Lab creates open-source optogenetics hardware, software

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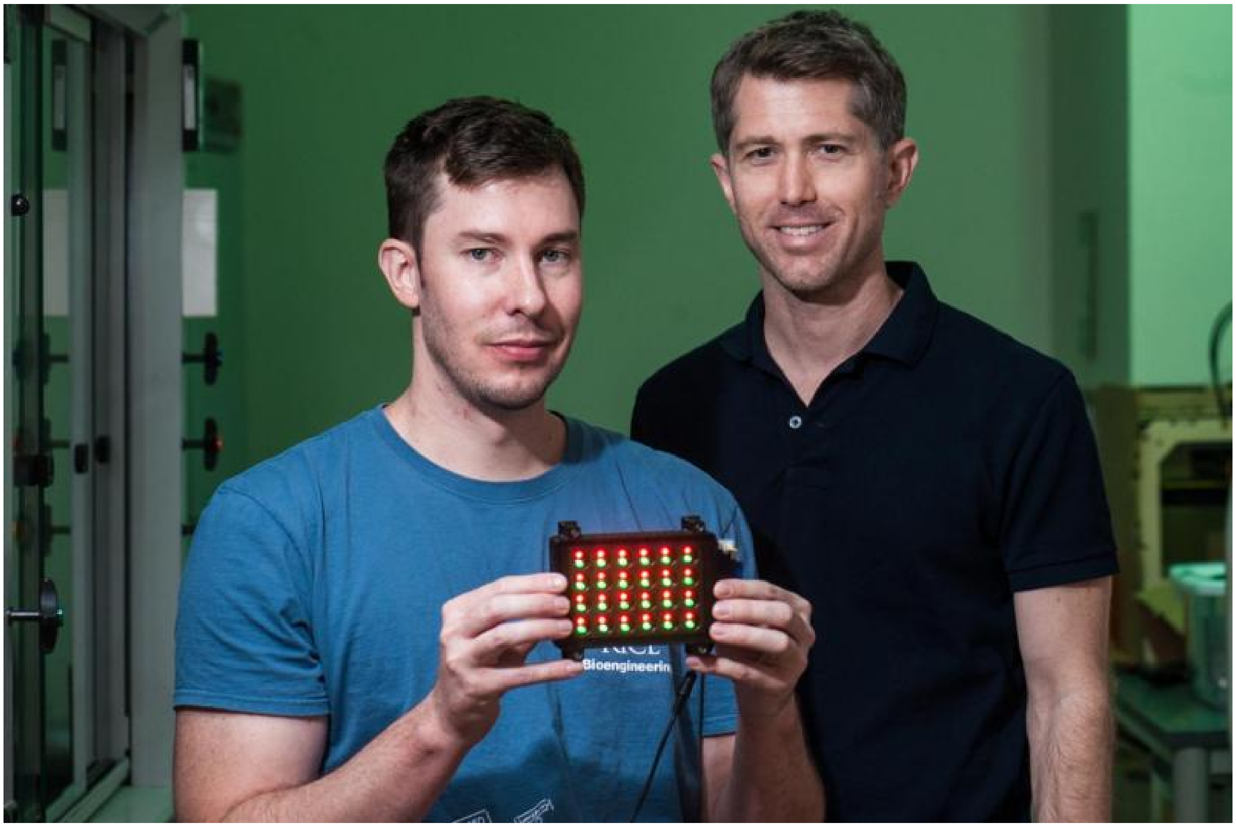
Rice University's low-cost, open-source Light Plate Apparatus can easily be used by nonengineers and noncomputer programmers and can be assembled by a nonexpert in one day from components costing less than $150. Credit: Jeff Fitlow/Rice University

Nobody likes a cheater, but Rice University bioengineering graduate student Karl Gerhardt wants people to copy his answers. That's the whole point.

Gerhardt and Rice colleagues have created the first low-cost, easy-to-use optogenetics hardware platform that biologists who have little or no training in engineering or software design can use to incorporate optogenetics testing in their labs.

Rice's Light Plate Apparatus (LPA) is described in a paper available for free online this week in the open-access journal *Scientific Reports*. The LPA, which was created in the lab of Jeffrey Tabor, assistant professor of bioengineering, uses open-source hardware and software. The apparatus can deliver two independent light signals to each well in a standard 24-well plate and has sockets that accept LEDs of wavelengths ranging from blue to far red. Total component costs for the LPA are less than $400—$150 for labs with a 3-D printer—and each unit can be assembled and calibrated by a nonexpert in one day.

