Asymmetric Quantum Well Far-Infrared Lasers

Zhi-Jun XIN and Harvey N Rutt
Group of Infrared Science and Technology, Optoelectronics Research Centre,
University of Southampton, Southampton SO17 1BJ, UK

In recent years, because of the availability of high quality quantum well (QW) wafers grown by MBE (molecular beam epitaxy) and MOCVD (metallic organic chemical vapour deposition) techniques, QW lasers have developed rapidly.

This has led to the rapid development of mid infrared MQW lasers, in particular the cascade lasers and optically pumped "quantum fountain" lasers, but the techniques have not yet been extended to the far infrared (FIR).

QW lasers emitting in the far infrared (FIR) region [1,2] from intersubband transitions have advantages in efficiency, size and cost. By analogy to conventional laser systems, 3-level and 4-level schemes, we proposed [3] two optically pumped FIR GaAs/AlGaAs QW lasers, a three-level structure in an asymmetric step QW and a four-level structure in a three coupling QWs.

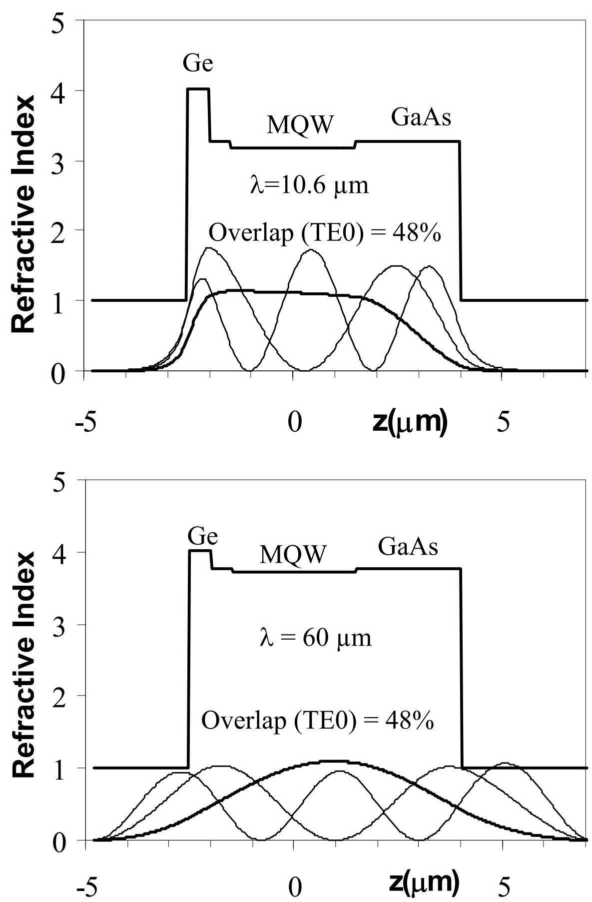

Fig 1. The intensity distribution of pump and laser modes in the transverse direction in a FIR laser.

The three level device can be considered a solid state analogue of a typical optically pumped gas laser; asymmetric quantum wells are used in order to allow the intersubband transitions for an optically pumped laser.

The overlap rates of pump and laser beams with multi-QW active layer can be improved if a thin device is used and a germanium layer is deposited on the top of the device. The high refractive index germanium layer is used to increase the TE0 waveguide mode overlapping in the MQW region. Figure 1 shows the mode overlapping in the transverse direction for a 7 μm thick device at a pump wavelength 10.6 μm and laser wavelength 60 μm respectively.

