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InAs/AlAsSb Mid-Infrared Quantum Cascade Lasers and Narrowband Thermal Emitters for Industrial Process Monitoring and Hazardous-Gas Detection.

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Antimonide-based mid-infrared (mid-IR) optical sources offer a versatile platform for demanding sensing applications in the molecular fingerprint region. Here, we report advances in the molecular beam epitaxy (MBE) of InAs/AlAsSb heterostructures for both quantum cascade lasers (QCLs) and spectrally selective narrow-band thermal emitters, implemented within a common material system and epitaxial technology.

A central aspect of this work is an optimised MBE process for antimonide heterostructures based on an indirect arsenic-supply scheme. This approach markedly suppresses the formation of extended defects and provides a robust foundation for high-performance mid-IR device structures. Using this platform, we design and grow application-specific QCLs, including devices emitting near 8 μm for monitoring industrial curing processes and longer-wavelength structures operating around 11.5 μm for the detection of toxic gases, including phosgene. All QCLs employ InAs/AlAsSb active regions and are mounted epi-side down. The devices exhibit high maximum operating temperatures and maintain operation over a broad range of pulsed driving conditions, supporting their further development towards quasi-continuous-wave operation.

We also demonstrate metal-free, narrow-band mid-IR thermal emitters comprising heavily doped InAs active layers separated by AlAsSb barriers. Although their operating principle differs fundamentally from that of QCLs, these emitters exploit the same antimonide material system and MBE processes, offering a simple and attractive source architecture for compact sensing systems. Their emission wavelength can be engineered through the active-layer design, enabling spectrally selective emission without external optical filters

These results highlight the versatility of the InAs/AlAsSb antimonide platform for realising complementary mid-IR sources tailored to industrial process monitoring and hazardous-gas detection. The use of a common epitaxial technology for both coherent and thermal emitters also provides a promising basis for future integrated mid-IR sensing systems.