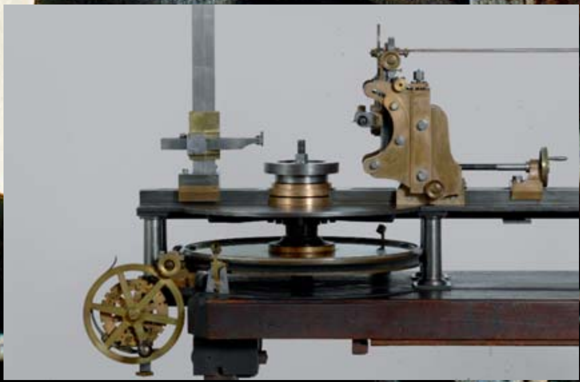


Fraunhofer in Benediktbeuern
Glassworks and Workshop

Fraunhofer

Fraunhofer in Benediktbeuern
Glassworks and Workshop

Contents

Dr. Wolfgang Jahn
"He brought us closer to the stars."
The life of Joseph von Fraunhofer 4

Joseph von Fraunhofer
Time line 16

Dr. Josef Kirmeier
Research and production
Glassworks and Optical Institute in Benediktbeuern 18

Pater Prof. Dr. Dr. Leo Weber
Joseph von Utzschneider and Joseph von Fraunhofer
at the former Benedictine monastery of Benediktbeuern,
1805–1818 32

Christoph Mewes
The exhibition: Glassworks and workshop 40

Carl R. Preyß
Fraunhofer's significance 44

References 47

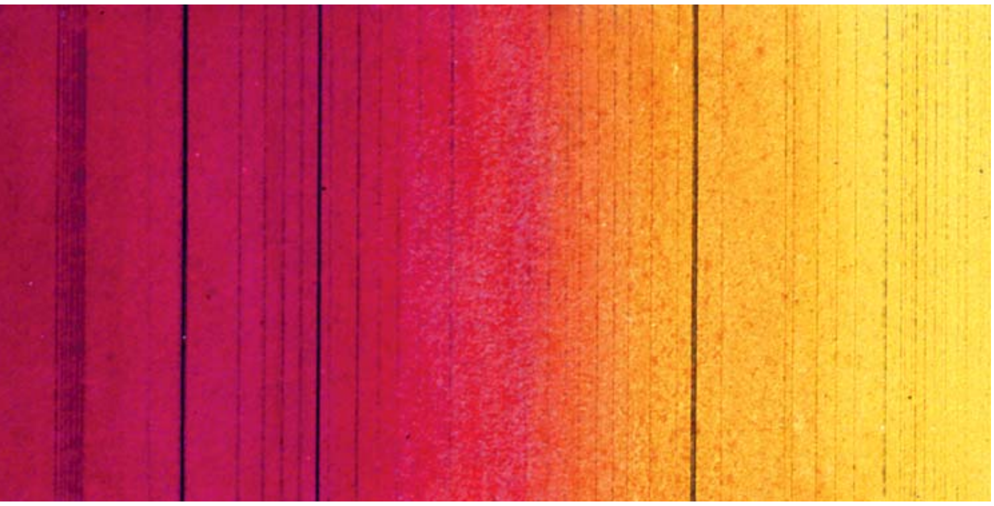
Editorial notes 48

"He brought us closer to the stars."
The life of Joseph von Fraunhofer

"He brought

Dr. Wolfgang Jahn
reports on Joseph von Fraunhofer, the hardships suffered during his childhood and apprenticeship, his achievements and his acclaimed success as a scientist and entrepreneur.

us closer



The solar spectrum drawn by Joseph von Fraunhofer. The clearly discernible black absorption lines discovered by Fraunhofer are now known as Fraunhofer lines.

"Joseph von Fraunhofer is the man that without ever having regularly attended school ... overcame all manner of obstacles in his vocational training. (...) I hope this life story will inspire other young people to apply the same spirit, whatever their discipline, to become an outstanding member of society. The following outlines Fraunhofer's progressive steps in training, his impact on his business circles, and the wealth of useful knowledge he created for the good of mankind."

Thus the obituary published in the "Kunst- und Gewerbeblatt des polytechnischen Vereins für das Königreich Bayern" (art and commerce journal of the polytechnic club for the Bavarian empire) in July 1826, when privy councilor Joseph von Utzschneider paid tribute to his long-standing business partner Joseph von Fraunhofer, who had recently passed away.

Early loss of parents

Joseph Fraunhofer was born in Straubing on March 6, 1787, the youngest of eleven children of the glazier Franz Xaver Fraunhofer and his wife Anna Maria. The Fraunhofer family, originally from Miesbach, had been based in Straubing since the 18th century. For several generations the Fraunhofers had links to glass production; the grandfather and an uncle had been glaziers. Joseph most certainly worked in his father's workshop.

He was orphaned at the tender age of 12, following the untimely death of both parents. In August 1799, his guardians sent Joseph to Munich to work as an apprentice for the mirror maker and decorative glass cutter, Philipp Anton Weichselberger. His apprenticeship was marred by difficulties with his master, who prevented Fraunhofer from reading up on science.

to the

The young Fraunhofer came into contact with prince-elector Maximilian IV Joseph by chance while being rescued from the ruins of his master's house.

An accident – favorable turn of fate

A tragic event in 1801 proved a decisive turning point in Joseph Fraunhofer's life. The apprentice was buried in the ruins of Weichselberger's house. The widespread public interest in the rescue work – prince-elector Maximilian IV Joseph attended in person – brought Fraunhofer into contact with Joseph von Utzschneider, who would from then on play an important role in his life.

stars."

Utzschneider had held influential positions in the prince-elector's administration before being suspended from public office in 1801. He nurtured Fraunhofer's thirst for knowledge with textbooks on mathematics and optics: "In these books he found that a knowledge of pure mathematics was absolutely essential to his studies; that is why he also started to study pure mathematics along with optics, becoming familiar with most of its elements through optics", Utzschneider writes in his obituary, claiming the credit for having discovered and energetically nurtured the existing talents of the young Fraunhofer.

The remainder of his apprenticeship through 1804 was fairly unremarkable. Fraunhofer's endeavors to extend his theoretical and practical knowledge in the field of optics are worthy of note. He used part of a donation from the prince-elector to buy an optical grinding machine. Meanwhile, he managed to put his lens-grinding skills to practical use by working for an optician. Fraunhofer remained Weichselberger's assistant through 1806, after an initial attempt to set up in business printing visiting cards had failed.

Left:
Joseph von Fraunhofer, researcher, inventor and entrepreneur.
Right:
Joseph von Utzschneider, one of Bavaria's first industrial entrepreneurs.

Fraunhofer turns optician

Fraunhofer's and Utzschneider's paths did not cross again until Utzschneider made Fraunhofer an offer to join him and Liebherr as an optician at the Reichenbach Mathematical-Mechanical Institute in 1806. At the time, Fraunhofer had clearly already acquired a good reputation as an optician. An examination lasting several days carried out by Professor Ulrich Schiegg, who had been a monk in the Ottobeuren monastery before secularization and was now working as an astronomer and ordinance surveyor, confirmed Fraunhofer's talents.

The foundation of the Mathematical-Mechanical Institute was a consquence of the increased need for optical instruments in fields such as ordinance surveying and research in the natural sciences. Thus the intention from the outset was to manufacture high-quality optical instruments. A distinct lack of suitable glass posed a major problem for production. Utzschneider therefore devoted much of his energies to pressing ahead with establishing his own manufacturing facility in the former Benediktbeuern Monastery, under the direction of the Swiss glass-maker Pierre Louis Guinand. The new role taken on by Fraunhofer in the glassworks in Benediktbeuern was to grind the glass produced under Guinand's direction.

Although Fraunhofer was still answerable to Guinand for the time being, his extraordinary talents came to the fore in 1807 when he submitted his first scientific paper. Entitled "Über parabolische Spiegel und Beschreibung krummliniger Segmente ..." (On parabolic mirrors and the description of curvilinear segments ...), it examined theories aimed at improving the design of reflecting telescopes.

Aerial shot of the Benediktbeuern monastery taken in 1921.

Research for glass production

Fraunhofer's most important task during these years was, however, his involvement in glass production and the processing of glass destined for the institute in Munich. It was here that Fraunhofer's methodology became patently clear. The researcher utilized his theoretical knowledge to improve and supplement existing methods. Along these lines, he developed a polishing machine to process glass more precisely, along with a measurement method to control the regular shape of lenses. The success of his approach was not just based on good ideas but also on painstaking experimentation aimed at systematically fine-tuning the production processes.

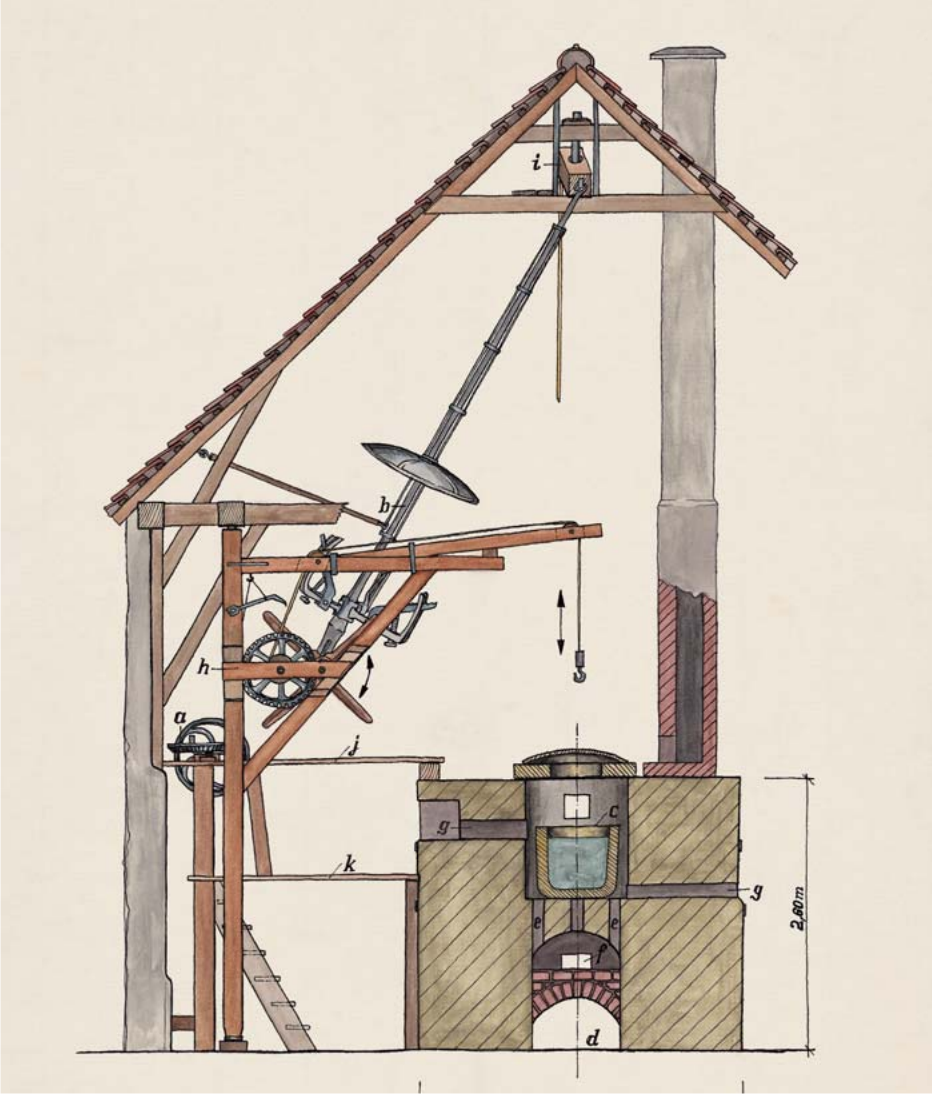


Illustration of a glass furnace with stirrer. This technology decisively helped improve glass quality.

Fraunhofer's work caused tensions with Guinand, who was still responsible for supervising the glass melting process, while prompting Utzschneider to rethink the focus of the Optical Institute in Benediktbeuern. The most pressing problem at the time was how to manufacture glass to the highest possible standards. Besides the appearance of streaks, small particles would flake off from the crucible and appear as schlieren in the glass. To improve quality, Guinand had already worked with an improved stirrer designed to produce a more even, bubble-free cast. However, the Mathematical-Mechanical Institute was receiving more and more complaints about the poor quality of the glass being supplied, not to mention the long lead-times, a situation that did not bode well either for the business's competitiveness.

The Swiss glassmaker Pierre Louis Guinand was the first director of the glassworks in Benediktbeuern. He applied the stirring process used for casting bells to glass production.

