CONACYT program 2015

PhD project proposal form

Discipline

Engineering Sciences

Doctoral School

422 - Sciences and Technologies for Information, Telecommunications and Systems

Numerical Modeling of Telecom devices based on small band gap semiconductor in the THz frequency range

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Summary (1000):

The terahertz (THz) frequency range has became recently a hot topic. We investigate compact size detectors and sources the most efficient possible. Previous works have been done in the team concerning :Thz waveguides, detectors based on 2D plasmon polaritons hybrid mode in semiconductor quantum well, and THz photoconductor based on 1.55 µm femtosecond laser pulses using homemade solvers coupling Maxwell Equations and Boltzmann Transport Equation (BTE).The work proposed here deals with the enhancement of the 3D Maxwell-Boltzmann solver through a focus on non-local effects in THz structures and using III-V semiconductors. Several devices will be investigated and compared such as GaAs, InGaAs and InSb photo-mixer. Several approach for the solving of the BTE for electrons and holes will be investigated such as hydrodynamic and Monte-Carlo models. Self-heating effects will be taken into account by a realistic modeling of phonons dynamic.

It is supported by the collaboration between the Instituto Politécnico Nacional-Mexico and the Institut d'Electronique Fondamentale-Orsay.

Résumé

Le THz est un domaine en pleine effervescence. Notre thème de recherche concerne les détecteurs et des sources compacts Thz et à haut rendement. Des études antérieures menées dans l'équipe ont adressé : les guides d'ondes THz, les détecteurs à base de

plasmon-polaritons 2D dans un puits quantique, et la modélisation de photocommutateur THz (@1.55 µm) utilisant un outil de modélisation numérique résolvant les équations de Maxwell et de Boltzmann.
Le travail proposé ici concerne l'amélioration de cet outil de calcul 3D avec une attention spécifique portés aux effets non-locaux Plusieurs dispositifs seront analysés tels que des photo-mélangeurs GaAs, InGaAs and InSb. Des approches de type hydrodynamique et Monte-Carlo seront considérées pour la résolution du transport des électrons et des trous. L'auto échauffement sera pris en compte avec un modèle réaliste de la dynamique des phonons.
Le travail s'inscrit dans le cadre d'une collaboration entre l'Instituto Politécnico Nacional-Mexico et l'Institut d'Electronique Fondamentale-Orsay.

- **Thesis proposal (max 1500 words)**

The terahertz (THz) frequency range is between 300 GHz and 3 THz; it forms the border between the optical and microwave ranges. This frequency domain includes many interesting physical properties. The lack of powerful and compact sources and detectors is a drawback for applications in telecommunications, spectroscopy (chemistry, physics, astronomy), in medical imaging and in the field of security which now exist.
The approach of our team is to search and optimize detector and sources in compact size, electrically tunable, with low power, low-cost and the most efficient as possible. At IEF, we investigate all the components of the future THz systems, and our work consists in minimizing the losses (dielectric, conductive) and optimizing the THz transmission and detection using the plasmonic properties in metals and semiconductors quantum well and quantum wires. Several studies have already been performed in this direction. Some technological processes have already been elaborated in the clean room of IEF to carry out passive elements (including antenna) and devices including 2D metallic gratings, already achieved to detect plasmon polaritons hybrid mode in a quantum well. Concerning numerical modelling homemade solvers coupling Maxwell Equations and Boltzmann Transport Equation (BTE) have been developed and allow a deep analysis of THz Photoconductive switching performing with a fs 1.55µm laser pulse.
Recently we have started a collaboration with a research team of the Instituto Politécnico Nacional-Mexico (IPN-Mx) formed by some Professors who obtained their Ph-D in our research team in France and then obtained a Professor position at IPN-Mx. These researchers are Mauro Alberto Enciso Aguilar, Luis Manuel Rodríguez Méndez, and Eloy Ramírez García, who also work with the associated Professors Donato Valdez Pérez, and Edson Garduño Nolasco. This research team name's is Advanced Devices for Telecommunications. All of them work for the post-graduate department of Telecommunications at Escuela Superior de Ingeniería Mecánica y Eléctrica unidad Zacatenco (IPN-ESIME-Zac). THz electronics is the core of the collaboration. We have started this collaboration in the late 90's in the field of high-speed electronic devices such as IV-IV HFET and HBT.
The new PhD work, proposed here, is in part the continuity of this first work. The main goal is to develop the know how to design efficient devices to perform THz detectors, sources and amplifiers using III-V semiconductors for telecommunications circuits and systems. The numerical modelling of devices is a key issue. Then a large part of the proposed work will deal with the enhancement of the 3D Maxwell-Boltzmann solver through a focus on non local effect in THz structures. Several devices will be investigated and compared such as GaAs, InGaAs and InSb photo-mixer able to work as detector, mixer or source. Several approach for the solving of the BTE for electrons and holes will be investigated such as

hydrodynamic and Monte-Carlo models. Self-heating effects will be taken into account by a realistic modelling of phonons dynamic.
The student must show deep interested for physics and for numerical modelling.

- **Publications of the laboratory in the field (max 5)**

1. CAO L., GRIMAULT-JACQUIN A.-S., ANIEL F. "COMPARISON AND OPTIMIZATION OF DISPERSION AND LOSSES OF PLANAR WAVEGUIDES ON BENZOCYCLOBUTENE (BCB) AT THZ FREQUENCIES: CO-PLANAR WAVEGUIDE (CPW), MICROSTRIP, STRIPLINE AND SLOTLINE" PROGRESS IN ELECTROMAGNETICS RESEARCH B, VOL. 52, P. 161, 23 PAGES, 2013
2. E. Tea, H. Hamzeh, F. Aniel, "Hot carriers relaxation in highly excited polar semiconductors: Hot phonons versus phonon–plasmon coupling" Journal of Applied Physics, Dec 2011 Vol 110 Issue:11, pp. 113108 - 113108-8
3. *CAO L., GRIMAULT-JACQUIN A.-S., ANIEL F.* "Optimal structure for resonant THz detection of plasmons–polaritons in the 2D quantum wells" Applied Physics. A, Materials Science and Processing, vol. 109, num. 4, p. 985, 7 pages, 2012
4. B. Tissafi, F. Aniel, L. Pichon, B. Essaki, C. Guiffaut, S. Lepaul,"Comparative Study of Three Wave Propagation Softwares for theModeling of Coupled Maxwell and Boltzmann Equations at THz Frequency", Applied Computational Electromagnetics Society Journal, vol. 24, num. 4, p. 382, 9 pages, 2009
5. M. Sirbu, S. Lepaul, F. Aniel, 3D Numerical modeling ofMaxwell and Boltzmann Equations: Analysis of a Photoconductive Switch, IEEE Transactions on Microwave Theory and Techniques, Volume 53, Issue 9, September 2005, pp. 2991-2998.