in the diffraction signal between the known materials.

In their study, Sun *et al.* employed a two-material sample comprising a gold test structure (391 μm × 5.1 μm × 36 nm) mounted on a silicon substrate and an interfacial wetting layer. They measured diffraction patterns for a variety of incident angles around the critical angle, and interpreted these patterns to yield a three-dimensional representation of the sample at a resolution of 2.6 μm × 22 nm × 2.7 nm. These new findings demonstrate the application of grazing incidence, three-dimensional CXDI using a synchrotron source, thus opening the way for the imaging of nanostructured materials mounted on or buried within a substrate at high resolution, particularly in the sample's height direction. As a specific example, one could imagine an experiment in which the technique of Sun *et al.* is combined with the analytical methods of ref. 2, resulting in the high-resolution, three-dimensional mapping of the deformation field inside a single InGaAs quantum dot grown on silicon.

At present, the key limitation of this grazing incident technique is the relatively poor resolution in the direction parallel to the beam propagation — in this case 2.6 μm, compared with 22 nm and 2.7 nm in the two orthogonal directions. In future work, the resolution in the direction along the beam could be improved by varying not only the incident angle α_{i} but also the azimuthal angle Φ (Fig. 1c).

Although this form of three-dimensional coherent imaging is not amenable to the destructive imaging processes available at new, ultrabright sources of coherent X-rays such as free-electron lasers — as multiple shots on the same, intact sample are needed — it does represent an important practical extension of grazing incidence CXDI to three-dimensions, allowing the probing of technologically important nanostructures to nanometre resolution. ❒

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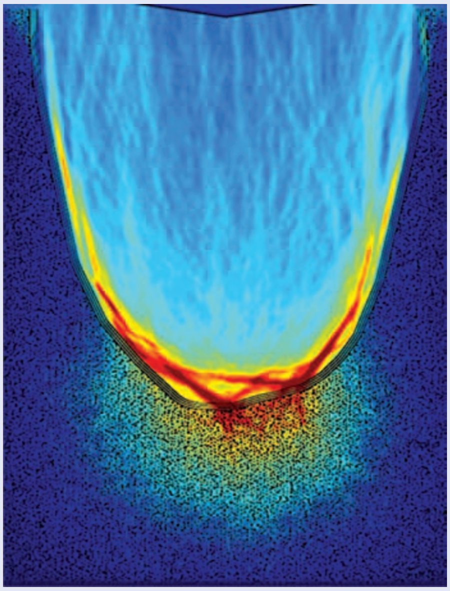
BIOPHOTONICS

Photonic crystals aid fish's night vision

Until relatively recently, scientists believed the elephantnose fish to be completely blind. An interdisciplinary collaboration comprising scientists from 16 institutes across the UK, Germany and Russia have now discovered that the unusual configuration of photoreceptors in the retina of an elephantnose fish makes it colour-blind and insensitive to spatial clarity, which aids navigation through dark and turbid waters (*Science* **336,** 1700–1703; 2012).

The retina of a vertebrate contains two types of photoreceptor cells — rods and cones — for operation at different light levels. Cone receptors are less light-sensitive than rods and therefore provide higher acuity, which makes them useful for daytime or bright-light conditions. Rod receptors, on the other hand, lack acuity but are capable of sensing even a few photons, which allows them to dominate at night or in low-light conditions such as the deep sea. Andreas Reichenbach and co-workers have now shown that the grouped retinas of the elephantnose fish suggest a third specialization of the retina, in which both types of photoreceptor are active simultaneously.



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The retina of the elephantnose fish is lined with cup-shaped photonic crystals made from four thin layers of guanine-crystal lamellae. These photonic crystals form a parabolic mirror, with grouped cone receptors embedded at the base and rods located directly underneath. Simulated results from the finite-difference time-domain implementation of Maxwell's equations show that the reflecting walls of the cup cause the cones to receive around five times the intensity of the incident light, while only a small fraction of light reaches the rods. This is at the expense of reduced spatial resolution; because each cone sees the same part of the image, a group of cones essentially act as one. The reflection is wavelength-dependent and most sensitive in the red, which is fittingly the colour of the fish's native waters in West and Central Africa.

The structure of the grouped cones means that only very large objects can be detected; if a large predator is surrounded by bubbles and floating debris, the elephantnose fish will see only the predator. The researchers confirmed this inherent spatial low-pass filtering by conducting behavioural tests. When pitted against a goldfish, which are known for their high-acuity vision, the elephantnose fish outperformed its competitor by displaying more reliable flight reactions when subject to digital simulations of a predator surrounded by small particles.

The researchers anticipate that future sensing technology could make use of this configuration to detect objects in noisy environments.

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