From Metamaterials to Metadevices

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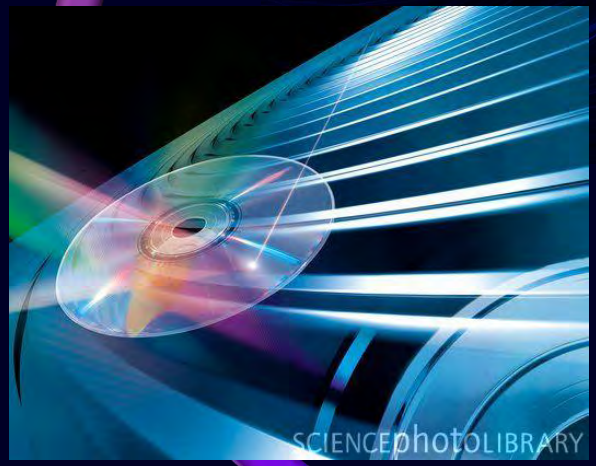
www.nanophotonics.org.uk

13 September 2012, Southampton industrial day on Metamaterials

The 1st Photonic Revolution

Global Telecommunications

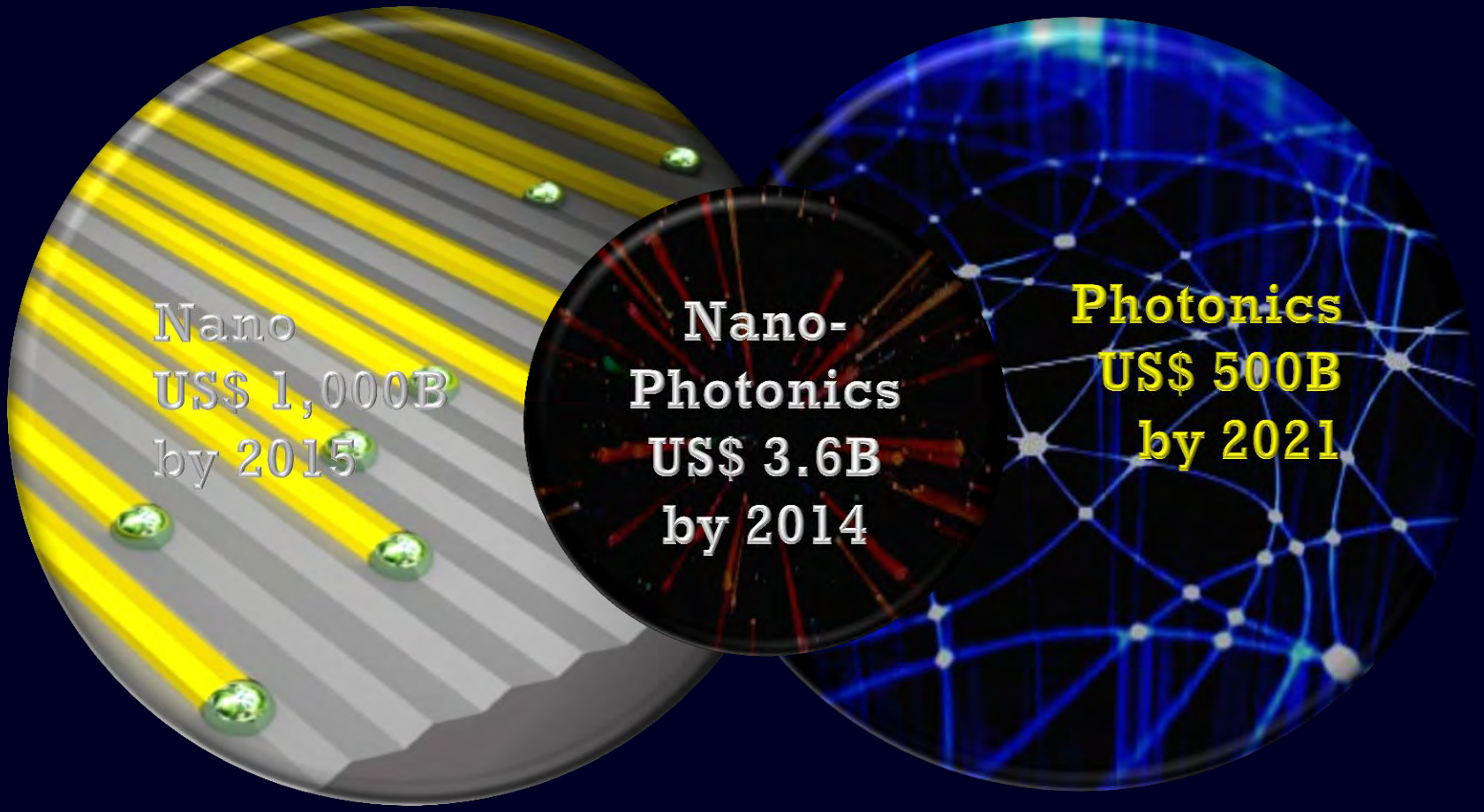


Optical Data Storage

Laser medicine

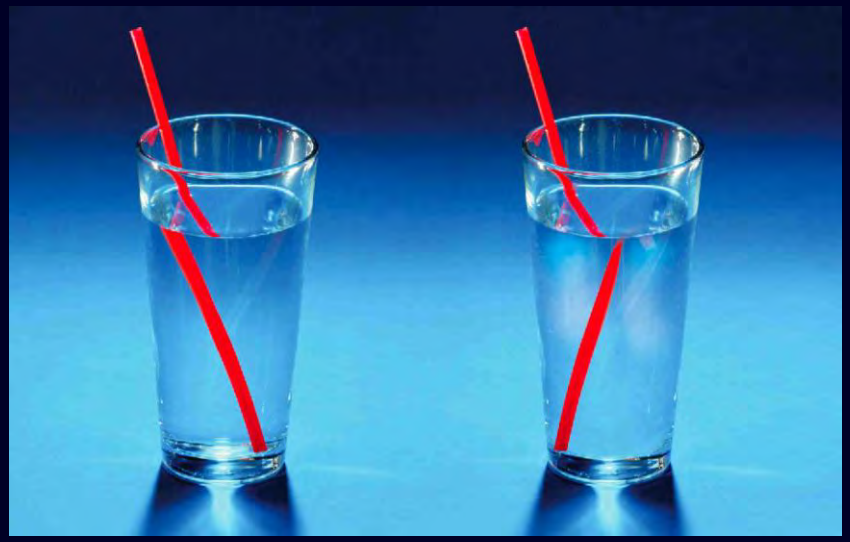
Laser manufacturing

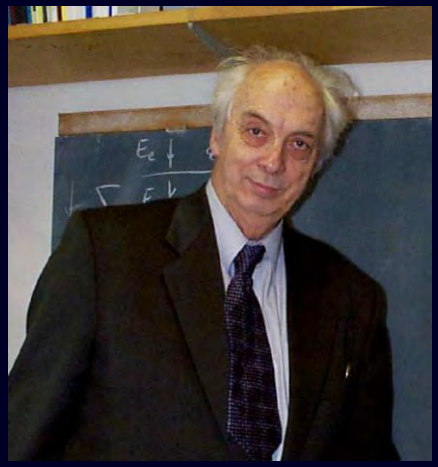
Disruptive Photonic Technologies of the XXI Century



Global Market Report by MarketsandMarkets

Metamaterials = Negative Index Media & Superlens?
