Supplemental material to the article

Stimulated emissions at transition between Wannier-Stark ladders in semiconductor superlattices

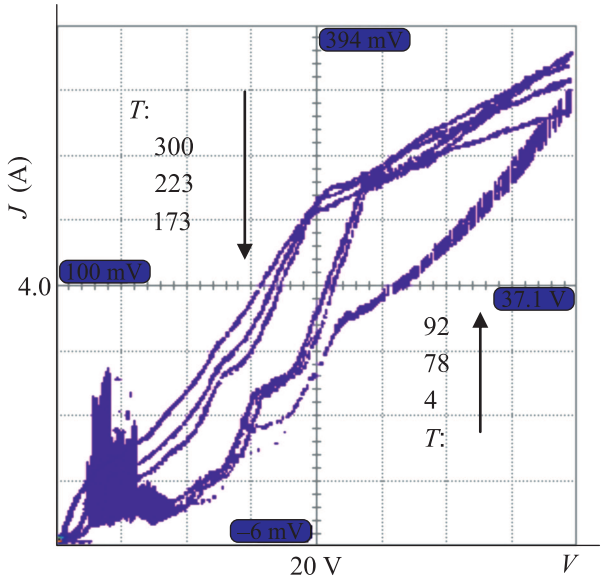

Figure 1: Current–voltage (J–V) curves for one of the chips at several temperatures. Kink (shoulder) at the curves around 20–23 V (where emissions occur at low temperatures) exist up to 300 K. For $T = 4-92$ K in Esaki–Tsu NDC region current oscillations are recorded. Rise in current with rise in temperature presumably is due to breakdown of some deep impurities

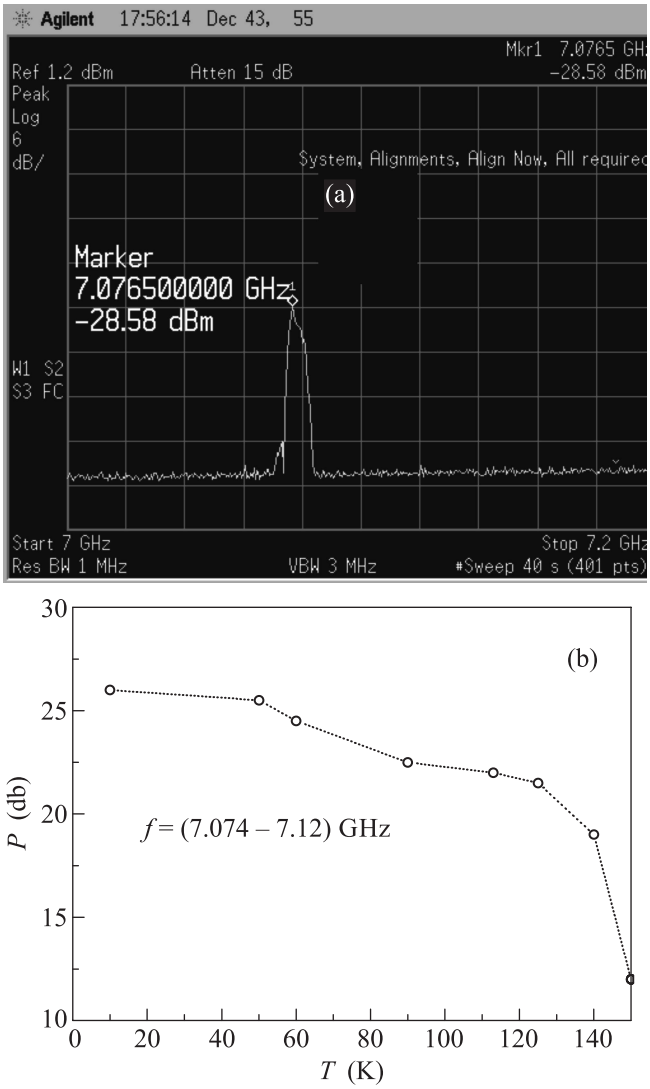

Figure 2: GHz emission spectrum observed by Hewlett–Packard receiver (a) and emission spectrum peak versus temperature for chip N 33 (b)

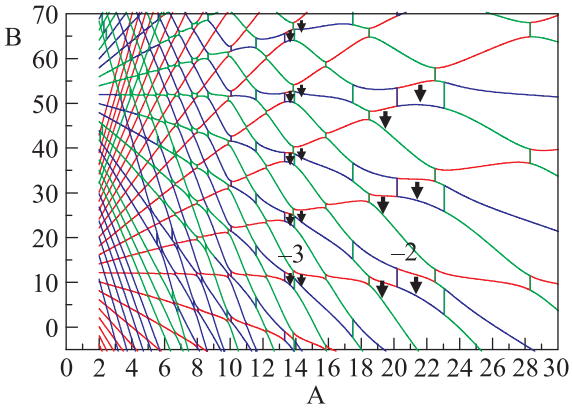

Figure 3: Calculated W.-S. levels (mV) for the SL studied versus voltage per period (mV) demonstrating the amount of level repulsion at crossings which was used in Rabi frequency estimate. Red, blue and green line represent levels related to first (ground), second and third W.-S. levels in a well. Arrows show inverted transitions. The curves demonstrate that all three levels in a well are involved in interaction at resonances. Calculations performed for similar superlattice with weaker barrier (Al 9 %) show that the repulsion is twice as high

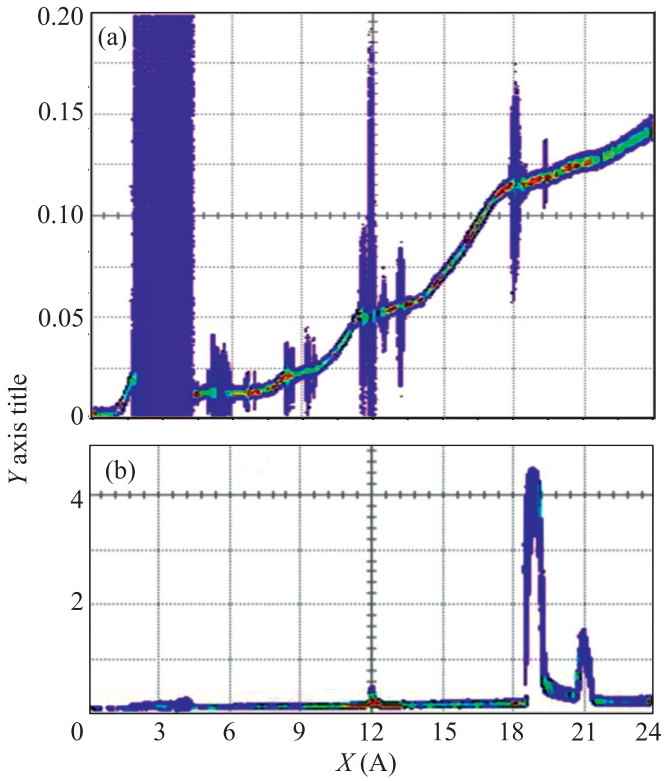

Figure 4: Current (a.u.) – voltage (Volts) curve for one of the chips recorded with wide frequency band oscilloscope to get MHz current oscillations (a). InSb detector signal (GHz emission, a.u.) curve with chip head connected to contact pad with 50 microns gold wire (b); $T = 4\,\mathrm{K}$ Bands of current oscillation and GHz emissions do not overlap in 18–22 Volts region. Peaks of detector signals correspond to inter W.-S. level transitions shown in Fig. 3. With chip head connected additionally with 25 micron wire the emission signal takes whole 18–21 Volts region