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From Galileo to Abbe: the Contribution of Lenses to the Foundation of Modern Sciences. What is the Role of Lens in the Coming Quantum Era?

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The invention of the compound microscope dates back to 1590 and, while visiting Venice in 1609, Galileo first heard of the spyglass invented by Dutch. He realized that a device based on lenses could be modified to made distant objects appearing closer with obvious military and potential financial value. By combining concave and convex lenses he was able to improve the original design by increasing the magnification. Galileo presented his improved telescope to the senate of Venice and demonstrated how ships at sea could be identified as friend or foe many hours. Actually, improving his telescope with higher magnifying power, improved lens shaping and polishing techniques, he started the observations of the heavens making incredible discoveries on the moon, Jupiter and many other stellar objects. He is certainly the father of the observational astronomy and Stephen Hawking, described him as the single individual most responsible for the birth of modern science.The lens-based microscope became increasingly popular in the mid-17th century giving rise also to the modern biology. It was used by Hooke that in the Micrographia volume, showed a wide range of microscopic views of organic systems. In this book appeared for the first time the term cell.

The physics of lens construction was studied by the physicist Ernst Abbe. In 1868 he invented an apochromatic system of lenses, and in 1873 he published a comprehensive analysis of lens theory. The magnifying power of lens-based instruments always fascinated men and women, but the users of optical microscopes know that the lens power is limited by diffraction. As explained by Abbe: any object, no matter how small, will be imaged by a conventional optical system as a finite-sized spot, with a minimum dimension obtained for point-like objects approximately equal to the wavelength of light multiplied by the optical magnification and divided by the numerical aperture. Light microscopes produced in the closing quarter of the 19th century reached the effective limits of optical microscopy. Subsequent instruments such as phase-contrast microscopes, interference microscopes, and confocal microscopes solved specific problems allowing the study of important objects such as living cells.

The 19th century is certainly the age of microscopy. In 1903 Richard Zsigmondy develops the ultramicroscope showing objects with size below the wavelength of light (Nobel Prize in Chemistry in 1925). In 1932 Frits Zernike invents the phase-contrast microscope that allows the study of colorless and transparent biological materials (Nobel Prize in Physics in 1953). Later in 1938 Ernst Ruska develops the electron microscope greatly improving the resolution and expanding the use of this instrument. Gerd Binnig and Heinrich Rohrer introduced in 1981 the scanning tunneling microscope that gives three-dimensional images of objects down to the atomic level. They won the Nobel Prize in Physics in 1986 together with Ruska. But the story is not ended with the century and Eric Betzig, Stefan W. Hell and William E. Moerner were awarded with the Nobel Prize in Chemistry in 2014 for having taken optical microscopy into a new dimension using fluorescent molecules, bringing microscopy to nanoscopy. Finally in 2017, the Nobel chemistry prize has been awarded for a revolution in biochemistry. Jacques Dubochet, Joachim Frank, and Richard Henderson were recognized for their work that led to the "cryo-electron microscopy". This technique allows to see individual atoms within biological molecules and can be used to generate 3D images of extremely small objects such as the Zika virus.

All these advancements in science are due to the technology and to the production of better and better lenses thanks to new ideas and technologies, but also, in particular in the last decades, to the advent of synchrotron sources, powerful and brilliant sources of radiation from THz to hard x-rays. The size of the SR community, and the potential applications experienced an exponential growth continuously triggering the design, manufacture and test of new optical systems at all wavelengths. The SR sources with lower emittance and higher coherence now appearing and also the continuous developments of conventional sources such as lasers, QCL, Continuum, etc. represent the real engine for the next generation of optics.

Summary

Photonics is the science and technology that allow us to generate, control, and detect photons. Photonics underpins our daily life from smartphones to computer, to Internet to medical instruments to lighting technology. Indeed, science and technology address societal needs such as energy, health and lifestyle, and without doubt, the increase of fundamental knowledge. The 21st century with the advent of nanoscience greatly depends on radiation and the availability of new lenses. The novel multidisciplinary approach, involving always more and more frequently separated disciplines, represents a scenario similar to the early age of microscopy. Photonics and the "control"of radiation may really represent the "link"among disparate scientific disciplines of our world and the way to find solutions to the many demands of our society.

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