(278.9 ± 1.6)	348
	350
	349
	350
	349.4 ± 1.4

T=22.6°C

279
.350
629

≈ 278,5 ± 2
349.4 ± 1.5
627.9

6453.14 ± 2

6'(968)
+645280
277
280
280
280
281
278
282

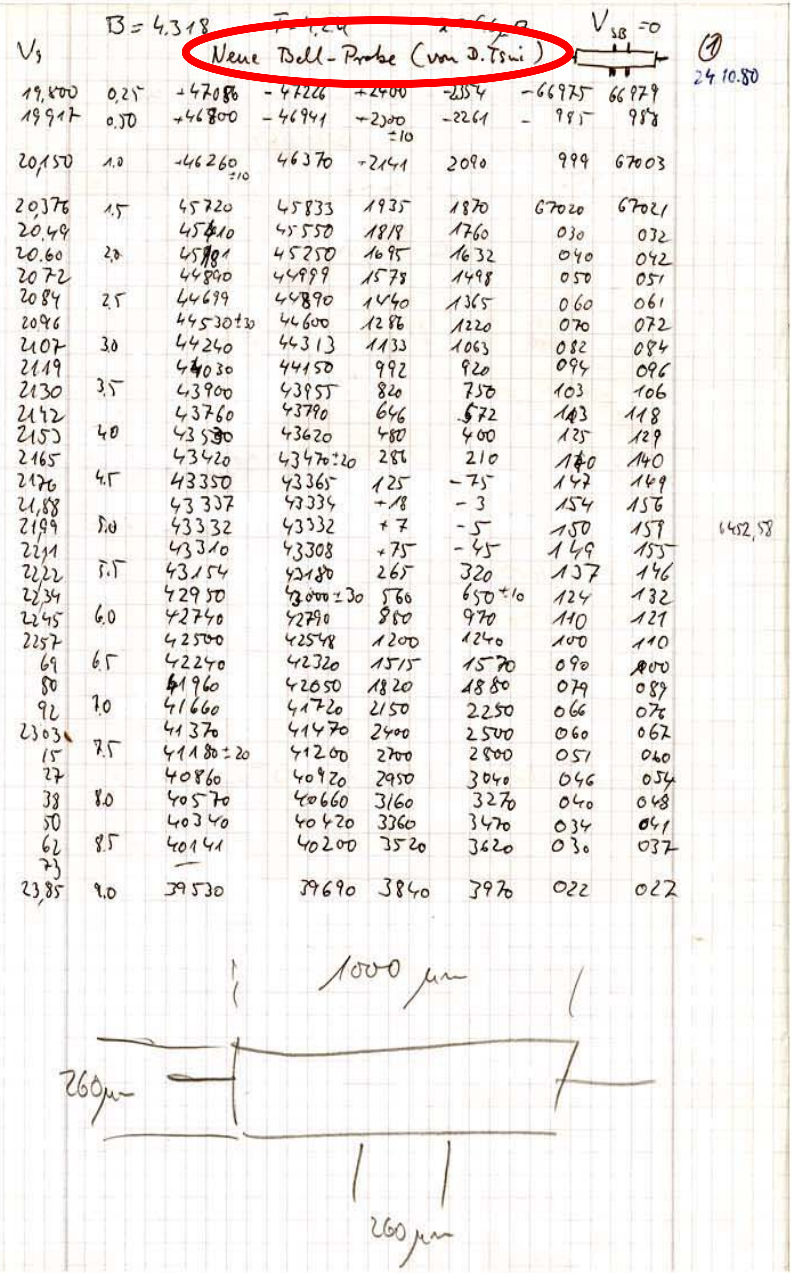
umgepolt weiß ○ braun

6' (968)	6 (973)		6' (968)
-645281	-645355	358	-645286
280	357	354	285
279	357	353	284
281	353	353	285
281	358	354	
283	354		
280	354		
	353		

⇒ 6453,19

T=22.9°C

mittagspause



B = 4,318   T = 1,24   [illegible] V_{SB} = 0

Neue Bell-Probe (von D. Tsui)

①
24.10.80

V_g								
19,800	0,25	+47086	-47226	+2400	-2354	-66975	66979	
19917	0,50	+46800	-46941	+2300 ±10	-2261	- 985	988	
20,150	1.0	-46260 ±10	46370	+2141	2090	999	67003	
20376	1.5	45720	45833	1935	1870	67020	67021	
20.49		45410	45550	1818	1760	030	032	
20.60	2.0	45181	45250	1695	1632	040	042	
2072		44890	44999	1578	1498	050	051	
2084	2.5	44699	44890	1440	1365	060	061	
2096		44530±30	44600	1286	1220	070	072	
2107	3.0	44240	44313	1133	1063	082	084	
2119		44030	44150	992	920	094	096	
2130	3.5	43900	43955	820	750	103	106	
2142		43760	43790	646	572	113	118	
2153	4.0	43530	43620	480	400	125	129	
2165		43420	43470±20	286	210	140	140	
2176	4.5	43350	43365	125	-75	147	149	
21,88		43337	43334	+18	- 3	154	156	
21,99	5.0	43332	43332	+ 7	- 5	150	159	6452,58
22,11		43310	43308	+75	- 45	149	155	
22,22	5.5	43154	43180	265	320	137	146	
22,34		42950	43000±30	560	650±10	124	132	
22,45	6.0	42740	42790	880	970	110	121	
2257		42500	42548	1200	1240	100	110	
69	6.5	42240	42320	1515	1570	090	100	
80		41960	42050	1820	1880	079	087	
92	7.0	41660	41720	2150	2250	066	076	
2303		41370	41470	2400	2500	060	067	
15	7.5	41180±20	41200	2700	2800	051	060	
27		40860	40920	2950	3040	046	054	
38	8.0	40570	40660	3160	3270	040	048	
50		40340	40420	3360	3470	034	041	
62	8.5	40141	40200	3520	3620	030	037	
73								
23,85	9.0	39530	39690	3840	3970	022	022	

1000 μm

260 μm

260 μm

Improvisation of High Precision Experiments

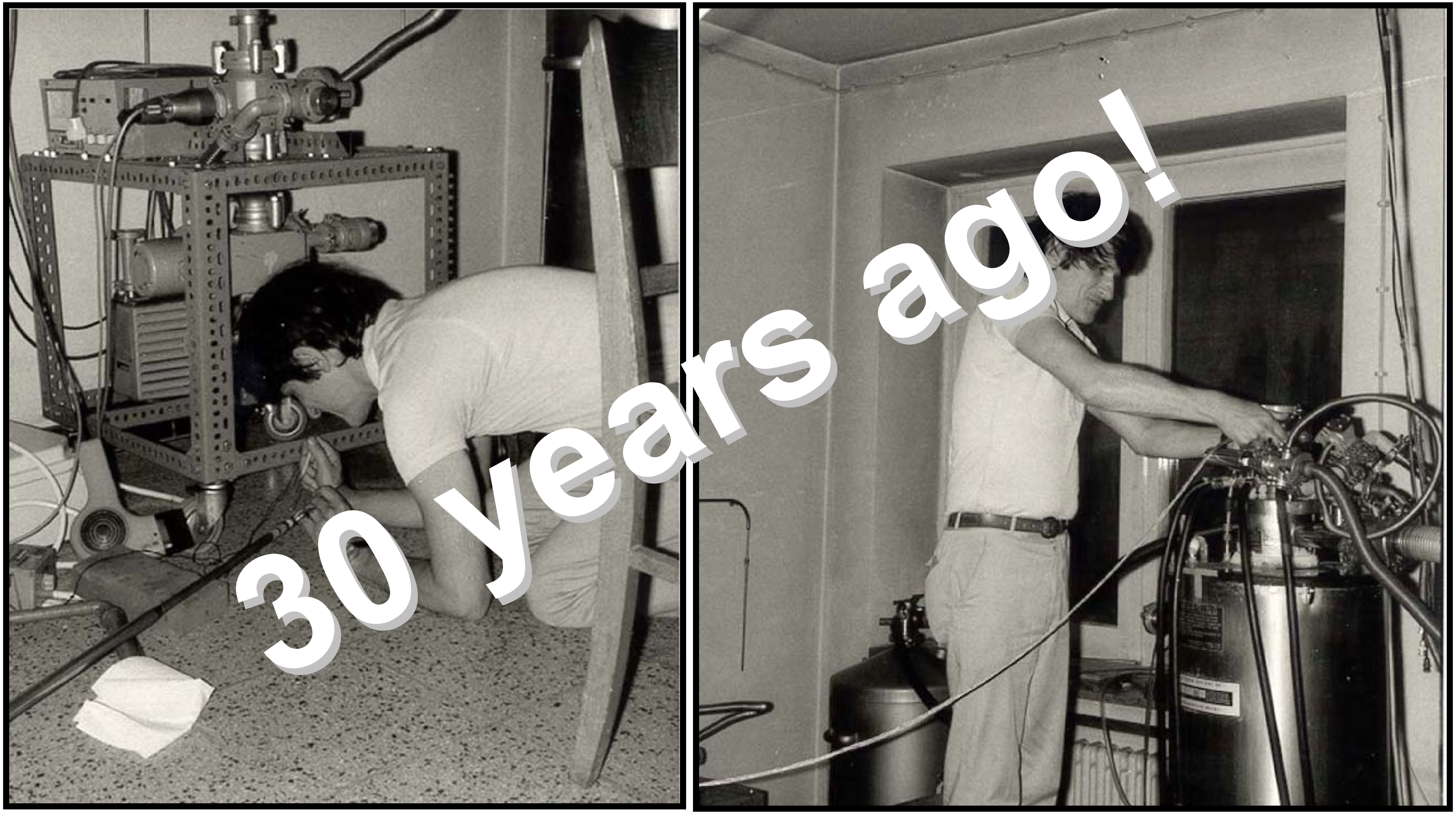
Research Laboratory Würzburg

DATA AQUISITION WITH DVM

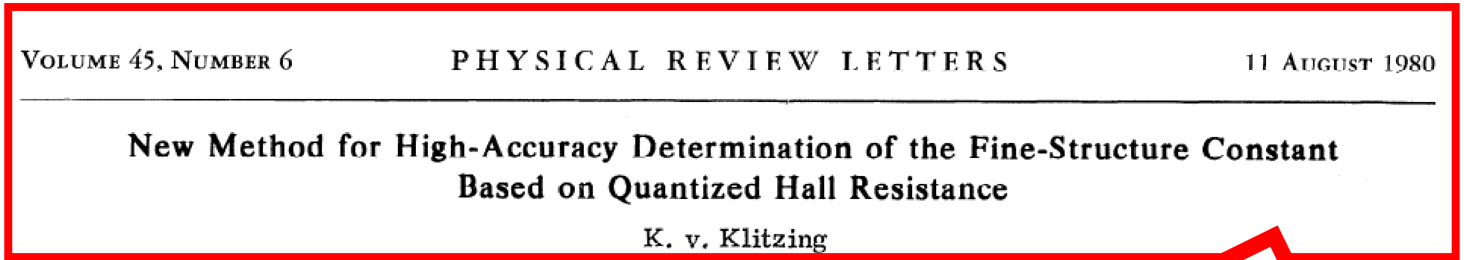
… WITH FILTER (Würzburg 1980)

High precision measurements of the QHE at the Physics Department EPIII, Würzburg

(April 1980)



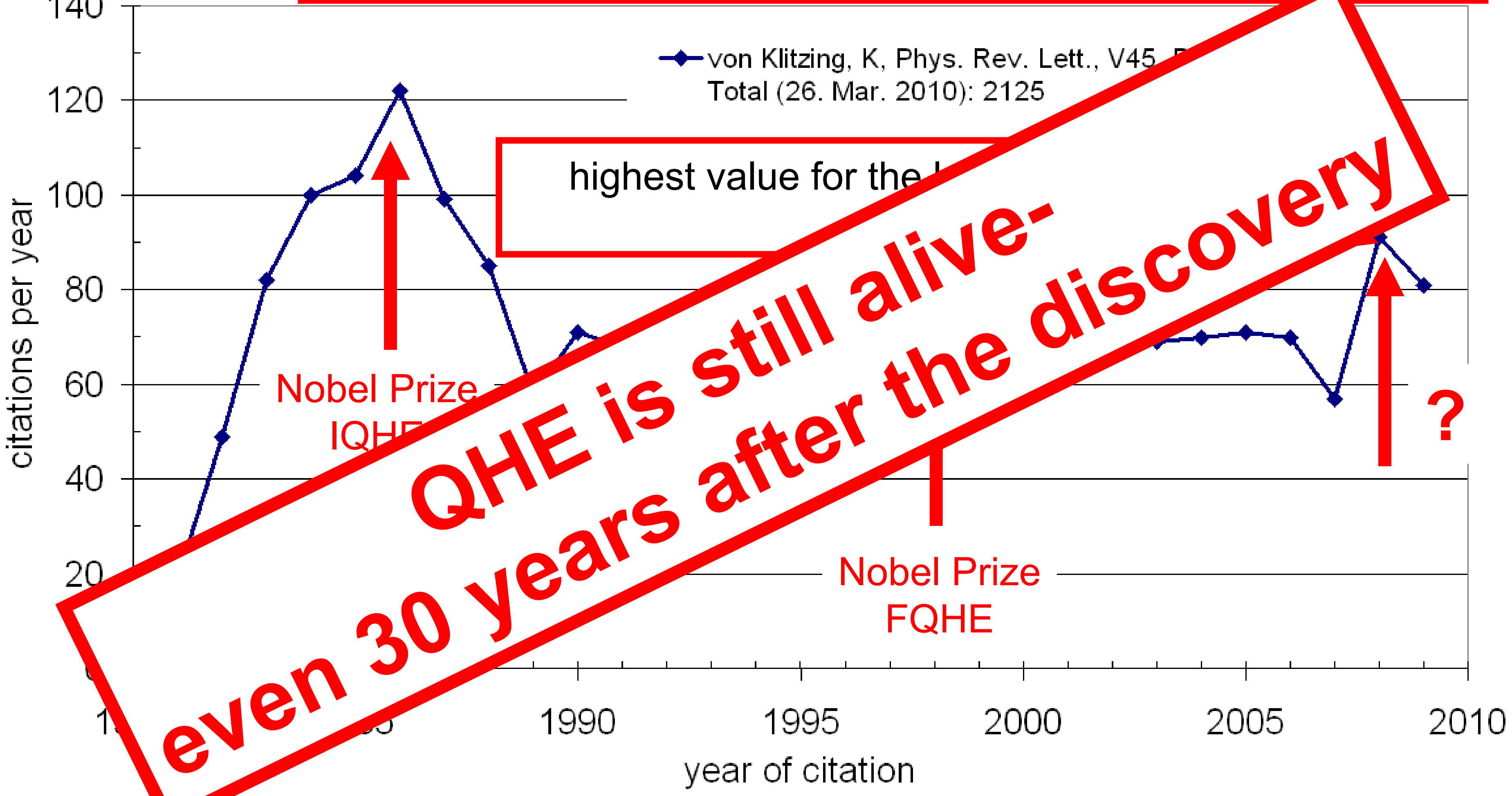
30 years ago!



VOLUME 45, NUMBER 6 PHYSICAL REVIEW LETTERS 11 AUGUST 1980

New Method for High-Accuracy Determination of the Fine-Structure Constant Based on Quantized Hall Resistance

K. v. Klitzing



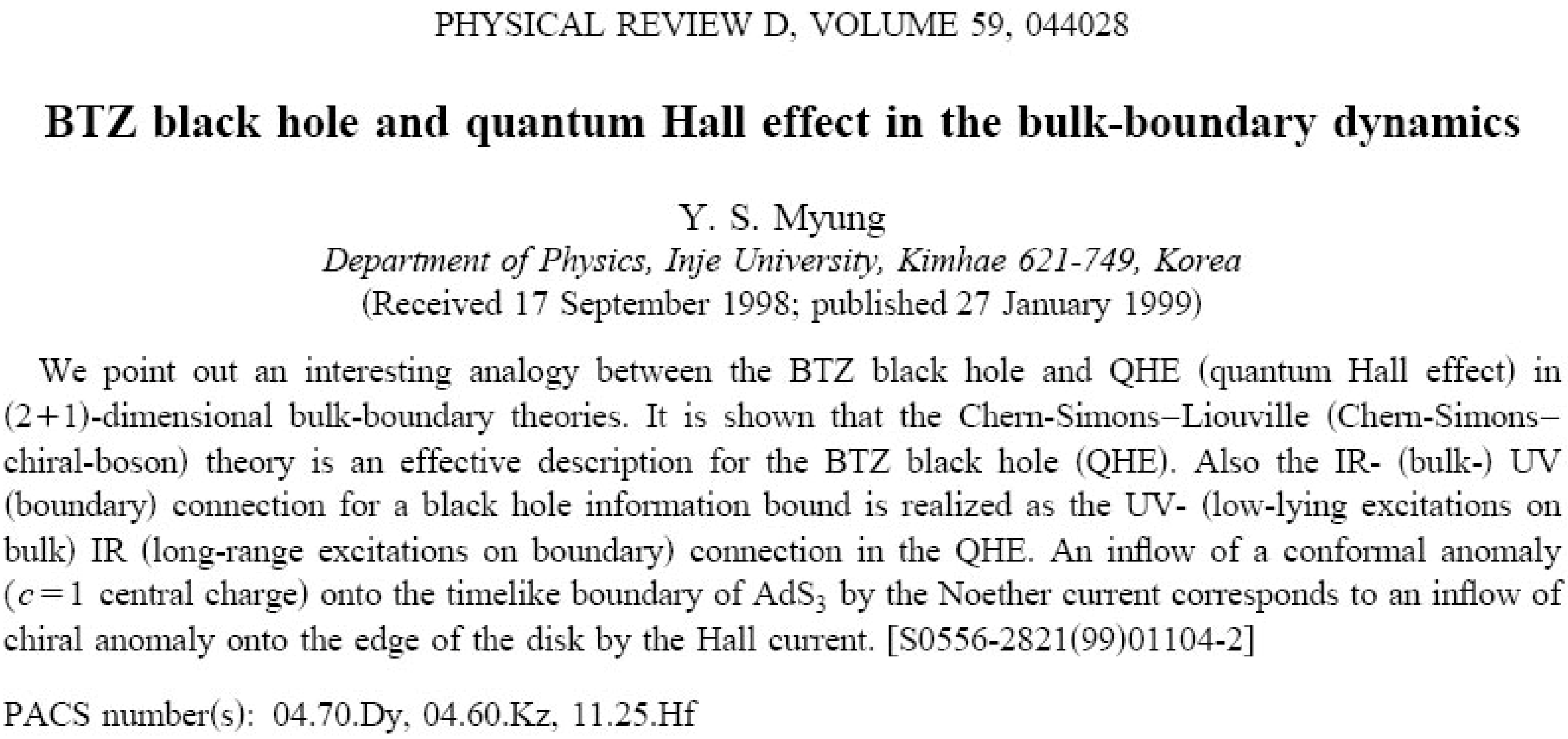
QHE is still alive-

even 30 years after the discovery

QHE and astrophysics?

The quantum Hall effect-
a phenomenon for
(nearly) all area in physics

QUANTUM HALL EFFECT
and BLACK HOLES



PHYSICAL REVIEW D, VOLUME 59, 044028

BTZ black hole and quantum Hall effect in the bulk-boundary dynamics

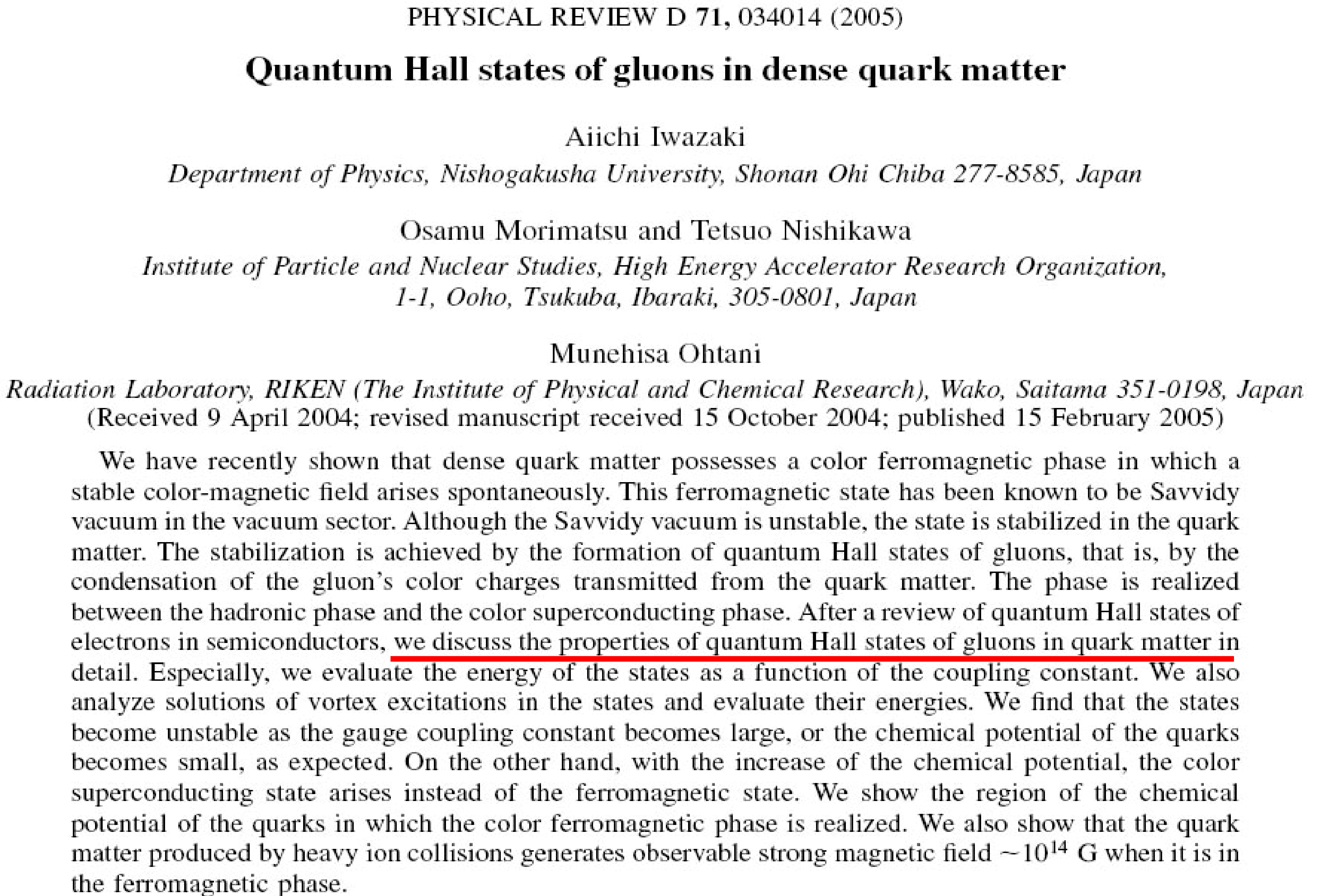
Y. S. Myung
Department of Physics, Inje University, Kimhae 621-749, Korea

(Received 17 September 1998; published 27 January 1999)

We point out an interesting analogy between the BTZ black hole and QHE (quantum Hall effect) in (2+1)-dimensional bulk-boundary theories. It is shown that the Chern-Simons–Liouville (Chern-Simons–chiral-boson) theory is an effective description for the BTZ black hole (QHE). Also the IR- (bulk-) UV (boundary) connection for a black hole information bound is realized as the UV- (low-lying excitations on bulk) IR (long-range excitations on boundary) connection in the QHE. An inflow of a conformal anomaly ($c=1$ central charge) onto the timelike boundary of AdS_3 by the Noether current corresponds to an inflow of chiral anomaly onto the edge of the disk by the Hall current. [S0556-2821(99)01104-2]

PACS number(s): 04.70.Dy, 04.60.Kz, 11.25.Hf

QUANTUM HALL EFFECT and QUARKS



PHYSICAL REVIEW D 71, 034014 (2005)

