NON-STATIONARY EFFECTS OF SPACE CHARGE IN InN FILMS

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Amplification of traveling space charge waves (SCW) in the microwave range in n-GaAs films due to negative differential conductivity (NDC) has been under investigations for many years [1]. The frequency range, in which amplification of SCW occurs is found to be $f < 44$ GHz for GaAs thin films and $f < 70$ GHz for InP thin films, respectively [2]. Among the materials, possessing NDC, InN appears to be a strong contender for achieving amplification at even higher frequencies $f = 100$ GHz to 700 GHz, because of its expected very high electron mobility and peak drift velocity [3]. Additional promise gives the higher threshold field (40kV/cm, compared to ~4kV/cm in GaAs) at which similarly strong negative differential mobility occurs [3]. This compound semiconductor material has become interesting for use in many semiconductor devices for optoelectronic and high-frequency electronic applications.

We use a Monte Carlo approach to investigate the electron transport in wurzite InN, considering the band structure and scattering model parameters as described in [3]. All relevant scattering mechanisms with optical phonons (inter-valley non-polar and intra-valley polar) as well as with acoustic phonons (via deformation potential and piezoelectric interaction) are accounted for in the simulation, in order to obtain the dependence of the electron drift velocity, effective mass, and average energy on the electric field applied. A study about of how a small, periodic disturbance may propagate in thin InN film is carried out by applying the dispersion equation $D(\omega,k) = 0$, because it determines the modes of propagation, their phase and group velocities, but also shows if instabilities can exist. The space charge waves are amplified in the regime of NDC ($dv/dE < 0$), instead of being damped. We consider the cases where $\omega = 2\pi f$ is real and $k = k' + ik''$ has real and imaginary part. The case $k'' > 0$ corresponds to spatial increment (amplification), whereas the case $k'' < 0$ corresponds to the decrement (damping). The spatial distributions of the alternate components of the electric field $\tilde{E}_z$ and $\tilde{E}_y$ are presented in this work, where a microwave frequency conversion using the NDC phenomenon is carried out when the harmonics of the input signal are generated. Amplification is observed in n-InN films at essentially higher frequencies $f > 300$ GHz.

References:
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