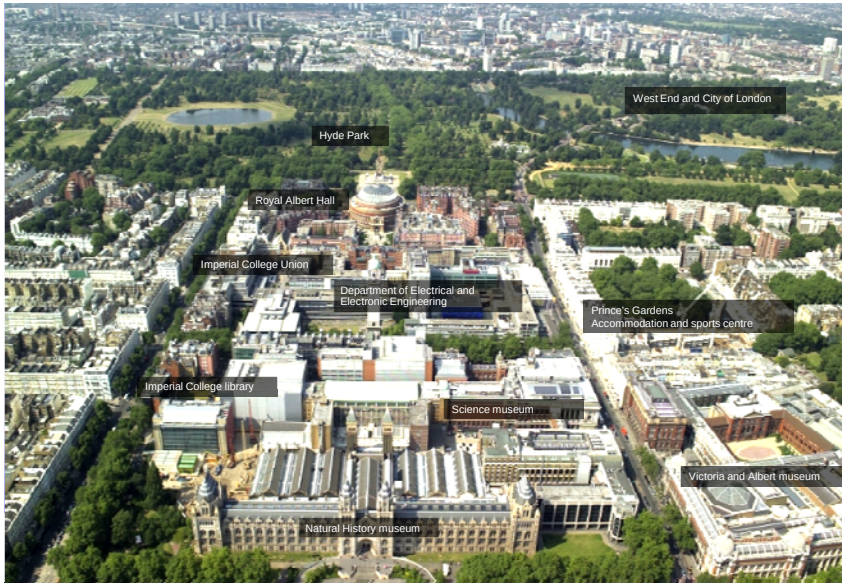
Radio Frequency Engineering

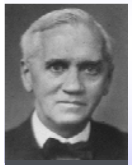
Presented by
Stepan Lucyszyn
Department of Electrical and Electronic Engineering
Imperial College London

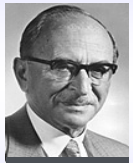


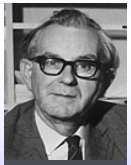
OVERVIEW

- Imperial College London
- Optical and Semiconductor Devices Group
- Lecture Course Rational and Contents

14 Nobel Prize Winners Associated with Imperial College


Alexander Fleming: **Penicillin**


Denis Gabor: **Holography**


Rodney Porter: **Stucture of Antibodies**

Andrew Huxley: **Nerve Impulses**

Abdus Salam: **Theoretical Physics**

Some of the Past Scientists

George Finch (1888-1970) developed breathing apparatus to be used at high altitudes, testing his designs personally. In 1922 he reached 27,300 feet on Everest, higher than any human had previously climbed

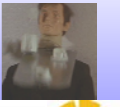
Henry Tizard (1885-1959) contributed to the development of the radar, which he supervised and championed as chairman of the Aeronautical Research Committee in the run-up to WWII

Eric Laithwaite (1921-1997) developed magnetically-levitated (maglev) high-speed trains

David Potter (1943-) joined Imperial in 1970 as a lecturer in physics. He went on to form the IT company PSION that launched its first volume-produced handheld computer in 1984

William Hamilton (1936-2000) was one of the greatest evolutionary theorists of the twentieth century. His work provided the basis for a gene-centric view of evolution

Pioneers in EEE Department



Aryton and Perry - designers of the permanent magnet ammeter in 1883

Hertha Aryton - first woman member of the IEE (now IET)
Developed the Aryton Flapper Fan which was use to clear trenches of poison gas in the First World War

Alec Harley Reeves CBE - invented pulse-code modulation in 1937

Denis Gabor – invented holography. Nobel prize winner.

Eric Laithwaite - linear motors and magnetic levitation (Maglev).
Shanghai Maglev Train (SMT) is the fastest commercial train in the world, 431 km/h (268 mph). See the SCMaglev and Railway Park in Nagoya, Japan!
Q's decapitating tea tray in the James Bond film *'The Spy Who Loved Me'*

Some of Today's Scientists

John Burland prevented the Leaning Tower of Pisa from toppling over

Magdi Yacoub is one of the pioneers of heart surgery. He helped to develop the techniques of heart and heart-lung transplantation

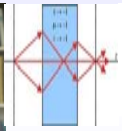
Donal Bradley developed polymer light emitting diodes today translated into lightweight, low-power displays for products such as mobile phones

Julia Higgins is known both for her research on the behaviour of complex materials and her work to promote the participation of women in science, engineering and technology

Ravinder Maini and Marc Feldmann have researched extensively on rheumatoid arthritis and made major breakthroughs in its treatment

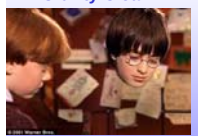
Professor Sir John Pendry
Department of Physics

