PRIZE ESSAY

FINALIST

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Luke Cox received his undergraduate degree and PhD from the University of Bristol. After completing postdoctoral work at the University of Bristol and working as a research engineer for start-up Ultraleap, Luke started his company, Impulsonics, in 2023. His research focuses on moving cells using acoustic waves for biotechnology automation.**www.science.org/doi/10.1126/science.adw0393**

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BIOINNOVATION

Dancing with the cells

How acoustically levitating a diamond enabled a redesign of biotech automation

By **Luke Cox**

At the start of my PhD, I was asked if I wanted to try and levitate a diamond using acoustic waves. I said yes, but at the time I did not realize this challenge was my first puzzle piece in a technology that would eventually enable us to redesign biotechnology automation from the ground up.

Behind every pharmaceutical development lies hundreds of thousands of thankless hours spent by scientists hunched over a laboratory bench, growing and maintaining cells in culture. Even in 2025, most labs still perform their cell culture by hand. The demand for this is only set to grow with over 1000 cell and gene therapies in clinical development in the USA that require cell culture at the point of care (*1*). Manual processes are expensive, lead to unreliable results, and are prone to contamination. Why, then, is this critical process still overwhelmingly manual?

The answer lies in the complexity of the physical process. Some simple tasks such as pipetting have been successfully automated; liquid-handling robots are now available for under $20,000 (*2*). However, automating the growth of cells requires that many different devices be reliably integrated, from centrifuges to incubators. From an engineering perspective, every new component added to the system increases complexity, which raises costs and reduces reliability. In many laboratories, the cost of this equipment can mean that payback times frequently exceed the devices' life span, with many systems costing in excess of $1 million.

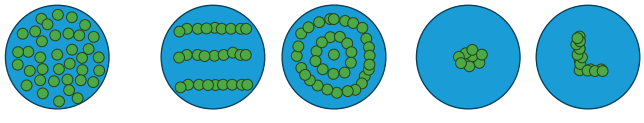
This is where our acoustic wave technology comes in. If we move cells around inside their existing sterile containers, rather than requiring them to be moved multiple times into different devices, workflows can be massively simplified. This process makes automation compact, accessible, and affordable. A process that once required a machine the size of a campervan to be automated can now be performed on a benchtop.

Most people do not think of sound as a force, but we can hear acoustic waves because they exert one. When you speak, you produce tiny vibrations that move through the air. These vibrations shake the membrane inside your ear and allow you to hear. Acoustic forces have been used safely on cells for decades (*3*), developing the capabilities to make acoustic forces compatible with existing workflows has required ingenuity, which is where my research at the University of Bristol came in.

A plethora of acoustic devices have been created that manipulate cells in academic research; however, few have found commercial traction. This failure has been due to their incompatibility with how laboratory scientists work—in petri dishes, well plates, and flasks. Most acoustic systems are

Acoustic impulse control enables new capabilities across fields

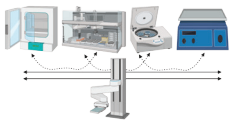
Combining different acoustic fields in sequence with specific impulse control allowed the levitation of dense, nonspherical objects such as this impure diamond. It is levitated in air alongside some polystyrene guide beads.



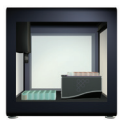
The problem in biology starts with a distribution of cells in a dish.

Using acoustic waves made it easy to create some arrangements such as parallel lines or concentric circles. But this was highly dependent on the container.

Impulse control allows more complex patterns and clusters to be produced and for areas to be cleared. This allows automation applications to be realized.



Without acoustic technology, cell passaging requires many interconnected machines.



With acoustic impulse technology, this can be achieved in a single benchtop device.

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simple static systems. By getting a reflected wave to interact with itself, one can create static regions of high and low pressure. Objects tend to be pushed away from the high-pressure regions and into the low-pressure ones. Such systems are then very limited in the movement of objects they can achieve. In standard laboratory containers, they can enable some very specific patterns (e.g., parallel lines or concentric circles) but not the complex manipulation needed to be useful in automation. The geometry of how the cells were moved was inherently coupled with the geometry of the device.

Where previous techniques had used only a single, static acoustic field, we worked to combine them in sequence. In the original problem, the diamond was chosen because nonspherical objects presented a major problem for standing-wave acoustic levitation. Although roughly spherical objects were stably levitated, there was no correcting force against angular momentum. This meant that nonspherical objects would start to spin and were then rapidly expelled. One solution was an acoustic field called a "twin trap," which could stop the angular momentum but not provide sufficient vertical force to keep the object levitated against gravity. We solved this challenge by switching between these two fields faster than the response time of the object, which combined their capabilities and levitated a diamond (*4*).

My work then delved deeper into this phenomenon on biocompatible liquid systems. I carefully studied the relationship between the size of the force applied and the time for which it was applied. By combining these two, we identified the impulse as the variable that predicted how the objects would be moved. Our detailed characterization of this phenomenon unlocked a much broader range of control capabilities and gave us a powerful tool to arbitrarily reconfigure the arrangements of cells and particles. We had successfully decoupled the geometry of the acoustic field from the geometry of the container (*5*), which allowed us to move the cells however we wanted with a simple system.

We patented this technique within the University of Bristol and set up a spinout company with an exclusive license to the intellectual property. Our company Impulsonics now focuses on biotechnology automation applications, to allow an entire cell passage to be performed in a benchtop unit. It works in standard well plates and will be applicable to a much broader range of applications, including organoid manipulation. The simplicity and compactness allows scalability compatible across the spectrum: 10× reductions in capital expenditures for small laboratories or 30× increases in throughput for high-throughput scenarios. We have raised over £300,000 in nondilutive funding and £450,000 in investment in our first year and are currently beginning to run select customer trials. I look forward to expanding this technology platform to accelerate development across the pharmaceutical and health care industries wherever cells are grown. ■

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REFERENCES AND NOTES

1. https://www.biospace.com/fda-braces-for-looming-boom-in-cell-and-gene-therapy-submissions
2. https://opentrons.com/products/ot-2-robot?sku=999-00111,%20999-00002,%20999-00004
3. A. G. Guex, N. Di Marzio, D. Eglin, M. Alini, T. Serra, *Mater. Today Bio* **10**, 100110 (2021).
4. L. Cox, A. Croxford, B. W. Drinkwater, A. Marzo, *Appl. Phys. Lett.* **113**, 054101 (2018).
5. L. Cox, A. Croxford, B. W. Drinkwater, *Sci. Rep.* **12**, 14549 (2022).

10.1126/science.adw0393