
European
Photonics

From Venice to the Dutch Republic

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The early-17th-century Netherlands, benefiting from dynamic and robust socioeconomic development, was at the forefront of early optics progress—an effort that involved both luminaries and less-known contributors.

Detail of Jan van der Straet's "Spectacles" (1584).

Rijksmuseum, the Netherlands / Purchased with the support of the F.G. Waller-Fonds

A 19th-century woodcut of Venice shows, in the background, the island of Murano, which hosted the city-state's glassmaking operations after 1291. Getty Images

Over the past 500 years, a number of early pioneers of optical science have risen to prominence in general historical accounts—Isaac Newton and Galileo Galilei, for example, who blazed trails in mathematical physics and astronomy, and Robert Hooke and Antonie van Leeuwenhoek, who brought the microscope and the insights into nature that it has enabled. Yet this focus on household names overlooks a plethora of people, places and events that have influenced the field's progress.

This article provides a few annotations to that received historical record—sketches of several less-known, sometimes colorful figures related to the craft of optics and optical glass. The focus is on the 17th-century Dutch Republic, an area corresponding roughly to the present-day Netherlands. Despite (or, perhaps, partly because of) religious and political strife that engulfed the region, the Dutch Republic of that era, a period now called the Dutch Golden Age, helped to foster a range of advances in European science generally and in optics in particular. And those advances drew on earlier progress and artisanship elsewhere in Europe—particularly across the Alps, in the Venetian Republic.

Venetian precursors

The history and geography of glassmaking and early optics are intrinsically related. Glassmaking itself started as early as 2500 B.C.E. in Egypt and Mesopotamia and developed and improved in India, the Roman Empire, the Islamic world and elsewhere in the centuries that followed. Lenses and lens-like objects made of quartz or "rock glass" date to 750 B.C.E., and by the 9th century C.E., lens-like objects were used as reading stones, exemplified in the work of Abbas ibn Firnas in Moorish Spain.

The first mention in the Western literature of a glass lens to be used for optical purposes dates from the 13th century, when in 1268 a glassmaker installed one in a reliquary—a box containing a saint's relics. By the end of the 13th century, eyeglasses were described in public records of the Italian states and even depicted in the contemporary portraits of some personalities. Concave lenses were available for sale in Florence by the 1460s.

Mirrors, meanwhile, were initially made out of metal as early as five thousand years ago. The use of glass in mirror making came later, in Egypt and China in the 1st century C.E. In Venice, various techniques and materials were developed to yield exquisite mirror works by the 1200s. So great was the resulting commercial boom that the glassworks came to be treated as a state secret, with guild members and their families sworn to secrecy on penalty of death. By 1275, Venetian laws forbade the export of sand and broken glass. Due to the frequent fires occurring in the city, the Venetian glassworks moved to the island of Murano around 1291.

By then, the technical progress of mirror making was ahead of that of lens making. It wasn't until four centuries later, in 1668, however, that a mirror would be used in Newton's reflector telescope, and would thereby become an essential ingredient for the maturation of astronomy.

Why Venice?

Venice's role in the development of glassmaking, and optics, throughout the European medieval period and into the early modern one, grew from its economic

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The Dutch Republic of the late 16th and early 17th century experienced growth similar to that of Venice in the late 12th and early 13th century—but in a very different geopolitical context.

stature—shaped, in turn, by contemporary geopolitics and by the city-state's location, which afforded easy access to raw materials, skilled workers and information.

To make glass, one needs a former (typically silica [SiO_2], from sand), a flux to reduce the melting temperature (typically soda [Na_2O] or potash [K_2O]), and a stabilizer or strengthening agent (such as lime [CaO]). Other additives control coloring, strength, and elasticity or workability. The Venetians had local access to wood (as an energy source), sand, marine plants and sodium carbonate–bearing brines—everything required for robust glassworks. As knowledge improved, Venice could tap nearby areas in Italy for higher-quality materials.