Star Trek's Romulan War Bird Cloaking Device

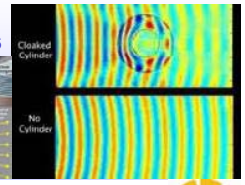


The Perfect Lens
(ISBN: 0843414028 / 0-84341-402-8)
John Pendry
Bookseller: Books From California (Simi Valley, CA, U.S.A.)
Bookseller Rating:
Quantity Available: 1

Harry Potter's Invisibility Cloak



Duke University, 2006



Professor Stefan Maier
Department of Physics

Centre for Plasmonics and Metamaterials
http://www3.imperial.ac.uk/plasmonmeta

Department of Physics
Professor John Pendry, THz metamaterials
http://www3.imperial.ac.uk/people/j.pendry
Professor Stefan Maier, THz Plasmonics
http://www3.imperial.ac.uk/people/s.maier

Department of Materials
Professor Norber Klein, THz Material Characterization
http://www3.imperial.ac.uk/people/n.klein

Department of Electrical and Electronic Engineering
Professor Richard R. A. Syms

OSD Group Facilities

- 1 CAD lab
- 1 general clean room
- 1 nanotechnology Lab
- 1 chemistry lab
- 1 laser lab
- 1optics lab
- 1 packaging lab

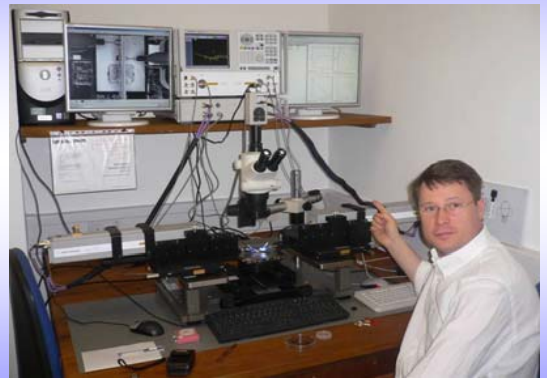
Optical & Semiconductor Devices Group (OSDG)

Members of the OSD Group

- One of 5 groups in EEE
- Founded 1980
- ~ 40 Members
- 8 Academic staff
- 4 Visiting Professors
- ~ 15 Research fellows
- ~ 15 PhD students

- **Design**
  - Cadence, Mentor, ANSYS
  - HFSS, CST, Microwave Studio
- **Fabrication**
  - Implantation, diffusion
  - Oxidation, Metallisation
  - Electroplating
  - S/S & D/S lithography
  - RIE & DRIE; KOH
- **Test**
  - Surface analysis, SEM
  - Electronics, optics, mechanics
  - 10 MHz to 110 GHz RFOW

Agilent N5250A Performance Network Analyser (PNA) for Single-Sweep 10 MHz to 110 GHz On-Wafer RF Measurements (the device under test is a 2 GHz RF MEMS power switch)



THz Research within OSD Group

Dr Ekaterina Shamonina, together with one of our research fellows **Dr Oleksiy Sydoruk**, have publishing (with **Professor Laszlo Solymar** at Oxford) the following 2010 papers:

1. Sydoruk O., Syms R.R.A., Solymar L. “Plasma oscillations and terahertz instability in field-effect transistors with Corbino geometry・Appl. Phys. Lett. 97, 263504 (2010)
2. Tatartschuk E., Radkovskaya A., Shamonina E., Solymar L. “Generalized Brillouin diagrams for evanescent waves in metamaterials with interelement coupling・Phys. Rev. B 81, 115110 (2010)
3. Sydoruk O., Savenkov S. N. "White polarization sandwiches: optical elements with non-orthogonal polarizations" J. Opt 12, 035702. 1-5 (2010)
4. Sydoruk O., Shamonina E., Solymar L. "Solid-state traveling-wave amplifiers and oscillators in the THz range: effect of electron collisions" Eur. Phys. J. D 59, 233・40 (2010)
5. Sydoruk O., Kalinin V., Solymar L. "Terahertz instability of optical phonons interacting with plasmons in two-dimensional electron channels" Appl. Phys. Lett. 97, 062107 (2010)
6. Sydoruk O., Shamonina E., Kalinin V., Solymar L. "Terahertz instability of surface optical-phonon polaritons that interact with surface plasmon polaritons in the presence of electron drift" Phys. Plasmas 17, 102103 (2010)
7. Radkovskaya A., Tatartschuk E., Sydoruk O., Shamonina E., Stevens C. J., Edwards D. J. Solymar L. "Surface waves at an interface of two metamaterial structures with interelement coupling“ Phys. Rev. B 82, 045430 (2010)

Metamaterials Research with OSD Group

Professor Richard R. A. Syms
Head of the OSD Group

Magneto-inductive waveguides, Parametric amplification,
Near-field imaging devices, Devices for magnetic resonance imaging,
Plasmonics, THz amplifiers

2 Book:
Practical Volume Holography, Oxford University Press, 1990
Optical Guided Waves and Devices, McGraw-Hill Companies,1992

