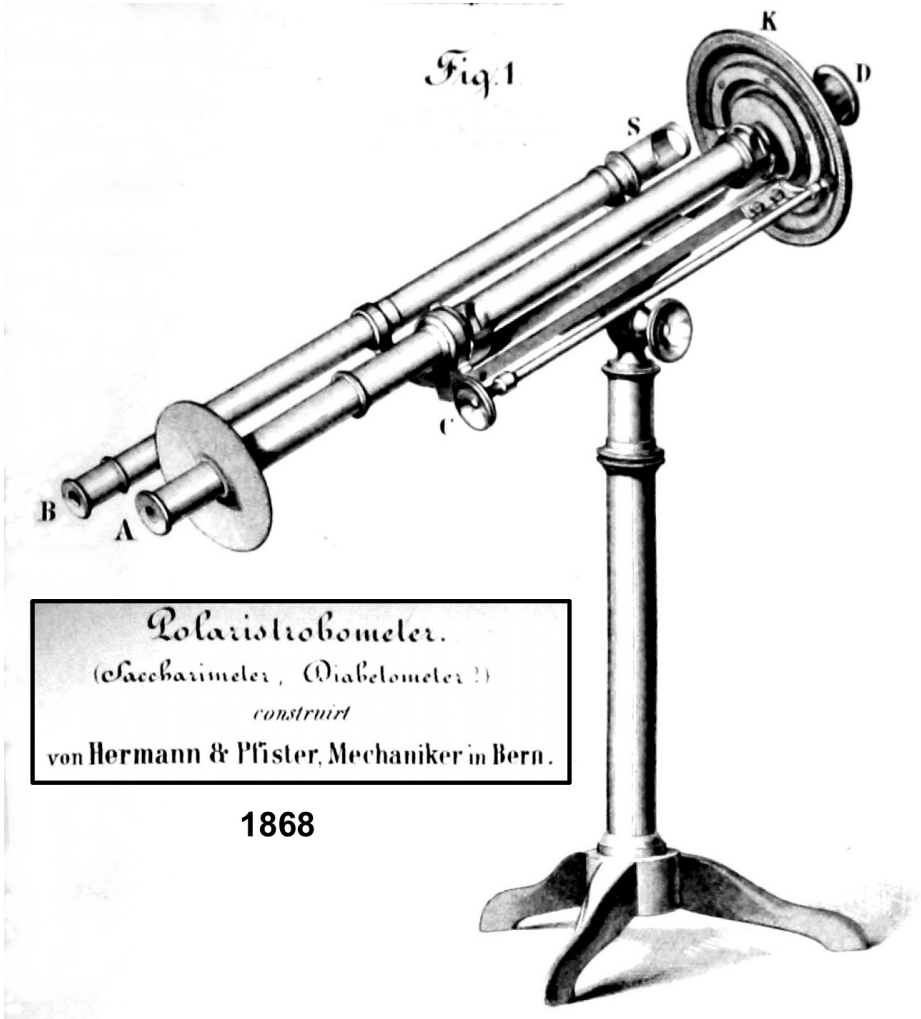
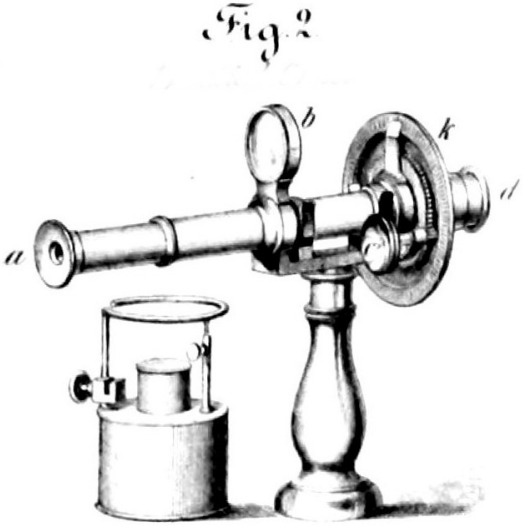
Heinrich Wild's Polaristrobometer:
An early form of chemical polarimeter





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Abstract

Heinrich Wild's Polaristrobometer: An early form of chemical polarimeter

The year 2011 having been proclaimed by UNESCO and IUPAP "International Year of Chemistry", it seems fitting to have a close look at a physical chemistry instrument, the Polaristrobometer, an early form of polarimeter/saccharimeter, at its inventor, the Swiss physicist Heinrich Wild, at its enthusiastic reception by chemists, and at its principal manufacturer, Hermann & Pfister at Bern.

Heinrich Wild (1833-1902) was appointed professor of physics at the University of Bern and director of the (mainly meteorological) Observatory in 1858. Called in 1868 to the direction of the Central Physical (Meteorological) Observatory in Saint Petersburg, he spent the next 27 years in Russia, extending enormously the network of observing stations and working on the improvement and standardisation of meteorological instruments. He retired to Zurich in 1895.

His Polaristrobometer, first described in 1865, is built around the very sensitive polariscope invented by Savart a quarter of a century earlier. To achieve the measurement of the angle of rotation of the plane of polarisation of monochromatic light by optically active substances, the polariser is rotated until a network of parallel interference fringes disappears, as opposed to the more modern types of polarimeters where one looks for an equality of tint or of luminosity of two or more adjacent fields. This truly original, precise and practical polarimeter remained the best one available until the end of the 19th century, when it was superseded by instruments less prone to systematic errors and more convenient to use.

