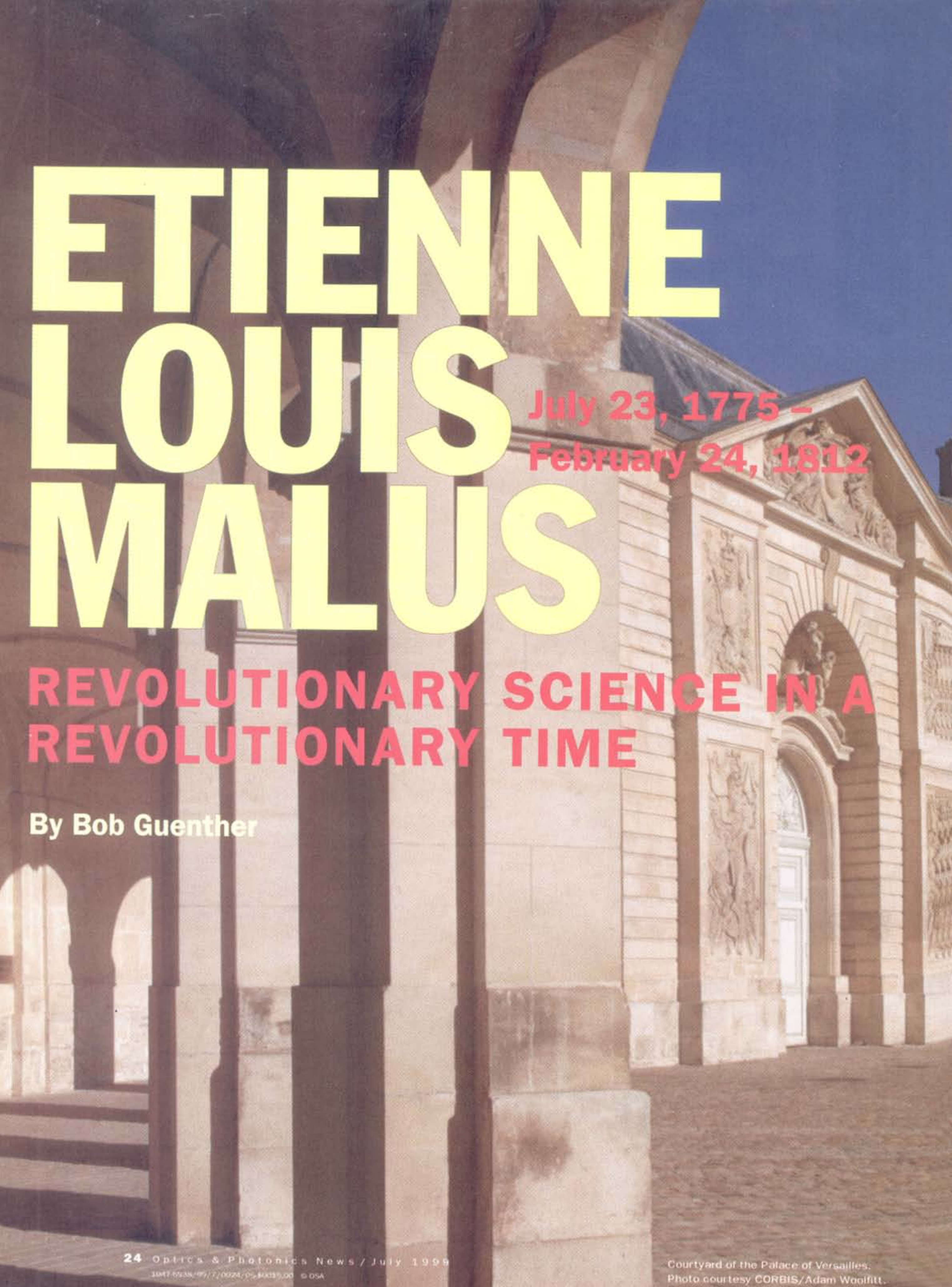

ETIENNE LOUIS MALUS

July 23, 1775 – February 24, 1812

REVOLUTIONARY SCIENCE IN A REVOLUTIONARY TIME

By Bob Guenther

Courtyard of the Palace of Versailles. Photo courtesy CORBIS/Adam Woolfitt.

