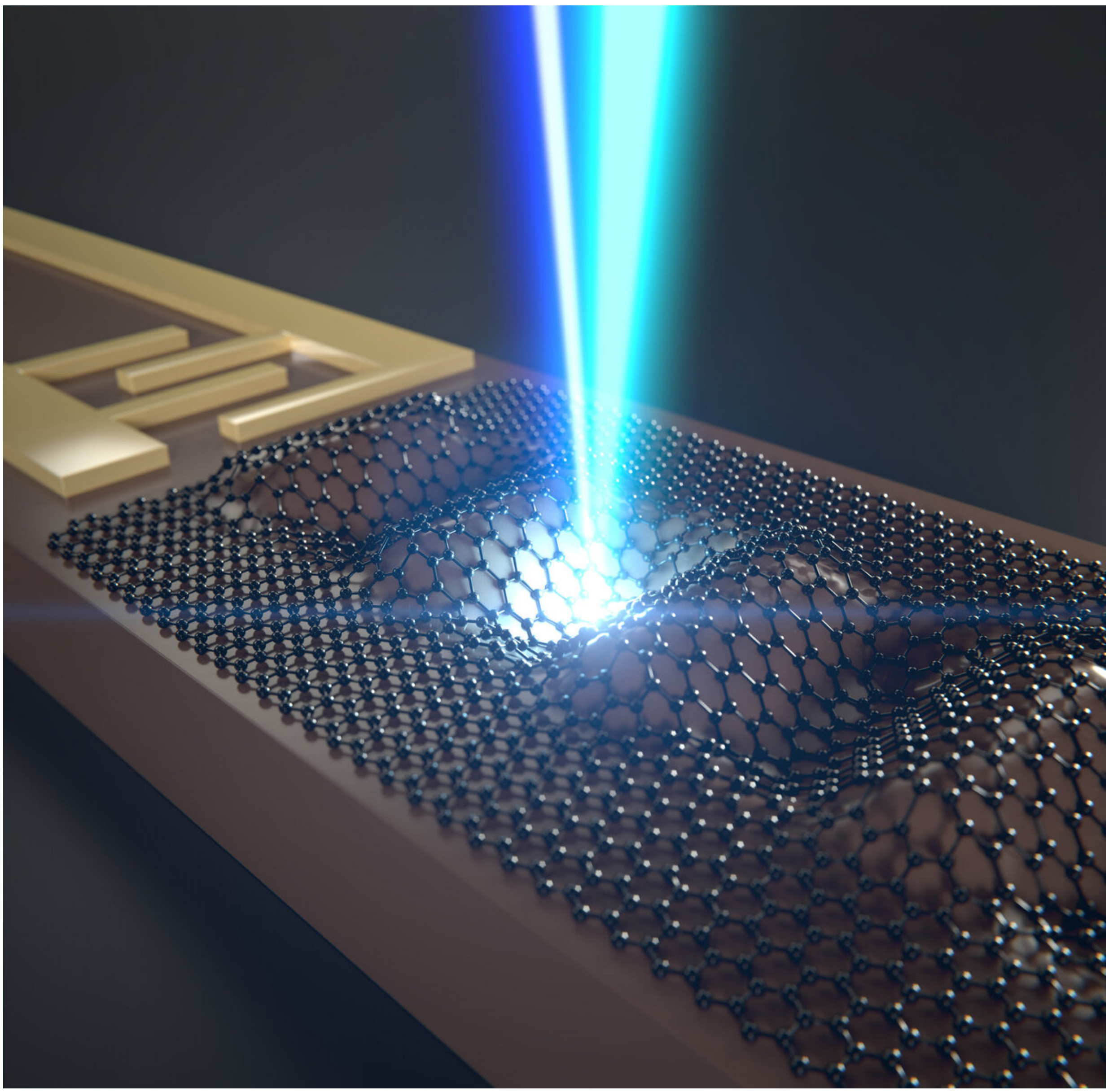
Surface acoustic waves in graphene: straintronics with nanoquakes

December 27 2019, by Jorge Pedrós



A surface acoustic wave generated with an interdigital transducer deforms the graphene inducing strain in the lattice and modifying its phonons, and thus the Raman response of the material. Credit: Jorge Pedrós, Rajveer Fandan (UPM) and Enrique Sahagún (Scixel).

Researchers from the Institute for Optoelectronic Systems and Microtechnology at Universidad Politécnica de Madrid (UPM), in collaboration with the Paul Drude Institute in Berlin and the State University of Campinas, have shown that the properties of graphene can be locally and dynamically modulated by means of a surface acoustic wave (SAW), a kind of "earthquake on a chip" generated with an integrated transducer on a piezoelectric substrate holding the graphene sheet. This mechanism permits the strain engineering of graphene at ultra high frequencies (of the order of a few hundred megahertz to a few gigahertz), paving the way for the development of new straintronic devices and applications.

Straintronics is one of the newest research areas being explored in condensed matter physics, in which strain-induced physical effects are used to develop new technologies. Strain in graphene has been shown to give rise to extraordinary phenomena. "Typically, strain is introduced by placing graphene on a stretchable and bendable substrate. However, approaches capable of generating strain locally with fast actuation mechanisms are highly desirable for the development of integrated devices," the researchers wrote in the study.

"SAWs generated by an interdigital transducer on a piezoelectric substrate are a very convenient way to generate strain locally on supported graphene," says Rajveer Fandan, first author of the study. These waves are similar to seismic waves produced by earthquakes, and their strain is strongly concentrated at the surface. The great advantage here is that the transducer on the piezoelectric substrate electrically produces the quakes on demand, launching spatially and temporally tailored waves of a controlled magnitude.

"The dynamic strain field of the SAW can be then actively controlled at ultra-high frequency, allowing us to tune the vibrational properties of graphene," says Jorge Pedrós, leading scientist of this study. In particular, the researchers have proved this modulation mechanism by assessing the graphene Raman scattering under the action of the SAW, where the G (optical phonon) and 2-D (two optical phonons) Raman bands have been observed to shift due to the phonon mode softening (hardening) under the tensile (compressive) strain of the SAW.

This study concludes that the SAW-driven strain modulation mechanism reported can be extended to other single- or few-layer 2-D materials (many of them piezoelectric themselves) and van der Waals heterostructures, making SAWs powerful tools to explore and exploit these novel 2-D systems "where the physics is especially rich and strain engineering opens a whole range of new possibilities."

The study results are published in *Nano Letters*.

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More information: Rajveer Fandan et al. Dynamic Local Strain in Graphene Generated by Surface Acoustic Waves, *Nano Letters* (2019). DOI: 10.1021/acs.nanolett.9b04085