"Our intent is to bring optogenetics to any researcher interested in using it," said Tabor, whose students created the LPA. In doing so, they found ways to make most of its parts with 3-D printers and also created software called Iris that uses simple buttons and pull-down menus to allow researchers to program the instrument for a wide range of experiments.



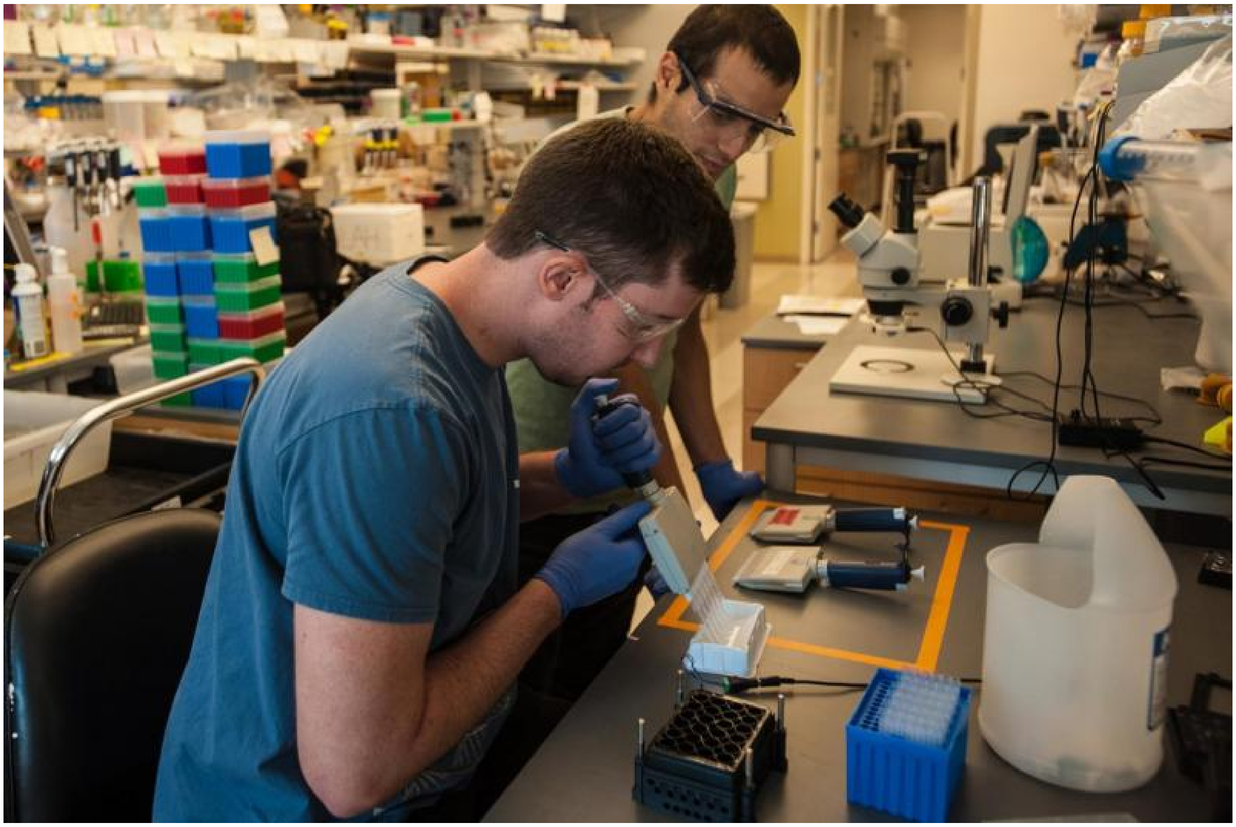
Rice bioengineers Karl Gerhardt (left) and Jeffrey Tabor with the Light Plate Apparatus, a low-cost, open-source optogenetics platform. Credit: Jeff Fitlow/Rice University

Optogenetics, which was developed in the past 15 years, involves genetically modifying cells with light-sensing molecules so that light can be used to turn genes and other cellular processes on or off. Its most notable successes have come in neuroscience following the invention of brain-implantable optical neuro interfaces, which have explored the cells and mechanisms associated with aggression, parenting, drug addiction, mating, same-sex attraction, anxiety, obsessive-compulsive disorders and more.

