Allied Vision

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Liquid Lens Technology for Pharmaceutical Inspection

How to achieve sharp images and reliable analysis at varying distances

In the realm of vision applications for pharmaceutical inspection, a significant challenge arises when products such as ampoules, cartridges, syringes, vials or pharmaceutical boxes are positioned at slightly different distances from the camera – for example in rotary inspection machines, filling lines, or packaging conveyors. This variability complicates the ability to capture sharp images essential for reliable particle detection in liquid products, fill-and-finish verification, and code readability. Traditional lenses with fixed optics often fall short in such scenarios, struggling to maintain focus when product height or position change. Motorized lenses are also frequently ruled out as a solution due to their relatively slow adjustment speeds and mechanical wear.

Liquid lenses emerge as an innovative solution to these challenges. Their ability to dynamically adjust focus allows for rapid and precise imaging, crucial for tasks such as inspecting the sealing surface of bottles or vials for leaks or defects, verifying the fill level in vials, or ensuring readability and authenticity of codes and labels on packaging surfaces fighting against counterfeiting. This technology is particularly advantageous in high-speed production lines where maintaining high resolution and low latency is paramount for efficient and compliant operations.

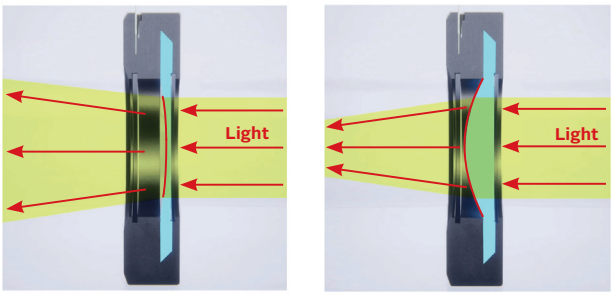
But how can an application take full advantage of the benefits of a liquid lens? How can a single camera focus on objects at varying distances?

Focusing like a human eye

Since the first photo was taken about 200 years ago, lenses have been an integral part of a camera. Since then, the camera technology has continued to evolve. The working principle of traditional camera lenses is based on optical refraction and focusing. The light reflects off the subject and enters the lens, where it is refracted and focused by multiple lenses to form a clear inverted image on the camera sensor or negative. The aperture in the lens controls the amount of light that enters, which affects exposure and depth of field. By adjusting the position of the lenses, the focal length can be changed to achieve focus.

Unlike traditional, motorized lenses with fixed focus, the eye can dynamically adjust the focal length, aperture, and sensitivity to quickly adapt to different environments and needs. The lens focuses the light entering through the pupil and thus ensures a sharp image on the retina. It is elastic and can adjust its shape with the help of the so-called ciliary muscle to focus on both distant and close objects. By mimicking the imaging principles of the human eye lens, a new type of lens was born: the liquid lens.

A liquid lens module typically consists of a chamber containing a conductive liquid, often paired with an immiscible liquid (like oil) to prevent mixing. There are different ways to change the focus dynamically.



The lenses exploit the electrowetting effect, where the surface tension of a conducting liquid changes in response to an applied electric charge. Electrodes apply the necessary voltage to change the liquid's shape, while a membrane or other containment system holds the liquid in place. This allows the liquid's shape to be dynamically adjusted, altering the curvature of the lens surface and thus the focal length. This method is used, for example, by Corning's Liquid Lenses.

Optotune's focus tunable lenses are shape-changing lenses based on a combination of optical fluids and a polymer membrane. The core element consists of a container, which is filled with an optical liquid and sealed off with a thin, elastic polymer membrane. A circular ring that pushes onto the center of the membrane shapes the tunable lens The deflection of the membrane, and consequently the radius of the lens, can be changed by pushing the ring towards the membrane. This can be achieved by exerting pressure on the outer part of the membrane or by pumping liquid into or out of the container.

Advantages of liquid lenses for pharmaceutical inspection

Improved Focus and Reliability

Liquid lenses enable automatic adjustment of focus, ensuring that bottles, vials, or codes are captured sharply regardless of minor variations in distance. This significantly reduces the likelihood of blurry or unreliable inspection results on moving products.

Adaptability to Variable Surfaces

Whether checking the reflective surface of a crimp cap, the curvature of a syringe barrel, or printed text on a carton, liquid lenses maintain consistent focus for reliable defect detection.

Versatility Across Product Variants

Switching between multiple vial formats or syringe types often requires mechanical re-adjustment with traditional optics. With liquid lenses, focus profiles can be changed electronically, enabling seamless format changes without downtime.

