



Agnes Pockels: Life, Letters and Papers

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Agnes Wilhelmine Louise Pockels

14.2.1862 – 21.11.1935



Born in Venice to parents originally from Northern Germany

Father: officer in the Austrian Army.

One brother, Fritz, born 1865 in Vincenca.

Problem: malaria wide-spread in North-Italy.

⇒ retirement of Captain Pockels in 1871



Theodor Pockels, father
(1830-1906)



1872-1877: Municipal High School for Girls, Brunswick



No degree available for girls, two natural science classes per week in the final two years of high school

„ (...) without conferring to a special scientific systematic thought“ (curriculum)

„I had a passionate interest in natural science, especially physics, and would have liked to study“ (Agnes Pockels) in Autobiographical Notes in W. Ostwald (1932), *Kolloid-Zeitschrift*, 58, 1

⇒ retreat to private life after school (care for sickly parents)

1883: Brother Fritz begins his studies in physics



Fritz Pockels



⇒ access to physics and mathematics books
and autodidactic learning

⇒ access to „Naturwissenschaftliche Rundschau“ (akin to Physics Today)

Agnes and Fritz Pockels: Working at Home



Fritz Pockels



Agnes Pockels

“Their studies were often conducted in the kitchen where Agnes, being the daughter of the household, had to do her chores and where it was always nice and warm. In this way, Agnes conducted her first observations in the field of surface science. This is really true, and no joke or poetic licence: what millions of women see every day without pleasure and are anxious to get rid of, i.e. the greasy washing-up water, encouraged this girl to make observations and eventually do ... scientific investigations.”

Electro-Optic Effect

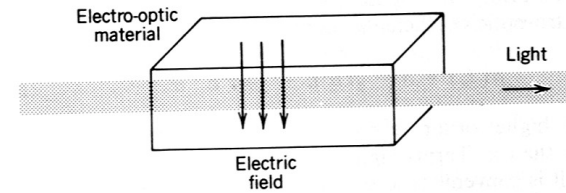


Figure 18.0-1 A steady electric field applied to an electro-optic material changes its refractive index. This, in turn, changes the effect of the material on light traveling through it. The electric field therefore controls the light.



Friedrich Carl Alwin
Pockels (1865 - 1913)

Ph.D. from Göttingen
University in 1888

1900 - 1913 Prof. of
theoretical physics in
Heidelberg

for certain materials n is a function of E ,
as the variation is only slightly we can Taylor-expand $n(E)$:

$$n(E) = n + a_1 E + \frac{1}{2} a_2 E^2 + \dots$$

linear electro-optic effect
(**Pockels effect**, 1893):

$$n(E) = n - \frac{1}{2} r \cdot n^3 E \quad r = -2 \frac{a_1}{n^3}$$

quadratic electro-optic effect
(**Kerr effect**, 1875):

$$n(E) = n - \frac{1}{2} s \cdot n^3 E^2 \quad s = -\frac{a_2}{n^3}$$

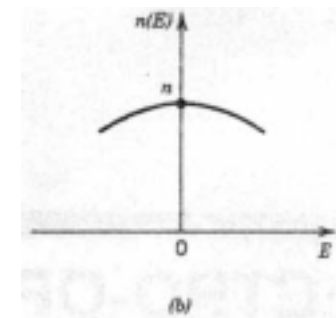
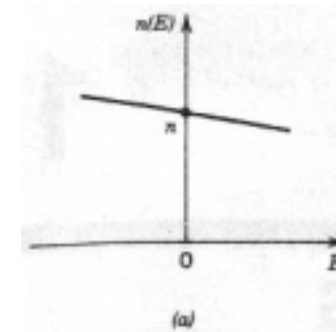
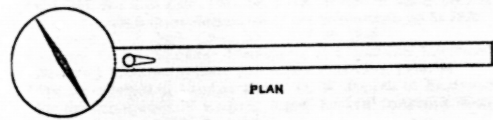


Figure 18.1-1 Dependence of the refractive index on the electric field: (a) Pockels medium; (b) Kerr medium.

Rayleigh's Interest in Water Surfaces



Trough and oscillating
needle apparatus

Rayleigh, Lord, Proc.

