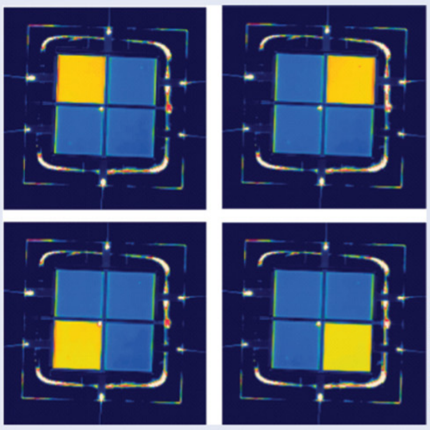
MID-INFRARED OPTICS

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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