That the Polaristrobometer was much in demand by chemists and commercially successful is shown by the many citations and images in physics textbooks and, above all, by the long descriptions and detailed instructions appearing in books and articles written by chemists from 1875 onwards, notably by the pioneer of polarimetry H. Landolt. Today, many Polaristrobometers can be found, often unidentified, in remote corners of science museums.

Hermann & Pfister (later Pfister & Streit) at Bern became the main, but not exclusive manufacturer of this instrument. A model of reduced size (tubes of 50 mm instead of 220 mm) was first made by J. G. Hofmann at Paris and by Dr. Meyerstein at Göttingen. Both models are still mentioned in the 1896 catalog of Schmidt & Haensch at Berlin.

Preliminary Remarks

1) No known relationship between
Heinrich WILD (1877-1951), the famous builder of surveying instruments and founder of "Wild Heerbrugg", and the (almost) forgotten Heinrich (von) WILD (1833-1902), meteorologist and inventor of the Polaristrobometer.

2) Chemical Polarimeter:
Measures the rotation of the plane of polarisation of light, generally monochromatic (sodium yellow light, $\lambda = 589$ nm), by chemically "active" substances, mainly liquids or solutions.

3) Saccharimeter:
Polarimeter specially designed to measure the sugar content of solutions, for technical use in the sugar industry (cane, beet) or for medical / pharmaceutical use (analysis of urine for diabetes diagnostic).

It normally works with a white light source and is provided with a scale giving directly the sugar content.

Wild promoted his Polaristrobometer as a Saccharimeter/Diabetometer, altough it is fundamentally a general purpose polarimeter. Those made by Hermannn & Pfister have 2 scales: one giving the angle, the other the sugar content.

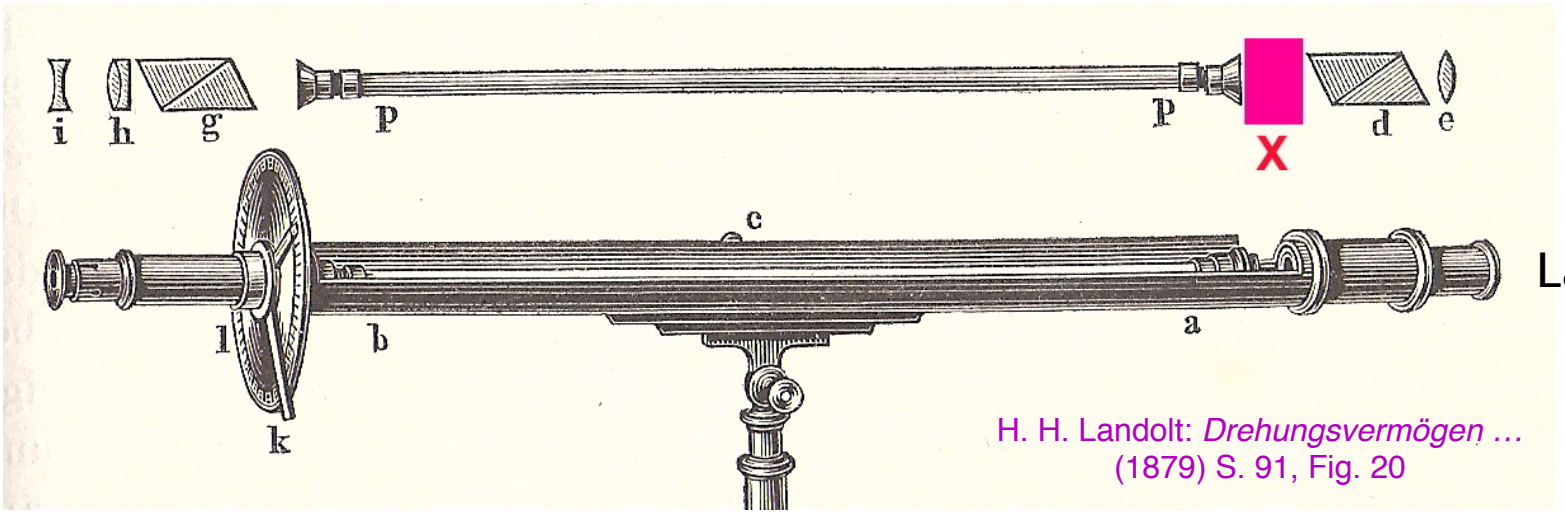
Polarisation : A short Chronology

- 1808 Malus: linear polarisation of light
- 1811 Arago: quartz (⊥) rotates the plane polarisation of light
- 1815 Biot: rotation by turpentine, sugars (also Seebeck), etc.
- >1815 Biot: laws of polarimetry
- 1822 Fresnel: linear polarisation = 2 x contrary-rotating circular pol.
- 1828 Nicol: "nicol" (calcite polariser)
- 1844 Mitscherlich: improved Biot polarimeter (using nicols)
- 1845 Robiquet-Soleil: "tint of passage" polarimeter (bi-quartz ⊥)
- 1848 Pasteur: mirror-image molecules (salts of tartaric acid)
- 1868 Wild: improved Polaristrobometer
- 1870 Duboscq (Jellet-Cornu) half-shade polarimeter
- **1874 Laurent: half-shade polarimeter**
- 1879 Landolt: *Das optische Drehungs-vermögen organischer Substanzen*
- 1881 Glan-Thomson polariser
- **1885 Lippich: half-shade polarimeter**

Chemical Polarimeter

Analyser (rotating) — Sample tube (typ. 5 cm – 20 cm) — Polariser

Eyepiece — Lamp



H. H. Landolt: *Drehungsvermögen …* (1879) S. 91, Fig. 20

¿ How to increase the sensitivity ?

