Nonlinear Optical Modulator at Terahertz Speeds

Dynamical control of the optical properties is central to modern high-speed fibre-optic communication and signal processing. However, conventional approaches - where the light is controlled via electronic signals - are approaching their fundamental limits and will soon present a bottleneck in the pursuit of faster, terahertz (10^{12} cycles⁄second) or even petahertz (10^{15} cycles⁄second) modulation speeds. For comparison, a typical desktop CPU operates at only a few gigahertz (10^9 Hz).

Researchers from the Nonlinear Optics Group at the Institute of Applied Physics, University of Bern, the Gun Laser Group at the Paul Scherrer Institute, and the Institut de Physique de Nice (Université Côte d'Azur, France) have demonstrated a promising route to overcome these limitations. Their study, published in *Nature Communications*, introduces a method to dynamically control the optical second-harmonic generation (SHG)—a key process in laser frequency conversion and photonics.

Instead of relying on electronics, the team uses intense terahertz (THz) pulses to excite lattice vibrations in the nonlinear crystal β-BaB_2O_4. This coherent atomic motion directly modifies how light propagates through the material, enabling ultrafast optical control without altering the crystal's structure.

Using this approach, the researchers achieved a 30% modulation of the second-harmonic signal within a picosecond (at terahertz frequency). This represents a significant step toward purely optical switching mechanisms operating on ultrafast timescales—with the potential to reach the femtosecond regime and corresponding petahertz clock speeds.

This breakthrough opens new possibilities for all-optical control in ultrafast photonics, adaptive optics, and next-generation optical technologies.

Reference

Giorgianni, F., Colonna, N., Nagamine, G. *et al.* All-optical control of second-harmonic generation in β-BaB_2O_4 via coherent, terahertz-driven acentric lattice displacement. *Nat Commun* (2026). https://doi.org/10.1038/s41467-026-70532-x

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