The Venetian Republic's strategic location as an Adriatic port, with access to the Mediterranean, made it a leading European power by the 13th century, with overseas trade driving the development of industries ranging from sailing and shipbuilding to salt making. Wealth accumulation found expression in grandiose buildings, whose prodigious requirements for window glass further bolstered the glassmaking industry. The 1204 fall of the Constantinople at the end of the Fourth Crusade may, through the migration of skilled workers, have brought access to novel techniques and introduced new raw materials. Wood, called *kali* by Arabs, was imported from Egypt; plant-ash, from Egypt and Syria. Indeed, the development of *cristallo di Murano* by Angelo Barovier in the mid-15th century resulted from a process for purifying the flux made from the newly imported plant-ash.

The Venetian Republic also controlled and supported the University of Padua (one of the oldest universities still active in the world today), where Galileo (1564–1642) would hold the Chair of Mathematics from 1592 until 1610. Galileo had connections from Padua to Venice and to Rome that provided access to information from across the European continent, especially through diplomatic channels. It was through one such connection, in 1609, that he learned from Paolo Sarpi (1552–1653), an erudite Venetian statesman with diplomatic ties of his own, about an interesting new invention from the Dutch Republic—the telescope.

The Dutch Republic and the Spanish Netherlands, early 1600s.

The Dutch Republic

The Dutch Republic of the late 16th and early 17th century experienced economic growth similar to that of Venice in the late 12th and early 13th century—but in a very different geopolitical context, and against a backdrop of political and religious turmoil. In 1568, the provinces constituting the area that includes present-day Belgium, the Netherlands and Luxembourg revolted against rule by the Spanish branch of the Habsburg dynasty. While the Spanish had regained control of most of the southern provinces by the early 1580s, the seven northern provinces declared their independence from Habsburg rule in 1581, to form the Dutch Republic.

The war for Dutch independence, which came to be known as the Eighty Years' War, lasted until 1648, when Spain finally recognized the Dutch Republic as an independent state. Yet despite that upheaval, the late 16th century also marked the beginning of the Dutch Golden Age, with the expansion of the local industries like shipbuilding and navigation, textiles, fishing and agriculture, finance and banking, and with substantial

In addition to his optical work, the polymath inventor Cornelius Drebbel (left) was known for developing the world's first working submarine, demonstrated in London sometime around 1620 (right).
Wikimedia Commons

economic growth both through regional commerce and through far-reaching sea trade. Port cities like Antwerp, Rotterdam and Amsterdam grew tremendously.

The increasingly urbanized Dutch society proved fertile ground for scientific and technological innovation associated with the financial and trade growth. Simon Stevin (1548–1620) and Rudolf Snellius (1546–1613)—the father of Willebrord Snellius (1580–1626), the namesake of Snell's refraction law—promoted practical mathematical knowledge to entire classes of tradespeople, from military engineers to carpenters to astronomers. Distancing from the Catholic Spain also led to a measure of religious tolerance and freedom of thought, attractive to thinkers such as René Descartes (1596–1650) who lived and worked in the Dutch Republic. Increasing literacy spurred interest in the study of natural and historical phenomena and increased the demand for books.

The period's accumulation of wealth also led to growing interest in the arts, fine clothing and furnishings—areas that influenced, and were influenced by, the advance of optical science. Scholars have generally concluded that Dutch painting masters used optical techniques in their work. Less widely known is the use of optics in the textile industry, which employed instruments such as wide-field microscopes or silhouette projectors. Yet another example is the artistic embellishment of glass objects (drinking ware, mirrors, reliquaries, flutes and horns), using techniques such as diamond engraving that involved a careful, laborious copying effort. The exquisite accuracy of works of Anna Roemers Visscher (1584–1651) suggests that optical means were used to project the pattern on the glass surface.

But how did the Dutch get their knowledge of glassmaking? While such knowledge was slowly diffusing across the continent, two factors suggest a Venetian connection. First was the spread across Europe of migrants from Venice, home of the Murano glassworks, and from a second glassmaking center, at Altare (near Genoa), which produced glass of comparable quality to that of Venice. Within the region of the Habsburg-controlled Netherlands, Murano workers seemed to prefer Antwerp, while the Altare workers settled mostly in Liege.

