WHAT IS GRAPHENE AND WHY IS IT SO AMAZING?

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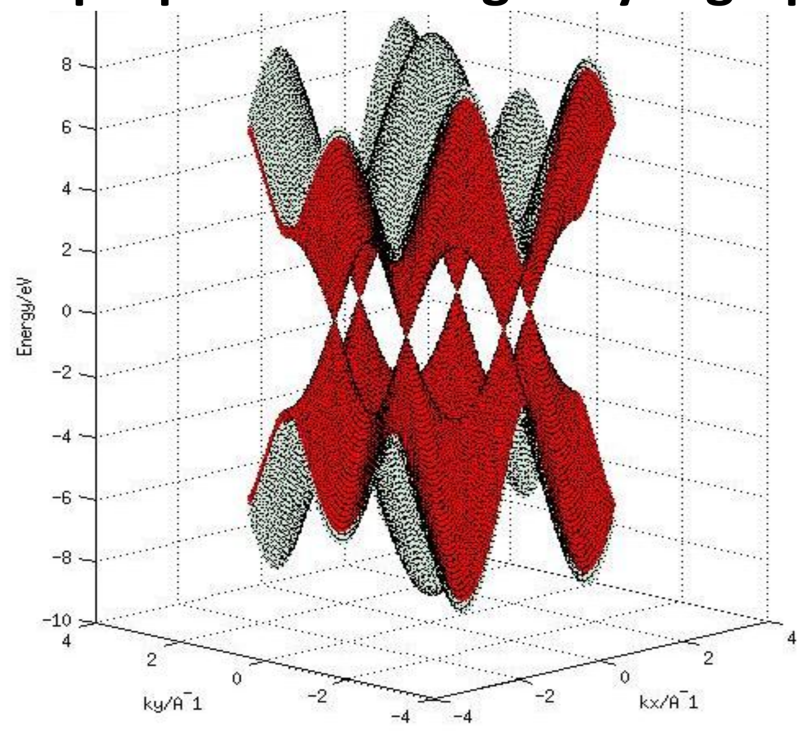
1) WHAT IS GRAPHENE?

- Graphene is the “wonder material of the 21st century”.
- It is a single layer of carbon atoms arranged in a hexagonal structure.
- It is the strongest, thinnest, most conductive material , absorbs 2.3% of light incident on it and has unique thermal properties
- In a semiconductor, there is a valence band (where electrons are stuck and unable to move) and the conduction band (where electrons can move freely).
- The gap between these bands is the band gap.
- In silicon this is about 1eV, but graphene is a zero band gap semiconductor

2) WHAT IS BILAYER GRAPHENE?

- Bilayer graphene is two layers of carbon atoms on top of each other.
- We can open a tuneable band gap in bilayer graphene by applying an electric field, by doping or by applying a straining force to it.
- Bilayer graphene absorbs 4.6% of light incident on it, and retains the unique optical, mechanical and thermal properties of single layer graphene.



3) WHAT ARE WE DEVELOPING?

- We are looking to develop a single photon counting photodetector.
- A single photon is incident on the graphene and excites an electron from the valence band to the conduction band.
- The electron relaxes, loses energy and excites more electrons into the conduction band.
- We then count the number of electrons produced and determine the energy of the photon.

4) WHAT ARE THE ADVANTAGES?

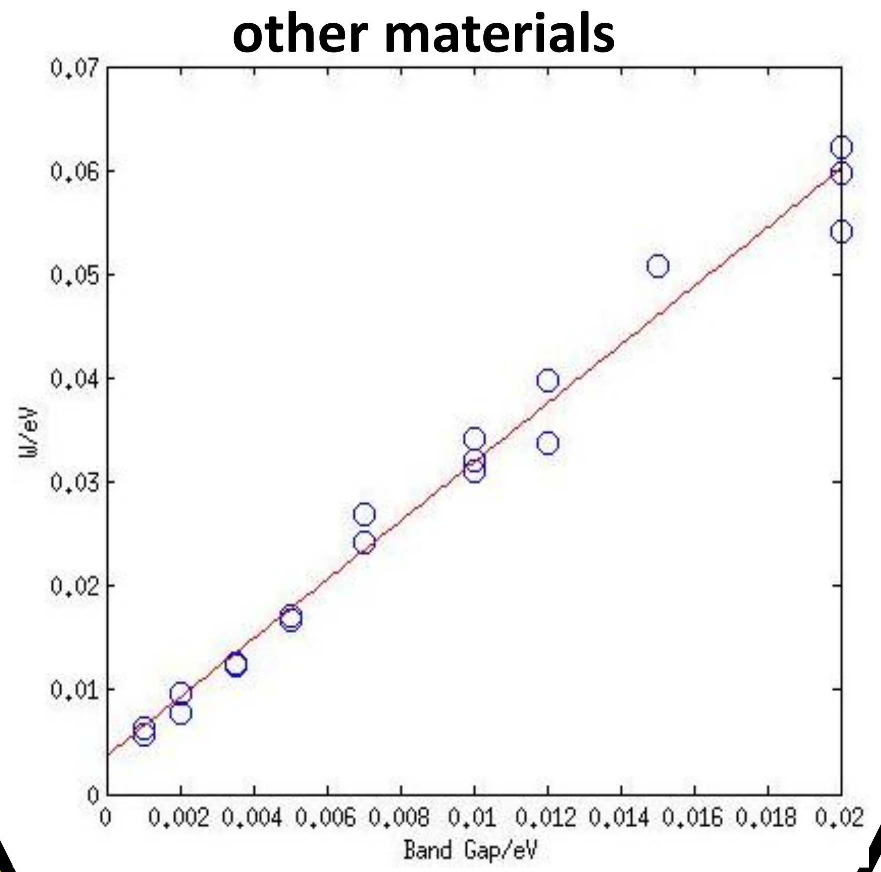
- Can operate at higher temperatures, and therefore cheaper to operate – doesn’t require expensive cryogenic cooling.
- Able to trade off resolution against temperature
- “Ultrafast” detector
- Can be built into an array

