Ultrashort-pulse laser opens the way to microwelding

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Direct joining of transparent substrates via localized melting and resolidification shows promise for integrating photonic devices.

Development of techniques for joining and welding materials on a micrometer scale is of great importance in a number of applications, including fabrication of electronic, electromechanical, and medical devices. Laser joining is better suited to high-flexibility and high-precision manufacturing of parts and geometries on the very small scale compared with widely used joining techniques such as anodic bonding, direct wafer bonding, and eutectic bonding. In conventional laser joining, which is based on linear absorption, the laser beam penetrates the upper sample and is absorbed at the surface of the lower sample, where it produces localized heating. Joining of transparent materials is possible, but usually requires coating one of the surfaces with an intermediate layer.

We recently demonstrated direct laser joining of transparent substrates using ultrashort laser pulses. Two substrates are stacked and pressed together to achieve close contact. Laser pulses are focused at the interface of the materials, which melt and resolidify, thus becoming welded without recourse to an intermediate layer (see Figure 1). Here, we describe the joining of borosilicate glass and fused silica, whose coefficients of thermal expansion are different.

Ultrashort 85fs laser pulses from an amplified Ti:sapphire laser system (emitting at 800nm, with a pulse repetition rate of 1kHz) are focused at the interface of the two substrates. The focal region is elongated along the optical axis due to nonlinear propagation, or filamentation. This effect bridges the two substrates along the laser propagation axis, and the focal region is then translated in the plane perpendicular to the optical axis (see Figure 2). Figure 3 shows a photomicrograph of the 4 × 4 array of joint volumes (100 × 100 × 30μm) after joining the glasses by irradiating femtosecond laser pulses with an energy of 1.0μJ/pulse and a translation rate of 0.1mm/s. The joint strength was ~15MPa.

The femtosecond-laser-joining technique has advantages that derive from nonlinear absorption around the focal volume of the laser pulses. Note that the approach is not necessarily restricted to samples that have high absorption at the wavelength of the applied pulses. This is confirmed by welding silicon and nonalkali glass using 1558nm laser pulses, at which wavelength silicon is transparent.

Ultrashort-pulse laser micromachining has been widely used in fabricating optical elements inside the bulk of transparent glasses and polymer materials, including waveguides, couplers,

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The microscopic optical image shows (a) top and (b) side views after joining of borosilicate glass and fused silica.

diffractive lenses, and microfluidic channels. The joining and welding technique has the additional attraction that it can be used to assemble different bulk materials. When an optical element is embedded in a piece of transparent material, we can directly fabricate the desired photonic integrated circuit by joining various materials without inserting intermediate layers. The versatility of the technique is amenable to producing electronic, electromechanical, and medical devices, especially sensors, microsystem components, and microfluidic and microelectromechanical systems (MEMS).

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