Quantum Hall states of gluons in dense quark matter

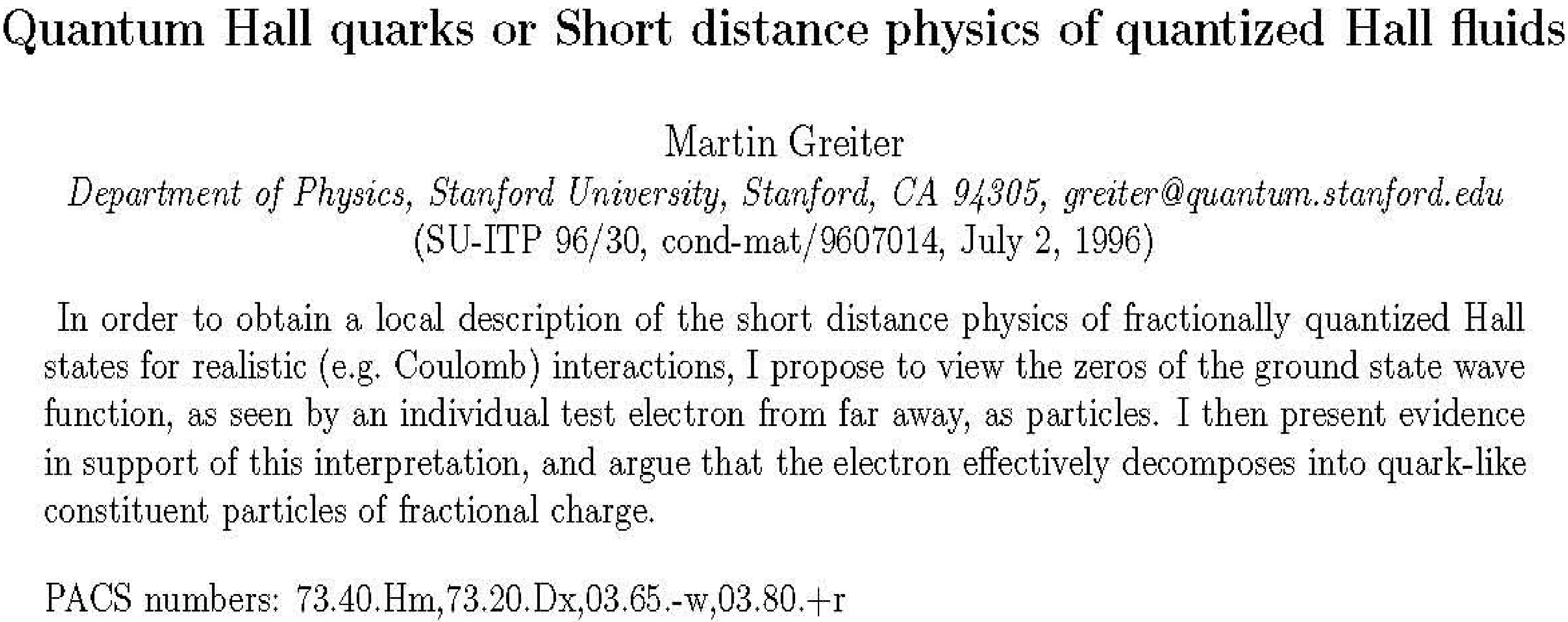
Aiichi Iwazaki
Department of Physics, Nishogakusha University, Shonan Ohi Chiba 277-8585, Japan

Osamu Morimatsu and Tetsuo Nishikawa
Institute of Particle and Nuclear Studies, High Energy Accelerator Research Organization,
1-1, Ooho, Tsukuba, Ibaraki, 305-0801, Japan

Munehisa Ohtani
Radiation Laboratory, RIKEN (The Institute of Physical and Chemical Research), Wako, Saitama 351-0198, Japan
(Received 9 April 2004; revised manuscript received 15 October 2004; published 15 February 2005)

We have recently shown that dense quark matter possesses a color ferromagnetic phase in which a stable color-magnetic field arises spontaneously. This ferromagnetic state has been known to be Savvidy vacuum in the vacuum sector. Although the Savvidy vacuum is unstable, the state is stabilized in the quark matter. The stabilization is achieved by the formation of quantum Hall states of gluons, that is, by the condensation of the gluon's color charges transmitted from the quark matter. The phase is realized between the hadronic phase and the color superconducting phase. After a review of quantum Hall states of electrons in semiconductors, we discuss the properties of quantum Hall states of gluons in quark matter in detail. Especially, we evaluate the energy of the states as a function of the coupling constant. We also analyze solutions of vortex excitations in the states and evaluate their energies. We find that the states become unstable as the gauge coupling constant becomes large, or the chemical potential of the quarks becomes small, as expected. On the other hand, with the increase of the chemical potential, the color superconducting state arises instead of the ferromagnetic state. We show the region of the chemical potential of the quarks in which the color ferromagnetic phase is realized. We also show that the quark matter produced by heavy ion collisions generates observable strong magnetic field $\sim 10^{14}$ G when it is in the ferromagnetic phase.

QUANTUM HALL EFFECT and QUARKS



Quantum Hall quarks or Short distance physics of quantized Hall fluids

Martin Greiter

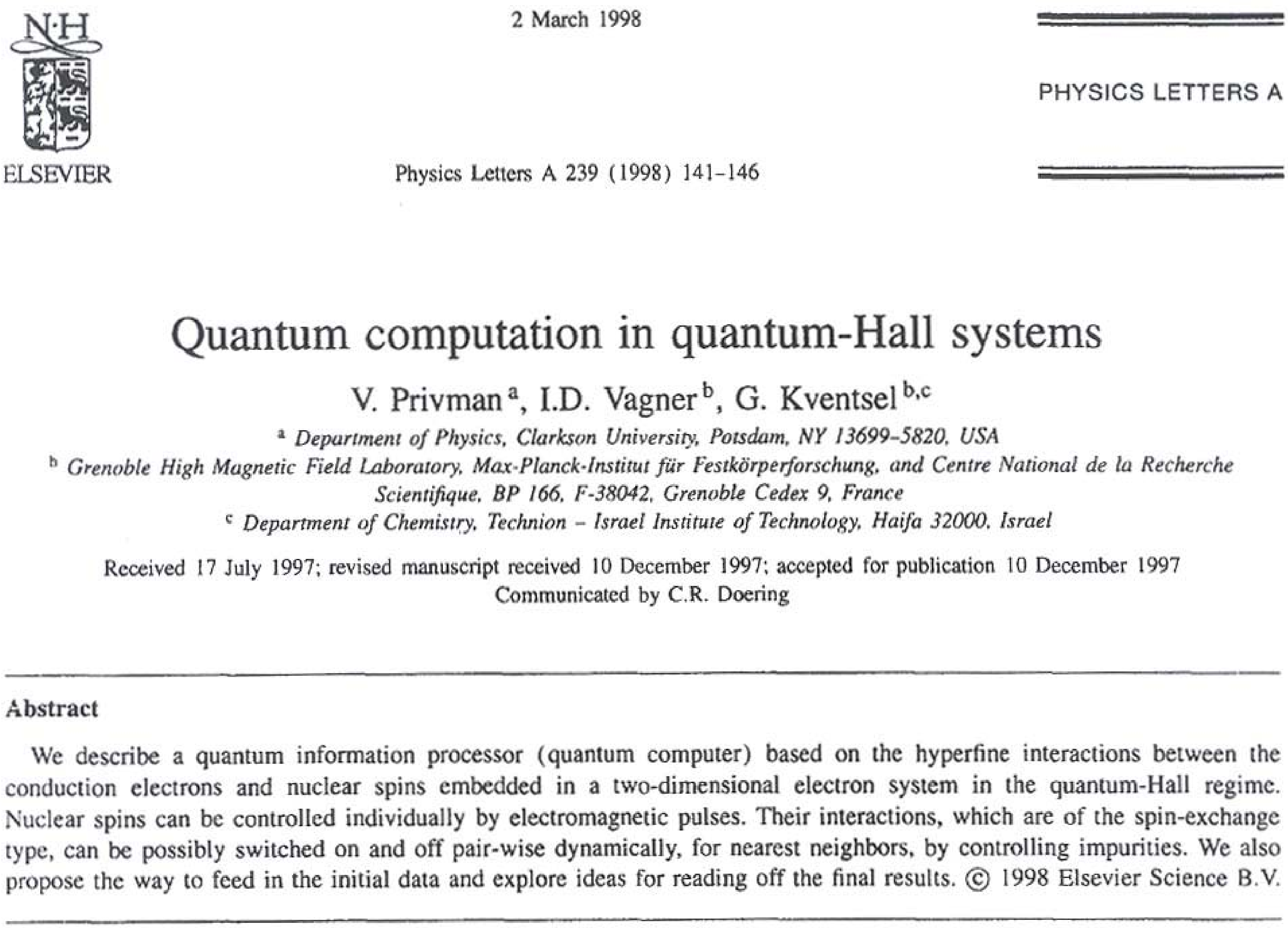
Department of Physics, Stanford University, Stanford, CA 94305, greiter@quantum.stanford.edu

(SU-ITP 96/30, cond-mat/9607014, July 2, 1996)

In order to obtain a local description of the short distance physics of fractionally quantized Hall states for realistic (e.g. Coulomb) interactions, I propose to view the zeros of the ground state wave function, as seen by an individual test electron from far away, as particles. I then present evidence in support of this interpretation, and argue that the electron effectively decomposes into quark-like constituent particles of fractional charge.

PACS numbers: 73.40.Hm,73.20.Dx,03.65.-w,03.80.+r

QUANTUM HALL EFFECT and QUANTUMCOMPUTER



ELSEVIER

2 March 1998

PHYSICS LETTERS A

Physics Letters A 239 (1998) 141–146

Quantum computation in quantum-Hall systems

V. Privman [a], I.D. Vagner [b], G. Kventsel [b,c]

[a] *Department of Physics, Clarkson University, Potsdam, NY 13699-5820, USA*

[b] *Grenoble High Magnetic Field Laboratory, Max-Planck-Institut für Festkörperforschung, and Centre National de la Recherche Scientifique, BP 166, F-38042, Grenoble Cedex 9, France*

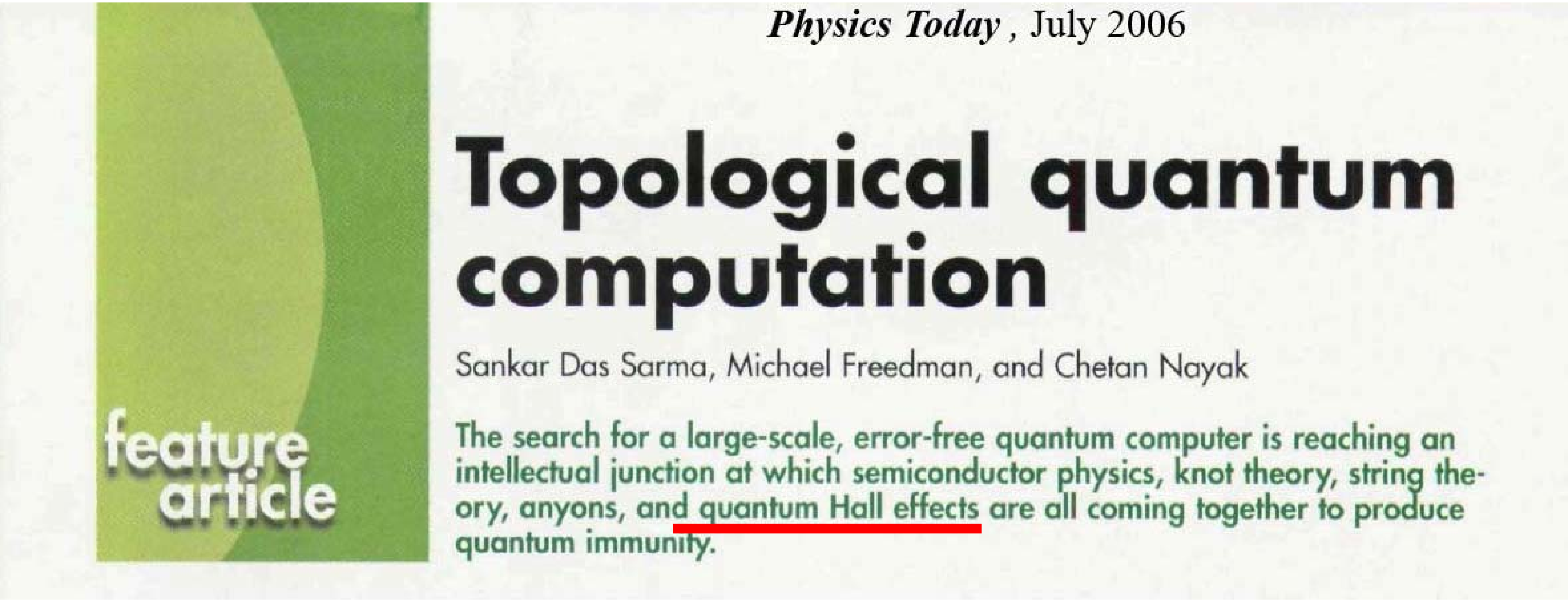
[c] *Department of Chemistry, Technion – Israel Institute of Technology, Haifa 32000, Israel*

Received 17 July 1997; revised manuscript received 10 December 1997; accepted for publication 10 December 1997
Communicated by C.R. Doering

Abstract

We describe a quantum information processor (quantum computer) based on the hyperfine interactions between the conduction electrons and nuclear spins embedded in a two-dimensional electron system in the quantum-Hall regime. Nuclear spins can be controlled individually by electromagnetic pulses. Their interactions, which are of the spin-exchange type, can be possibly switched on and off pair-wise dynamically, for nearest neighbors, by controlling impurities. We also propose the way to feed in the initial data and explore ideas for reading off the final results. © 1998 Elsevier Science B.V.

Research Project supported by Microsoft



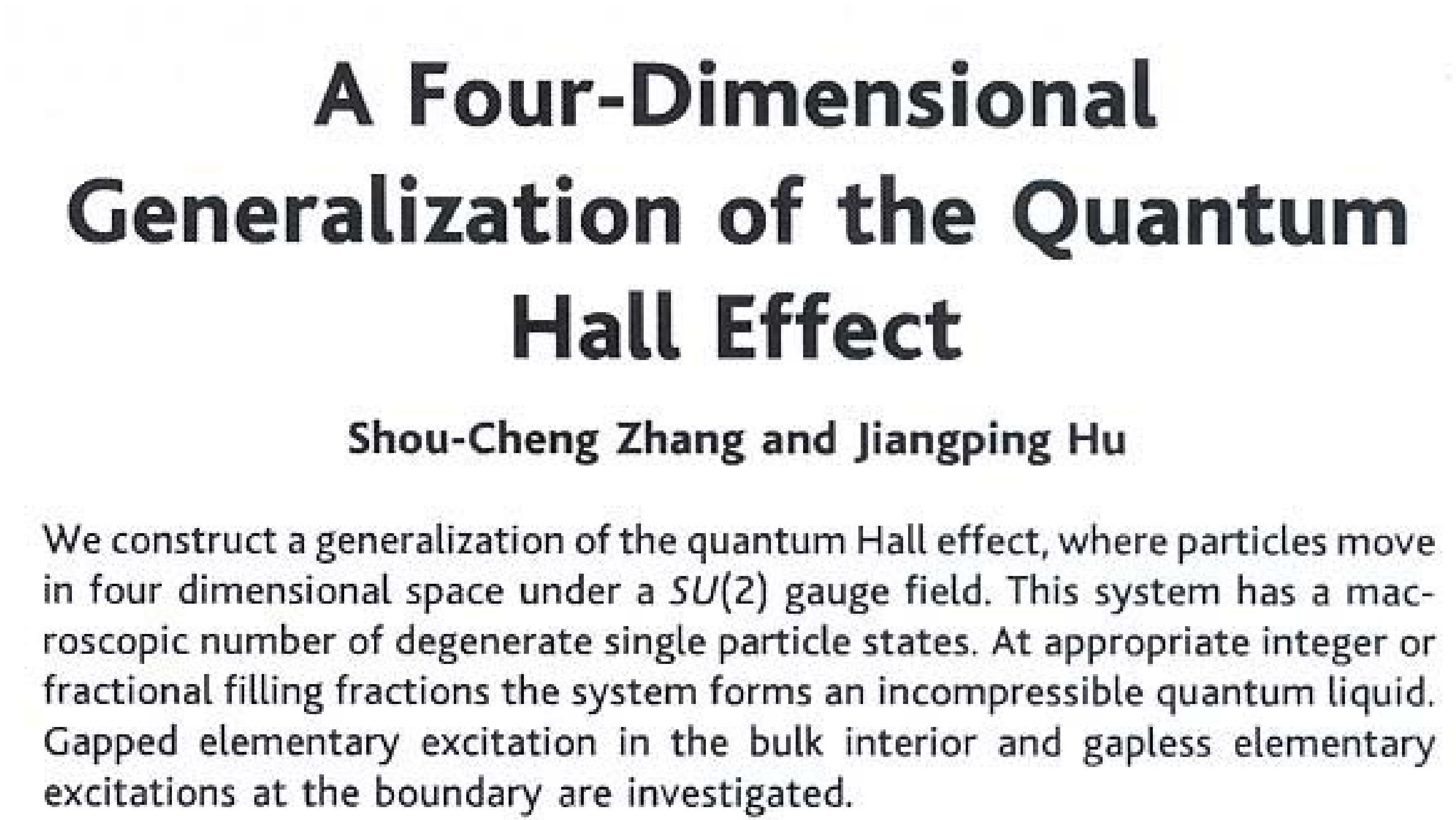
Physics Today, July 2006

feature article

Topological quantum computation

Sankar Das Sarma, Michael Freedman, and Chetan Nayak

The search for a large-scale, error-free quantum computer is reaching an intellectual junction at which semiconductor physics, knot theory, string theory, anyons, and quantum Hall effects are all coming together to produce quantum immunity.

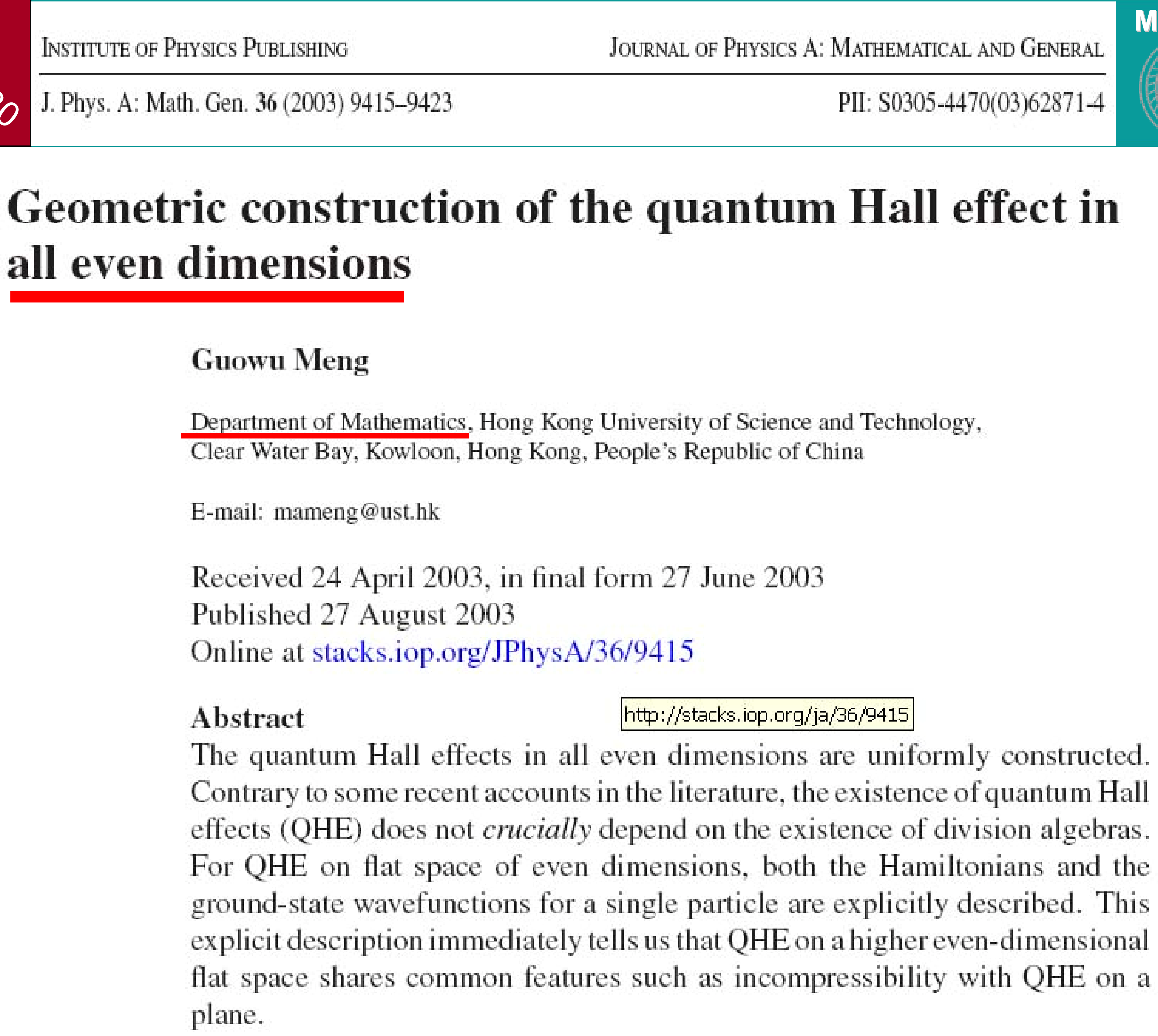


A Four-Dimensional Generalization of the Quantum Hall Effect

Shou-Cheng Zhang and Jiangping Hu

We construct a generalization of the quantum Hall effect, where particles move in four dimensional space under a $SU(2)$ gauge field. This system has a macroscopic number of degenerate single particle states. At appropriate integer or fractional filling fractions the system forms an incompressible quantum liquid. Gapped elementary excitation in the bulk interior and gapless elementary excitations at the boundary are investigated.

PhysicsWeb: **The work by Shou-Cheng Zhang and Jianping Hu of Stanford University in California and Tsinghua University in China might even represent a small step towards one of the ultimate goals in theoretical physics - a quantum theory of gravity (S-C Zhang and J Hu 2001 *Science* 294 823).**



INSTITUTE OF PHYSICS PUBLISHING JOURNAL OF PHYSICS A: MATHEMATICAL AND GENERAL

J. Phys. A: Math. Gen. **36** (2003) 9415–9423 PII: S0305-4470(03)62871-4

Geometric construction of the quantum Hall effect in all even dimensions

Guowu Meng

Department of Mathematics, Hong Kong University of Science and Technology,
Clear Water Bay, Kowloon, Hong Kong, People's Republic of China

E-mail: mameng@ust.hk

Received 24 April 2003, in final form 27 June 2003
Published 27 August 2003
Online at stacks.iop.org/JPhysA/36/9415

http://stacks.iop.org/ja/36/9415

Abstract

The quantum Hall effects in all even dimensions are uniformly constructed. Contrary to some recent accounts in the literature, the existence of quantum Hall effects (QHE) does not *crucially* depend on the existence of division algebras. For QHE on flat space of even dimensions, both the Hamiltonians and the ground-state wavefunctions for a single particle are explicitly described. This explicit description immediately tells us that QHE on a higher even-dimensional flat space shares common features such as incompressibility with QHE on a plane.