Associate Editor for the IEEE/ASME Journal of Microelectromechanical Systems
Associate Editor for Metamaterials

Dr Ekaterina Shamonina

Waves in Metamaterials , Oxford University Press, 2009

My THz Research Within the OSD Group

Dr Stepan Lucyszyn

Analytical modelling of metallic THz structures

2 Books:
RFIC and MMIC Design and Technology, Institution of Electrical Engineers (IEE), 2001
Advanced RF MEMS, Cambridge University Press, 2010

My Current PhD students working in THz:

William Otter	THz EM modelling and plasmonic filter banks
Fangjing Hu	Ultra-low cost wireless THz communication links
Stergios Papantonis	Novel THz metal waveguide structures
Elpida Episkopou	Reconfigurable THz Integrated Architectures
Manuel Pinuela	EM Energy Scavenging

1. Y. Zhou and S. Lucyszyn, "Modelling of reconfigurable terahertz integrated architecture (RETINA) SIW structures", EM Academy's PIER Journal, vol. 105, pp. 71-92, Jun. 2010
2. S. Lucyszyn and Y. Zhou, "Characterising room temperature THz metal shielding using the engineering approach", EM Academy's PIER Journal, vol. 103, pp. 17-31, Apr. 2010
3. S. Lucyszyn and Y. Zhou, "THz applications for the engineering approach to modelling frequency dispersion within normal metals at room temperature", EM Academy's PIERS Online Journal, vol. 6, no. 3, pp. 293-299, Feb. 2010
4. S. Lucyszyn and Y. Zhou, "Engineering approach to modelling frequency dispersion within normal metals at room temperature for THz applications", EM Academy's PIER Journal, vol. 101, pp. 257-275, Feb. 2010
5. Y. Zhou and S. Lucyszyn, "HFSS modelling anomalies with THz metal-pipe rectangular waveguide structures at room temperature", EM Academy's PIERS Online Journal, vol. 5, no. 3, pp. 201-211,Mar. 2009
6. S. Lucyszyn, "Microwave characterization of nickel", EM Academy's PIERS Online Journal, vol. 4, no. 6, pp. 686-690, Jun. 2008
7. S. Lucyszyn, "Evaluating surface impedance models for terahertz frequencies at room temperature", EM Academy's PIERS Online Journal, vol. 3, no. 4, pp. 554-559, Jun. 2007
8. S. Lucyszyn, "Investigation of Wang's model for room temperature conduction losses in normal metals at terahertz frequencies", IEEE Transactions on Microwave Theory Tech., vol. 53, no. 4, pp. 1398-1403, Apr. 2005
9. S. Lucyszyn, "Investigation of anomalous room temperature conduction losses in normal metals at terahertz frequencies", IEE Proceedings - Microwaves, Antennas and Propagation, vol. 151, no. 4, pp. 321-329, Aug. 2004
10. S. Lucyszyn, D. Budimir, Q. H. Wang and I. D. Robertson, "Design of compact monolithic dielectric-filled metal-pipe rectangular waveguides for millimetre-wave applications", IEE Proceedings – Microwaves, Antennas and Propagation, vol. 143, no. 5, pp. 451-453, Oct. 1996

LECTURE COURSE: RADIO FREQUENCY ENGINEERING

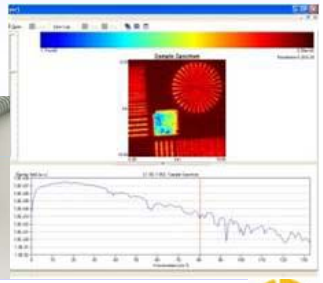
RATIONALE
This is a radio frequency (i.e. from dc to sub-millimetre-wavelength) engineering course, with 6 lectures, aimed at postgraduate physics and engineering students wishing to bridge their gap in knowledge of how theoretical principles can be engineered for real life applications. A coherent theme runs throughout this course, with a view to 'seeing' interrelated technologies from different perspectives. It is hoped that the physics students will be able to discover synergies between these RF engineering topics and their existing understanding of photonic principles.

CONTENTS
Lecture #1: Passives
Lecture #2: Devices, Mixers and Modulators
Lecture #3: Radio Frequency Microelectromechanical Systems (RF MEMS)
Lecture #4: Scattering (S)-Parameter Analysis
Lecture #5: Metal-pipe Rectangular Waveguides
Lecture #6: *Engineering Approach* for Analytical Electromagnetic Modelling of THz Metal Structures

Department of Materials

TeraView TPS Spectra 3000 is the world's first commercial terahertz spectrometer capable of performing both transmission and attenuated total reflection (ATR) measurements from 0.06 – 4 THz

TeraView's spectrometers do not require liquid helium cooling or any vacuum systems for its operation, enabling results to be obtained in a minute or less, all while operating under ambient temperature conditions.



Acknowledgements

Professor Makoto Kuwata-Gonokami

Akane Oshima

Photon Science Center of the University of Tokyo