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Space Research Centre,
Department of Physics and Astronomy

Graphene as an Enabler for Earth Observation

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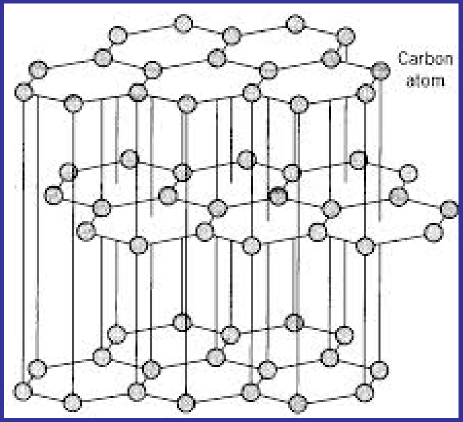
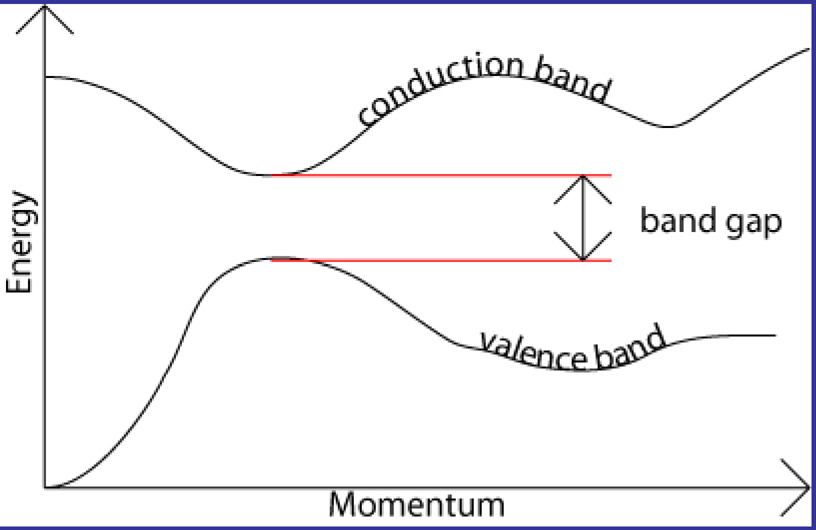
Current Photodetector Technology

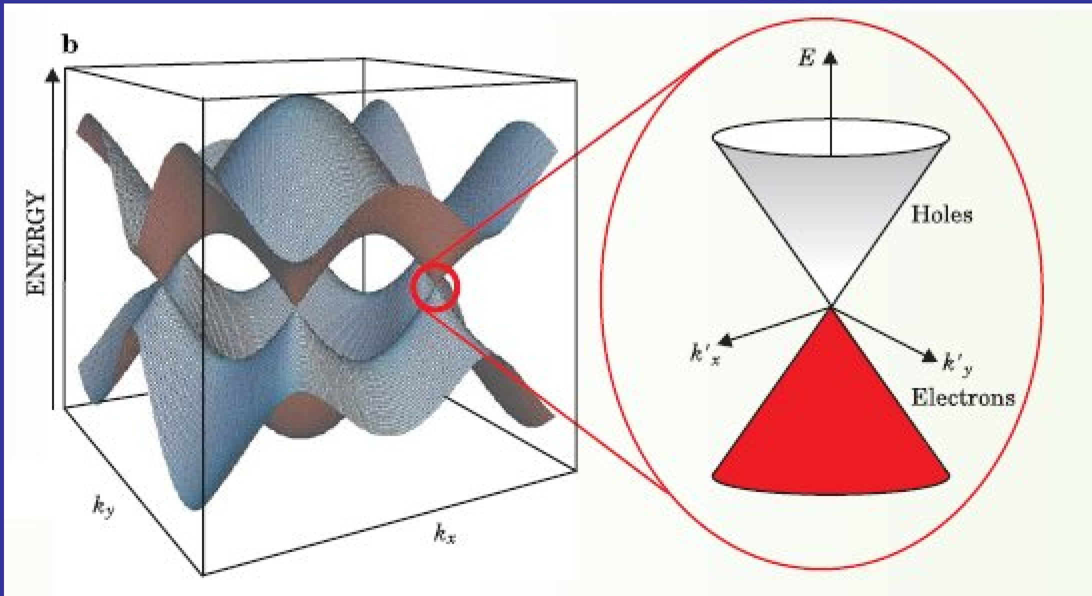
- Single Photon Counting Photodetectors:
  - Superconducting Tunnelling Junctions
  - Microwave Kinetic Inductance Detector
  - Transition Edge Sensor
  - **Operation at sub-Kelvin temperatures requires He-3 cooling**
- Higher energy photodetectors such as CZT, Scintillators etc

