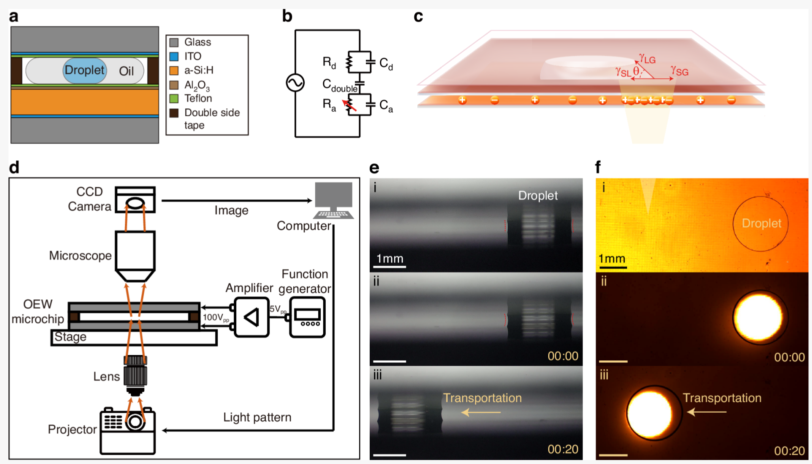
Projecting light to dispense liquids: A new route to ultra-precise microdroplets

GA, UNITED STATES, February 4, 2026 /EINPresswire.com/ -- Precise control of tiny liquid volumes is essential for modern biochemical analysis, yet reliably dispensing nanoliter-scale droplets remains technically challenging. This study presents a light-controlled droplet dispensing strategy that enables highly accurate generation of tunable nanoliter droplets on a microfluidic chip. By combining optoelectrowetting with dynamically designed light patterns, the system guides droplets to deform, shrink, and detach in a controlled manner. The approach achieves exceptional volume consistency across a wide range of droplet sizes and supports stable formation of uniform droplet arrays. Beyond technical precision, the work demonstrates that light-driven droplet control can reliably support small-scale biochemical reactions, offering a powerful alternative to conventional liquid-handling methods.



Overview of the OEW-based droplet dispensing system.

[Droplet-based microfluidic systems](#) are widely used for biochemical assays, diagnostics, and drug discovery because they reduce reagent consumption and improve reaction control. However, dispensing individual droplets with high accuracy is difficult, especially at volumes below hundreds of nanoliters. Traditional electrowetting systems rely on fixed electrodes, which limit flexibility and require complex fabrication. Optical control methods offer greater freedom but often suffer from inconsistent droplet size and poor reproducibility. In particular, uncontrolled droplet necking and random pinch-off during dispensing lead to large volume errors. Based on these challenges, there is a strong need to develop a controllable, high-precision droplet dispensing strategy capable of stable nanoliter-scale operation.

Researchers from the Southern University of Science and Technology, reporting on November 28, 2025, in Microsystems & Nanoengineering, describe a new optoelectrowetting-based droplet dispensing system that uses programmable light patterns to precisely control droplet formation. The study introduces a dynamic light-guided strategy that enables reliable dispensing of nanoliter droplets with tunable volumes. By projecting tailored optical patterns onto a microfluidic chip, the system achieves accurate droplet shaping, separation, and transport, demonstrating both high precision and strong reproducibility in small-volume liquid handling.

The core innovation of the study lies in a dynamic light-pattern design that actively controls droplet deformation and pinch-off during dispensing. Instead of relying on fixed electrodes, the system creates "virtual electrodes" through localized illumination, allowing droplets to be guided solely by projected light. A specially designed necking light pattern plays a critical role by stabilizing the liquid bridge that forms between the parent droplet and the emerging daughter droplet.

During dispensing, the droplet first extends under illumination, then undergoes a controlled back-pumping step that reshapes the liquid to match the light pattern. This process slows down the pinch-off event, eliminating random splitting and significantly improving volume accuracy. Through systematic optimization of light pattern geometry, voltage, and necking position, the researchers achieved a minimum relative error of 0.45% and a coefficient of variation of 2.49% for droplets around 36 nanoliters.

The system also demonstrated strong flexibility, accurately dispensing droplets across a broad size range while maintaining precision below commonly accepted error thresholds. Importantly, the researchers validated the platform using polymerase chain reaction (PCR) amplification, showing that on-chip droplets performed comparably to manually pipetted samples, even at volumes below 200 nanoliters.

"This work shows that light can be used not just to move droplets, but to precisely define their final volume," said the study's corresponding author. “By controlling the entire dispensing process with programmable optical patterns, we eliminate many sources of randomness that limit conventional microfluidic systems. The ability to generate uniform nanoliter droplets with such low error opens new possibilities for automated biochemical workflows, especially where consistency and miniaturization are critical."

The light-guided droplet dispensing strategy offers a versatile solution for lab-on-a-chip platforms used in molecular diagnostics, drug screening, and organ-on-chip research. Its ability to reliably handle sub-200-nanoliter volumes addresses a long-standing gap between conventional pipetting and microfluidic automation. Because the system avoids complex electrode fabrication, it also simplifies device design and improves scalability. More broadly, the work highlights how optical control can transform digital microfluidics into a flexible, reconfigurable tool for precision chemistry and biology, with potential impact across clinical testing, pharmaceutical development, and high-throughput biochemical analysis.

References

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