5) WHAT ARE OUR THEORETICAL RESULTS?

Our simulations show the desired characteristics for a single photon counter.

A) IONISATION ENERGY vs BAND GAP

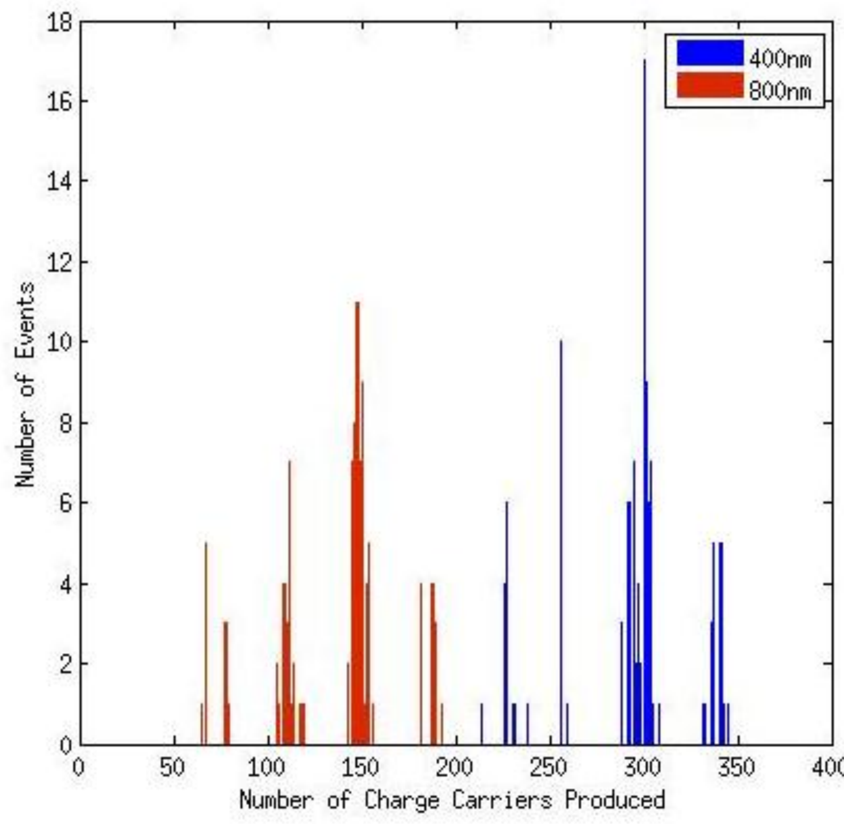
The relationship between the energy to excite an electron and the band gap is similar to other materials



5) WHAT ARE OUR THEORETICAL RESULTS?

B) COLOUR SENSITIVITY (for visible photons)

