Dynamical Properties of Terahertz Radiation from Coherent Longitudinal Optical Phonon-Plasmon Coupled Modes in an Undoped GaAs/*n*-type GaAs Epitaxial Structure

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***Abstract*—We have investigated the dynamical properties of terahertz radiation from coherent longitudinal optical phonon-plasmon coupled (LOPC) modes in an undoped GaAs/*n*-type GaAs epitaxial structure using time-domain terahertz spectroscopy. It was confirmed that the frequencies of the lower and upper LOPC modes are dominated by a photogenerated carrier density. The dynamical properties of the LOPC modes, the lifetimes of which are about 0.2 ps, were examined by time-partitioning Fourier transformed spectra of the time-domain terahertz signals. It was found that the lifetimes of the LOPC modes depend on their frequencies.**

I. INTRODUCTION

COHERENT optical phonons are one of potential candidates for terahertz radiation sources. It is well known that longitudinal optical (LO) phonons couples with plasmon, which results in lower and upper LO phonon-plasmon coupled (LOPC) modes. The frequencies of the LOPC modes depend on a carrier density. Thus, the coherent LOPC mode can be utilized as a frequency tunable terahertz radiation source. In our previous work, we demonstrated that the coherent LOPC modes are clearly observed in undoped GaAs/*n*-type GaAs (*i*-GaAs/*n*-GaAs) epitaxial structures [1]. In the *i*-GaAs/*n*-GaAs epitaxial structure, surface Fermi-level pinning produces a considerable built-in electric field in the *i*-GaAs layer, which enhances terahertz radiation from coherent LO phonons because of electric-field induced LO-phonon polarization [2]. The enhancement of terahertz radiation from coherent LO phonons is advantageous in generating terahertz radiation from the LOPC modes.

In this work, we have investigated the dynamical properties of terahertz radiation from the lower and upper LOPC modes in an *i*-GaAs/*n*-GaAs epitaxial structure with the use of time-domain terahertz spectroscopy.

II. RESULTS

The sample of the *i*-GaAs/*n*-GaAs epitaxial structure was gown on an *n*-type (001) GaAs substrate by metalorganic vapor phase epitaxy. The thickness of the *i*-GaAs (*n*-GaAs) layer was 200 nm (3.0 μm), and the doping concentration in the *n*-GaAs layer was 3.0×10^{18} cm^{-3}. The excitation light source was a mode-locked Ti:sapphire laser with a pulse duration of 60 fs, a repetition rate of 90 MHz, and a peak wavelength of 800 nm. Time-domain terahertz signals were detected at room temperature using an optical gating method with a photoconductive dipole antenna fabricated on a low-temperature-grown GaAs layer.

Figure 1 shows the time-portioning Fourier transformed (FT) spectra at various delay times. It is evident that there exist four kinds of FT band. The lowest frequency broad band is due to a monocycle signal in time domain, the so-called first burst, originating from a surge current of photogenerated carriers flowing through the *i*-GaAs layer. The sharp band labeled LO originates from the coherent LO phonon. The two bands labeled LOPC(-) and LOPC(+) are attributed to the lower and upper LOPC modes, respectively. We confirmed that the frequencies of the LOPC modes are determined by a photogenerated carrier density, which demonstrates that the LOPC modes are generated in the *i*-GaAs layer. The lifetimes of the LOPC modes are much shorter than that of the coherent LO phonon, while are comparable to that of the monocycle-signal band. This fact indicates that the surge current acts as plasmon. The very short lifetime of the LOPC mode reflects an escape time from the *i*-GaAs layer. Furthermore, the spectral shapes of the LOPC modes depend on delay time: The frequency shifts toward a higher frequency side with increasing delay time. This time-dependent frequency shift originates from a carrier-density distribution along the growth direction: The carrier density decreases with increasing a distance from the surface. A lower carrier density leads to a lower frequency of the LOPC mode.

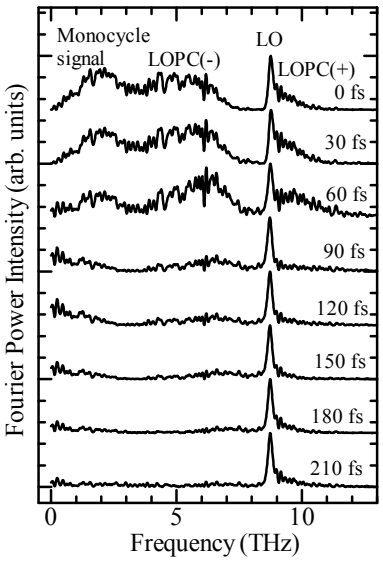

Fig.1: Time-portioning FT spectra at various delay times in the *i*-GaAs (200 nm)/*n*-GaAs epitaxial structure. Each spectrum is normalized by the peak intensity of the coherent LO phonon.

REFERENCES

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