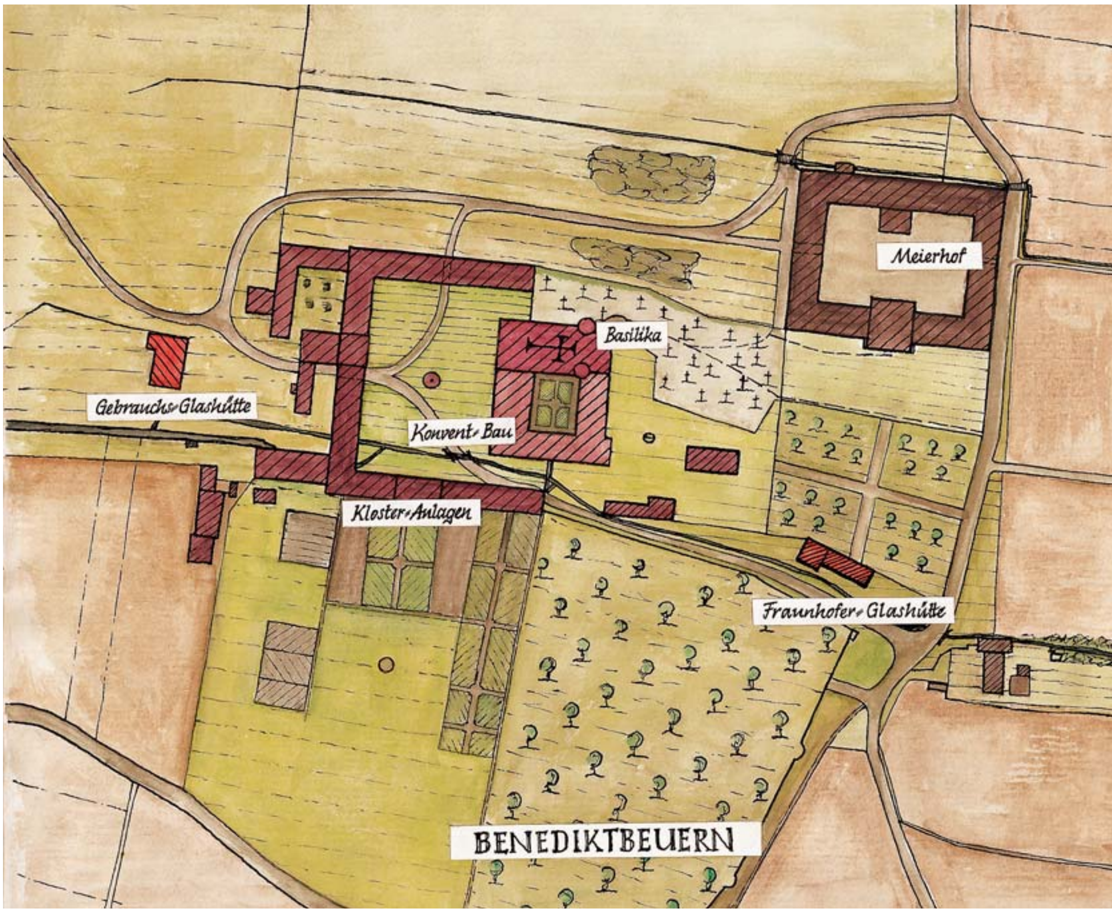
Institute reorganization hands more responsibility to Fraunhofer

In 1808 and 1809, Utzschneider reorganized the Mathematical-Mechanical Institute in Munich and the Optical Institute in Benediktbeuern, instigating a major reallocation of duties. As such, Fraunhofer was now responsible for the entire downstream processing, apart from the glass melting process that remained under Guinand's control. “My job is therefore to supervise the entire institute, to grind the most important lenses, calculate and check the lenses”, is how Fraunhofer describes his role during this period.

The dispute with Guinand only got worse as Fraunhofer also tried to have a say in the glass melting process. Hitherto, Guinand had kept the precise melting process a closely guarded industrial secret, with Utzschneider left to decide who was given access to this valuable information. Utzschneider now instructed Guinand to brief Fraunhofer on the secrets of the glass melting process. In 1811, Fraunhofer finally assumed supervisory responsibilities for the glass melting process. This extended, responsible role is also reflected in Utzschneider's decision to make Fraunhofer a partner of the Optical Institute. Fraunhofer believed the Optical Institute should in future effectively become a component supplier for the Mathematical-Mechanical Institute in Munich. The plan would be to manufacture lenses in various sizes and sufficient quantities within set delivery times.

View of the inside of the glassworks in Benediktbeuern around 1900.

Layout of the Benediktbeuern monastery according to Benediktbeuern land-registry records from 1811.



Better glass for more accurate instruments

Over the next few years, Fraunhofer focused on improving the workflows for glass processing. Painstaking experimentation focusing on materials and the production process soon enabled him to improve the quality of glass production substantially. As such, increasingly larger lenses for telescopes were being manufactured after 1811. A price list from this period shows a wide range of products, covering everything from various types of telescopes through microscopes to magnifying glasses and opera glasses.

Fraunhofer's increased involvement in the management of the Optical Institute gave rise to a rapid change in the product portfolio. The increasing quality of lenses paved the way for the production of higher quality optical instruments. A new price list published by the Optical Institute in 1812 flags up a decided shift toward producing astronomical instruments.

This improvement in production techniques went hand in hand with Fraunhofer's empirical research. Initially he focused on improving the image quality of the lenses he manufactured. The lenses were a combination of a convex lens made out of crown glass and a concave lens comprising flint glass with a lower refractive index. Both varieties of glass were produced in Benediktbeuern. The problem with calculating these achromatic lenses was knowing the exact refractive index of the types of glass used in relation to the various colors in the spectrum.

Growing success as a researcher

In April 1817, Fraunhofer submitted the first results of his research to the Royal Bavarian Academy of Sciences (now known as the Bavarian Academy of Sciences and Humanities) in Munich in the form of an essay entitled: "Bestimmung des Brechungs- und Farbenzerstreuungs-Vermögens verschiedener Glasarten in Bezug auf die Vervollkommnung achromatischer Fernröhre" (Determination of the refractive and dispersive indices of differing types of glass in relation to the perfection of achromatic telescopes). He reports that many years of experience had allowed him to develop new methods for ascertaining the diffraction and dispersion indices, and describes his methodology. He first experimented with prisms; he would alter the two refractive angles by grinding until he suppressed the color dispersion and refraction. His intention was now to determine the color dispersion indices in each type of glass. Fraunhofer stressed that numerous tests had convinced him the lines and stripes he had discovered were an inherent property of sunlight and not some random phenomenon. He counted 574 lines of various thicknesses, which he drew and annexed to his Academy essay.

The discovery of these dark lines in the solar spectrum, which were subsequently named after him, enabled the diffraction indices of various types of lenses to be computed precisely, with Fraunhofer achieving an astonishing degree of accuracy for his results.

Various other test setups enabled him to determine the intensity of the spectrum colors and the diffraction indices of various pieces of glass. The quality of the molten glass meant it was now possible to compare various types of lenses from the same melt.

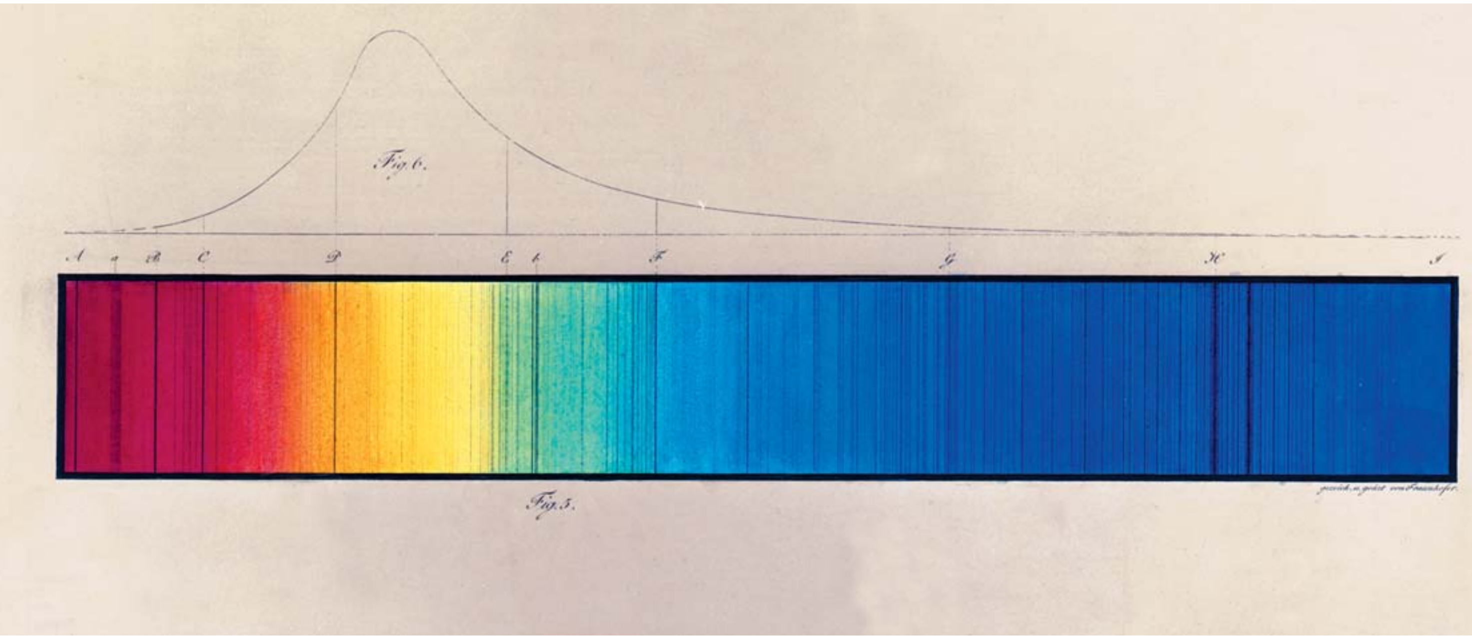
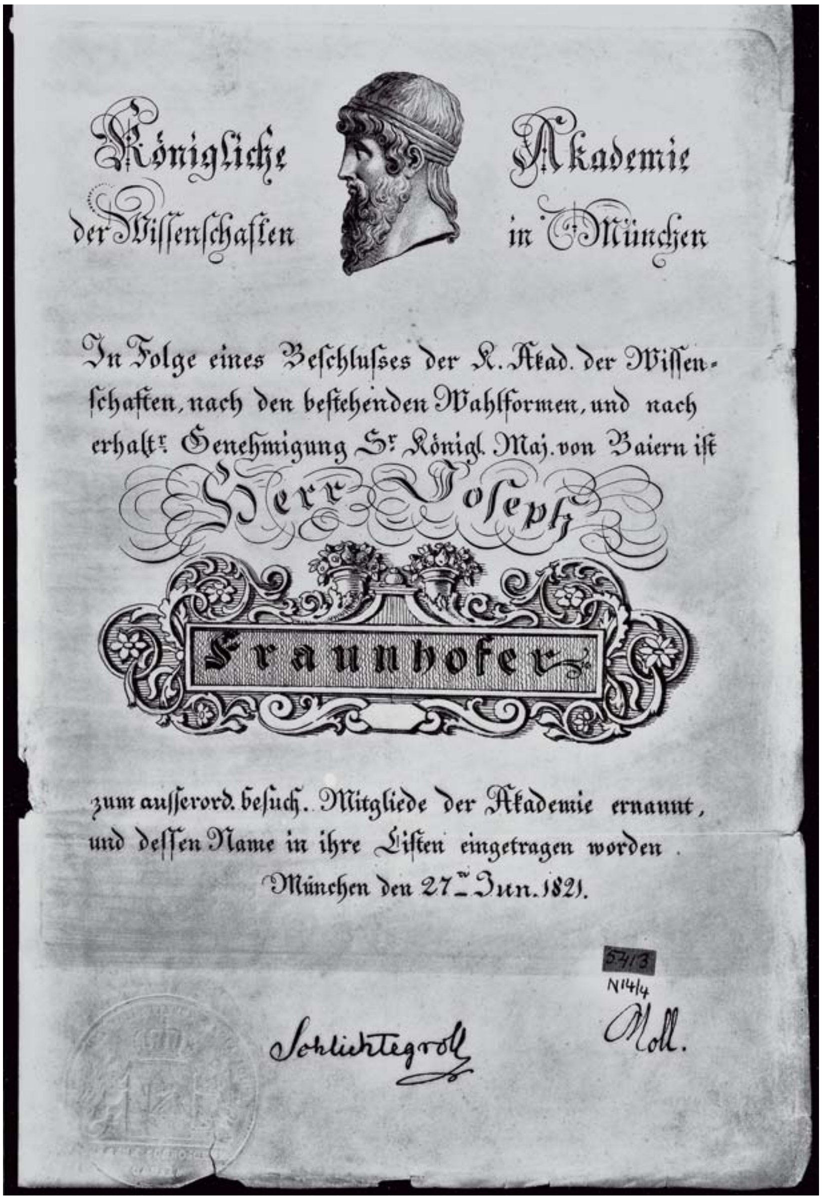


Illustration of the solar spectrum drawn and colored by Joseph von Fraunhofer with the dark lines named after him – testimony to the scientist's precise measurement techniques.



Königliche Akademie der Wissenschaften in München

In Folge eines Beschlusses der K. Akad. der Wissenschaften, nach den bestehenden Wahlformen, und nach erhaltr. Genehmigung Sr. Königl. Maj. von Baiern ist

Herr Joseph Fraunhofer

zum ausserord. besuch. Mitgliede der Akademie ernannt, und dessen Name in ihre Listen eingetragen worden.

München den 27. Jun. 1821.

Schlichtegroll Moll.

On June 27, 1821, Joseph von Fraunhofer was appointed an extraordinary visiting member of the Royal Bavarian Academy of Sciences.

Fraunhofer impresses the scientific world

The exposé for the Royal Bavarian Academy of Sciences in 1817 provided the first high point in Fraunhofer's scientific work. Through his research and practical work in Benediktbeuern he had gained a formidable scientific reputation. The court astronomer and director of the Munich Observatory, Johann Georg Soldner, for instance, wrote to the Academy, requesting Fraunhofer be allowed into the Mathematics and Physics Section. In February 1817, he was named a corresponding member.

