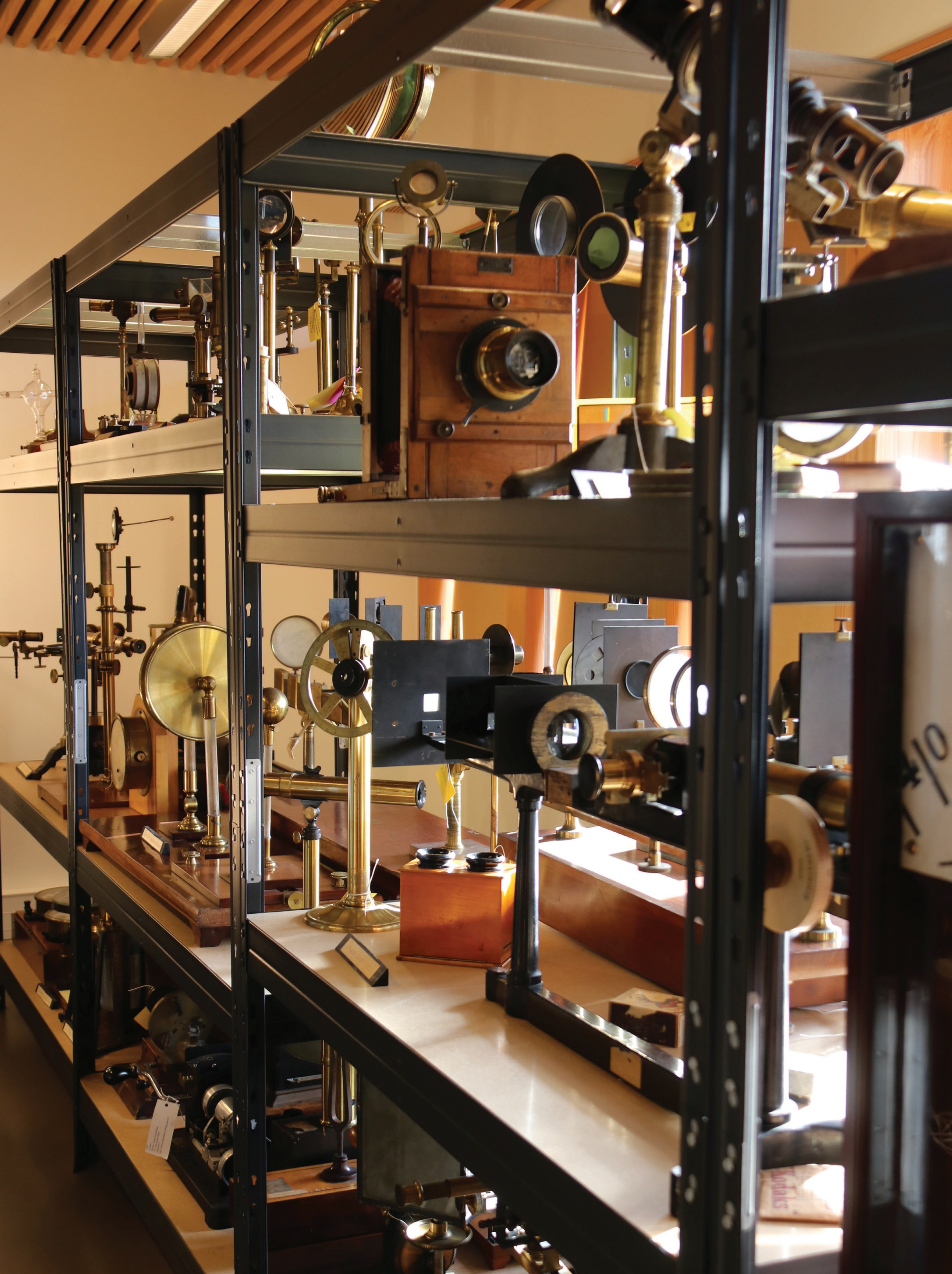


Preserving Optics Heritage
at the University of Franche-Comté

John M. Dudley, Luc Froehly, Jerome Salvi,
Pierre Verschueren and Maxime Jacquot

An effort to safeguard the legacy of optics includes a museum of historical instruments, some dating to 1845.

