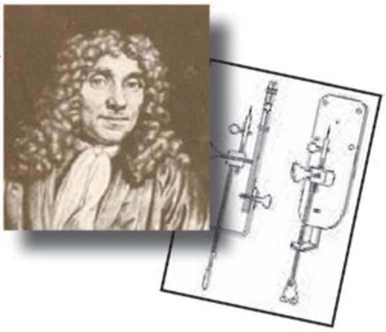
# Pioneers in Optics: James Bradley and August Köhler



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## James Bradley
### (1693–1762)

James Bradley was an English astronomer most famous for his discovery of the aberration of starlight. The finding was an important piece of evidence supporting Copernicus's theory that the Earth moved around the sun and also provided an alternative way to estimate the velocity of light.

Born in Sherborne, England, Bradley was the nephew of clergyman and amateur astronomer James Pound. His uncle trained him in astronomy from an early age, and Bradley formally studied at Oxford University, where he received a bachelor's degree in 1714 and a master's degree in 1717. Fearing an inability to support himself financially as an astronomer, Bradley became a member of the clergy and earned a living at Bridstow. However, due to his scientific efforts and friendship with Edmund Halley, Bradley was elected a fellow of the Royal Society in 1718. An offer of professorship at Oxford followed in 1721, and twenty-eight-year-old Bradley quickly gave up his living at Bridstow to teach astronomy at the prestigious school.

A driving force in Bradley's career was his desire to measure the parallax of the stars, an apparent change in their positions that mirrored the change in the Earth's position in its orbit around the sun. Using the observatory of his friend Samuel Molyneux, Bradley systematically studied the star Gamma Draconis and, though he did not successfully observe parallax, he made an important discovery while attempting to do so. Bradley found that Gamma Draconis did indeed shift in its location, but in the opposite direction from what was expected. He then deduced that the observed stellar variation in position was brought about by the aberration of light, a result of the finite speed of light and the forward movement of the Earth in its orbit.

Bradley announced his discovery to the Royal Society in 1728. The aberration of stellar light was of particular interest to the organization's members because it provided some proof for the extremely controversial heliocentric theory. The findings were also significant because they provided another technique for calculating the speed of light. By analyzing measurements of stellar aberration angle and applying those data to the orbital speed of the Earth, Bradley was able to arrive at the remarkably accurate estimate of 183,000 miles (295,000 kilometers) per second.

Another important scientific contribution made by Bradley was the discovery of the nutation, or oscillation, of the Earth's axis. Bradley first noticed the fluctuation when he was carrying out his studies on parallax at Molyneux's observatory. However, because he believed that nutation was caused by the moon's gravitational pull, he decided to observe a full cycle of the motion of the moon's nodes, approximately 18.6 years, before announcing any findings. Completing his research in 1747, Bradley's discovery was finally made public in 1748 and was honored with the Copley Medal of the Royal Society that same year.

When Edmund Halley died in 1742, Bradley was named his successor as Astronomer Royal at Greenwich Observatory. He held the influential position for the rest of his life, greatly improving upon the condition of the observatory and the instruments it contained. Bradley also continued to study the stars and composed extremely accurate star charts, though the bulk of his observations would be published posthumously. He died on July 13, 1762, never realizing his hope of detecting the parallactic motion of the stars, but profoundly affecting the field of astronomy in his attempts to observe the elusive phenomenon.

## August Köhler
### (1866–1948)

August Köhler, a German scientist and expert microscopist born in 1866, is best known for his development of the superior microscope illumination technique bearing his name (Köhler illumination), which is still in general use today. In 1893, when he developed the technique, Köhler was working as an assistant to Professor J. W. Spengel at the Institute of Zoology at the University of Geissen, where he was also pursuing advanced studies. The success of Köhler's academic and occupational pursuits was heavily dependent on his ability to produce high-quality photographs in the microscope. The task, however, was not easy due to the relatively primitive methods of illumination and limited light response

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of photographic emulsions available at the time. A high degree of evenly distributed brightness is necessary to produce good photomicrographs, but the non-uniform illumination field exhibited by gas lamps and other primitive light sources of the period tended to induce flaws and uneven backgrounds in photomicrographs.

In order to overcome the problems he was experiencing with photomicrography, Köhler developed a unique microscope configuration that employs both a field and an aperture iris diaphragm (also known as double diaphragm illumination) to produce an evenly illuminated field of view and a brighter image without obscuring glare. In the Köhler illumination technique, a collector lens focuses an image of the lamp filament in the condenser aperture (front focal plane), which in turn projects an image of the field diaphragm into the specimen plane. The scheme relies on two independent sets of conjugate planes, one for the apertures and another for the images, which traverse the microscope optical train from the light source to the observer.

Köhler published his work in a German microscopical journal at the end of 1893, and a short English summary of his work appeared in the *Journal of the Royal Microscopical Society* the following year. However, other researchers in the field did not immediately realize the significance and importance of the Köhler's illumination methodology. In fact, after receiving his doctorate, Köhler's name seemed as if it might vanish into obscurity as he left the University of Geissen to work as a grammar school teacher in Bingen, Germany.