JOURNAL OF MATHEMATICAL PHYSICS **46**, 022302 (2005)

Algebraic geometry realization of quantum Hall soliton

R. Abounasr, M. Ait Ben Haddou,[a] A. El Rhalami, and E. H. Saidi[b]
Lab/UFR-Physique des Hautes Energies, Faculté des Sciences de Rabat, Morocco and Groupement National de Physique des Hautes Energies, GNPHE; Siege focal, Rabat, Morocco

(Received 24 September 2004; accepted 29 September 2004;
published online 31 January 2005)

Using the Iqbal–Netzike–Vafa dictionary giving the correspondence between the H_2 homology of del Pezzo surfaces and *p*-branes, we develop a way to approach the system of brane bounds in M-theory on S^1. We first review the structure of 10-dimensional quantum Hall soliton (QHS) from the view of M-theory on S^1. Then, we show how the *D*0 dissolution in *D*2-brane is realized in M-theory language and derive the *p*-brane constraint equations used to define appropriately the QHS. Finally, we build an algebraic geometry realization of the QHS in type IIA superstring and show how to get its type IIB dual. Other aspects are also discussed. [DOI: 10.1063/1.1834695]

IIB string quantum hall

Suche: ● Das Web ○ Seiten auf Deutsch ○ Seiten au

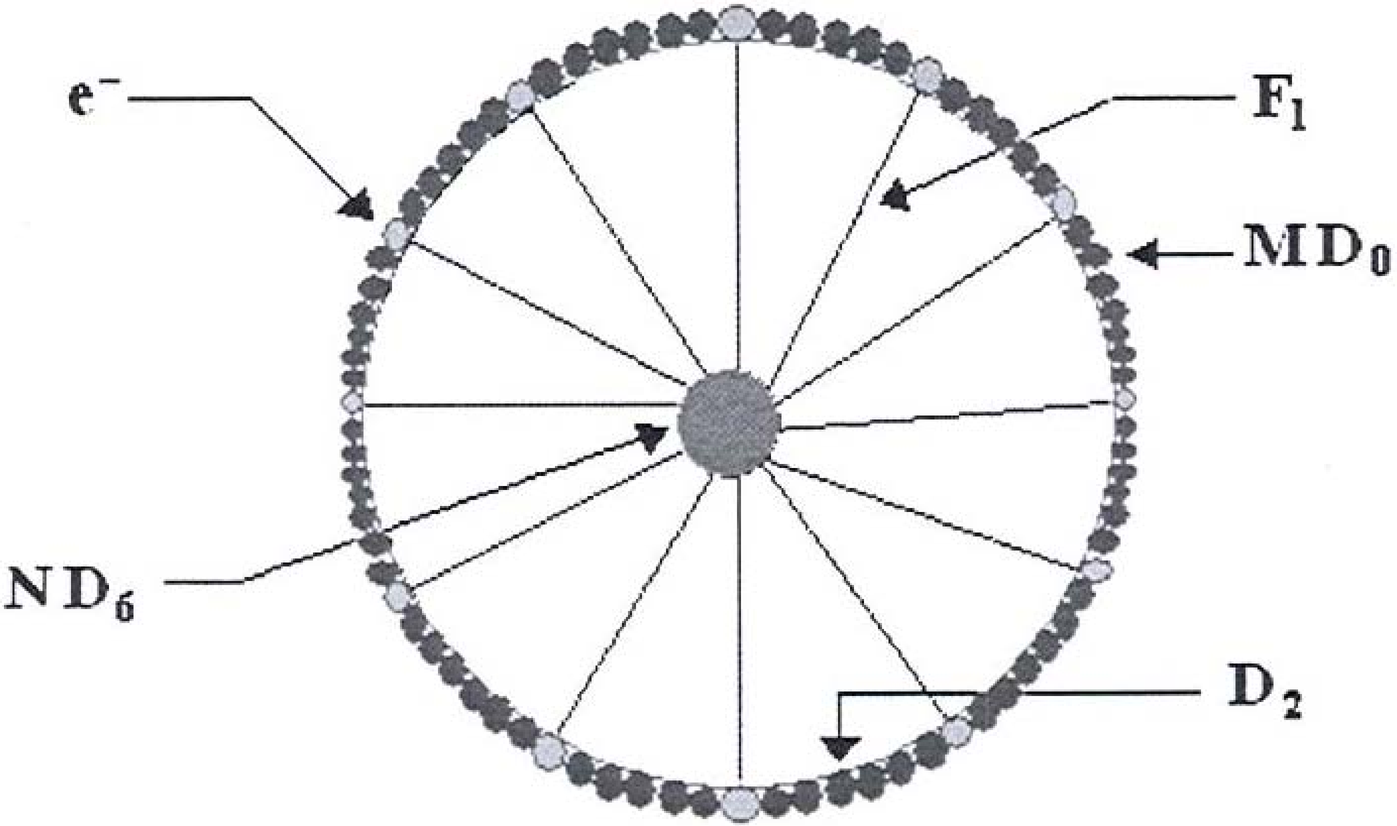
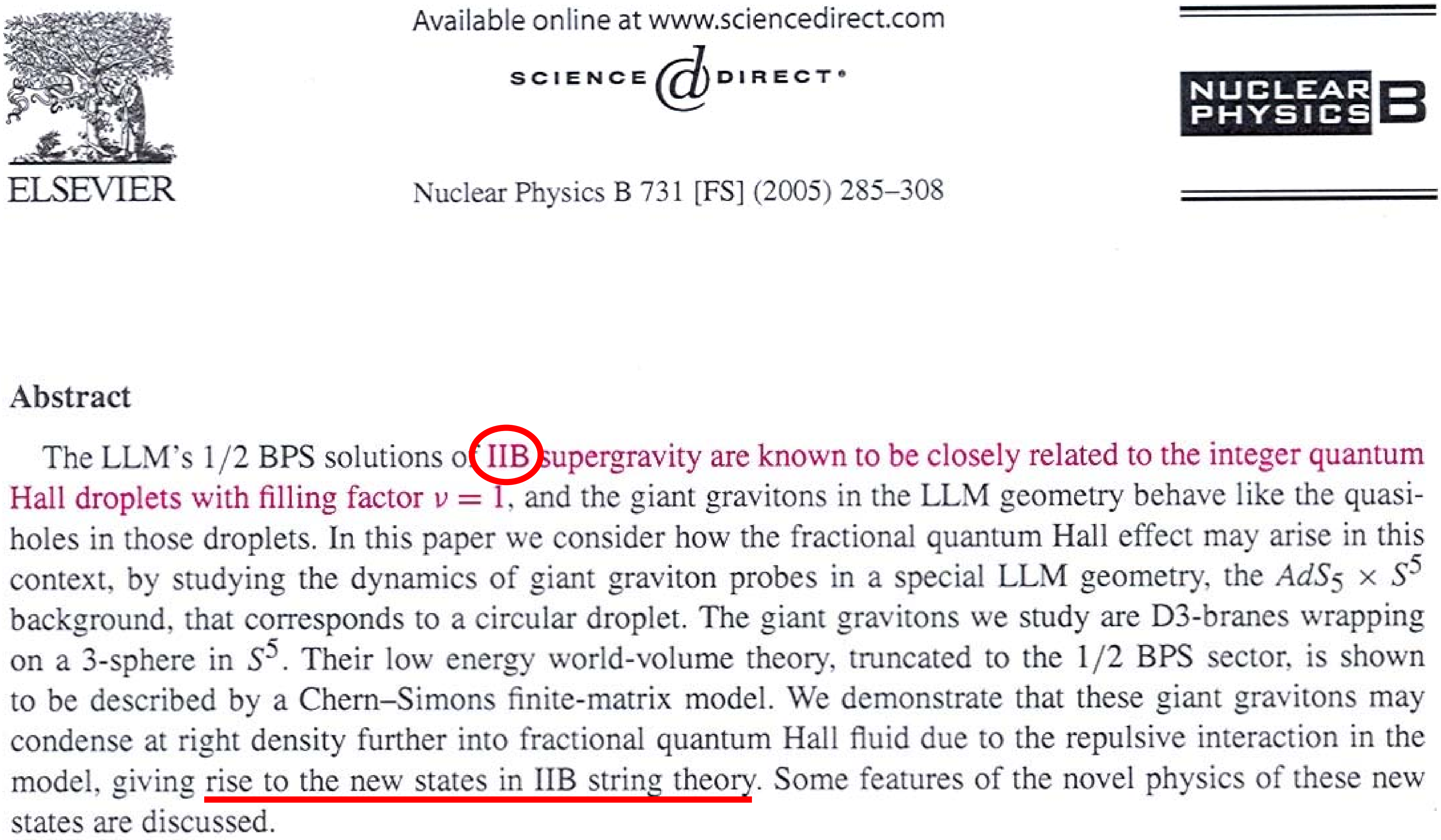


FIG. 1. This figure represents the type IIA stringy representation of a fractional quantum Hall soliton.



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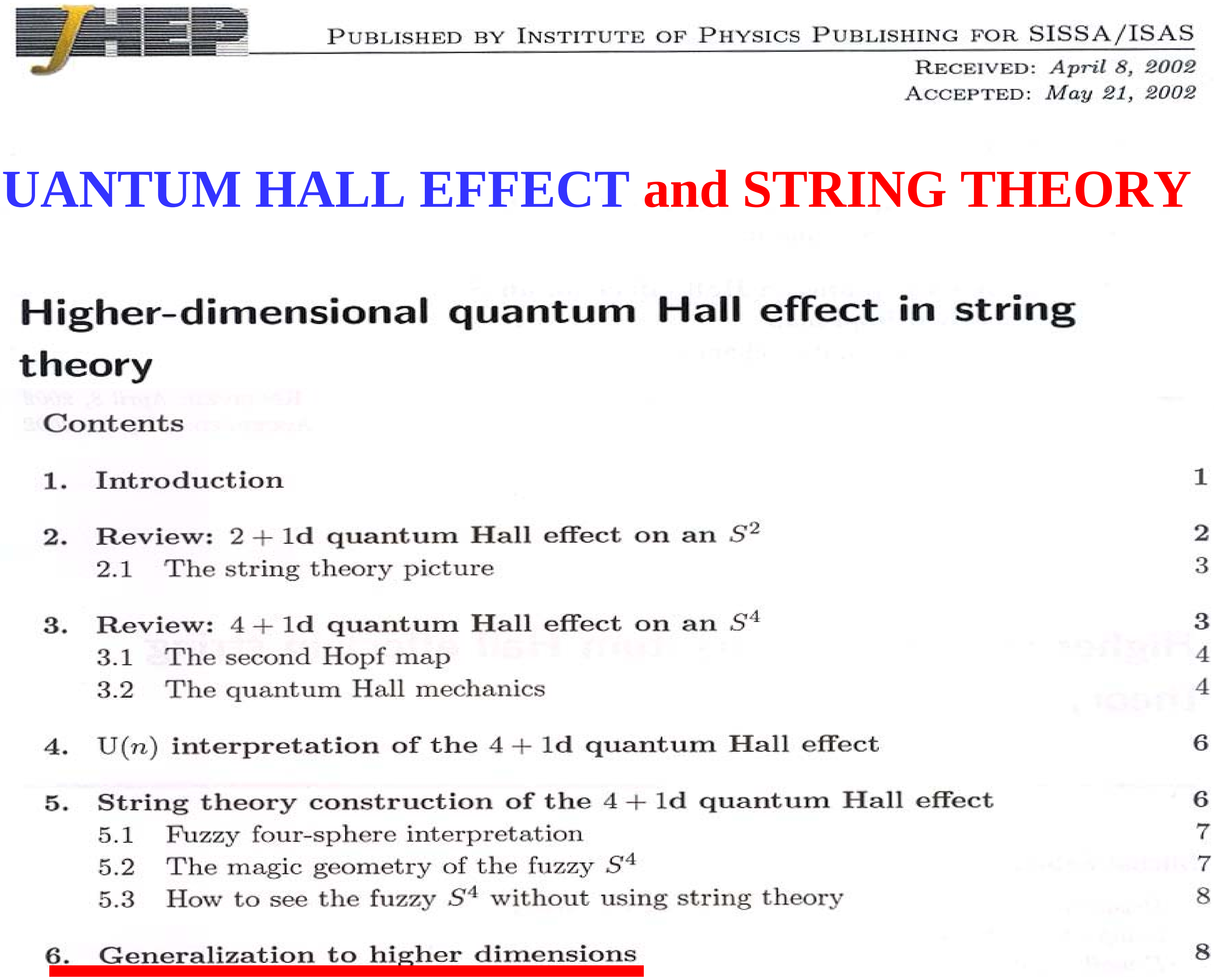
NUCLEAR PHYSICS B

Nuclear Physics B 731 [FS] (2005) 285–308

Abstract

The LLM's 1/2 BPS solutions of IIB supergravity are known to be closely related to the integer quantum Hall droplets with filling factor $\nu = 1$, and the giant gravitons in the LLM geometry behave like the quasi-holes in those droplets. In this paper we consider how the fractional quantum Hall effect may arise in this context, by studying the dynamics of giant graviton probes in a special LLM geometry, the $AdS_5 \times S^5$ background, that corresponds to a circular droplet. The giant gravitons we study are D3-branes wrapping on a 3-sphere in S^5. Their low energy world-volume theory, truncated to the 1/2 BPS sector, is shown to be described by a Chern–Simons finite-matrix model. We demonstrate that these giant gravitons may condense at right density further into fractional quantum Hall fluid due to the repulsive interaction in the model, giving rise to the new states in IIB string theory. Some features of the novel physics of these new states are discussed.

QUANTUM HALL EFFECT and STRING THEORY



PUBLISHED BY INSTITUTE OF PHYSICS PUBLISHING FOR SISSA/ISAS
RECEIVED: *April 8, 2002*
ACCEPTED: *May 21, 2002*

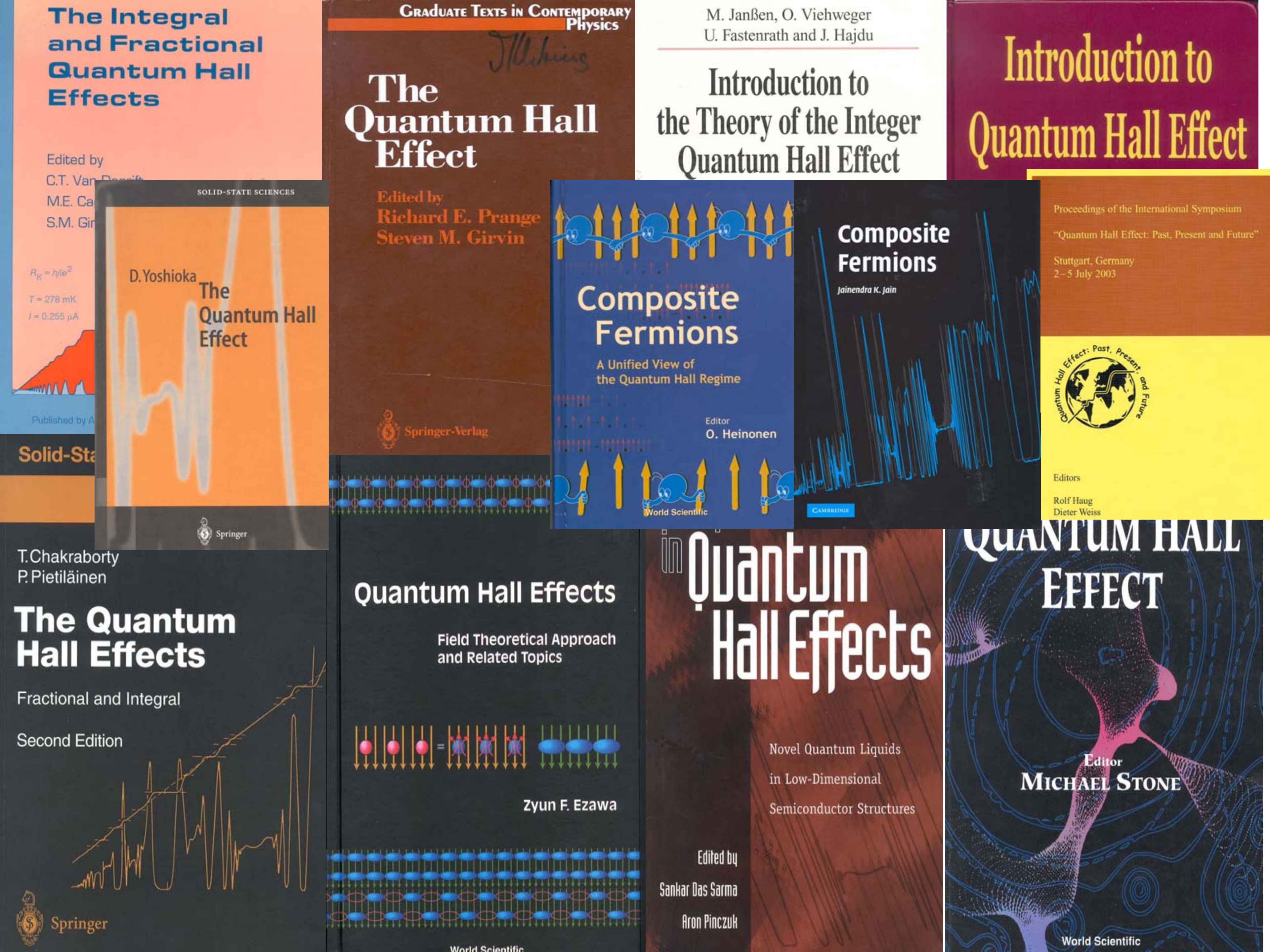
Higher-dimensional quantum Hall effect in string theory

Contents

QUANTUM HALL EFFECT FOR THEORETICIAN

Please don’t ask me questions!
Ask our theoreticians!

A heterotic string is a mixture of the bosonic string and the superstring



The Integral and Fractional Quantum Hall Effects

Edited by
C.T. Van
M.E. Ca
S.M. Gi

$R_K = h/ie^2$
$T = 278$ mK
$I = 0.255$ μA

Published by A

Solid-Sta

SOLID-STATE SCIENCES

D. Yoshioka
The Quantum Hall Effect

Springer

GRADUATE TEXTS IN CONTEMPORARY PHYSICS

The Quantum Hall Effect

Edited by
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Steven M. Girvin

Springer-Verlag

M. Janßen, O. Viehweger
U. Fastenrath and J. Hajdu

Introduction to the Theory of the Integer Quantum Hall Effect

Introduction to Quantum Hall Effect

Composite Fermions
A Unified View of the Quantum Hall Regime

Editor
O. Heinonen

World Scientific

Composite Fermions
Jainendra K. Jain

CAMBRIDGE

Proceedings of the International Symposium
"Quantum Hall Effect: Past, Present and Future"
Stuttgart, Germany
2–5 July 2003

Quantum Hall Effect: Past, Present, and Future

Editors
Rolf Haug
Dieter Weiss

T. Chakraborty
P. Pietiläinen

The Quantum Hall Effects
Fractional and Integral
Second Edition

Springer

Quantum Hall Effects
Field Theoretical Approach and Related Topics

Zyun F. Ezawa

World Scientific

in Quantum Hall Effects

Novel Quantum Liquids in Low-Dimensional Semiconductor Structures

Edited by
Sankar Das Sarma
Aron Pinczuk

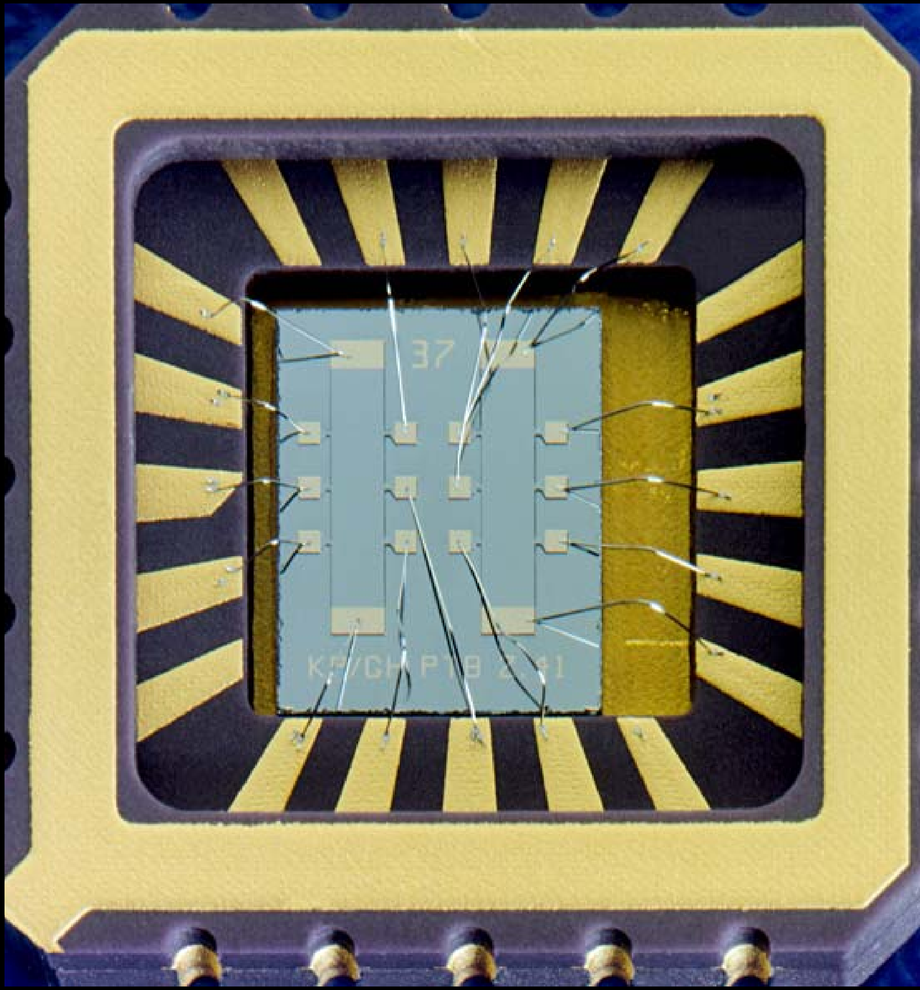
QUANTUM HALL EFFECT

Editor
MICHAEL STONE

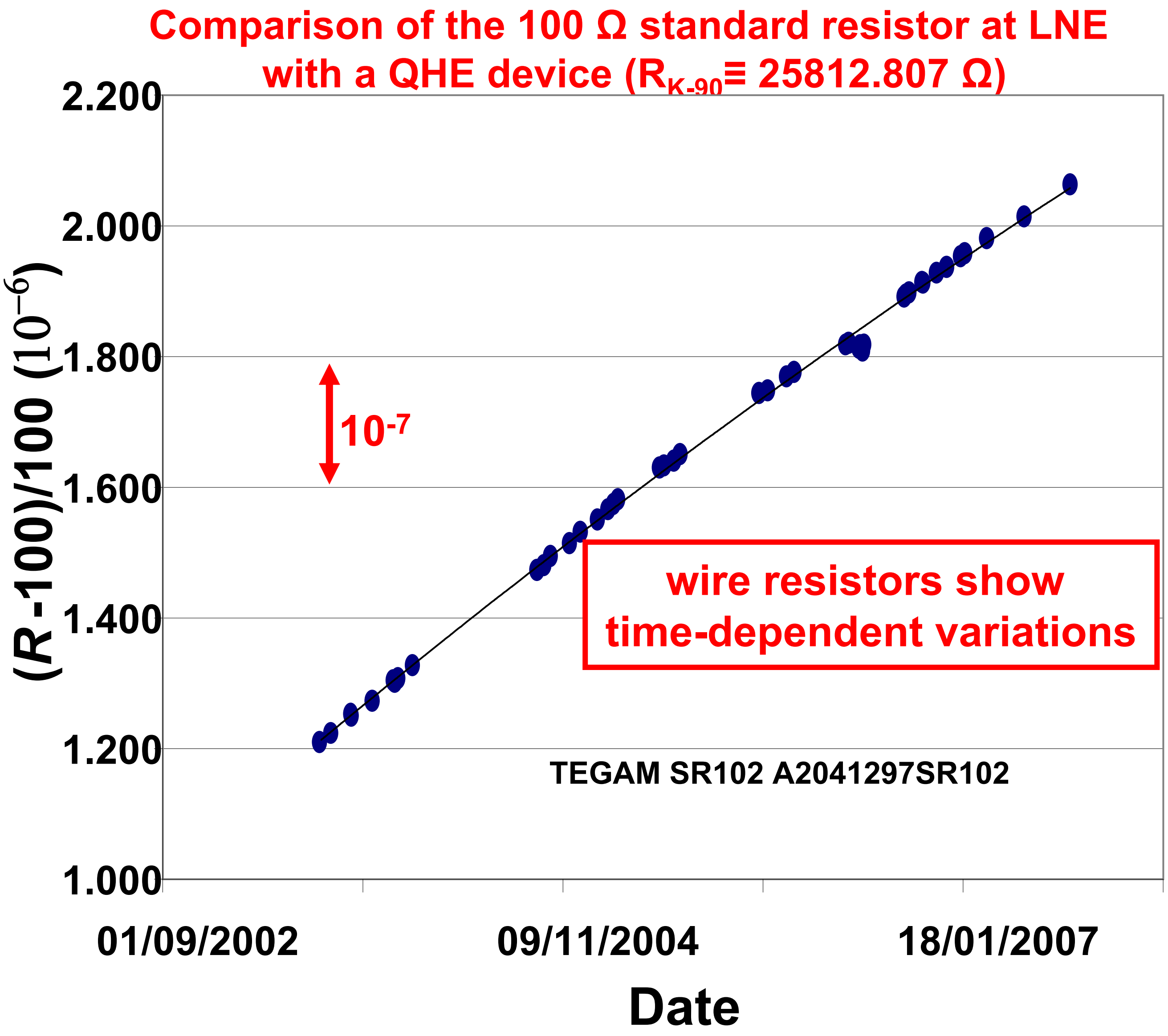
World Scientific

QUANTUM HALL EFFECT

Most Important Application of QHE:

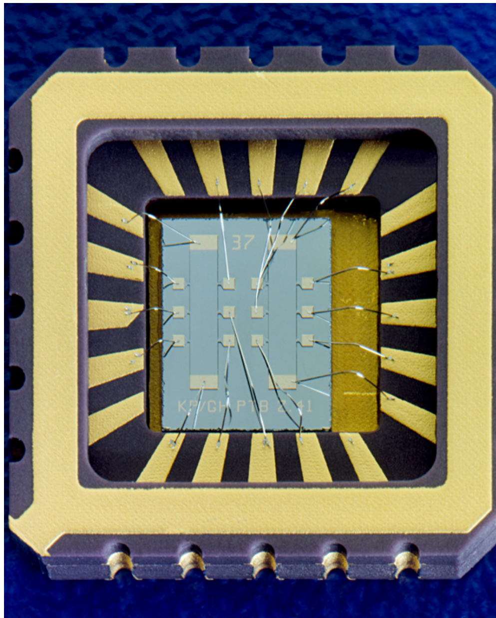


QHE against wire resistor



Comparison of the 100 Ω standard resistor at LNE with a QHE device ($R_{K-90} \equiv 25812.807\ \Omega$)

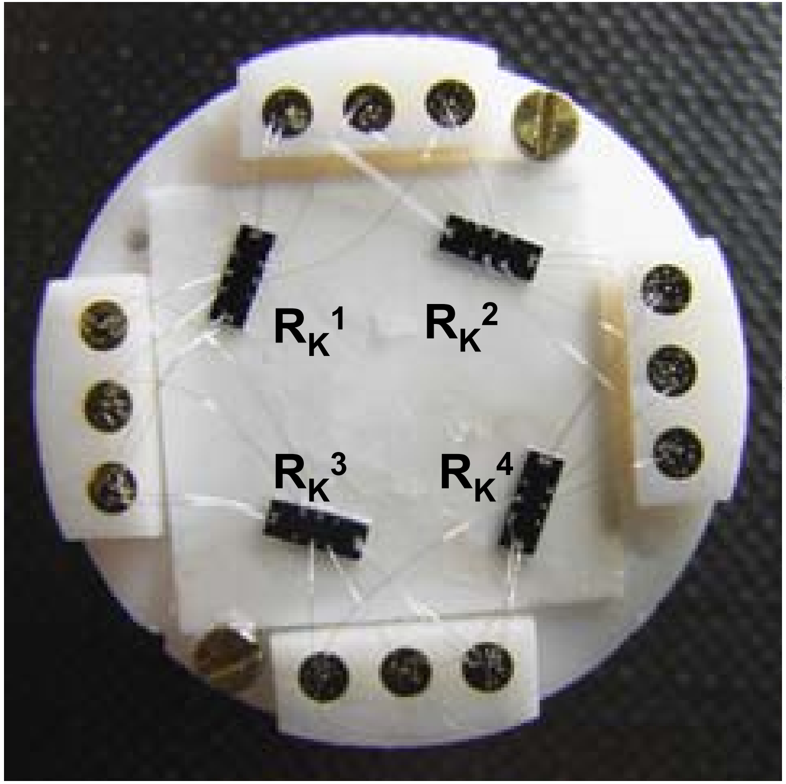
wire resistors show time-dependent variations



Comparison between four different QHE devices

(F.Schopfer, 2006)

Wheatstone bridge



If output voltage = 0,
all resistances $R_K^{1,2,3,4}$ are identical
(interchange of input and output)

Result:

$R_K^{1,2,3,4}$ identical within an accuracy of some parts in 10^{11}

*(acquisition time **t = 46 000 s**)*

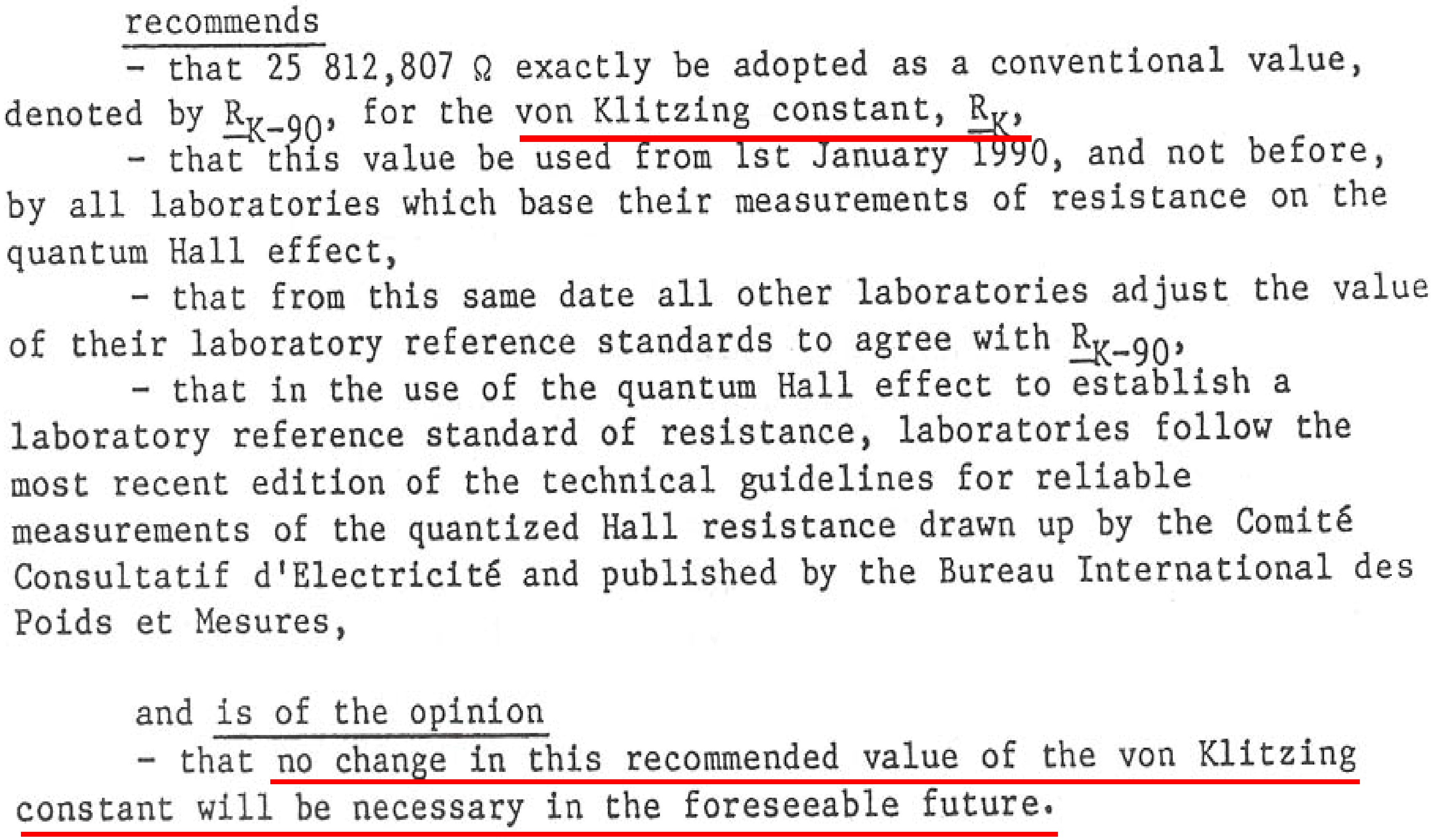
$$R_K = 25812{,}807\text{xxx}\ \ \Omega$$

x-digits unknown within our *International System of Units (SI)*

Recommendations

Comité International des Poids et Mesures

(October 4-6, 1988)



recommends

- that 25 812,807 Ω exactly be adopted as a conventional value, denoted by R_{K-90}, for the von Klitzing constant, R_K,

- that this value be used from 1st January 1990, and not before, by all laboratories which base their measurements of resistance on the quantum Hall effect,

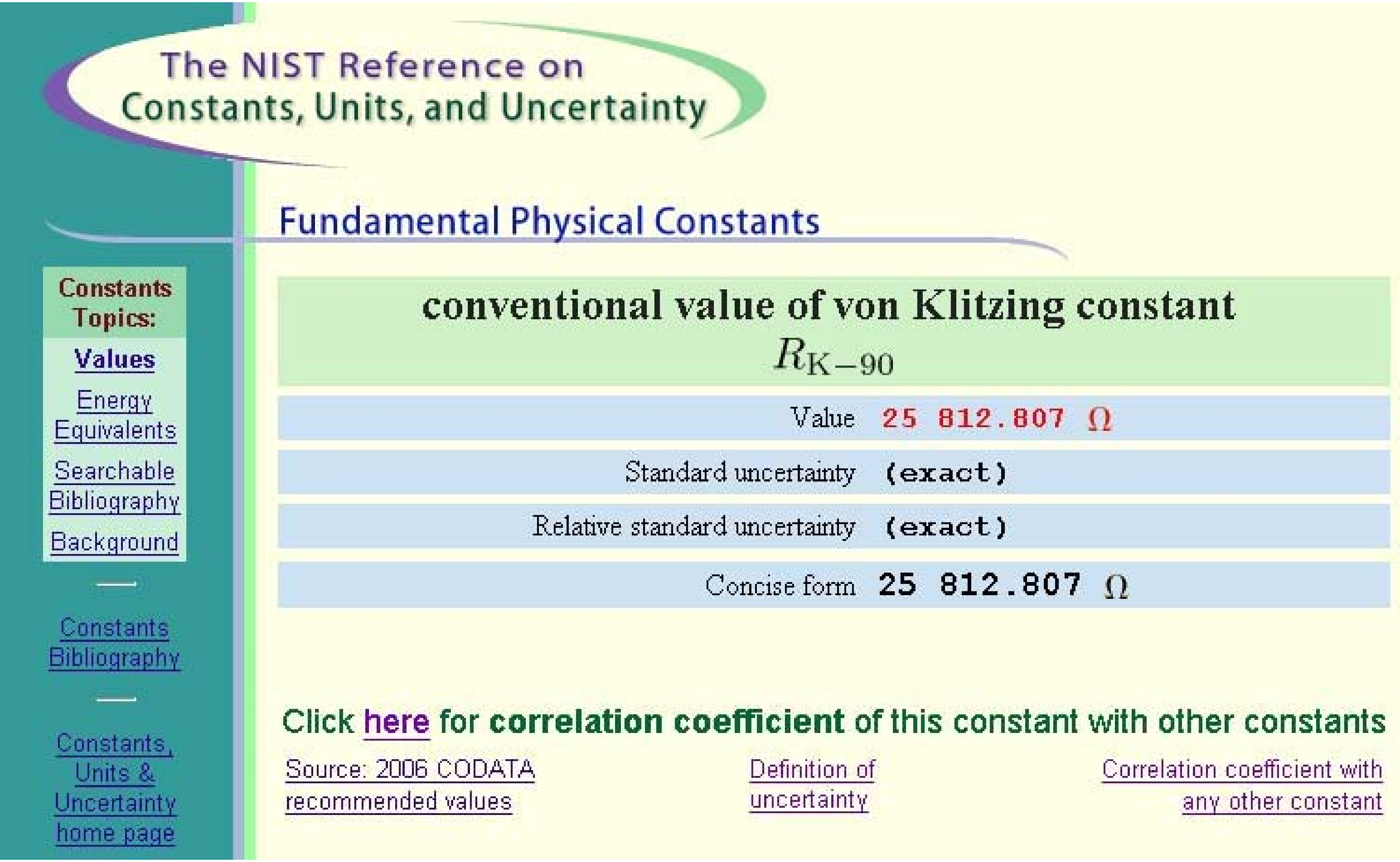
- that from this same date all other laboratories adjust the value of their laboratory reference standards to agree with R_{K-90},

- that in the use of the quantum Hall effect to establish a laboratory reference standard of resistance, laboratories follow the most recent edition of the technical guidelines for reliable measurements of the quantized Hall resistance drawn up by the Comité Consultatif d'Electricité and published by the Bureau International des Poids et Mesures,

and is of the opinion

- that no change in this recommended value of the von Klitzing constant will be necessary in the foreseeable future.

http://physics.nist.gov/cuu/Constants/index.html



The NIST Reference on
Constants, Units, and Uncertainty

Fundamental Physical Constants

Constants Topics:

- **Values**
- Energy Equivalents
- Searchable Bibliography
- Background

—

Constants Bibliography

—

Constants, Units & Uncertainty home page

conventional value of von Klitzing constant
R_{K-90}

Value	25 812.807 Ω
Standard uncertainty	(exact)
Relative standard uncertainty	(exact)
Concise form	25 812.807 Ω

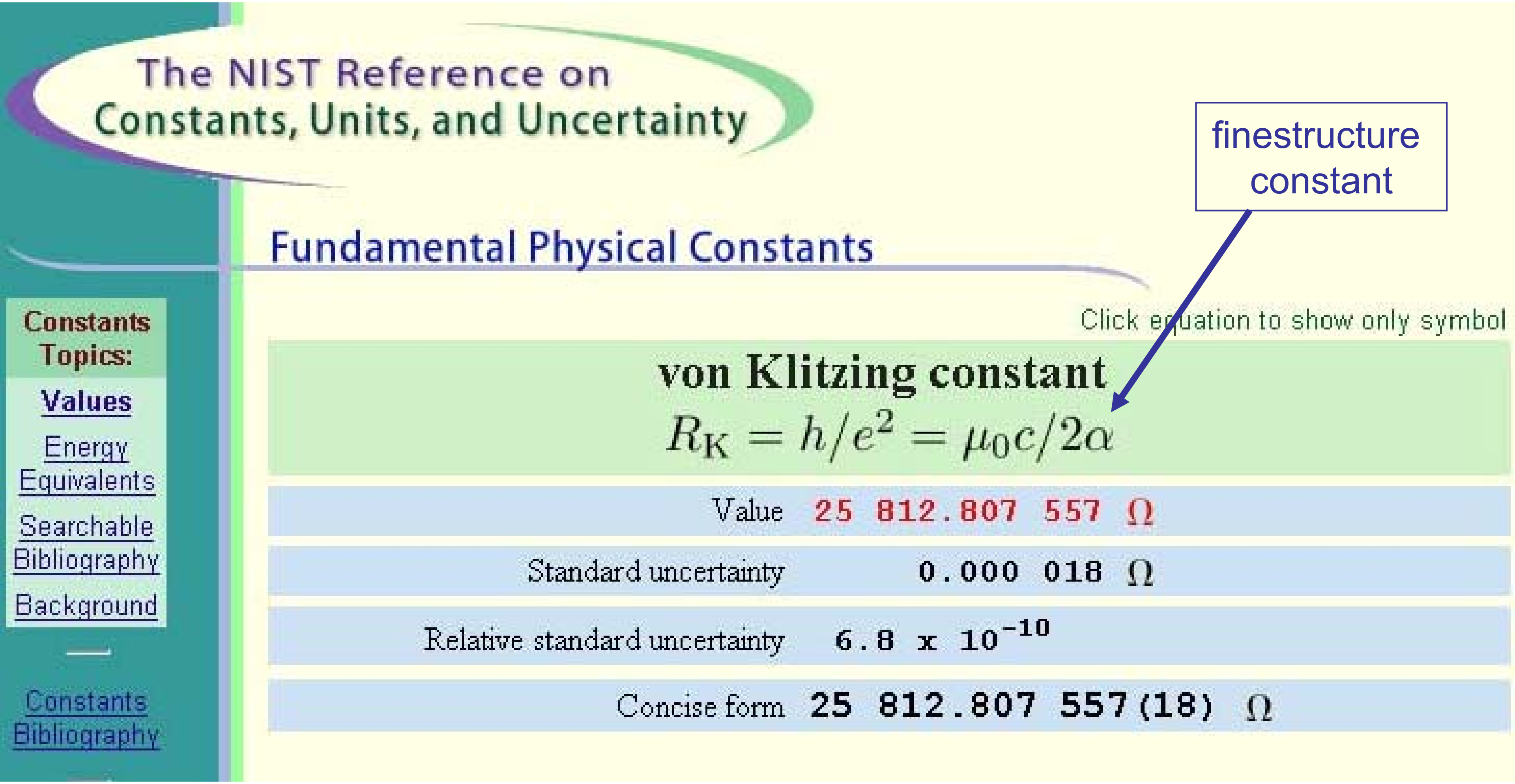
Click here for **correlation coefficient** of this constant with other constants

Source: 2006 CODATA recommended values

Definition of uncertainty

Correlation coefficient with any other constant

http://physics.nist.gov/cuu/Constants/index.html



The NIST Reference on Constants, Units, and Uncertainty

Fundamental Physical Constants

von Klitzing constant

$$R_K = h/e^2 = \mu_0 c/2\alpha$$

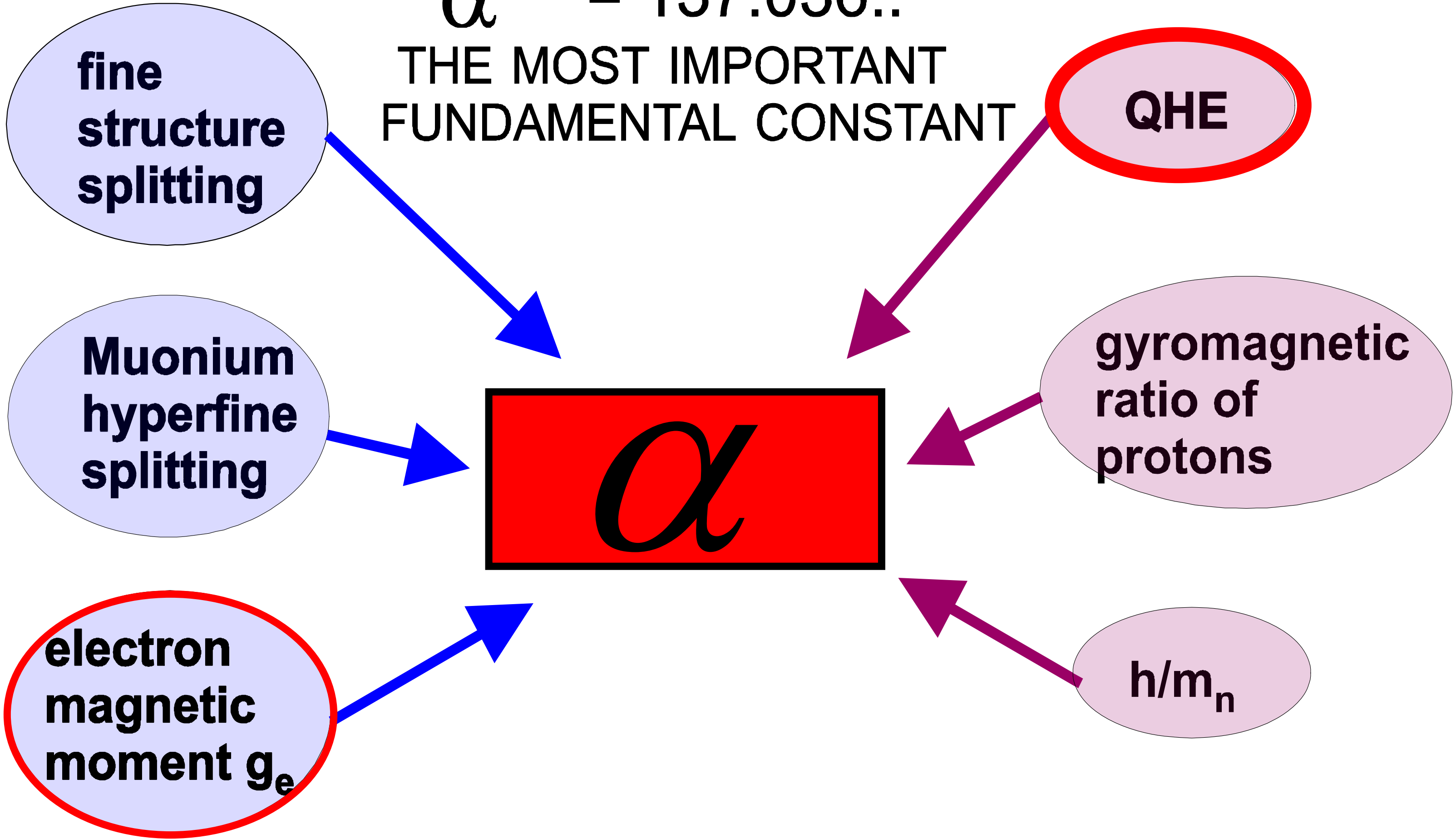
Value	25 812.807 557 Ω
Standard uncertainty	0.000 018 Ω
Relative standard uncertainty	6.8×10^{-10}
Concise form	25 812.807 557(18) Ω

finestructure constant

Different routes to ALPHA

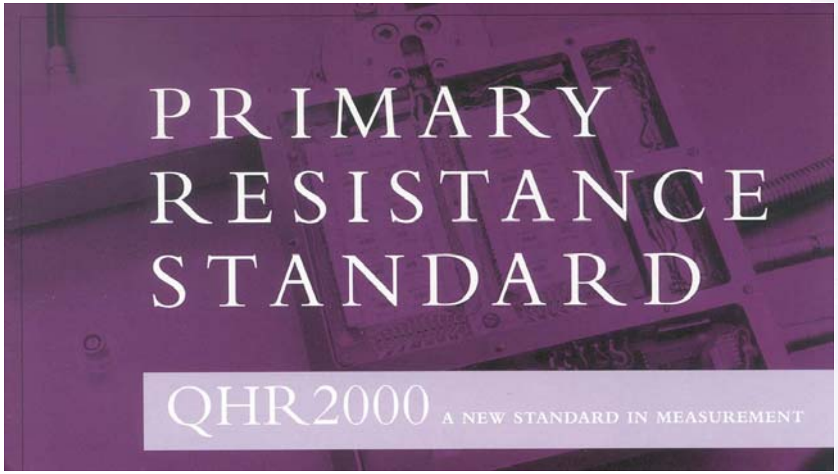
$$\alpha^{-1} = 137.036..$$

THE MOST IMPORTANT
FUNDAMENTAL CONSTANT



QED-THEORY
NECESSARY

WITHOUT
QED


PRIMARY
RESISTANCE
STANDARD

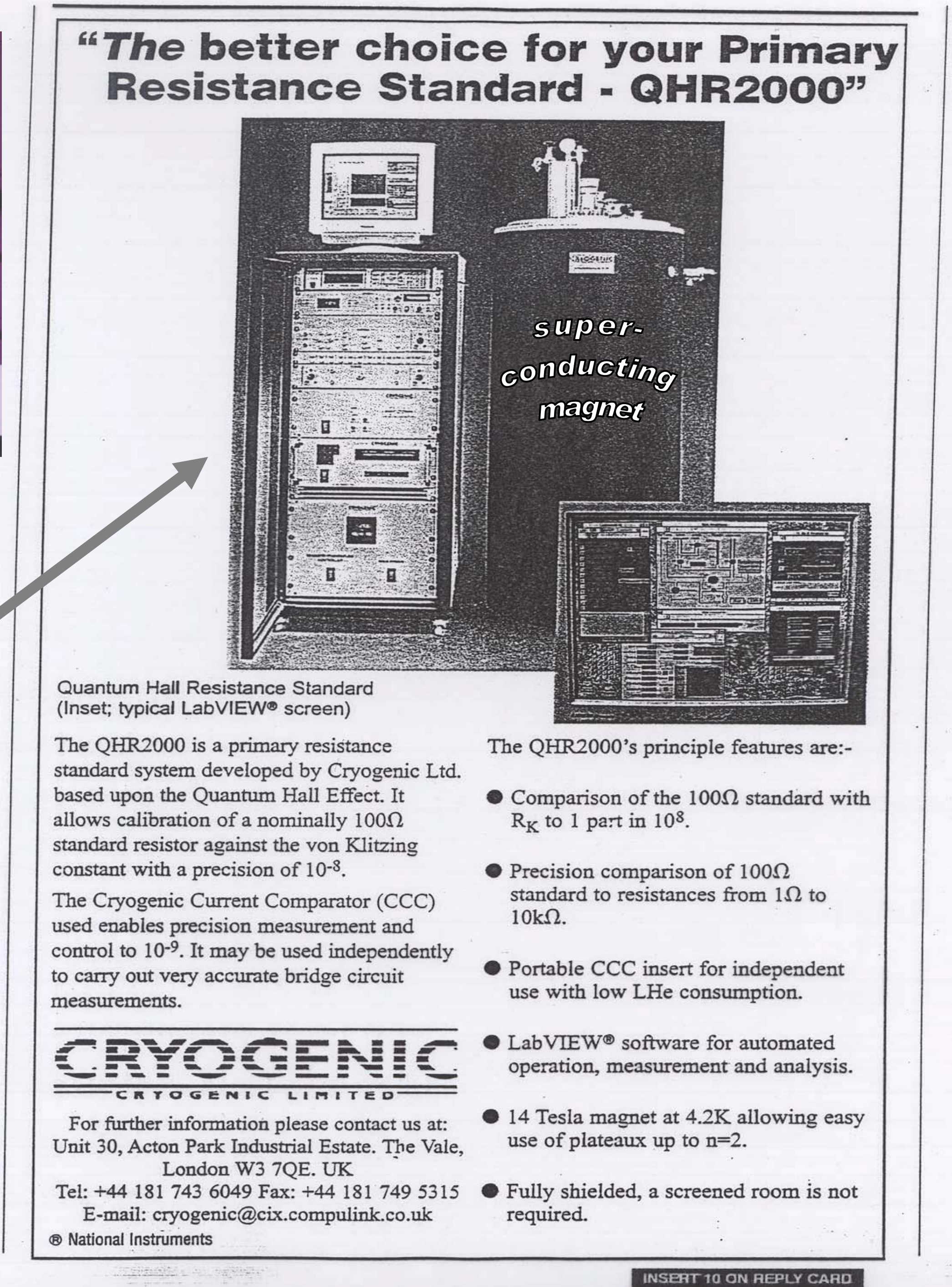
QHR2000 A NEW STANDARD IN MEASUREMENT

EVERYONE IN THE WORLD

(if he spends about 300 T€ for this equipment)

IS ABLE TO CALIBRATE RESISTANCES WITH AN UNCERTAINTY OF LESS THAN 10^{-8}

R_{K-90}


"The better choice for your Primary Resistance Standard - QHR2000"

Quantum Hall Resistance Standard
(Inset; typical LabVIEW® screen)

The QHR2000 is a primary resistance standard system developed by Cryogenic Ltd. based upon the Quantum Hall Effect. It allows calibration of a nominally 100Ω standard resistor against the von Klitzing constant with a precision of 10^{-8}.