Device X:	
———————	Mitscherlich (any wavelength λ)
Bi-quartz (⊥)	Soleil-Robiquet “sensitive tint” (white light)
Savart plate	**Wild Polaristrobometer** (fringes, best with D-line)
Split nicol	Jellet-Cornu-Duboscq “half-shade” (fixed angle, D-line)
Quartz (//)	Laurent “half-shade” (variable angle, D-line)
Small nicol	Lippich “half-shade” (variable angle, any λ)

H. WILD's Life & Work : An Overwiew

- **1833** **Birth** near Zurich
- 1833–1858 Physics studies
- 1858–1868 Professor at Bern
- **1868–1895** **Called** to Saint Petersburg (Russia), as Director of the Central Physical (meteorological) Observatory
- 1895 His Excellency Heinrich von Wild, "Wirklicher Staatsrat", member of the Imperial Academy of Sciences, **retires** after 27 years of intense activity
- **1902** **Death** at Zurich

Mainly active in:

— **Meteorology & earth magnetism**

— Scientific instruments

— Metrology

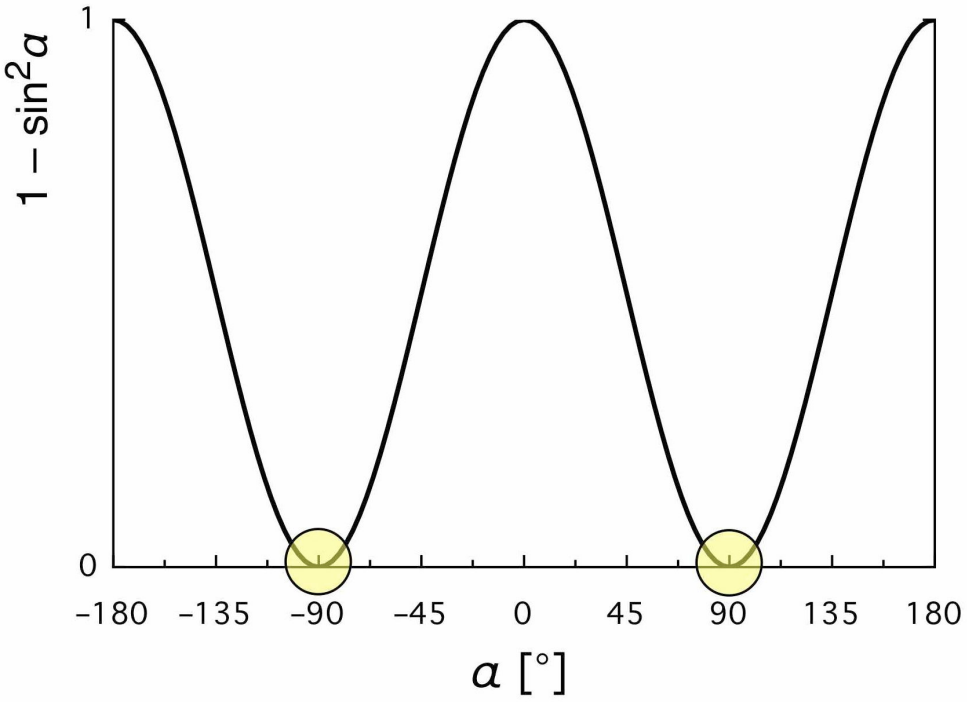
More about H. Wild in:

http://lphe.epfl.ch/publications/2011/JFL_SPS_2011_2.pdf

The Polaristrobometer (1864, improved 1869)

From 1850, polarimetry becomes an important field of chemical research.
Improved saccharimeters are needed by the sugar industry.

Polarimeters available in the mid-1860s (Mitscherlich) do not allow a precise enough determination of the angle of rotation with a liquid sample of reasonable length (about 20 cm) using monochromatic light.



