

Lasers enable engineers to weld ceramics, no furnace required

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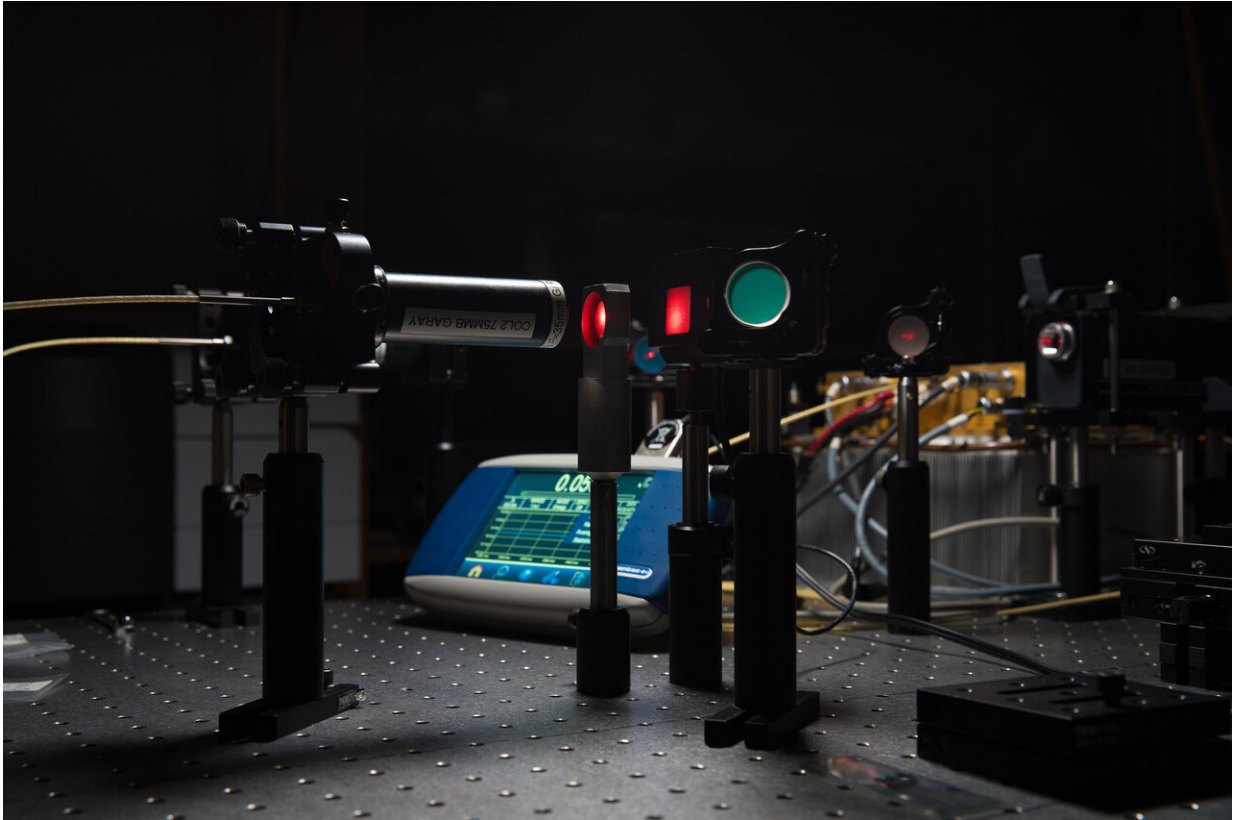
Laser welded ceramic assembly consisting of a transparent cylindrical cap joined to a ceramic tube. Credit: Garay lab/UC San Diego Jacobs School of Engineering

Smartphones that don't scratch or shatter. Metal-free pacemakers. Electronics for space and other harsh environments. These could all be made possible thanks to a new ceramic welding technology developed by a team of engineers at the University of California San Diego and the University of California Riverside.

The process, published in the Aug. 23 issue of *Science*, uses an ultrafast pulsed [laser](#) to melt [ceramic materials](#) along the interface and fuse them together. It works in ambient conditions and uses less than 50 watts of laser power, making it more practical than current ceramic welding methods that require heating the parts in a furnace.

Ceramics have been fundamentally challenging to weld together because they need extremely high temperatures to melt, exposing them to extreme temperature gradients that cause cracking, explained senior author Javier E. Garay, a professor of mechanical engineering and [materials science](#) and engineering at UC San Diego, who led the work in collaboration with UC Riverside professor and chair of mechanical engineering Guillermo Aguilar.

Ceramic materials are of great interest because they are biocompatible, extremely hard and shatter resistant, making them ideal for biomedical implants and protective casings for electronics. However, current ceramic welding procedures are not conducive to making such devices.



