then become mobile enough to allow the organic dopants (chromophores) embedded in the host polymer to rotate under the influence of an applied electric field, thus enabling EO behaviour. This procedure is known as 'poling' as the resulting arrangement of (normally highly dipolar) chromophores is a polar, azimuthally symmetric alignment. After cooling the polymer host back down to room temperature and removing the external field, the molecular configuration becomes 'frozen' in place.

Although this molecular arrangement is not thermodynamically stable, there are ways to reduce the decay of the polar order so that devices can be made to last for several years. What the US team brings to the table are fabrication tricks that boost the stability of the polar order. They introduce a noteworthy self-assembly method — whereby fluorinated and non-fluorinated dendrons provide a molecular-level scaffold that enhances the poling efficiency of the chromophores and increases the temporal stability.

This is not the end of the story, however. Constructing devices from EO polymer composites brings other challenges: namely, how can we preserve the strong EO properties offered by single thin films once those films become integrated into a multilayered waveguide structure? Again, the approach of Enami *et al.* is unique in that they use the high conductivity of the sol–gel cladding to ensure that virtually all of the external poling voltage is applied across the thin EO polymer layer. The result is that the EO coefficients of the hybrid modulator match those measured in thin-film versions of the same materials.

In my opinion, the two major achievements of this work are the near-perfect poling efficiency (due to the conductivity of the sol–gel) and the optical-mode-matching properties of the organic–inorganic structure, which lead to lower device-insertion losses and improved compatibility with optical fibres. The EO coefficient obtained by the team, 170 pm V^{-1}, represents a record for these types of modulators. This record is likely to be broken very quickly now that a prescription exists for translating the high EO coefficients measured in thin films to those obtained in actual working devices.

The question still remains: will these hybrid modulators ever become commercially viable? Other technologies are being developed that may supplant both existing devices and potential EO polymer-based ones, such as direct optical generation, modulation and detection in silicon[3]. In addition, organic modulators face the possibility of light-induced degradation of the chromophores themselves during extended operation. Although careful lattice-hardening techniques and encapsulation methods that prevent the in-diffusion of damaging oxygen molecules can help, they involve extra fabrication roadblocks that must be overcome. However, this is nothing new to those developing EO polymer modulators. Their field has taken a marked turn up in the past few years, witnessing very large increases in EO coefficients (and correspondingly, decreases in the modulation voltages that are needed). This latest work shows that feasible devices may be just around the corner.

References

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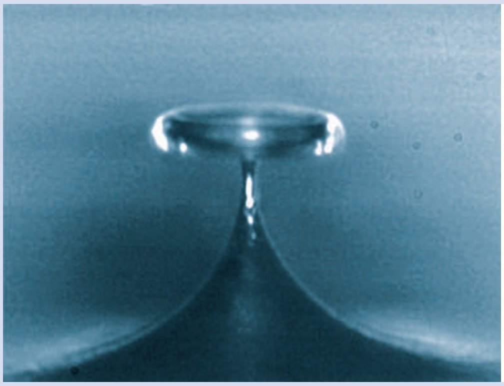
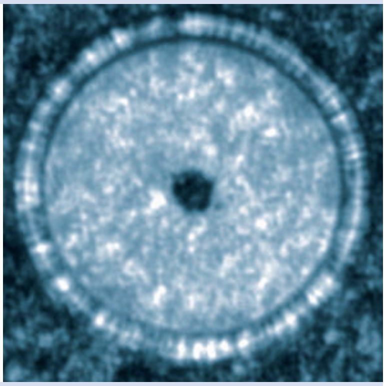
MICRORESONATORS

Optical doughnuts

Portable tiny doughnut-shaped glass structures with exceedingly smooth surfaces and high *Q*-factors of around 30 million have now been made by scientists in California. The 'microtoroidal silica resonators' allow light to circulate around their outer ring with low loss and are potentially ideal for creating high-performance optical filters and exploring cavity quantum electrodynamics (QED) (*Opt. Express* **15,** 166–175; 2007).





Fabricating and handling the 50-micrometre diameter microtoroids is a tricky business. Mani Hossein-Zadeh and Kerry Vahala, from the California Institute of Technology, first deposit a thin disk of glass (2 μm thick) onto a silicon wafer. They then etch away the silicon substrate with XeF_2 to create a small pillar beneath the silica disk. The glass disk is then irradiated with a CO_2 laser beam, which melts its edges, and surface tension causes the glass to flow with exceptional smoothness into a doughnut shape that features a very thin membrane of glass in its centre. Finally, the silicon pillar is etched to a point and the tip of a tapered optical fibre is used to break the microtoroid from the pillar and detach it.

Although detaching the toroid creates a small hole (4–6 μm in diameter) in the central silica membrane, the researchers say that this does not adversely affect the optical properties or *Q*-factor in any way because the light is confined within the ring part of the structure.

As any contamination or physical damage to the microtoroid would degrade its *Q*-factor, the team from Calfornia have also designed and fabricated so-called silica microforks to help make the detachment and handling much easier and safer. As for its future plans, the team is now gearing up to integrate several such microtoroids together on a silicon–silica bench and couple them to waveguides.

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