Metamaterials = Invisibility & Cloaking?





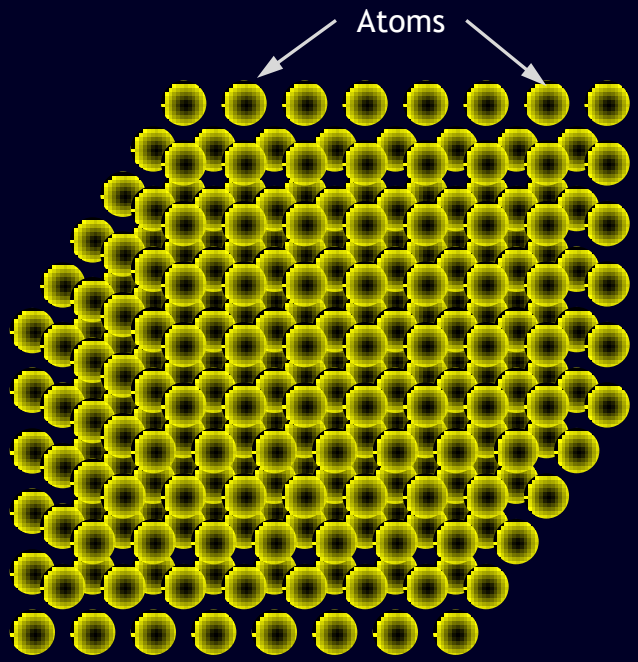
Viktor Veselago (Moscow)

Sir John Pendry (Imperial)

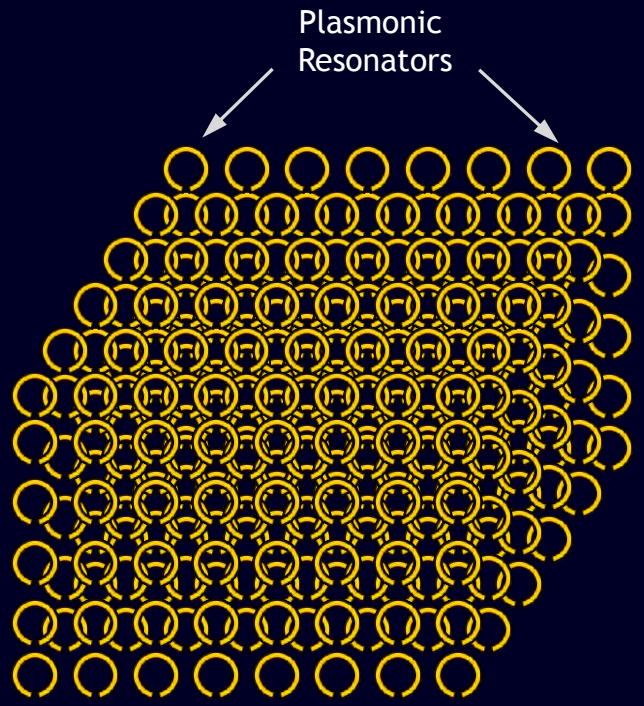
Metamaterials: mimicking Nature, step 1

Metamaterial is a manmade media with all sorts of unusual functionalities that can be achieved by **artificial structuring smaller than the length scale of the external stimulus**.

NIZ. Nature Materials **7**, 420 (2008)

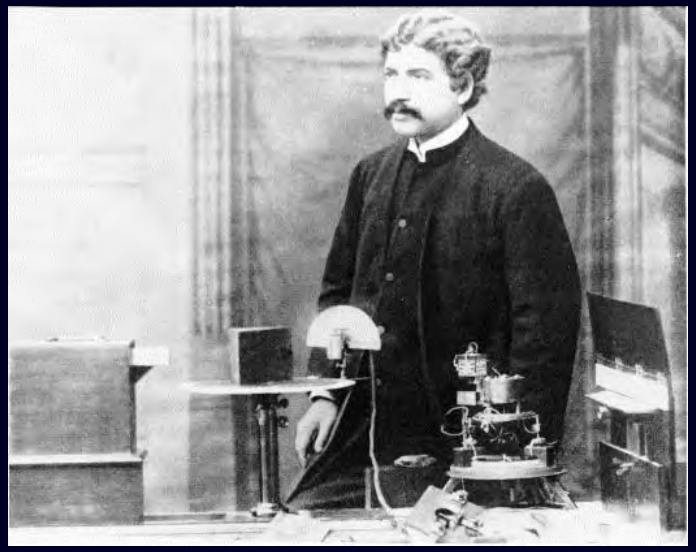


Natural Solid



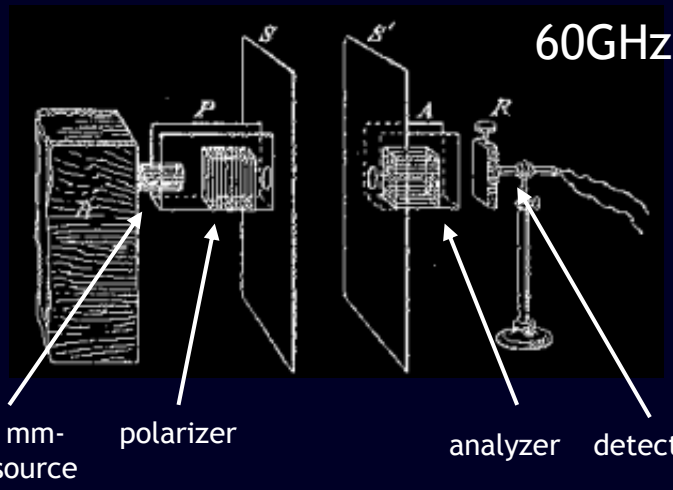
Electromagnetic
Metamaterial

1st Metamaterial (J.Bose, 1898)