The Cryogenic Current Comparator (CCC) used enables precision measurement and control to 10^{-9}. It may be used independently to carry out very accurate bridge circuit measurements.

CRYOGENIC
CRYOGENIC LIMITED

For further information please contact us at:
Unit 30, Acton Park Industrial Estate. The Vale,
London W3 7QE. UK
Tel: +44 181 743 6049 Fax: +44 181 749 5315
E-mail: cryogenic@cix.compulink.co.uk

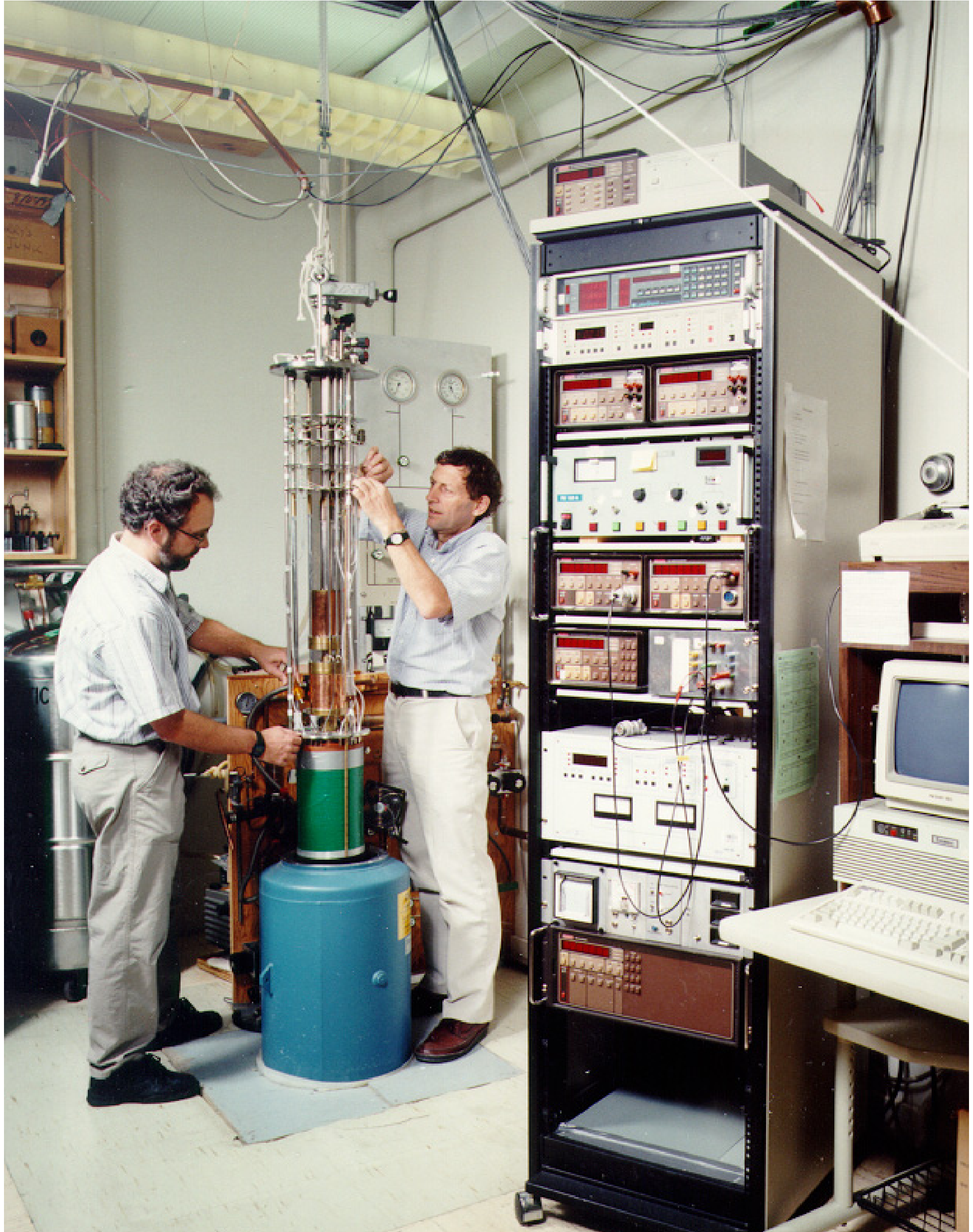
® National Instruments

The QHR2000's principle features are:-

- Comparison of the 100Ω standard with R_K to 1 part in 10^8.
- Precision comparison of 100Ω standard to resistances from 1Ω to 10kΩ.
- Portable CCC insert for independent use with low LHe consumption.
- LabVIEW® software for automated operation, measurement and analysis.
- 14 Tesla magnet at 4.2K allowing easy use of plateaux up to n=2.
- Fully shielded, a screened room is not required.

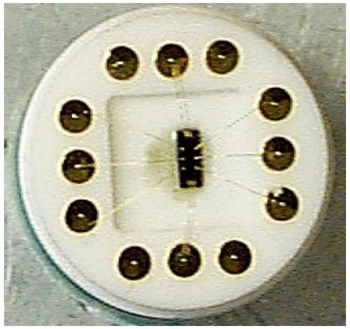
INSERT 10 ON REPLY CARD

DC Quantum Hall - resistance



Primary Standard

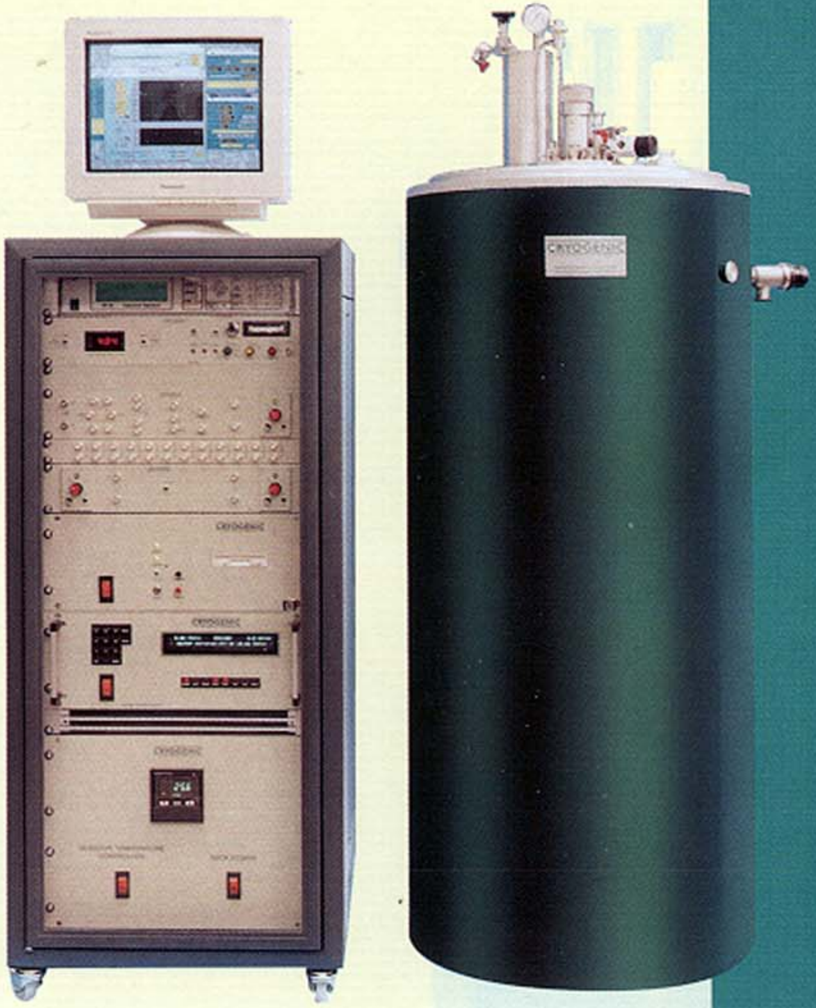
14T Magnet
^{3}He Cryostat
CCC Bridge
DC samples from



LEP, DFM
PTB, OFMET
NRC, ...

www.cryogenic.co.uk

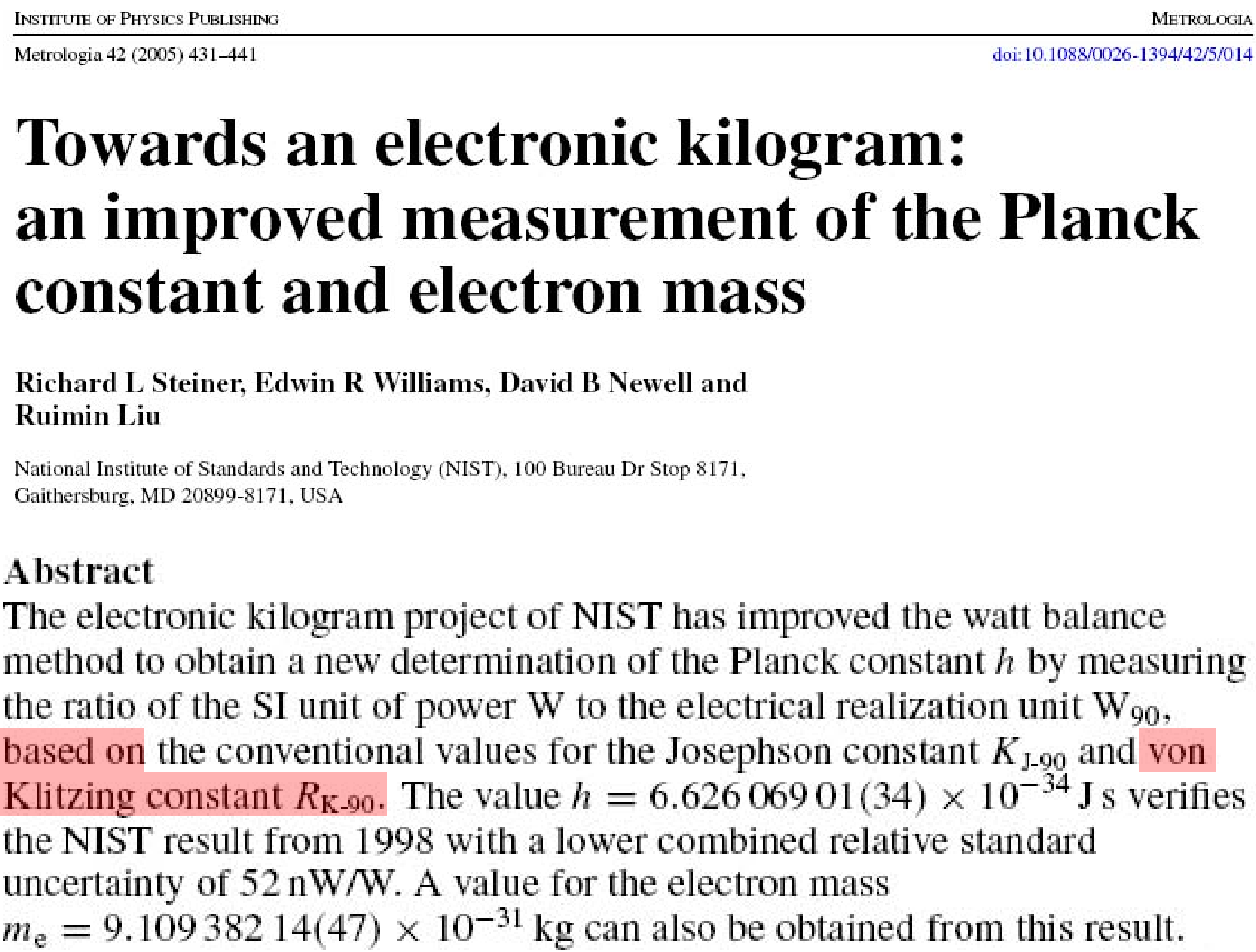
CRYOGENIC
CRYOGENIC LIMITED



NEW QHR MAGNET FOR THE NPL

Cryogenic has been selected once again by the National Physical Laboratory (NPL) to design and manufacture a high field magnet complete with a low loss cryostat for Quantum Hall Metrology. The magnet has been delivered for use as a Quantum Hall Resistance transfer standard. It will form part of a basic physics and fundamental constant experiment, which seeks to determine the kilogram in terms of electrical standards. This follows a successful delivery of a similar project carried out for the Physikalisch-Technische Bundesanstalt (PTB) in Germany last year. The system is installed in a stainless steel cryostat and provides a 14 Tesla magnetic field.

Cryogenic have also supplied the NPL with a glass fibre helium cryostat with HTS leads to be used for their 100 Amp Cryogenic Current Comparator for precision metrology.



INSTITUTE OF PHYSICS PUBLISHING METROLOGIA

Metrologia 42 (2005) 431–441 doi:10.1088/0026-1394/42/5/014

Towards an electronic kilogram: an improved measurement of the Planck constant and electron mass

Richard L Steiner, Edwin R Williams, David B Newell and Ruimin Liu

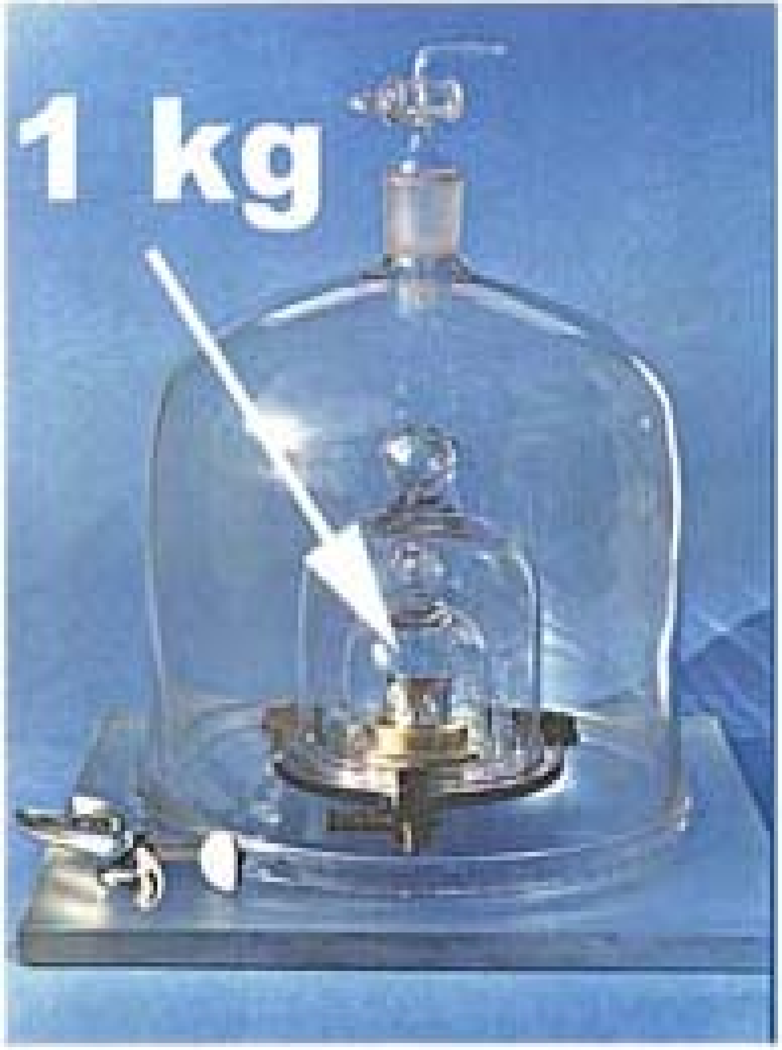
National Institute of Standards and Technology (NIST), 100 Bureau Dr Stop 8171,
Gaithersburg, MD 20899-8171, USA

Abstract

The electronic kilogram project of NIST has improved the watt balance method to obtain a new determination of the Planck constant h by measuring the ratio of the SI unit of power W to the electrical realization unit W_{90}, based on the conventional values for the Josephson constant $K_{J\text{-}90}$ and von Klitzing constant $R_{K\text{-}90}$. The value $h = 6.626\,069\,01(34) \times 10^{-34}$ J s verifies the NIST result from 1998 with a lower combined relative standard uncertainty of 52 nW/W. A value for the electron mass $m_e = 9.109\,382\,14(47) \times 10^{-31}$ kg can also be obtained from this result.

SI base unit for the MASS

ONLY ONE OFFICIAL kg
IN THE WORLD (prototype)




3sat

Once a year the safe is opened

Safe in
Paris

Official definition:

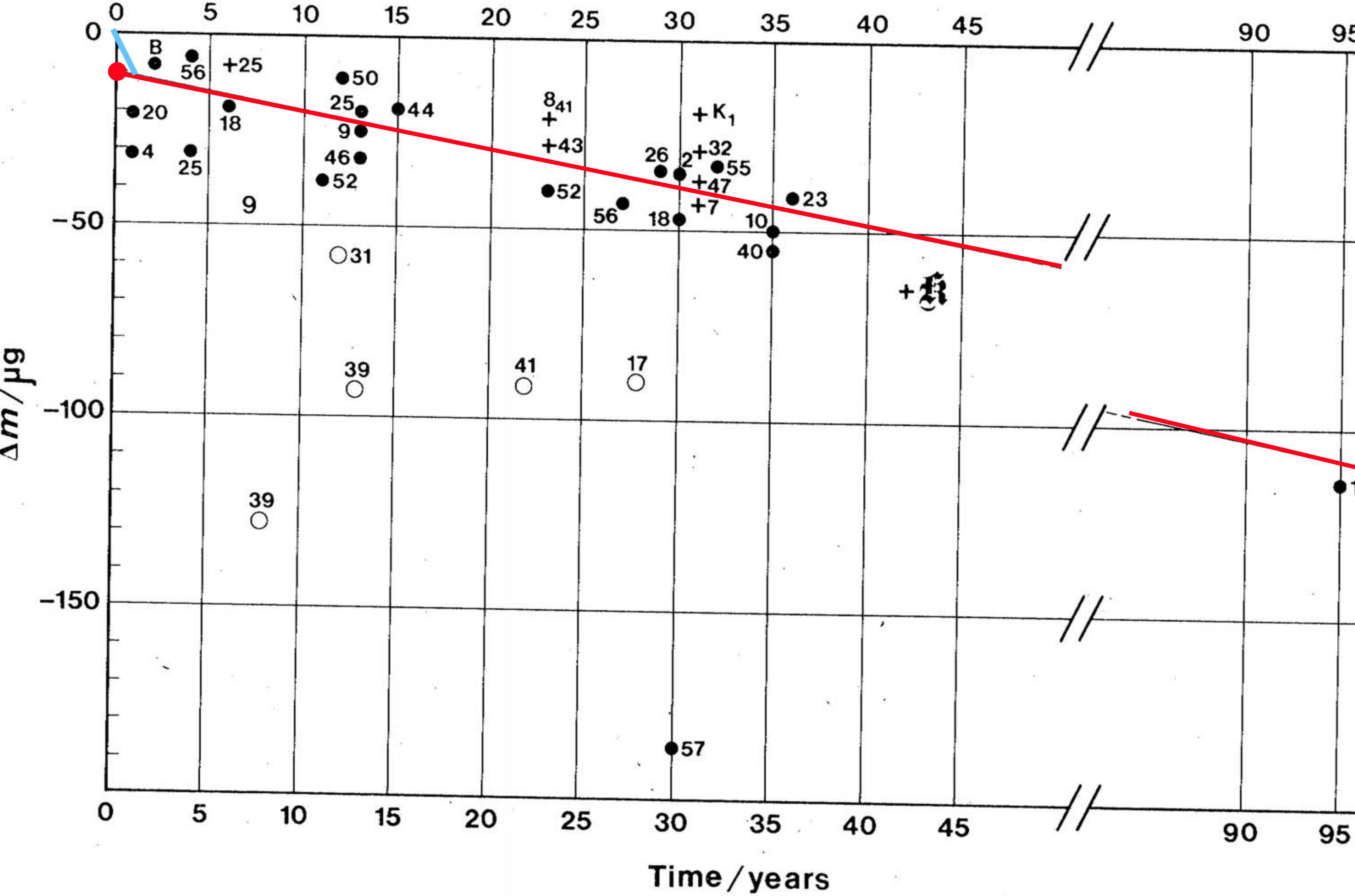
“The Kilogram is equal to the mass of the International Prototype of the Kilogram **after cleaning and washing using the BIPM method.”**

(CIPM, 1989)

BIPM Cleaning Method

- Rub artifact with chamois cloth soaked in ether / alcohol mixture.
- Wash in a jet of steam.