"Over the past 5-10 years, practically every biological process has been put under optogenetics control," said Gerhardt, who works in Tabor's lab. "The problem is that while everyone has been developing the biological tools to do optogenetics—the light-sensing proteins, gene-expression systems, protein interactions, etc.—outside of neuroscience, no one has really developed good hardware that makes it easy to use those tools."

To demonstrate the broad applicability of LPA, Tabor, Gerhardt and co-authors used the system to perform a series of optogenetics tests on a diverse set of model organisms, including gut bacteria, yeast, mammalian cells and photosynthetic cyanobacteria.

Gerhardt didn't come to Rice intending to invent the world's first easy-to-use optogenetics research platform. A biochemist by training, he initially was interested in simply creating something that would allow him to incorporate optogenetics in his own research. In early 2014, Gerhardt was studying the social amoeba Dictyostelium discoideum. Evan Olson, another Ph.D. student in Tabor's group, had just created the "light tube array," or LTA, an automated system for doing optogenetics on up to 64 test tubes at a time.



Rice University graduate students Karl Gerhardt (left) and Sebastián Castillo-Hair prepare cell cultures for optogenetics testing with the Light Plate Apparatus, an open-source system they developed with colleagues in the laboratory of Rice's Jeffrey Tabor, assistant professor of bioengineering. Credit: Jeff Fitlow/Rice University

Unfortunately for Gerhardt, D. discoideum, which biologists commonly call "dicty," prefers to grow on flat surfaces, like Petri dishes and flat-bottomed well plates. Dicty is also sensitive to vibrations and movement. Like dicty, many organisms commonly studied in biology labs, including many animal cell lines and virtually all human cells, require similar conditions.

"I couldn't culture dicty in the LTA, so I built a sort of plate-based version, and I used it for a couple of experiments, but it didn't work very well," Gerhardt said. "Then, some other people in our lab who had training in electrical engineering and Evan, with his physics background, said, 'We can take this version and make it a lot better.'"

Gerhardt said the group kept innovating and coming up with new versions of the hardware. For example, to make it easy to change the wavelength of light, the team incorporated standard sockets so it would be easy to swap out different colored LEDs. They also added a low-cost microcontroller with an SD card reader, drivers capable of producing more than 4,000 levels of light intensity and millisecond time control.

"We got more and more ambitious in terms of the features we wanted to add, and now we're on version three or four of the hardware," he said. "Then Lucas (Hartsough), Brian (Landry) and Felix (Ekness), members of our group who had expertise in programming and website design, said, 'We'll make the software,' and that's where Iris came from."

Rice University graduate student Sebastián Castillo-Hair conducts tests with the Light Plate Apparatus, an open-source optogenetics research platform developed in the laboratory of Rice’s Jeffrey Tabor, assistant professor of bioengineering. Credit: Jeff Fitlow/Rice University

Iris makes use of a graphical user interface to allow people without specialized computer training to easily program experiments for the LPA.

"Programming is a major barrier for some biologists who want to work with this kind of hardware," Gerhardt said. "Optogenetics hardware, most of the time, requires someone with programming experience who can go into the command line and write code. We wanted to eliminate that barrier."

To simplify the process for getting started with LPA, Tabor and Gerhardt have published all the software, design files and specifications for the system on GitHub, a site that caters to the do-it-yourself community by making it easy to create, share and distinguish different versions of software and files for open-source platforms like LPA.

Gerhardt said at least a half-dozen research groups began making LPAs after an early version of the paper was posted on a biology preprint server, and he hopes many more begin using it now that the *Scientific Reports* paper has been published.

"I hope this becomes the standard format for doing general optogenetics experiments, especially for people on the biology end of the spectrum who would never think about building their own hardware," Gerhardt said. "I hope they'll see this and say, 'OK. We can do optogenetics now.'"

More information: Karl P. Gerhardt et al, An open-hardware platform for optogenetics and photobiology, *Scientific Reports* (2016). DOI: 10.1038/srep35363

Provided by Rice University