on a graphene moiré superlattice can have enough energy to excite a miniband interband electron–hole pair, promoting an electron from a filled to an empty state in the miniband structure. These processes, which can occur even in the total absence of external agents, reflect into an increased absorption of infrared light in a graphene moiré superlattice (in comparison with plain graphene), and thus a larger damping rate of plasmons. Basov and co-workers measure the plasmon directly by using infrared scattering near-field optical spectroscopy and observe a fivefold increase with respect to the plain graphene case[11]. This technique enables direct measurements of the complex conductivity of the two-dimensional electron system in a graphene moiré superlattice, opening the door to a deeper understanding of its microscopic details.

The work by Basov and colleagues[11] also poses interesting challenges for the near future. By extending their work to the terahertz frequency domain, it should be possible to test experimentally the appearance of an additional terahertz plasmon branch in a highly doped graphene sheet on hBN, which has also been theoretically predicted[9]. Furthermore, it is now clear that graphene sheets placed on (or encapsulated between) hBN crystals in a commensurate fashion display a topologically non-trivial band structure with Berry curvature hot spots[12], which are responsible for large non-local transport signals due to the propagation of valley currents. It would be extremely interesting to carry out optical and plasmonic spectroscopy of such systems, with the hope of observing valley plasmons after optical pumping and chiral plasmons in the absence of a magnetic field[13,14]. ❐

Marco Polini is at the Istituto Italiano di Tecnologia, Graphene Labs, Via Morego 30, I-16163 Genova, Italy, and at the Scuola Normale Superiore, I-56126 Pisa, Italy. Frank H. L. Koppens is at the ICFO-Institut de Ciencies Fotoniques, Barcelona Institute of Science and Technology, 08860 Castelldefels (Barcelona), Spain and at the ICREA-Institució Catalana de Recerca i Estudis Avançats, 08010 Barcelona, Spain.
e-mail: marco.polini@iit.it; frank.koppens@icfo.eu

References

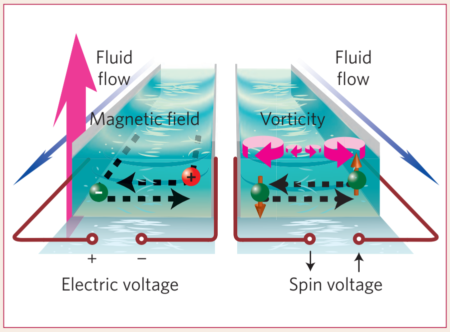
1. Dean, C. R. *et al. Nature Nanotech.* **5,** 722–726 (2010).
2. Mayorov, A. S. *et al. Nano Lett.* **11,** 2396–2399 (2011).
3. Wang, L. *et al. Science* **342,** 614–617 (2013).
4. Ponomarenko, L. A. *et al. Nature* **497,** 594–597 (2013).
5. Dean, C. R. *et al. Nature* **497,** 598–602 (2013).
6. Hunt, B. *et al. Science* **340,** 1427–1430 (2013).
7. Xue, J. *et al. Nature Mater.* **10,** 282–285 (2011).
8. Decker, R. *et al. Nano Lett.* **11,** 2291–2295 (2011).
9. Tomadin, A., Guinea, F. & Polini, M. *Phys. Rev. B* **90,** 161406(R) (2014).
10. Woessner, A. *et al. Nature Mater.* **14,** 421–425 (2015).
11. Ni, G. X. *et al. Nature Mater.* **14,** 1217–1222 (2015).
12. Gorbachev, R. V. *et al. Science* **346,** 448–451 (2014).
13. Song, J. C. W. & Rudner, M. S. Preprint at http://arXiv.org/abs/1506.04743 (2015).
14. Kumar, A. *et al.* Preprint at http://arXiv.org/abs/1509.00790 (2015).

SPINTRONICS

Turbulent power

The kinetic energy of an electrically conducting fluid can be converted into electricity by means of the Lorentz force. This process, called magnetohydrodynamic generation, was first envisioned by Michael Faraday. He discovered that moving an electric conductor through a fixed magnetic field can be used as a voltage source — he even tried, although unsuccessfully, to measure the voltage generated by the salty estuarine water flowing through London's Waterloo Bridge due to the Earth's magnetic field. This conversion mechanism, schematically shown in the left panel of the figure, has been explored in recent times to improve the efficiency of steam power plants. Now, Ryo Takahashi and collaborators show that a potential difference can be generated in a conductive fluid in the absence of a magnetic field, as the result of the spin-current produced by the vortices formed in the fluid[1].

Pure spin currents — a flow of spin that does not require a net motion of charges — can be generated by different means, all of them relying on spin angular momentum transfer triggered by some kind of coupling with the spin and the angular momentum conservation. This causes a spin voltage that drives the spin distribution out of equilibrium. Although the coupling between mechanical rotations and magnetization has long been well-established with pioneering works developed one century ago by Barnett, Einstein and de Haas, the coupling of mechanical rotations and spin has only been explored very recently by Mamoru Matsuo and colleagues. In their work they theoretically study, within the frame of general relativistic quantum mechanics, the effect of mechanical rotation on a spin current[2], deriving the explicit form of the spin–orbit interaction including the inertial effects associated with the mechanical rotation (or spin–rotation coupling). Such a coupling between mechanical rotation and nuclear spin has already been proven by nuclear magnetic resonance-based experiments[3]. The same group predicted that rotational deformations — such as those involved in surface acoustic waves — can be a possible source for spin voltages and spin currents[4]. In other words, a spin-hydrodynamic generator can be built based on the turbulences, vortices or propagating waves in liquids with large enough spin–orbit coupling.



NPG

In their experiment, Ryo Takahashi and collaborators make a fluid metal (Hg or $Ga_{62}In_{25}Sn_{13}$) flow through a cylindrical insulating pipe in the turbulent regime[1]. Due to its viscosity, vortices are formed in the fluid close to the pipe walls and, as depicted in the right panel of the figure using pink curled arrows with different radii, a gradient of mechanical rotation is formed in the liquid transverse to its flow. The spin–rotation coupling converts this mechanical gradient into a spin voltage across the liquid. Spin voltages in metals are typically detected electrically through the inverse spin Hall effect which converts a spin current into an electric field due to the spin–orbit coupling. In the case of the metallic fluid, this electric field is parallel to the liquid flow causing an electric voltage difference, or inverse spin Hall voltage, between any two points along the pipeline. The generation of spin-current and electric voltage without applying magnetic fields is thus demonstrated.

References

1. Takahashi, R. *Nature Phys.* http://doi.org/8xp (2015).
2. Matsuo, M., Ieda, J., Saitoh, E. & Maekawa, S. *Phys. Rev. Lett.* **106,** 076601 (2011).
3. Chudo, H. *et al. App. Phys. Exp.* **7,** 063004 (2014).
4. Matsuo, M., Ieda, J., Harii, K., Saitoh, E. & Maekawa, S. *Phys. Rev. B* **87,** 180402(R) (2013).

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