mass change after cleaning



INSTITUTE OF PHYSICS PUBLISHING METROLOGIA

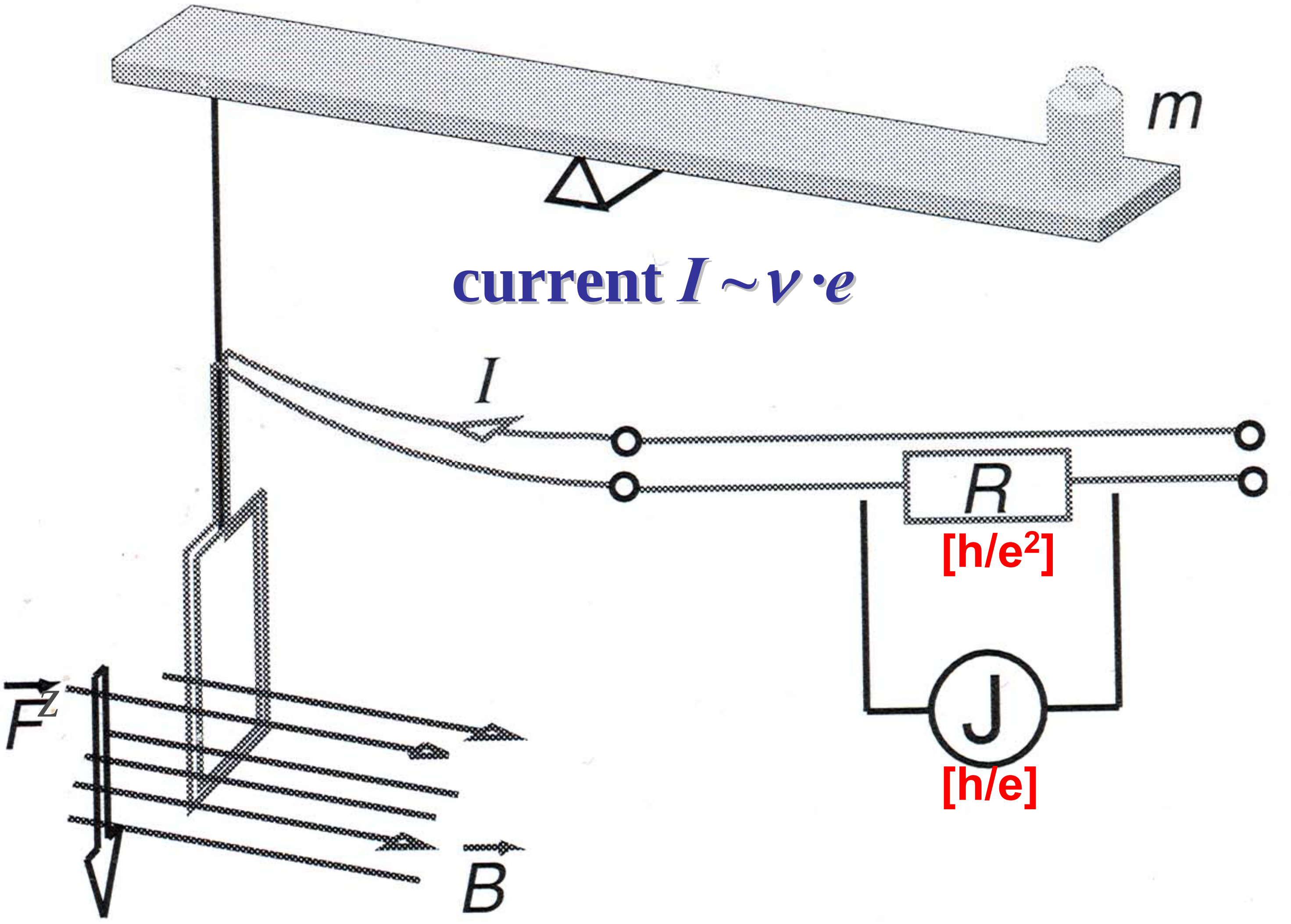
Metrologia **42** (2005) 71–80 doi:10.1088/0026-1394/42/2/001

Redefinition of the kilogram: a decision whose time has come

Ian M Mills[1], Peter J Mohr[2], Terry J Quinn[3], Barry N Taylor[2] and Edwin R Williams[2]

The quantum Hall effect may be important
for the redefinition of the kilogram!!

Watt balance (first part)

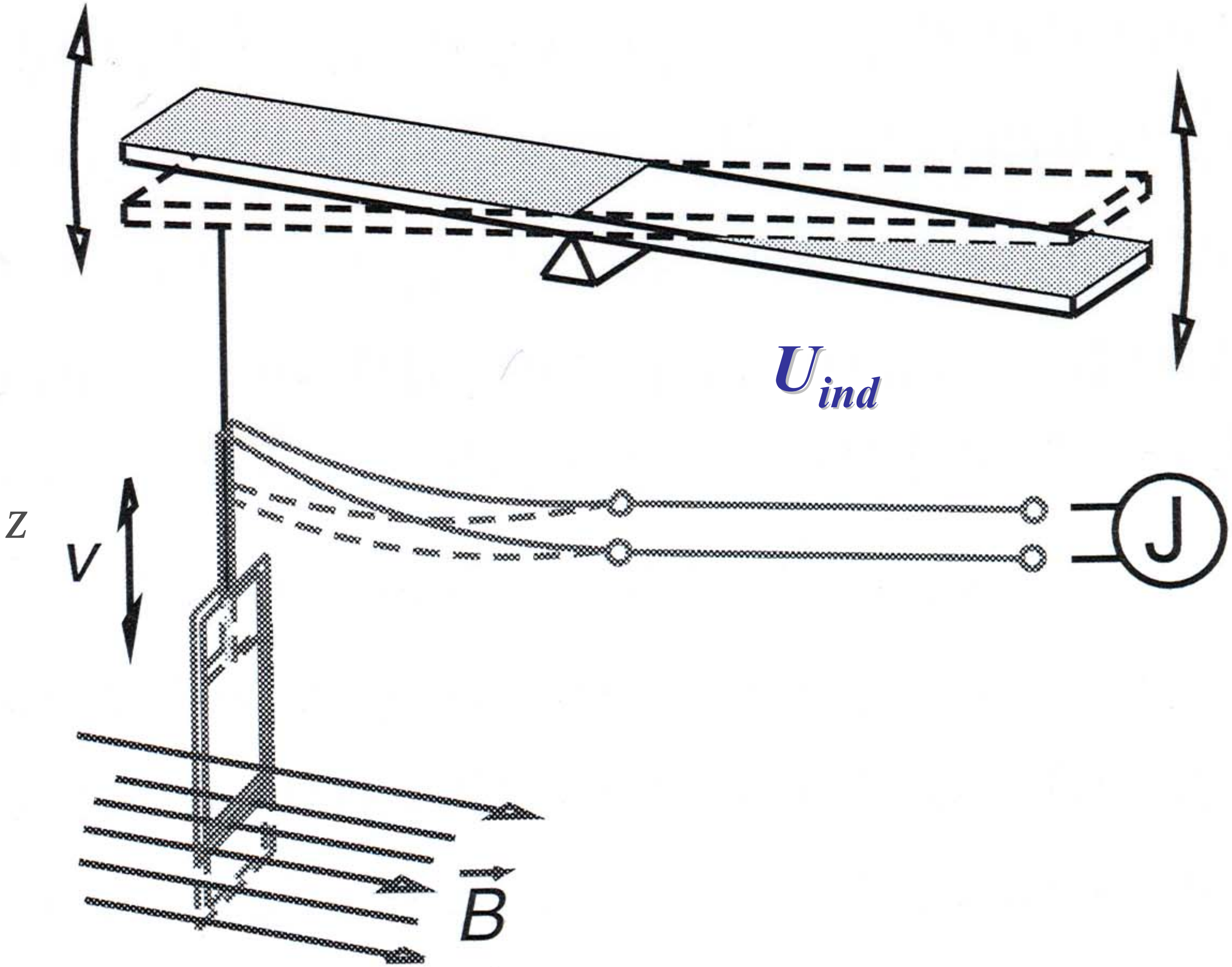


current ***I*** **~** ***ν*·*e***

[h/e²]

[h/e]

Watt balance (second part)



First experiment

Second experiment

$$\boxed{F = -\partial\Phi/\partial z \cdot I}$$

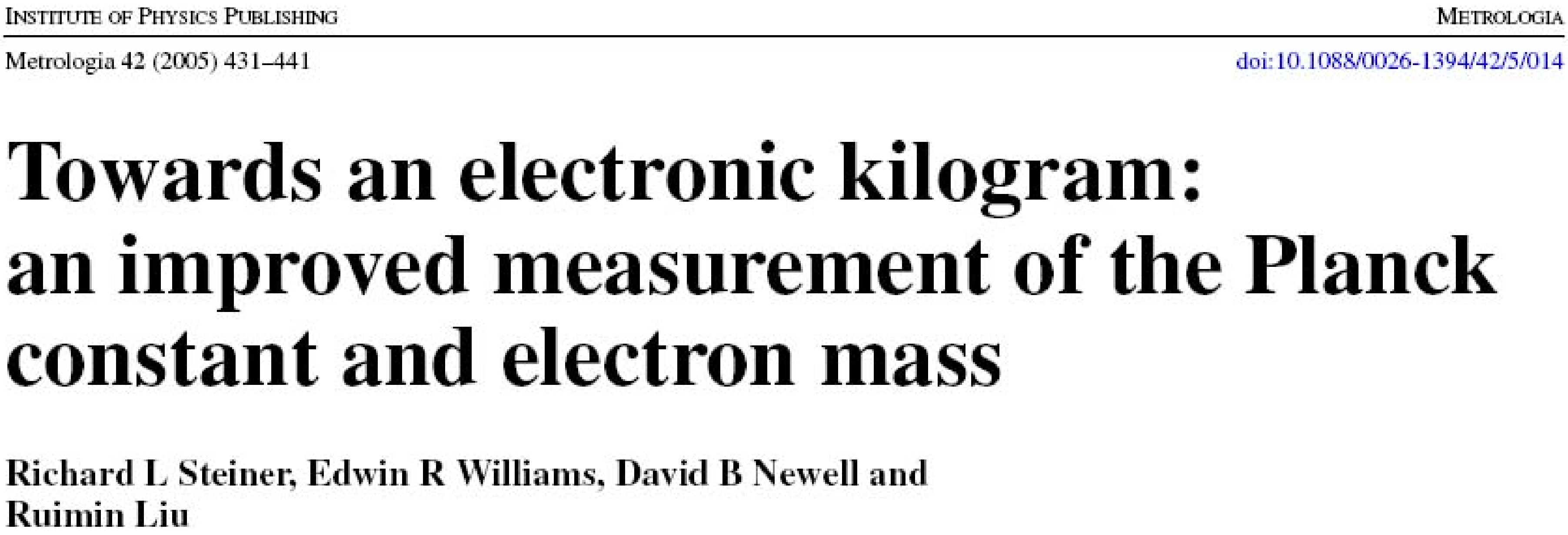
$$\boxed{U_{ind} = -\partial\Phi/\partial z \; v}$$

$$\underset{\sim h/e}{U_{ind}} \cdot \underset{\sim e}{I} = \underset{m\cdot g}{F} \cdot v$$

The most inaccurate quantities in this equation are the Planck constant h and the mass m

$$\mathbf{h \sim m}$$

$h \leftrightarrow m$



INSTITUTE OF PHYSICS PUBLISHING METROLOGIA
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Towards an electronic kilogram: an improved measurement of the Planck constant and electron mass

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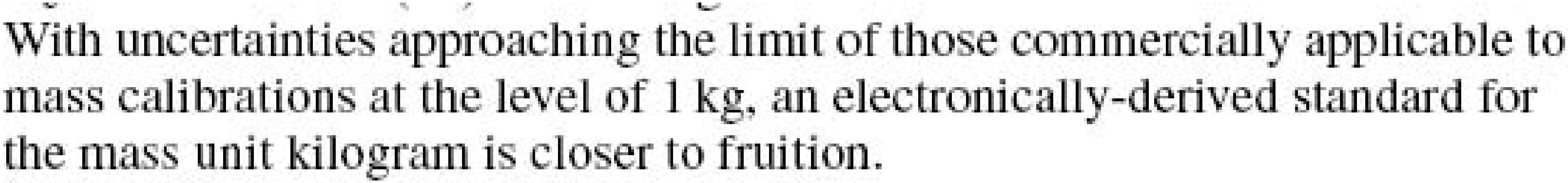


With uncertainties approaching the limit of those commercially applicable to mass calibrations at the level of 1 kg, an electronically-derived standard for the mass unit kilogram is closer to fruition.

A possibility for a new definition of the kilogram in 2011:

The kilogram is the mass, which by comparison of mechanical and electrical power results in a value of the Planck constant of

$h = 6.626\ 069\ 01 \times 10^{-34}$ Js (exact).

electrical power: $U^2/R \sim h$
Josephson voltage $U \sim h/e$
quantized Hall resistance $R \sim h/e^2$

Ann.Physik 1, 69-122 (1900)

Max Planck:

“....with the help of fundamental constants we have the possibility of establishing units of length, time, mass, and temperature, which necessarily retain their significance for all cultures, even unearthly and nonhuman ones.“

NATURAL UNITS

(Max Planck 1899)

length: $$\sqrt{\frac{h\cdot f}{c^3}} = \boxed{4{,}13\cdot 10^{-33}\,cm}$$

mass: $$\sqrt{\frac{h\cdot c}{f}} = \boxed{5{,}56\cdot 10^{-5}\,g}$$

time: $$\sqrt{\frac{h\cdot f}{c^5}} = \boxed{1{,}38\cdot 10^{-43}\,s}$$

temperature: $$\sqrt{\frac{h\cdot c^5}{k^2\cdot f}} = \boxed{3{,}50\cdot 10^{32}\,K}$$

resistance: $$\sqrt{\frac{h^2}{e^4}} = \boxed{2{,}58\cdot 10^{4}\,\Omega}$$

h = Planck constant

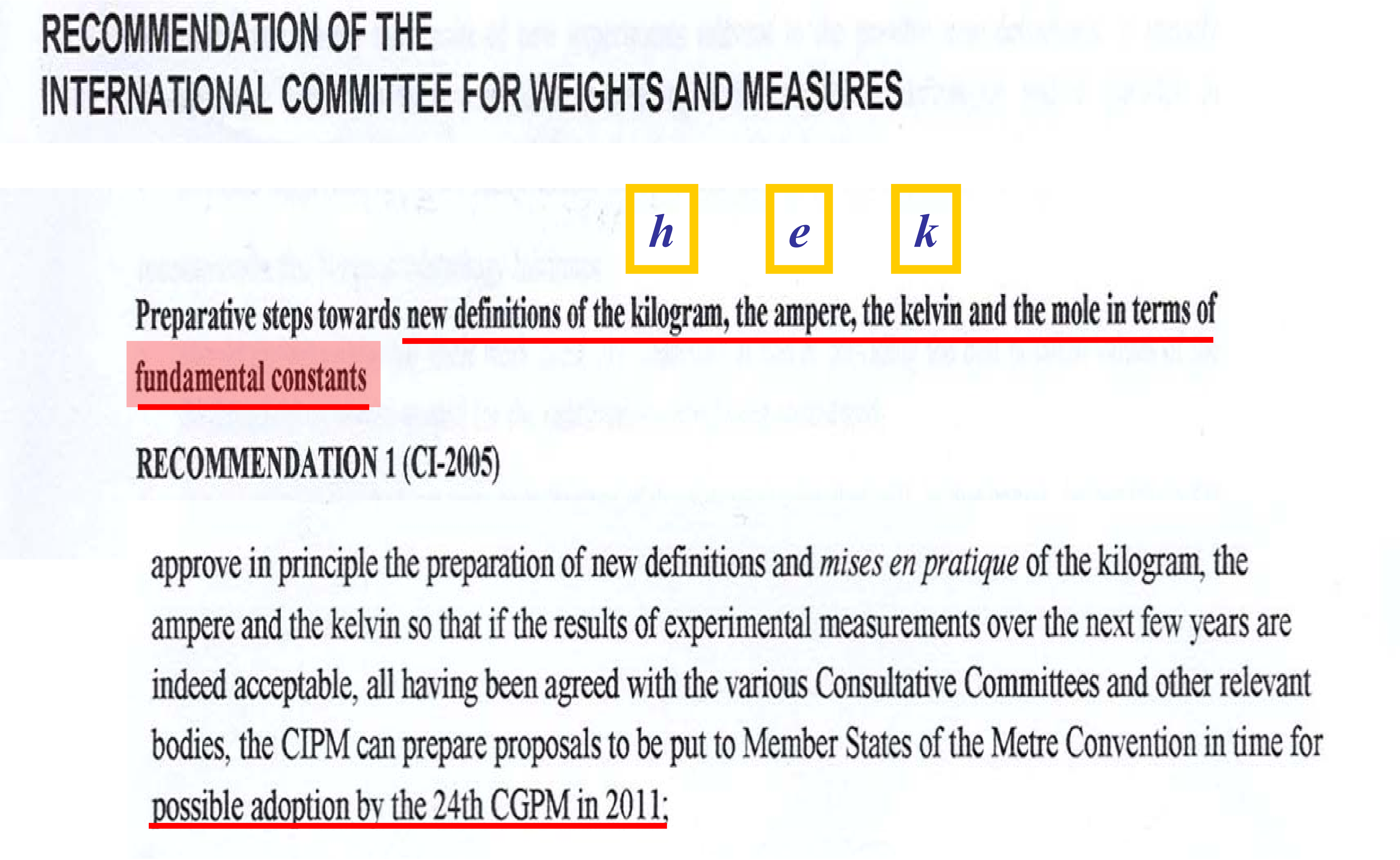
f = gravitational constant

c = light velocity

k = Boltzmann onstant

e = elementary charge

Realization of Planck’s idea?



RECOMMENDATION OF THE
INTERNATIONAL COMMITTEE FOR WEIGHTS AND MEASURES

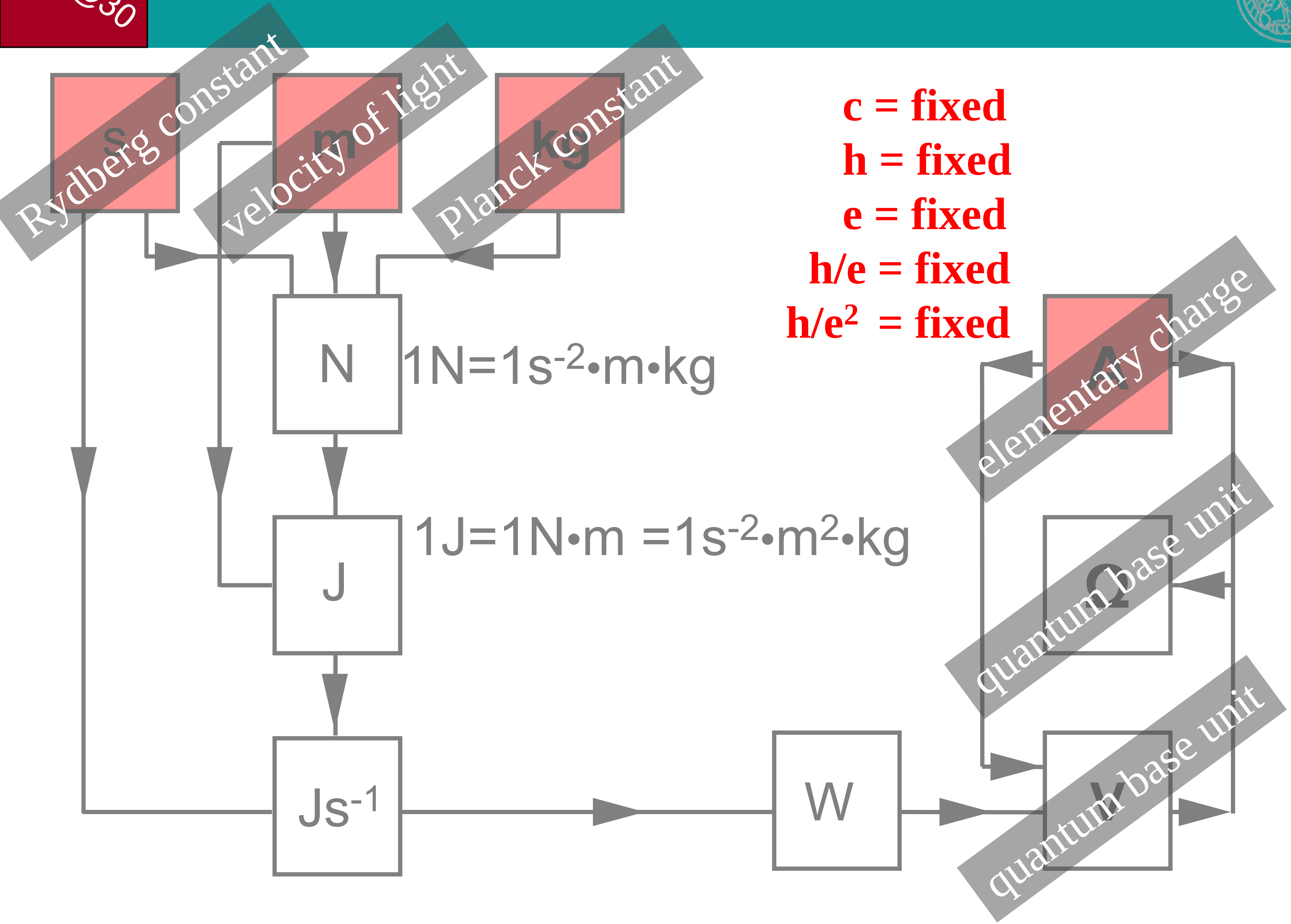
h *e* *k*

Preparative steps towards new definitions of the kilogram, the ampere, the kelvin and the mole in terms of fundamental constants

RECOMMENDATION 1 (CI-2005)

approve in principle the preparation of new definitions and *mises en pratique* of the kilogram, the ampere and the kelvin so that if the results of experimental measurements over the next few years are indeed acceptable, all having been agreed with the various Consultative Committees and other relevant bodies, the CIPM can prepare proposals to be put to Member States of the Metre Convention in time for possible adoption by the 24th CGPM in 2011;

International System (basic SI units)



$1N=1s^{-2}\bullet m\bullet kg$

$1J=1N\bullet m=1s^{-2}\bullet m^{2}\bullet kg$

c = fixed

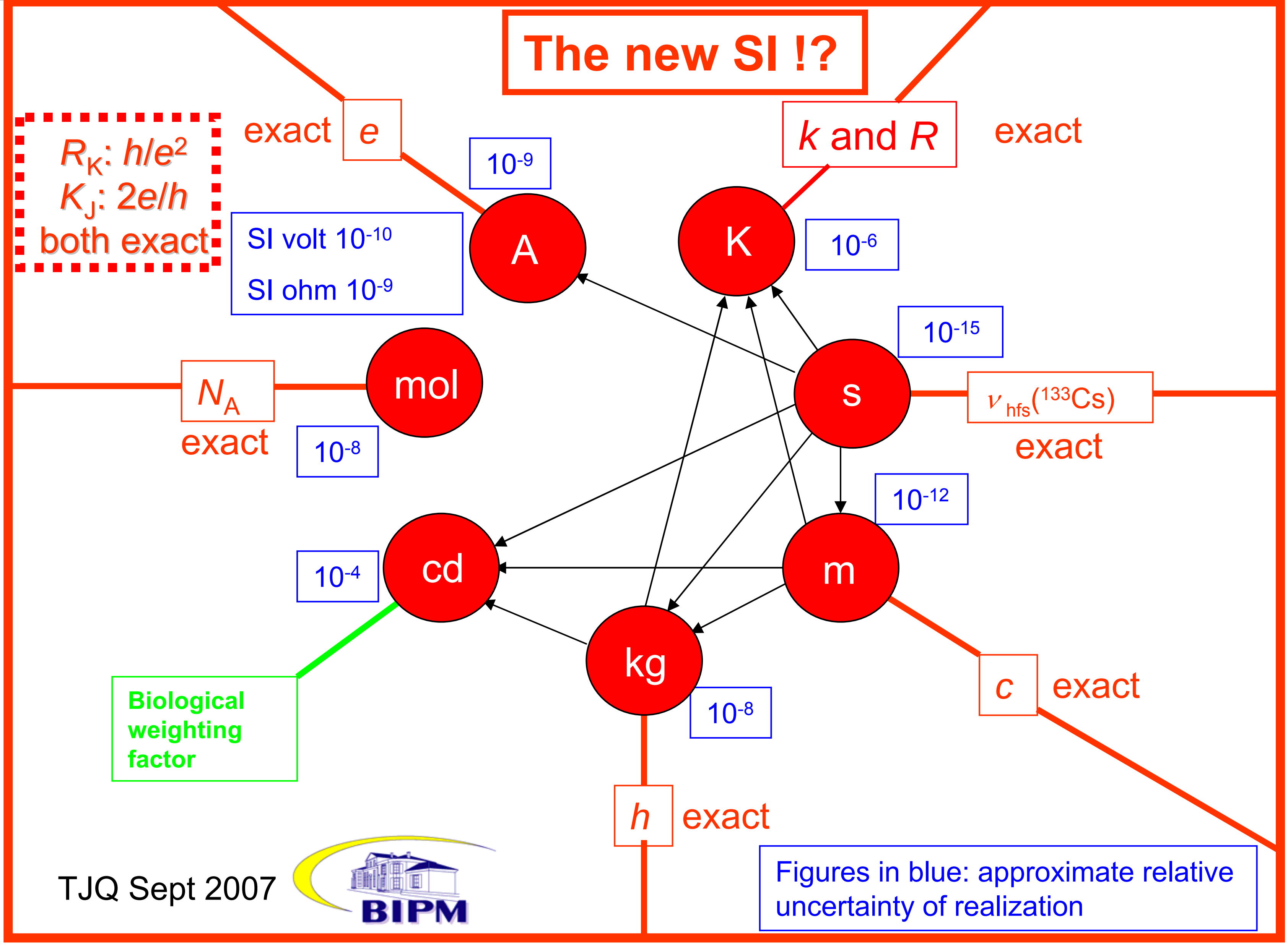
h = fixed

e = fixed

h/e = fixed

h/e^2 = fixed

Fundamental constants and SI units



The new SI !?