The second factor was the Eighty Years' War. A pivotal event of the war's first phase—the 1585 fall of Antwerp at the hand of Alexander Farnese, the Duke of Parma, the field commander for the Spanish forces—led to a significant exodus of inhabitants to cities and towns across the border in the new Dutch Republic. And that exodus included the migration of a number of skilled Italian glass workers.

A tale of three cities

With the fall of Antwerp, the stage was set for a rise in the lens-making craft in the newly united Dutch Republic that would have implications for science, art and commerce. In the rest of this article, we offer snapshots of three early-17th-century Dutch cities that played a role in glass and lens craftsmanship and optics—and of a few known and less-known personalities found there.

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Middelburg: Spectacles and telescopes

Middelburg, approximately 60 km northeast of Antwerp in the Dutch province of Zeeland, was, like Venice, located on important trade routes, with access to materials required for glassmaking. The Middelburg glassworks, already established in 1581, were by 1600 under the supervision of the Italian glass master Antonio Miotto, who migrated from Antwerp after the city's fall. Excavations at the Middelburg castle reveal the existence at that time of locally made glass, but also of glass from Germany, France and Bohemia. About 60 percent of the glass is in the Venetian style (*façon de Venise*) with the rest being mostly colorless or green.

Middelburg lies at the center of the story, and controversy, regarding the invention of the telescope, both of which are well-documented in *The Origins of the Telescope* (KNAW Press, Amsterdam, 2010). It was in Middelburg where the first known patent application for a refracting telescope—which came to be known in the era as the "Dutch perspective lens" or, to the Dutch themselves, as a "looker" (*kijker*)—was made by the lens maker Hans Lippershey (1570–1619). Two other Middelburg "spectacle makers" also, however, crop up in the early history of the telescope: Cornelius Drebbel (1572–1633) and Zacharias Janssen (1585–1638).

These lens makers, while all linked to the telescope claim, were otherwise rather different characters. Lippershey was German, but early in life settled in Middelburg, where he became a master lens and eyeglass maker. In addition to the refracting telescope, Lippershey also claimed to have invented a binocular telescope made with quartz rather than glass lenses—a fact that has received little attention to date.

Drebbel was a true Dutch Renaissance man—of an Anabaptist family, and versed not only in the technical skills of glass blowing and lens making but also in natural philosophy, painting, cartography and hydraulics. Born in Alkmaar (see below), he worked in Middelburg and, for an extended period, in England. He is credited not only with inventing a telescope-like instrument, but also a compound microscope, a barometer, and the first submarine. His mastery of hydraulics was demonstrated by work on water fountains, hot-air-actuated mechanical clavichords, and even chicken incubators.

Alexander Chalmers, in his *General Biographical Dictionary* from the early 1800s, credits Drebbel with constructing "a glass, which attracted the light of a candle placed at the other end of the hall, and which gave light sufficient for reading by it with great ease." The claim is hard to prove; further, Drebbel may have been inspired by the ideas of Lippershey, who lived and worked nearby.

Drebbel was, however, a good businessman, and marketed his inventions in Bohemia, France, Italy and particularly in England, where he devoted considerable effort to publicizing his telescope and camera obscura. That brought attention both as an inventor and a businessman. By Chalmers' account, Constantijn Huygens (1596–1687), the father of the physicist Christiaan Huygens (1629–1695), met and learned from Drebbel. Robert Hooke (1635–1703) also was a Drebbel family friend, and is said to have used Drebbel's instruments, or close variants, for the work published in his own *Micrographia* in 1665.

