2025.

Light field–controlled PHz currents in metals — Electric currents in metals are typically established by applying an external voltage. While electrons react to electric fields on attosecond time scales, conventional electronic devices rarely exploit this intrinsic speed. In contrast, ultrashort laser pulses with tailored waveforms—whose electric field reverses at petahertz rates—offer a route to steer currents in metals directly with light. Lightwave-driven currents have already been demonstrated in materials such as dielectrics, semiconductors, and topological insulators. In our work published in *Science Advances* [1], we show that metals can be driven to carry and manipulate orders of magnitude more charge with practical, low-energy (picojoule) pulses, enabling ultrafast switching. Increasing the thickness of the metallic nanolayers leads to an increased current yield, thereby unambiguously identifying the metal as the origin of the measured currents and supporting the expectation that the CEP-dependent yield scales with the number of electrons in the driven system. Moreover, embedding these metal layers within a dielectric host boosts the response by up to a factor of 40 compared with a bare dielectric, thereby lowering the intensity threshold for lightwave electronics (Figure 1.).

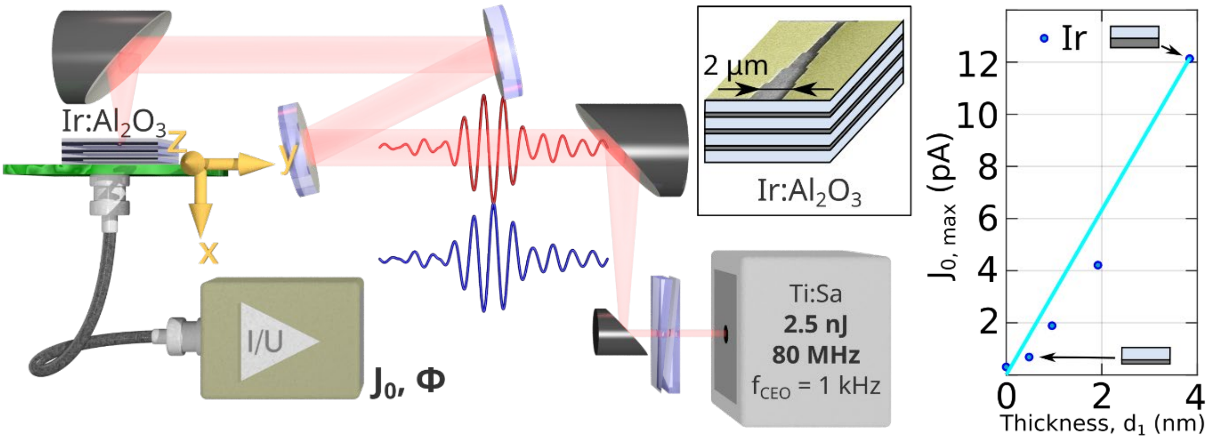

Figure 1. Scheme of the experimental setup. Few-cycle laser pulses with a controlled carrier-envelope phase (red and blue waveforms) impinge a nanolaminate sample with a controlled thickness of alternating Ir and Al_2O_3 layers. Characteristic amplitude $J_{0, max}$ of the current variation is obtained for every sample. Right panel: Characteristic CEP-dependent current $J_{0, max}$ as a function of thickness of the Ir layer.

Strongly coupled plasmon oscillations — We performed measurements with ultrahigh spatiotemporal resolution on strong plamonic coupling in plasmonic dimers. In addition to the characterization of the coupling process, we also confirmed the existence of few-cycle localized plasmon oscillations for the first time to our knowledge. Furthermore, we investigated how the coupling strength depends on the interparticle gap and how this coupling affects the plasmon dynamics. Finally, we observed a gap-size–dependent redshift of the plasmon oscillations [2].

Thermally assisted femtosecond breakdown of metals – By analyzing femtosecond laser-induced breakdown processes in metals, we identified a thermally assisted breakdown mechanism in the femtosecond regime. Capitalizing on the fact that our experimental data show excellent agreement with a three-temperature model of our samples, mechanisms of this new breakdown process are clearly identified.

References

[1] Fehér, B. *et al.* Light field–controlled PHz currents in intrinsic metals. *Sci. Adv.* **11**, 1–10 (2025).

[2] Ligeti, G. *et al.,* manuscript in preparation (2026).

[3] Inger, Á. *et al.,* manuscript submitted for publication (2026).