On the Shoulders of Giants: a brief History of Physics in Göttingen

18th and 19th centuries

Georg Ch. Lichtenberg (1742-1799) may be considered the forefather of experimental physics in Göttingen. His lectures were accompanied by many experiments with equipment which he had bought privately. To the general public, he is better known for his thoughtful and witty aphorisms. Following Lichtenberg, the next physicist of world renown would be *Wilhelm Weber* (1804-1891), a student, coworker and colleague of the „prince of mathematics" C. F. Gauss, who not only excelled in electrodynamics but fought for his constitutional rights against the king of Hannover (1830). After his re-installment as a professor in 1849, the two Göttingen physics chairs , W. Weber and B. Listing, approximately corresponded to chairs of experimental and mathematical physics. After Listing, *Woldemar Voigt* (1850-1919), working in optics, took over the theoretical physics department. He discovered what Poincaré named „Lorentz transformations". During this time *Eduard Riecke* (1845-1915) held the experimental chair and *Johannes Stark* (1874-1957) did his experiments on the Doppler effect of canal rays (1905) in Göttingen. This brought him a Nobel prize (Stark Effect). In experimental physics, a division for applied electricity under H. Th. Simon was created in 1907.

Since C. F. Gauss, the astronomical observatory has been in contact with physics. Its director from 1901-1909 was *Karl Schwarzschild* (1873-1916), who derived a famous solution of Einstein's gravitational theory which led to the concept of the black hole. Also, a geophysical institute was founded in 1898 under *Emil Wiechert* (1861-1928), where seismic methods for the study of the Earth's interior were developed. An institute for applied mathematics and mechanics under the joint directorship of the mathematician *Carl Runge* (1856-1927) (Runge-Kutta method) and the pioneer of aerodynamics, or boundary layers, *Ludwig Prandtl* (1875-1953) complemented the range of institutions related to physics proper. In 1925, Prandtl became the director of a newly established Kaiser-Wilhelm-Institute for Fluid Dynamics.

A new and well-equipped physics building opened at the end of 1905. After the turn to the 20th century, *Walter Kaufmann* (1871-1947) did precision measurements on the velocity dependence of electron mass; they played an important role for the discussion of Einstein's special relativity and a rival theory of the Göttingen lecturer Max Abraham. In 1914, a professorship for the Dutch theoretician and later Nobel prize winner *Peter Debye* (1884-1966) was established (Debye-Scherrer method). Debye left Göttingen in 1920. When the three chairs in physics had to be refilled around 1920, a fortunate choice brought the theoretician *Max Born* (1882-1970) as well as the experimental physicists *James Franck* (1982-1964) and *Robert Pohl* (1884-1976) to the university. Early in the 1920's, physics was reorganized into four institutes: two experimental, a theoretical, and an upgraded „Institute for Applied Electricity" under *Max Reich* (1874-1941). The „faculty for mathematics and natural sciences"separated from the philosophical faculty only in 1922.

Fig. 1: Wolfgang Pauli and Paul Ehrenfest (1929)

Fig. 2: Viktor Weisskopf, Maria Goeppert, Max Born

Fig. 3: I. Institute of Physics and II. Institute of Physics

Weimar Republic

With the coming to Göttingen of the three friends Born, Franck and Pohl, an exceptional decade for physics began. Franck received a Nobel Prize in 1925 (Franck-Hertz experiment). Among his students, the names *Patrick M. S. Blackett* (Nobel prize 1948) and *Edward Condon* (Franck-Condon effect) appear as well as those of numerous subsequent physics professors (e.g., W. Hanle, H. Kopfermann, H. Maier-Leibnitz, Herta Sponer). Born and his coworkers *Werner Heisenberg* (1901-1976, in Göttingen 1923/26 and 1948/57) and *Pascual Jordan* (1902-1980) were responsible for the completion of quantum theory (1925-1927). The concept „quantum mechanics" was coined by Born in 1924. From the observed atomic spectra Heisenberg distilled a mathematical formalism permitting the calculation of observables like transition frequencies, intensity and polarization of atomic radiation (Nobel Prize 1932). Born recognized the hidden mathematical structure (matrices, linear operators) and showed that Schrödinger's wave function must be connected with a probability interpretation (Nobel Prize 1954). P. Jordan, at the same time as P. A. M. Dirac, published a formalism combining both Schrödinger's wave- and Heisenberg's matrix theory. He also found what now is called Fermi-Dirac statistics. Born's probability interpretation and Heisenberg's uncertainty relations have immensely furthered our understanding of nature. Among Born's PhD students, assistants and scientific guests were five later Nobel prize winners: Max Delbrück, Maria Goeppert-Mayer, Wolfgang Pauli, Enrico Fermi and Gerhard Herzberg. Many other outstanding physicists also worked under Born, among them George Gamov, Walter Heitler, Erich Hückel, Friedrich Hund, Lothar Nordheim, Robert Oppenheimer, G. Uhlenbeck and Viktor Weisskopf. The long-time tradition of a strong interaction with mathematics continued, as is exemplified by the 1926 lecture on quantum mechanics by David Hilbert, and the subsequent mathematical foundation of quantum theory by John v. Neumann in Göttingen.

