Mastering power and efficiency of mid-infrared semiconductor lasers

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In celebration of 50 years' anniversary of laser, the world is also witnessing breakthroughs in power and efficiency of mid-infrared semiconductor lasers. Especially with InP based material system [1], quantum cascade laser (QCL) has proven to be ideally suited to emit coherent radiation in the mid-infrared spectrum region [2, 3]. In the short wavelength side of 3-4 μm, recent exploration leads to watt level output at 3.7 μm in room temperature continuous wave (cw) operation. The highest output power and wall plug efficiency (WPE) is seen in the 4-5 μm range with concentrated research efforts. Steady improvement over the past 3 years has brought the output power and efficiency to values that were never envisioned before. At present, we have demonstrated 4.7 μm QCL with 5 W output power and 20% WPE in room temperature cw operation. At the long wavelength side around 10 μm, 620 mW cw operation is obtained at room temperature.

In order to explore the ultimate efficiency capability, a single-well-injector design is made specifically for low temperature operation and a record WPE of 53% is demonstrated at 40 K. This means a QCLs that emit more light than heat. Psychologically, we can say the glass is half full.

A study on broad area devices reveals that QCLs are exceptionally resistant to filamentation. As a result, a record high peak power of 120 W is obtained from a single device at room temperature. The far field and the emission spectrum of broad area QCLs can be controlled at the same time using a photonic crystal distributed feedback (PCDFB) mechanism. Our recent PCDFB-QCL has a diffraction limited far field and a single mode emission spectrum, with a peak output power of 34 W.

Looking into the future, the availability of high power and high efficiency quantum cascade lasers will undoubtedly revolutionize mid-infrared semiconductor laser based applications in chemical sensing, free space communication, and infrared countermeasures, etc.

Reference:

[1]. M. Razeghi, *The MOCVD Challenge Volume 1: A Survey of GaInAsP-InP for Photonic and Electronic Applications*, Adam Hilger, Bristol, UK, 1989.
[2]. M. Razeghi, *Technology of Quantum Devices*, Springer, 2009.
[3]. M. Razeghi, "High-Performance InP-Based Mid-IR Quantum Cascade Lasers," IEEE Journal of Selected Topics in Quantum Electronics, **15**, 941, 2009.