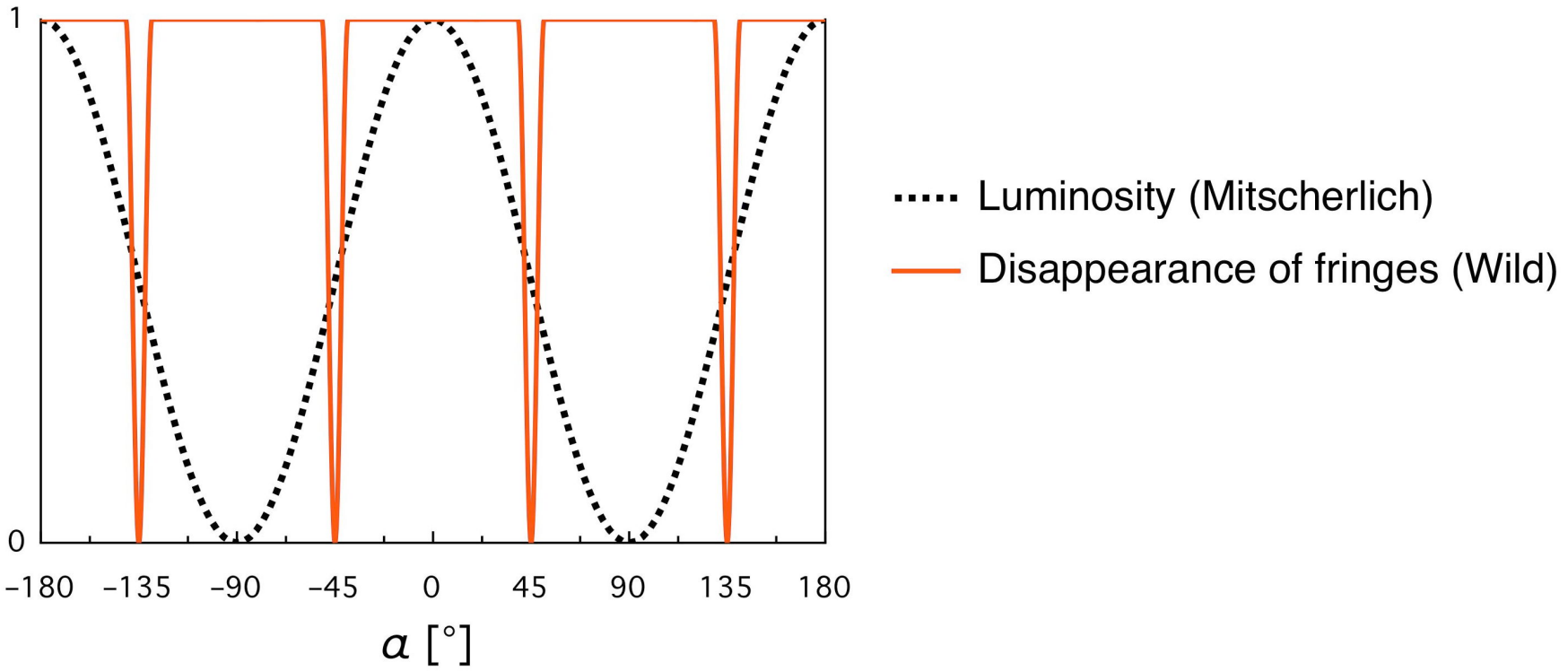
Light transmission shows two broad minima.

Determination of extrema of response problematic !

Something better is needed!

The Polaristrobometer, invented in 1864 while Wild was professor at Bern, answers the needs of the chemists.

Original: shows interference fringes instead of changes of tints or luminosity in one or more adjacent fields.



The pattern of fringes disappears at 4 sharply defined, (almost exactly) equidistant, (easily missed!) angular positions.

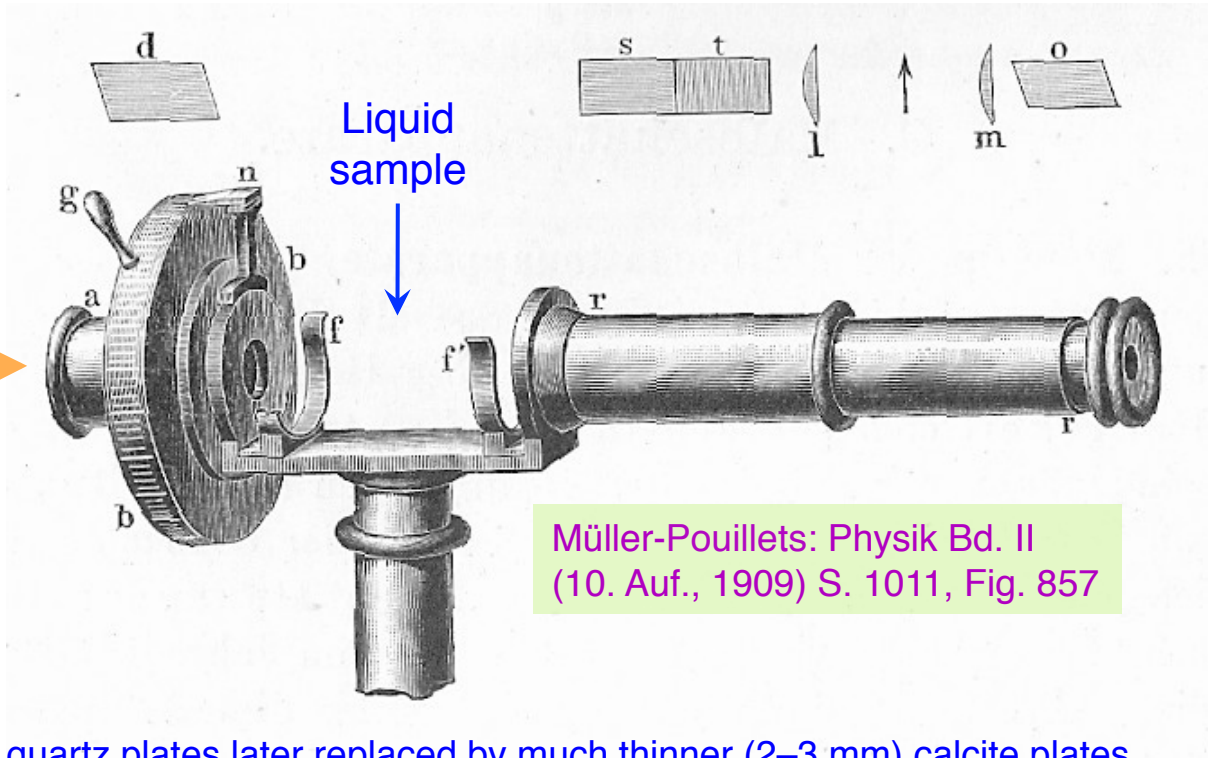
Optical system of the small Polaristrobometer (50 mm tubes)