Several years later, however, Köhler came to the attention of Zeiss Optical Works and his life soon changed. The company, through the combined efforts of its co-founder, Ernst Abbe, and glass-specialist Otto Schott, had already vastly improved microscopes of the period through a solid foundation built on precise optical theory and the utilization of appropriate glass formulations. Nevertheless, the company needed to improve illumination techniques before optimum resolution at high magnifications could be realized. Thus, Köhler was invited to join Zeiss, where he began working in 1900. He initially contributed his illumination technique but later led the company's efforts in other areas of microscope development. Köhler remained with Zeiss for the next 45 years producing several additional innovations during his career.

Although Köhler is most famous for his illumination method, he made several other significant contributions to the world of science. In 1904, Köhler and a Zeiss colleague, Moritz von Rohr, worked together to design a microscope that operated in the ultraviolet region of the electromagnetic spectrum. The microscope was illuminated by ultraviolet radiation generated through a cadmium arc and lenses fabricated with fused quartz. Although this first ultraviolet microscope had significant limitations, it opened up an entire new realm of possibilities for ultraviolet and fluorescence microscopy. Five years later, Köhler was the first to discover grid radiation, which has proved extremely valuable in the medical field, especially in the treatment of tumors. Then, in 1911, Köhler suggested that Zeiss should make all of the matched objectives on a microscope nosepiece parfocal (with matching focal planes), enabling an image to remain in focus when an observer changed magnification. Zeiss trusted the opinion of their microscopy leader and soon implemented the idea with great success.

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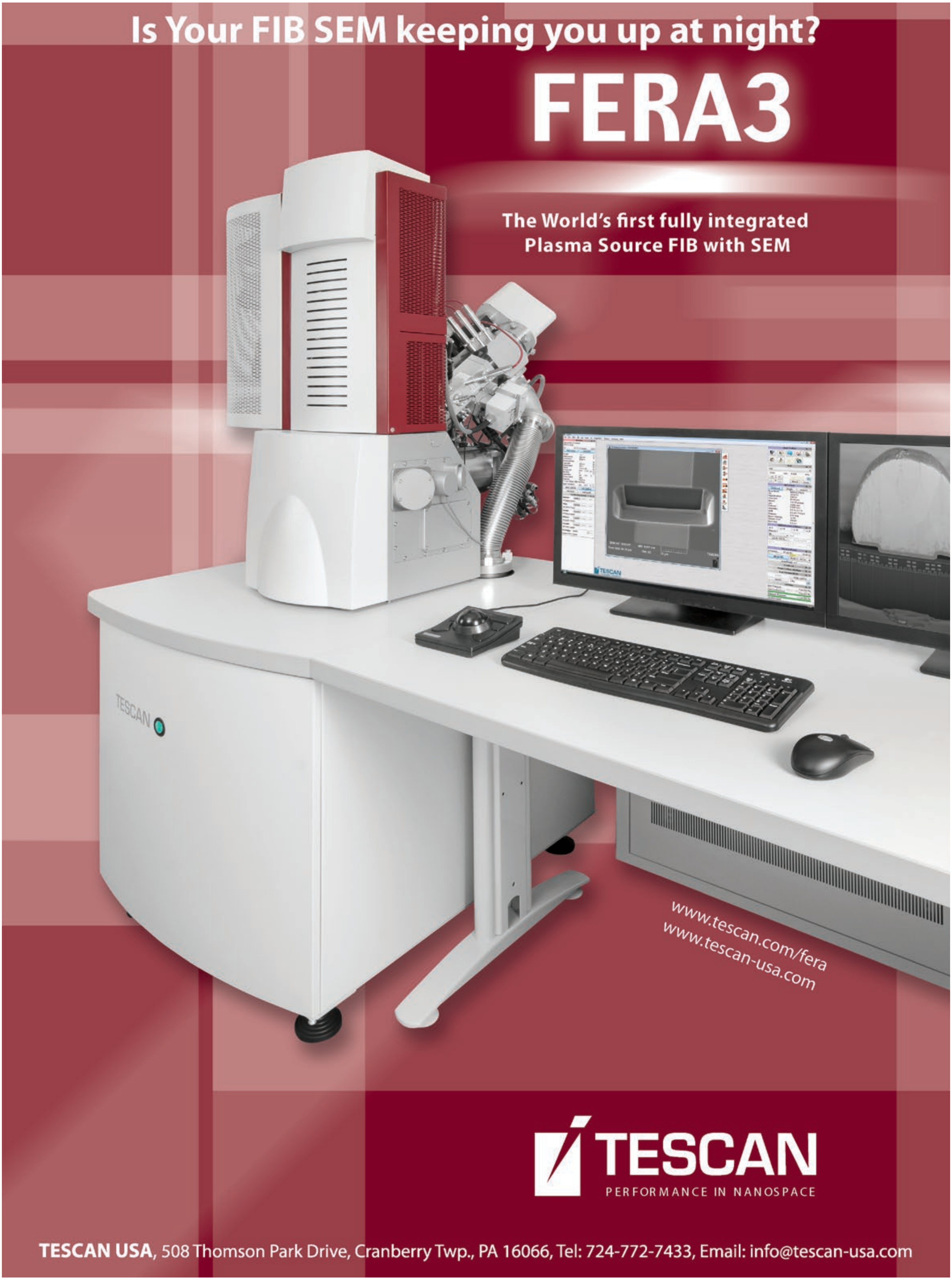


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