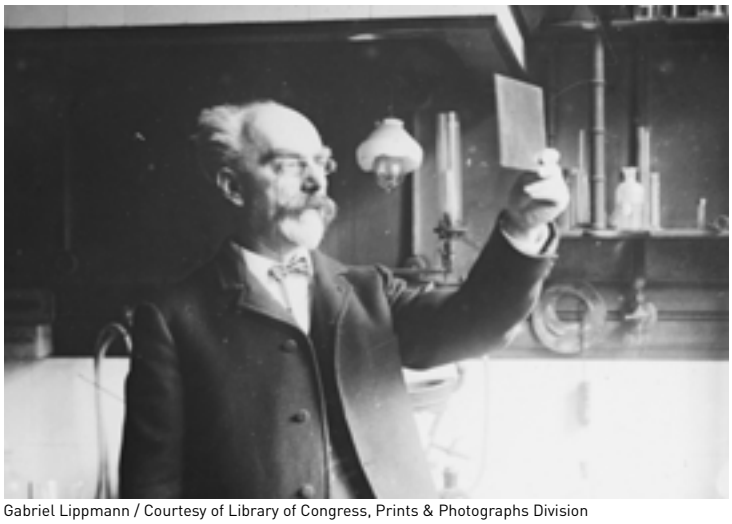
then

Lenses Go Liquid

The discovery of electrowetting nearly 150 years ago set the stage for manipulating liquid to act as a tunable lens, mimicking the crystalline lenses of human eyes.



Gabriel Lippmann / Courtesy of Library of Congress, Prints & Photographs Division

1875: Introducing electrocapillarity

Although people had been peering through water to magnify objects since ancient times, it wasn't until 1875 that Nobel-prize-winning French physicist Gabriel Lippmann described the basis for modern liquid-lens technology in his famous paper on electrocapillarity. Lippman demonstrated the phenomenon, a precursor to electrowetting, by applying voltage to liquid on a conducting surface (in this case, mercury and electrolyte), showing how the electric charge manipulated the liquid and flattened the droplet's shape.

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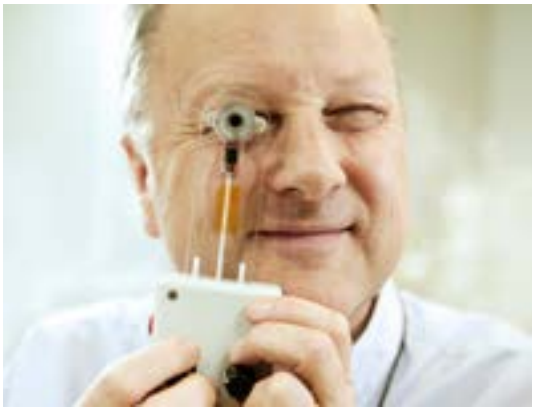
20th century: A wealth of research

Throughout the 20th century, many lenses were designed to include liquid components. Researchers experimented with variable-focal-length lenses, in which flexible membranes enclosed a liquid, the curvature and the focus of which could be changed by applying pressure. Electrically controlled devices using two different immiscible liquids and based on the electrocapillarity effect were another research route. Yet each device faced issues, such as leakage, the amount of voltage needed or mixing of the two immiscible liquids.



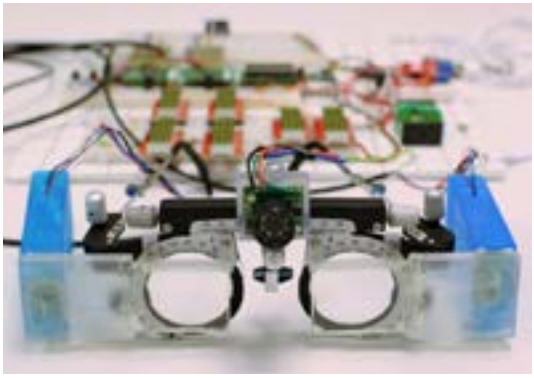
Bruno Berge / Courtesy of European Patent Office

2002: Marketing liquid lenses

In the 1990s, French physicist and entrepreneur Bruno Berge succeeded in deploying electrowetting technology in a lens, patenting his liquid lens after a decade of research and launching a startup, Varioptic, to commercialize the devices in 2002. Berge added an insulating layer of hydrophobic material between the conductive metal and the liquid, eliminating the problem of electrolysis, and then applied voltage to control the shape of the droplet. Varying the voltage allowed for tunable focal lengths.

The Fast-Focus Advantage

Today, the autofocus capability of liquid lenses has extended the technology's utility across machine vision, microscopy, compact camera modules and more.



J. Jarosz et al. Opt. Express **27**, 10533 (2019)

2019: Seeing clearly

One application area for liquid lenses is ophthalmology. In 2019, Berge co-authored a paper that presented adaptive eyeglasses for correction of presbyopia, or farsightedness. The fluid-filled variable-focus lenses are combined with a microfluidic actuator and a distance-sensing system to provide automatic focusing. The idea is to customizably correct for presbyopia as it worsens with age.

Optotune electrically focus-tunable lens / Courtesy of Optotune

2020: In the lab

Tunable-focus lenses based on liquid-lens tech are also in high demand for microscopy. Companies like Optotune in Switzerland sell lenses that are meant to mimic the eye and are based on a combination of optical fluids and a polymer membrane, varying the radius to tune the lens. Last year, an Optotune lens was used to establish a 4D microscopy method to visualize the zebrafish cardiovascular system.

Getty Images

2020: Identity verified

Biometric systems are another industrial sector where liquid lenses are making waves. Just last year, Corning, which bought Varioptic in 2017, published a white paper detailing how liquid-lens-based autofocus technology can be integrated into optical systems to maximize image sharpness. The liquid-lens upgrade could extend the iris-recognition distance of biometric systems from a few millimeters to several meters, thanks to the fast-focus technology with no moving parts.

Focusing on the future

Liquid lenses represent a growing industrial sector with ever-expanding applications. One advance that the market is eagerly awaiting, however, is the integration of the technology into smartphones—and the wait may be nearly over. Chinese tech giant Huawei is reportedly in the final stages of testing a liquid-lens smartphone camera, having patented the technology design in April 2020. The innovation could potentially replace the telephoto lens, reducing focus and image stabilization time to a just few milliseconds.

For a list of references and further resources on liquid lenses, go online: **www.osa-opn.org/then-now/liquid-lenses**.