SAVART POLARISCOPE

Rotating polariser (Nicol prism)

Savart plate (2 quartz crystals)

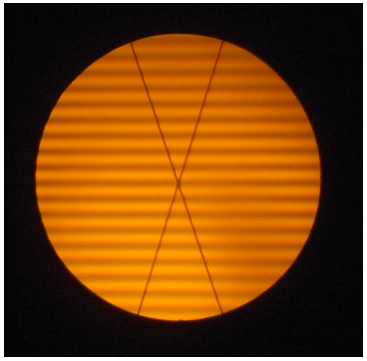
Analyser (Nicol)



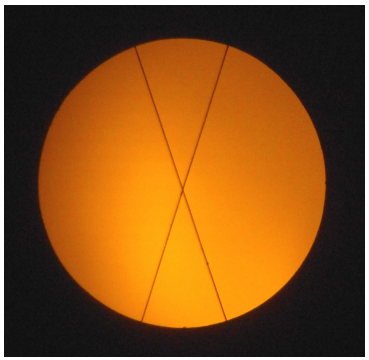
Liquid sample

Na lamp

Müller-Pouillets: Physik Bd. II (10. Auf., 1909) S. 1011, Fig. 857



The polarizer is rotated (slowly!) until the fringes disappear

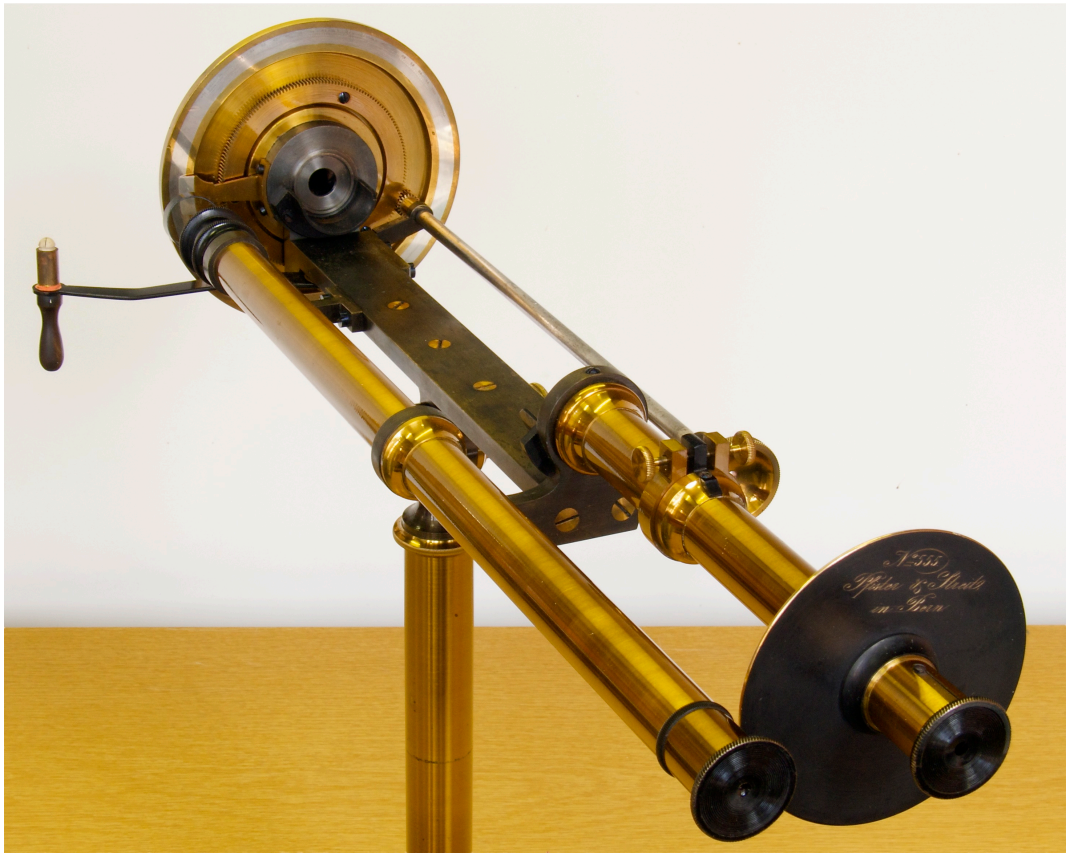


4 fringeless angular positions

Remark: thick quartz plates later replaced by much thinner (2–3 mm) calcite plates

Dr. H. Wild: *Ueber ein neues Polaristrobometer* (Bern, 1865)

The improved Polaristrobometer of 1869 (tube length up to 220 mm):



- Polarimeter/saccharimeter with *rotating polarizer*
- *Telescopic readout* of angular position
- To be preferably used with *monochromatic light* (for instance Na lamp)
- Luminous: light transmission is high

H. Wild: Über die neueste Gestalt meines Polaristrobometers (Saccharimeter, Diabetometer)
Bull. Acad. impériale des Sciences de Saint-Pétersbourg Vol. 14 (1870) 149-163 +1 Taf.