Fraunhofer's growing importance both in manufacturing high-quality optical instruments as well as in his research work in Benediktbeuern is also reflected in contacts with leading scientists of his day. In 1816, the Göttingen-based physicist Carl Friedrich Gauß visited the Optical Institute in Benediktbeuern to place an order for instruments for astronomical observations. His verdict on Fraunhofer's work was glowing: "The Optical Institute in Benediktbeuern is now itself under the direct leadership of a highly talented and energetic man, Fraunhofer, and supplies telescopes as well as all astronomical instruments."

Fraunhofer's practical work changed in 1819 when the Optical Institute moved to Munich. Back in 1814, Fraunhofer had become Utzschneider's sole partner with the reorganization of the Mathematical-Mechanical and the Optical Institute. Financial difficulties forced Utzschneider to sell the extensive Benediktbeuern building complex to the Bavarian State in 1818. Utzschneider only held on to the glassworks; the idea was to keep providing glass to produce optical instruments. Fraunhofer also travelled regularly to Benediktbeuern to personally supervise each glass melt and maintain the high standards of quality.

Joseph von Fraunhofer demonstrates the spectrometer to Joseph von Utzschneider, Georg von Reichenbach and Georg Merz.

The move to Munich now brought Fraunhofer into closer contact with the Royal Bavarian Academy of Sciences. After a series of internal academy quarrels, partly the result of Fraunhofer's lack of academic training, he became an extraordinary visiting member of the Academy in 1821.

During this period he also examined various physical problems in a series of essays and Academy speeches. He looked at the "causes of the tarnishing and matting of glass and means of preventing this" ("Ursachen des Anlaufens und Mattwerdens des Glases und die Mittel, demselben zuvorzukommen"). Another piece of work involved experiments on the laws of light and phenomena produced by the movement of light.

Epochal optical research: Fraunhofer in the limelight

Two of Fraunhofer's groundbreaking papers on light diffraction were published between 1821 and 1823. The first paper entitled "Neue Modifikation des Lichts durch gegenseitige Einwirkungen und Beugung der Strahlen, und Gesetze derselben" (New modification of light through reciprocal effects and diffraction of rays, and associated laws) was initially submitted to the Academy as a speech. In his second paper, Fraunhofer reported on his new experiments on light wave theory. Diffraction needs to be seen as the deviation of light dispersion from the laws of geometric optics; obstacles impair the straight line dispersion of light waves. His papers on the diffraction of light were an important piece of basic research, which also had repercussions on the manufacture of telescopes.

Fraunhofer describes his approach as follows: He set up a screen with an adjustable aperture in front of the lens of a theodolite telescope. He then let the sunlight shine on the screen; the sunlight was diffracted by the aperture. "Through the telescope I could then observe the phenomena created by the diffraction of the light, enlarged, and yet with sufficient brightness, while at the same time also being able to measure the deviation angles of the light with the theodolite."

As the next stage he investigated the reciprocal effects of a large number of diffracted rays and experimented with various means of diffracting light rays. Fraunhofer could now measure experimentally the wavelength of all color light rays. He produced various grids with hitherto unsurpassed precision in order to measure the diffraction spectrum.

His materials included glass in which he ruled a series of parallel lines, using a diamond to place them just 0.00330 millimeters apart. The measured wavelength values are extraordinarily accurate, bearing in mind the tools available at the time. Fraunhofer used the lines he had discovered previously in the color spectrum as part of these computations.

Joseph von Fraunhofer in his workshop.

The theodolite (left) enables angles to be measured very precisely; the Heliostat (right) always directs the reflected sunlight to the same point so observations can be made irrespective of the earth's rotation.

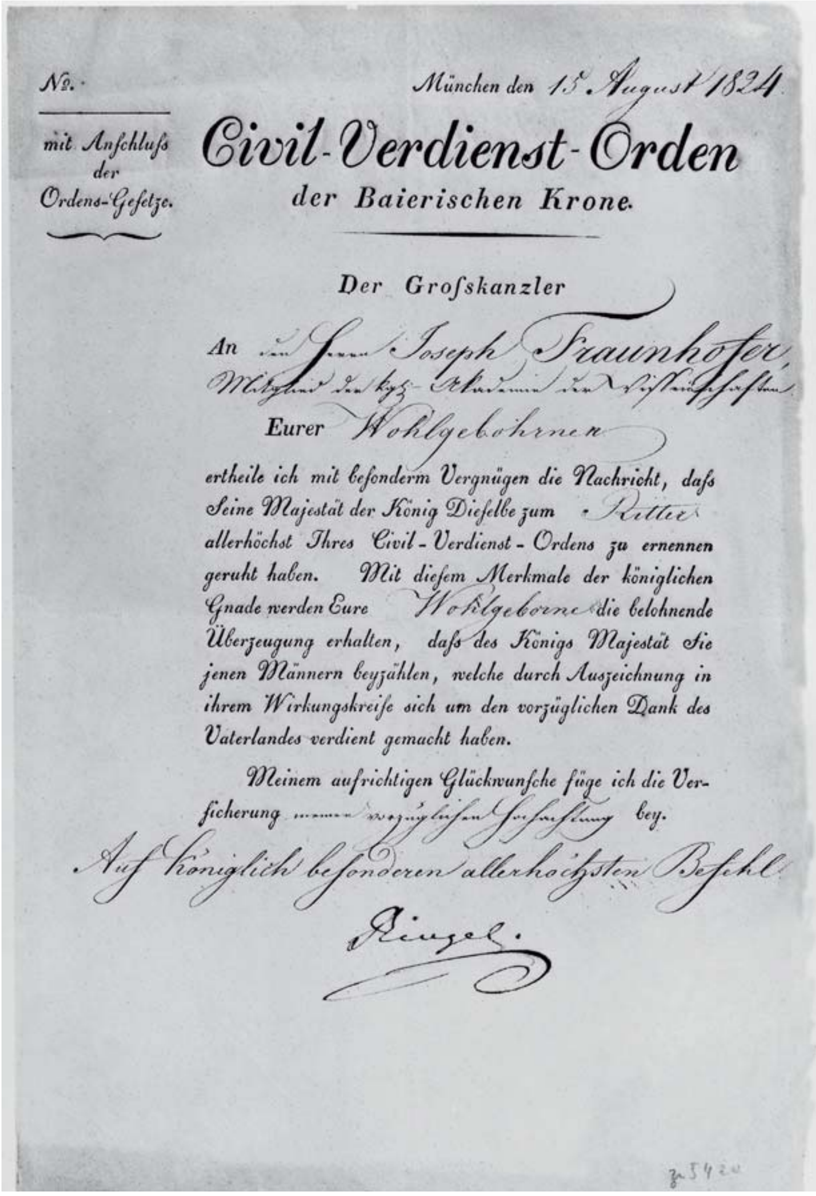
Fraunhofer's scientific reputation, which had been acquired not just on the basis of these scholarly publications, was also reflected in his personal connections to important European researchers. In addition to the aforementioned visit of Gauß to Benediktbeuern, other scientists were also interested in forging links with Fraunhofer. Visits to Benediktbeuern to place orders for the renowned high-quality optical instruments provided an opportunity to talk to Fraunhofer. For instance, the scientists Karl Dietrich von Münchow, Hans Christian Ørsted and John Frederic Herschel, son of the astronomer Wilhelm Herschel, all travelled to Benediktbeuern.

Visits to the Optical Institute by the political elite of the day also attest to the increasing importance of natural sciences. Alongside Bavarian King Max I Joseph and his minister Count Montgelas, the Russian Czar Alexander also probably visited the research facilities in Benediktbeuern.

A leap in the quality of optical instruments

Under Fraunhofer's direction, production had increasingly moved toward manufacturing high-quality optical instruments after 1811. The progress made on the basis of Fraunhofer's practical experience and his scientific research is manifested in the various price lists issued by the Optical Institute. In contrast to the modest beginnings, production switched to manufacturing telescopes, trigonometrical measurement instruments and microscopes. The institute was a pioneer particularly in the field of manufacturing lenses for telescopes. The diameter of telescope lenses increased from 83 millimeters in 1813 to 245 millimeters with the large refractor produced in 1819 for the Russian Imperial Observatory in Dorpat. Plans even included lenses measuring up to 490 millimeters.

Utzschneider listed in his obituary the instruments Fraunhofer had helped invent or improve. Among them were "the Heliometer, the multiple lamp filar micrometer, the achromatic microscope used to provide measurements in absolute dimensions, the ring micrometer, the lamp circle and network micrometer" and the aforementioned parallactic refractor for the Dorpat Observatory.


No.

mit Anschluß der Ordens-Gesetze.

München den 15. August 1824.

Civil-Verdienst-Orden der Baierischen Krone.

Der Großkanzler

An Herrn Joseph Fraunhofer, Mitglied der kgl. Akademie der Wissenschaften

Eurer Wohlgebohrnen

ertheile ich mit besonderm Vergnügen die Nachricht, daß Seine Majestät der König Dieselbe zum Ritter allerhöchst Ihres Civil-Verdienst-Ordens zu ernennen geruht haben. Mit diesem Merkmale der königlichen Gnade werden Eure Wohlgeborne die belohnende Überzeugung erhalten, daß des Königs Majestät Sie jenen Männern beyzählen, welche durch Auszeichnung in ihrem Wirkungskreise sich um den vorzüglichen Dank des Vaterlandes verdient gemacht haben.

Meinem aufrichtigen Glückwunsche füge ich die Versicherung [illegible] vorzüglichen Hochachtung bey.

Auf königlich besonderen allerhöchsten Befehl

Ringel.

The honorary Knighthood of the Order of Civil Service of the Bavarian Crown awarded on August 15, 1824 saw Joseph von Fraunhofer join the ranks of the nobility.

The difficulties that Fraunhofer had to overcome to manufacture this refractor – a unique instrument at the time – demonstrate the scientific standards during this period. In 1819, the lens was the largest manufactured to date, with a focal length of 4.10 meters.

Distortion and possible temperature differences had to be taken into account when fitting the lens. The production of the tube and the base took until 1824. Thanks to the parallactic mounting, Fraunhofer managed to follow a particular star simply by turning around a single axis. He also designed a centrifugal regulator to make it easier to track the telescope.

Fraunhofer's publications in these years also confirm his substantial input to this large astronomical instrument. He published two essays "on the construction of a large, recently completed refractor" ("Über die Construction eines grossen soeben vollendeten Refractors") and examined astronomical problems, researching into phenomena such as sun dogs as well as solar and lunar corona.

High esteem – and an untimely death

Fraunhofer's scientific acclaim grew as a result of the production of this refractor. In 1822, he was awarded an honorary doctorate from the University of Erlangen. A year later he was appointed curator of the physics collection of the Royal Bavarian Academy of Sciences. King Max I Joseph made him a Knight of the Order of Civil Service of the Bavarian Crown in 1824, enabling him to join the ranks of the nobility. Various international scientific associations also named Fraunhofer a member.

His personal circumstances, the grueling work in the glass furnaces, poisonous lead oxide and his frail physical constitution all probably contributed to Joseph von Fraunhofer's untimely death from "lung tuberculosis" on June 7, 1826, at the age of just 39. Fraunhofer's gravestone in Munich bears the words "Approximavit sidera": "He brought us closer to the stars."

Life

March 6, 1787
Joseph Fraunhofer is born, the eleventh child of Franz Xaver and Anna Maria Fraunhofer in Straubing, Lower Bavaria.

1799–1804
The young Fraunhofer completes an apprenticeship with the mirror maker and decorative glass cutter Philipp Anton Weichselberger in Munich.

1801
Weichselberger's house collapses; Fraunhofer is buried among the ruins. During the rescue work he comes into contact with the privy councilor Joseph von Utzschneider and prince-elector Maximilian IV Joseph.

1804–1806
Fraunhofer works as an assistant to Weichselberger.

1806
Fraunhofer becomes an optician at the Mathematical-Mechanical Institute run by Reichenbach, Utzschneider and Liebherr in Munich.

Joseph von Fraunhofer.

1808
Fraunhofer works as a glass grinder in the Benediktbeuern glassworks, part of the Mathematical-Mechanical Institute; he publishes his first scholarly essay.

1809
Apart from melting the glass, Fraunhofer is responsible for the entire glass production process in Benediktbeuern.

1811
Fraunhofer takes over as overall head of the glassworks of the Mathematical-Mechanical Institute in Benediktbeuern.

1814
Fraunhofer becomes Utzschneider’s sole partner and overall director of the Mathematical-Mechanical Institute.

Joseph von Fraunhofer next to his spectrometer.

1817
The Royal Bavarian Academy of Sciences names Fraunhofer a corresponding member.

1819
The Mathematical-Mechanical Institute moves to Munich.

1821
After some heated debate surrounding his lack of academic training, Fraunhofer is appointed extraordinary visiting member of the Royal Bavarian Academy of Sciences.

1822
University of Erlangen awards Fraunhofer an honorary doctorate.

1823
Fraunhofer becomes titular professor and curator of the physics collection at the Royal Bavarian Academy of Sciences.

1824
King Max I Joseph names Fraunhofer Knight of the Order of Civil Service of the Bavarian Crown, enabling him to join the ranks of the nobility.

7. Juni 1826
Joseph von Fraunhofer dies in Munich.

The Optical

Benediktbeuern Abbey.

Dr. Josef Kirmeier
recounts the history of Benediktbeuern Abbey, its political and economic background, and the lifework of researcher and entrepreneur Joseph von Fraunhofer and of several important people he encountered.