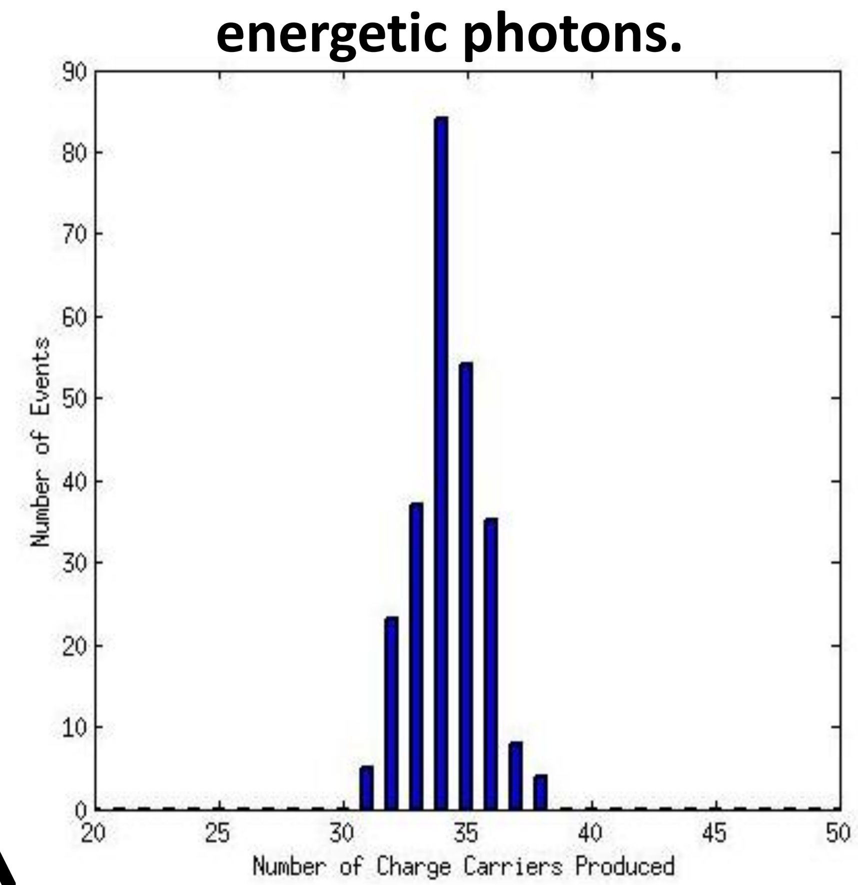
We show that the number of electrons produced is proportional to the initial energy of the photon.



5) WHAT ARE OUR THEORETICAL RESULTS?

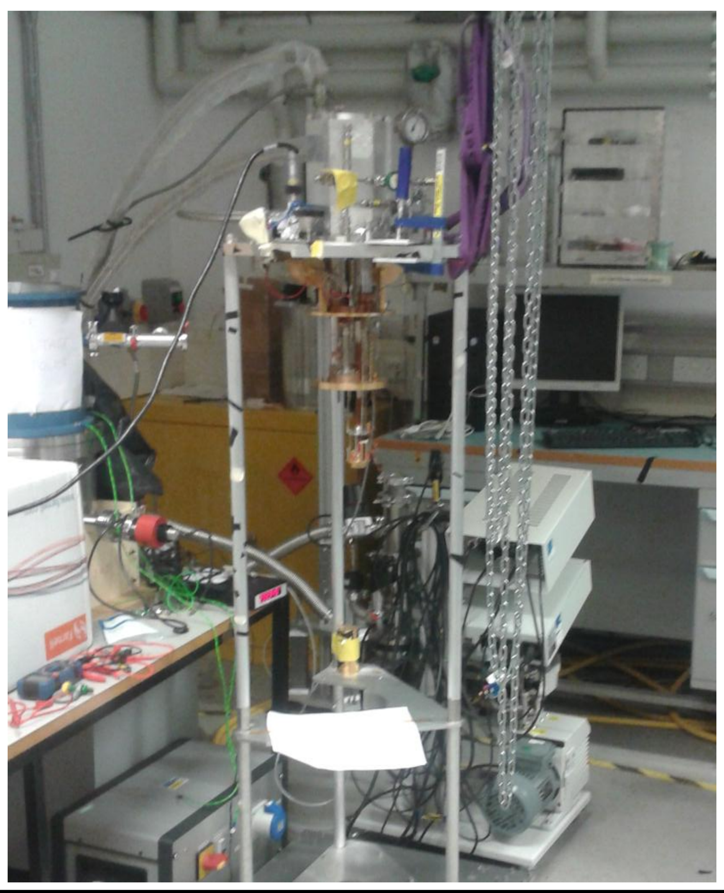
C) COLOUR SENSITIVITY (for infrared photons)

We see a response from the absorption of an IR photon. We lose the “peaks” seen for more energetic photons.



6) WHAT ARE WE DOING EXPERIMENTALLY?

- We have designed a prototype device and will cool this to 3K in our fridge (below).
- We are looking to show ionisation energy, colour sensitivity etc in our experiments.
- This will allow us to iterate our design.



7) WHAT ARE THE APPLICATIONS?

Our detector has many different applications across many different sectors:

- MEDICAL APPLICATIONS – We could potentially incorporate a bilayer single photon counter for medical uses such as CT scanning.
- SPACE BASED APPLICATIONS – We could incorporate a single photon counter on a satellite and use it for exoplanet detection and characterisations
- TIME RESOLVED PHOTODETECTION – With the high speed detection in this detector, we could use this to do time resolved fluoresence spectroscopy with applications in biosciences.

8) SUMMARY

- Our work shows that a bilayer graphene photodetector appears feasible for visible and IR single photon counting.
- Our ionisation energy-band gap relationship is similar to silicon and germanium.
- We show colour sensitivity in the visible and IR.
- This device can operate at higher temperatures, requiring cheaper cryogens, by trading off against resolution.
- These photon counters, especially in the IR spectrum, would have many applications in scientific research.

Simulations were done using the SPECTRE High Performance Computer at the University of Leicester.

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