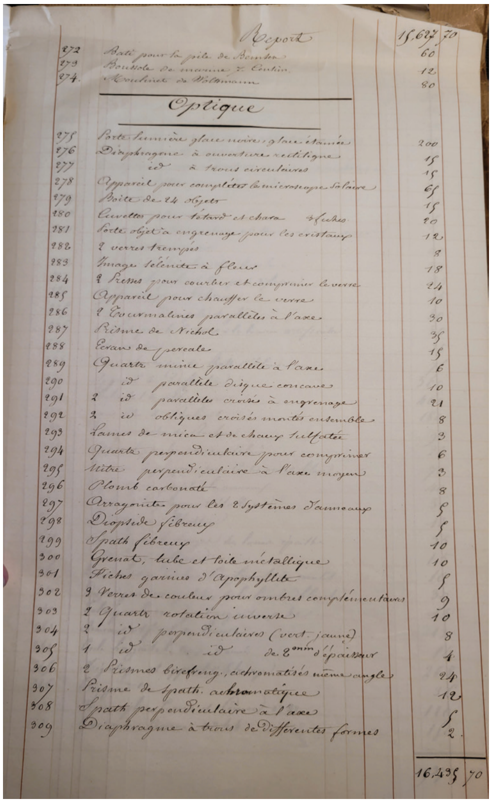
The faculty of science at the University of Franche-Comté in Besançon, France, was established in 1845, with a mission to teach a broad range of theoretical and experimental topics across the natural and physical sciences. In the area of physics, the faculty was set up with an extensive collection of 382 instruments related to the fields of mechanics, electricity, thermodynamics, acoustics and, of course, optics. Many of these historical instruments have survived in good (sometimes even working) condition and are displayed in a science heritage collection hosted at the Centre national de la recherche scientifique (CNRS) Institute FEMTO-ST at the university. This collection is extremely popular with visitors, from science luminaries to the general public, and it forms an essential component of outreach and public engagement activities for the university.

Facing page: View of museum instruments. Above: Koenig's apparatus for the analysis of sound.
Photos by J.M. Dudley

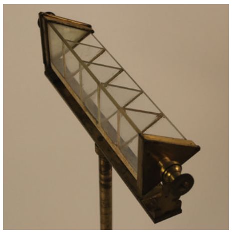
View of telescopes, prisms and microscopes.
J.M. Dudley

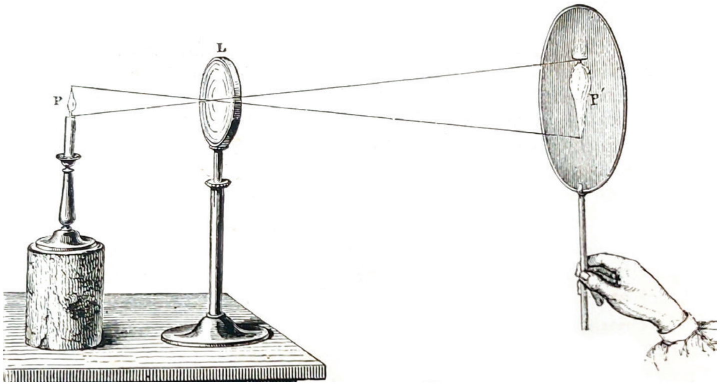
Original optics inventory

The national archives of France have saved the original inventory of optics instruments purchased for the faculty in 1844.
FranceArchives / P. Verschueren