R. Soc. London 1890,47,281

Idem, ibid. 1890,47,364

Idem, ibid. 1890,48,127



John William Strutt, 1842-1919
Third Baron Rayleigh (since 1873)

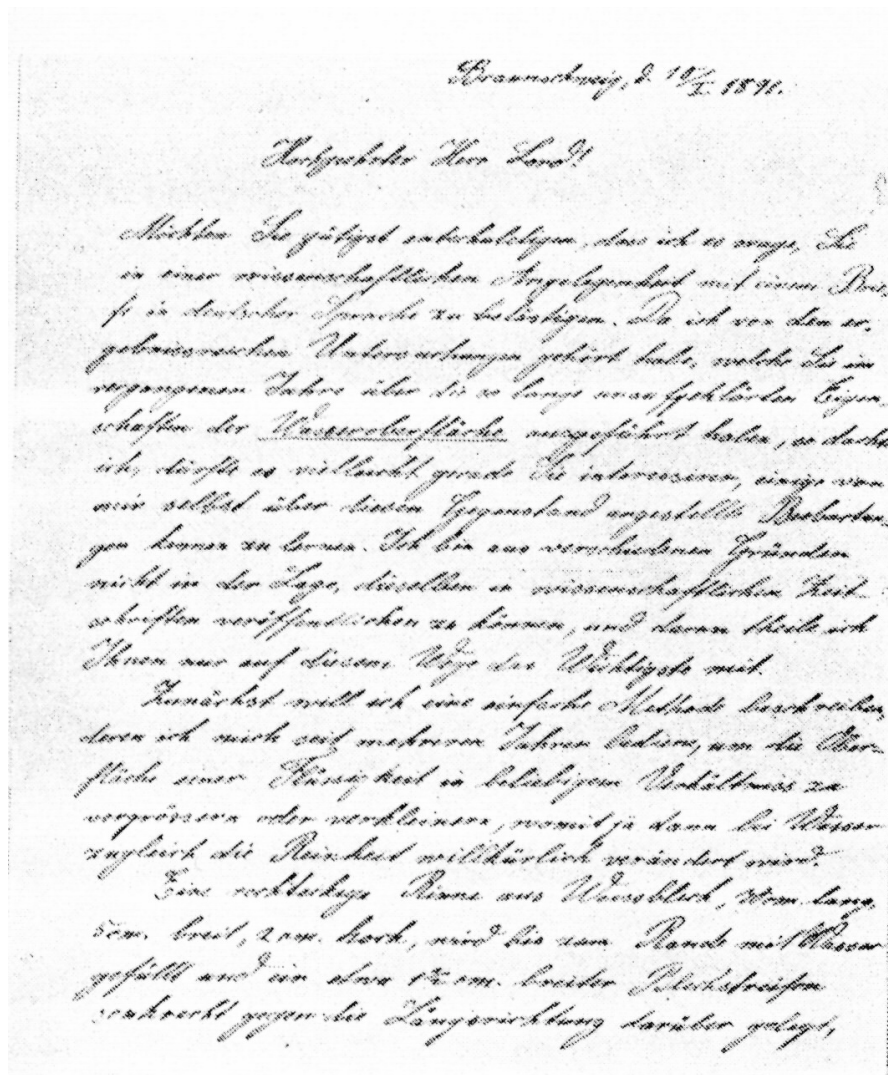
- Surface tension decreased if a body is inserted into the liquid (soap or camphor) - or by 'contamination' with a surface film of insoluble grease or oil (or finger in water)
- Wave damping by a drop of oil placed on the surface (waves produced by a fan)
- Powder (sulphur) disperses uniformly on clean water (Aitken)

? films of oil or grease on water ultimately extend until they become one molecule thin

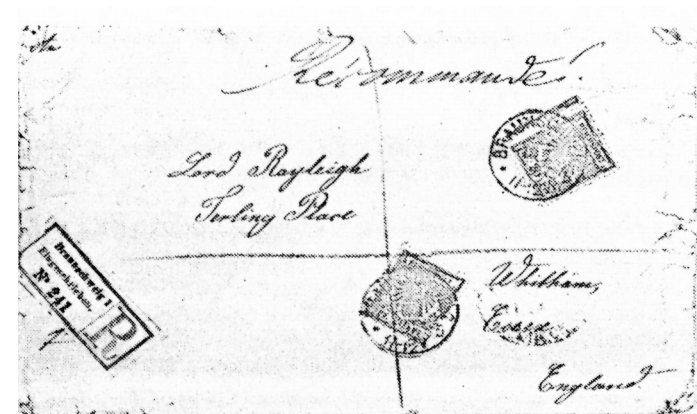
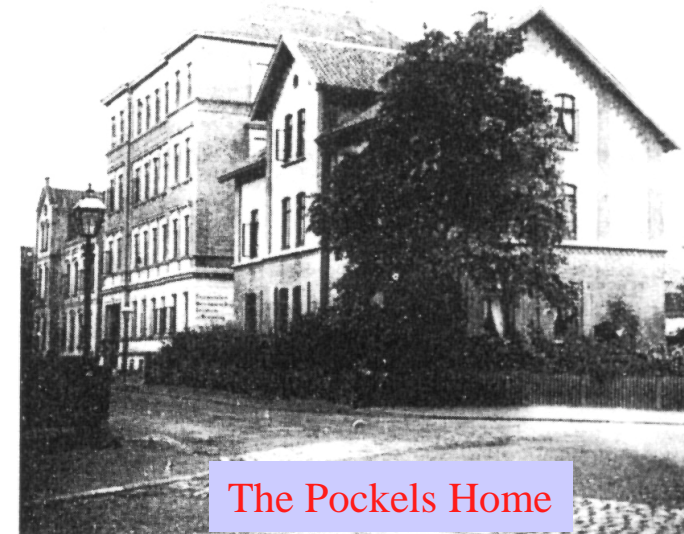
? a method to determine the exact degree to which the oil film must be extended to form a complete single layer of molecules, each in contact with its nearest neighbours