Sir Jagadish Chandra Bose, 1858 – 1937

Anisotropic Meta-molecule



J.Bose. Proc. Royal Soc. of London, **63**, 146 (1898)

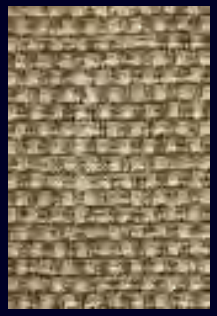
Chiral Meta-molecule

Artificial Metamaterial: from Mega to Nano

Pyramid Brick wall: 1m

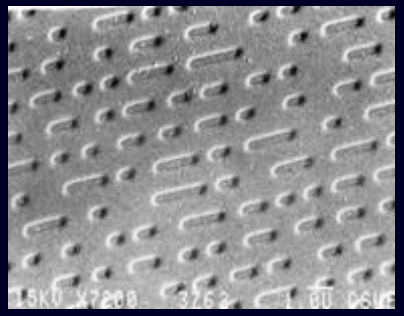
1000:1

Tweed wool: 1mm



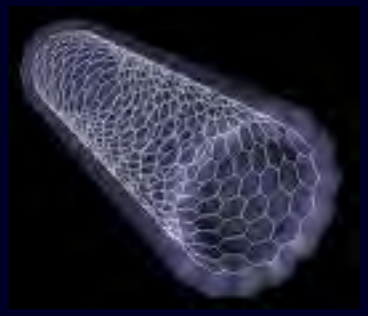
1000:1

CD tracks:1micron



1000:1

Carbon nano-tubes:1nm



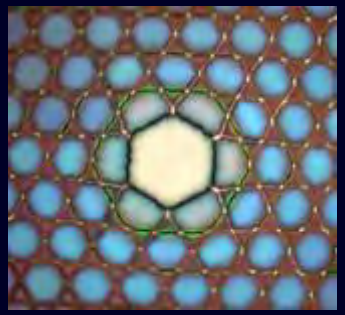
Parthenon columns: 1m

1000:1

Computer PCB: 1mm

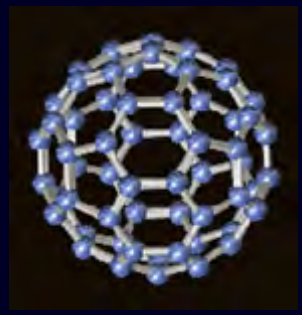
1000:1

Crystal fiber:1micron



1000:1

Carbon buckyball:1nm



Microwave meta-materials

THz meta-materials

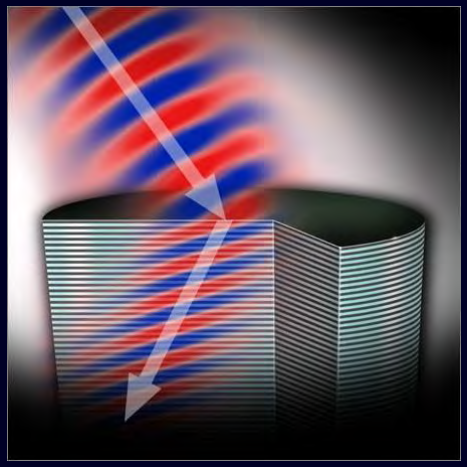
Photonic meta-materials

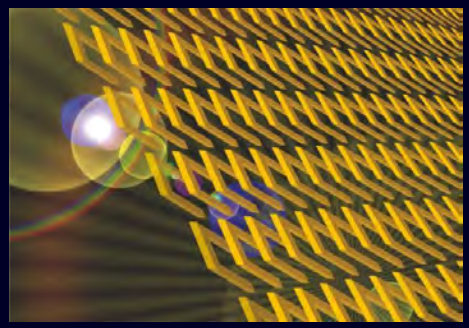
The first Generation of Metamaterials

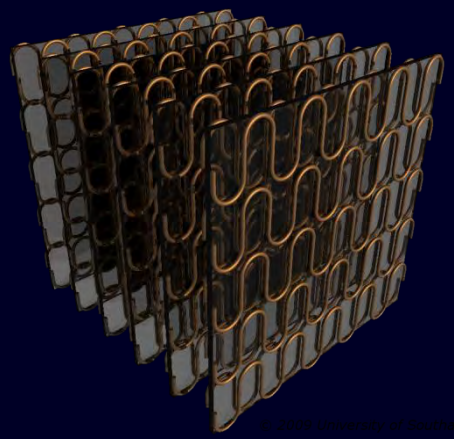
- Optical magnetism
- Negative refraction
- Negative index

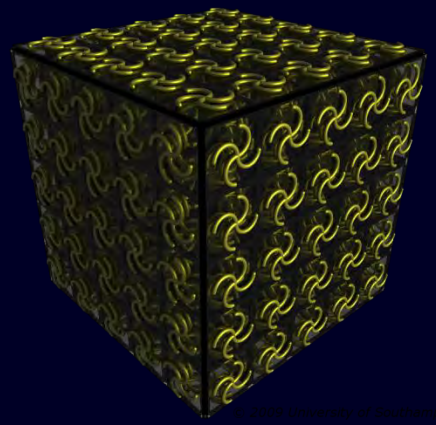
- Chirality and anisotropy
- Engineered dispersion