Katsnelson 2012



What is Graphene?





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GRAPHENE

Graphenea

- Graphene is a "zero-bandgap-semiconductor"

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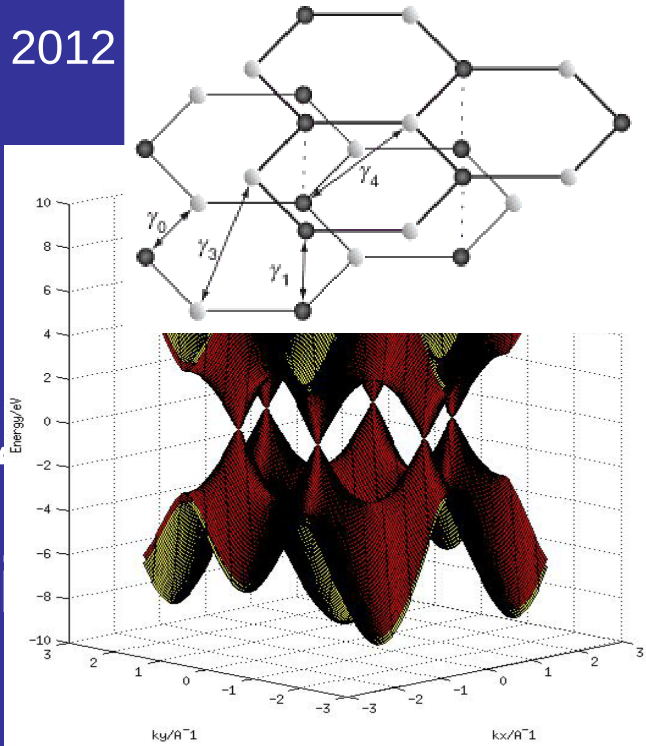
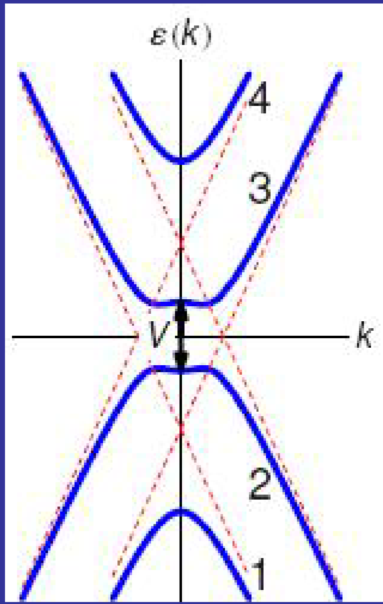
Katsnelson 2012

What is Bilayer Graphene?

