Recent Structures for Plasma Instability Search

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Due to the experimental limitations, the high current density domain (where instability can occur at high frequencies) was not accessed in previous experiments. A new set of structures, the sample g595 as a modified version of g494, was designed to bring the instability phenomenon within the range of experimental observation. The dimensions of the parabolic and the pocket regions were increased to bring down the intersubband energies, thus ensuring that instability will occur at lower frequencies, possibly in the detection region of the InSb setup, i.e. below 25 meV. Half of the digital grown parabolic injector region which lies next to the active region was replaced by an 10 nm wide layer with constant Al-content (x = 0.0462) and the width of the active region was increased form 15.5 nm to 18.5 nm.

Simultaneously, the thickness of the entry barrier was increased from 1.2 nm to 1.8 nm and the RTD barriers were increased from 2.4 nm to 2.8 nm and thus the extraction rate of the RTF slightly reduced. This was aimed at reducing the current flow while keeping a high density of carriers inside the active region. This would allow instabilities to occur at lower current densities, thus avoiding heating.

Figure 1 shows the conduction band and the energy levels of the eigenstates in the injector region and the active region of G595. At the bias given in Fig. 1 the second level of the pre well locks to the RTD level.

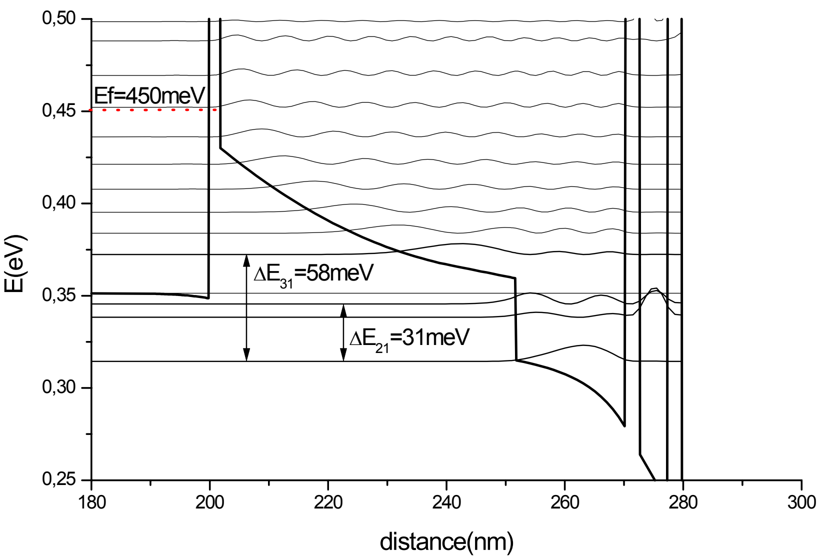

Fig. 1: Conduction band of G595 including squared electronic wave functions for V = 450mV bias enabling resonant tunneling out of the middle level of the pre well.

Figure 2 shows the differential conductivity versus the bias voltage. At low bias voltages up to V = 400mV (ΔV_1) one finds low differential conductivity with pronounced oscillations. These oscillations indicate the quantization of the parabolic injection region. At higher voltages (ΔV_1) the differential conductivity raises. This indicates the locking between the second level of the active region and the RTD level.

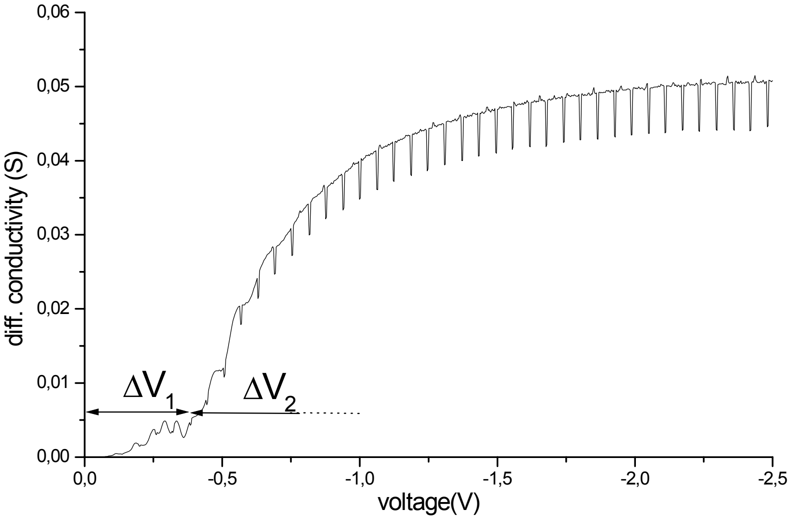

Fig. 2: Differential conductivity vs. bias voltage of G595 (periodic breakdown is from digitized measurement).

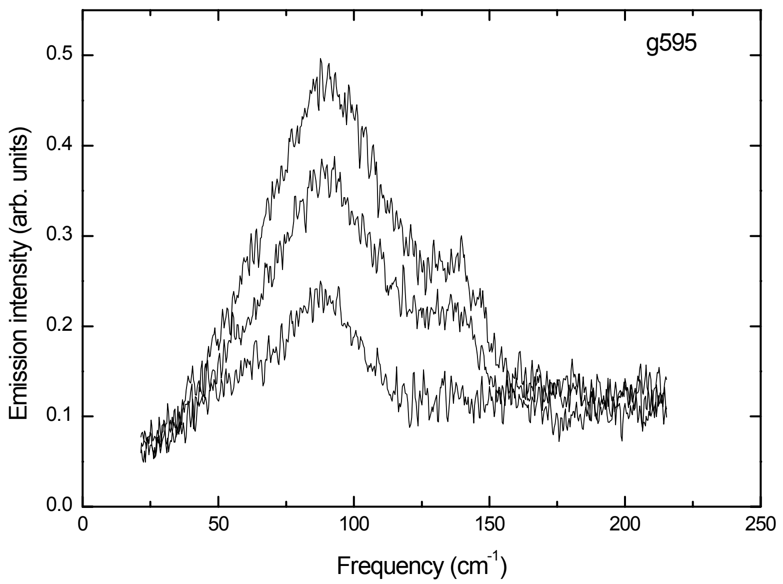

Fig. 3: Emission of g595 under normal operating bias direction.

The emission spectra of g595 were recorded by the InSb setup. Figure 3 shows the emission obtained when the electrons enter the structure through the single barrier on the left. The three curves (from bottom to top) represent biases and currents (–2.28 V, –0.132 A), (–2.48 V, –0.160 A), (–2.94 V, –0.237 A), respectively. The emission increases with the magnitude of the current. The approximate total area of the emission strips is 4×10^{-3} cm^2. There are two noteworthy features. There is a strong peak at 90 cm^{-1} (about 11 meV, or 2.75 THz), whose strength increases with current. There is also a second feature at 140 cm^{-1}, clearly visible in the upper two curves. Based on the transport model and response calculations we interpret the peak around 11 meV to be due to the oscillation frequency of the electrons in the parabolic section of our active region (the Kohn resonance). The second peak can be ascribed to an intersubband transition in the pocket region. The second feature has a half width of about 1.25 meV. This is much smaller than the line width of radiation from the earlier structure g301. That sample had internal doping in the active region, causing scattering and a resulting half width of 2.5meV. A reduction of line width by eliminating internal doping therefore has clearly been demonstrated by Fig. 3. The instrumental broadening contributes about 0.5 meV to the line width. Thus, the collisional (including interface scattering) effects only amount to 0.75 meV in g595.

Achieving plasma instability growth of 1 meV, or more, should therefore suffice to have a positive net growth rate in such structures.