1933-1945 and thereafter

With the seizure of power by the National Socialists and the expulsion of both Jewish and democratically minded physicists from the university and from Germany, this golden era of physics came to an abrupt end. During the Nazi period and the 2nd world war, Robert Pohl pursued his research in the foundations of solid state physics (inner photo effect in crystals, thin layers) and transformed the lecture hall into a show room. He and the nuclear physicist *Hans Kopfermann* (1895-1963) (hyperfine structure, nuclear moments, betatron for medical use) and the theoretical physicist Richard Becker (1887-1953) working on magnetic properties of materials, succeeded to keep a high standard both in teaching and research. All four institutes continued uninterrupted through 1945. One of the people who took over courses from M. Born was Gustav Heckmann from the observatory. In the early 30's, he had made an important contribution to cosmology. During the war, the observatory's director *Paul ten Bruggencate* (1901-1961) even built a special station for studies of the sun's activity.

The end of the second world war had some advantageous consequences for the university. The town had remained in good order such that many well-known physicists, among them the three Nobel prize recipients (Max Planck, Max v. Laue, and the chemist Otto Hahn) moved here from a ruined Berlin. Others coming from the areas lost to Poland and the USSR followed suit. In 1946, the Kaiser-Wilhelm- (later Max Planck) Institute for Physics in Berlin with its director, Heisenberg, re-opened in Göttingen and stayed here until 1958. This included a department headed by C. F. v. Weizsäcker. In Kopfermann's Institute, *Wolfgang Paul* (1913-1993) worked as a professor on nuclear quadrupole moments while *Hans Georg Dehmelt* (1922-) wrote his PhD thesis. Together, they received the Nobel Prize in 1989 (atom traps). In 1952, at the Institute for Theoretical Physics, *Herbert Kroemer* received his doctoral degree under Fritz Sauter (1906-1983), who would