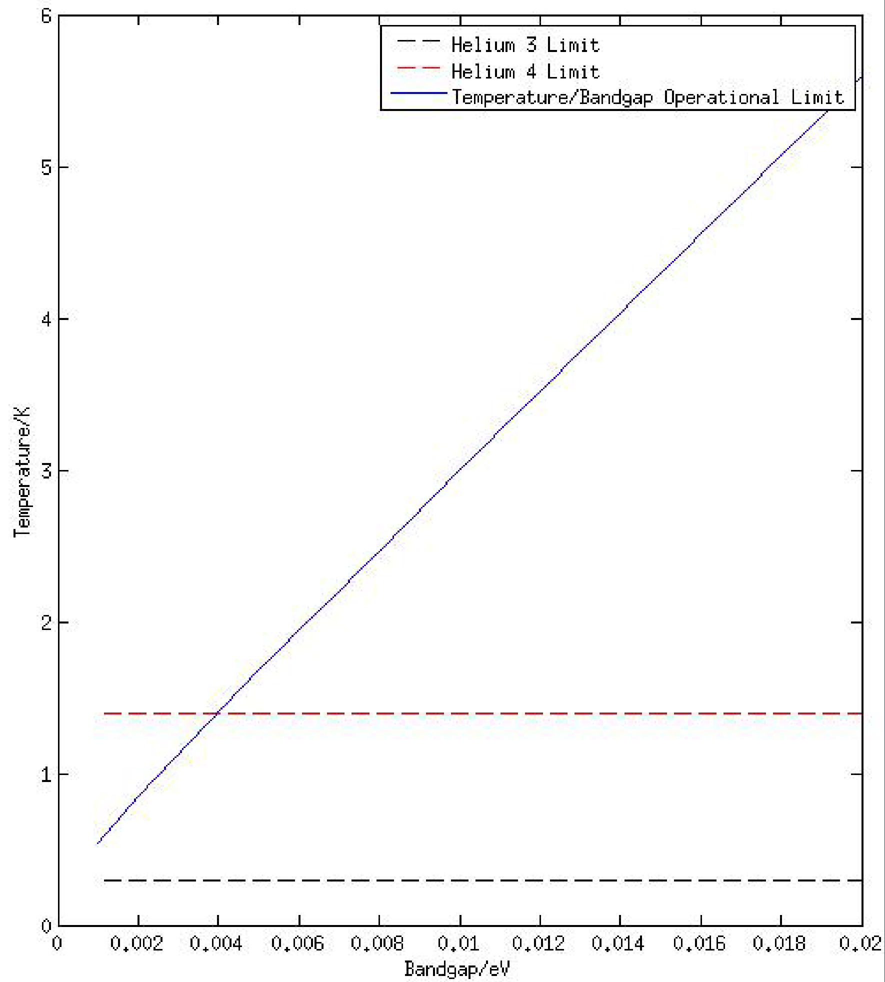


- Two layers of Carbon atoms in “
- Naturally a “zero-bandgap-semi
- Tuneable band gap
  - Can be opened by electric field, doping, nanomodulation...
- Low energy terms → trigonality
- Maintains mobility and absorption coefficient per layer



Zhang, Li 2008,

Bilayer Graphene Single Photon Counting Photodetector



- Density of states dependent on band gap and temperature → can deduce an operational limit
- Calculate the density of states and integrate over the F-D distribution to get the charge carrier density
- Look for nA<1
- Obtain operational limit → Temperature–EG trade off

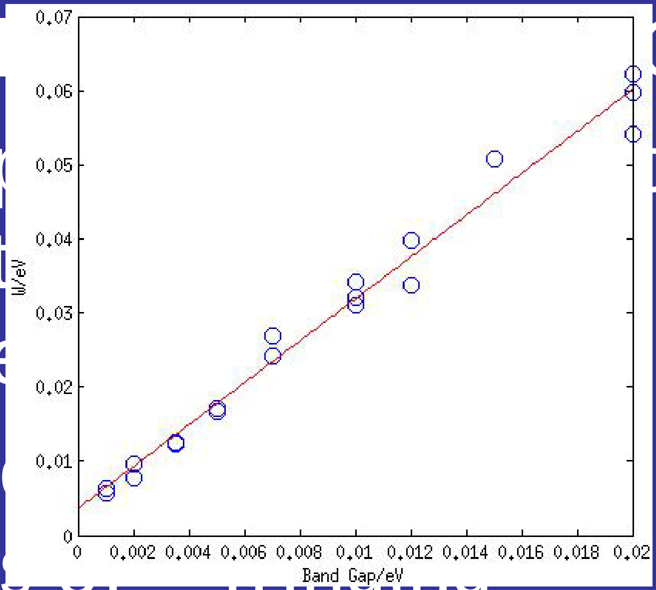
Bilayer Graphene Single Photon Counting Photodetector

