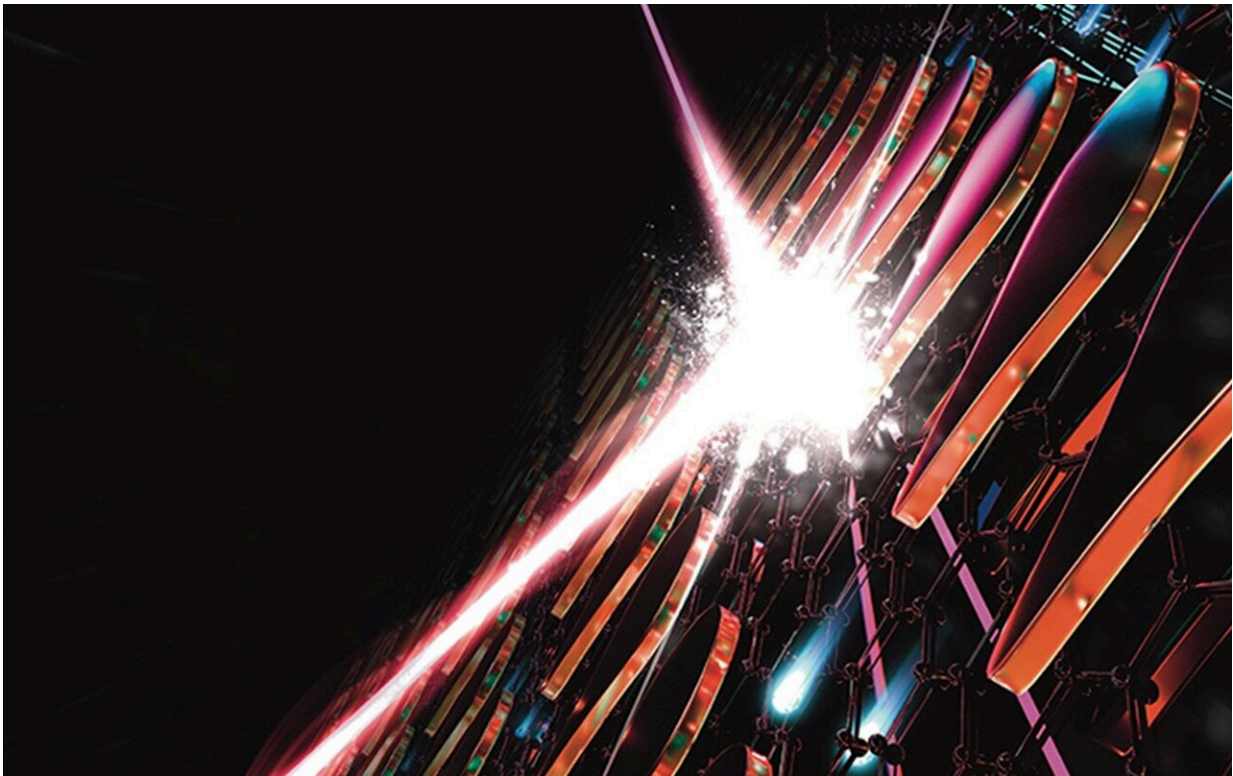


Harnessing light-powered nanoscale electrical currents to propel emerging technologies

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Gold nanoantennas concentrate light waves into intense nanoscale “hot spots,” which excite electrons within an underlying atomically thin graphene layer. The asymmetric structure then points the electrons along a specific direction, driving electrical currents that are controllable and tunable at nanometer scales. Credit: Julia Chen

Traditional microelectronic architectures, with transistors to control

electrical currents along wires, power everything from advanced computers to everyday devices.

But with the [integrated circuits](#) offering diminishing returns in terms of speed and adaptability, Los Alamos National Laboratory scientists are developing nanometer-scale light-based systems that could deliver breakthroughs for ultrafast microelectronics, room-temperature infrared detection (for example, [night vision](#)) and a wide variety of technological applications.

"Most modern technologies, from computers to applications like [energy harvesting](#), are built on the ability to push electrons around," said Jacob Pettine, Los Alamos physicist at the Center for Integrated Nanotechnologies (CINT). "But the way we control this charge flow remains very limited by conventional materials and structures."

Nanoantennas capture and focus light

As described in an [article](#) just published in *Nature*, the research team designed and fabricated asymmetric, nano-sized gold structures on an atomically thin layer of graphene. The gold structures are dubbed "nanoantennas" based on the way they capture and focus light waves, forming optical "hot spots" that excite the electrons within the graphene. Only the graphene electrons very near the hot spots are excited, with the rest of the graphene remaining much less excited.

The research team adopted a teardrop shape of gold nanoantennas, where the breaking of inversion symmetry defines a directionality along the structure. The hot spots are located only at the sharp tips of the nanoantennas, leading to a pathway on which the excited hot electrons flow with net directionality—a charge current, controllable and tunable at the nanometer scale by exciting different combinations of hot spots.

"These metasurfaces provide an easy way to control the amplitude, location and direction of [hot spots](#) and nanoscale charge current with a response speed faster than a picosecond," said Hou-Tong Chen, a scientist at CINT supervising the research. "You can then think about more detailed functionalities."

Promising applications for controllable, tunable charge current

The conceptual demonstration in these optoelectronic metasurfaces have a number of promising applications. The generated charge current can be naturally utilized as the signal for photodetection, particularly important at long wavelength infrared region. The system can serve as a source of terahertz radiation, useful in a range of applications from ultra-high-speed wireless communications to spectroscopy characterization of materials. The system could also offer new opportunities for controlling nanomagnetism, in which the specialized currents may be designed for adaptable, nano-scale magnetic fields.

The new capability may also prove important for ultrafast information processing, including computation and microelectronics. The ability to use the [laser pulses](#) and metasurfaces for adaptive circuits could allow for the dispatching of slower and less versatile transistor-based computer and electronics architectures. Unlike conventional circuits, adaptive structured light fields could offer completely new design possibilities.

"These results lay the groundwork for versatile patterning and optical control over nanoscale currents," said Pettine. "Along with the valuable applications in the laboratory, vectorial metasurfaces may enable advances in many different technological realms."

More information: Jacob Pettine et al, Light-driven nanoscale

vectorial currents, *Nature* (2024). [DOI: 10.1038/s41586-024-07037-4](https://doi.org/10.1038/s41586-024-07037-4)

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