	Report	15,627 70
272	Bati pour la pile de Bunsen	60
273	Boussole de marine 7. Centin.	12
274.	Moulinet de Woltmann	80
	Optique	
275	Porte lumière glace noire, glace étamée	200
276	Diaphragme à ouverture rectiligne	15
277	id à trous circulaires	15
278	Appareil pour compléter le microscope solaire	65
279	Boite de 24 objets	15
280	Cuvettes pour têtard et chara 4 fiches	20
281	Porte objet à engrenage pour les cristaux	12
282	2 verres trempés	8
283	Image sélénite à fleur	18
284	2 Presses pour courber et comprimer le verre	24
285	Appareil pour chauffer le verre	10
286	2 Tourmalines parallèles à l'axe	30
287	Prisme de Nichol	35
288	Ecran de percale	15
289	Quartz mince parallèle à l'axe	6
290	id parallèle disque concave	10
291	2 id parallèles croisés à engrenage	21
292	2 id obliques croisés montés ensemble	8
293	Lames de mica et de chaux sulfatée	3
294	Quartz perpendiculaire pour comprimer	6
295	Nitre perpendiculaire à l'axe moyen	3
296	Plomb carbonaté	8
297	Arragonite pour les 2 systèmes d'anneaux	5
298	Diopside fibreux	5
299	Spath fibreux	10
300	Grenat, tube et toile métallique	10
301	Fiches garnies d'Apophyllite	5
302	9 Verres de couleur pour ombres complémentaires	9
303	2 Quartz rotation inverse	10
304	2 id perpendiculaires (vert. jaune)	8
305	1 id id de 2mm d'épaisseur	4
306	2 Prismes biréfring., achromatisés même angle	24
307	Prisme de spath. achromatique	12
308	Spath perpendiculaire à l'axe	5
309	Diaphragme à trous de différentes formes	2
		16,435 70





Examples of an early lens (left), prisms (center, right) and a sketch from Drion and Fernet (bottom).

Geometrical optics instruments 1845–1850

The study of lenses, mirrors and prisms forms the basis of geometrical optics, but as every student of physics knows, understanding the imaging properties of these instruments in detail can be subtle. It is not surprising that studying these characteristics formed an important part of the optics curriculum, and that an experimental physics laboratory contained an extensive collection of such tools. Their size and fine workmanship may surprise a modern student, but there is no doubt that the instruments greatly facilitate the demonstration of essential imaging properties. Studying the dispersion characteristics of different glasses was also a priority in teaching, and the collection contains a variety of different prisms, including a very innovative-looking polyprism that allows the dispersion of different liquids to be readily compared.

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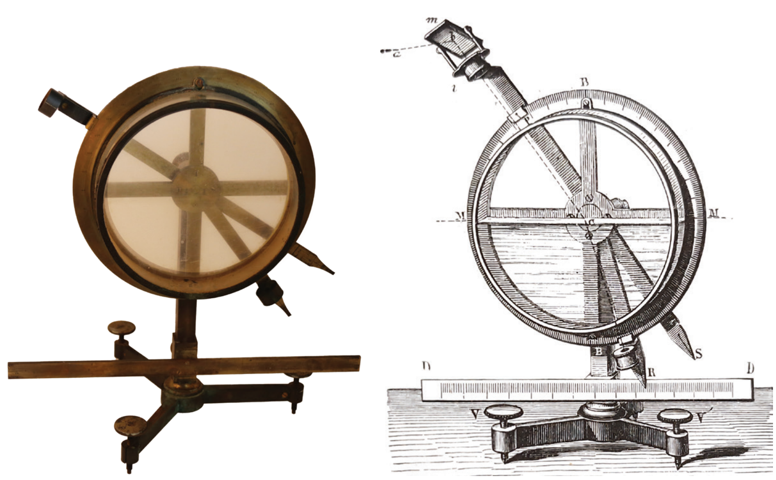
Silbermann heliostat 1843–1900

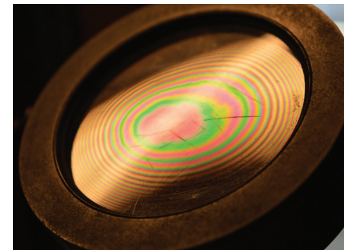
A heliostat consists of a large mirror mounted on a clockwork mechanism designed so that it turns to follow the movement of the sun in the sky during the day, reflecting solar rays in a constant direction independent of the sun's movement. The parameters of the heliostat had to be carefully adjusted based on the location of the observer, but once set, it yields a fixed source of light so that optical experiments can be carried out conveniently in a laboratory. A Silbermann heliostat was listed in the original optics inventory of the university from 1845.



A refraction apparatus (left) and a sketch from Drion and Fernet (right).