Reception by scientists

- H. G. van de Sande Bakhuyzen (1872):

Zur Theorie des Polaristrobometers und des drehenden Nicols

Mathematical analysis of the systematic errors due to inaccuracies in the construction of the Polaristrobometer, which can be completely eliminated by measuring in the 4 quadrants and taking the mean value of the readouts.

- H. BUIGNET (1877):

Manipulations de physique

« L'appareil de M. Wild ne donne pas des résultats très sensibles, et la persistance des impressions sur la rétine rend les observations très difficiles. L'œil se fatigue en regardant ces stries et continue à les voir, lors même qu'elles ont disparu ».

- B. Tollens (1877 and 1878):

Ueber die specifische Drehung des Rohrzuchers

Measurements exclusively made with the large Polaristrobometer made by Hermann & Pfister, "improved" by increasing the angle between the Savart plate and the the nicol analyser.

Claims to get ± 3' (0.05°) readout error (2 quadrants only).

• H. H. LANDOLT (1879), still known for the Landolt-Börnstein Tables:
Das optische Drehungsvermögen organischer Substanzen
Gives a detailed description, describes how best to use it.
Mentions the modifications (improvements ?) made by Tollens.
Compares the results of measurements made with other available polariscopes: Laurent's, Mitscherlich's and Wild's polarimeters are in agreement, within 0.1° or less.

Fig. 27.

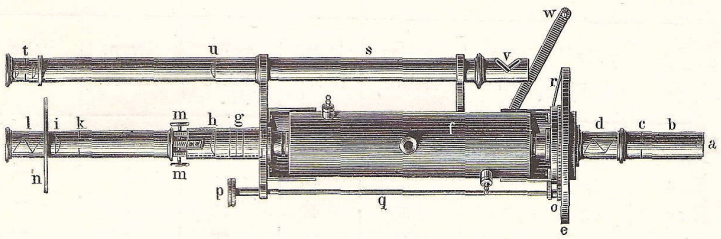
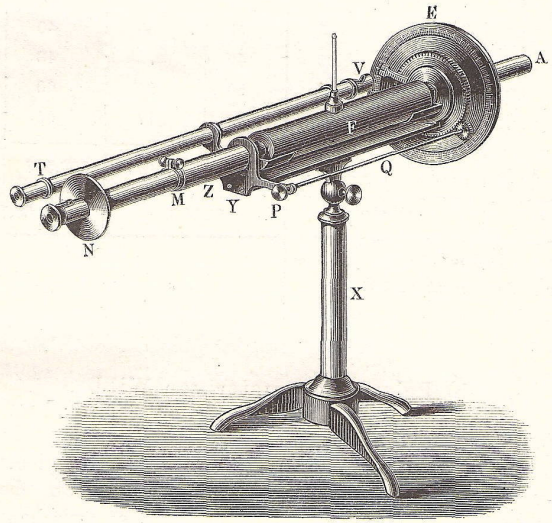
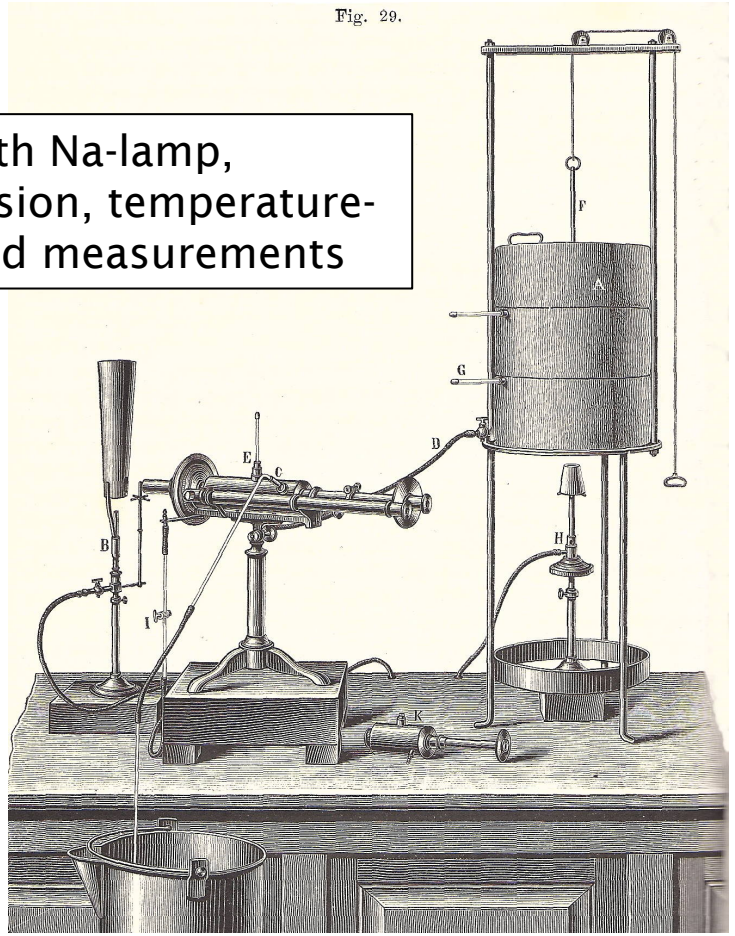


Fig. 28.