R_K: h/e^2
K_J: $2e/h$
both exact

SI volt 10^{-10}
SI ohm 10^{-9}

exact e

10^{-9} A

k and R exact

K 10^{-6}

s 10^{-15}

$\nu_{hfs}(^{133}Cs)$ exact

m 10^{-12}

c exact

N_A exact

mol 10^{-8}

cd 10^{-4}

kg 10^{-8}

h exact

Biological weighting factor

Figures in blue: approximate relative uncertainty of realization

TJQ Sept 2007

BIPM

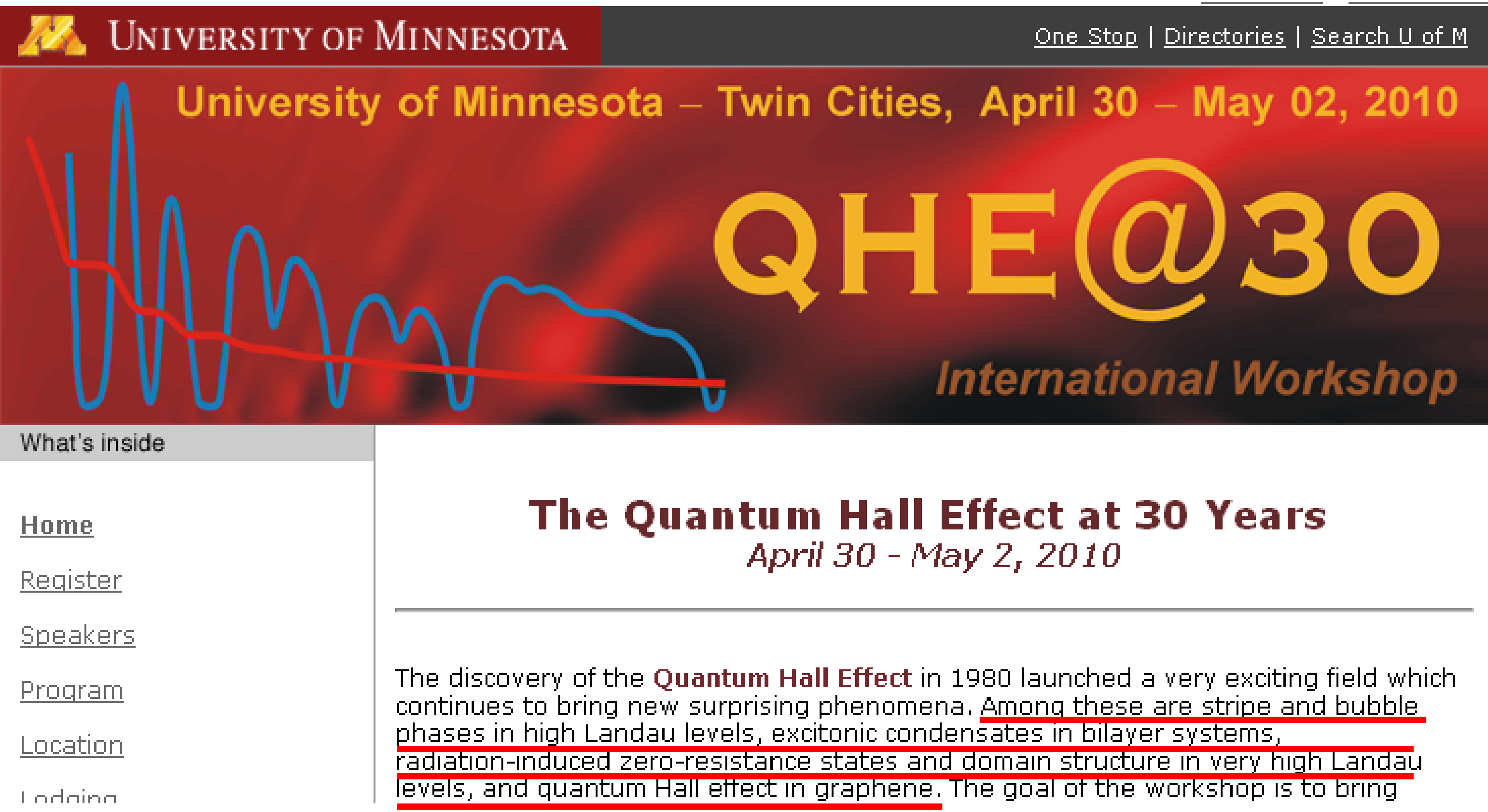
2011 (c, h, e, h/e, h/e^2 fixed)

The End of Quantized Hall Resistance Measurements!?

QHE@30

QHE@30

MPI-FKF



UNIVERSITY OF MINNESOTA

One Stop | Directories | Search U of M

University of Minnesota – Twin Cities, April 30 – May 02, 2010

QHE@30

International Workshop

What's inside

Home

Register

Speakers

Program

Location

Lodging

The Quantum Hall Effect at 30 Years

April 30 - May 2, 2010

The discovery of the **Quantum Hall Effect** in 1980 launched a very exciting field which continues to bring new surprising phenomena. Among these are stripe and bubble phases in high Landau levels, excitonic condensates in bilayer systems, radiation-induced zero-resistance states and domain structure in very high Landau levels, and quantum Hall effect in graphene. The goal of the workshop is to bring

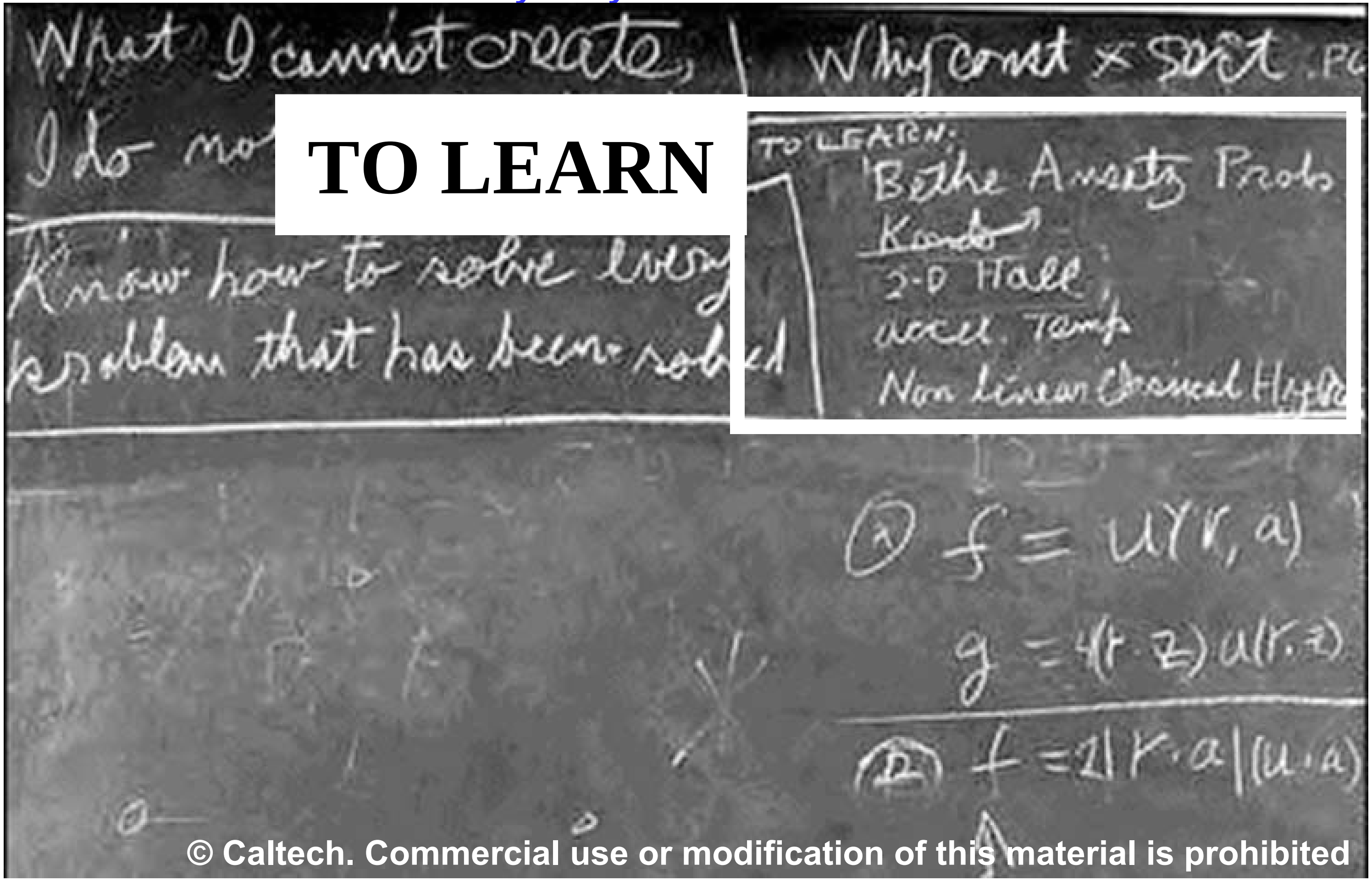
Richard Feynman (* 1918; † 1988)

There's Plenty of Room at the Bottom

An Invitation to Enter a New Field of Physics

(published **February 1960** in Engineering and Science)

Final blackboard left by Feynman in his office when he died:



What I cannot create, I do no

Know how to solve every problem that has been solved

Why const × sort PC

TO LEARN

TO LEARN:
Bethe Ansatz Probs
Kondo
2-D Hall
accel. Temp
Non Linear Classical Hydro

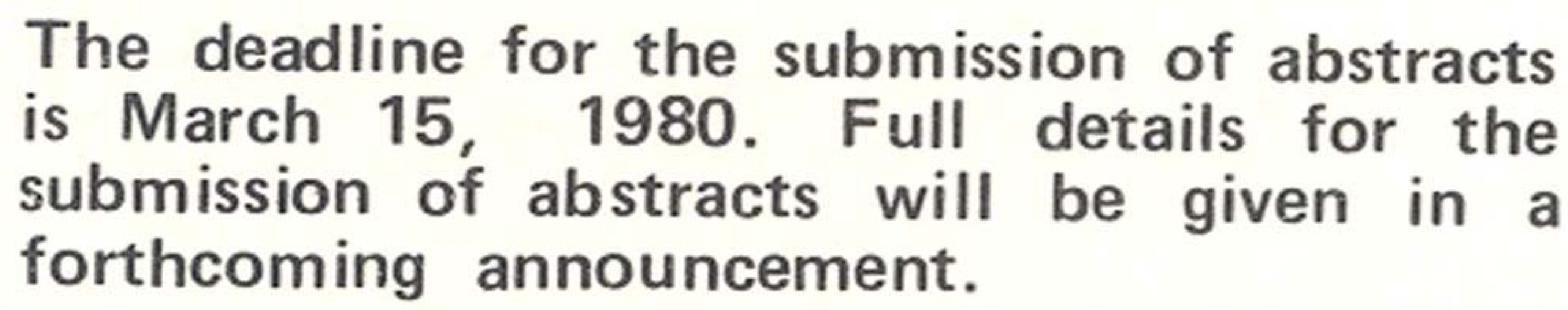
① $f = u(r, a)$

$g = 4(r \cdot z)\, u(r \cdot z)$

② $f = 2|r \cdot a|(u \cdot a)$

First attempt to present the results at a semiconductor conference (ICPS-15)

ABSTRACTS (ICPS15 in Kyoto)



The deadline for the submission of abstracts is March 15, 1980. Full details for the submission of abstracts will be given in a forthcoming announcement.

XV INTERNATIONAL CONFERENCE ON THE PHYSICS OF SEMICONDUCTORS
KYOTO, 1980 SEPTEMBER 1-5

MAILING ADDRESS : PROFESSOR YUTAKA TOYOZAWA PROGRAM CHAIRMAN
INSTITUTE FOR SOLID STATE PHYSICS
UNIVERSITY OF TOKYO
7-22-1 ROPPONGI, MINATO-KU, TOKYO 106, JAPAN

May 14, 1980

Transport properties of a two-dimensional electron gas at the surface of InP-field effect transistors
VON KLITZING Grenoble
ENGLERT

XV INTERNATIONAL CONFERENCE ON THE PHYSICS OF SEMICONDUCTORS
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INSTITUTE FOR SOLID STATE PHYSICS
UNIVERSITY OF TOKYO
7-22-1 ROPPONGI, MINATO-KU, TOKYO 106, JAPAN

June 3, 1980

Dr. K. von Klitzing
Physikalisches Institut
der Universität Würzburg
8700 Würzburg, Röntgenring 8
West Germany

Dear Dr. von Klitzing,

Thank you for your letter of June 19. I also got Prof. Landwehr's telegram to Prof. Kamimura concerning your new work. I am very much interested in your new method for the determination of h/e^2 based on Hall resistance measurements on MOSFETs.

Ⓓ Friday 5. 14^{30}

As a program chairman, however, I cannot agree with your proposal of replacing your accepted paper (5pD-2) by this new work. The reasons are as follows. (1) Selection of the papers was done under the attendances

Post-deadline Presentation at Satellite Conference "Physics in High Magnetic Fields" (Hakone 10.-13.9.1980)

Kubo: *Tomorrow, everything will be clear*

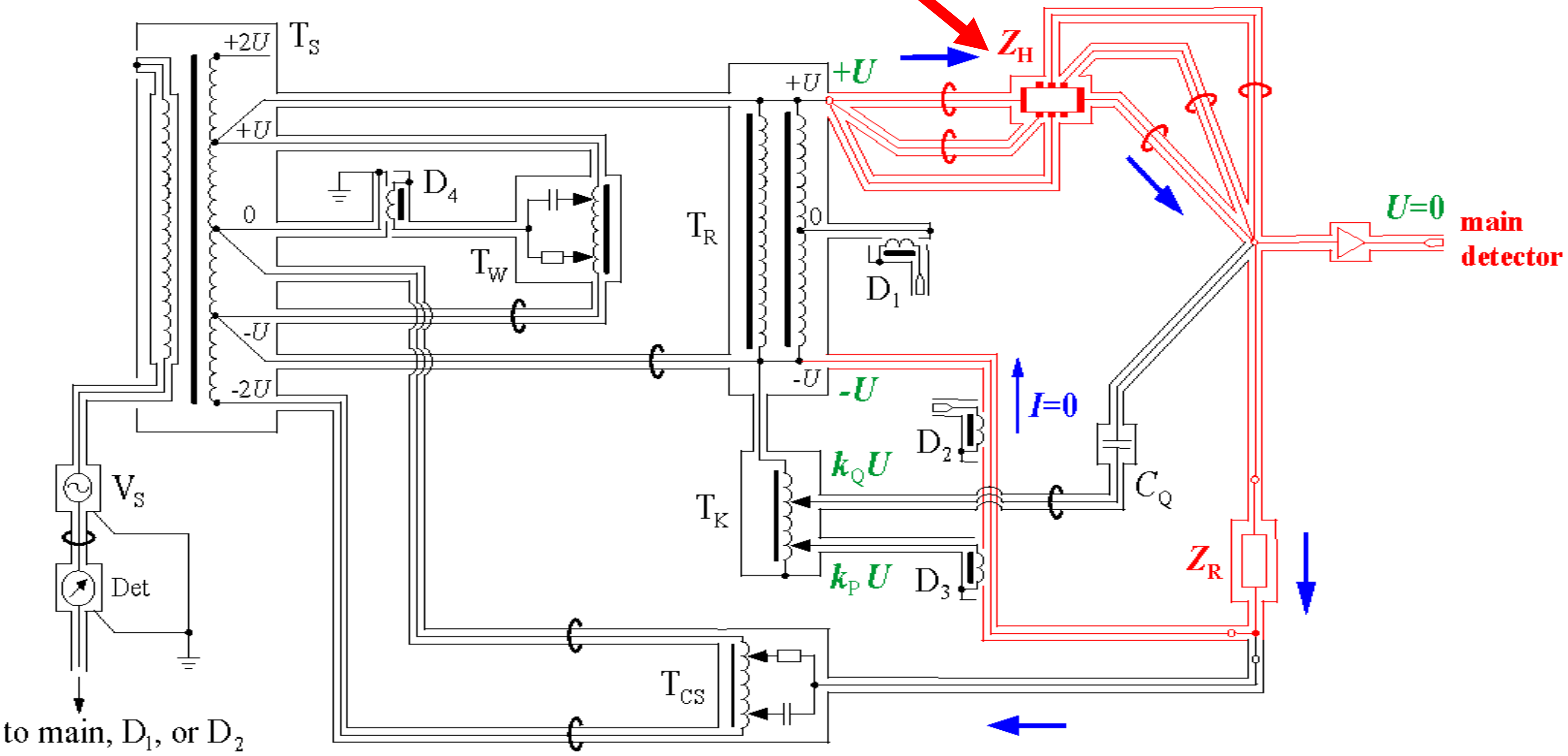
HAKONE (Sept. 1980)

- QHE equipment for metrology:

Automated calibration system for capacitors based on the ac QHR

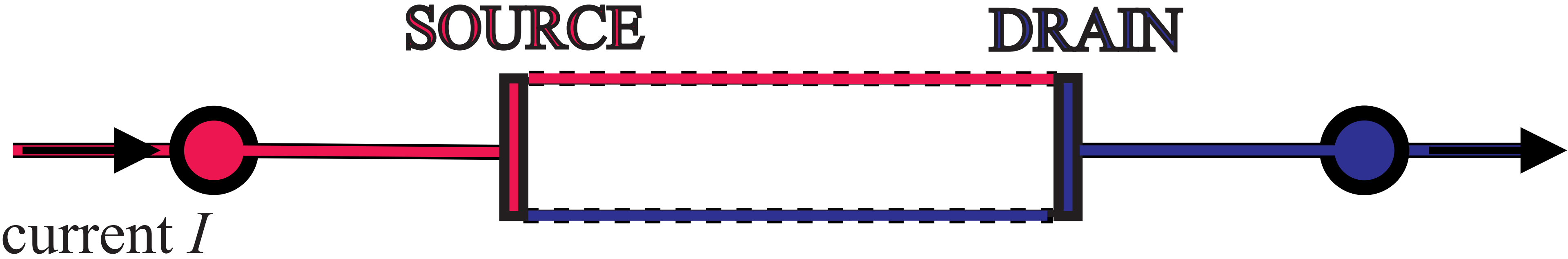
PTB
NPL
IEN
METAS
CTU
NML
INETI

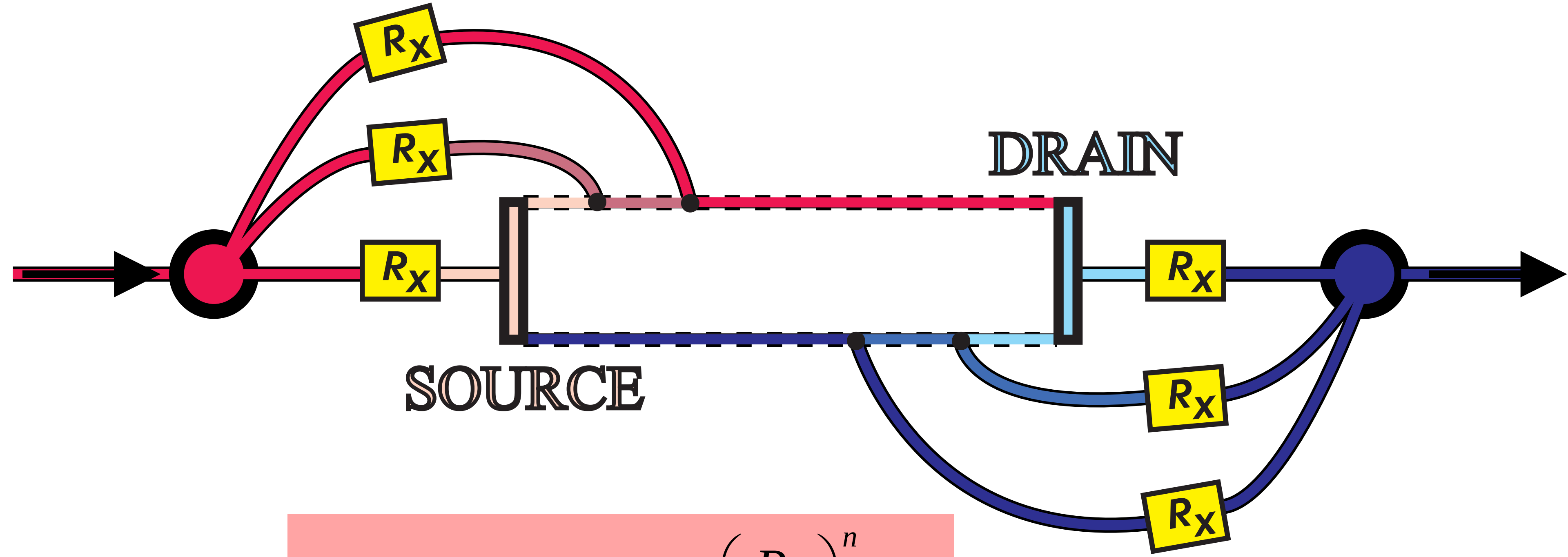
Coaxial ac bridge



QHE device

$$\frac{(Z_H - Z_R)}{Z_R} = -\delta - 10^{-2} k_P - j\,\omega k_Q R_H C_Q$$





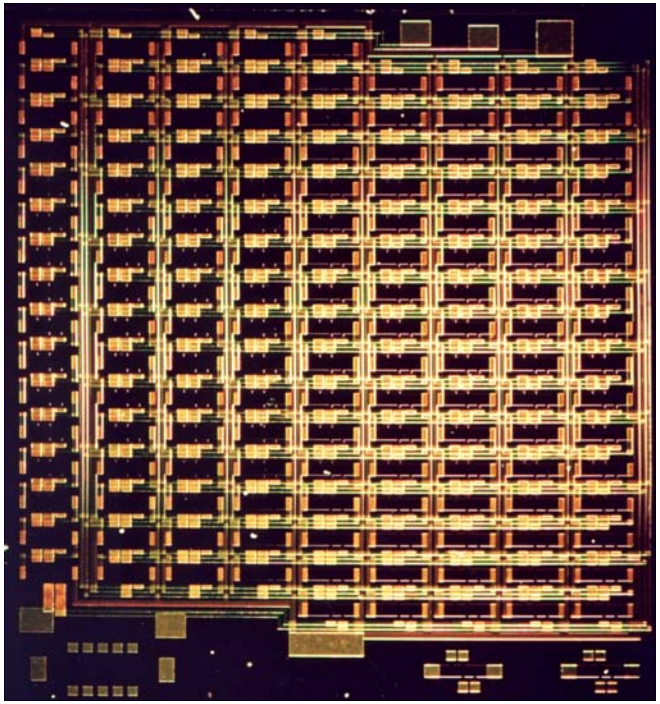
$$R_{TWO-TERMINAL} = R_K + \left(\frac{R_x}{R_K}\right)^n \cdot R_K$$

