Conclusions: We have reported CW operation of 1·5 μm buried ridge structure lasers grown entirely by LP-MOCVD. These results from a structure which is not yet optimised suggest that the LP-MOCVD technique is well adapted for large-scale production of GaInAsP index-guided laser diodes.

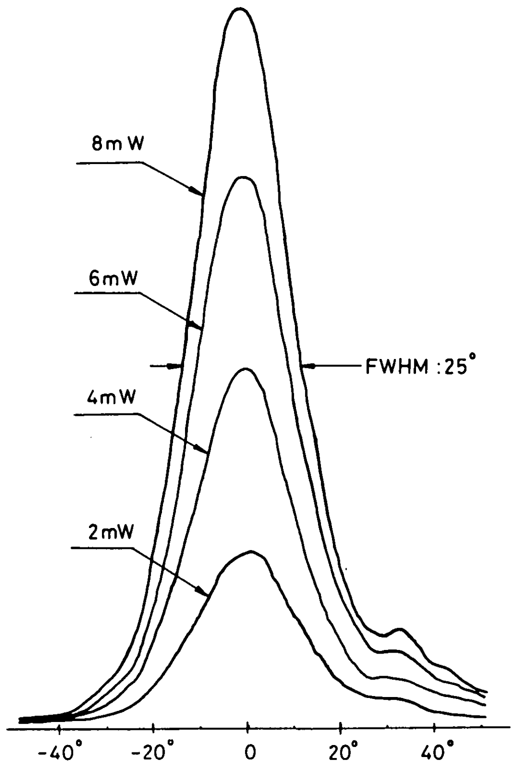

Fig. 3 *Far-field patterns parallel to the junction of a BRS laser for different output powers*

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HOT ELECTRON SPECTROSCOPY

Indexing terms: Semiconductor devices and materials, Spectroscopy

Using a modified GaAs planar doped barrier transistor, grown by MBE, we are able to determine the nonequilibrium distribution function of hot electrons arriving at the base/collector junction. Knowledge of the electron distribution allows one to determine the physical processes necessary for the understanding of hot electron transport which assumes prominence as device dimensions decrease.

As device dimensions decrease, the physics of nonequilibrium transport becomes increasingly important. However, the study of nonequilibrium transport has suffered from one serious disadvantage, namely that the distribution function of electrons has not been determined directly. We demonstrate a method for obtaining the distribution function using a planar doped barrier as a 'hot electron spectrometer'. We measure the distribution function of electrons that have traversed 1600 Å of n-type (1×10^{18} cm^{-3}) GaAs after being injected from a potential of 0·2 eV. Our results demonstrate that the electron distribution peaks at very low energies and is not Maxwellian, which would be expected if the electrons thermalised while transiting the base. Neither is the distribution a displaced Maxwellian, which would be expected if little scattering occurred.

Our measurements are based on the planar doped barrier transistor (PDBT), which has received attention in recent years[1,2] because of its possible application as a high-frequency microwave amplifier. Unfortunately, the transistor showed poor emitter grounded characteristics, attributed to the scattering of hot electrons by coupled plasmon-optical phonon modes in the base.[3] With a small modification, the transistor structure shows considerable promise for the study of nonequilibrium effects which are important for the understanding of future devices characterised by hot-electron effects.

The PDBT was formed by the MBE growth of two back-to-back planar doped barriers (PDBs) on a ⟨100⟩ semi-insulating GaAs substrate. The PDB is a bulk triangular barrier that was formed by placing a thin p^+ (Be-doped) layer in an undoped region bounded on each side by n^+ (Si-doped) layers. The device structure used to determine the nonequilibrium distribution function of electrons differs from previous PDBTs in that the collector barrier (ϕ_{bc}) was at a higher energy than the emitter barrier (ϕ_{be}). The GaAs semiconductor layers comprising the device are shown in Fig. 1 and the resulting conduction bandedge is shown in Fig. 2.

When the emitter junction is forward-biased with 0·2 V it injects a displaced Maxwellian distribution with an excess energy above the Fermi energy of 0·2 eV. The injected electron distribution is modified by inelastic scattering events while transiting the n^+ (1×10^{18} cm^{-3}) 1600 Å base region. The device is designed such that electrons are injected at a relatively low mean energy (0·2 eV) so that intervalley scattering will not greatly influence the results.

With the base and collector grounded, no electrons are collected as none have sufficient energy to surmount the base/

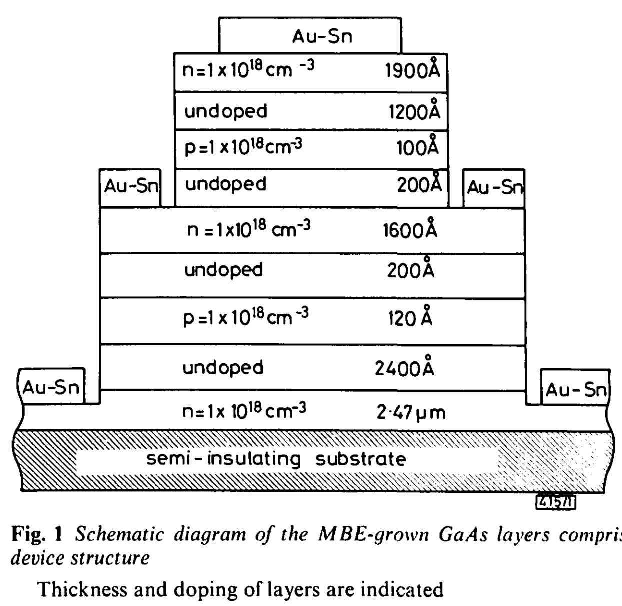

Fig. 1 *Schematic diagram of the MBE-grown GaAs layers comprising device structure*

Thickness and doping of layers are indicated collector barrier (ϕ_{bc}). As the base/collector junction is reverse-biased the barrier (ϕ_{bc}) is lowered and electrons arriving at the junction with energy above the collector barrier are collected as the collector current (I_c). Those with insufficient energy contribute to the base current. The base/collector barrier energy (ϕ_{bc}) for a given bias can be determined from the base/collector current/voltage characteristics[4] with no emitter current. It can now be seen that by reverse-biasing the base/collector junction we have a means of energetically resolving the electrons that arrive at the junction. By differentiating the collector current with respect to the base/collector voltage, we can determine the distribution function of electrons arriving at the junction.