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Everyone who has taken a class in physics may remember the story of the discovery of polarized reflected light by Etienne Louis Malus. While sitting in his apartment in the Rue d'Enfer, he gazed through a crystal of Iceland spar ($CaCO_3$), and noticed that the two images of the Sun in the windows of the Luxembourg Palace across the street varied in intensity as the crystal rotated.

There is a Malus Law that describes transmission through a polarizer:

$$I = I_0 \cos^2\theta$$

Throughout his life, Malus had a considerable impact on optics. Amazingly, his accomplishments were made in spite of many hardships and interruptions during his life. He overcame political intrigue, war, and the plague.

A review of his life shows that Malus was no accidental contributor to optics. He conducted experiments that verified Huygens' theory of birefringence and was able to express the theory analytically. His work at that time was so highly received that in 1811 he was awarded the Rumford medal of the Royal Society (London), established in the early 1800s by the American-born Benjamin Thompson, Count Rumford. This award was presented to Malus even though France and England were in a war that led to the involvement of the United States in 1812.

Etienne Louis Malus was born in Paris on July 23, 1775, to a well connected family. With only an informal education, he applied to and was accepted by the École Royale de Genie at Mezieres (the school attended by Charles Augustin de Coulomb), but was prevented from attending because of politics. It is important to reflect on the history that was unfolding as an 18-year-old Malus attempted to become an engineer. France had declared war on Austria on April 20, 1792, and the war was not going well. The public treasury was bankrupt, which many historians say led to the French Revolution and the execution of Louis XVI, the King of France in January 1793.

Upon the forced termination of his education, Malus joined the army. He became a manual laborer in the 15th Battalion of Paris, constructing field fortifications. M. Lepère, the chief engineer on the project, noticed that one of the crews used unique construction techniques introduced by Malus. The engineer was so impressed with Malus that he sent the young man to the newly created École Polytechnique as a pupil.

The École Polytechnique was an extraordinary university. In France during much of the time Malus was in the École, the Reign of Terror, a two-year period of military dictatorship and terrorism, was underway. One statistic in particular illustrates the magnitude of the turbulence taking place at this stage of the revolution:

Engraving of French Revolution battle. Courtesy of CORBIS/Christel Gerstenberg.

While in Syria [Malus] caught the plague. [He] wrote, "St. Simon arrived in Egypt . . . in perfect health, but two days afterwards he was dead . . . I was now alone, without strength, without help, without friends . . . ."

during one 47-day period, 1376 people were guillotined. The famous French social theorist, Charles Fourier, was arrested in 1794 and 1795, and may have escaped the guillotine only by the fact that the execution of Francois Marie de Isidore Robespierre, who was the dominant figure during the Reign of Terror, resulted in a change in the political climate. Even during this turbulence, the École was producing scientists who would bring optics into the modern era.

The École Polytechnique was founded in 1794 at the site of the former École Centrale des Travaux Publiques. It is the most renowned of les Grandes Écoles of France and many great names of optics were students or professors there. Malus studied under Fourier and attended classes with Jean-Baptiste Biot, who was renowned for his work in applied mathematics in numerous fields, including optics. Biot later helped formulate the Biot-Savart law for magnetic fields, and Dominique Francois Jean Arago, who, along with Augustin Jean Fresnel, a physicist who specialized in the study of light, developed the laws of interference of polarized light. Other graduates at that time were Denis Poisson, whose most important work included research and advances in Fourier series, and Fresnel. The two-year program at the École covered math, chemistry, and physics, and prepared Malus for work as a civil engineer in the military.

During this time, the French army, led by one of history's greatest military geniuses, Napoleon Bonaparte, was fighting the combined armies of several European countries. Upon graduation from the École Polytechnique, Malus joined the French army for battles on the Rhine and, in 1798, participated in Napoleon's invasion of Egypt during which Malus rose to the rank of Colonel. After the invasion, Napoleon had the Cairo Institute created with Malus as one of the 12 mathematical members, along with Gaspard Monge, one of the preeminent mathematicians of the day, Fourier, and Napoleon. However, it remained a time of war and suffering, rather than a time of scientific studies.