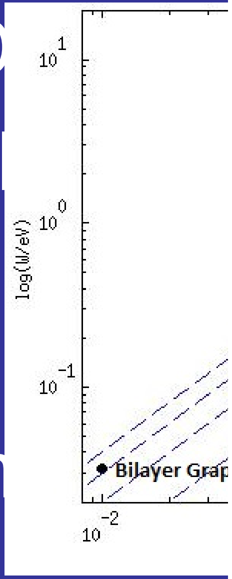
- Design Requirements:-
  - Ultrafast detector – exploit very high mobility
  - Colour sensitivity in the visible spectrum
  - Be able to operate at higher temperatures with resolution trade off
    - Wide operating range → into IR as well?

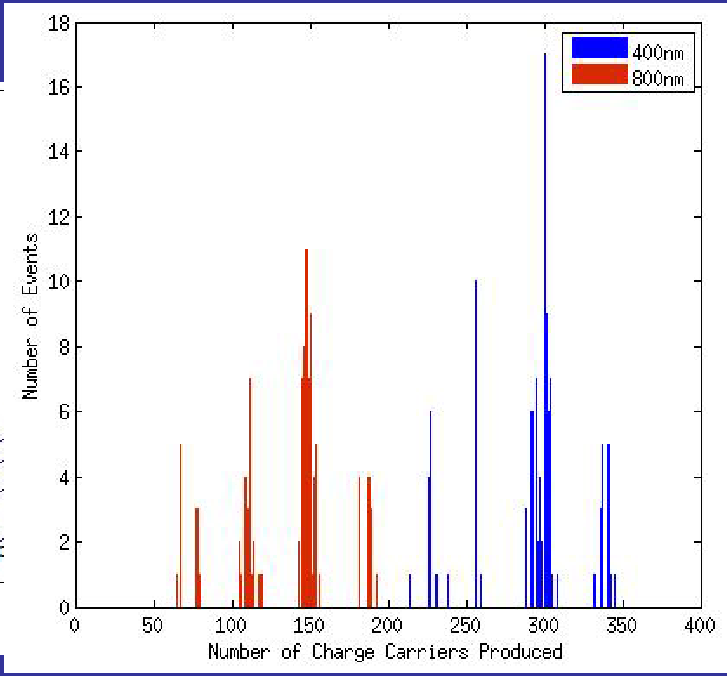
Bilayer Graphene Single Photon Counting Photodetector

Results show:

- W/E_G=3-4 ratio similar to that of silicon and germanium
- Co O
- Imp ol wit ene
- Op h loss of imaging







European Space Agency, “Future Missions Preparations Office”