Benediktbeuern Abbey secularized and sold

All of the monasteries in Bavaria were dissolved in the years 1802 and 1803. This affected both the monasteries of the mendicant order, which were mostly situated in the towns, and the rich abbeys of the rural orders. A total of 150 monasteries were secularized and taken over by the state. Their valuable books and works of art were transferred to the state collections in Munich or were auctioned off. Even the monastery buildings themselves, and the land acquired by the orders over what was often a thousand years of history, were sold to fill the state treasury. This *mortmain* ("dead hand") property, as the monastery assets were derogatively referred to at the time, was divided up and sold to private buyers or given to the monasteries' occupants as compensation.

Benediktbeuern Abbey, one of the oldest monastic settlements in the *Bayerisches Oberland* (Bavarian upper land) in Upper Bavaria, was also subjected to this wave of secularization. Its approximately 700 hectares of agricultural fields and meadows, some of which were in excellent condition, were distributed among more than 150 buyers, most of them farmers from the surrounding area.

Institute

It proved rather more difficult to sell the actual monastery building itself. The same problem applied to other monasteries, too. After all the rural cloisters had been abolished, there was a surplus of large properties on offer. Without their land, which had usually been sold off, these properties could barely be managed. The huge buildings themselves were only marginally suitable for commercial use, and they were also hugely overpriced at first.

In the light of this situation, architect and *Hofbaurat* (royal privy councilor for buildings) Friedrich von Gärtner considered tearing down Benediktbeuern Abbey to obtain building material for projects in Munich. The only reason this plan failed to materialize was because the transport costs would have been too high, and so Benediktbeuern was spared the fate of Wessobrunn Abbey, which was almost entirely pulled down and used to rebuild the fire-ravaged town of Weilheim.

The Historic Fraunhofer Glassworks with Benediktbeuern Abbey in the background.

It was not until 1804 and 1805 that interested buyers were found to purchase the abbey. After a failed takeover by Bohemian industrialist Schmaus von Stubenbach in 1804 and a refused offer of 78,000 guldens by Lucas, likewise an industrialist from Bohemia, the former Bavarian privy councilor and entrepreneur Joseph von Utzschneider made a proposal on May 3, 1805 to buy Benediktbeuern Abbey for 55,000 guldens. This sum was finally accepted. The purchase contract signed between Utzschneider and the state of Bavaria covered a total of 28 items. In addition to the monastery itself – which included the library building, the hospital, the brewery and the old parish church – Utzschneider acquired the alpine dairy farm of Häusern, and various estates and buildings that had formerly belonged to the abbey. He cleverly took advantage of the fact that these properties were part of the unsold remains of the former abbey, and beat down the price to even further below the offer originally made by Lucas.
He went on to buy the steward's house ("Maierhof") in 1806 and a large part of the monastery forest north of the Benediktenwand mountains in the years to follow. This increased his property to 2000 hectares, 1300 of which were forest, thus bringing it back to the size of the former abbey.

Utzschneider's plan: glassmaking

Utzschneider's purchase was motivated not only by plans to continue farming the monastery's land but also to set up a glassworks in the abbey. At first glance, the interest displayed by the two Bohemian glassmakers in the property, and Utzschneider's intention of establishing a glass factory on site, appear to be explained by the presence of silica sand and wood nearby. However, most of the woodlands required for melting glass had already been sold off elsewhere and had to be bought back – which is exactly what Utzschneider did. The most important resource, silica sand, was to be found in a place called Quarzbichel, just south of Wolfratshausen. But both the sand and the wood could easily have been transported to another site.

The main reason behind this interest is therefore more likely to have been the reduced price of the abbey's "remaining stock" and perhaps also the proximity to Tyrol, which was a promising sales market for glass. Tyrol had no glass production of its own, but had a traditionally high demand for the material.

Glass and politics

What will remain unclear is to what extent Utzschneider sensed that Tyrol would be ceded to Bavaria in December 1805 when he made his offer in May of the same year, and that this separation from Austria would also cut it off from the Bohemian glass market. This decision, made in the context of the Peace of Pressburg, meant that the sales market of Tyrol was suddenly accessible to Bavarian glass products without any border restrictions or competition.

Utzschneider's decision to buy the abbey could thus have been swayed largely by the opportunity to produce cheap consumer glassware, rather than the high-quality optical glass that became important later on. It was not until the sudden loss of Tyrol following the fight for freedom led by Andreas Hofer that the glassware production tapered off and eventually ceased. The glassworks for these products, which was located in a detached building on the west side of the monastery, was torn down in 1843. At the same time, the production of optical glass became increasingly important, mainly thanks to the accomplishments of Joseph Fraunhofer. The factory for optical glass remained in operation until 1887, and is still largely intact today.

Inside view of the glassworks in Benediktbeuern, where Joseph von Fraunhofer tested new methods of producing high-quality glass.

Georg von Reichenbach was co-founder and associate of the Mathematical-Mechanical Institute, which was joined by optics expert Fraunhofer in 1806.

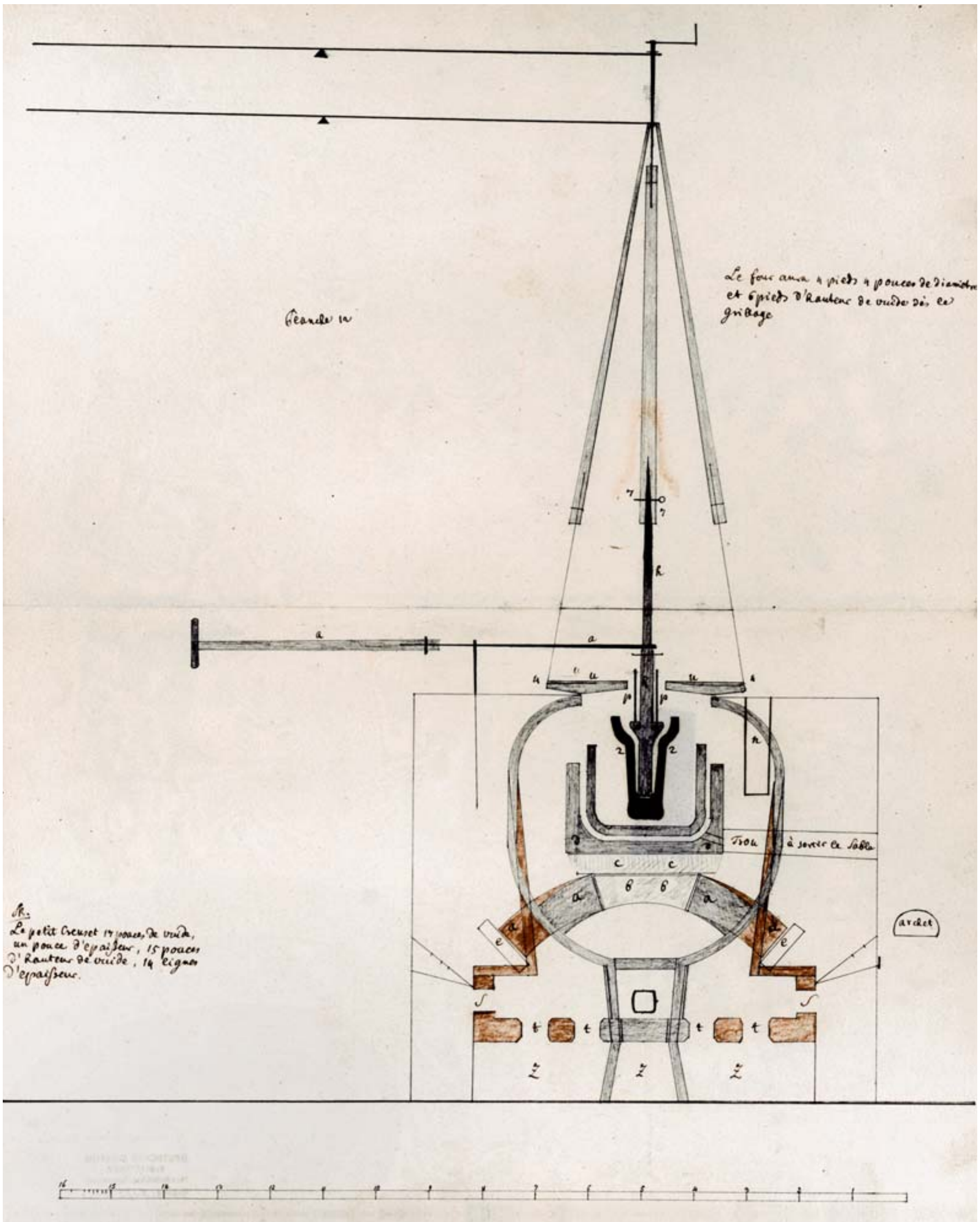
Utzschneider had temporarily left his post as a civil servant in 1801, although he continued to receive his salary, and had immediately embarked on a number of private-sector activities, establishing himself as one of the first industrial entrepreneurs in Bavaria. He founded a leather goods factory in a former Carmelite monastery in Munich in 1802 which, together with its affiliated glue factory, soon counted 170 employees and was thus one of the largest industrial enterprises in Munich.

His interest in glassmaking and optics had accrued from his participation in the Mathematical-Mechanical Institute founded by Georg von Reichenbach and Joseph Liebherr in Munich in 1804. Reichenbach and Liebherr, who were manufacturing astronomical devices and measurement instruments based on the circle-dividing machine developed by Reichenbach, found Utzschneider to be a strong partner with plenty of capital and willing to take risks. He equipped the institute with the necessary funds and facilities, and also took charge of selling its products.

The goal: to make quality glass for precision instruments

Utzschneider's goal was to remedy the lack of high-quality glass which had hitherto greatly hindered the production of optical devices. Optical precision instruments could only be manufactured using an ingenious combination of faultless crown and flint glass, each of which has different refraction and dispersion characteristics. There was simply no other way of producing powerful optical devices with a relatively high rate of magnification. The glasses had to be homogeneous, i.e. free of streaks and bubbles, in order to be used in optical devices. Until the beginning of the 19th century, they had been produced exclusively by two English glassworks, which were unable to supply sufficient quantities and often only delivered mediocre quality.

For this reason, Utzschneider had attempted to produce the glasses himself even before Napoleon's Continental System came into effect in 1806. However, his first experiments in the glassworks at Grafenaschau – originally part of Ettal Abbey, into which Utzschneider's sister had married – failed. His acquisition of the monastery in Benediktbeuern, and the construction of a glassworks there, filled him with fresh hope.



The stirring process developed by Guinand and enhanced by Fraunhofer contributed significantly towards improving the quality of the glass. The picture shows a cross-section through the furnace and the stirring device.

Stirring process brings first successes

In searching for a suitable expert, Utzschneider traveled to Les Brenets in Switzerland, where he met Pierre Louis Guinand. Guinand had been producing high-quality glass for a good many years, and Utzschneider managed to recruit him for Benediktbeuern for a high wage of 1600 guldens.

The first melting trials at Benediktbeuern took place in January 1806. Initially, the resulting glass was of varying quality, but a suitably adapted stirring process derived from the bell-founding technique put Guinand on the right track to producing purer glass. The problems encountered in glass melting were attributable to the insufficient temperatures achieved by the fuels and furnaces available at the time. The wood-fired furnaces were barely capable of generating the 1300 degrees Celsius needed to melt the glass, let alone the 1500 degrees used today, and this meant that the glass lacked the required homogeneity. Guinand then attempted to compensate for this shortfall by inserting a stirring device into the glass melt in his self-developed furnace. This device thoroughly stirred the mass once the glass became molten in the sealed furnace. The stirring arm, which was equipped with fire-proof clay and could be swung over the furnace and lowered into the melt, can still be seen at the glassworks today.

The new technique employed in Benediktbeuern made it possible to produce about 20 kilograms of glass in one melting cycle, which took several weeks. As soon as the glass had cooled off enough, it was lifted out of the furnace and subjected to a quality inspection. Parts that were suitable for further processing were placed in a specially designed furnace to cool down slowly, so that they would set without any tension. The plants and furnaces on display at the glassworks today are from a later date but also worked according to Guinand's principle.

The process was further developed by Guinand and later by Fraunhofer, leading to the highest-quality special glass of its time for optical devices. Initially, the glass was processed exclusively by the Mathematical-Mechanical Institute in Munich, but an increasing number of optical devices were also manufactured at Benediktbeuern after Fraunhofer joined the venture.

Polishing dishes from Fraunhofer's factory.

Guinand takes his know-how back to Switzerland

The initially clear division of tasks between Munich, Benediktbeuern and the company's associates became more and more blurred over time, which led to a number of difficulties and eventually changes in staff. In 1807 Utzschneider integrated the Benediktbeuern glassworks, which had operated independently until then, into the Mathematical-Mechanical Institute so that only this enterprise would benefit from the glass produced.

Fraunhofer carried out several series of systematic tests to develop new types of optical glass. The picture shows a pentaprism produced by him.

Gear milling machine from
Fraunhofer's glassworks.

The decision to shift part of the processing to Benediktbeuern turned out to have serious consequences. Guinand failed to achieve the desired success as head of the Optical Institute, so Utzschneider handed the responsibility for this part of production in Benediktbeuern over to Joseph von Fraunhofer. Guinand, who had worked entirely independently until then, felt discriminated by this decision and by the competition he saw in Fraunhofer. The situation escalated even further in 1811, when Fraunhofer was appointed head of the entire Benediktbeuern company, and thus became Guinand's superior. This made it impossible for the two to work together, so Guinand decided to leave the glassworks in 1814, and returned to Switzerland.