- Control of wave propagation
- Transformation optics
- Cloaking









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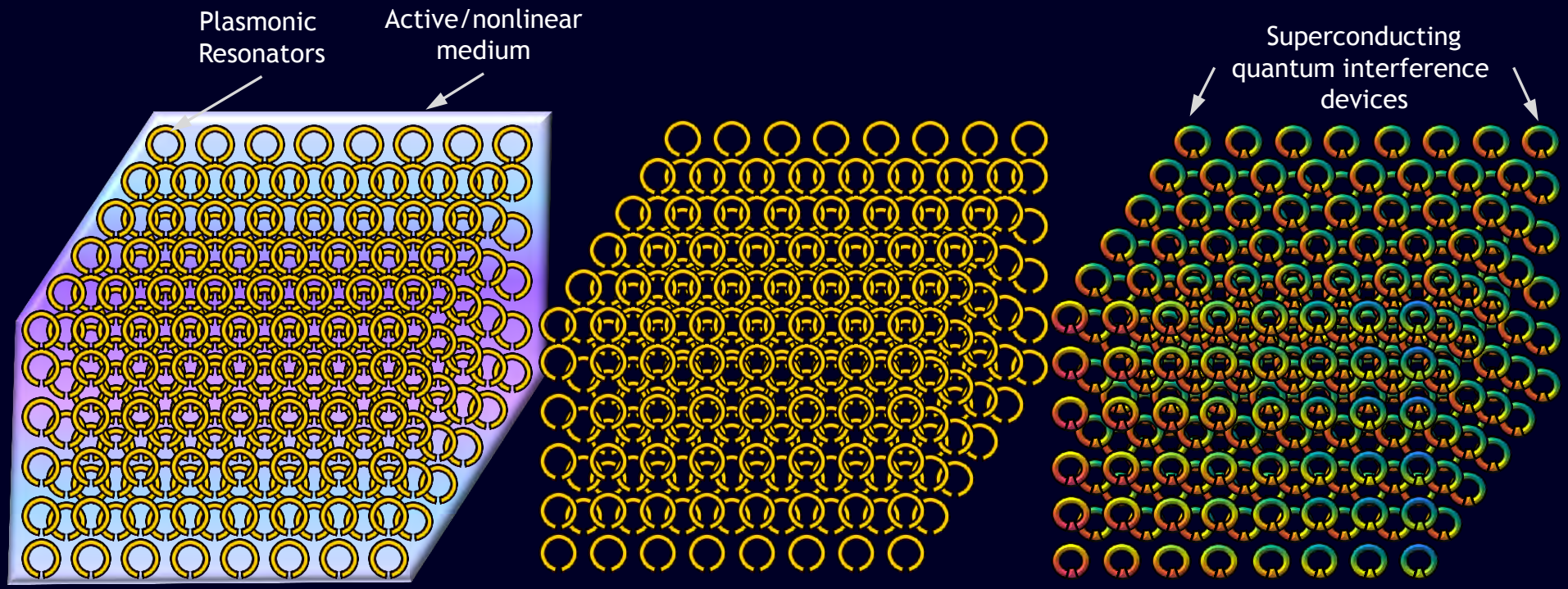
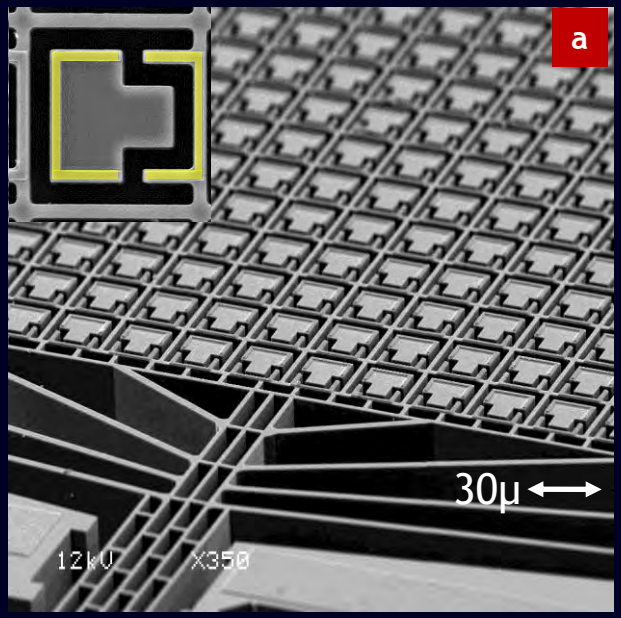
Metamaterials: mimicking Nature, step 2



