and colleagues' results reveal an intermittent and broadband (between 600 and 1,000 nm) emission of light at hotspots of the molecular layer, which confirms the plasmonic origin of the emission.

An important aspect of this work is linked to the use of different molecules to control the properties of the excited plasmons. By playing with the chemical nature and the length of the sandwiched molecules, the researchers show that the intensity and the voltage dependencies of the electric current can be tuned. Because this current also acts as a source for the plasmons, this approach provides a way to control their emission. Therefore, whereas reducing the length of the molecules leads to a more intense emission, their chemical nature may be adjusted to control the response of the optical source to the voltage polarity. More unexpected, is the impact of the angle of the molecular chains with respect to the gold surface, which is shown to influence the polarization of the emitted light. Here, one would assume that this property is intimately linked to the nanometre-scale geometry of the plasmonic electrodes. The choice of the molecules may therefore be used to adjust the emission angle. This observation is likely to stimulate new theoretical works. Also, the experimental configuration used by Du and colleagues provides evidence for the ability of the source to excite propagating plasmons. An example where this source is coupled to a plasmonic waveguide is even provided, constituting a first step towards electrically driven sources integrated in plasmonic circuitry. A possible drawback of this 'organic' approach is the little control the researchers seem to have over the number and the organization of the emitting centres. They are randomly distributed at the device's surface and, although they are probably due to local defects in the molecular layer, their detailed structure is not yet known. Solving this aspect is important for the realization of functional devices.

Future work will likely make use of the ability of organic chemists to synthesize molecules with desired shape and structure to obtain new optoelectronic functionalities. Integrating molecules capable of changing their conformation under optical or electrical stimuli within the monolayer may provide external ways to switch the source on and off. Chiral molecules may be used to tune the emission polarization. From a more fundamental view, the configuration of Du and colleagues may also be adapted to study the interaction between plasmons and molecular excitons. This would involve implementing decoupled chromophores within the organic layers. Confinement of these emitters between the plasmonic electrodes may even lead to a strong plasmon–exciton coupling, which would constitute a fascinating observation with probable benefits in terms of device performance and functionalities. ❐

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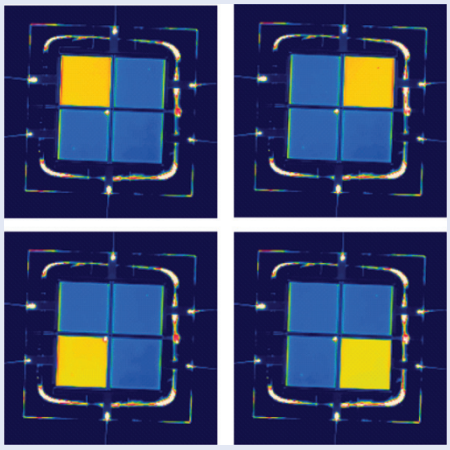
MID-INFRARED OPTICS

Photonic crystal thermal emitters

Highly efficient chip-based sources of narrowband mid-infrared (IR) light that can be rapidly switched on and off could prove to be attractive for applications in environmental monitoring and sensing. Takuya Inoue and co-workers from Kyoto University in Japan have now successfully integrated four discrete semiconductor thermal emitters of mid-IR light, each of which can be designed to emit at a different wavelength and individually switched (see figure), on a GaAs substrate (*Appl. Phys. Lett.* **108,** 091101; 2016).

Each emitter has a square shape measuring 1.2 × 1.2 mm^2 and consists of a p–n GaAs diode structure featuring a layer of GaAs/$Al_{0.3}Ga_{0.7}As$ multi quantum wells (MQWs) that is sandwiched between an n-doped GaAs lower layer and a p-doped GaAs upper layer. Importantly, the structure is etched with a triangular lattice of small air holes (lattice constant of 4.6 to 4.9 μm) to create a photonic crystal pattern with a narrowband resonant spectral response. The doped electrons in the MQWs exhibit strong absorption of mid-IR light due to an intersubband transition that couples to the photonic crystal resonance. The result is a structure that acts as a highly efficient narrowband absorber, or thermal emitter (once hot), of mid-IR light (wavelength of ~9.1 μm) with a *Q* factor of ~70. The device is heated by applying an electrical current that flows through the lower n-GaAs layer.



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Applying an additional reverse bias voltage (−8 V) to the p–n diode extracts doped electrons from the MQWs altering the emission characteristics of the structure and allowing the emission to be electrically modulated at a switching rate of up to 100 kHz. Experiments indicate that the efficiency of the devices is far superior to that of a conventional broadband black-body thermal emitter. For example, the power consumption of one of these narrowband emitters of 3.9 mW is estimated to be just one sixth of a black-body emitter. However, further improvements in efficiency should still be possible as theoretical calculations suggest that this power consumption could in principle be at the submilliwatt scale. The team believe that to get closer to this figure, thermal conduction and radiation loss from the frame of the structure and its connecting electrodes will need to be reduced. Even in its present form though, compared with traditional sensing systems that involve the use of multiple filters, detectors and mechanical choppers, this new breed of on-chip thermal emitter could help make sensors far smaller and more efficient.

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