Guinand took his newly acquired know-how on glass production and processing from Benediktbeuern to Switzerland, where he brought his former glassworks in Les Brenets up to the latest standards and significantly contributed to promoting glass production in Switzerland and France. Utzschneider's attempts at binding Guinand to the company by paying him a pension, failed.

The company is reorganized and divided

However, there was also an increasing amount of tension between the company's associates in Munich, not least as a result of the expanded production in Benediktbeuern. Liebherr and Reichenbach had little interest in expanding their institute, as they were not industrial entrepreneurs but rather saw their work as a form of arts and crafts. This was accompanied by the special situation in which Utzschneider, through his financial commitment to Benediktbeuern, increasingly took charge of how the company was managed. Because the substantial investments made in the Benediktbeuern glassworks had not yet paid off in the short space of time since its foundation, Utzschneider invested another 60,000 guldens out of his own pocket in addition to the Munich institute's contribution of 12,000 guldens. This transaction, and the shift of part of the optical processing to Benediktbeuern, was bound to make the other partners feel alienated.

These differences in opinion and perhaps also mentality between Utzschneider, Reichenbach and Liebherr eventually drove Liebherr to temporarily leave the Munich institute in 1812, and caused Utzschneider and Reichenbach to go their separate ways in 1814. While Liebherr's decision to leave was most likely swayed by disputes with Reichenbach concerning Liebherr's share in the invention of the circle-dividing machine, it also emerges from various statements that neither of them wished to support Utzschneider's risk-friendly, market-driven management policy any longer. Reichenbach's main accusation was that the Benediktbeuern company was useless and had produced nothing but losses from 1809 to 1814, whereas the Mathematical-Mechanical Institute in Munich had achieved a profit of 100,000 guldens over the same period.

Top:
Raw glass block produced in a melting process at the glassworks in Benediktbeuern.
Bottom:
Cross-section through a filled melting crucible.

The discord between Utzschneider and Reichenbach led to the separation of the Munich and Benediktbeuern enterprises in 1814. Reichenbach carried on the Munich institute together with a mechanic called Traugott Leberecht Ertel, initially under the name of Mathematical-Mechanical Institute of Reichenbach and then Mathematical-Mechanical Institute of Reichenbach and Ertel from 1815 onwards. Utzschneider immediately founded a competing enterprise, which was joined by Reichenbach's former partner Liebherr and tradesman C. I. Werner. The glassworks at Benediktbeuern acted as an independent supplier and was not integrated into the new institute. Joseph Fraunhofer was given a 10,000-gulden share in the enterprise. However, he was not entitled to withdraw this sum from the company's equity. Former partner Reichenbach continued to be supplied with glass from Benediktbeuern, but was not granted any special conditions.

Despite the allegedly difficult financial situation of the Benediktbeuern company and the changes taking place in the organization, it evolved into a distinguished enterprise with a staff of 48 in just a few years. Twenty glass grinders, five turners, two tube drawers, two wheel drivers, a caster, an optician, a stoker, two girdlers and fourteen other workers were employed there. According to a state survey, they generated a production value of approximately 50,000 guldens, although this sum almost certainly includes the revenues of the consumer glassware factory. Company documents reveal that 95 large melting processes took place in Benediktbeuern between 1811 and 1825. The resulting yield of usable flint and crown glass stood at 30 percent and comprised a total volume of 6000 kilograms.

Prisms were used to examine the quality of the glass.

Left:
Multilayer prism.
Below:
Equilateral prisms in different colors.

Fraunhofer focuses on quality

When Joseph Fraunhofer became manager of the company, he focused the production even more strongly on high-quality scientific glasses. The manufacture of consumer glassware took a back seat and was eventually abandoned. The optical products made from Benediktbeuern glass were deemed to be of unparalleled quality throughout Europe.

The precondition for such quality was to use absolutely pure glass, and this was made possible by the stirring method developed by Guinand. This was Guinand's major contribution to the production of optical glass. However, the essential innovations that made the Benediktbeuern glass so valuable can largely be ascribed to Joseph Fraunhofer and his scientific working approach. Guinand was an adept craftsman, who sometimes made progress almost coincidentally by trial and error. Fraunhofer, by contrast, took a much more goal-oriented, systematic and ultimately more successful approach. He started by selecting suitable raw materials, and set great store by their purity. He did not use the sand from Quarzbichel, for example, but had silica brought over from Tyrol. After significantly improving the purity of the raw materials employed, he determined the best mixture in a series of tests.

Fraunhofer's work soon bore fruit. The Benediktbeuern glass made it possible to produce larger and larger lenses that attracted customers not only in Bavaria but throughout Europe. The main secret behind these large lenses was an improved melting process achieved by Fraunhofer in collaboration with Guinand. In this "sinking" or "bending" process, a finished glass mass was re-heated until it could be molded into the negative shape of a lens. This blank was then ground and polished.

Three-tiered telescope bearing the inscription “Utzschneider, Reichenbach und Fraunhofer in Benediktbeurn”.

Telescopes establish the good reputation of Fraunhofer and Benediktbeuern

Other achievements by Fraunhofer include his method of evaluating the glass produced, his improved processing methods involving his grinding machine, and his techniques for transforming the glass into optical devices that were of particular importance to astronomy. On the basis of his knowledge about the refractive behavior of light and his exceptionally accurate calculation methods, Fraunhofer was able to build achromatic telescopes with lens apertures of 25 centimeters, which had been deemed impossible until then. These telescopes continued to dominate the astronomy scene for half a century, and the glassworks at Benediktbeuern became renowned even far beyond the Bavarian borders. Many of the major observatories in Europe were equipped with instruments from the Utzschneider-Fraunhofer business.

The reason why Fraunhofer’s research on refractive behavior was so important becomes evident on taking a closer look at the operating principle behind the achromatic telescopes. The basic problem in producing telescopes is that white light is refracted differently after passing through a glass prism. This phenomenon, known as dispersion, made it impossible to build refracting telescopes with more than 30-fold magnification, as the color shift occurring at higher magnification levels rendered the results useless. Achromatic telescopes make use of the fact that different types of glass have

Production recipe for quality glass is revealed

The composition of raw materials specified by Fraunhofer for making flint and crown glass was top secret. In addition to silica sand, the most important materials for the weakly refracting crown glass were alkaline salts, silicic acid and lime, while the strongly refracting flint glass produced in the second furnace was made using lead in place of lime.

However, the recipe could not be kept secret in the long run, as the leading position of Utzschneider's company rested on Fraunhofer's skills and research findings, which Fraunhofer himself published and made accessible. Then, after Guinand and other workers left Benediktbeuern, the operating principle of the furnace and the approximate composition of the glass became known much further afield. The same was true for the sinking process, which Guinand had helped to develop, or, as his correspondence indicates, about which he possessed detailed information.

Above:
Lenses produced in Benediktbeuern.
Below:
Small watchmaker's lathe on a vise from Fraunhofer's glassworks.

different degrees of refraction. The crown glass mentioned earlier on barely refracts the light at all, while flint glass refracts it to a very strong degree. The idea behind achromatic telescopes was to offset the dispersion of light by lining up the different glasses alongside one another. Earlier attempts made without this knowledge about the behavior of light only succeeded occasionally by chance and were limited to a certain size of telescope. Fraunhofer's great achievement was that he recognized the physics behind it and developed precise measuring techniques that were of crucial importance to the composition of the lenses. This explains the leading role played by the Benediktbeuern glassworks and the optical devices developed under Fraunhofer's auspices.

Fraunhofer’s telescopes were renowned for their excellent quality, which helped the entrepreneur to become as successful as he was.

Benediktbeuern becomes state-owned once again

The financial returns of the optical enterprises were limited, even when the business was doing well. The institute in Munich and the glassworks in Benediktbeuern could not decisively remedy Utzschneider’s tight financial situation in the long run. Utzschneider’s widely ramified enterprises which, in addition to the optical businesses, included the previously mentioned leather goods factory, a cloth mill and a brewery, were highly indebted.
The ambitious entrepreneur, who had moreover resumed his work as a civil servant in 1807, had clearly overreached himself. After a failed attempt at securing state funding for parts of his businesses – especially for the glassworks, which were also of strategic and political importance to the kingdom – Utzschneider felt impelled to sell Benediktbeuern Abbey in 1818.

In January that year, he offered the king his estate for an overall sum of 362,587 guldens. As early as March, Utzschneider reached an agreement with the Bavarian state, and sold the property for 250,000 guldens. The former monastery of Benediktbeuern was used to breed military horses, following the destiny of the originally elector-owned estates of Schwaiganger and Schleißheim and the secularized monasteries of Fürstenfeld and Steingaden. The former alpine monastic settlements of Straßberg and Wall were also bought up by the Bavarian army. At the beginning of the First World War, the formerly monastic industrial complex comprised 2600 hectares of property with 800 horses and 100 cattle, and was Bavaria’s largest *Remontedepot*, as such foal-raising estates were called. The consumer glassware factory was sold together with the monastery and, since no interested buyer was found, it continued to be run by the Bavarian army until its production was ceased.

Left:
Fraunhofer as portrayed a few months before his death.
Below:
The two melting furnaces at the glassworks in Benediktbeuern.

Fraunhofer's successor at the glassworks

The factory's optical glass production initially remained unaffected by the sale of the monastery. Under the technical direction of Fraunhofer, the Benediktbeuern glassworks was able to maintain its position on the market. And the two optical institutes in Munich and Benediktbeuern were, after all, among the healthiest and most profitable companies set up by Utzschneider, whose widely ramified activities had led many people to doubt his solidity. It was not until Fraunhofer's premature death that Utzschneider's optical businesses, too, plunged into a crisis. Friedrich August von Pauli, whom Fraunhofer had favored as his successor, did not take up the challenge and so, after failed negotiations with C. A. Steinheil, Utzschneider replaced him with Georg Merz, who had already been working in Benediktbeuern for 18 years. Merz was supported by Joseph Mahler, who was appointed head of processing operations.

The years following Fraunhofer's death were dedicated to finishing the tasks that had been taken over from him – tasks which his successors did their best to fulfill. Because the two practitioners had limited theoretical knowledge, they occasionally sought the advice of astronomer Thomas Clausen. Merz did not appear to have gained Utzschneider's full trust from the outset, being denied access to work on the glass melting process, which was kept strictly secret for a long time.
It was not until 1832, six years after Fraunhofer's death, that Merz took over this task. In 1839, Merz and Mahler finally bought the Benediktbeuern glassworks and the Munich institute from the then 76-year-old Utzschneider, and named the business "Merz & Mahler". Joseph von Utzschneider died in 1840.

The production in Benediktbeuern was carried on until 1883, and the factory continued to produce optical glasses under the direction of Georg Merz's sons. The glassworks was eventually decommissioned, not only in the face of competition – particularly that from Bohemia, which had long since caught up with the technologies of Guinand and Fraunhofer that had originally given the business a head start – but ultimately due to the Bavarian forest administration, which refused to tolerate the ongoing depletion of the Bavarian army's forest lands any longer.

Joseph von Utzschneider and Joseph von Fraunhofer

at the former Benedictine monastery of Benediktbeuern, 1805–1818

Benediktbeuern Abbey.

Pater Prof. Dr. Dr. Leo Weber describes and documents the history of the glassworks and the Optical Institute at Benediktbeuern in the days of Joseph von Fraunhofer.

Joseph von Utzschneider purchases the monastery complex in Benediktbeuern

Joseph von Utzschneider applied to purchase the buildings of the former monastery in Benediktbeuern in May 1805.[1] He was planning to establish a modern "optical institute" there. The monastery buildings were "extradited" to him on July 6, 1805. Various documents dating from September 17, October 8 and November 4, 1805, designate him as the "owner of the local dissolved monastery", namely Benediktbeuern.[2]

In 1805 Utzschneider had taken possession of most of the monastery buildings, but not the steward's house ("Maierhof"). The bill of sale is dated October 23, 1807.[3] A distinction must be made between the purchase and the bill of sale. This was the case when Utzschneider sold the monastery complex to the king of Bavaria. The buildings were handed over on February 15, 1818 as customary after a sale, but the bill of sale concerning this transaction is dated March 2, 1818.[4]

The bill of sale dated October 23, 1807 assumes inclusion of the barrelmaker's shop, the wainwright's shop, the smithy and the brewery cooperage. These buildings were erected before 1803.[5] The sum quoted in the bill of sale is 58,150 guldens.

Utzschneider

The marked window of the house adjacent to the glassworks was probably the location of the six lamps with which Fraunhofer carried out experiments on the refraction of glass for light of different wavelengths over a distance of precisely 225 meters.

and Fraunhofer

The former monastic washhouse next to the millstream at the south-eastern corner of the monastery complex, which actually bridged the stream, and the large four-wing steward's house in the north-east of the complex are not included in this bill of sale. Joseph von Utzschneider purchased these separately from the other buildings. He bought the monastery washhouse as early as October 8, 1805, paying a price of 450 guldens to its resident Anastasia Herzlin, the widow of a teacher. Mrs. Herzlin was moreover granted life tenancy free of charge in the nearby village of Häusern.[6]

The large "former monastery steward's house", an extensive four-wing edifice in the north-eastern part of the monastery complex, had originally been purchased by Johann Georg Joseph Fuchs of Munich "from the royal local administration commission in Benediktbeuern" on January 20, 1804.[7] Fuchs was the treasurer of the "royal and rural joint debt-settlement commission" in Munich. As "royal privy councilor", Joseph von Utzschneider purchased the monastery steward's house from treasurer Fuchs for 26,000 guldens on September 18, 1806.[8] The property did not pass to Utzschneider in 1805, as some accounts still claim. His starting investment of 58,150 guldens for the monastery complex thus increases by at least the 450 guldens for the erstwhile washhouse and the 26,000 guldens for the steward's house to a total of 84,600 guldens. His expenses rose even higher through various minor additional payments and through buying back former monastery lands which had been auctioned off during secularization.