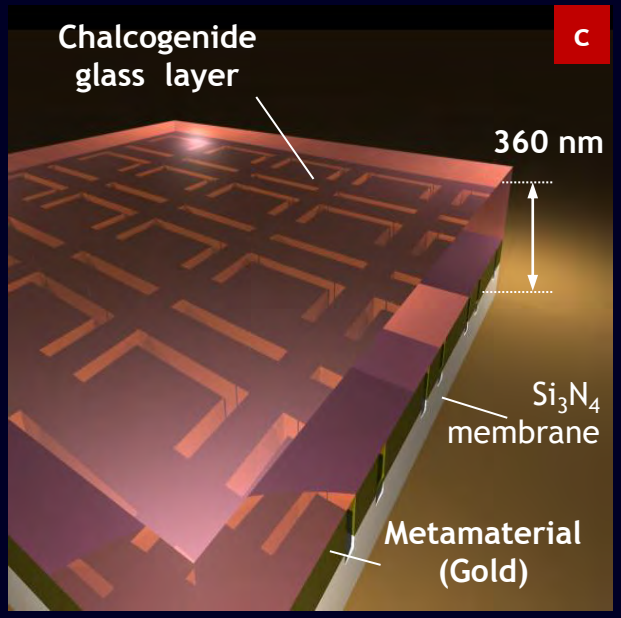
Electromagnetic Metamaterial

Reconfigurable metamaterial

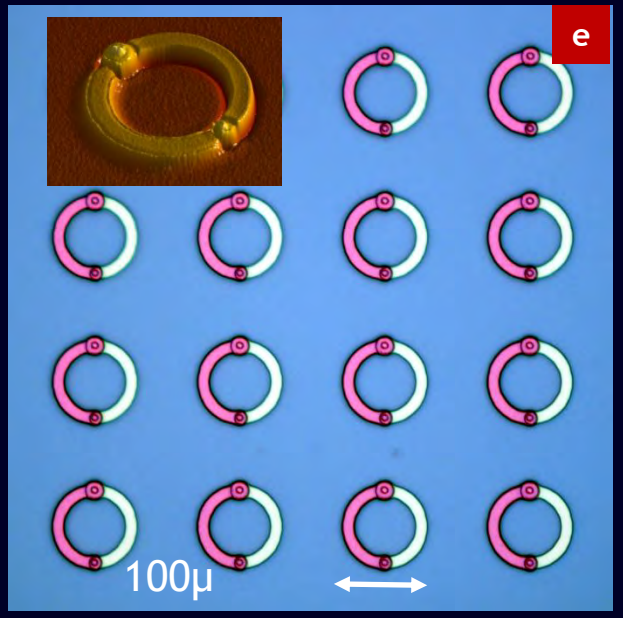
“Quantum” Metamaterial



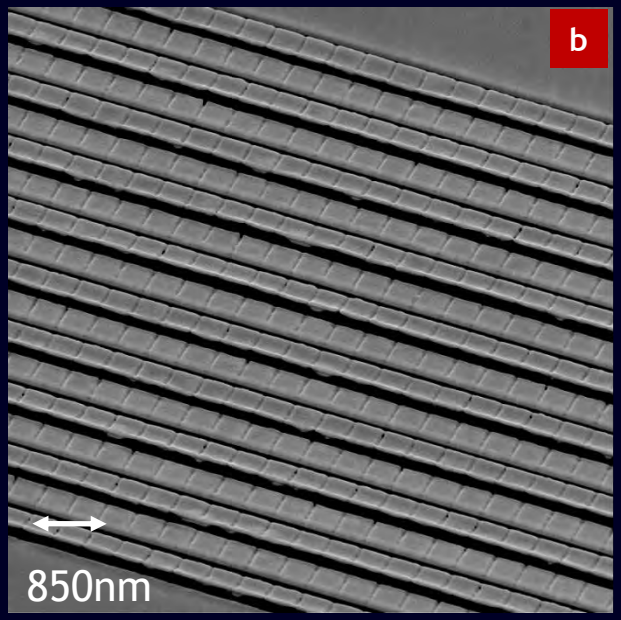
MEMS metamaterial, Nanyang Singapore



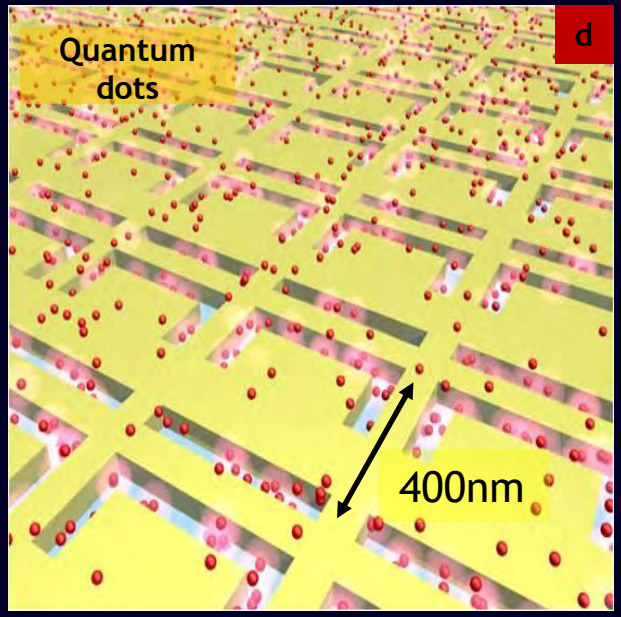
Switchable metamaterial (ChG), Southampton



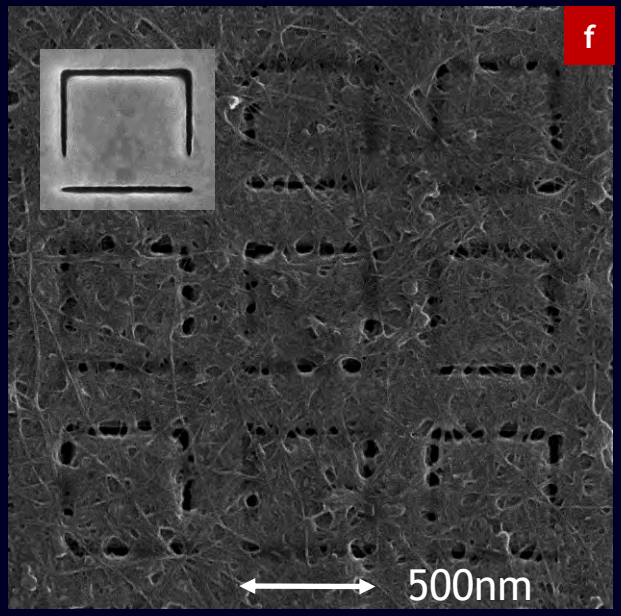
Quantum metamaterial, Southampton



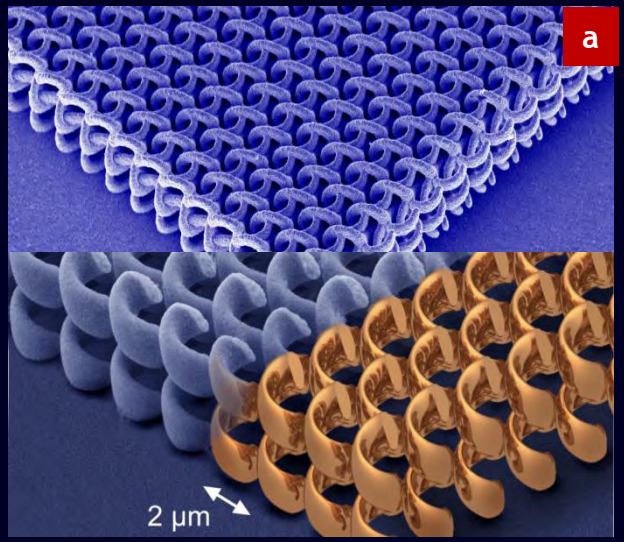
NEMS metamaterial Southampton



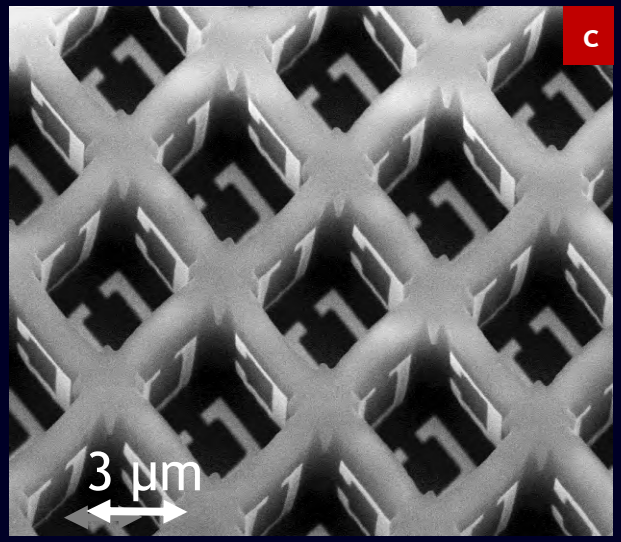
Switchable metamaterial (QDs), Southampton



