Buckling Up for Self-Assembled Waveguides

If you are making computer chips, delaminating films are disasters. But a group of researchers at the University of Alberta is using buckling delamination constructively, to make integrated hollow waveguides.

Using multiple layers of chalcogenide glass and polymer, Ray DeCorby and colleagues created straight, curved, crossing and tapered microchannels in parallel (Opt. Express **15**, 3902). For polarized light, they measured losses as low as 15 dB/cm for 40-μm-wide, 2.5-μm-high channels.

The channels are clad by omnidirectional dielectric reflectors designed for low-loss light guiding from 1,550 to 1,700 nm. Hollow-core fibers clad with omnidirectional dielectric reflectors were first announced in 2002 by a group at MIT. A potential benefit of this design is that it may enable low-loss transmission, even around tight bends. Hollow-core planar waveguides could extend the benefits to integrated photonics.

How are the waveguides made? Buckling can occur in films if there is sufficient compressive energy and if the energy release rate on buckling is higher than the adhesion energy per unit area between the film and its substrate. Key to the process is a technique for optical patterning regions of reduced adhesion at one interface within the multilayer stack.

The researchers found they could make a range of widths with straight sides, and demonstrated buckled waveguides from 10 μm to 80 μm. The larger widths, however, had secondary wrinkling. They also made circular ring channels by delaminating an entire disk, then allowing the center to collapse.

Light did not propagate down the 10-μm channels (perhaps because of the very small height). Furthermore, the efficiency of the wider channels was limited by wrinkles along their length. Therefore, the researchers focused on 40-μm channels.

Also, defects in these first devices limited their useful lengths to about 1 cm, although the researchers expect that defects can be reduced substantially with refinements in the process, such as conducting all fabrication steps in a cleanroom.

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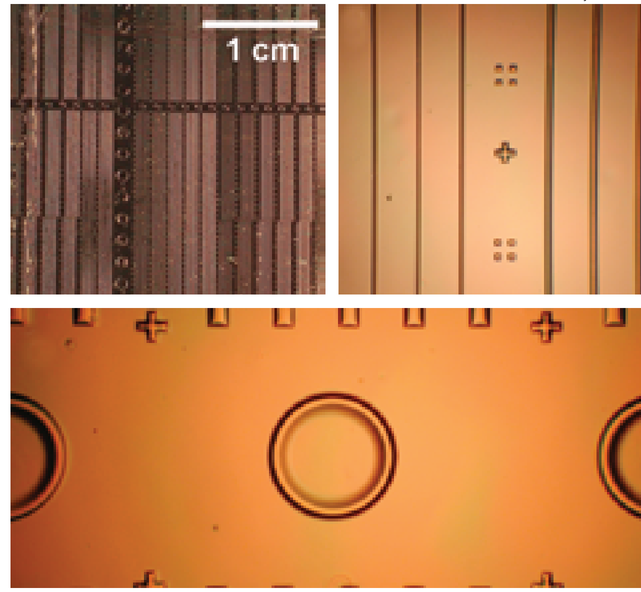


(Top left) Straight-sided buckled waveguides with widths ranging from 10 to 80 μm (in groups of 5), 80 to 20 μm, and 80 to 10 μm tapers, sinusoidal s-bends, and rings with diameters of 500 and 1,000 μm. (Top right) Optical micrograph of 20- and 40-μm straight-sided guides, with buckled alignment mark features (crosses and squares) in between. (Bottom) Optical micrograph of 500-μm-diameter rings.

Did You Know?

When the London Eye first opened in 1999, the lighting around its rim was provided by fluorescent tubes. The huge observation wheel on London's South Bank is visited by more than 10,000 people each day. At 135 m high, it is visible from more than a mile away. But the fluorescent lights were costly to maintain and required the manual installation of gels to produce colored light for special events.

The owners had U.K.-based Architainment Lighting Ltd. and Lighting Technology Projects supply, install and program an LED-based lighting system that allows the colors to be changed by command. The 640 units, supplied by Color Kinetics, were operational in December 2006. Color Kinetics is also bidding on the contract to use LEDs to light the Empire State Building in New York.

David Morrell, courtesy Lighting Technology Projects

Light Pushes Liquids

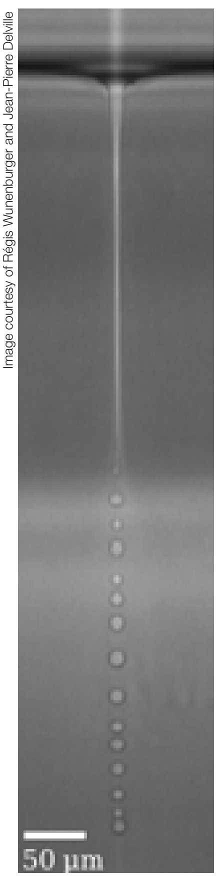
Move over, optical tweezers. In recent experiments, researchers have been able to use light pressure to move small particles in liquids collectively, rather than capturing one particle at a time (as the tweezers do). Theorists and experimentalists at the University of Chicago and Université Bordeaux described how a laser beam can generate bulk flow in fluids—a technique that could prove useful for directing liquids in microfluidic systems (Phys. Rev. Lett. **98**, 133601).

The researchers found that light-scattering produced a significant flow in a structured fluid—in this case, a water-in-oil micellar fluid that separated into two phases, with different densities and refractive indices. ("It's basically soap," says author and professor Wendy Zhang at Chicago.) Light scattering off the density fluctuations at the interface between the liquids produced a strong flow.

Jean-Pierre Delville and colleagues at Bordeaux noticed that, when they shined a laser beam through the liquid interface, the upper liquid (with a higher index of refraction) formed a jet into the lower layer driven by the momentum transferred from scattered photons. Moreover, at the interface around the jet, a hump formed.

After ruling out the possibility that heat caused the movement, the theorists found that light pressure from the beam was strong enough to cause both the jet and the hump effect. They used a linearly polarized Gaussian-profiled argon ion laser, emitting in the green at 514.5 nm, and with beam powers of less than 2 W.

Image courtesy of Régis Wunenburger and Jean-Pierre Delville



A jet of liquid and stream of droplets formed by a laser shining from above.

The direction of the beam influenced the behavior of the jet. When the laser was aimed downward onto the interface (moving from the higher-refractive-index liquid to the lower one), a long, thin jet of the upper liquid formed along the beam axis and intruded deep into the lower fluid. The researchers measured flows of several tens of cubic microns per second. At higher laser powers, the jet shed droplets.

When the laser was directed upward, on the other hand, the upper layer still encroached into the lower layer, but not as far and without creating droplets. In this scenario, a hump formed away from the beam's axis, and it was much wider than the beam width.

The hump can be explained by recirculation of the liquid in the container. When the beam was propagating upward, fluid within the beam (but not at the center) was pushed upward as well. In the container in general, it created a donut-shaped flow—up from the bottom around the beam, outward below the interface, downward at the edges of the container, and inward at the bottom.

When the fluid layer was about 1 mm thick, the hump measured about 10 μm high. Oddly enough, the hump's shape did not depend on the beam's width but on its power.

The researchers believe the effect will occur whenever fluids have a mesoscopic spatial variation in the refractive index and that it could be useful for moving small colloidal particles. "We know the jetting process is very intricate," said Zhang. "We are working to understand the dynamics of the jetting better."

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