? precise determination of the surface tension of oily surfaces

Agnes Pockels: A Letter to Rayleigh after Reading about his Results in “Naturwissenschaftliche Rundschau”



Erstes Blatt des Briefes an Lord Rayleigh





Agnes Pockels

“My lord, will you kindly excuse my venturing to trouble you with a German letter on a scientific subject? Having heard of the fruitful researches carried on by you last year on the hitherto little-understood properties of water surfaces, I thought it might interest you to know of my own observations on the subject. For various reasons I am not in a position to publish them in scientific periodicals, and I therefore adopt this means of communicating to you the most important of them.

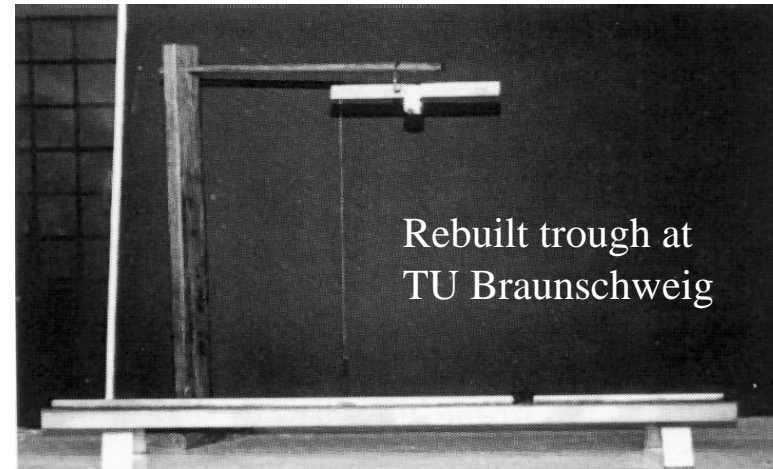
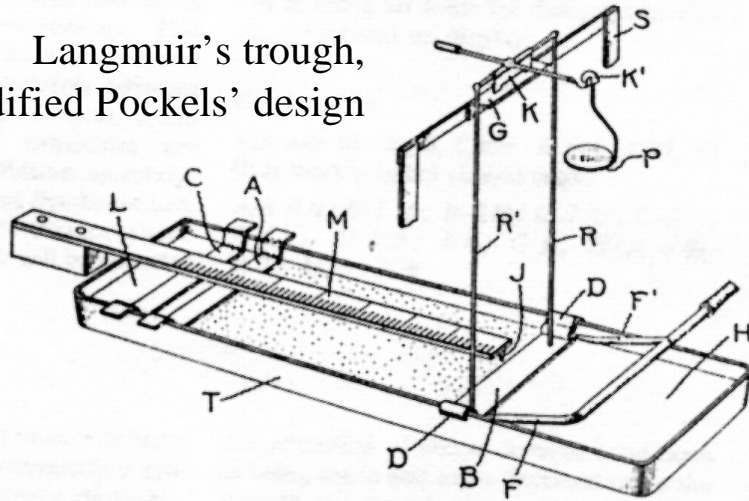
I thought I ought not to withhold from you these facts which I have observed, although I am no professional physicist; and again begging you to excuse my boldness, I remain with sincere respect.”---POCKELS, January 10

“I shall be obliged if you can find space for the accompanying translation of an interesting letter which I have received from a German lady, who with very homely appliances has arrived at valuable results respecting the behaviour of contaminated water surfaces. The earlier part of Miss Pockels' letter covers nearly the same ground as some of my own recent work, and in the main harmonizes with it. The later sections seem to me very suggestive, raising, if they do not fully answer, many important questions. I hope soon to find opportunity for repeating some of Miss Pockels' experiments.” --- RAYLEIGH, March 2

Nature, March 12, 1891

Agnes Pockels: Tools for Characterizing the Water Surface

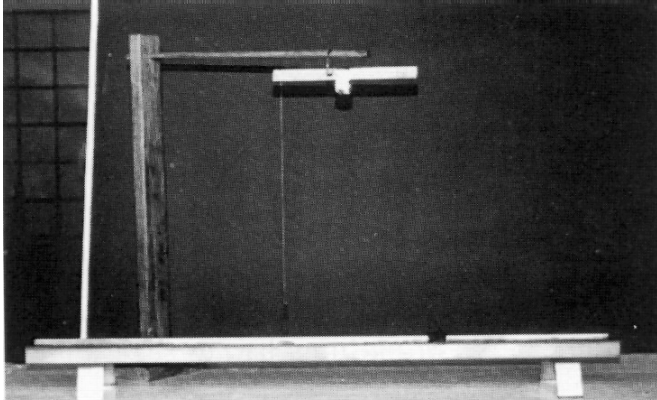
Langmuir's trough,
modified Pockels' design