Joseph von Utzschneider intended to set up a model agricultural business in the former Benediktbeuern monastery, which is why he also wanted to purchase the steward's house.[9] He was also very keen to reunite the properties and fields that had been "torn apart" by the secularization.[10]

As of 1807, "the alpine dairy farm known as Häusern", east of Laingruben – since 1865 the village of Benediktbeuern –, once again became part of the estate, i.e. the totality of the original monastery complex. The Bavarian government had meanwhile sold it to the Mennonites, as no other purchaser could be found. It is probable that Utzschneider continued to cultivate the monastery garden. Nevertheless, he used one of the greenhouses to set up his optical instruments.[11] He actively campaigned for the reclamation of marshy ground. Two marshy areas totaling 708 Tagwerk (about 62 acres) were assigned to him "for cultivation". He drained them as he had done with other areas.[12] Today we count it as progress to waterlog these areas once again.

The establishment of the Optical Institute and Fraunhofer's living quarters

Joseph von Utzschneider deliberately planned to keep together and maintain the buildings of Benediktbeuern Abbey, which had been dissolved in the 1803 secularization movement, by giving them a new meaning and purpose – in itself a great service to the history and culture of Bavaria, specifically Benediktbeuern. The most important facility in the former monastery of Benediktbeuern is the "Optical Institute", which he founded jointly with Joseph Liebherr and Georg von Reichenbach in 1805/06 as a branch of the institute in Munich.[13] Its objective was to meet the need for optical measuring instruments for the planned land survey, but also to provide better optical devices for everyday use, such as telescopes and microscopes.

This required top-quality "optical" glass. Formerly called ripple-free flint glass, it is known today as "non-striated" or "homogeneous" glass. Only with glass quality of this kind could any success be achieved in the highly sensitive optical industry. To begin with, Utzschneider planned a melting facility with large, and permanently installed melting furnaces. This was set up next to the former washhouse of Benediktbeuern Abbey, not inside the washhouse, as older literature repeatedly asserts.

Crown glass and flint glass were to be melted in these large furnaces. The latter had a stronger coefficient of refraction. Its glass melt contained lead. It has recently been surmised that Joseph von Fraunhofer contracted lead poisoning through handling these materials.

The newly built glassworks is known in the literary sources as the "harbor workshop" or "glass furnace works" with "2 optical glass furnaces" and an "iron secondary furnace".[14] There was also a "large walled-in boiler". The "optical glass grinding shop", on the other hand, was accommodated in the former washhouse next-door. This was also called the "optical factory building". At ground level it had "6 small workshops with a water wheel", and on the upper story, where the glass was ground, it had 5 rooms and 1 kitchen.[15] Joseph von Fraunhofer was the first person to direct this "glass grinding shop".

A clear distinction was made between the "washhouse" and the new "glass furnace works" directly adjacent to it. Against the garden wall behind this glassworks was a "Dari furnace containing iron doors and rods, ... likewise the sandworks in front of and behind the house down to the stream".

Soon after the "optical glassworks" Utzschneider founded a "common glassworks" for normal consumer glassware.[16] Its building was located to the west of the west wing, about 80 to 100 meters distant, on the central axis of the monastery complex.[17]

The Swiss scientist Pierre Louis Guinand had invented the new stirring method used at the glassworks, and Joseph Fraunhofer improved this method. He was the first person to succeed in producing a homogeneous glass quality; he also created lenses with a much larger diameter than ever before, even larger than those from the best production facilities in England. After Pierre Guinand had left, Joseph von Fraunhofer also assumed responsibility for the melting process and thus for the entire glassworks.

Joseph von Fraunhofer revolutionized the production of high-quality glass.

Fraunhofer also designed micro-scopes with outstanding optical properties.

A few years later, he also became head of "Optical Mechanics" and director of the entire "Optical Institute" in Benediktbeuern. Fraunhofer achieved his trailblazing successes during his activities in Benediktbeuern from 1809 to 1819, causing the former Benedictine monastery of Benediktbeuern to become a world leader in the optical industry. Thanks to the quality of his glass, his small and large lenses and prisms, and his method of grinding and polishing the lenses and assembling the optical instruments, Fraunhofer rose to the forefront of the industry. In addition, he carried out research on the behavior of light using his best optical glasses and gained completely new insights in this area, too. In return, he was made a member of the aristocracy, adding "von" to his name to become Joseph von Fraunhofer.

His most important discovery is the "Fraunhofer lines", a set of spectral lines in the spectrum of the sun's light that are named after him. This marked the start of spectral analysis, which plays an important role in the investigation of the universe to this very day. Benediktbeuern became the "cradle of scientific glass technology".[18]

It is therefore all the more interesting to know exactly where and in which rooms Fraunhofer lived, worked and studied, where he was at home. A stone plaque which King Ludwig I of Bavaria had hung above a door in the wall in the corridor of the *Fürstenflügel* ("prince's wing") on the upper story in 1841, fifteen years after Fraunhofer's premature death, provided a first clue: "Joseph von Fraunhofer, inventor of ripple-free flint glass, worked here from 1809 to 1819".

Joseph Fraunhofer came to Benediktbeuern in about 1808/09.[19] Probably from 1809 onwards, he lived in the first five rooms of the outer south wing, which is known today as the *Fürstenflügel* or *Fürstentrakt*, starting from the west end of the long corridor in the upper story as far as the "great hall", the *Kurfürstensaal*, which today serves as a house chapel for the Salesians of Don Bosco. It was used as a "hall of optical instruments".[20]

In the list of rooms drawn up in 1818, the description of No. 145, immediately after the door in the corridor from the west wing to the south wing, the "new building" or "summer abbey", today's *Fürstentrakt*, runs as follows: "Kitchen, contains a cast-iron wash boiler and a copper boiler", the property of Mr. Fraunhofer. This is followed by room numbers 146, 147, 148, 149. These are described as "Mr. Fraunhofer's living quarters". They are immediately followed by No. 150, the "great hall", or the "hall of optical instruments". This room could not be heated. Joseph Fraunhofer's immediate living and study areas are thus clearly identified. This is where he lived, studied and carried out experiments with the optical instruments in the great hall directly next-door – but probably not the light experiment with the six light sources. The distance from the target building was too short for this, and moreover there was no unobstructed view.[21] But it was essentially Fraunhofer's domain. It was probably in these rooms that he discovered the "Fraunhofer lines" in the spectrum of the sunlight, which were later named after him.

Spectral prism device from Fraunhofer's workshop. Such devices were used to separate the incident light into different wavelengths.

The "great hall" *(Kurfürstensaal)*, with its high windows on the east, south and west sides, turned out to be the hall of spectral colored sunlight displays, as the writer of this text has been privileged to observe many times at sunrise. In spring, when the weather is good, the incident sun beams penetrating the window glass from the East cause fields of light with the clear spectral colors of red, orange, yellow, green, blue and violet to occur at short intervals one after the other, and to creep across the floor, between chair legs, and up the inner north and west walls of the hall. Fraunhofer, too, must have experienced these colored light fields, as he often spent time in this hall experimenting with the optical instruments. It is almost certainly this display, and not just his experience with a feather in the monastery tavern, that inspired him to further investigate the phenomenon and led him to discover the numerous absorption lines in the sun's rays.

Because of Fraunhofer's success in glass technology and science, these rooms associated with his personal life are of greatest historical importance.

A narrow spiral staircase led downwards from the kitchen (Nr. 145) to the ground floor.[22] Possibly its purpose was to provide the researcher with a short cut to the workshops for "Optics" and "Mechanics" in the front part of the eastern ground floor. In front of the "great hall", however, was the "master staircase", known today as the *Fürstentreppe* ("prince's stairs"). It was via these stairs that the optical instruments were transported into the "great hall".

The rooms on the ground floor of the "new building" were not as elaborately equipped as those on the upper floor. They were suitable for use as precision engineering workshops for the manufacture of optical instruments. Lathes and joining benches, machines for the "mechanical workshop", later to become the "mathematical-mechanical-optical institute", were installed and used here. Five rooms on the ground floor, numbered 82, 83, 84, 85 and 86, were set aside for these machines, starting at the eastern end of the building and extending as far as the stairs to the basement and the "main stairs" to the upper story. They constituted the third area of the Optical Institute in the former Benediktbeuern monastery.

The fourth set of rooms were Fraunhofer's own living quarters and study rooms. These represent the "think tank" of the entire complex. It was from here that the decisive and progressive impulses, the innovations, emanated. The rooms in the third area, the mathematical-mechanical-optical workshops, were likewise rented for the Optical Institute, which continued to exist when the monastery complex was sold to the Bavarian king.

The first area of the Optical Institute consisted of the "harbor works", and the second area was the "glass grinding shop" in the former washhouse immediately adjacent to the harbor works. All three areas were ultimately under the control of Joseph von Fraunhofer. In 1817 the astronomer Johann Georg von Soldner, who was a friend of Fraunhofer's, organized for him to become a member of the Royal Bavarian Academy of Sciences. He described him as "the best practical optician alive", who at the same time was an excellent "theoretical optician and experimenter". Soldner also noted that: "He has all the resources one could possibly want at his disposal; he has an admirable workshop in which he himself has built all the devices that he requires; he mixes and melts his glasses just as he needs them, and grinds them to his own calculation."[23]

The 9-inch refractor in the Deutsches Museum was built to Fraunhofer's plans.

Supplementary notes

A "six-year-old brown saddle-horse; a one-wheel yellow Swiss cart; a rope-pulled sled; an oat-bin" are listed as "the property of optician Jos. Fraunhofer" in 1818. They were located in the "Oeconomie", i.e. on the premises of the stables that were controlled by the steward's house.[24]

Even after the "mathematical-mechanical-optical institute" had been relocated to Munich in 1819, Joseph von Fraunhofer frequently returned to Benediktbeuern to supervise the glass melts. It is likely that he lived in the rooms described until his premature death in 1826.

1818, Utzschneider kept on numerous rooms on a rental basis, as he wanted to continue with the manufacture of both optical glass and normal glass. Glass was melted at the "optical glass-works" until about 1887.[25] Sigmund Ritter von Merz, the son of Georg Merz von Bichl, continued the practice.

On the ground floor of the erstwhile monastery "hospital", also known as the "pharmacy", between the former washhouse and the "new building", there were two rooms "containing furnaces for casting and mold drying belonging to the Optical Institute". The glass grinders had their bedrooms and living quarters on that same ground floor, and the "individuals for mechanics and optics" were one story above them. Five further "bedrooms and living quarters for mechanics" were located in the convent building. It is probable that the family of Georg Merz von Bichl, Joseph von Fraunhofer's first associate, also lived there.[26]

A "large-scale lens radius grinding machine" was walled into the ground floor of the library building. The "upper part of the large-scale radius grinding machine" was accommodated in the "room" above it, the former monastic archive. Nailed to the ceiling were "a large pulley" and "a small ... hoisting frame", as well as the "frame of the large roller-burnishing machine". "Under the roof" of the library – presumably reached from the attic – there was "a large elevator" to the large-scale radius grinding machine. All these instruments and machines were the "property of the Optical Institute" and were not sold on February 15, 1818. They remained in the hands of Joseph von Utzschneider.[27]

