Engineering Tripos Part IIB, 4B26: Advanced Devices for High Frequency Electronics and Biosensing, 2019-20

Module Leader
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Timing and Structure
Lent term. 15 lectures + 1 Examples class. Assessment: 100% exam

Prerequisites
3B1, 3B5 recommended, 4B24 useful

Aims
The aims of the course are to:

- This course aims to introduce advanced active devices for integrated electronics, with particular emphasis on microwave, mm-wave, THz and biosensing.
- The course will provide a comprehensive review of state-of-the-art active devices used in high frequency applications (such as MOSFET, HEMT and HBT) as well as novel devices enabled by new materials such as graphene and transition metal dichalcogenides.
- A significant part of the course will be dedicated to mm-wave and THz electronics, introducing fundamental physics, enabling technologies and applications.
- The focus then will shift towards biological applications of high frequency devices, in particular for sensing using micro and mm-wave at molecular and cell level.
- Finally, fabrication techniques for devices and integrated circuits will be discussed, with particular attention paid to the integration of novel materials with established technologies.

Objectives
As specific objectives, by the end of the course students should be able to:

- Understand the importance of active devices in high frequency circuits and systems.
- Learn fundamental physics and operation of advanced high frequency devices such as RF MOSFET, HEMT and HBT.
- Understand the role of material in active high frequency devices, advantages and limitation of current technologies and potential offered by new materials.
- Learn about 2D/layered materials and the novel device concepts they enable.
- Understand basics of mm-wave and THz physics, their application and the technology requirement for such high frequency.
- Understand interaction between micro and mm-wave and biological materials and their use in biosensing (impedance spectroscopy), in particular at molecular and cell level.
- Learn state of the art devices (waveguides, resonators, microfluidics, etc.) used for micro and mm-wave
biosensing.
- Understand fabrication methods for high frequency integrated circuits (in particular MMIC) and advantages and challenges related to introduction of new materials. Also, appreciate the importance of integrating new materials and existing technologies.

Content

Introduction to high frequency electronics (1h)
- RF, microwave, mm-wave and THz
- Brief history of high frequency electronics
- Advantages and challenges of increasing frequency
- Enabling technologies: planar (monolithic and hybrid) and waveguide circuits
- The role of active devices in high frequency circuits and systems

Semiconductor micro and mm-wave transistors (4h)
- High frequency field effect transistors (FETs)
- High electron mobility transistors (HEMTs)
- Heterojunction bipolar transistors (HBT)
- High frequency passive components

Novel devices based on 2D/layered materials (4h)
- 2D/layered materials and heterostructures
- Graphene FETs
- Gate-modulated Schottky barrier transistors
- Tunnel transistors based on graphene
- Band to band tunneling devices based on transition metal dichalcogenide
- Hot electron transistors

mm-wave and THz electronics (3h)
- Introduction to mm-wave and THz
- Applications
- Time domain and CW
- Sources: electronic (GUNN diodes, etc.) and QCL
- Detectors: thermal (bolometers, etc.) and integrated (Schottky, FET)
- Applications: communication, spectroscopy, imaging
- THz applications based on 2D/layered materials

Microwave and mm-wave biosensing (2h)
- Interaction between microwaves and biological materials
- Impedance spectroscopy
- Sensors types: waveguide, resonators, etc.
- Miniaturized devices and systems

Technology and integration (1h)
- Planar technology and MMIC fabrication
- New materials: advantages and challenges
- Heterostructures assembly
- Integration: hybrid, monolithic, etc.

Example class (1h)

Booklists
Please see the Booklist for Group B Courses [2] for references for this module.

Examination Guidelines

Please refer to Form & conduct of the examinations [3].

UK-SPEC

The UK Standard for Professional Engineering Competence (UK-SPEC) [4] describes the requirements that have to be met in order to become a Chartered Engineer, and gives examples of ways of doing this.

UK-SPEC is published by the Engineering Council on behalf of the UK engineering profession. The standard has been developed, and is regularly updated, by panels representing professional engineering institutions, employers and engineering educators. Of particular relevance here is the 'Accreditation of Higher Education Programmes' (AHEP) document [5] which sets out the standard for degree accreditation.

The Output Standards Matrices [6] indicate where each of the Output Criteria as specified in the AHEP 3rd edition document is addressed within the Engineering and Manufacturing Engineering Triposes.

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Links
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