- Rectangular tin trough, 70 cm long, 5 cm wide and 2 cm high filled with water to the brim and a strip of tin about 1.5 cm wide laid across it perpendicular to its length, so that the underside of the strip is in contact with the water.
- Variation of surface area by altering the strip position.
- Surface tension measured with an apothecary's balance to determine the weight necessary to lift a small disk, 6 mm diameter (i.e. a button) from the water.

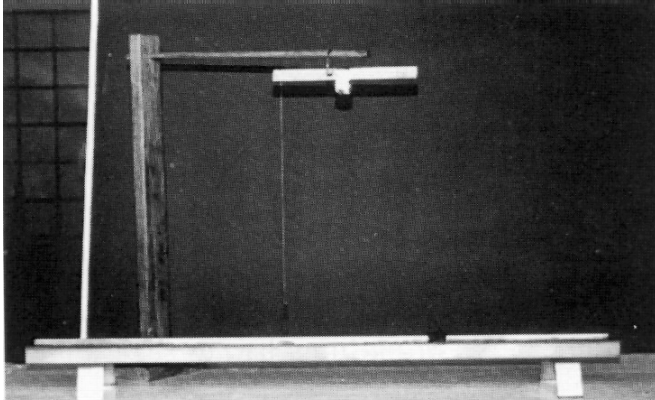
She sent her results to the professors of physics of the University of Göttingen who did not express any special interest in them.

Agnes Pockels, **Surface Tension** (1891) *Nature* **46**, 437: Ten Years of Research in One Paper



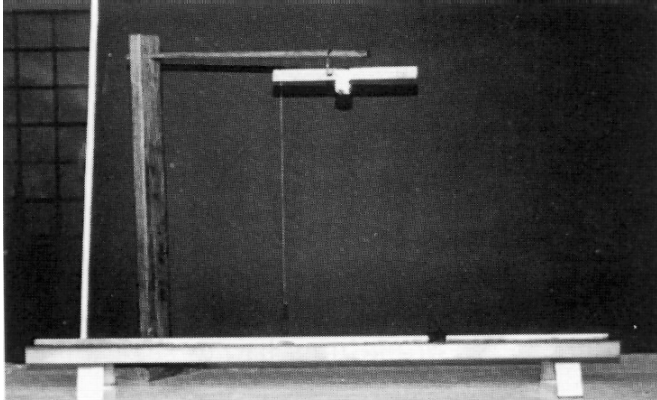
- I. The surface tension of a **‘contaminated’** water surface varies if the surface is compressed or expanded. **On compression, the surface tension decreases up to a factor of two. On expansion, it increases until a maximum value is reached, then remains constant.**
- II. Thus, a water surface can exist in two states, a *normal* condition in which the surface tension remains constant if the surface size is changed, and an *anomalous* condition, where varying the surface size leads to a change in surface tension.
- III. **The cleaner the surface, the more it can be compressed while the surface pressure remains at its maximum value.**
- IV. A surface in the *anomalous* state can be cleaned by removing the surface layer by immersing and withdrawing a paper strip.
- V. The lower the surface tension, the more pronounced is the wave damping.

Agnes Pockels, **Surface Tension** (1891) *Nature* **46**, 437, cont.: Ten Years of Research in One Paper



- VI. All solid bodies, no matter how clean, contaminate a water surface that is in *normal* state.
- VII. Solid materials like glass or metals increase the relative ,contamination‘.
- VIII. Other materials like camphor or flour reduce the surface tension until an equilibrium value is reached that is different for each substance. The solid is the source of a current of ,contaminating‘ material. A **contact line** between water surface and the **material current** can be **made visible** by dusting the water with flowers of sulfur.
- IX. A material current occurs between surfaces with the same surface tension if the ,contamination‘ is caused by different substances. „Equal relative contamination by different substances does not indicate equality of **that (osmotic?) pressure -in surface films** - which is the cause of the material current between surfaces of equal surface tension.“

Agnes Pockels, **Surface Tension** (1891) *Nature* **46**, 437,
cont.: Ten Years of Research in One Paper



X. **Solutions of sugar** have a *normal* surface and a **higher surface tension** than pure water. Yet a piece of sugar brought to its surface causes material current and surface tension reduction.

