Making Plasmonic Pixels

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A team of scientists in France has created a metasurface on which individual plasmonic nanoantennas act as infrared “pixels,” allowing the surface to encode infrared images of surprising detail. The fabrication technique can encode multiple images on a single metasurface that can be read out by using different settings of polarization and wavelength—a characteristic that the researchers believe could make the metasurfaces useful in applications such as anti-counterfeit devices.

Metasurfaces consisting of tiny, resonant metallic antennas at subwavelength length scales have already captured attention for their ability to control and concentrate optical energy at the nanoscale, with potential applications ranging from data storage to spectroscopy. But according to Patrick Bouchon of the French Aerospace Lab, the corresponding author on the new study, most such metasurfaces are based on periodic repetition of the same pattern—sometimes called a “meta-atom”—across the entire surface. That makes the optical properties homogenous across the surface, and potentially limits some applications in imaging and sensing.

To take the next step, the French team set its sights on a nonperiodic surface in which individual nanoantennas could control light both spatially and spectrally. The antennas themselves consisted of 50-nm-thick rectangular gold patches, set atop a 220-nm-thick insulating layer which in turn lay atop a 200-nm-gold layer. In principle, each of these metal-insulator-metal (MIM) patches could be designed to resonate at a different wavelength, acting as a pixel for emitted thermal radiation and allowing for spatial control of the emitted radiation across the surface.

As a proof of principle, the team began by fabricating a surface consisting of six arrays of MIM patches and, using an infrared camera, studying its emission response when heated to a temperature of 373 K. Then, more impressively, they scaled up the process to the order of 100 million antennas on a surface, calculating the array of antennas that would be needed to encode a tiny grayscale reproduction of a painting of the French playwright Moliere. They also added, on the same designed surface, a complementary set of nanoantennas encoding ordinary alphabetic characters, with the nanoantenna design tuned to emit at different polarizations and wavelengths. Under the scheme, each of the antennas on the array would act as an independent subwavelength emitter for a given polarization and wavelength, allowing it to act as a sort of pixel at that position on the metasurface.

The metasurface in visible light (top left) shows no easily decoded information, but emits a picture of the playwright Moliere when heated to 373 K and imaged in the infrared at horizontal polarization (top right), and shows the letters “A” and “O” when imaged at vertical polarization and wavelengths of 4.73 and 5.24 microns, respectively (bottom). [Image: M. Makhsiyan/ONERA]

The team next fashioned the designed metasurface, using software and fabrication techniques developed by the group. While the sample showed no obvious pattern when viewed in visible light (top left in accompanying picture), the image of Moliere emerged when the sample was heated to 373 K (top right) and imaged in a specific wavelength band and polarization. Moreover, in cross polarization, the encoded letters emerged—with each letter visible when filtered at a different wavelength (bottom left and right).

The French scientists believe that the work constitutes an important step forward in the ability to control thermal emission, with relevance to applications such as biochemical sensing, optical storage, and anti-counterfeit devices. Indeed, Bouchon and colleagues are in the process of creating a start-up business to extend the technology into anti-counterfeiting applications.