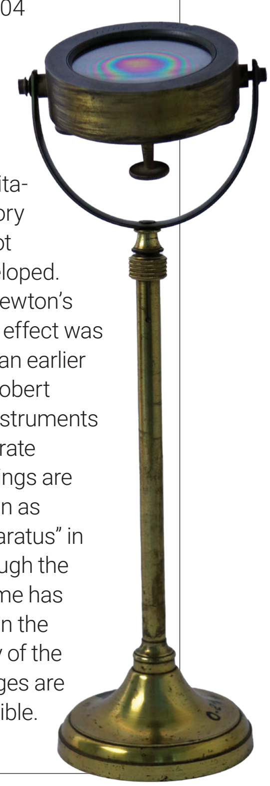
Refraction apparatus 1825–1849

This simple apparatus was used to illustrate the well-known sine law of refraction, usually known as Snell's Law (or Descartes' law in France). By filling the half-cylinder container with a liquid, the deviation of an incident ray of light can be easily observed, and a graduated angular scale can be used to measure the incident and refracted angles. The instrument in this form seems to have been widely used in teaching, with a typical application being to determine the refractive index of a liquid. It is so elegant in its simplicity that its purpose should be immediately recognizable to any student of optics.



Newton's rings apparatus 1850–1900

By the 1840s, the wave theory of light was becoming well established, and notions of fringe formation from the constructive and destructive interference of light waves were well understood. The collection contains several instruments probably dating from the late 1800s that demonstrate Newton's rings—the pattern of concentric colored circles that arise from the interference of light waves reflecting from two surfaces, typically a convex lens placed on a flat glass plate. Newton described these rings in his 1704 work *Opticks*, although he struggled to explain his observations, since a quantitative wave theory of light had not yet been developed. Intriguingly, Newton's interest in the effect was motivated by an earlier report from Robert Hooke, and instruments that demonstrate interference rings are actually known as "Hooke's apparatus" in France. Although the passage of time has taken its toll on the optical quality of the surfaces, fringes are still clearly visible.



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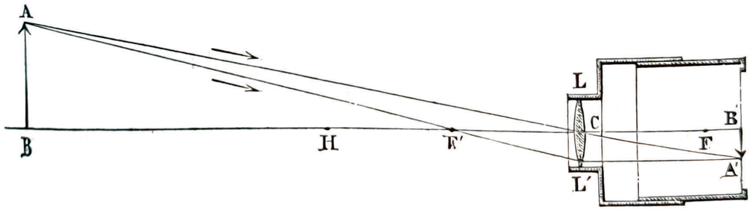
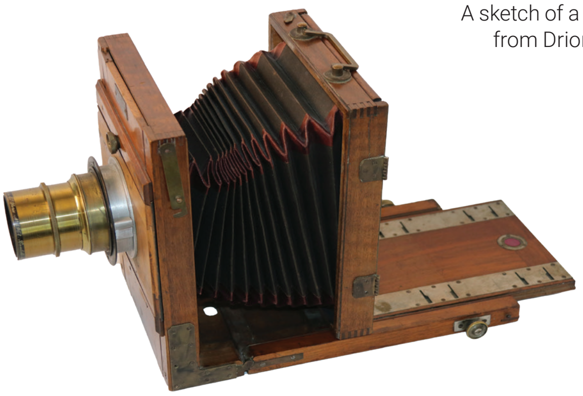
Koenig's acoustic spectral analyzer with "streak-camera" readout

1865

Rudolph Koenig's manometric flame apparatus, developed in the 1860s, is often considered the first example of a harmonic spectral analyzer. It was used to visualize the spectral content of sound waves by connecting a series of eight Helmholtz resonators to manometric flame capsules. The resonators cover a range from 128 Hz to 1024 Hz. When a sound wave excites a particular resonator, it vibrates a membrane in its connected manometer, which induces oscillation in the flow of gas used to feed a small flame. To visualize the resonance, the flame is imaged in a four-sided rotating mirror, which sweeps the resulting variations in flame intensity into the spatial dimension of the image plane. This remarkable approach to time-to-space mapping essentially operates as an optical streak camera. For a flame excited by a 512-Hz oscillation, a rotation frequency of around 1 Hz induces a clearly visible spatial separation of 1 to 2 mm between images in the rotating mirror. Koenig sold these instruments from his workshop in Paris, and they appeared for sale in his catalog as early as 1865.

