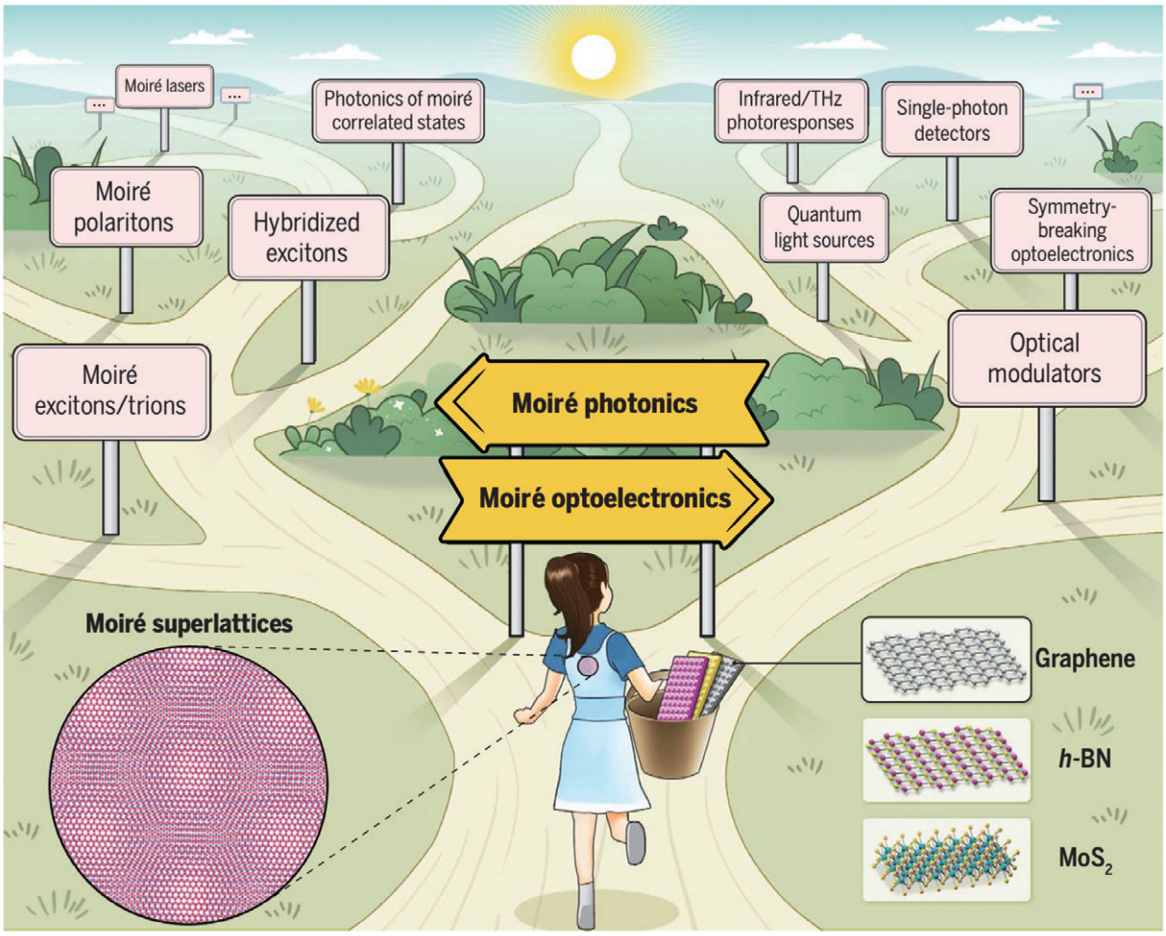
Moiré Superlattices Show Superpower in Photonics and Optoelectronics

Researchers from the Institute of Physics (IOP) of the Chinese Academy of Sciences, collaborating with international colleagues, have presented an overview of recent progress in emerging moiré photonics and optoelectronics.

The review was published in *Science* on March 30.

Moiré superlattices are artificial quantum materials formed by vertically stacking two or more two-dimensional (2D) layered materials with a slight lattice mismatch and/or a small rotational twist. They introduce a potential landscape of much larger length scale than the crystal periodicity of the constituent 2D layers, providing a novel paradigm for engineering the band structures and hence a plethora of exotic quantum phenomena.

For instance, the moiré potential landscape can fold



Moiré photonics and optoelectronics. (Image by Institute of Physics) the electronic band structure into a mini-Brillouin zone, resulting in the formation of flat bands and a rich phase diagram of strongly correlated and topological states, such as superconductivity, orbital magnetism, Wigner crystal states, Chern insulator states and quantum simulators.

When moiré superlattices couple with light, they open up unprecedented possibilities for catching the first glimpse of many emergent photonic and optoelectronic phenomena. For example, moiré superlattices offer a powerful strategy for engineering excitonic quasiparticles in both real and momentum spaces, giving rise to quantum-dot-like moiré excitons and Bragg-umklapp moiré excitons, respectively.

Triggered by the breakthrough of moiré excitons, a plethora of fascinating photonic and optoelectronic properties have been witnessed in moiré superlattices over the past few years with unprecedented speed, including but not limited to moiré excitons/polaritons, resonantly hybridized excitons, reconstructed collective excitations, strong mid-/far-infrared photoresponses, terahertz single-photon detection, and symmetry-breaking optoelectronics.

The new degree of freedom afforded by using moiré superlattices provides new paradigms for engineering light-matter interactions for numerous applications, such as versatile quantum light sources, ultralow-threshold broadband excitonic lasing and intelligent infrared sensors.

The researchers also discussed future opportunities and research directions in this field, such as developing advanced techniques for probing emergent photonics and optoelectronics in an individual moiré supercell, exploring new ferroelectric, magnetic, and multiferroic moiré systems, and using external degrees of freedom to engineer moiré properties, thus resulting in exciting physics and potential technological innovations.

"The dizzying pace of recent achievements suggests that we are just starting down the path of exploring moiré photonics and optoelectronics," said Prof. DU Luojun from IOP, first author of the study. DU also noted that the future progression of the field will undoubtedly bring more surprises and further transform the landscape of basic scientific research and technological innovation in physics, materials science, optical quantum technologies, energy harvesting, information and beyond. Overall, the era of moiré photonics and optoelectronics is coming.

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