Coherent Terahertz Emission from Optically Pumped Parabolic Quantum Wells

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We report on few-cycle terahertz (THz) emission from modulation-doped parabolic quantum wells. The quantum wells are optically excited by near-infrared femtosecond laser pulses. The observed THz emission corresponds to the intersubband plasmon of the parabolic quantum well. The emission frequency is independent of the number of optically generated carriers. We identify the excitation mechanism of the intersubband plasmon and hence THz emission to be ultrafast field screening. This mechanism allows for an optically driven THz emission from a completely symmetric nanostructure, in contrast to quantum beats which require a broken symmetry for their excitation.

1. Introduction

Recently, Sekine et al. [1] reported on the optically pumped emission of THz radiation from grating-coupled *intra*subband plasmons in a doped single quantum well. We present experiments which show that *modulation doped* parabolic quantum wells (PQWs) emit coherent THz radiation corresponding to the *inter*subband plasmon when excited by near infrared femtosecond laser pulses.

2. Experimental

The samples used in the experiments are modulation doped GaAs/AlGaAs PQWs, with widths in the range of 1200 – 2000 Å and carrier sheet densities of 1.7×10^{11} – 5×10^{11} cm^{-2}. We perform THz autocorrelation (AC) measurements where two temporarily delayed visible femtosecond laser pulses hit the sample. The emitted THz radiation is collected by parabolic mirrors and detected by a bolometer. The Fourier transform of the recorded AC signal then gives the spectrum of the coherent radiation emitted by the source. The samples are mounted in a continuous flow cryostat to cool them to approximately 5 K, and the whole setup is purged with nitrogen gas to avoid absorption of the THz radiation by water vapor.

Figure 1 shows an AC trace of a modulation doped PQW (W=1400 Å, n_{2D} = 5×10^{11} cm^{-2}) excited by 780 nm (τ_{FWHM} = 80 fs) laser pulses. The density of the optically generated carriers is kept well below the carrier density inside the PQW due to the modulation doping.

The spectrum of the emitted THz radiation (inset of Fig. 1) consists of two components, a broad one around 0.8 THz and a narrow one (FWHM: 0.3 THz) with a center frequency of 2.55 THz. These two emission peaks can be observed within a wide range of excitation wavelengths (815 – 760 nm).

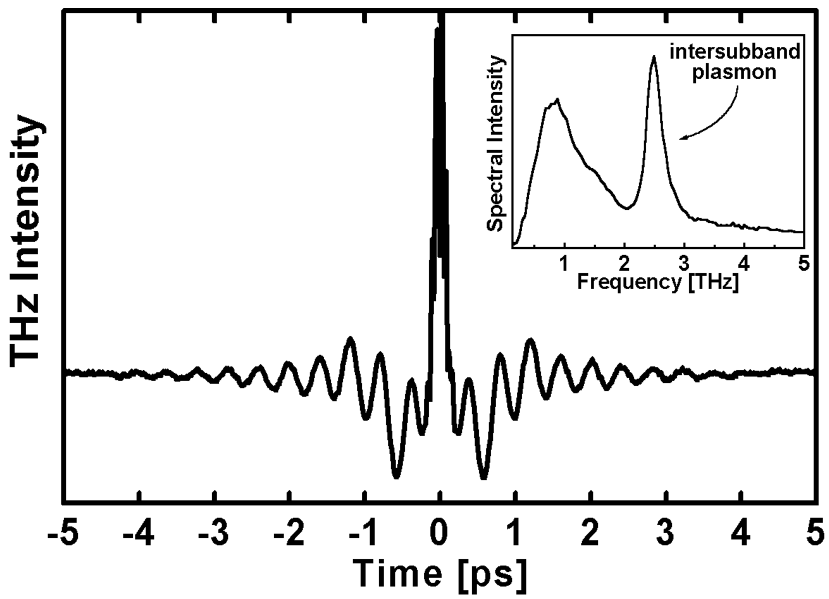

Fig. 1: THz autocorrelation signal of the 1400 Å PQW excited by 780 nm laser pulses (T = 5 K). Inset: Fourier transform of the recorded AC.

While the broadband component varies in frequency, the emission at 2.55 THz doesn't change. The low frequency broadband component is found with all the different PQW samples and shows roughly the same frequency dependence, i.e. it is independent of the PQW sample structure. The origin of the broadband component is due to THz generation at the surface of the sample [2].

The narrowband emission results from the oscillation of the carriers inside the PQW [3]. FTIR absorption and THz-Time Domain Spectroscopy measurements [4] show nearly the same resonance frequency of 2.2 THz which is the characteristic frequency of the intersubband plasmon of this PQW. The width of the THz emission line is as narrow as 0.2 THz for the 2000 Å PQW sample.

The excitation mechanism for the intersubband plasmon is due to screening of the surface depletion field by the electron-hole pairs injected by the ultrafast laser pulse [5]. In this way the electrons inside the quantum well experience a kick and begin to oscillate with their *eigenfrequency* (Fig. 2).

This is supported by the fact that the oscillation can be excited over a large wavelength range of the femtosecond pulses (815 – 760 nm). This large range implies that the excitation mechanism is clearly a non-resonant phenomenon, in contrast to THz quantum beat experiments. The difference between the two excitation mechanisms — quantum beats and ultrafast field screening — is also discernible when we perform THz emission experiments on an *undoped* PQW of the same width (L = 1400 Å). In this case no THz emission associated with the PQW can be observed, i.e. no quantum beats can be excited.

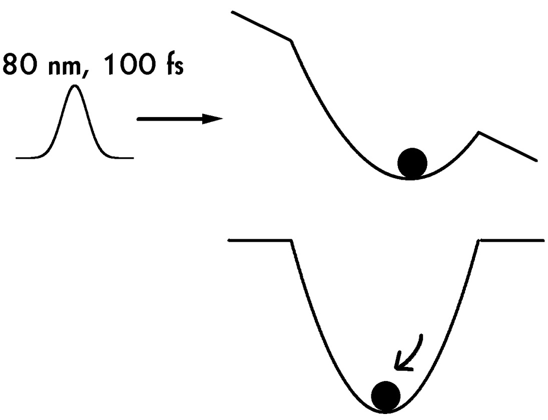

Fig. 2: Schematic drawing of the excitation mechanism: An oscillation of the carriers in the parabolic potential is initiated by ultrafast field screening.

3. Conclusion

We have demonstrated optically driven THz emission from intersubband plasmons in modulation-doped parabolic quantum wells. The excitation mechanism is due to screening of the surface depletion field by electron-hole pairs injected by an ultrafast laser pulse. Due to this non-resonant excitation mechanism, a completely symmetric nanostructure can emit optically driven THz radiation. THz emission due to quantum beats can be excluded since we observe no THz radiation from an identical but undoped PQW. The combination of the designability of the transition frequency, the narrowband emission, and the absence of any processing of the sample make modulation-doped PQWs attractive and easy-to-use THz emitters.

Acknowledgements

This work has been supported by the *Fond zur Förderung der Wissenschaftlichen Forschung* (START-Y47).

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