Faster and More Accurate Processing

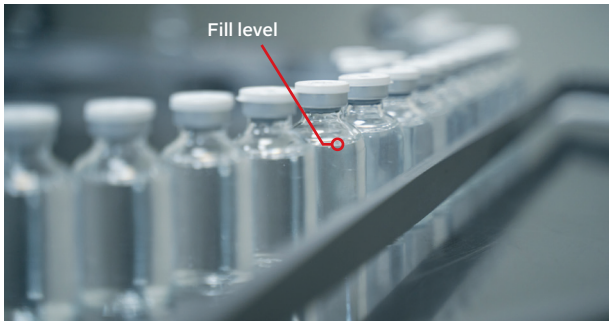
Enables real-time quality control in fill-and-finish lines or label verification stations where every millisecond counts.

Durability and Reduced Maintenance

As focus adjustment is electronic and not mechanical, liquid lenses reduce wear and tear, leading to higher reliability and lower maintenance costs in 24/7 production environments.

Compliance & Quality Assurance

While initially more expensive, liquid lenses can reduce the need for multiple camera setups or complex focusing mechanisms. More importantly, they help minimize false rejects and inspection errors – a critical factor for ensuring compliance, avoiding recalls, and maintaining consistent product quality.



The advantages of liquid lenses can only be achieved when paired with a camera and lens configuration that supports their functionality. A well-designed hardware setup is essential for seamless integration, efficient control, and reliable operation of the liquid lens.

Hardware set-up: The perfect teamwork of camera and liquid lens

To take advantage of liquid lens functionality, a camera that is already equipped with a liquid lens module is required – or a liquid lens can be integrated into a lens used in combination with a high-performance camera supporting the lens functions.

For the second approach, Allied Vision's compact and flexible Alvium cameras and liquid lenses from Optotune are an ideal team. The GigE Vision Alvium G1 cameras and the Alvium G5 cameras with 5GigE Vision interface not only support liquid lens functionality but also simplify integration with a dedicated Y-cable connecting the I/O port of the camera to the lens. The lens is powered via the camera and controlled directly via Allied Vision's Software Development Kit (Vimba). No external autofocus algorithm or additional drivers are required.

The Alvium G1 combines the advantages of the established GigE Vision standard with the flexibility of the Alvium platform. In addition to a comprehensive feature set and a broad sensor selection, it offers great versatility. With its extraordinarily small size (41 mm × 29 mm × 29 mm (Closed Housing)), it can easily be integrated into any vision system for pharmaceutical inspection while ensuring long-term availability and reliability. If the application requires a performance boost, it can easily be upgraded with an Alvium G5 camera with a 5GigE interface for more bandwidth. A robust thermal design ensures reliable camera operation even in demanding production environments (operating temperatures of -20°C to 65°C).

Alvium G1 with Liquid Lens

5GigE interface

Alvium G5

Alvium G1

Enhancing Precision in Quality Control

The compact and adaptable design of liquid lenses makes them ideal for pharmaceutical inspection systems where high flexibility, precision, and reliability are essential. They seamlessly integrate into existing systems, whether for inspecting fill levels in vials, detecting particles in ampoules, verifying stopper positions in cartridges, or checking labels on folding boxes. Manufacturers can thus maintain consistent focus and image quality across a wide range of pharmaceutical packaging and container types.

By integrating liquid lenses with Allied Vision's powerful Alvium cameras, manufacturers can significantly improve their pharmaceutical quality control processes.

This combination enables dynamic focus adjustment, adaptability to varying product geometries and surfaces, and efficient integration, ultimately leading to enhanced compliance, reduced costs, and increased throughput. With this robust solution, pharmaceutical producers can overcome common inspection challenges, streamline their quality control workflows, and gain a competitive advantage in the market.

About Optotune AG

Optotune AG is a Swiss company that specializes in the production of optical components with adjustable focal lengths. Founded in 2008, the company features liquid lens technology, which adjusts the focal length in milliseconds by changing the lens shape. It is widely used in medical imaging, industrial automation, machine vision, laser applications, and other fields. Optotune's liquid lenses are faster, more flexible, and more durable than traditional focusing methods. The company also offers optical custom solutions to meet the specific needs of different customers. Optotune AG is a company leading the field of tunable focal length optics. Based on its innovative liquid lens technology, it is committed to providing flexible and efficient optical solutions for a variety of industries.

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