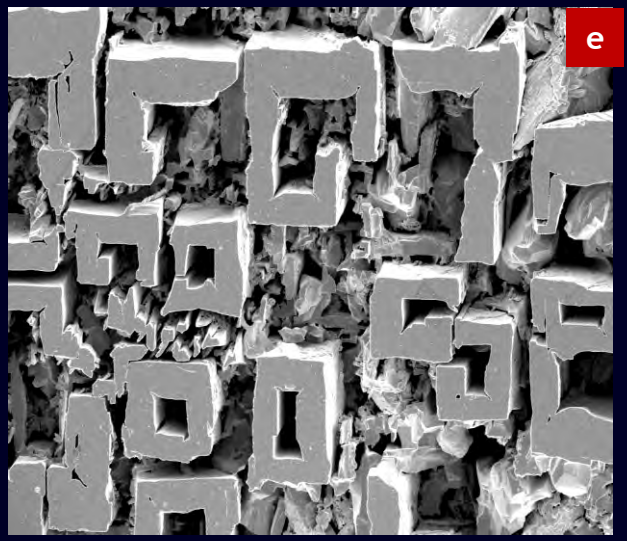
Nonlinear metamaterial (CNTs), Southampton



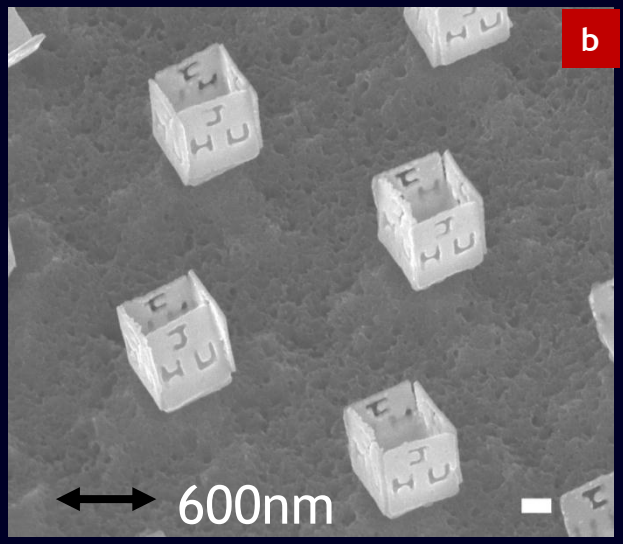
Laser Lithography,
Stuttgart & Karlsruhe



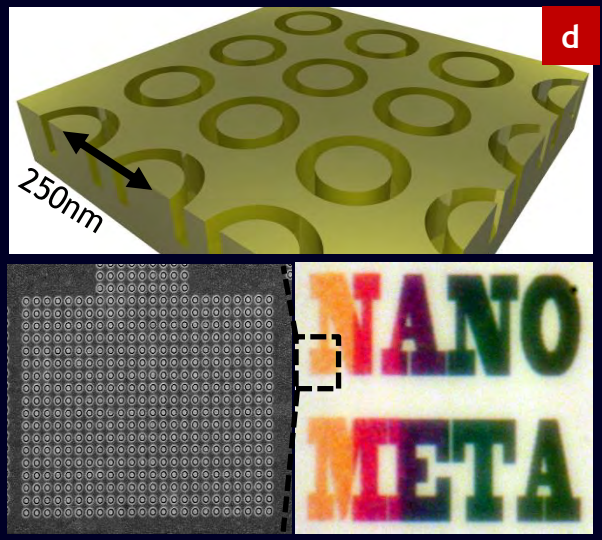
Projection lithography,
Sandia



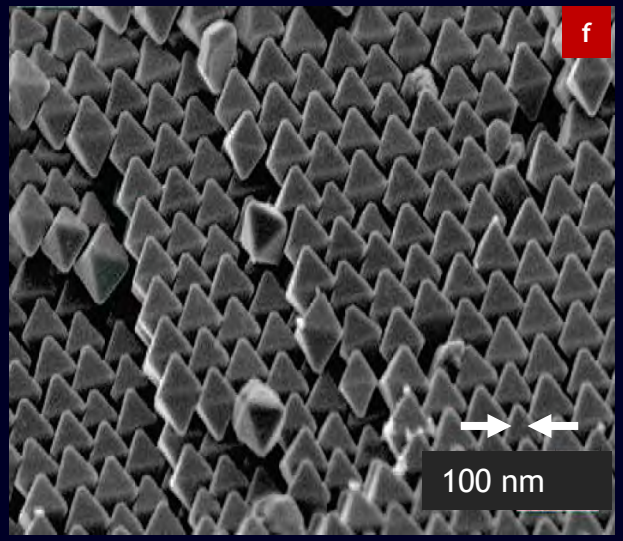
Directional solidification of eutectic,
IEM, Warsaw