Janssen, the third of the Middelburg spectacle makers, was born in 1585, the year Antwerp fell, and his family migrated from Antwerp to Middelburg as well. While Janssen's father was supposedly a spectacle maker, Zacharias himself is mentioned in that craft by around 1616, a year after he inherited the tools of another local spectacle maker, Lowys Lowyssen. Zacharias Janssen's claim to have invented the telescope is sketchy, however, resting mainly on the testimony of his son, Johannes Sachariassen (1611–?). What is more certain is that Janssen was a coin counterfeiter; he is known to have produced a large series of fake Spanish coins on at least two occasions. Lenses or even microscopes would have greatly helped with this "hobby," and an optical workshop would have been a great cover for such activities.

The last recorded entry on Zacharias Janssen is from 1626, when he was sued for not paying his mortgage on his home in Middelburg. Notably, however, his son Johannes did provide lens-grinding lessons to the Middelburg native Isaac Beeckman (1588–1637), a Dutch Calvinist philosopher and scientist who played

A portrait of Antonie van Leeuwenhoek by the Dutch artist Jan Verkolje, c. 1680-1686.
Rijksmuseum, Netherlands

an important role in the beginning of the scientific revolution. A friend and teacher to Descartes, Beeckman was deeply involved in the advancement of lens and telescope making and is credited with some of the first photometric measurements.

Delft: Art, lenses, philosophy

Further north, outside of the great port of Rotterdam, near The Hague, lies the city of Delft. Well-known for its school of painting, Delft was home of Johannes Vermeer (1632–1675), one of many artists interested in new techniques of perspective and detail. That Dutch painters used optics in their work by the mid-1600s has become increasingly well established, and Vermeer's work in particular has been singled out for potential use of an optical system as a tool for "painting with light." (One recent suggestion argues that the system included a camera obscura fitted with a lens, along with two mirrors for projection. The system is said to allow a highly accurate rendering of details both geometrically and in terms of color saturation.)

Delft was also known for high-quality lenses, a fact correlated with the existence of local glassworks. And, characteristic of the times, there was a strong symbiosis between lens making and optics, the pursuit of scientific discovery, and the exploration of art and refinement. A little-known lens maker, Johan van Wyck (1586–1629), provided lenses to the Huygens family—a clan involved not only in science, but in the making of miniature paintings, engravings and pottery.

Another local lens maker, and a friend of Vermeer's, was the fabric merchant Antonie van Leeuwenhoek (1632–1723). Leeuwenhoek learned to grind lenses around 1688 (and, interestingly, is said to have met Cornelius Drebbel in England around the same time). He then started his own microscopic investigations using tiny glass spheres—which, through skill and persistence, allowed him to observe specimens with uniquely high magnifications for the time. (A 2-mm-diameter, 1.5 index glass sphere can provide up to 160× magnification, for example.) To enhance lighting and contrast, he used silver for the sample holder and learned to stain transparent specimens with saffron. While lacking a university education, he authored around 300 scientific letters, roughly 190 of them addressed to the Royal Society in London.

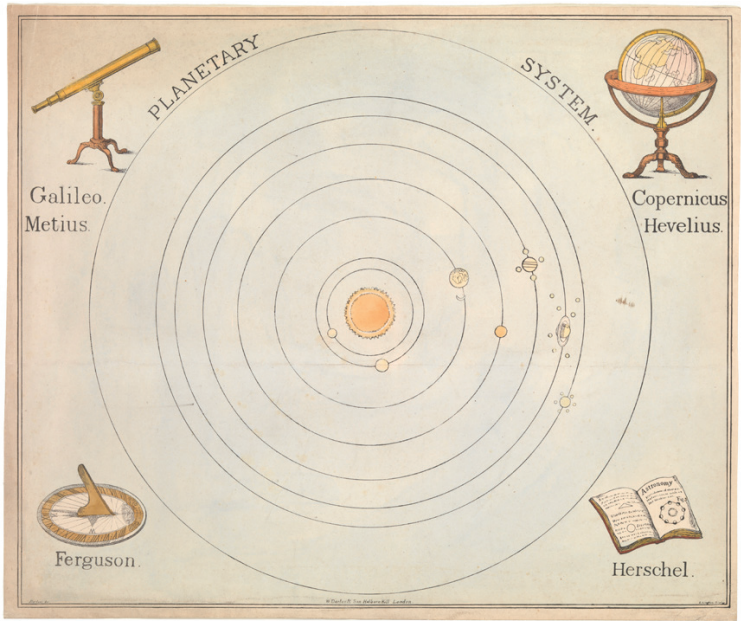
One other lens maker in the area deserves mention: the philosopher Baruch Spinoza (1632–1677), who resided not in Delft but in the nearby town of Voorburg, just outside of The Hague. Spinoza's Jewish family has fled the Portuguese Inquisition sometime around the 1530s. Beyond his known contributions to rationalism and the Enlightenment, the historical record suggests that Spinoza picked up the occupation of lens making as well, mainly to make ends meet—a consequence of his being expelled from the Jewish community for his "abominable heresies," and of his reluctance to receive pay from people he disagreed with. Lens making may even have contributed to his early death from silicosis-like symptoms.