The QHARS: a new development of the metrological application of QHE

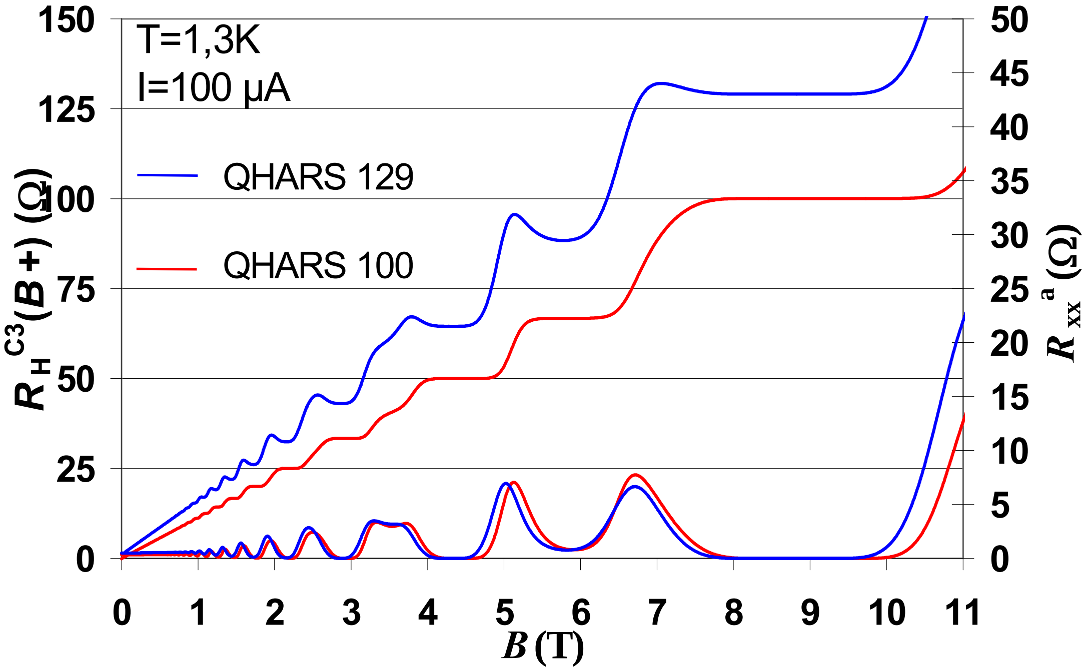
QHARS 129: 100 Hall bars in parallel

QHARS 100: 16 Hall bars in series +129 Hall bars in parallel

$R_H = 16R_K/4130 \approx 100\ \Omega$ (within 10^{-5})



Hall bar width= 400 μm

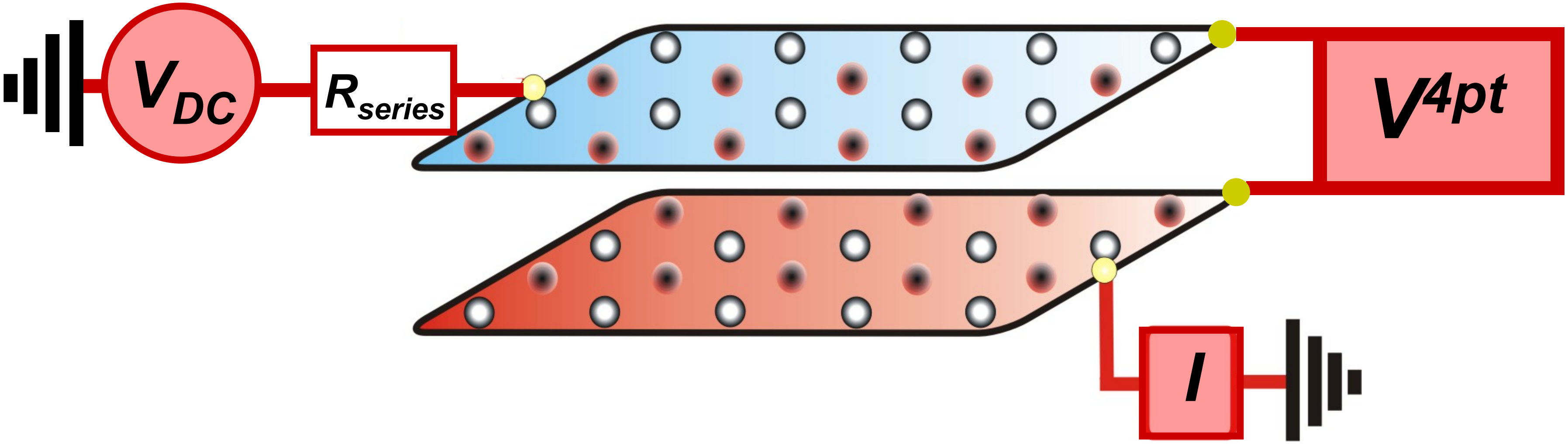


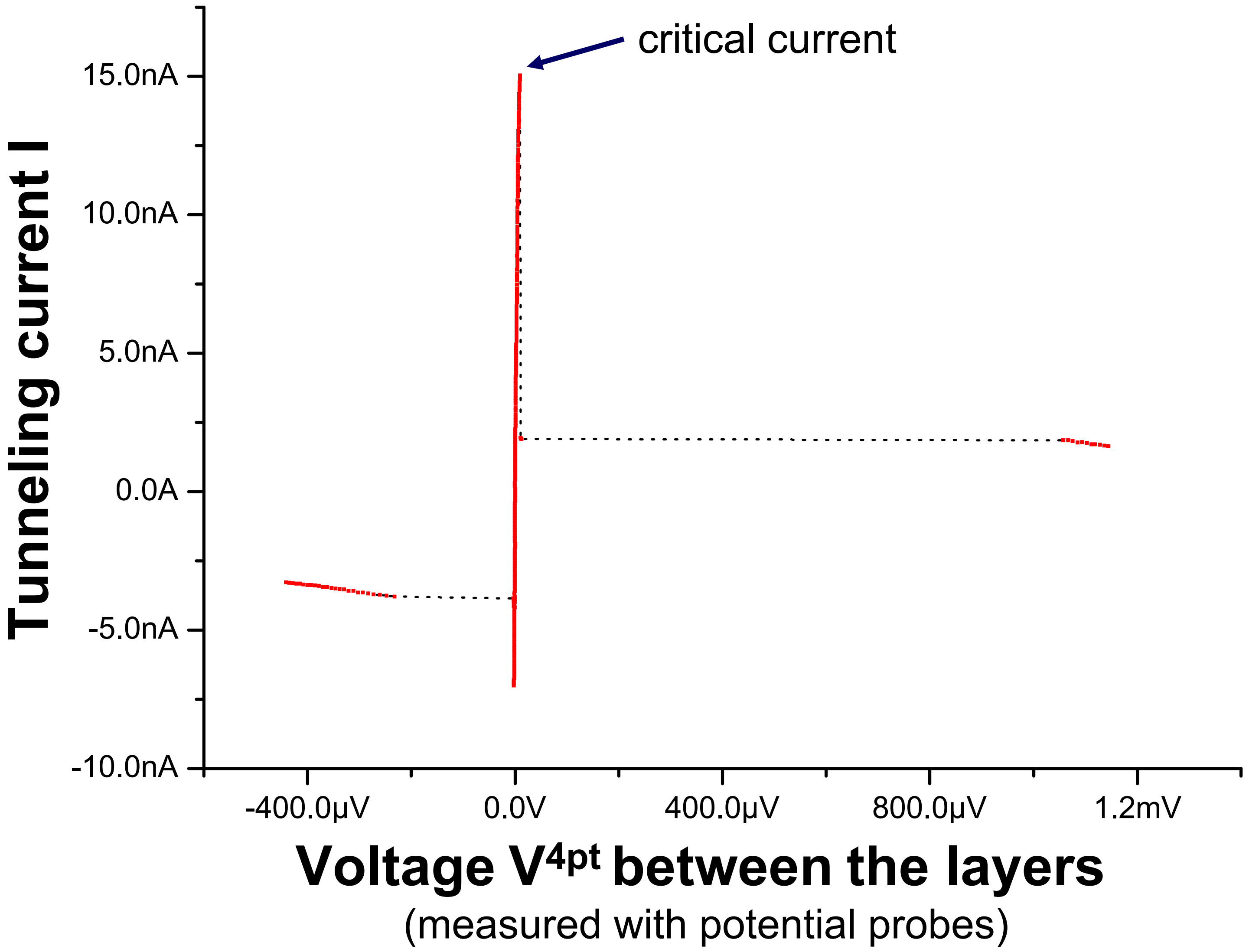
$n_s = 4.3.10^{11}$ cm^{-2}

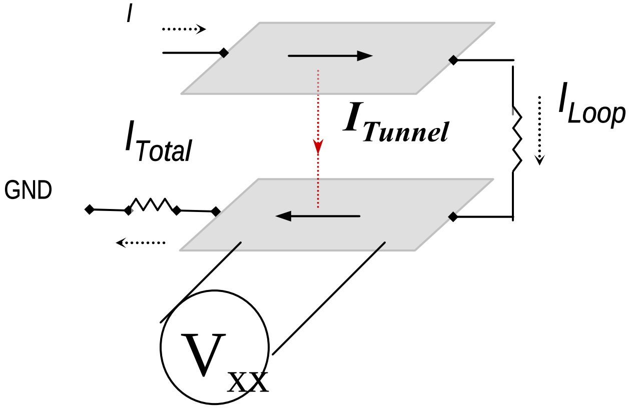
μ = 310 000 cm^{2}V^{-1}s^{-1}

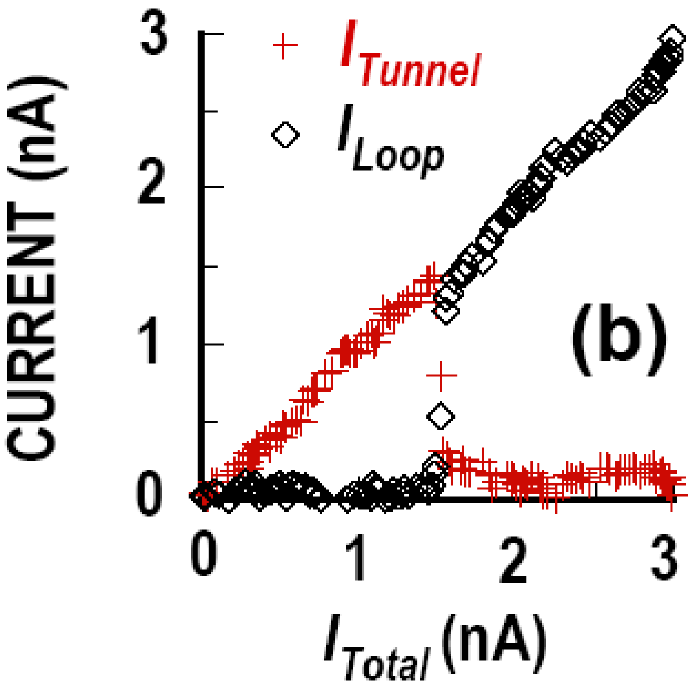
W. Poirier *et al.*, *J. Appl. Phys.* **92**, 2853 (2002)

W. Poirier *et al.*, *Metrologia* **41**, 285 (2004)

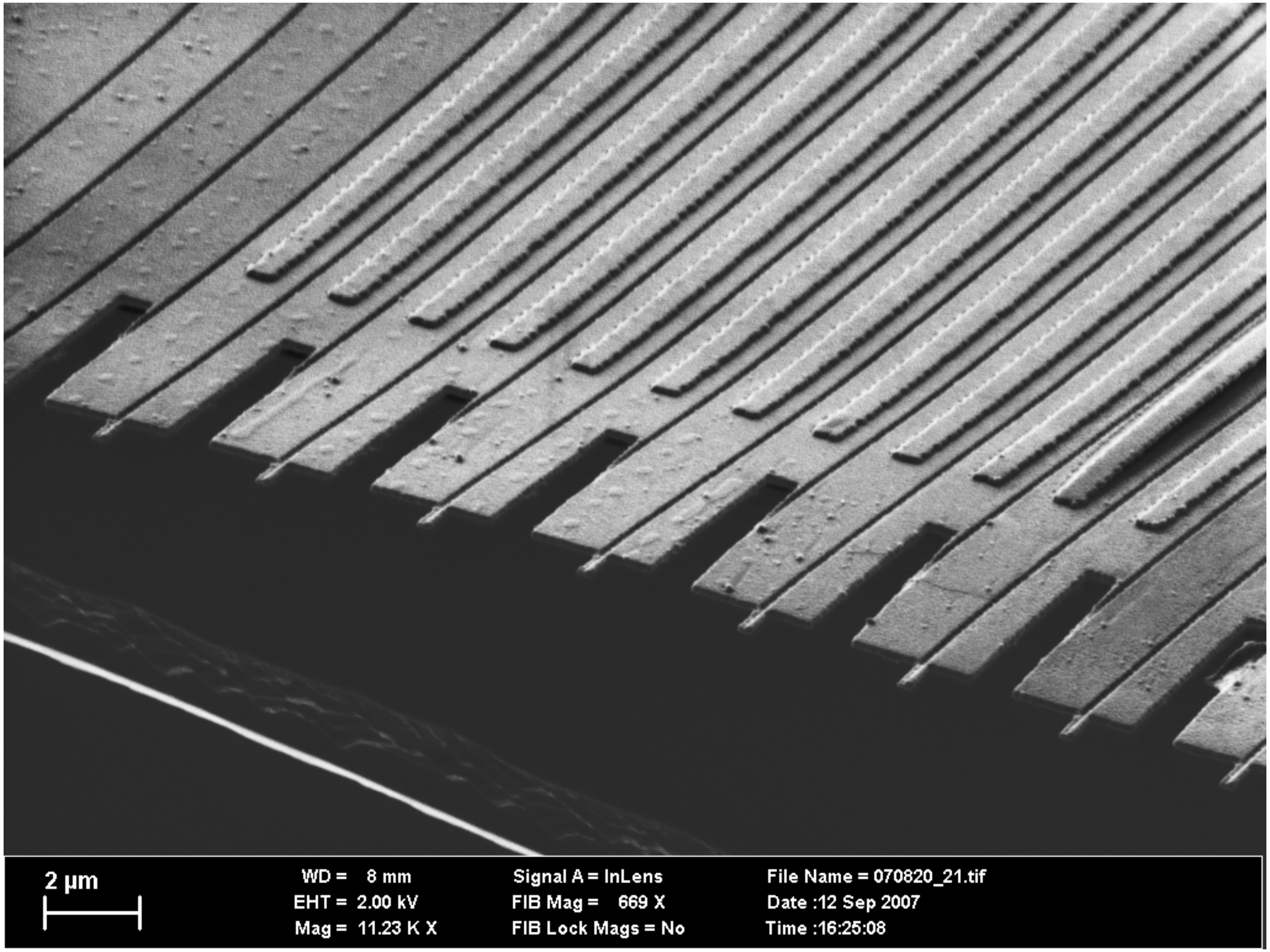

V_{DC}
R_{series}
V^{4pt}
I


critical current
15.0nA
10.0nA
5.0nA
0.0A
-5.0nA
-10.0nA
Tunneling current I
-400.0µV
0.0V
400.0µV
800.0µV
1.2mV
Voltage V^{4pt} between the layers
(measured with potential probes)



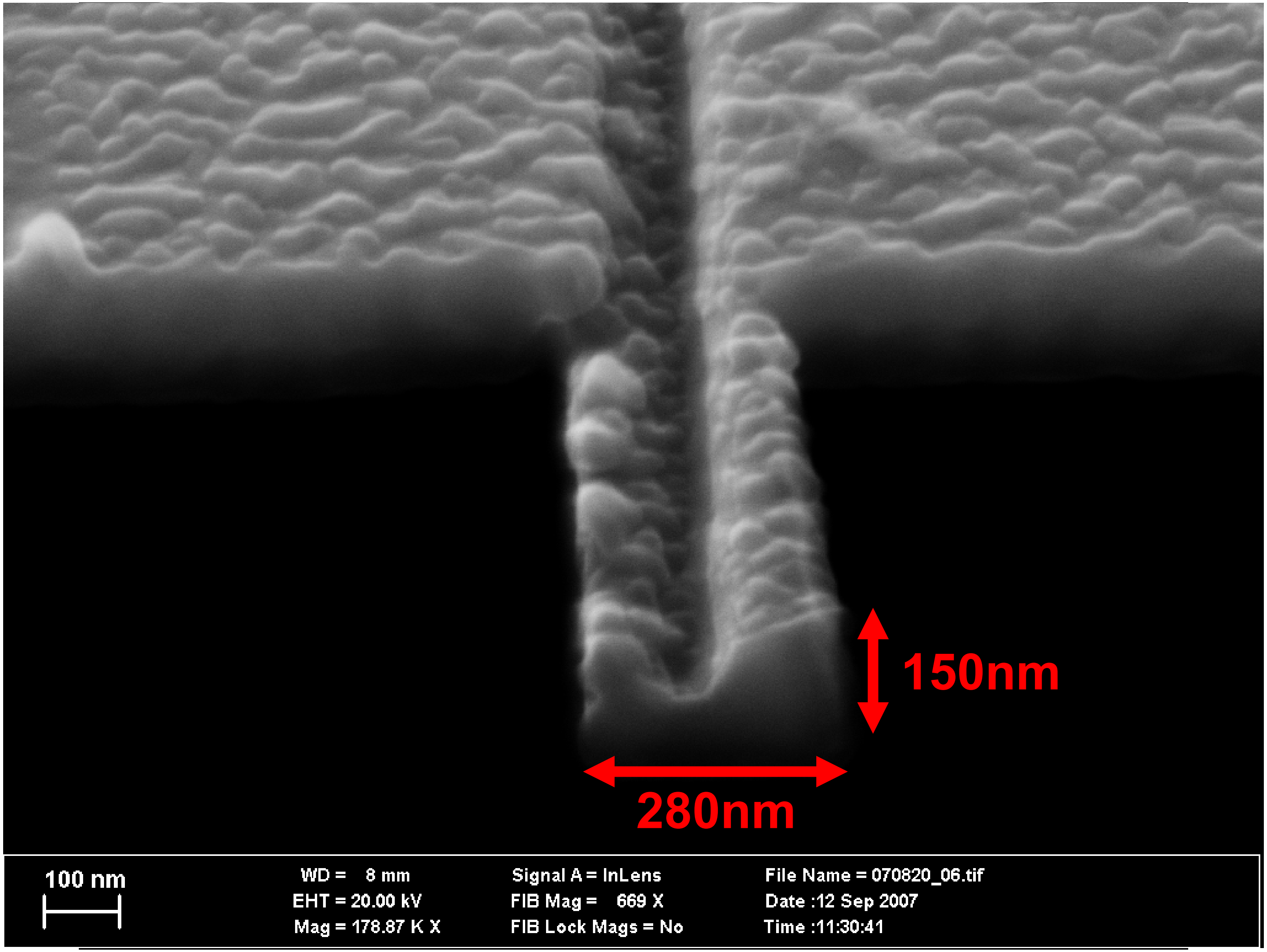


Y. Yoon, W.D., 2009



Jochen Weber, MPI-FKF

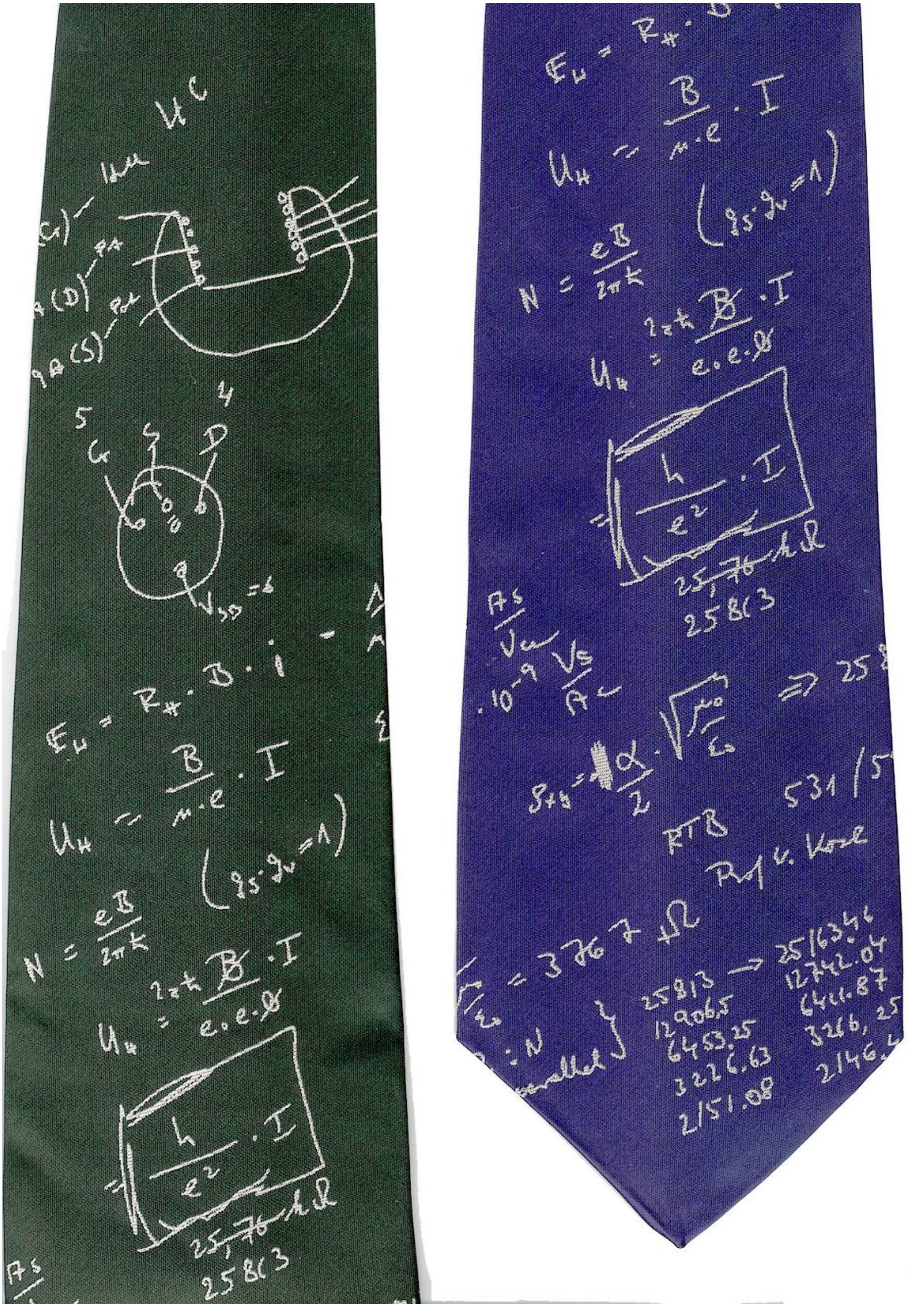
A tip with a single-electron transistor



WD = 8 mm
EHT = 20.00 kV
Mag = 178.87 K X

Signal A = InLens
FIB Mag = 669 X
FIB Lock Mags = No

File Name = 070820_06.tif
Date :12 Sep 2007
Time :11:30:41


$E_H = R_H \cdot B \cdot i$
$U_H = \frac{B}{n \cdot e} \cdot I$
$(g_s \cdot g_v = 1)$
$N = \frac{eB}{2\pi\hbar}$
$U_H = \frac{2\pi\hbar}{e \cdot e \cdot \vartheta} \cdot B \cdot I$
$\frac{h}{e^2} \cdot I$
25,76 kΩ
25813
PTB
= 376,7 Ω
25813 → 25163,46
12906,5 12742,04
6453,25 6411,87
3226,63
2151,08