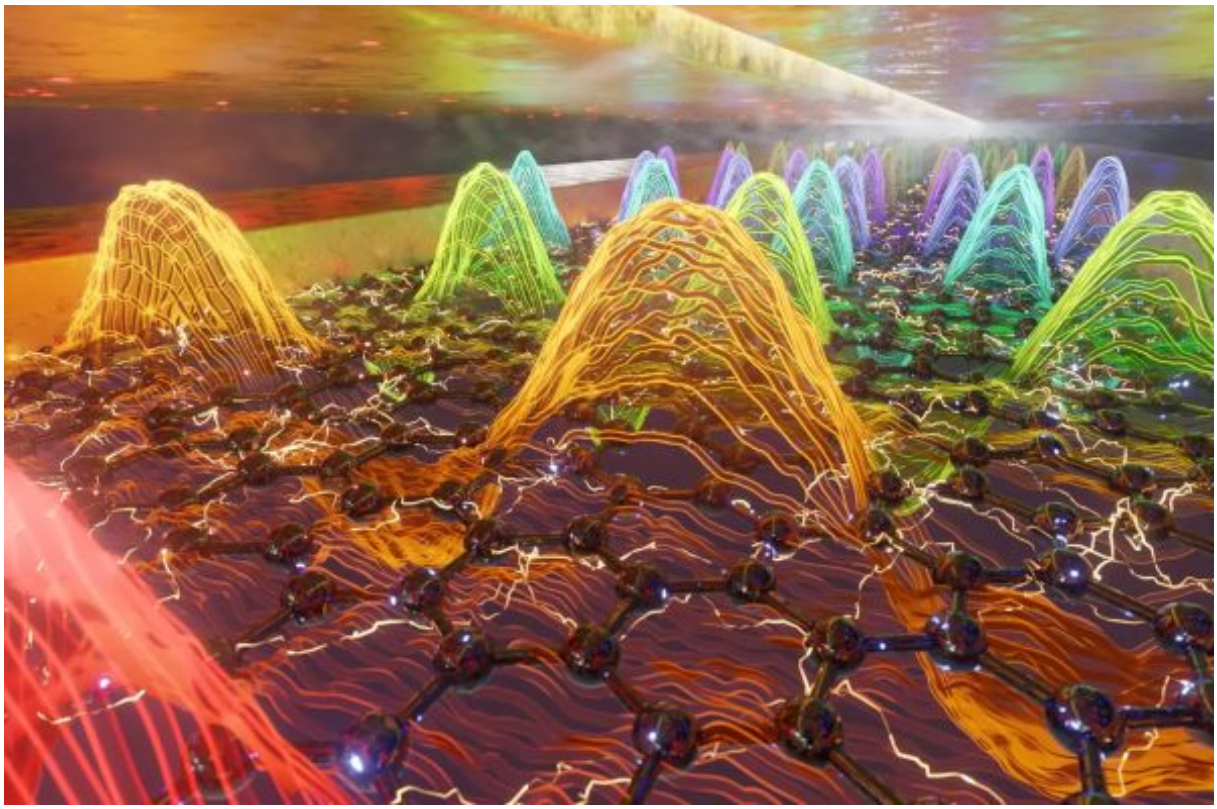

Graphene plasmon cavities enable advanced and scalable terahertz photodetectors

ICFO researchers have developed a novel platform based on monolayer graphene that produces an efficient electrical response when exposed to terahertz light. Terahertz photodetection is enhanced by using a cavity with acoustic graphene plasmons, a set-up that overcomes a major manufacturing bottleneck while boosting device performance. These results, published in ACS Photonics, pave the way for practical, high-sensitivity THz photodetectors with potential applications in fields like biomedicine and telecommunications.

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How could we non-invasively distinguish between healthy and cancerous tissue? And how could we increase the speed of wireless communications? These two seemingly unrelated questions may share the same answer: **terahertz (THz) light**. Spanning frequencies between

0.3 and 20 THz, THz light interacts with matter without causing damage and allows for faster data transfer than radio waves. It is thus ideal for advancing many applications in biomedicine and telecommunications, for which simple yet sensitive and fast detectors are needed.

The challenge, however, is enormous: When detectors are fast enough and operate at room temperature, they suffer from high noise levels; and when noise is minimized, some only work within a narrow frequency range and under cryogenic cooling, while others offer broadband operation but at much slower response times. Far from defeated, researchers keep seeking ways to develop the (close to) ideal THz detector -one that could potentially turn non-invasive melanoma diagnosis or high-speed wireless communication into a reality.

ICFO researchers, **Dr. Domenico De Fazio**, **Dr. Sebastian Castilla**, **Dr. Karuppasamy P. Soundarapandian**, **Dr. Simone Marconi**, **Riccardo Bertini**, **Dr. Roshan K. Kumar**, led by **ICREA Prof. Frank Koppens**, together with Instituto de Nanociencia y Materiales de Aragon (INMA), Universidad de Zaragoza, University of Ioannina, Queen Mary University of London, University of Manchester, Catalan Institute of Nanoscience and Nanotechnology (ICN2), have now taken a step forward in that direction. The team has designed a novel device based on **monolayer graphene** that, under liquid nitrogen cooling, **emits a strong electric signal when struck by THz radiation.** The results, published in ACS Photonics, open **a route to build practical, tunable, and selective THz detectors**.

Exploiting a terahertz cavity with acoustic graphene plasmons

The key innovation of the work was the creation of a terahertz cavity based on the so-called **acoustic graphene plasmons (AGPs),** wave-like oscillations of electrons moving together on the surface of graphene. The device uses a THz antenna that concentrates the incoming terahertz radiation and launches AGPs inside graphene, where they become trapped and form standing-wave resonances, similar to the way sound resonates inside a musical instrument.

These acoustic plasmons in particular squeeze light into spaces much smaller than the wavelength of light itself (at the nanoscale), dramatically enhancing light's interaction with graphene and its consequent absorption. Such absorption leads to localized heating in two distinct regions of graphene, raising their temperatures by different amounts and then converting this temperature difference into a measurable electrical signal, which indicates light was detected.

Graphene had already been employed for THz detection in the past, mainly due to its ability to interact with a wide range of THz frequencies, its fast and efficient current generation when exposed to THz radiation, and its high tunability. This material, however, being just one atom thick, absorbs little free-space THz radiation unless the light-matter interaction is strongly enhanced. As a result, previous graphene plasmons were too weak, leading to insufficient responses to THz light, or required encapsulation with hexagonal boron nitride

(hBN), a step that adds significant complexity to the fabrication process and makes large-scale manufacturing challenging and expensive.

i¿½In contrast, **we demonstrate a photoresponse enhanced by a plasmonic cavity that is 30% higher than the maximum conventional one, even without hBN encapsulation**,i¿½ explai s ICREA Prof. Frank Koppens, lead researcher of the study. The platform could therefore e exploited to build compact and efficient sensors for material identification, as ma y chemicals absorb and emit light in the THz regime. i¿½The key,i¿½ shares Dr. Seb stian Castilla, who was also involved in the study, i¿½was producing graphene single rystals through a specific growth method called **chemical vapor deposition** (CVD), and the exploitation of AGP cavity resonances to concentrate the incident THz field.i¿ ? According to the team, their proposal could inspire novel growth approaches to redu e plasmon losses even further, so that AGPs remain strong up to room temperature; a milestone that would definitely mark a turning point for THz sensin

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