Recent Advances in Interband Cascade Lasers for Mid-Wave Infrared Free-Space Optical Communications

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Free-space laser communications constitute a promising alternative for transmitting high bandwidth data when fiber optic cable is neither practical nor feasible. This technology has emerged as a strong candidate with a large potential of applications from daily-basis broadband internet to satellite links. Recently, a record transmission speed in free space of up to 1 Tbits/s has been reported over a single wavelength and a distance of 53 km [1]. Although the availability of high-quality transmitters and detectors operating in the near-infrared window makes the 1.55-μm optical wavelength a natural choice for free-space optical systems, two other wavelength ranges can also be considered. First, the mid-wave infrared (MWIR) window between 3 and 5-μm, and second, the long-wave infrared (LWIR) window between 8 and 12-μm. Both are well known for their superior transmission performance through adverse atmospheric phenomena, such as fog, clouds, and dust [2]. In order to develop free-space laser communications in the MWIR, interband cascade lasers (ICL) are currently emerging as very serious candidates [3]. Such advanced semiconductor lasers are based on interband recombinations in a broken-gap configuration, using the same cascade principle as quantum cascade lasers (QCL). However, compared to their QCL counterparts, ICLs offer more advantages. To name a few, they have the ability to bypass fast phonon scattering losses while achieving sufficiently high output powers, on the order of tens of milliwatts [4]. In addition, thanks to their very low threshold currents, ICLs are very much attractive for applications requiring low power consumption. Finally, the development of inter-band cascaded photonic integrated circuits is a key step towards the wider use of ICL technology, which is of growing interest since the first demonstration of an ICL bonded to silicon [5]. A recent work also unveiled the possibility of mitigating a very high dislocation factor, while maintaining the same characteristics as ordinary ICLs grown on GaSb [6]. As a consequence of that, with the advent of new telecommunication standards and the ever-increasing need for data transfer speed, the ICL community is now keenly interested in powerful room-temperature sources operating with high modulation capabilities. In this presentation, we will review our recent progress in the physics and applications of interband cascaded devices. We will discuss their intensity noise and modulation properties and reveal the existence of the oscillation relaxation frequency that is of paramount importance to achieve very fast modulation rates. We will then present state-of-the-art testbed experiments performed with 4.2-μm Fabry-Perot ICLs, which achieved data rates of up to 12 Gbps (OOK) and up to 14 Gbps (PAM-4) under direct modulation of light [7]. In summary, these novel findings in interband cascade devices provide clear scientific guidelines that will be very useful to researchers and engineers in the design and deployment of future free-space MWIR laser communication systems.

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