Sources in German

1 BayHStAM IV, Kriegsarchiv, M Kr 14 953 Remontedepot Benediktbeuern Bund 1, 1806–1822. Kaufvertrag vom 23. Oktober 1807, XX.
2 A. a. O. Bund 1.
3 Wie Anm. 1. – Vgl. Bayern und seine Armee. Eine Ausstellung des Bayerischen Hauptstaatsarchivs aus den Beständen des Kriegsarchivs (Ausstellung und Katalog: Rainer Braun in Zusammenarb. m. Gerhard Heyl/ Andrea Groß; Red.: Albrecht Liess; 9. Juli – 30. August 1987), München 1987, 300, Nr. 163.
4 Wie Anm. 1, Unterkonvolut IV.
5 So auch das Gutachten von Baufachmann Strehler 2005.
6 Wie Anm. 2.
7 Ebd.
8 Ebd.
9 Günter D. Roth, Joseph von Fraunhofer. Handwerker, Forscher, Akademiemitglied 1787–1826 [= Große Naturforscher 39], Stuttgart 1976, 70.
10 KAM, A XIX b.1. Remontierung Benediktbeuern – Kap. IV, Lit. Benediktbeuern Nr. 1. Militär-Fohlenhof Benedictbeuern. Ankauf des ehem. Klosters vom Jahre 1818 bis 1822. Fasc. III (NB.: Auf dem Innendeckel heißt es: »1818–1821, Fasc. II«). 3. Konvolut, 25. Jänner 1818 (Jos. Utzschneider an König Maximilian I.; eigenhändig), eingelegt im Produkt v. 6.II.1818. – Vgl. Bayern und seine Armee (wie Anm. 3), 297.
11 Wie Anm. 10, 1. Konvolut, Unternummer 5 ad 87. – »Das alte Treibhaus im Hofgarten« war »zur Aufstellung eines großen Fernrohrs bestimmt«.
12 Wie Anm. 10, 1. Konvolut, Unternummer 38. – Vgl. Bayern und seine Armee (wie Anm. 3), 300, Nr. 163.
13 Alto Brachner, Die Münchener Optik in der Geschichte. Entstehung, Unternehmungen, Sternwarten, Lokalitäten, Ausbreitung 1750–1984, München 1986, 113–118, 160–165. – Roth, Joseph von Fraunhofer (wie Anm. 9), 49–63. – Hans Jebsen-Marwedel, Joseph von Fraunhofer und die Glashütte in Benediktbeuern, München 1982, 11–26. – Ilse Mackenthun, Joseph v. Utzschneider. Sein Leben, sein Wirken, seine Zeit. Ein Beitrag zur bayerischen Wirtschaftsgeschichte [= Neue Schriftenreihe des Stadtarchivs München 11], München 1958, 125f. – Hans-Peter Sang, Joseph von Fraunhofer. Forscher, Erfinder, Unternehmer, München 1987, 24f. – Wolfgang Stahl, Joseph von Utzschneider und seine Bedeutung für die deutsche optische Industrie, München 1929, bes. 116–171.
14 Wie Anm.10, 1. Konvolut, Unternummer 5 ad 172; Unternummer 25 (Rückseite).
15 Ebd., dazu a. a. O. 3. Konvolut: Gebäudebeschreibung (»Abschrift«), eingelegt im Produkt v. 6.II.1818, fol. 2: – Dabei liegt ein Übersichtsplan von den Klostergebäuden aus dem Jahre 1818, Buchstabe o. (Die beiden großen Schmelzöfen in der »Glas-Ofen-Hütte« sind vermutlich in späterer Zeit erneuert worden). – Vgl. Carl R. Preyß, Joseph von Fraunhofer. Optiker – Erfinder – Pionier [= Stöppel-Kaleidoskop 203], Weilheim 1989, 53.
16 Wie Anm. 10 – 1. Konvolut, Unternummer 16: »G. gemeine Glashütte u. Glas-Schleiferey«. – NB: Es wird unterschiedlich »Glashütte« und »Glaßhütte« geschrieben. – 1. Konvolut, Unternummer 10 ad 98, 99. – Brachner, Die Münchener Optik (wie Anm. 13), 117f.
17 Wie Anm. 15 – Josef Kirmeier/Evamaria Brockhoff (Red.), Die historische Fraunhofer Glashütte in Benediktbeuern (Begleitheft zur Ausstellung »Glanz und Ende der alten Klöster. Säkularisation im bayerischen Oberland 1803«), München 1990, 18. Im September und Oktober 2005 wurden die Fundamente der »gemeinen Glashütte« bei Aushubarbeiten für den Neubau der »Kath. Stiftungsfachhochschule für soziale Arbeit« freigelegt. Vgl. Stefan Biermeier M.A., SingulArch. Grabungen. Grabungsbericht, Benediktbeuern 2005, Westbau II.
18 Roth, Joseph von Fraunhofer (wie Anm. 9), 49. – Sang (wie Anm. 13), 50f., 56. – Jebsen-Marwedel, Joseph von Fraunhofer (wie Anm. 13), 25. – Brachner, Die Münchener Optik (wie Anm. 13), 147–150. – Preyß, Joseph von Fraunhofer (wie Anm. 15), 51f., 62: »Fraunhofers neue Denkweise ... auf wissenschaftlicher Grundlage gab ein signifikantes Beispiel weit über die Optik hinaus« (S. 52). – Kirmeier/Brockhoff (wie Anm.17), 8f., 14 (Wolfgang Jahn). – Stahl (wie Anm. 13),138–144.
19 KAM, Remonte Inspektion und Depots. Bund 211, Unterbund Fraunhofer, Produkt 4. – Roth, Joseph von Fraunhofer (wie Anm. 9), 43–48. – Sang, Joseph von Fraunhofer (wie Anm.13), 39–41. – A. Seitz, Josef Fraunhofer, in: Deutsche optische Wochen-Schrift 11 (1925) Nr. 41, S. 626. – Brachner, Die Münchener Optik (wie Anm. 13), 121.
20 Wie Anm. 10, 3. Konvolut; Gebäudebeschreibung »G. Die Sommerabtei«, eingelegt im Produkt v. 6.II.1818; 1. Konvolut, Unternummer 5 ad 150. – KAM, A XIX, Bund 161. – Bayern und seine Armee (wie Anm. 3), 304. – Vgl. Leo Weber, Kloster Benediktbeuern (Großer Kunstführer 23), Regensburg 2003, 59–61. Die Salesianer Don Boscos sind seit 1930 im Kloster Benediktbeuern: Leo Weber (Hg.), Kloster Benediktbeuern. Gegenwart und Geschichte, Benediktbeuern 1981, 9–80.
21 Jebsen-Marwedel, Joseph von Fraunhofer (wie Anm. 13), 12. – Sang, Joseph von Fraunhofer (wie Anm. 13), 64.
22 Vgl. Fotos von P. Dr. Raymund Luschin SDB (Zimmergestaltung im Jahre 2002).
23 Carl Max von Bauernfeind, Gedächtnisrede auf Joseph von Fraunhofer zur Feier seines hundertsten Geburtstags, München 1887, 16. Vgl. Franz Past, Johann Georg von Soldner (1776–1833) und seine Zeit (Veröffentlichungen der Bayerischen Kommission für die internationale Erdmessung der Bayerischen Akademie der Wissenschaften; Astronomisch-Geodätische Arbeiten, Heft Nr. 62), München 2005.
24 Wie Anm. 10, 1. Konvolut, Nr. 21.
25 Textaufschrift auf der Spanschachtel mit dem Wappen von Joseph von Fraunhofer: KLAB, Abtlg. »Weltliche Zeit«, Fraunhofer.
26 ADB 21, 480. – Roth, Joseph von Fraunhofer (wie Anm. 9), 90f. – KAM (wie Anm. 10), 3. Konvolut, Produkt v. 6.II.1818. – Vgl. Stahl (wie Anm. 13), 137, 151–153.
27 Wie Anm. 10, 1. Konvolut, Unternummer 7.

Abbreviations
ADB: Allgemeine Deutsche Biographie
BayHStAM: Bayerisches Hauptstaatsarchiv München
KAM: Kriegsarchiv München
KLAB: Klosterarchiv Benediktbeuern

Exhibition

Christoph Mewes
gives an account of the restoration of the historic glassworks in Benediktbeuern and explains the concept behind today's, more extensive exhibition.

The historic glassworks underneath the spires of Benediktbeuern Abbey.

Conservation of the historic site

For many years, the Fraunhofer-Gesellschaft has taken a special interest in the glassworks founded by Joseph von Fraunhofer. Every effort has been made to conserve the authentic character of this historic site as far as possible, only making alterations where necessary to assure the structural integrity and safety of the building and improve access.

The 175th anniversary of Fraunhofer's birth in 1962 provided the impetus to launch a new conservation program to restore the old building. One of the many people who lent their support to this project was Hans Jebsen-Marwedel, who published a special anniversary paper on the life and works of Joseph von Fraunhofer and the history of his workshop in Benediktbeuern.

The workbenches in Fraunhofer's workshop used to grind and polish lenses.

Architectural features of the glassworks

The original structure of the glassworks consists of a barn-like timber-framed building with wooden planking on the side elevations, resting on a single-story masonry wall, with visible tie beams marking the interface between the two elements of the construction. A number of small windows on the rear elevation overlook the orchard belonging to the Abbey. On the side facing the road, a more recently added double doorway serves as the entrance. It is the only opening in the otherwise windowless façade. In Fraunhofer's day, there was a millstream flowing parallel to the road. It led to a waterwheel connected to a shaft that drove a stamping mill. The original main entrance was situated in the northwest wall of the building, and accessed via a bridge over the stream. It was in use until the 1980s, but has now been closed off.

The southwest gable end of the glassworks adjoins the former monastery washhouse, which once also housed the workshop that Fraunhofer used for grinding lenses. The building's unlined saddle roof is open to the rafters and rests on timber crossbeams that in places provide accessible attic space. Certain of the plain tiles that cover the roof have been replaced with authentic period tiles of the same design, to repair leaks. The load-bearing structure was reinforced a few years ago by discretely adding metal tie beams where necessary. The floor inside the glassworks consists of unevenly laid brickwork and smooth slabs of natural stone. The interior consists of a single large room containing two impressive pot furnaces and the associated paddle mixers for the manufacture of glass.

The restoration project

In 1991, thanks to a joint initiative by the Haus der Bayerischen Geschichte (Centre of Bavarian History) and the Fraunhofer-Gesellschaft, the historic glassworks was transformed into a modern scientific and historical museum and study center.

The restoration work enabled items directly related to Fraunhofer's work to be exhibited in their authentic setting. One of the display cases contains Fraunhofer's personal beer mug alongside telescopes and a theodolite.

Glass screens set in a framework of galvanized steel protect the valuable exhibits without distracting attention. Explanative texts and images printed on the glass provide visitors with information and at the same time serve as a protective barrier, also covering the mouth of the glass furnaces. In addition to the telescopes and a cast-metal bust of Joseph von Fraunhofer, many visitors are fascinated by an experimental setup donated by the Fraunhofer Institute for Laser Technology ILT in Aachen. The hands-on display permits visitors to visualize the transmission and diffraction of light through lenses, and appreciate the quality of the antireflective lenses created by Fraunhofer.

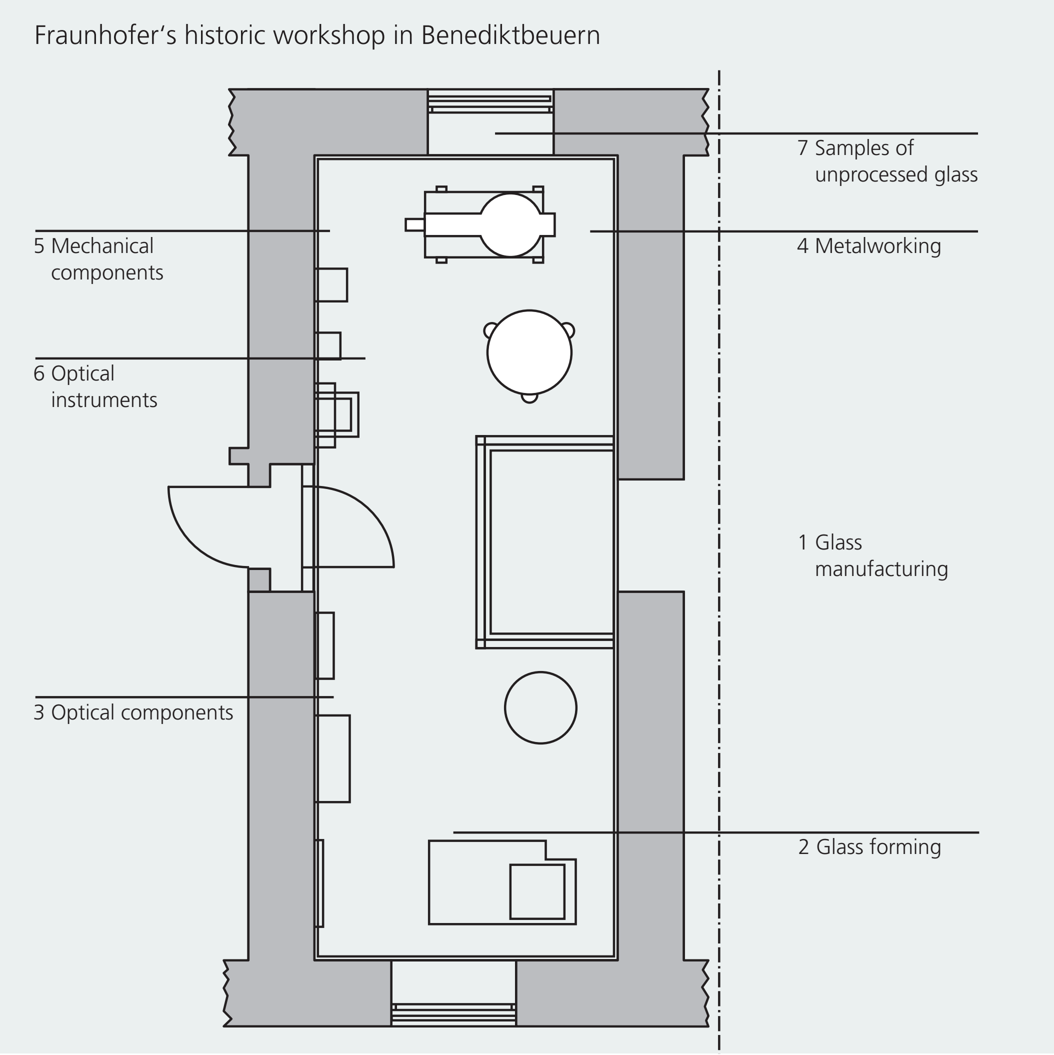
The extension of the museum: Fraunhofer's workshop

In 2006, Carl R. Preyß, a founding member of the Fraunhofer-Gesellschaft, Pater Leo Weber, Salesian pastor in Benediktbeuern Abbey, a group of Fraunhofer experts, and Christoph Mewes from the Fraunhofer-Gesellschaft's department for construction projects and property, drew up plans for an exhibition in Benediktbeuern featuring the tools and optical instruments with which Joseph von Fraunhofer had worked 200 years ago. Until then, these items had been stored in the vaults of the Deutsches Museum and the Munich Stadtmuseum, owing to the fact that the historic glassworks was unable to provide appropriate display facilities conforming to modern-day museum standards. Faced with this dilemma, the initiators of the project consulted architect Knut Prill (Baldauf·Prill Architekten, Schongau) with the aim of reopening the passage between the glassworks and the former Abbey washhouse, which had been closed off. This space, which once housed Joseph von Fraunhofer's lens-grinding workshop, nowadays serves as the guest wing for visitors to the monastery. Two of the rooms have now been converted into an additional exhibition room for the museum, thanks to the generosity of the monks who agreed to donate part of their guest facilities for this purpose.

