Engineering Tripos Part IIB, 4B6: Solid State Devices & Chemical & Biological Sensors, 2019-20

Module Leader

Dr A Lombardo [1]

Lecturer

Dr A Lombardo

Timing and Structure

Lent term. 15 lectures + 1 examples class. Assessment 100%

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.
- Provide a comprehensive review of state-of-the-art active devices used in high frequency applications (such as MOSFET, HEMT and HBT)
- Introducing novel devices enabled by new materials such as graphene and transition metal dichalcogenides (TMD).
- 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.
- Leant 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 challenged 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 tunnelling 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

This syllabus contributes to the following areas of the UK-SPEC [4] standard:

Toggle display of UK-SPEC areas.

General Learning Outcomes

Graduates with the exemplifying qualifications, irrespective of registration category or qualification level, must satisfy the following criteria:

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Links
[1] mailto:al515@cam.ac.uk
[2] https://www.vle.cam.ac.uk/mod/book/view.php?id=364101&chapterid=50391
[3] https://teaching21-22.eng.cam.ac.uk/content/form-conduct-examinations
[4] https://teaching21-22.eng.cam.ac.uk/content/uk-spec