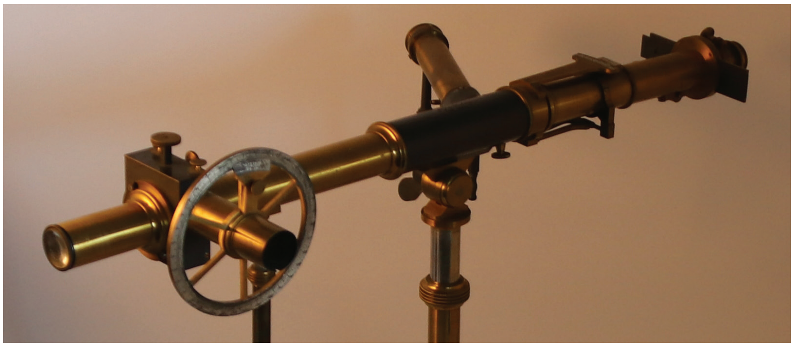


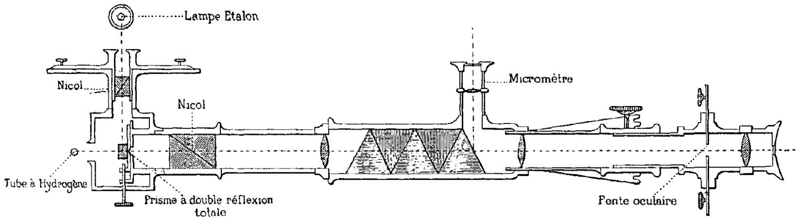
A sketch of a view camera from Drion and Fernet.



View camera **1845–1900**

The view camera was developed during the era of the daguerreotype (1840s to 1850s) and consists of a system where a lens forms an inverted image on a ground-glass screen directly at the film plane. The image is composed and focused, then the glass screen is replaced with the film for exposure. In French, this kind of device is often described as a "*chambre noir*" (camera obscura) as it produces images similar to a pinhole camera, but with improved light collection thanks to a convex lens. In the 19th century, cameras were used in university classes and public lectures to illustrate the principles of imaging and to support the growing field of photography. The university inventory records the purchase of such an instrument in 1845.





A spectrophotometer (top) and a sketch from Lagarde's 1885 publication (bottom).
gallica.bnf.fr / BnF

Crova spectrophotometer c. 1885

The Crova spectrophotometer, first described by André Crova in 1883, combined dispersive, collimating and polarization optics in a convenient linear "direct vision" design. The polarization optics enabled the adjustment of the relative intensity of a source under study and a reference spectrum, and an integrated micrometer enabled calibration of the instrument using known spectral lines from standard sources. Henri Lagarde, chair of physics in Besançon from 1885 to 1890, used a Crova spectrometer in 1885 to measure the spectral lines of hydrogen. The study of spectral lines was an extremely important area of physics at the time, although in 1885 there was only empirical understanding of the position of the visible hydrogen lines in terms of the Balmer series. Yet 1885 was also the year when Niels Bohr was born, and 27 years later, he developed the atomic model that finally revealed the origin of line spectra as arising from discrete atomic transitions.

Fresnel mirrors and Monsieur Gouy's apparatus 1890

Fresnel mirrors consist of two plane mirrors at a slight angle to each other, and they are used to demonstrate the wave-like nature of light arising from two virtual sources behind the mirrors. The Fresnel mirror setup is a complement to the classic Young's double-slit experiment, with the advantage that single-slit diffraction is not present. Operating at grazing incidence, the "mirrors" could in fact be blackened glass. By using silvered mirrors, one of them concave, the setup could be adapted to demonstrate the Gouy phase shift across a focus. The fact that this particular apparatus is engraved with the name of Louis Georges Gouy allows us to date it after 1890, which marked the first publication on the subject.

Understanding how historical instruments were used

While the beauty and workmanship in century-old scientific instruments are obvious even to the casual observer, understanding how they were used is more challenging. Luckily, there are several recent catalogs of historical scientific instrument collections in France, but fully appreciating the intricacies of optical design sometimes requires returning to the original publications from the 1800s.

In addition, for many simpler optical instruments, widely used textbooks of the time are a valuable resource because they often provide sketches and descriptions of how equipment should be used. Many of the sketches shown here come from a textbook coauthored by Charles Alexandre Drion, who was chair of physics in Besançon from 1859 to 1862.