XI. „From these experiments I concluded (a) that the **surface layer of water can take up *more of soluble substances than the bulk solution***; (b) that the compressed surface of a solution gets *anomalous*, always and only, if it contains more of the dissolved substance than the bulk.“

**Basis for Quantitative Study of
Surface Films**



Diary
until
1907

The Pockels Domestic Scene

1877 Konfirmiert. Im Sommer
Reise nach Lüneburg wegen
Mummers Verschlechterung.
1880 über 81. Im Sommer bei Mutter
überflüssig aufbewahrt.
1881 Großeltern Lasker gestorben.
1884-85 Mutter häufig bettlägerig.
1882 Typhuskrankheit aufgetreten.
Überflüssige Bekleidungs-
dinge eingekauft.

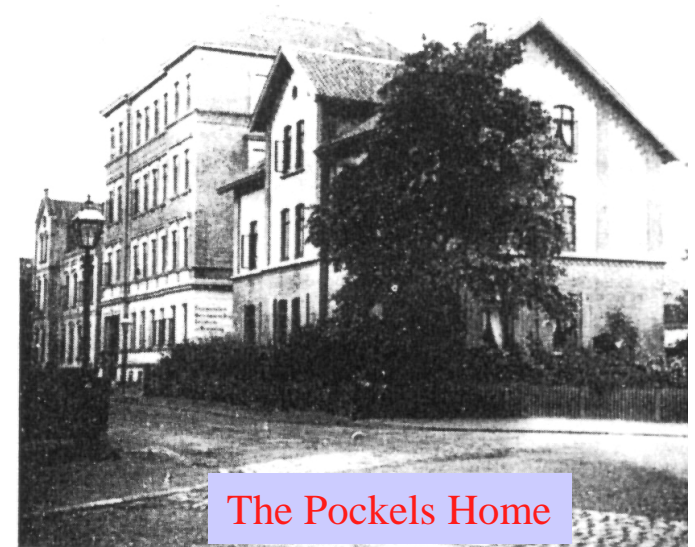
‘1877: ... Mummy’s nerve trouble;’ ‘1881-85: Mummy often ill in bed;’ ‘1887: In winter, Daddy had carbuncles;’ ‘1888: In summer, Daddy had catarrh of the bladder;’ ‘1890: Daddy was ill in March and October;’ ‘1892: In January, Fritz had influenza. In March and April, Daddy was ill...At the end of July... Daddy was ill;’ ‘1894: In February, Fritz had influenza. At Easter ... Daddy was ill;’ ...

Elisabeth Pockels, Bericht der Oberhessischen Gesellschaft für Natur-und Heilkunde **24** (1949) 303

“the family suffered ... with much illness, and some pessimism was also in evidence so that a large part of her life, during the years 1890-1914, was spent in home nursing. Her scientific work had to take second place... When she was warned to pay attention to her own health, she said once: “Like a soldier, I stand firm at my post caring for my aged parents.”

Agnes Pockels: Her Life

Autobiographical Notes in
W. Ostwald (1932), *Kolloid-Zeitschrift*, 58, 1



The Pockels Home

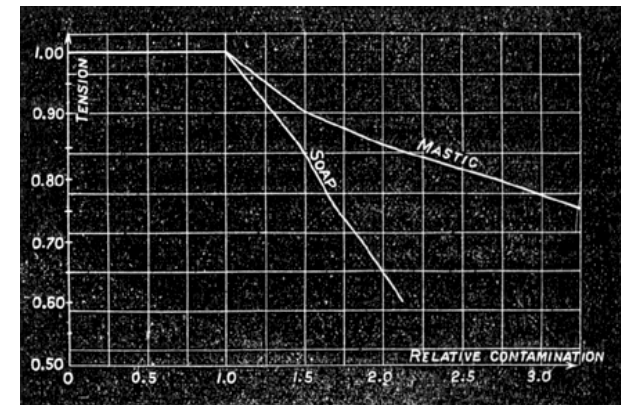
“Encouraged by the support of Lord Rayleigh and the publications in *Nature*, I dared to submit papers to German journals, and conducted about 10 years of succesful investigations. The care of my sick parents was very challenging, therefore after 1902 I did few experiments, but I did a translation and wrote comments for “Beiblätter zu den Annalen”, which my brother edited. In 1909 I published my observations of the contact angle.”