FIR QW lasers use stacked multi-QW (MQW) structures to reduce the threshold pump power. In practice in molecular beam epitaxial growth of MQW, many factors, such as molecular beam flux, pressure, temperature etc., can give rise to structural inhomogeneity owing to fluctuation of

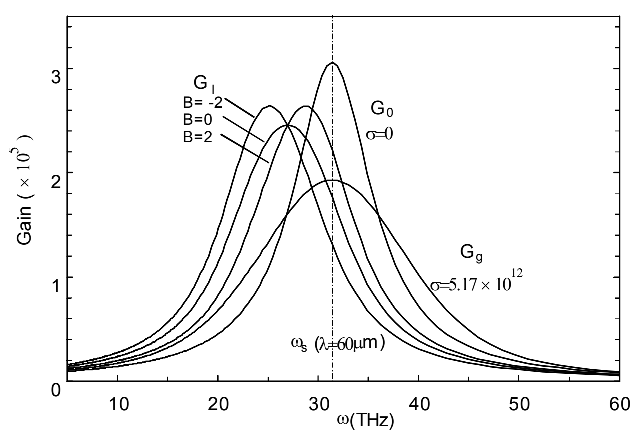

Figure 2. The gains for various fluctuations.

the factors during growth of MQW structures [4]. Hence the characteristics of the inhomogeneity can vary according to the detailed growth of the structures.

The MIR and FIR MQW lasers are vulnerable to gain reduction and inhomogeneous broadening from these effects, and it is crucial to minimise them in a viable design.

Figure 2 models the peak gain reduction, broadening and drift for various inhomogeneities caused by the systematic and random fluctuations, where G_0 is the spectral gain free of inhomogeneity, G_l the gain with systematic drift and G_g the gain with random fluctuation.

Absorption measurement on a 40 step QW structure has been performed using a polarized source by a Fourier transform infrared spectrometer at the Brewster angle, room temperature and 5.8 K respectively, as shown in Figure 3. 4% absorption has been observed at the temperatures. The solid bold curves in the figure are experimental results. The dotted curves are fitted to the absorption in the transitions from the ground subband to the first and second subbands respectively using Lorantzian lineshape. The solid thin lines are the sums of the two dotted curves. Dephasing times T_2 0.054 ps and 0.07 ps are applied in the modelling. The ratios of peak absorption strengths at the two wavelengths agree well with the oscillation strength ratios calculated for the QW structure.

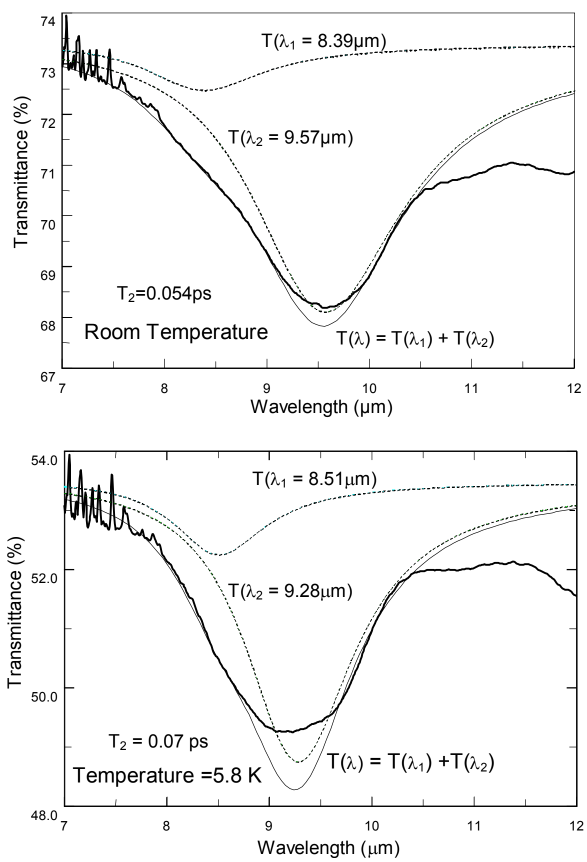

Figure 3. Transmittance measurements of sample B795 at room temperature and 5.8 K respectively when the polarization of the incident light is in the TM orientation (E vector is in a plane of the QW growth direction) and at the Brewster angle.

In summary, a thin device with a germanium layer is proposed for an optically pumped FIR laser. Our research also shows that structural inhomogeneity can result in gain reduction, broadening. Intersubband absorption has been observed from two transitions. Experimental results agree well with theoretical predictions.

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