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Title:Terahertz-field-induced insulator-to-metal transition in vanadium dioxide metamaterial

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Abstract:Electron-electron interactions can render an otherwise conducting material insulating(1), with the insulator-metal phase transition in correlated-electron materials being the canonical macroscopic manifestation of the competition between charge-carrier itinerancy and localization. The transition can arise from underlying microscopic interactions among the charge, lattice, orbital and spin degrees of freedom, the complexity of which leads to multiple phase-transition pathways. For example, in many transition metal oxides, the insulator-metal transition has been achieved with external stimuli, including temperature, light, electric field, mechanical strain or magnetic field(2-7). Vanadium dioxide is particularly intriguing because both the lattice and on-site Coulomb repulsion contribute to the insulator-to-metal transition at 340K (ref. 8). Thus, although the precise microscopic origin of the phase transition remains elusive, vanadium dioxide serves as a testbed for correlated-electron phase-transition dynamics. Here we report the observation of an insulator-metal transition in vanadium dioxide induced by a terahertz electric field. This is achieved using metamaterial-enhanced picosecond, high-field terahertz pulses to reduce the Coulomb-induced potential barrier for carrier transport(9). A nonlinear metamaterial response is observed through the phase transition, demonstrating that high-field terahertz pulses provide alternative pathways to induce collective electronic and structural rearrangements. The metamaterial resonators play a dual role, providing sub-wavelength field enhancement that locally drives the nonlinear response, and global sensitivity to the local changes, thereby enabling macroscopic observation of the dynamics(10,11). This methodology provides a powerful platform to investigate low-energy dynamics in condensed matter and, further, demonstrates that integration of metamaterials with complex matter is a viable pathway to realize functional nonlinear electromagnetic composites.

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