Setup with Na-lamp,
for precision, temperature-controlled measurements

Fig. 29.



• Dr. C. Gänge (1880):
Die Polarisation des Lichtes im Dienste des Chemikers
« Trotz des höheren Anschaffungspreise, … . ist daher der Polaristrobometer von Wild unter allen Umständen den anderen Instrumenten vorzuziehen ».

• Etc., etc.

Until 1914, the Polaristrobometer is mentioned in every book about chemical polarimetry, as an useful (at least) instrument, and described in every treatise of physics. But:

• Franz Schmidt & Haensch (**1896**): *Katalog der optischen Instrumente*
« Die Wild'schen Apparate sind trotz ihrer Empfindlichkeit für längeres Arbeiten nicht geeignet, da das Auge sehr angestrengt wird ».

Lippich "half-shade" polarimeter, using Glan-Thompson polarisers, had been invented (1885).
Wild's Polaristrobometer was becoming obsolescent.

1865 – 1890:

The Polaristrobometer was a commercial success, sold in “large” numbers.

Manufacturers:

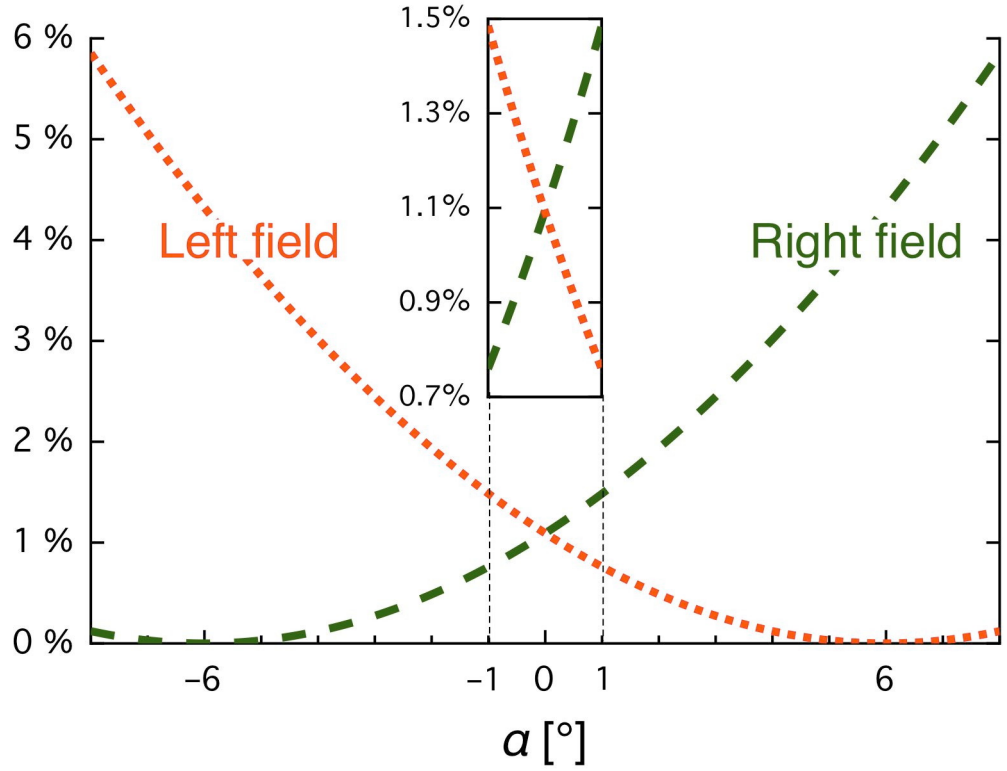
- Hermann & Pfister (later Pfister & Streit) at Bern
- Franz Schmidt & Haensch (Berlin)
- H. G. Hofmann (Paris) and Meyerstein (Göttingen).

Price: Hermann & Pfister: small instrument Mk 185; large instrument Mk 385 (including sample tubes, Na-lamp, transportation box).

“Best” polarimeter from 1870 up to the invention of the Laurent (1874) and of the Lippich(1885) “half-shade” polarimeters.

"Half-shade" Polarimeters:
Jellet-Cornu-Duboscq, Laurent, Lippich, ...

Comparison of the luminosities of 2 (or 3) adjacent fields:



The human eye (and later photocells) are excellent comparators of luminosity => much increased sensitivity, but low light transmission.

1868–1895: Wild at St-Petersburg

27 years of prodigious activity !

Active in meteorology, terrestrial magnetism (Pavlovsk Observatory 1878), metrology, polar research.

Participates in or chairs international conferences.

