Meta-optics: The disruptive technology you didn't see coming

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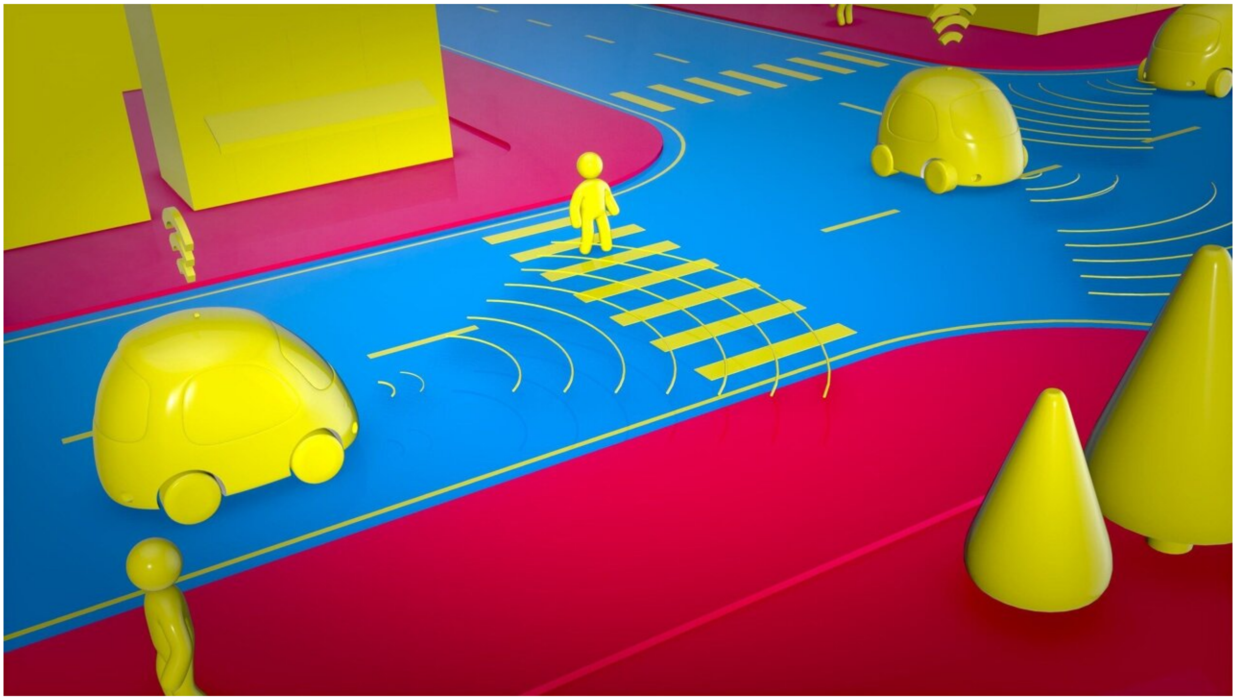

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Robots and autonomous cars will have eyes that see much more than the human eye is capable of, a review of the growing field of meta-optics has found.

Meta-optics is advancing science and technology far beyond the 3,000-year-old optical paradigm that we rely on for the visual humanmachine interface, such as through cameras in our mobile phones, the lenses in microscopes, drones, and telescopes. Optical components are the technology bottleneck that meta-optics aims to transform, bringing the stuff of science-fiction stories into everyday devices.

The field, which blossomed after the early 2000s thanks to the conceptualization of a material with negative refractive index that could form a perfect lens, has grown rapidly in the last five years and now sees around 3000 publications a year.

This accelerating volume of research is impossible for scientists and technologists to navigate, which prompted *Nature Photonics* to commission a review from leaders in meta-optics research, Professor Dragomir Neshev, Centre Director of the ARC Centre of Excellence for Transformative Meta-Optical Systems, and Professor of Physics at the Australian National University, and Professor Andrey Miroshnichenko from UNSW Canberra.

They found the field was on the verge of industrial disruption.

"The biggest driver for the meta-optics field comes from integrating meta-optical elements and devices into optical systems, offering consumer optoelectronics applications," the authors wrote.

"Importantly, meta-optical systems enable novel applications not conceivable before, adding to so-called Industry 4.0. Such applications include the Internet of Things, autonomous cars, wearable devices, augmented reality and remote sensing."

The importance of the technology is shown by the large-scale investment from big industry players such as Apple, Google, and Samsung, who have been hiring graduates and investing in the field, especially to develop vision applications.

But the authors note that beyond vision, the non-traditional characteristics of meta-optics could also be used for light sails, LiFi and thermal management.

These characteristics come from meta-optics' use of surfaces patterned with regular nanoscale structures, in contrast with the traditional optics of mirrors and lenses. The result is miniature components that scatter and manipulate light in ways that would have astounded Isaac Newton.

The first commercial components using these properties are already on the market, with companies such as Metalenz, NILT technologies and Meta Materials Inc delivering flat metalenses, polarization imaging, microscopy and biosensing.

These devices also enable access to properties of light that the human eye cannot detect—polarization and phase, for example, and even can be used to engineer, manipulate and quantum states of light, that could be employed for quantum imaging, sensing and communications.

But the authors also found challenges for the field. The first of these is the ability to scale up to industrial processes that are compatible with the current industry standard CMOS (Complementary Metal Oxide Semiconductor) manufacturing techniques—especially because most meta-optical components rely on a transparent substrate, which CMOS is not.

Secondly, they found the ability to make tunable or reconfigurable metamaterials to enable dynamic components—just as the pixels on a TV screen can change color many times per second—was elusive.

"This is an unsolved problem that we put forward as the main challenge for the field. It's the key element for the field, everybody needs it now," Professor Neshev said.

"There is a misconception that it has been done—people do a small step and in their papers project to a faraway future. But no one can actually modulate the phase at a pixel level for a large array."

If these challenges can be solved then meta-optics technology has enormous potential, Professor Neshev said.

"As a platform meta-optics is so flexible it can go into any product—for example, phones, computers, cars, satellites."

"It offers the ultimate in miniaturization of optical components, for size weight and power; it enables a human device interface that not possible with conventional optics—such as 3D vision and augmented reality, that is really hard with conventional optics," Professor Neshev said.

"And lastly, if we can modify the phase of light that passes through a component, then we will be able to do just about any image processing. That will be the big game changer."

More information: Dragomir Neshev, Enabling smart vision with metasurfaces, *Nature Photonics* (2022). DOI: 10.1038/s41566-022-01126-4.
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