The bunch length and time jitter of the electron beam were measured using a cross-correlation technique based on a laser-generated terahertz wave impinging on a metallic slit located in the electron beam path⁸. When electrons arrive early (late) they get deflected by the terahertz field up (down) so that the time of arrival is directly encoded in the vertical beam position on a screen downstream⁸. An experiment studying the ultrafast structural change in a photoexcited bismuth film — a well-known ultrafast process that has a time constant of 150 fs — was used to validate the terahertz streaking measurements and to determine the instrument's temporal response (31 fs).

With multiple high-energy UED user facilities coming online^{9,10}, the technique described by Kim and colleagues sets a new milestone in the temporal resolution of MeV UED machines, which will now be able to probe hard phonons in condensed matter as well as the fastest molecular reactions in gas phase. Looking at the future, the authors claim that it might be possible to reach single-digit femtosecond temporal resolution and thus to detect electronic motion.

Many challenges remain for developing the next generation of instrumentation such as improving spatial resolution, signal-to-noise ratio and long-term stability, but we now have a new set of (very fast) eyes to peer into the depths of nature. □

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BIOPHOTONICS

Shrimp eye scattering

An ultrathin reflective layer in the eye of certain types of crustacean has been found to consist of an array of highly scattering nanometre-scale hollow spheres of an organic crystal. The findings (B. A. Palmer et al. *Nat. Nanotechnol.* **15**, 138–144; 2020) could provide inspiration for the design of new types of photonic crystal. Benjamin Palmer and co-workers from various institutions in Israel studied the compound eyes in the so-called whiteleg shrimp (*Litopenaeus vannamei*). They discovered that a reflective layer, the tapetum, at the back of the shrimp's eye, near the photon-absorbing retinal cells was found to consist of an arrangement of highly birefringent nanoscopic spheres of crystalline isoxanthopterin with an optimized lamellar structure (pictured) and exceptional scattering strength.

Images obtained by transmission electron microscopy and cryoscanning electron microscopy showed that the isoxanthopterin particles were composed of many nanoscale platelets arranged in concentric lamellae around a hollow core. The platelets were irregular planar polygons with dimensions of approximately $50 \times 50 \times 10$ nm and formed hollow spheres with an average diameter of 330 nm and a shell thickness of 70 nm.

Biogenic isoxanthopterin is a biaxial crystal, possessing three principal refractive indices along the a , b and c directions: $n_a = 1.40$, $n_b = 2.02$ and $n_c = 1.90$.

Credit: Springer Nature Ltd

The nanoparticles were composed of single-crystal isoxanthopterin plates, with the a axes of the individual platelets projecting radially from the surface of the sphere to form spherically symmetric birefringent particles. As a result, the isoxanthopterin particles exhibited as a uniaxial material with an in-plane ordinary refractive index (n_o) of 1.96 (the average of n_b and n_c) and an out-of-plane extraordinary refractive index (n_e) of 1.40.

The back-scattering efficiency of the isoxanthopterin particles was calculated using a modified Mie theory and it was found that the back-scattering efficiency of the birefringent nanoparticles was approximately two times higher than that of the effective isotropic material (with a refractive index equal to the average

of n_o , n_b and n_c). Most interestingly, the maximum back-scattering efficiency with a minimum amount of material was obtained at the thickness of 70 nm, which was equivalent to the experimentally observed shell thickness. The design is thought to maximize the sensitivity and acuity of the shrimp's eyes.

“Our findings provide a rationalization for the optical functionality of the tapetum and offer inspiration for the development of previously unexplored photonic materials, made from spherically symmetric birefringent particles”, Palmer said. □

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