Note that the dates of use given in the descriptions of the instruments are in most cases only known approximately, as the instruments were often sold over years or decades for use in teaching at both universities and advanced high schools.

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- Encyclopédie des instruments de l'enseignement de la Physique du XVIIIe au milieu du XXe siècle. F. Gires, ASEISTE (2016).
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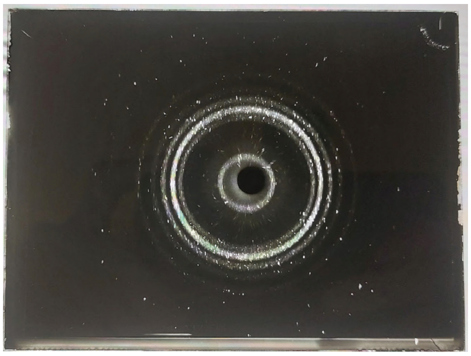
Prism spectrometer
1875–1900

Prism spectrometers were essential optical instruments in the 19th century, as pioneers such as Fraunhofer, Kirchoff and Bunsen laid the foundations for modern spectroscopy. Before the widespread availability of diffraction gratings, some prism spectrometers used multiple prisms to increase dispersion and yield greater separation of closely spaced wavelengths. The spectrometer shown uses two such prisms, and it was fabricated by Dubosq and Pellin in Paris between 1875 and 1900.



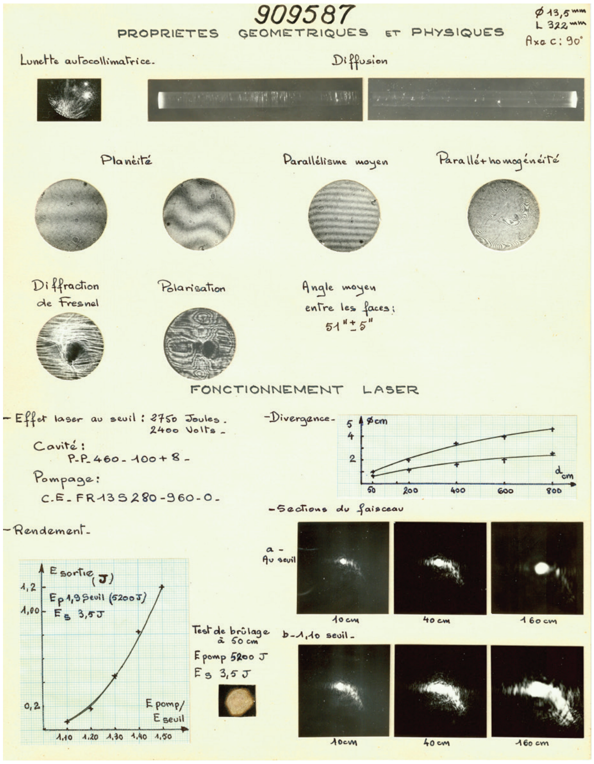
A photographic plate of an X-ray diffraction pattern. J.-J. Trillat

X-ray diffraction 1930s

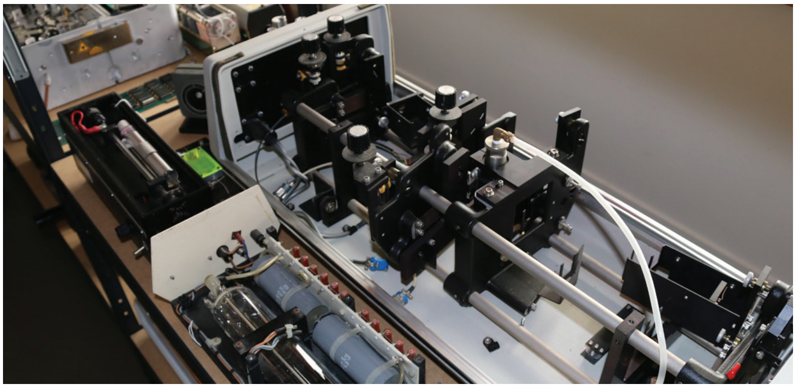
An important area of physics research worldwide in the early 20th century was the study of materials using the methods of X-ray and electron diffraction, based on concepts that were already familiar from theory and experiments in physical optics. The historical collection includes an extensive series of photographic plates of X-ray diffraction patterns that were taken by Jean-Jacques Trillat, professor of physics in Besançon from 1933 to 1948, who pioneered these fields during his doctoral thesis with Maurice de Broglie in 1928.

