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MEETING REPORT

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Condensed matter in a new light

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Drawing around 140 attendees to the serene hills of Tuscany, Italy, February's Gordon Research Conference (GRC) on Ultrafast Phenomena in Cooperative Systems explored recent advances in the understanding of light-induced phases of condensed matter.

Materials with several coupled degrees of freedom may be driven by coherent excitation into exotic non-equilibrium states, which may be stable over relatively long timescales. Progress towards the inclusion of such materials into on-chip optoelectronics has recently been made[1,2]. Whether coherent dynamics is initiated by sudden or periodic excitations, one observation of time-dependent properties unifies this field—everything wiggles.

Credit: Daniel T Payne/Springer Nature Limited

The lure of this field is the potential to induce phases and physical properties that are not thermally accessible. Time-domain measurements also allow the observation of 'wiggly' collective modes, such as the Higgs and Goldstone modes in superconductors, which are otherwise difficult to measure as they couple weakly to experimental observables. Hence, interpretation relies heavily on models beyond the capability of current linear-response theory. While defining

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and computing the required non-linear optical kernel is challenging, pioneering efforts suggesting differences between Raman and terahertz excitation mechanisms hint that more collective modes are waiting to be identified.

At the meeting, several talks suggested that new ways to control the dynamics of these materials could be achieved through the use of terahertz laser pulses. These low-energy excitations can only access electronic bands near the Fermi surface, and can be tuned to resonantly match millielectron-volt energy gaps. As the terahertz regime coincides with the energy scale of thermodynamics, the development of new terahertz sources offers a means to coax materials into states that are not normally stable. This raises the deceptively simple question of how to define the temperature of a material following ultrafast excitation, when one subsystem is transiently decoupled from other degrees of freedom. Motivated by unexpected experimental observations of multiple scattering rates, one solution suggested at the conference was to compare the electronic and phonon temperatures to determine when hot electrons reach equilibrium.

Although the field still faces some fundamental challenges, there is also a new focus on leveraging the ability to control physical properties on demand for application in devices. Recently, photoinduced topological Floquet bands were shown to open a bandgap in graphene on picosecond timescales, permitting an ultrafast photoconductive switch to be fabricated. Much longer-lived resistive states observed in the charge-density wave phase of TaS_2 following light or electric pulses have been suggested as candidates for nanoscale memory devices, due to the low, femtojoule switching energy required[3]. As the electrical energy consumption of data storage facilities is predicted to increase from 5% in 2019 to 20% of the global total by 2025, the ability to manipulate the properties of solid-state materials efficiently will become increasingly attractive.

The GRC on Ultrafast Phenomena in Cooperative Systems is held every 2 years. This meeting offers its attendees a space in which unpublished results may be communicated and discussed in confidence. Notably, the poster presentations were also of a high quality, presented by students, postdocs and professors alike. A remote location and ample time provided for informal discussion made this a stimulating and informative event.

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References

1. McIver, J. W. et al. Light-induced anomalous Hall effect in graphene. *Nat. Phys.* **16**, 38–41 (2020).
2. Madan, I. et al. Nonequilibrium optical control of dynamical states in superconducting nanowire circuits. *Sci. Adv.* **4**, 3 (2018).
3. Gerasimenko, Y. A. et al. Quantum jamming transition to a correlated electron glass in 1T-TaS_2. *Nat. Mater.* **18**, 1078–1083 (2019).

Additional information

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