Fundamental-Mode Operation of Superlattice Electronic Devices in D-Band (110–170 GHz)

H. Eisele*, S. P. Khanna, E. H. Linfield, and L. H. Li
University of Leeds, School of Electronic and Electrical Engineering, Leeds LS2 9JT, United Kingdom
* Contact: h.eisele@leeds.ac.uk +44-113-343-7074

This work was in part supported by the US Army and UK EPSRC.

***Abstract*—In 1970, Esaki and Tsu proposed a device structure where the Bragg reflection of miniband electrons in a semiconductor superlattice (SL) gives rise to regions of negative differential velocity [1]. Superlattice electronic devices (SLEDs) are based on this proposed device structure and have received much attention since the 1990s [2] because the underlying physical process, the Bloch effect, is associated with time constants that are much shorter than those of the transferred-electron effect in, for example, GaAs Gunn devices [3].**

Devices on integral heat sinks were evaluated from three wafers grown at Leeds. Their structures had 110 SL periods and each period consisted of two monolayers of GaAs for the quantum well, and 11 or 12 monolayers of AlAs for the barrier, to achieve estimated miniband widths [4] of more than 100 meV for fundamental-mode operation in D-band (110–170 GHz). Device fabrication followed the same process steps as described in [5] except that smaller SLEDs, with nominal diameters of 15–40 µm, were selected for packaging and RF testing. These SLEDs were mounted in the same type of package that had been employed previously [5] and were tested in the same type of top-hat WR-6 waveguide cavity as fundamental-mode InP Gunn devices at D-band frequencies [6]. Although operation in a second-harmonic mode below 190 GHz has never been observed in the more than 20 years of the cavities' use with GaAs impact ionization transit-time diodes and InP Gunn devices, the same procedure as in [5] was employed to verify fundamental-mode operation at D-band: These SLEDs could, at constant bias, be mechanically tuned with the back short by more than 1 GHz around their D-band frequencies, and their corresponding second-harmonic frequencies were confirmed to be in the range 240–310 GHz. Examples of measured record output powers are 5.0 mW at 123.3 GHz, 2.2 mW at 134.9 GHz, 0.62 mW at 151.5 GHz, and 1.1 mW at 155.1 GHz, all in the fundamental mode, and 0.52 mW at 252.8 GHz in a second-harmonic mode.

The fundamental-mode oscillation frequencies of theses GaAs/AlAs SLEDs are the highest reported to date and approximately twice as high as those that have been observed with GaAs Gunn devices [7]. The oscillation frequencies and also the output powers around 150 GHz are higher than those of InGaAs/InAlAs SLEDs [8], which confirms the strong potential of SLEDs for achieving power generation up to at least 1 THz [5]. Very similar to the at least six- to tenfold performance improvements in InP Gunn devices above 100 GHz [6], substantial increases in output power of SLEDs are expected from optimized thermal management.

References

[1] L. Esaki and R. Tsu, *IBM J. Res. Develop.*, vol. 14, no. 1, pp. 61–65, Jan. 1970.
[2] E. Schomburg, *et al*., *Appl. Phys. Lett.*, vol. 74, no. 15, pp. 2179–2181, Apr. 1999.
[3] R. Scheuerer, *et al*., *Appl. Phys. Lett.*, vol. 81, no. 8, pp. 1515–1517, Aug. 2002.
[4] G. Bastard, *Phys. Rev. B*, vol. 24, no. 10, pp. 5693–5697, Nov. 1981.
[5] H. Eisele, S. P. Khanna, and E. H. Linfield, *Applied Physics Letters*, vol. 96, no. 7, Feb. 2010, pp. 072101-1–072101-3.
[6] H. Eisele and G. I. Haddad, *IEEE Microwave and Guided Wave Letters*, vol. 5, no. 11, Nov. 1995, pp. 385–387.
[7] H. Eisele and G. I. Haddad, John Wiley & Sons, New York, 1997, pp. 343–407.
[8] E. Schomburg, *et al*., *Electron. Lett.*, vol. 35, no. 17, pp. 1491–1492, Aug. 1999.