Plasmon Enhanced THz Emission

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In 2001, a three energy level structure, based on the GaAs/AlGaAs material system, was proposed [1] as the active region of a plasma instability driven THz radiation source. The basic idea of this structure is to reach population inversion between the second and third energy level, while the lowest energy level is filled. Therefore electrons are injected in the third level and extracted from the second one which is in resonance to the extraction level of an RTD. We investigated a novel design now, based on the GaAs/InGaAs material system (Fig. 1). The active region of the new sample g564 consists of an $In_{0.05}Ga_{0.95}As$-well between a GaAs drift region and the extracting RTD followed by another GaAs layer. This well is an efficient electron trap. Thus we can assume the lowest level to be filled with electrons. The whole "unit cell" shown in Fig. 1 is repeated 10 times to increase the radiation output of the sample.

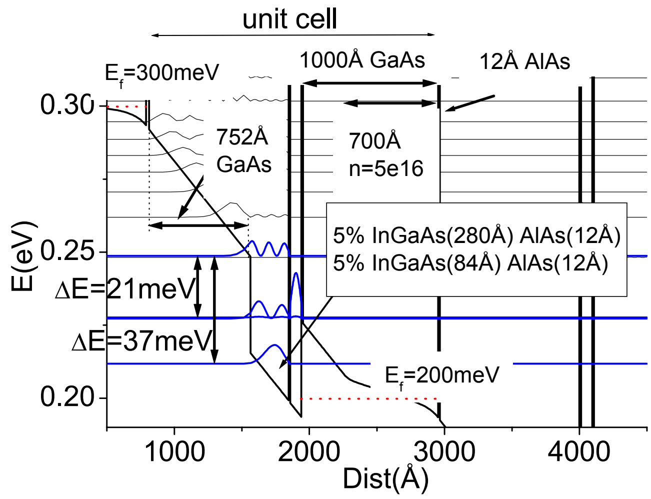

Fig. 1: Conduction band of g564 at working bias

The emission spectra of this structure were measured by using a FTIR step scan spectrometer. Figure 2 shows two typical spectra for each bias direction measured at 4K. Figure 2 (a) shows the emission in forward direction. The electrons are injected from the drift region and extracted through the RTD. One can see three sharp lines between 118 cm^{-1} and 125 cm^{-1} and a broad emission peak at around 145 cm^{-1}. In contrary to the broad peak, the sharp lines occur also in the spectra of the inverse biased sample (Fig. 2 (b)). Due to the asymmetric structure of the sample we cannot reach the needed population inversion in this case. This means that plasmon instability is not the origin of the sharp lines. While these lines seem to be insensitive to the applied bias the broad line shifts to higher energies with increasing bias (Fig. 3) and increasing current densities, until it vanishes at current densities higher than 60 Acm^{-2}. The energy of this peak is in good agreement to $\Delta E_{13}/2$, which is the expected energy region of the instability, but the current densities are too small to reach the required population inversion.

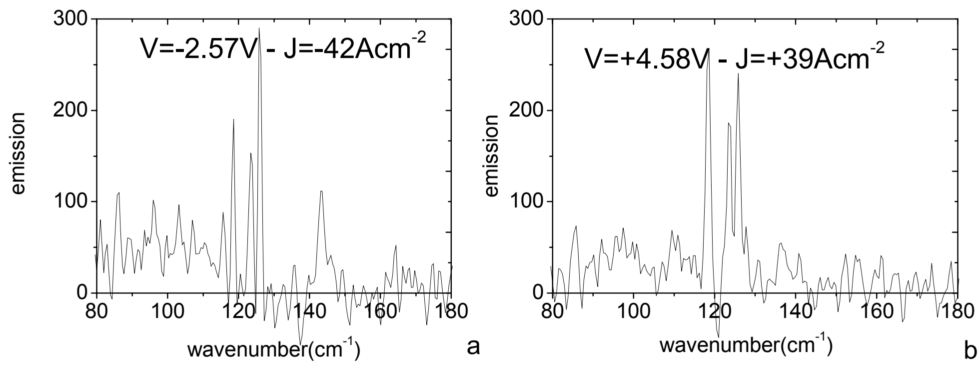

Fig. 2: Step scan measurements at 4K achieved from a negative biased device (a) and positive (inverse) biased device (b)

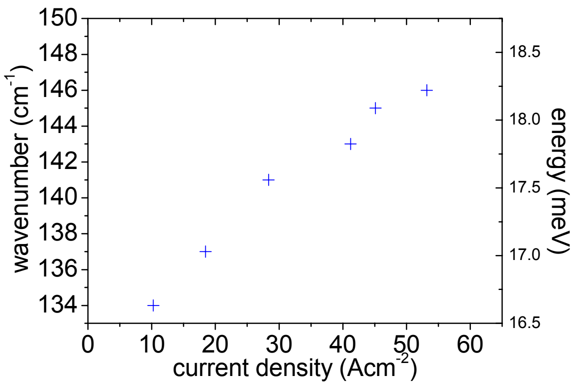

Fig. 3: Peak positions of the intersubband emission peak of g564 versus the current density

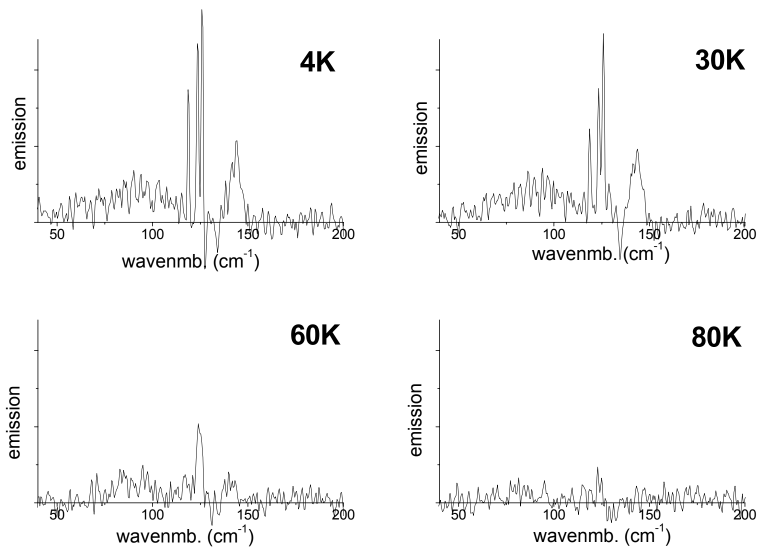

Fig. 4: Emission of g564 at different temperatures

A good proof for plasmon instability is the temperature dependence of the emission, because the instability is a many body effect and therefore is less sensitive to high temperatures than intersubband emission. Figure 4 shows the emission of the sample at different temperatures. One can see that the intensity of all features in the spectra decreases with increasing temperature and vanishes at temperatures around 80 K. This means that the emission of this sample is caused by intersubband scattering.

References

[1] GME Report 2001: “Search for Plasma Instability Driven THz Radiation Sources”, E. Gornik, G. Strasser, R. Zobl, M. Kast, C. Pacher