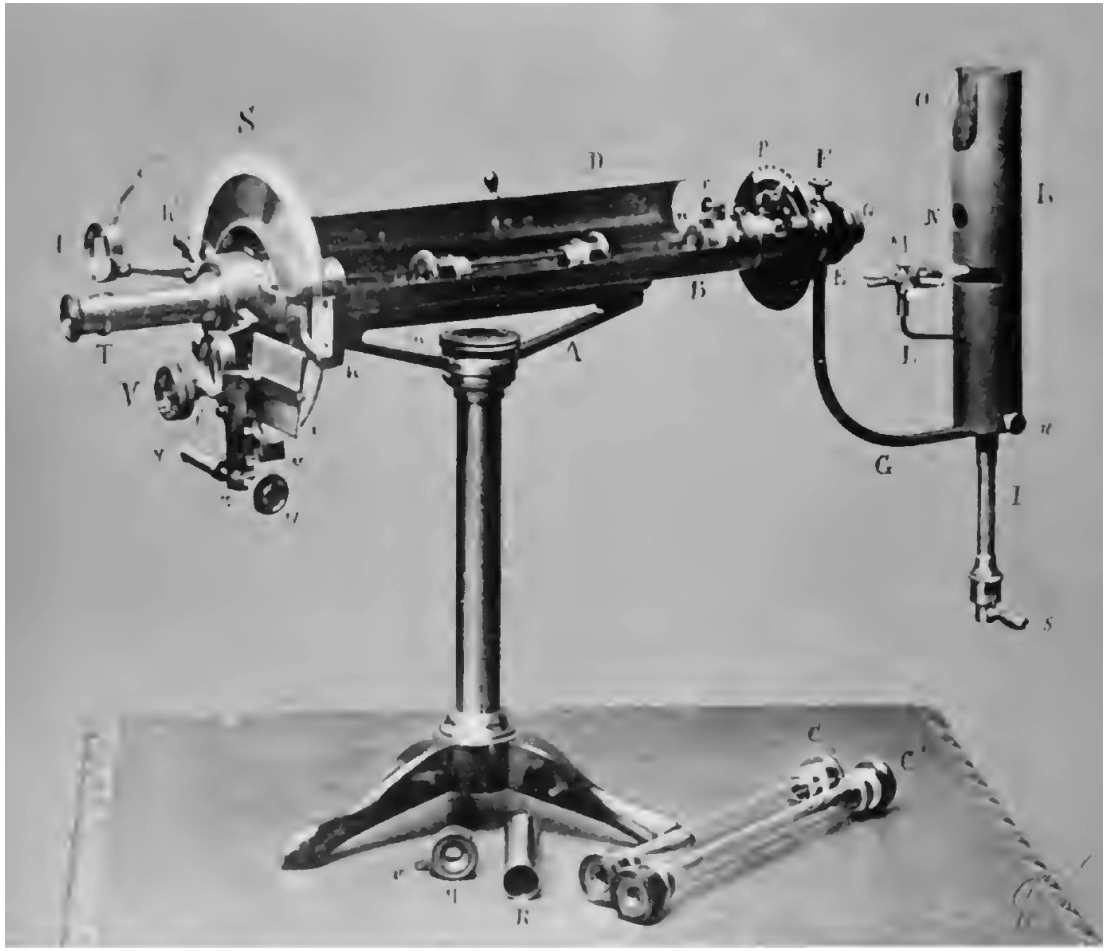
With his wife Rosa, doesn't neglects social life!

But no time left for polarimetry.

«The nearest approach to perfection yet attained is the Russian Observatory at Pavlovsk near St. Petersburg…»
C. C. Marsh: Magnetic Observatories of Europe (1889)

1895 In ill health, Wild retires and returns to Zurich.

Back to the Polaristrobometer (1898)



H. Wild: Verbesserung des Polaristrobometers
Vierteljahrsschrift der Naturforschenden Gesellschaft in Zürich,
43. Jahrgang, 1898, S. 37-80 + 1Taf.

- Wild recognises that his Polaristrobometer has been replaced by better instruments. He has a new, improved one built by Pfister & Streit at Bern:
  - Convertible to half-shade ("Halbschatten") polarimeter
  - Several other improvements such as a rotating *analyser*, and *Glan-Thompson* polarisers
- Wild claims his new Polaristrobometer to be twice as sensitive in fringe-mode than in half-shade mode
- Not a commercial success

Heinrich von Wild dies at Zürich on May 5, 1902

Two later comments about the Polaristrobometer:

• O. SCHÖNROCK (1928): *Polarimetrie*
He notes that the Polaristrobometer is not much in use in 1928.
« Für genaue Messungen ist mithin das Instrument nicht zu gebrauchen ».

• G. BRUHAT (1930): *Traité de Polarimétrie*
« … les analyseurs à disparition de franges devraient donner plus de précision que les analyseurs à pénombre. Il y aurait certainement intérêt à reprendre, avec des appareils plus perfectionnés que celui de Wild, l'étude des analyseurs à disparition de frange ».

2011 " International Year of Chemistry "
(UNESCO and IUPAP)

The pioneer of meteorology is remembered by a few meteorologists.

Polaristrobometers, still to be seen in many collections of instruments, are the sole material mementos of his work.

Acknowledgements

Without *Dr. R. Saba*, who gave me a Polaristrobometer he had salvaged many years ago, I would never have been incited to study the life of Heinrich Wild and explore the mysteries (for a physicist) of chemical polarimetry.

I am very grateful to the *EPFL*, through my laboratory, the *LPHE*, for its continued support.

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[partial reproductions of the obituary written by MAURER, of another one by RYKATSCHEW published in NZZ Nr. 354 (1902), followed by the article written by Karl SPITTELER *"Die Freitag-Abende im Petersburger Observatorium. Zum Andenken an Staatsrat von Wild"*, published in NZZ Nr. 250 (1902) Morgenblatt S.1.]

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