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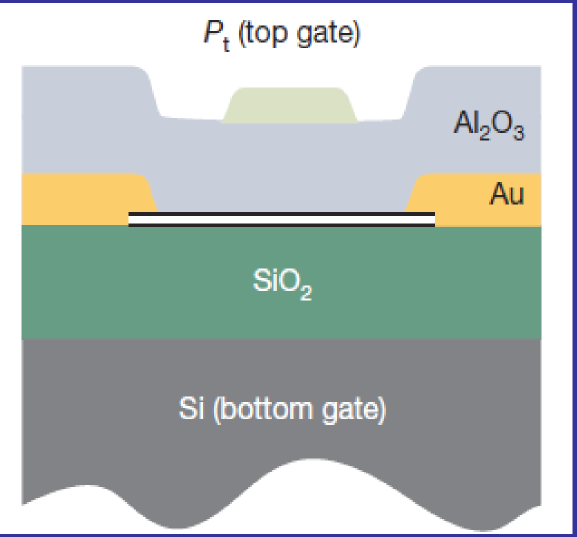
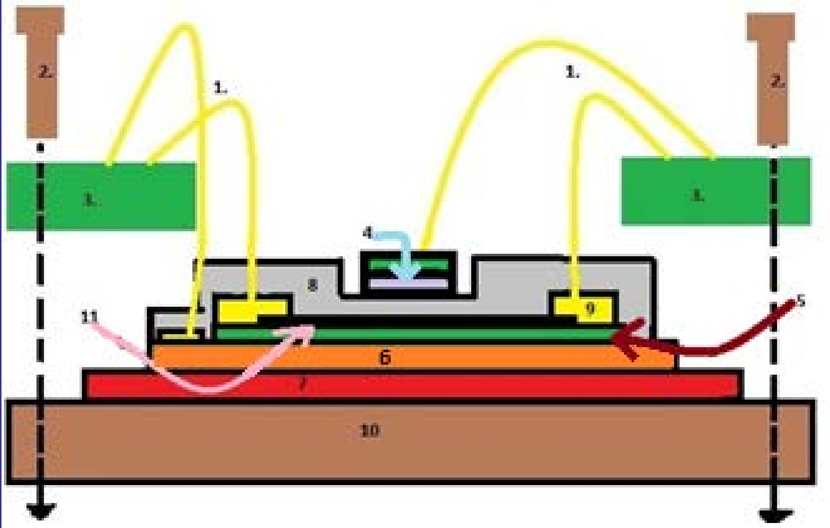
Bilayer Graphene Single Photon Counting Photodetector

- Initial prototype designs being manufactured by collaborators in Cambridge





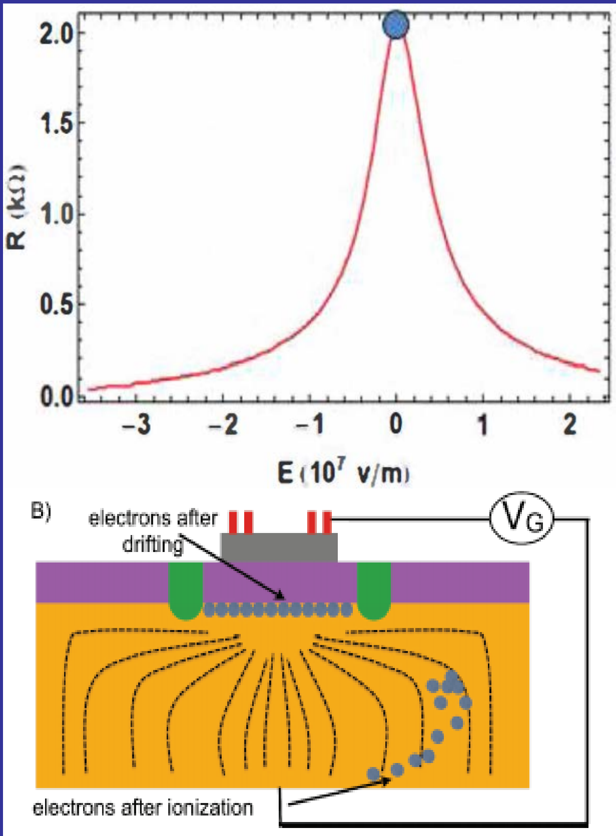
Potential EO application(s) in the Optical

- Applications would be able to operate at higher temperatures with band gap/temperature trade off

- Aerosol detection (MODIS, TOMS, OMI)
  - Single photon counter able to detect low intensity reflection peaks?
    http://disc.sci.gsfc.nasa.gov/data-holdings/PIP/aerosol_index.shtml
  - Has colour sensitivity – identify the aerosol?
- Plankton Fluoresence
  - similar to Envisat?
  - able to detect different plankton?
    http://www.esa.int/Our_Activities/Observing_the_Earth/Envisat_s_MERIS_captures_phytoplankton_bloom