Agnes Pockels: Further Publications (chronological)

- (1) **Surface Tension**, (1891) *Natur*, **46**, 437.
- (2) **On the relative contamination of the water surface by equal quantities of different substances**, (1892) *Nature* **47**, 418.
- (3) **Relations between the surface tension and relative contamination of water surfaces**, (1893) *Nature*, **48**, 152.
- (4) **On the spreading of oil upon water**, (1894) *Nature* **50**, 223.
- (5) **Beobachtungen über die Adhäsion verschiedener Flüssigkeiten an Glas**, ([Observations about the Adhesion of Different Liquids on Glass](#)), (1898) *Naturwissenschaftliche Rundschau*, **14**, 190.
- (6) **Randwinkel gesättigter Lösungen an Kristallen** ([Contact Angles of Saturated Solutions on Crystals](#)), (1899), *Naturwissenschaftliche Rundschau*, **14**, 383.
- (7) **Untersuchungen von Grenzflächenspannungen mit der Cohäsionswaage**, ([Investigations of the Surface Tension with the Cohesion Balance](#)), (1899) *Annalen der Physik*, **67**, 668.
- (8) **Über das spontane Sinken der Oberflächenspannung von Wasser, wässrigen Lösungen und Emulsionen**, ([On the Spontaneous Decrease of the Surface Tension of Water, Aqueous Solutions and Emulsions](#)), (1902) *Annalen der Physik*, **8**, 854.
- (9) **Über Randwinkel und Ausbreitung von Flüssigkeiten auf festen Körpern** ([On Contact Angles and the Flow of Fluids on Solid Bodies](#)), (1914) *Physikalische Zeitschrift*, **15**, 39.
- (10) **Zur Frage der zeitlichen Veränderung der Oberflächenspannung** ([On the Changes of the Surface Tension with Time](#)), (1916) *Physikalische Zeitschrift*, **17**, 141
- (11) **Über die Ausbreitung reiner und gemischter Flüssigkeiten auf Wasser** ([On the Spreading of Pure and Mixed Liquids on Water](#)) (1916) *Physikalische Zeitschrift*, **17**, 142.
- (12) **Die Anomalie der Wasseroberfläche** ([The Anomalous State of the Water Surface](#)) (1917) *Die Naturwissenschaften*, **5**, 137 u. 149.
- (13) **Zur Frage der Ölflecke auf Seen** ([On Oil Stains on Lakes](#)) (1918) *Die Naturwissenschaften*, **6**, 118.
- (14) **The measurement of surface tension with the balance** (1926) *Science* **64**, 304.

Agnes Pockels: The Subsequent *Nature* Papers

- I. „In order to divide very small masses exactly I chose the course of Lord Rayleigh of transferring the contaminating substance to the water-surface by means of a volatile solvent. But instead of ether I used *benzine*, and **let the drops of the solution evaporate directly from the water** instead of vaporizing them on a metal plate and then immersing this, as Lord Rayleigh did.“
- II. The area of onset of a decrease in surface tension: 1mg provencer oil 8460cm², 1mg stearic acid 4711cm², etc. The thickness of the film is very small, i.e. 1.3nm for provencer oil.
- III. The smallest thickness found amounts to 0.037nm, „It seems to me very probable that the contaminating substances *are not spread in coherent films at all*, but rather in a state of very fine distribution between the superficial water molecules **that must be named either emulsion or solution.**“
- IV. The first isotherms with quantitative units.