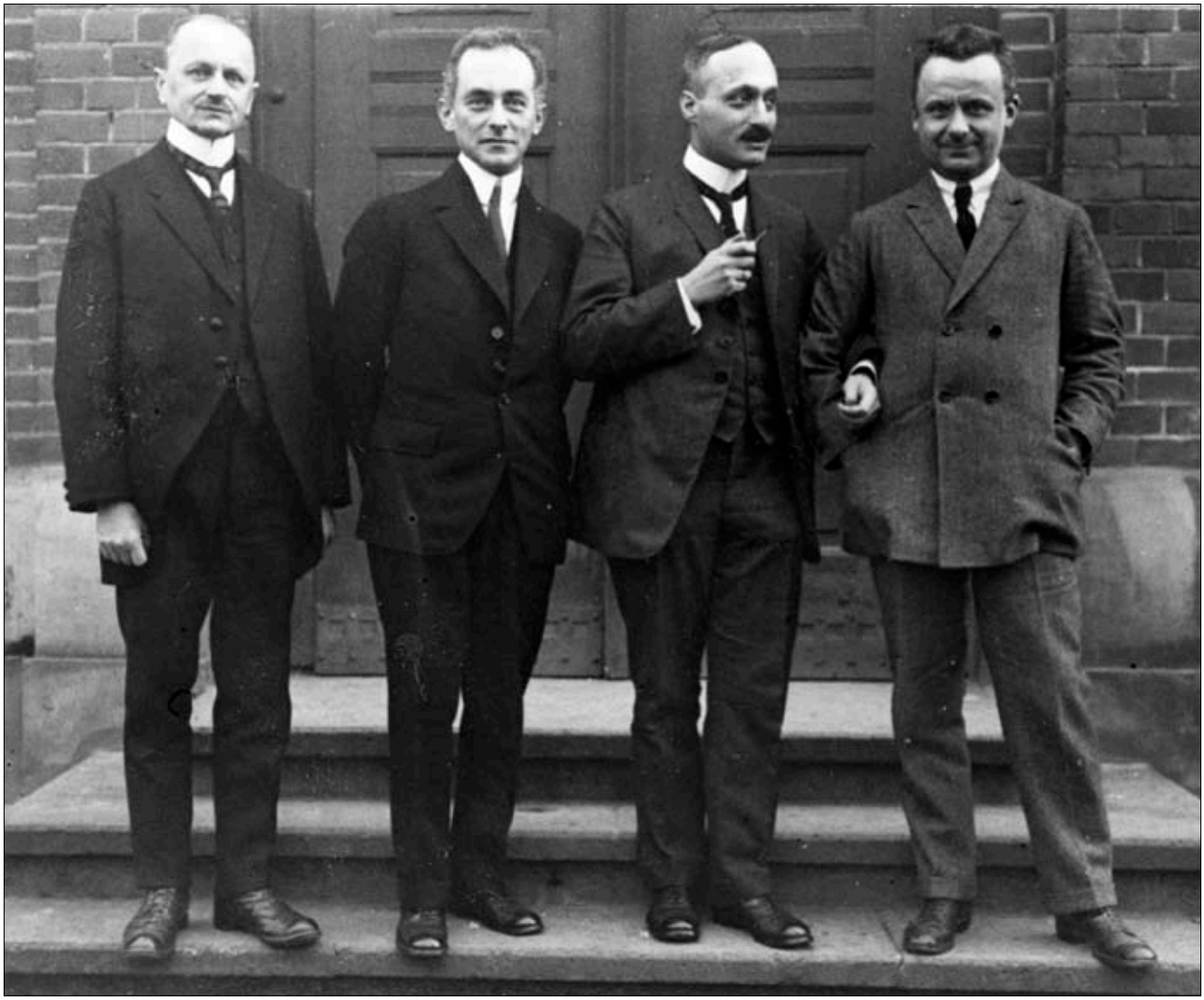

Fig. 4: Max Reich, Max Born, James Franck, Robert Pohl

later be full professor in Cologne. Kroemer became a Nobel prize winner in the year 2000 (opto-electronics). In place of the discontinued institutes for applied mechanics and applied electricity, a third experimental institute for the physics of vibrations and acoustics was opened in 1947. The Institute for Metal Physics was added to physics, having transfered from the chemistry department. It would later be expanded into an institute of Materials Science. Prandtl's successors as directors at the Max Planck Institute for Fluid Dynamic were also given the position of full professor of physics at the university. Likewise, a link of director's positions between geophysics and the Max Planck Institute for Aeronomy in Katlenburg/Lindau near Göttingen came about. In 1957, prominent physicists like M. v. Laue, M. Born (who had returned to Bad Pyrmont near Göttingen), W. Heisenberg, W. Paul, H. Kopfermann, and C. F. v. Weizsäcker formulated a protest against the nuclear arming of the German Armed Forces and worldwide nuclear arms build-up.

The late 1960's and early 1970's brought a big influx of students and a sizable increase in both positions and institutions in physics. A fourth experimental Institute for semiconductor physics had opened in 1965, and an institute for X-ray physics in the 70s (X-ray microscopy). A third Max Planck Institute, for Biophysical Chemistry, had been established in 1949. Under its subsequent directors, *Manfred Eigen* (Nobel prize in 1967) and *Erwin Neher* (Nobel prize in 1991), a closer relationship with physics ensued. The cooperation with the Max Planck Institutes complemented the research opportunities for physics students and post-docs. By 1994, the mere two professors of physics with a dozen of helpers in the 19th century had been replaced by 111 positions for research and teaching. The same number of technical and administrating personnel were added. The present size of physics in Göttingen reflects the changes in research: the increasing topical and instrumental differentiation of the field, and the trend away from the single researcher toward research groups and interdisciplinary interactions. At present, two Collaborative Research Centres on "Complex structures in condensed matter from atomic to mesoscopic scales" and "Nanoscale Photonic imaging" in the faculty of physics are funded by German Research Foundation. Nevertheless, as this summary focusing on the personalities behind some highlights of physics in Göttingen shows, creative ideas spring from individual minds.

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