The formula and calculation for the lasing threshold, taking into account the inhomogeneous broadening of the quantum dots, is an important result of Chestnov and colleagues' work. The crucial parameters turn out to be the quality factor of the terahertz resonator and the effective number of quantum dots resonant with the intra-doublet transition for a given pump fluency. This is in itself dependent on the total surface density of the dots and the width of the inhomogeneous broadening.

The critical question is of course whether, once realistic parameters are plugged into such a formula, the lasing regime turns out to be accessible. The answer is nuanced. While the proposed scheme could be experimentally implemented, reaching the lasing threshold will be challenging, requiring technological improvements over today's state-of-the-art fabrication. The authors consider a standard inhomogeneous broadening of a few tens of millielectronvolts and a very large quantum dot density of $10^{13}\,\text{cm}^{-2}$ that can be achieved only by stacking hundreds of quantum dot layers, and still lasing turns out to require a terahertz resonator with quality factors larger than 10^4. Those quality factors, while already experimentally achieved[9], impose strong constraints on the device design and severely limit its effective tunability.

Although not likely to be implementable with today's off-the-shelf technology, the proposal by Chestnov and co-workers clearly highlights an interesting avenue for future research. Technological advances in quantum dot fabrication could in fact pave the way for both the reduction of the inhomogeneous broadening and an increase in the surface density. This, together with improvements in the design of broadband, ultrahigh-quality-factor terahertz resonators, could turn this proposal into a ground-breaking viable device.

Moreover, the theory of the asymmetric and inhomogeneously broadened dressed-state laser developed here for quantum dots can now be applied to investigate other non-centrosymmetric systems. It is possible that either molecular or solid-state systems with larger dipole densities and smaller broadenings may support terahertz lasing with less stringent parameters.

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https://doi.org/10.1038/s41566-017-0074-3

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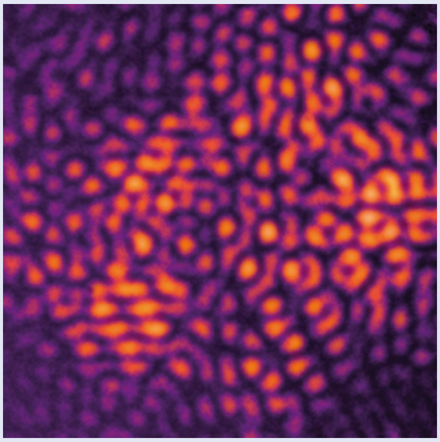
X-RAY IMAGING

Incoherent success

The diffraction of coherent X-rays is routinely used to determine the structure of crystals and molecules, and underpinned the discovery of the double-helix structure of DNA in 1953. As the method relies on diffraction and interference it requires the X-rays to be scattered coherently. When this is not the case, the incident and diffracted waves are not in phase, and X-ray imaging methods cannot generate the diffractive patterns needed to reconstruct the arrangement of the atoms in a crystal. This poses a big limit to coherent X-ray diffractive imaging since incoherent scattering predominates in the X-ray domain and much effort is needed to ensure coherence.

Now, this prerequisite no longer stands. Joachim von Zanthier and colleagues have demonstrated that incoherently scattered photons can be used to image tiny, complex structures (*Nat. Phys.* https://dx.doi.org/10.1038/nphys4301; 2017). Specifically, they have shown that incoherently scattered X-rays from a free-electron laser (FEL) can image 2D objects with a spatial resolution close to or even below the Abbe limit. The imaging capability in two dimensions was surprising to the researchers considering the much enlarged parameter space for the possible phase combinations used to determine the higher-order correlation functions. It allows, for example, imaging of arbitrary 2D objects on a substrate, and potentially transfers the ideas of quantum imaging from visible wavelengths to shorter wavelengths.



Credit: Macmillan Publishers Ltd

The team performed the experiment at the PG2 beamline of the Free-Electron Laser Hamburg (FLASH) at Deutsches Elektronen-Synchrotron (DESY), Hamburg. The FEL beam runs in a 10 Hz pulsed mode at 13.2 nm. It passes a monochromator and impinges on a moving diffusor. The pseudo-thermal light scattered by the diffusor is used to illuminate an object and the light passing through the object is measured by a charge-coupled device (CCD) image sensor. In the experiment, a 2D object mask, consisting of six square-cut holes in a hexagonal arrangement to mimic the carbon atoms in a benzene molecule, on the micrometre scale, was used to generate six quasi-monochromatic independently radiating incoherent sources. The researchers showed that they were able to determine the entire benzene structure based on the 10,800 single-shot speckle patterns (see image) obtained by the CCD detector.

"The requirements for the implementation — high brilliance, ultrashort excitations and high repetition rates — are well met by the FEL facility at DESY. Our next step is to apply the scheme in the hard X-ray regime to reveal structures of crystals, nanoparticles, or even single molecules at the atomic scale," said von Zanthier, who also added that the approach will likely improve structural analyses in biology and medicine.

Rachel Won

https://doi.org/10.1038/s41566-017-0080-5