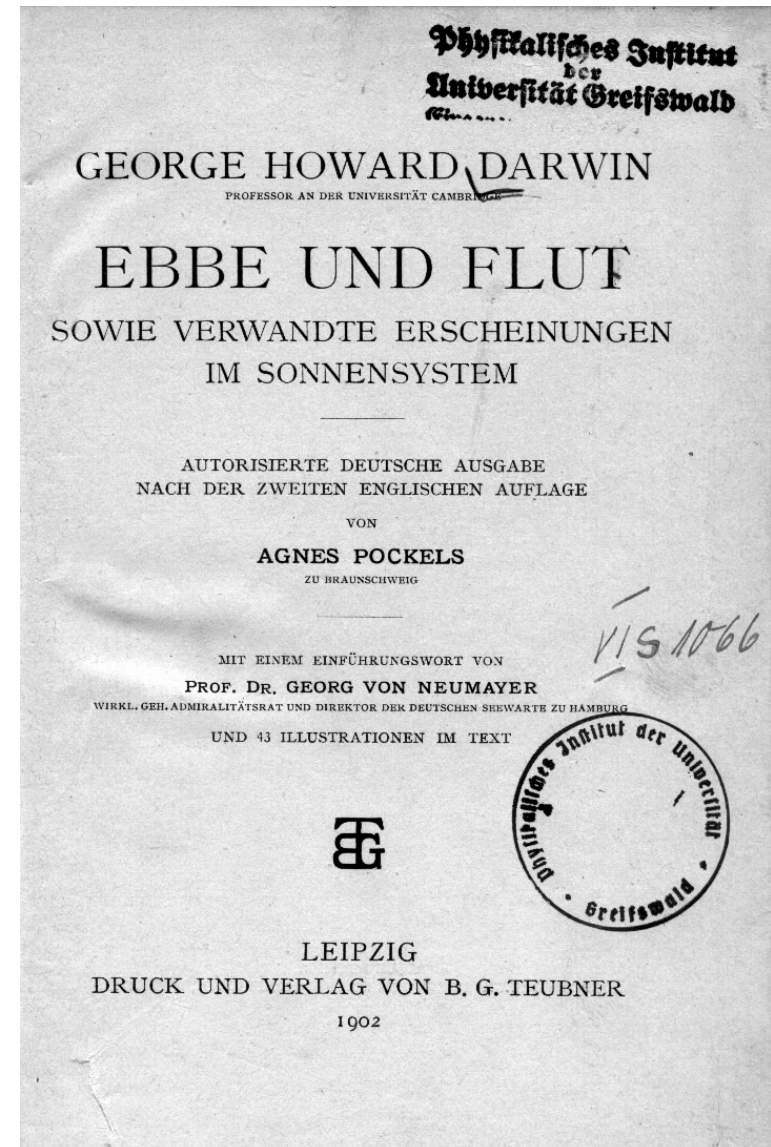
Agnes Pockels: Subsequent Papers

- I. Glass cleaning by heating it in a flame, and immersing it in water. If the glass is clean, no material current should occur.
- II. The material of the trough and the barrier should exhibit very high contact angles with water.
- III. Certain oils yield very homogeneous fluid layers of constant thickness (uniform interference colour); they thin on area expansion until they break at a thickness typical for the oil used.
- IV. Optimizing the ring method to determine surface tension (Science, 1926).

Other Interests: Translation of a Textbook

George Howard Darwin

**The Tides and Kindred
Phenomena in the Solar
System**



Agnes Pockels: Her Life

Autobiographical Notes in
W. Ostwald (1932), *Kolloid-Zeitschrift*, 58, 1



“When my brother died in 1913, the alarms of the war and post-war period engulfed me and the *Beiblätter (zu den Annalen der Physik)* ceased publication; I was no longer in a position to obtain the relevant literature and in the end I completely lost contact with research in my field, the deterioration in my eyesight and my health altogether being a contributing factor.”



“During her later years she led a quiet life as ‘Auntie Agnes’, like many other middle-aged women in Braunschweig. She had a wide circle of acquaintances, and two puzzle-solving societies met in her home. The war and the inflation hit this society hard. ...

She herself suffered relatively less because her American relatives provided for her financially, and because later on the capital invested in California produced extremely high dividends. As a result, she was able to help others in all kinds of ways, and shared her income for years. She herself always lived simply, and kept her thoughts to herself without saying much.

The information about her special scientific knowledge was now only mentioned abroad in whispers.”

Agnes Pockels: Late Recognition

Annual Laura-R.-Leonard Prize of the German Colloid Society

„for her quantitative investigation of the properties of interfaces and surface films, and for the methods she used, which have since become fundamental in modern colloid science“

She taught us not only cleanness in our work, she also taught us how to measure it! (W. Ostwald (1932), *Kolloid-Zeitschrift*, 58, 1)



1923	Prof. Dr. Wolfgang Pauli, sen. (1869 - 1955)	Physician (Wien, Au)
1923	Prof. Dr. Richard Zsigmondy (1865 - 1929)	Chemist (Göttingen) Nobel Prize 1925
1924	Prof. Dr. Martin H. Fischer (1879 - 1962)	Physician (Cincinnati, OH)
1925	Prof. Dr. Henry Siedentopf (1872 - 1940)	Physicist (Jena)
1926	Prof. Dr. Hermann Ambronn (1856 - 1927)	Biologist (Jena)
1927	Prof. Dr. Alfred Lottermoser (1870 - 1945)	Chemist (Dresden)
1928	Prof. Dr. Herbert Freundlich (1880 - 1941)	Chemist (Berlin)
1928	Prof. Dr. Sir William Hardy (1864 - 1934)	Chemist (Cambridge, GB)
1929	Dr. Dr. h. c. R. E. Liesegang (1869 - 1947)	Photographic Factory (Frankfurt/Main)
1930	Prof. Dr. Heinrich Bechhold (1866 - 1937)	Physician (Frankfurt/Main)
1931	Agnes Pockels (1862 - 1935)	Housewife (Braunschweig)
1932	Prof. Dr. Peter P. von Weimarn (1879 - 1935)	Chemist (Kobe, Japan)
1933	

Late Recognition, cont.