Napoleon Bonaparte was the greatest military genius of the 19th century. He conquered most of Western Europe and Egypt for France, while instituting reforms in these new territories aimed at guaranteeing civil liberties and improving the quality of life. He crowned himself emperor of France in 1804 and introduced reforms intended to unify the revolution-fractured nation. Engraving of Napoleon Bonaparte courtesy of CORBIS/Bettman.

In August of 1798, British Admiral Horatio Nelson led a squadron of ships to surround the French fleet anchored in Aboukir Bay. Of the 17 French ships, only four escaped. Malus wrote, "We began to lose hope of ever seeing our native land again." Napoleon abandoned the army in Egypt in 1799, but the war continued. Malus participated in the campaign in Palestine, where he witnessed the pillage of Jaffa by French troops. While in Syria he caught the plague. Malus wrote, "St. Simon arrived in Egypt and came to see me; he was then in perfect health, but two days afterwards he was dead . . . I was now alone, without strength, without help, without friends . . . two men of the corps of sappers undertook the care of me, and they perished one after the other."

Malus did recover and was assigned to an encampment, where he escaped the horrors of sickness and warfare. During this time, he turned to optics and composed his first paper. It was not published and has little importance to us now, but his objective was to prove that light was a compound of caloric and oxygen. The interest in combining optics and chemistry was evidently a result of his studies at the École. A similar interest in chemistry, rather than optics, was exhibited by Fresnel after he left the École.

Malus returned from Egypt in 1801, after France had signed peace treaties with Austria and the Papacy. He served in official posts at Antwerp and Strasbourg, but did not have any contact with Paris and mainstream science until 1809.

This isolation may have been the cause of his departure from traditional scientific investigation. While Biot and Arago had made accurate measurements of an arc length on the Earth to establish the meter, Malus pushed their technique beyond that concept by concentrating on error estimation and extensive testing of analytic formulation of theories using tables of data. In 1807, Malus won a prize for confirming Christiaan Huygens' construction for double refraction. He did so by first translating Huygens' construction in algebra, and then checking the analytic formulation by making a number of measurements at a variety of angles and averaging the repeated observations. To us this seems quite ordinary but, at the time, Malus was creating the foundations of experimental optics. No one had conducted an experiment with such precision before.

Detail showing Napoleon and victims from Napoleon visiting the plague-stricken at Jaffa by Antoine Jean Gros. Courtesy of CORBIS/Burstein Collection.

The times were not quiet, and once again, war broke out. England was at war with France, Napoleon had crowned himself Emperor, and the future of the empire appeared to be promising, although Admiral Nelson had again defeated the French navy.

In these turbulent times, Malus continued to contribute to the understanding of optics by placing the theory of polarization on a quantitative footing. This theory was an outgrowth of the famous observation made in the Rue d'Enfer residence in 1808. He presented his theory of polarization in 1810, and introduced the word "polarization" the following year.

Malus' accomplishments, in spite of the turbulence around him, are a tribute to his capabilities. After learning about his life, one might ask why we pay so little attention to him. The answer is that Malus was a firm believer in the emission theory first introduced by Newton and held by all but a few scientists throughout the 18th century. He shared his belief with Biot, Poisson, and Pierre Simon de Laplace, who was noted for his research on gravity. Observations by Arago, William Henry Young, whose approach to the functions of complex variables are used today in most advanced books on calculus, and Pierre de Fermat, another distinguished mathematician of the time, were just being announced. Also, the wave theory was not developed until after 1815, and the critical velocity of light measurements were not made until 1849 by Armand-Hippolyte-Louis Fizeau. The toll on Malus' health from the plague ended his life at the age of 37, before he was aware of the need to reject the emission theory and replace it with the wave theory.

Reference

1. J.Z. Buchwald, *The Rise of the Wave Theory of Light* (The University of Chicago Press, Chicago, IL, 1989).

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