Alkmaar: Engineering and "sea glass"

Further north still is Alkmaar, which at the beginning of the 17th century was the most important town in the Dutch province of North Holland. By the late 1500s Alkmaar had become a center of cutting-edge engineering in areas such as land reclamation, windmills, and ship and submarine building. The land reclamation led to advanced agriculture and to a profitable cheese industry. The town's knowledge of hydraulic engineering also proved essential to the defeat of the Spanish army through controlled flooding during a Spanish siege in 1573.

Today, the heritage of the early-17th-century work in optics in the Dutch Republic is mirrored and extended in the vibrant research communities of the Netherlands and Belgium.

Alkmaar—the birthplace of Middelburg's Cornelius Drebbel, and the site of his early submarine development—was also home to a remarkable pair of scientifically oriented brothers, Adriaan Metius (1571–1635) and Jacobus Metius (?–1628). Adriaan, a mathematician and astronomer (and one of the teachers of Descartes), studied under Rudolf Snellius and worked with Tycho Brahe at Tycho's lensless observatory on the island of Hven. Adriaan published the result reached by his father, Adriaan Anthonisz, that the ratio of the circle's circumference to its diameter is a constant given approximately by 355/113, known as Metius' number.



A 19th-century print of the planetary system from the publisher William Darton & Son lists Jacob Metius, who unsuccessfully applied for a telescope patent in 1608, with Galileo as one of the instrument's pioneers.

Adriaan's brother Jacobus was a more reclusive character, thought to have been touched by what now might be called autism spectrum disorder. A lens maker as well as an instrument maker, Jacobus was yet another Dutch figure to unsuccessfully apply in 1608 for a telescope patent. The Dutch authorities ultimately granted the patent rights to Lippershey but would nonetheless financially support Metius' work in building improved instruments. Drebbel's letters from England inquired about the Metius brothers' instruments, which he called "far-lookers" (*verrekijker*). Telescopes were also called "mathematical sea glass" at the time, due to their original use by the Dutch Navy. The Metius brothers themselves also reportedly made important astronomical observations in parallel with Galileo's work in Italy.

A heritage endures

This historical analysis has tried to show how a combination of geopolitics, commerce and proto-Enlightenment curiosity spurred advances in optics and science—and to cast light on some places, people and stories that, while connected with the likes of Galileo, Leeuwenhoek and Descartes, receive less attention in the history books. It is hoped that the historical annotations we've presented will spur the reader to further investigate these personalities, and other figures at the dawn of the Enlightenment.

Meanwhile, today, the heritage of the early-17th-century work in optics in the Dutch Republic is mirrored and extended in the vibrant research communities of the Netherlands and Belgium. Thriving academic research in optics, astronomy and associated fields builds on that heritage in centers like Liege, Antwerp, Delft and Eindhoven, through local universities and pan-European initiatives. World-renowned companies such as ASML, Umicore and Philips are headquartered in this small region—an area only half the size of the U.S. state of New York. OPN

References and resources can be found at www.osa-opn.org/venice-to-dutch-republic.

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