Self-assembled hinged pattern,
John Hopkins



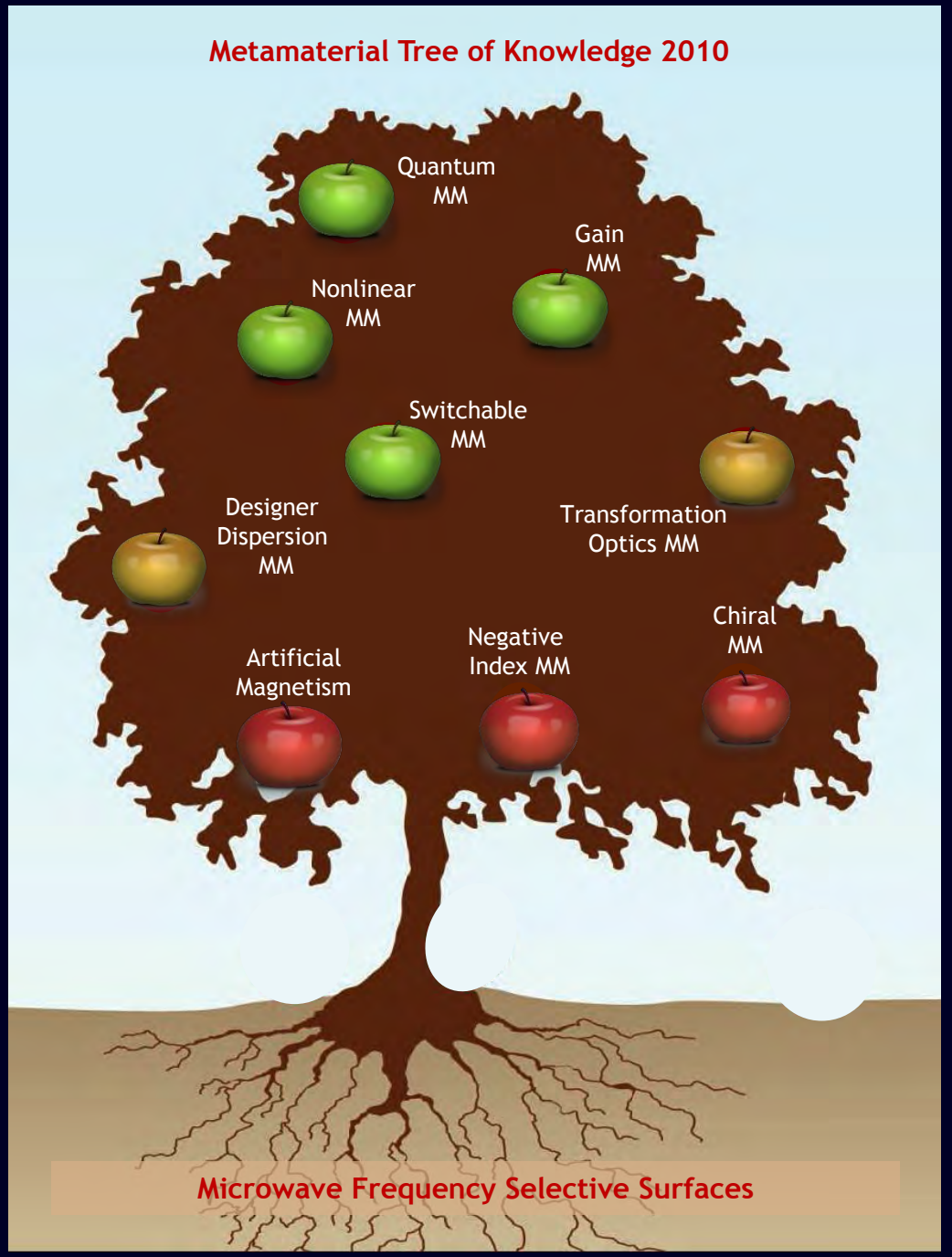
“Intaglio” all-metal metamaterial,
Southampton