Taking extreme care to preserve the existing vaulting, the partition walls were removed, the existing hallway was closed off with a steel door to meet fire safety requirements and concealed behind a jib door, and two windows were inserted in a style that harmonizes with the building's outward appearance while at the same time providing the necessary security for exhibition rooms.

Visitors can now step out of the glassworks building onto a viewing platform with glass screens on three sides that gives a clear all-round view of the current exhibition.

The restored glassworks with the melting furnaces. The round tub in the foreground is a paddle mixer in which the molten glass could be immersed and cooled.



Whereas the exhibits in the glassworks building focus on the manufacture of glass from silica sand (1 Glass manufacturing), the new exhibition space contains a series of displays devoted to the following topics:

2 Glass forming
3 Optical components
4 Metalworking
5 Mechanical components
6 Optical instruments
7 Samples of unprocessed glass

The largest items on display, such as a gear-milling machine and a glass grinding machine, which weigh close to 500 kilograms apiece, are so bulky that they had to be brought into the exhibition room before the carpenter had completely assembled the frame and glass screen of the viewing platform.

The number of objects on display may seem huge compared to what was here before, but there is still a considerable collection of Fraunhofer material in the two donor museums, waiting to find a new home in the historic glassworks in Benediktbeuern.

Structurally, it would be relatively easy to add further space to the new small museum.

Joseph von Fraunhofer.

Carl R. Preyß
describes Joseph von Fraunhofer's huge influence on the course of scientific, technological and industrial progress.

Fraunhofer's

Fraunhofer's ingenious approach to optical research

Joseph von Fraunhofer was born in 1787 in Straubing, south Germany. Towards the end of his all-too-brief life, he made a discovery that would one day lead to the emergence and remarkable rise of a whole new branch of industry: the physical relationship between the resolution of a microscope and the wavelength of light.

Fifty years later, Ernst Abbe in Jena rediscovered this same relationship, which was to form the basis for the outstanding success of a company named Zeiss. Speaking at a meeting in Jena to celebrate the centenary of Fraunhofer's birth in 1887, he said: "Fraunhofer's early demise was an irretrievable loss for both practical and experimental optics. The revolutionary ideas on which he was working during the latter years of his life would have advanced the field of optics by several decades if they had been implemented at the time. Instead, they were interred with him in his grave and, as history confirms, it took the work of another two generations of scientists to retread the same path, following in his footsteps …"

Significance

This is not the only reason why Fraunhofer is considered as a genius ahead of his time; other remarkable facts include:

– Fraunhofer amassed his considerable knowledge on his own, as a simple apprentice without any academic training.
– Besides being a scientist, he was also a gifted entrepreneur.
– The optical systems he created were of a far superior quality, enabling him to build the most highly efficient astronomical telescopes of his day.
– He was one of the first to understand and exploit the wave principles of light.
– His approach to the development and manufacture of technical systems was entirely without precedent, and formed the basis for modern industrial working practice.

Support for an ambitious young man

There have been many accounts of Fraunhofer's youth, often verging on the melodramatic. There is no doubt that he suffered hardship, but that was almost normal in those days. He learned a respectable trade, supported by one of his sisters after his parents died, being her only brother. The family owned a fine house in Straubing and the rights to work as a glassmaker. The thing that really oppressed him was the narrow-mindedness of his master, who saw no necessity for theoretical training and discouraged all forms of book learning.

The young Fraunhofer's fortunes were turned around by an unexpected accident, when his master's house in Thiereckgäßl in Munich collapsed in 1801, an event from which the young man barely escaped with his life. The homeless youngster with an insatiable thirst for knowledge was taken under the wing of Joseph von Utzschneider, a progressive entrepreneur and political economist, and the Bavarian prince-elector Maximilian IV Joseph granted him generous financial support. Another of his sponsors was the highly educated Benedictine pastor Ulrich Schiegg, who was a renowned authority in matters of science and engineering. With their support, Fraunhofer was able to continue his self-education and develop his ideas.

Fraunhofer's extraordinary talent finally came to the fore in 1806, when Utzschneider recruited the 19-year-old to work in his factory for optical instruments because he was in urgent need of someone capable of manufacturing the high-quality lenses to go with the finished, but still "blind" instruments. Fraunhofer broke with conventions to develop his own methods, and before long he was producing lenses that exceeded all expected requirements in terms of quality, quantity and costs.

The company had been originally founded by the noted engineer and inventor Georg von Reichenbach, together with Utzschneider. In 1807, the factory was relocated from Munich to the abbey buildings in Benediktbeuern that Utzschneider had recently purchased. Fraunhofer, who was only 21 at the time, drew up a new "business plan" and requested that he should be taken on as a partner. This was the start of his career as an entrepreneur, and in 1814 he became sole manager.

Blazing new trails for science and industry

It was at this point that Fraunhofer once again demonstrated his talent for originality. After having revolutionized manufacturing processes, he now went on to develop new instruments of unprecedented quality and, furthermore, turned his attention to theoretical science and started to investigate the wave structure of light.

This boosted his success as a manufacturer. His telescopes were delivered to customers all over the world and helped to advance astronomical science. His large telescopes and heliometers were installed in all the major observatories, including those of Munich, Moscow, Cincinnati, Christiania, Greenwich, Mexico and Sydney.
The Dorpat refractor, which was exhibited in public before being shipped to the observatory in Russia, represented the epitome of precision mechanics and optical engineering, and became synonymous with technological progress.

Fraunhofer was no less successful as a theoretical scientist. He systematically studied and measured the absorption lines of the solar spectrum, initially as a means of establishing objective standards for the development and testing of optical glass. Now known as "Fraunhofer lines", they have since become part of the standard terminology in the world of physics and have made a significant contribution to progress in spectral analysis and astrophysics.

For Fraunhofer, this was just the beginning of a long quest to elucidate the nature of light. He subsequently provided unequivocal proof of Young's wave theory, and was the first to produce absolute wavelength measurements using the optical diffraction filters that he had invented himself. His results deviate only by parts per thousand from those measured using modern instruments

Outstanding achievements crowned by early recognition

As a result of this work, Fraunhofer gained the recognition of the international scientific community and was accepted as a member of the Royal Bavarian Academy of Sciences and other scientific bodies, as well as receiving an honorary doctorate from the University of Erlangen, where he gave lectures on optics in his capacity as professor. In 1824, King Max I Joseph of Bavaria, who had faithfully followed his fortune since the time when the young apprentice glazier had escaped the destruction of his master's house, awarded him the title of Knight of the Order of Civil Service of the Bavarian Crown, enabling him to join the ranks of the nobility.

However, these honors do not reflect what was possibly Fraunhofer's most enduring achievement, which was the introduction of entirely new methods of developing and manufacturing industrial products. He was one of the first to recognize the limits of existing methods, preferring to explore all manner of possible alternatives in terms of materials, processes and products systematically and without preconceived ideas, and developed new materials, manufacturing machines and test methods. This approach ruled out sources of human error and inaccuracy, and gave the manufacturer complete control over quality, yield, time and costs. It was an entirely new way of thinking.

Ernst Abbe, too, was aware of this fact when he wrote that the thought of allowing the forming hand merely to serve the embodiment of a perfected idea represented an absolutely novel approach at the time. He went on to say that, "All true progress – even where it did not derive directly from Fraunhofer's groundbreaking work – came into being this way."

A revolutionary thinker for future generations

Fraunhofer's ideas were thus the source of modern industrial methods used to develop new materials, components, machines and instruments and to devise apparatus, working techniques and test equipment.

It was therefore highly appropriate that, in 1949, an institution devoted to applied research should choose to base itself on Fraunhofer's name and principles: the Fraunhofer-Gesellschaft.

The legacy of Fraunhofer's work has been highly influential, and is still alive today. A fortunate combination of circumstances has ensured that a great deal of the material evidence of his work has been preserved intact, and most particularly his glassworks at Benediktbeuern Abbey. Moreover, many important items from his workshop have been saved, especially through the foresightedness of Dr. Loher, whose initiative led to the creation of the Fotomuseum (museum of photography) in Munich. A part of this collection is now open to the public and, what's more, in a room that Fraunhofer himself used for manufacturing precision optics.

Many more items are being kept in storage, waiting for the day when they can be displayed to the public. Fraunhofer's immense significance to the history of physical optics, astronomy, and industrial manufacturing methods merits a small museum devoted to production engineering, which provides a suitable complement to the valuable collection of instruments on display in the Deutsches Museum.

References

Bayern und seine Armee. Eine Ausstellung des Bayerischen Hauptstaatsarchivs aus den Beständen des Kriegsarchivs, Rainer Braun u. a. München 1987 (Ausstellungskataloge der Staatlichen Archive Bayerns Nr. 21).

Brachner, Alto: Die Münchener Optik in der Geschichte. Entstehung, Unternehmungen, Sternwarten, Lokalitäten, Ausbreitung 1750–1984, Diss. München 1986.

Brachner, Alto/Seeberger, Max (Hg.): Joseph von Fraunhofer 1787–1826. Ausstellung zum 150. Todestag, Deutsches Museum, München 1976.

Jebsen-Marwedel, Hans: Joseph von Fraunhofer und die Glashütte in Benediktbeuern, München 1982.

Joseph von Fraunhofer 1787–1826, Ausstellung zum 200. Geburtstag, Konzeption: Johannes Prammer, Straubing 1987 (Katalog des Gäubodenmuseums Straubing Bd. 10).

Junkelmann, Markus: Joseph von Fraunhofer – Pionier der modernen Forschung, in: Unternehmer – Arbeitnehmer. Lebensbilder aus der Frühzeit der Industrialisierung in Bayern, hg. v. Rainer A. Müller, München 1985, S. 76–80 (Veröffentlichungen zur Bayerischen Geschichte und Kultur Bd. 7/85).

Kohler, Ernst: Georg von Reichenbach, Das Leben eines deutschen Erfinders, München 1933.

Kratz, Otto Paul/Renatus, Elisabeth: Zur Geschichte der Glashütten in Benediktbeuern, in: Kultur und Technik 7 (1983), S. 249–256.

Mackenthun, Ilse: Joseph v. Utzschneider, sein Leben, sein Wirken, seine Zeit. Ein Beitrag zur bayerischen Wirtschaftsgeschichte, München 1958.

Preyß, Carl R.: Joseph von Fraunhofer. Optiker – Erfinder – Pionier, Weilheim 1989.

Preyß, Carl R.: Joseph von Fraunhofer. Physiker – Industriepionier, (o.O.) 2007. Veränderter Nachdruck des Buchs »Joseph von Fraunhofer. Optiker – Erfinder – Pionier«.

Rollwagen, Walter: Joseph von Fraunhofer, München 1977.

Sang, Hans-Peter: Joseph von Utzschneider (1763–1801). Sein Leben, sein Wirken, Diss. München 1985.

Sang, Hans-Peter: Joseph von Fraunhofer. Forscher, Erfinder, Unternehmer, München 1987.

Schneider, Anton: Der Gewinn des bayerischen Staates von säkularisierten landständischen Klöstern in Altbayern, München 1970 (Miscellanea Bavarica Monacensia 23).

Seitz, Adolf: Joseph Fraunhofer und sein optisches Institut, Berlin 1926.

Utzschneider, Joseph von: Kurzer Umriß der Lebens-Geschichte des Herrn Dr. Joseph von Fraunhofer, in: Kunst- und Gewerbeblatt des polytechnischen Vereins für das Königreich Bayern 12 (1826), S. 411–424.

Editorial notes

Editorial team
Dr. Martin Thum
Christa Schraivogel (picture editor)

Authors
Dr. Wolfgang Jahn,
Haus der Bayerischen Geschichte
(Centre of Bavarian History)
Dr. Josef Kirmeier,
Haus der Bayerischen Geschichte
(Centre of Bavarian History)
Christoph Mewes,
Fraunhofer-Gesellschaft
Carl R. Preyß,
Founding member of the
Fraunhofer-Gesellschaft
Pater Prof. Dr. Dr. Leo Weber,
Benediktbeuern Abbey

The contributions by Dr. Wolfgang Jahn and Dr. Josef Kirmeier, and the photos on pages 5 – 13, 15 and 22, are taken from "Die historische Fraunhofer-Glashütte in Benediktbeuern", published jointly by Fraunhofer-Gesellschaft and Haus der Bayerischen Geschichte (Centre of Bavarian History), München 1990.

Layout
Gestaltungsbüro Hersberger SGD,
Munich

Production
Marie-Luise Keller-Winterstein

English edition
Burton, Van Iersel & Whitney GmbH,
Munich

Photo acknowledgments
Alexander Heck: 5 – 8,11,13 – 15, 21
Deutsches Museum: 17
Bernd Müller: 14, 23 – 29, 34 – 35,
Hans Wiedemann: 7 right, 9, 22

www.fraunhofer.de

Fraunhofer-Gesellschaft
Press and Public Relations:
Franz Miller
Hansastrasse 27 c
80686 München
Phone +49 89 1205-1300
presse@zv.fraunhofer.de

For general inquiries, please send e-mail to:
info@fraunhofer.de

Historic Fraunhofer Glassworks
Fraunhoferstrasse 1
83671 Benediktbeuern