Archival experimental results 1960s

The museum also possesses a series of original laboratory notes and experimental reports from the 1960s.



Document from a 1967 study of different classes of crystals used in a ruby laser. LOBE / J.M. Dudley



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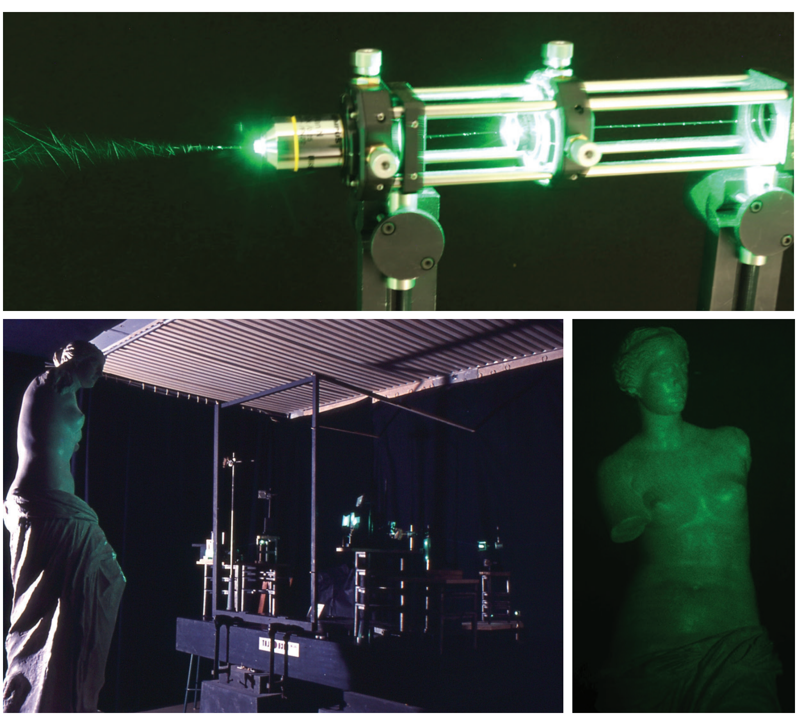
Early lasers 1960s

With this project, we aim to preserve not only the oldest instruments used in optics teaching and research, but also some of the earliest lasers and associated equipment that were purchased after the first observation of laser oscillation by Maiman in 1960. The collection consists of a variety of gas, dye and solid-state lasers, as well as related accessories and optics. The earliest item in the collection seems to be Spectra Physics 130 helium-neon laser, one of the first lasers to be commercialized around 1964.



LOBE / J.M. Dudley

Holograms 1970–1980

The optics laboratory of the University of Franche-Comté was one of the first in France to develop a major program in holography, and it had an emphasis on the creation of holograms in collaboration with artists and museums. We have a collection of more than 100 hologram plates that were created in the 1970s. In some cases, we also possess accompanying photographs showing the laboratory setups used at the time. One such hologram made at the university in 1976 was of a replica of the "Venus de Milo" provided by the Louvre.

Oral history project

The preservation of the instrument collection is only one part of a broader scientific heritage project. Equally important is work with the French Optical Society recording oral histories to support its PÉPITES national initiative. PÉPITES will safeguard the memories of the entire scientific ecosystem: academics, research scientists, engineering and technical staff, administrative staff and institutional leaders. It will encompass both academia and industry, and results will be summarized for the public. The project will bridge the gap between generations, illuminating the progression of optics and its many societal benefits.

Work at the University of Franche-Comté began in 2023, coinciding with the celebration of the 60th anniversary of the optics laboratory and 600 years since the university's founding. We aim to preserve the region's rich optics heritage by capturing and recording the recollections of retired laboratory members.

The projects on oral history and preserving the instrument collection have been supported by the university's Science, Art, and Culture Service, and we extend special thanks to Lucie Vidal, Baptiste Cottard, Jeanne Magnin and Julie Langlois.

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