Colloidal nanocrystal arrays,
Berkeley

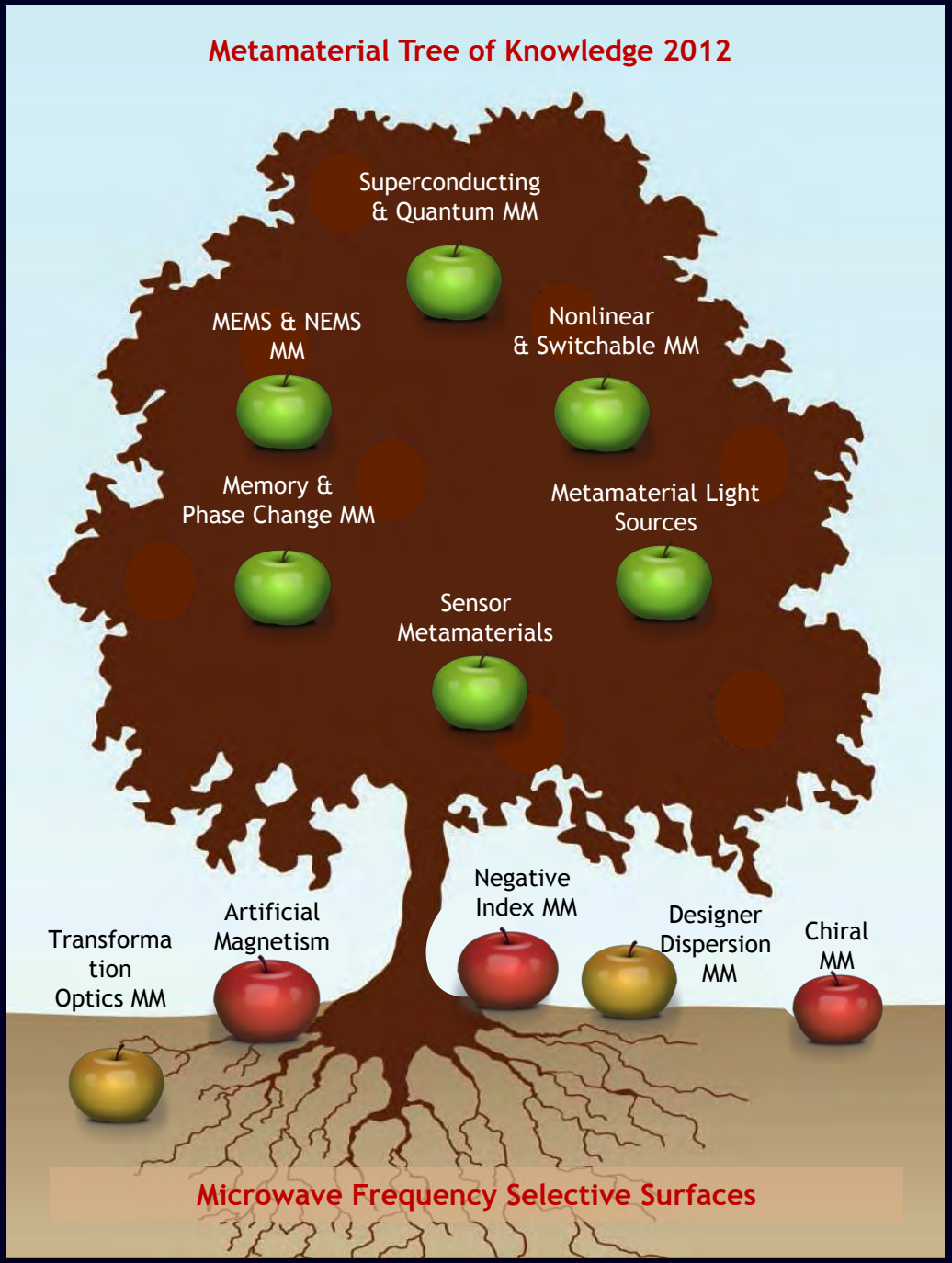
2010

N.I.Zheludev *The Road Ahead for Metamaterials*, **Science**, 328, 582 (2010)



2012


Metadevices


Metamaterial Tree of Knowledge 2012
Superconducting & Quantum MM
MEMS & NEMS MM
Nonlinear & Switchable MM
Memory & Phase Change MM
Metamaterial Light Sources
Sensor Metamaterials
Transformation Optics MM
Artificial Magnetism
Negative Index MM
Designer Dispersion MM
Chiral MM
Microwave Frequency Selective Surfaces

EPSRC Centre for Nanostructured Photonic Metamaterials
Interdisciplinary Effort


Prof. Nikolay Zheludev (ORC)


Prof. Peter Ashburn (ECS)


Prof. Peter de Groot (Physics)

Mountbatten Institute, 2012

Optoelectronics Research Centre

Prof Nikolay Zheudev (PI)
Nanophotonics and Metamaterials

Prof Rob Eason (co-I)
Microstructured Materials

Professor Dan Hewak (co-I)
Physics and Chemistry of New glasses

Dr Vassili Fedotov (co-I)
(EPSRC Carrere Acceleration Fellow)
Metamaterials

School of Physics and Astronomy

Prof Peter DeGroot (co-I)
Superconductivity
& Nano-magnetism

School of Electronics and Computer Science

Prof Peter Ashburn (co-I)
Nanofabrication
and nano-devices

School of Mathematics

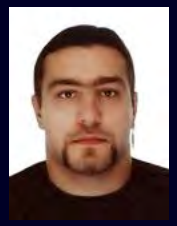
Dr Janne Ruostekoski (co-I)
Quantum Optics Theory


Prof. Dan Hewak(ORC)


Prof. Janne Ruostekoski (Maths)


Prof. Rob Eason (ORC)


Dr. Kevin MacDonald (ORC)


Dr. Vassili Fedotov (ORC)


Dr. S. Jenkins (Maths)


Dr. E. Plum (ORC)


Dr. N.Papasimakis (ORC)

Optics and Photonics: Essential Technologies for Our Nation

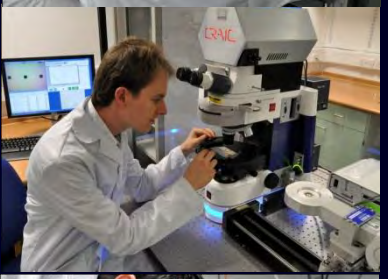
National Research Council of the National Academies, USA
August 2012

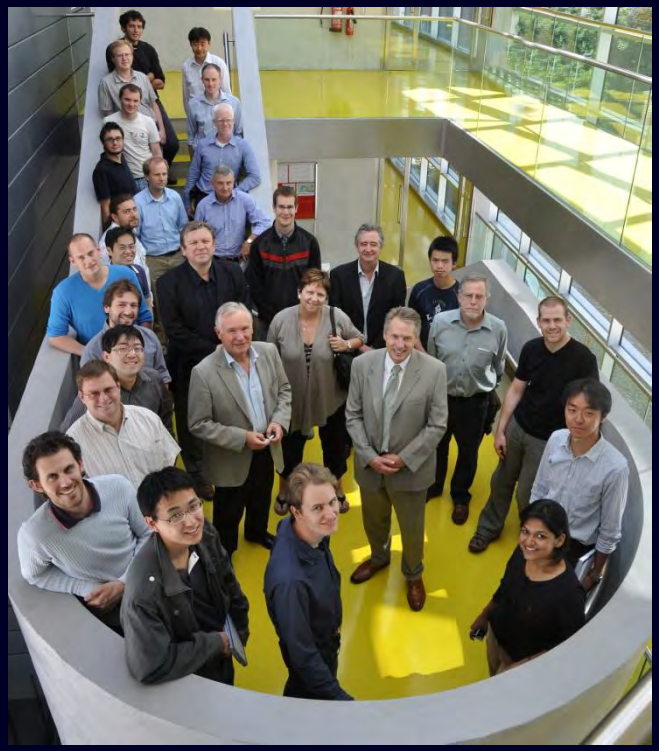
NOVEL STRUCTURES: SUBWAVELENGTH OPTICS, METAMATERIALS, AND PHOTONIC CRYSTALS

… there is much promise in tailoring existing materials in novel ways to produce innovative results. These new materials, known as metamaterials or nanophotonic materials, are materials that can be developed to exhibit new optical properties that the original materials themselves would not naturally possess. Structuring materials with features less than or close to one wavelength of light can lead to these novel properties, with the optical behavior coming more from the nanopatterning or nanostructuring than from the specific underlying materials. Such subwavelength structuring can be used with metals, semiconductors, or dielectrics, including combinations of these.

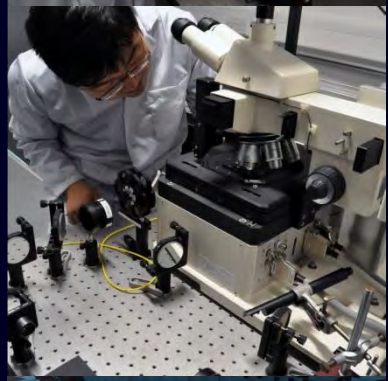
Southampton Centre for Photonic Metamaterials







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Institute of Technology of Electronic Materials, Poland
University of Freiburg, Germany, Data Storage Institute, Singapore
CUDOS-2 Consortium, Australia, Naval MURI: UPenn, Harvard,
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