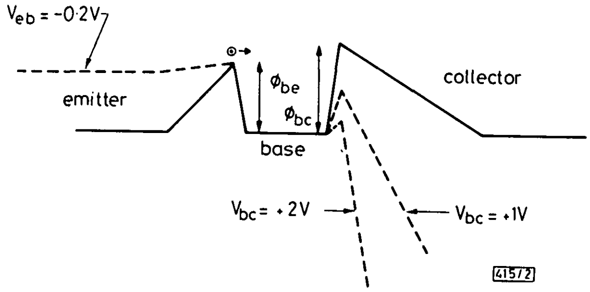

Fig. 2 *Conduction bandedge of device structure whose MBE-grown layers are shown in Fig. 1*

Broken lines indicate device in operation, with the emitter/base junction forward-biased, base grounded and base/collector junction reverse-biased

It was necessary to operate the devices at liquid helium temperatures in order to eliminate thermal smearing processes that mask the hot-electron effects we wish to observe. Fig. 3 shows the first derivative of the collector current (I_c) with respect to the base/collector voltage (V_{bc}) with no emitter current and an emitter current of 1 mA. By subtracting the base line curve ($I_e = 0$) from that with an emitter current ($I_e = 1$ mA) the distribution function can be obtained as indicated in Fig. 3.

The distribution function shows that very few electrons have sufficient energy to surmount the barrier at high energies

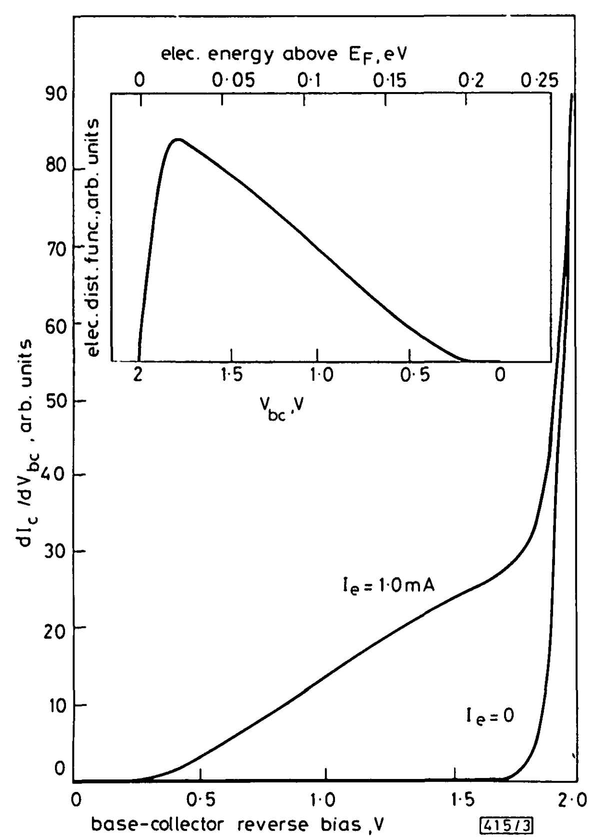

Fig. 3 *First derivative of collector current (I_c) with respect to base/collector reverse bias (V_{bc}) as a function of V_{bc} for two indicated emitter currents (I_e)*

Inset shows distribution function of electrons at base/collector barrier obtained by subtracting the two curves

(i.e. low base/collector reverse bias). Most electrons arrive at the base/collector junction with low energies, as seen by the close proximity of the peak to the Fermi energy (E_F). Simple calculations assuming plasmon scattering[5] indicate that the mean free path for electrons with an excess energy of 0·2 eV is 1500 Å. However, we can infer a mean-free path of only 500 Å from the distribution function. In order to explain these results it is necessary to invoke a scattering mechanism with either a very short mean free path or one favouring large angle scattering.

In conclusion we have shown that by using a PDB as a hot electron spectrometer we have outlined a very powerful method of directly determining the nonequilibrium distribution function of hot electrons. This new technique is a useful probe with which to explore the physics of nonequilibrium transport necessary for future device development. The method of analysing the distribution function is by no means restricted to PDBs but may, for example, be achieved with compositionally graded AlGaAs barriers.

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CLASS OF RECURSIVE SEQUENTIAL REGRESSION ALGORITHMS

Indexing terms: Signal processing, Adaptive systems, Digital filters

A class of sequential regression algorithms for recursive or infinite impulse response (IIR) adaptive filters is discussed. Results using these algorithms are given for an all-pole and a pole-zero example.

Introduction: The sequential regression (SER) algorithm for infinite impulse response (IIR) or recursive adaptive filters was first proposed by Parikh and Ahmed.[1] This letter discusses four types of recursive SER (RSER) algorithms. The first is taken from Reference 1, the second and third from simplification of the algorithm proposed in Reference 1, and the fourth is derived.