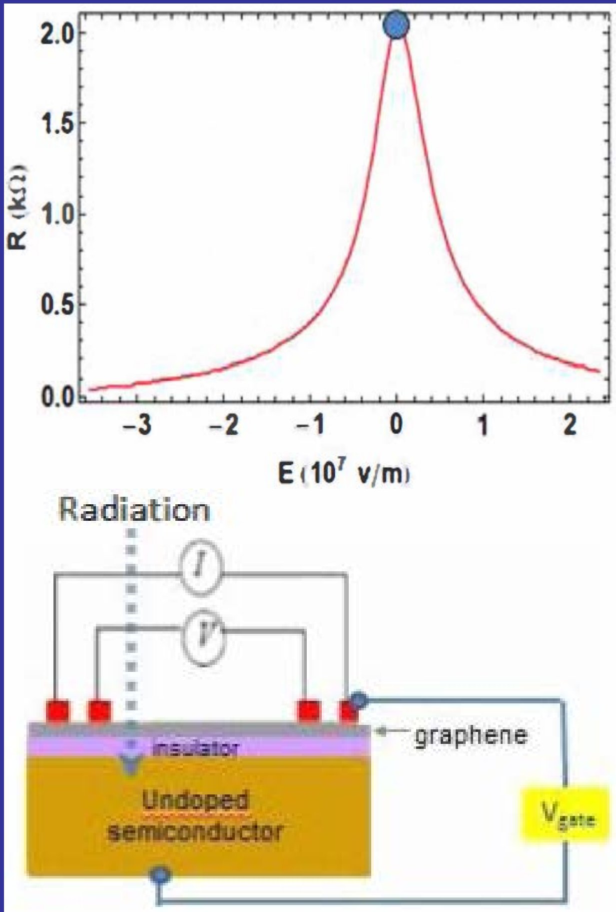
Graphene Field Effect Transistor

- Concept:-
  - Exploits Field Effect in graphene
  - Photon absorbed by Absorber material
  - Resulting ionisation liberates electrons
  - Gate voltage "funnels" electrons towards the buffer layer
  - Field across the buffer applied to graphene changes resistivity
  - Can resolve photon energy

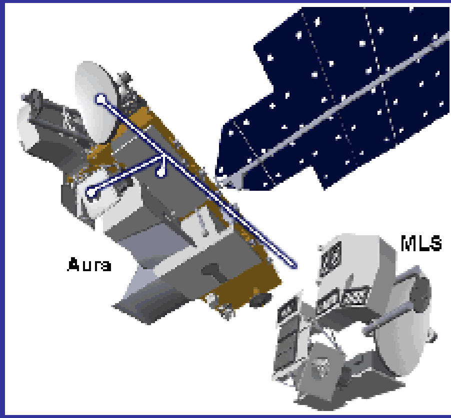


Graphene Field Effect Transistor

- Design Requirements:-
  - Prevent charge build up/ saturation
    - shown in previous GFET devices
    - avoided in GDEPFET device → harder to manufacture
  - Return the Fermi level to the Dirac point as quickly as possible → more sensitive detection
  - Project began in March 2015 so no results to show…yet



Potential EO application(s) in IR & THz



http://mls.jpl.nasa.gov/index-eos-mls.php

  - By clever design of the pixel layout, will have spatial sensitivity (as done by MKID)
- Microwave Limb Sounder
  - Measurements to understand the atmosphere through detection of thermal microwave emission from Earth's 'limb'
  - Use of graphene-based technology could allow for quicker, more sensitive detection and higher temperature with optimisation of absorber
- Radiometry
  - Issues with saturation on ASTER SWIR could be avoided

Conclusions

- Many opportunities for graphene-based technologies in Earth observation
- BLG detector able to count single photons, operating at higher temperature with colour sensitivity
- GFET to have improved energy resolution
- They would have spatial and energy sensitivity
- Aim is for a working 1-pixel BLG detector prototype by end of 2015.

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