GOSFEL

Graphene on Silicone
Free Electron Laser

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Project acronym: GOSFEL

Project title: Graphene on Silicon Free Electron Laser

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[1] Usually the contact person of the coordinator as specified in Art. 8.1. of the Grant Agreement.

[2] The home page of the website should contain the generic European flag and the FP7 logo which are available in electronic format at the Europa website (logo of the European flag: http://europa.eu/abc/symbols/emblem/index_en.htm logo of the 7th FP: http://ec.europa.eu/research/fp7/index_en.cfm?pg=logos). The area of activity of the project should also be mentioned.

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Project Summary

This project seeks a **breakthrough** in laser physics and engineering by exploiting the unique properties of graphene to demonstrate the first solid-state equivalent of a free electron laser. Compact, cost-effective, laser sources are required for such diverse applications as communications, security (e.g. missile countermeasures) and sensing (e.g. explosives). Although laser sources exist for many parts of the spectrum, there are still gaps where suitable sources are not yet available. This includes much of the far-infrared and THz. Free electron lasers (FELs) represent a radical alternative to conventional lasers, as they do not have the same restrictions on operating wavelengths and they are potentially the most flexible, high power and efficient generators of tuneable coherent radiation from the ultra-violet to the infrared.

Current free electron lasers are extremely large, expensive facilities and there are only approximately twenty operating FELs across the world. It has therefore been a long held goal of physicists and engineers to create a compact, relatively inexpensive, solid-state version of such a laser. However, to do so requires electrons in a solid to be travelling ballistically at extremely high saturation velocities. The recent isolation of graphene provides an exciting new avenue of exploration. Graphene is a single atomic layer of graphite that has a unique band structure, where the interaction of electrons with the periodic potential of graphene's honeycomb lattice gives rise to massless quasi-particles that travel at ~10^8 cm s^{-1}. Graphene also exhibits exceptionally high carrier mobility and ballistic transport up to room temperature.

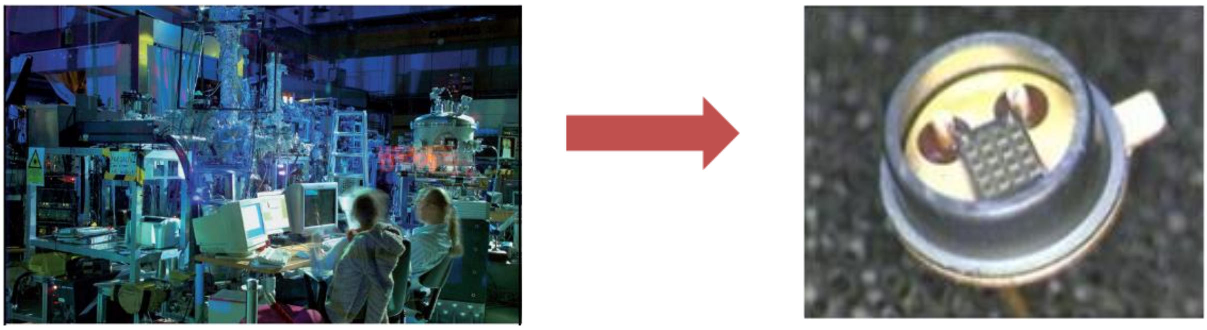

Figure 1: The aim of GOSFEL is to try and re-create the free electron laser shown on the left as a compact solid-sate device, like the device on the right.

One of the key prerequisites for the realisation of a graphene based free electron laser is the ability to prepare devices in which the graphene is of the highest quality. One of the aims of the novel work described here is to develop a silicon based architecture that enables devices to incorporate free standing graphene active regions. This approach therefore utilises the maturity and flexibility of silicon technology, and as the growth of large area graphene matures this will also offer a route to the scaling up of individual devices into eventual production.

In conclusion, the demonstration of a graphene based free electron laser has the potential to have significant impact in a number of ways: it will drive a jump in the ability to create graphene based devices, create laser sources at wavelengths at which there are no alternatives, and its operation would challenge established notions of laser operation, whilst opening up new avenues of research and development.

Accomplishments

- A fuller theoretical understanding of the underlying physics and principles of device operation has been developed, spurring new experimental investigations and new research avenues.
- A review has been made of the materials properties that can be achieved using different techniques for the preparation of the graphene, and the design trade-offs that follow from this.
- Methods have been developed for the fabrication of the key elements of the proposed device.
- The first optical devices have been fabricated and tested, including the demonstration of new collective electron effects (plasmons) in the far-infrared.

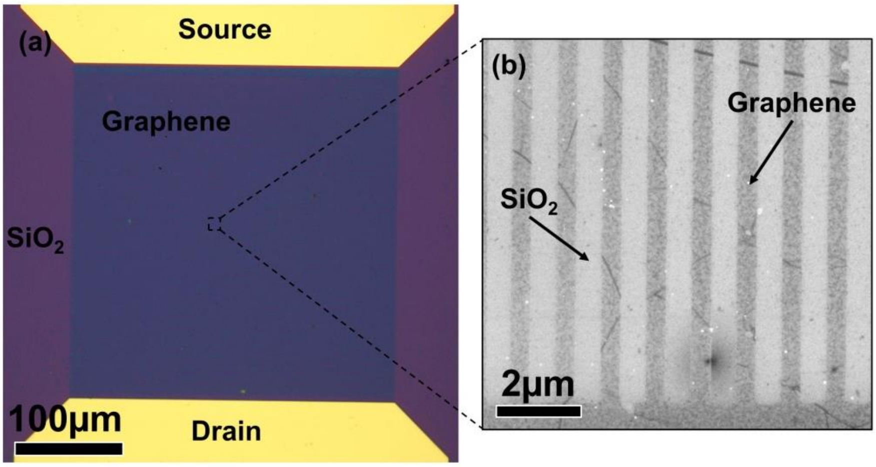

Figure 2: (a) Optical and (b) SEM image of graphene nanoribbon array device.

Project Partners

The University of Augsburg is leading the work aiming to establish a complete theoretical understanding of the proposed device so that the key experimental parameters can be identified and their limits established.

The University of Exeter is leading work aimed at establishing suitable material preparation and device fabrication techniques and then using these to fabricate devices containing all the elements of the proposed devices.

ETH Zurich is exploring different options for the laser cavity, and the integration of graphene devices with cavities in **work package 5,** which also includes full characterisation of devices fabricated in work package 4 and using this information to improve the understanding of the principles of operation and ways in which this could be optimised.

Finally, as suitable devices become available these will be assessed in an industrial laboratory at Norsk Elektro AS, who will provide the project with an industry perspective, in **work package 6**.