1932 First Woman to receive the Dr. h. c. from the Technical University Braunschweig, on the occasion of her 70th birthday

Sonntag, 14. Februar 1932

Die Carolo-Wilhelmina hat eine Ehrendoktorin ernannt

Heute, am 14. Februar, vollendet Fräulein Agnes Pockels ihr 70. Lebensjahr. Als stille Privatgelehrte ist sie in ihrer Heimatstadt wenig hervorgetreten. Aber im Reiche der Wissenschaft hat sie sich als intelligenzvollere Förderin an die Seite der drei Braunschweiger Großen: Elster, Giesel und Giesel zu stellen vermocht. Die Arbeiten von Fräulein Pockels, die auf dem Gebiete der Oberflächenpannungen ansetzten, erregten bereits vor vierzig Jahren die Aufmerksamkeit des berühmten englischen Physikers Lord Rayleigh, der sich damals mit ähnlichen Problemen beschäftigte. In neuerer Zeit ist auf der Grundlage der Pockelschen Arbeiten ein ausgedehnter Zweig der Kolloidwissenschaft entstanden, die Lehre von den Grenzschichten und Filmen. Aus diesem Grunde hat die Kolloidgesellschaft an Fräulein Pockels den „Leonardpreis“ für 1931 verliehen und die Technische Hochschule Braunschweig hat ihr die Würde eines Dr.-Ing. e.h. übertragen. Beide Ehrungen geschahen am Vortage ihres Geburtstages auf einer gerade zufällig in Braunschweig stattfindenden Tagung der Physikalischen Gesellschaft. Der aus Leipzig zu diesem Zweck erschienene Professor W. Ostwald überreichte die Medaille des Leonardpreises und der Rektor der Technischen Hochschule das Ehrendoktoratdiplom.

Die Technische Hochschule Carolo-Wilhelmina zu Braunschweig

verleiht unter dem Rektorate
des Professors Dr.-Ing. Otto Schmitz auf einstimmigen Antrag der Abteilung für Mathematik und Physik nach Beschluß von Rektor und Senat durch diese Urkunde

fräulein
Agnes Pockels
in Braunschweig

**Die Würde eines
Doktor-Ingenieurs Ehren halber**
in Anerkennung ihrer grundlegenden Arbeiten
zur Erforschung der Eigenschaften von Oberflächen und Grenzschichten

Braunschweig, den 27. Januar 1932.
Rektor und Senat
der Technischen Hochschule Carolo-Wilhelmina:

Schmitz

“I learned to my great joy that my work is being used by others for their investigations.” (Autobiographical Notes in W. Ostwald (1932), *Kolloid-Zeitschrift*, 58, 1)



THANK YOU!

Heike Schäffner

Uni Greifswald

Elisabeth Grossmann

TU Braunschweig

Sabine Gross

Univ. of Madison, WI

€: State Mecklenburg-Vorpommern

Literature

- (1) Agnes Pockels (ca 1880-1910) **Tagebuch: Lebensereignisse**; Original zusammen mit Familienfotos im Archiv der TU Braunschweig
- (2) Chemical Society (London): Xerographick copies of Agnes Pockels' diary, of the letters she and her brother wrote to Lord Rayleigh (the latter with translations into English) and reprints of photographs of various members of the Pockels family
- (3) Wolfgang Ostwald (1932) **Die Arbeiten von Agnes Pockels über Grenzflächen und Filme**; *Kolloid-Zeitschrift* (58) 1
- (4) Elisabeth Pockels (1949) **Ein gelehrtes Geschwisterpaar. Zur Erinnerung an Agnes Pockels (1862-1935)**; *Bericht der Oberhessenschen Gesellschaft für Natur- und Heilkunde* (24) 303
- (5) Stanley D. Forrester and Charles H. Giles (1971) **The origins of the surface film balance**; *Chemistry and Industry*, 43
- (6) Charles H. Giles und Stanley D. Forrester (1978) **Agnes Pockels und die Ursprünge der Oberflächenchemie** in "Mitteilungen der Technischen Universität Carolo-Wilhelmina zu Braunschweig 13", 15-28.
- (7) Stanley D. Forrester and Charles H. Giles (1979) **Rayleigh and the great monolayer discovery**; *Chemistry and Industry*, 469
- (8) Elizabeth M. Derrick (1982): **Agnes Pockels, 1862-1935**; *Journal of Chemical Education* (59) 1030
- (9) Gabriele Beisswanger (1991): **Agnes Pockels (1862-1935) und die Oberflächenchemie**; *Chemie in unserer Zeit* (25) 97
- (10) Klaus Beneke (1995): **"Die Untersuchungen von Agnes Pockels"** in "Zur Geschichte der Grenzflächenerscheinungen – mit ausgesuchten Beispielen. Mitteilungen der Kolloid-Gesellschaft. Beiträge zur Geschichte der Kolloidgesellschaft, IV ". Verlag Reinhard Knof, Kiel: 40-43
- (11) Liane Biermann: **Agnes Pockels, 1862-1935**; Broschüre der Presse- und Öffentlichkeitsarbeit der TU Braunschweig
- (12) Klaus Benecke (1996) **Laura-R.-Leonard-Preis** in "Über 70 Jahre Kolloid-Gesellschaft, Gründung, Geschichte, Tagungen (mit ausgesuchten Beispielen der Kolloidwissenschaften) Beiträge zur Geschichte der Kolloidgesellschaft, IV ". Verlag Reinhard Knof, Kiel: 94-98