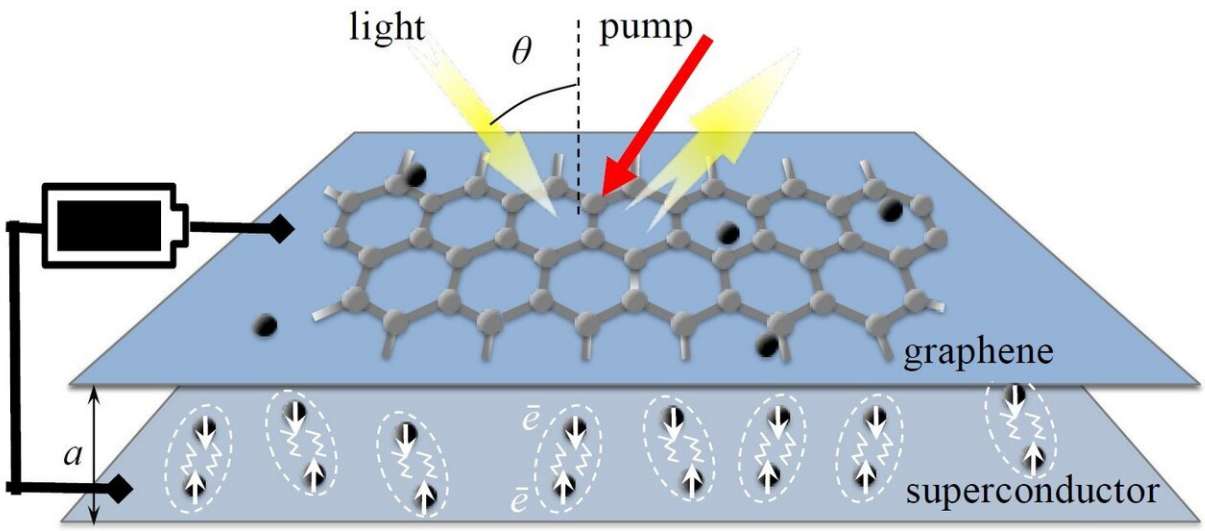
Graphene amplifier unlocks hidden frequencies in the electromagnetic spectrum

February 3 2020, by Peter Warzynski



Light in the THz frequencies hits the 'sandwich' and is reflected with additional energy. Credit: Loughborough University

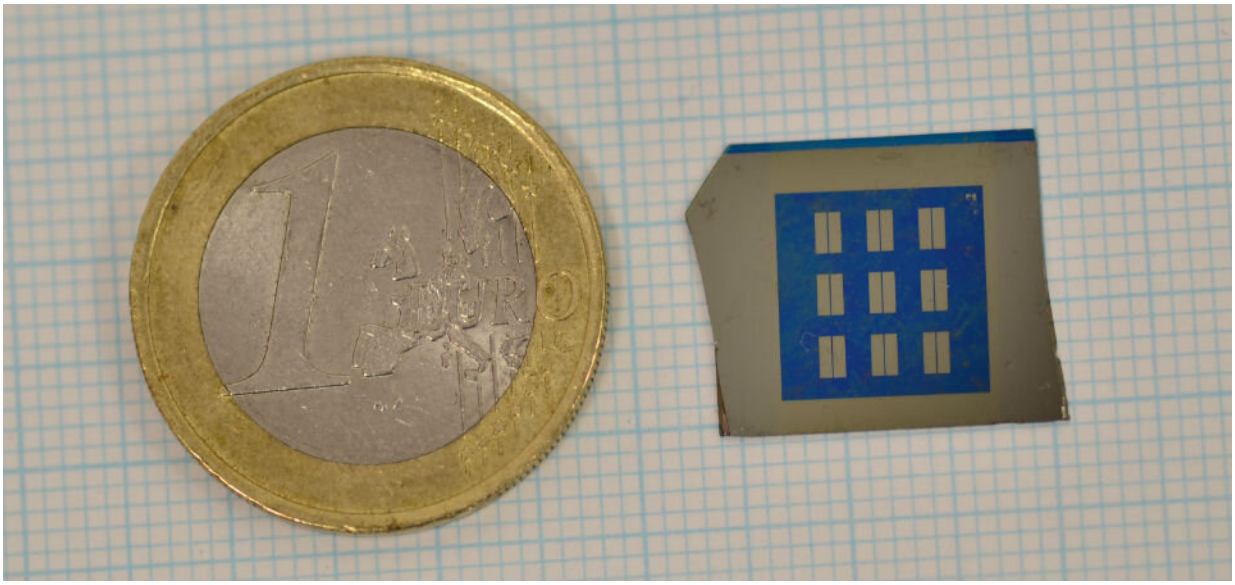
Researchers have created a unique device which will unlock the elusive terahertz wavelengths and make revolutionary new technologies possible.

Terahertz waves (THz) sit between microwaves and infrared in the light frequency spectrum, but due to their low energy, scientists have been unable to harness their potential. The conundrum is known in scientific circles as the "terahertz gap."

Being able to detect and amplify THz waves (T-rays) would open up a new era of medical, communications, satellite, cosmological and other technologies. One major application would be as a safe, non-destructive alternative to X-rays. However, until now, the wavelengths, which range between 3mm and 30μm, have proved impossible to use due to relatively weak signals from all existing sources.

A team of physicists has created a new type of optical transistor—a working THz amplifier—using graphene and a high-temperature superconductor. The physics behind the simple amplifier relies on the properties of graphene, which is transparent and is not sensitive to light and whose electrons have no mass. It is made up of two layers of graphene and a superconductor that trap the graphene massless electrons between them like a sandwich.

The device is then connected to a power source. When the THz radiation hits the graphene outer layer, the trapped particles inside attach themselves to the outgoing waves, amplifying them. Professor Fedor Kusmartsev, of Loughborough's Department of Physics, said, "As the THz light falls on the sandwich it is reflected, like a mirror."



A graphene amplifier. Credit: Loughborough University

"The main point is that there will be more light reflected than fell on the device. "It works because external energy is supplied by a battery or by light that hits the surface from other, higher frequencies in the electromagnetic spectrum. The THz photons are transformed by the graphene into massless electrons, which, in turn, are transformed back into reflected, energised, THz photons. Due to such a transformation, the THz photons take energy from the graphene—or from the battery—and the weak THz signals are amplified."

The breakthrough has been published in *Physical Review Letters*. The team is continuing to develop the device and hopes to have prototypes ready for testing soon. Prof Kusmartsev said they hope to have a working amplifier ready for commercialisation in about a year. He added that such a device would vastly improve current technology and allow scientists to reveal more about the human brain.

"The universe is full of terahertz radiation and signals, in fact, all biological organisms both absorb and emit it. I expect that with such an amplifier available, we will be able to discover many mysteries of nature, for example, how chemical reactions and biological processes are going on, or how our brain operates and how we think. The terahertz range is the last frequency of radiation to be adopted by humankind. Microwaves, infrared, visible, X-rays and other bandwidths are vital for countless scientific and technological advancements.

"It has properties which would greatly improve vast areas of science such as imaging, spectroscopy, tomography, medical diagnosis, health

monitoring, environmental control and chemical and biological identification.

"The device we have developed will allow scientists and engineers to harness the illusive bandwidth and create the next generation of medical equipment, detection hardware and wireless communication technology."

More information: Optical transistor for amplification of radiation in a broadband terahertz domain, *Physical Review Letters* (2020). journals.aps.org/prl/accepted/ … 134b1b07c1648b392836 , arxiv.org/abs/1812.01182

Provided by Loughborough University