Laser setup used to test and measure the transparency of ceramic materials.
Credit: David Baillot/UC San Diego Jacobs School of Engineering

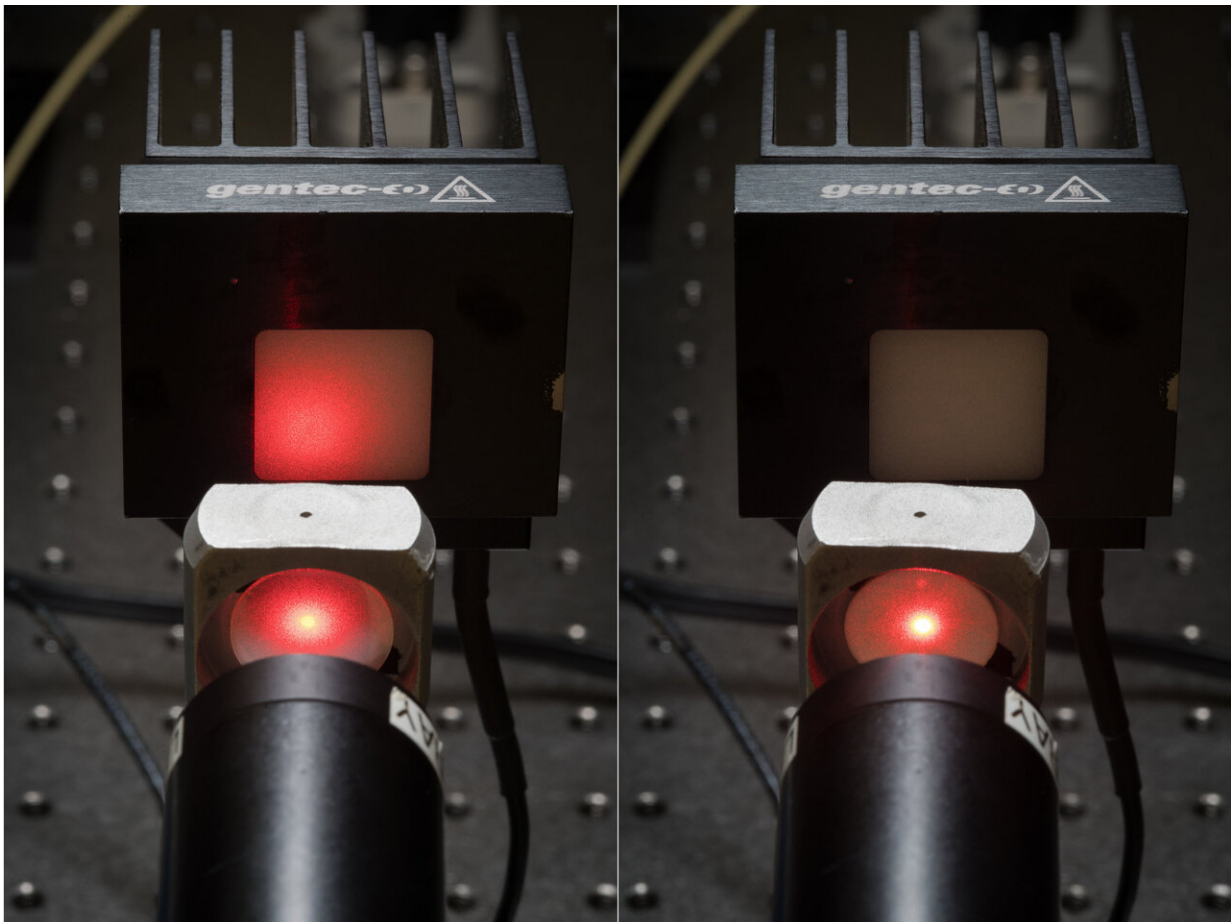
"Right now there is no way to encase or seal [electronic components](#) inside ceramics because you would have to put the entire assembly in a furnace, which would end up burning the electronics," Garay said.

Garay, Aguilar and colleagues' solution was to aim a series of short laser pulses along the interface between two ceramic parts so that heat builds up only at the interface and causes localized melting. They call their method ultrafast pulsed laser welding.

To make it work, the researchers had to optimize two aspects: the laser parameters (exposure time, number of laser pulses, and duration of

pulses) and the transparency of the ceramic material. With the right combination, the laser energy couples strongly to the ceramic, allowing welds to be made using low laser power (less than 50 watts) at room temperature.

"The sweet spot of ultrafast pulses was two picoseconds at the high repetition rate of one megahertz, along with a moderate total number of pulses. This maximized the melt diameter, minimized material ablation, and timed cooling just right for the best weld possible," Aguilar said.



Optical transmission through a transparent ceramic (left) vs. a traditional opaque ceramic (right). Credit: David Baillot/UC San Diego Jacobs School of Engineering

"By focusing the energy right where we want it, we avoid setting up temperature gradients throughout the ceramic, so we can encase temperature-sensitive materials without damaging them," Garay said.

As a proof of concept, the researchers welded a transparent cylindrical cap to the inside of a ceramic tube. Tests showed that the welds are strong enough to hold vacuum.

"The vacuum tests we used on our welds are the same tests that are used in industry to validate seals on electronic and optoelectronic devices," said first author Elias Penilla, who worked on the project as a postdoctoral researcher in Garay's research group at UC San Diego.

The process has so far only been used to weld small ceramic parts that are less than two centimeters in size. Future plans will involve optimizing the method for larger scales, as well as for different types of materials and geometries.

More information: "Ultrafast laser welding of ceramics" *Science* (2019). [science.sciencemag.org/cgi/doi ... 1126/science.aaw6699](https://science.sciencemag.org/cgi/doi/10.1126/science.aaw6699)

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