Scientific session of the Division of General Physics and Astronomy of the Academy of Sciences of the USSR (20–21 April 1988)

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A scientific session of the Division of General Physics and Astronomy of the USSR Academy of Sciences was held on April 20 and 21, 1988, at the S. I. Vavilov Institute of Physics Problems of the USSR Academy of Sciences. The following reports were presented at the session:

April 20

1. *V. M. Agranovich*. The current state and future prospects of linear and nonlinear spectroscopy of surfaces and thin films.

2. *V. M. Pudalov and S. G. Semenchinskiĭ*. A physical standard of the unit of electrical resistance based on the quantum Hall effect.

April 21

3. *R. A. Syunyaev*. "Röentgen": an international orbital observatory on the "Kvant" module (first results).

4. *V. L. Afanas'ev and N. V. Grudzinskiĭ*. Utilizing the "Kvant" complex for acquiring and analyzing visual images.

5. *A. D. Kuz'min*. The pulsar time scale. Brief summaries of two reports are presented below.

V. M. Pudalov and S. G. Semenchinskiĭ. *A physical standard of the unit of electrical resistance based on the quantum Hall effect.* The discovery of the quantum Hall effect (QHE) by K. von Klitzing in 1980 heralded the possibility of defining a standard physical unit of electrical resistance which would remain constant in time and be defined by the ratio of fundamental constants:

$$\frac{h}{e^2} = 25812.80\ \ldots\ \Omega. \qquad (1)$$

A series of investigations, carried out in 1981–1987 at the institutes of the USSR Academy of Sciences and the Gosstandart (State Bureau of Standards) (see reviews in Refs. 2, 3), have shed light on the physical nature of QHE and developed the scientific foundation for the use of this phenomenon in metrological and measurement technology. This scientific foundation is currently embodied in a high-precision measurement apparatus built and operated at the All-Union Scientific Research Institute of Metrology of the Gosstandart.[4–6] This apparatus can reproduce the unit of resistance, as defined by the ratio of fundmental constants, with 1×10^{-8} precision and transfer this standardized unit to resistance standards of the traditional type.

The heart of the measurement apparatus consists of a semiconductor structure cooled to a temperature of 0.35 K and placed in a strong magnetic field $B \leqslant 13$ T. Under these conditions the Hall resistance of the structure has a quantized value $R_H = 6453.20$ or 12906.40 Ω, respectively 1/4 and 1/2 of the h/e^2 ratio.

The measurement apparatus then transfers this quantized benchmark value to ordinary nominal resistance measures (with $1\cdot 10^{-8}$ precision), which maintain it between measurements (∼1 month), and also to decimal nominal measures of 100 Ω (with $5\cdot 10^{-8}$ precision). In the latter case a so-called Hamon divider is used,[7] consisting of a collection of resistors connected either parallel—for comparison with the 100 Ω measure, or in series—for comparison with R_H.

An impressive feature of the quantum Hall effect is the precision with which the $R_H^{\exp}$ plateau value (1) is reproduced in different experiments on different samples. In Fig. 1 we present a fragment of the Hall resistance $R_H^{\exp}$ as a function of Landau level filling factor ν near $\nu = 4$. A magnified central region of the plateau is shown for five independent measurements[4,5] taken over two days. Clearly, within experimental error the R_H plateau is horizontal. The reproducibility of these results was studied with different sets of measuring devices:[4,5] it was no worse than $(1–4)\cdot 10^{-8}$.

Nonetheless one cannot exclude in advance the possibility that $R_H^{\exp}$ could deviate from the quantized value (1), for example because of nonideal experimental conditions. In order to control the true precision with which $R_H^{\exp}$ is reproduced experimentally, we measure the residual dissipative resistance $\rho_{xx}^{\min}$. It had been previously determined (see, for instnce, Refs. 7, 8) that small deviations of R_H from the quantized value are proportional to ρ_{xx} with a coefficient of ∼0.1. Consequently, if 10^{-8} precision is desired $\rho_{xx}^{\min}$ cannot exceed 10^{-3} Ω/□.

This precision measuring apparatus has been used since 1987 to verify the long-term stability of extra-stable precision resistors of $(1–3)\cdot 10^{-8}$ precision. Figure 2 illustrates the temporal variation of the resistance of two resistors kept in a thermostat at $T = 20 \pm 0.005$ °C. These two resistors are part of the measurement apparatus: they maintain the

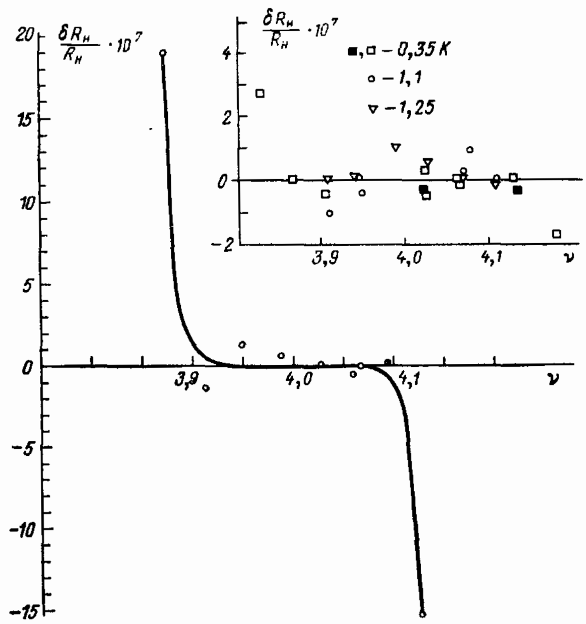

FIG. 1. Fragment of the curve of the Hall resistance as a function of the filling factor ν near $\nu = 4$.[5] The inset shows a magnified section of the curve with points taken at different temperatures over a period of two days.

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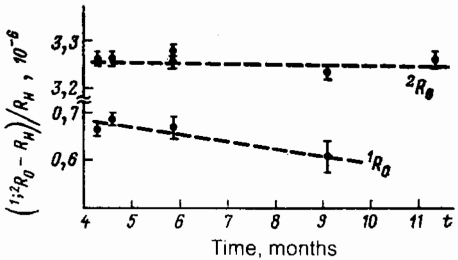

FIG. 2. Drift of resistance with time for two thermally stabilized resistors.[9]

quantized value between comparisons with R_{H}. At the end of 1987 the value of R_{H}, reproduced by the measurement device, was compared to the primary national Ohm standard, yielding the result[10]

$$\frac{h}{e^2} = 25812.8\cdot(1-0.068\cdot10^{-6}\pm0.13\cdot10^{-6})$$

In Ω_{USSR} units as of July 22, 1987. Referring to the 14th international comparison of national standards[11] we obtain the value

$$\frac{h}{e^2} = 25812.8\cdot(1+0.217\cdot10^{-6}\pm0.22\cdot10^{-6})\,\Omega_{\mathrm{SI}}. \qquad (2)$$

We note that this result differs from the value obtained at the last (1986) standardization of fundamental constants by only 2×10^{-9}.

In late 1988, on the basis of this and similar measurements of h/e^2 at other laboratories the Consulting Committee on electricity of the International Committee of Weights and Measures (BIPM) will designate a new value of h/e^2 appropriate for reproduction of the Ohm by national standards such that the reproducible Ohm units approach Ω_{SI} as closely as possible. The new definition of the Ohm (Ω_{90}) should come into effect on January 1, 1990. The above-described apparatus will be utilized to define practically the Ω_{90} standard, which will improve the precision and agreement with Ω_{SI} by a factor of 3–10 over existing standards.

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