EPJ Web of Conferences **287**, 14001 (2023) https://doi.org/10.1051/epjconf/202328714001
EOSAM 2023

Ultrafast control of conductivity with femtosecond lasers - INVITED

Davide Boschetto[1,*]

[1]Laboratoire d'Optique Appliquee, ENSTA Paris, Ecole Polytechnique, CNRS, Institut Polytechnique de Paris, Palaiseau, France

Abstract. Femtosecond laser pulse irradiation enables precise control of conductivity in materials, revolutionizing fields like nanoelectronics and materials science. It offers rapid modulation within femtosecond timescales, facilitating advancements in ultrafast electronics and high-speed data processing. In this talk, we will focus on the photoinduced reduction of conductivity in incommensurate crystals through excitation of electrons into localized states, revealing potential applications in optoelectronics, ultrafast switches, and photonic devices.

1 Introduction

Control of conductivity through femtosecond laser pulse irradiation has revolutionized the field of materials science and nanoelectronics, offering exciting prospects for advancements in various disciplines. The remarkable capability to induce transient changes in the electrical properties of materials on an ultrafast timescale has opened up a wealth of opportunities in optoelectronics, photonics, and information processing.

By using femtosecond laser pulses, it is possible to precisely manipulate the conductivity of materials, allowing for unprecedented control over their electronic behavior [1–3]. This technique offers a unique advantage over conventional methods by enabling rapid modulation of conductivity within femtosecond time domains. The ultrafast timescale allows for dynamic manipulation of electrical properties, paving the way for innovative applications in fields such as ultrafast electronics, high-speed data processing, and advanced photonic devices.

The ability to control conductivity through femtosecond laser pulse irradiation finds widespread relevance also in materials science. This opens the possibility now to engineer and tailor the electrical properties of materials with exceptional precision. This level of control is crucial for developing advanced electronic devices with enhanced performance and functionality. Moreover, this technique enables the exploration of new material platforms and nanostructures, which exhibit novel conductivity phenomena that can be harnessed for next-generation devices.

In the realm of optoelectronics, femtosecond laser-induced conductivity control holds great potential. The transient changes in electrical properties can be exploited to develop ultrafast switches, modulators, and detectors, enabling rapid and efficient manipulation of optical signals. This advancement is critical for achieving high-speed optical communication, all-optical computing, and ultrafast signal processing. Additionally, this technique can be applied to the development of novel light-emitting devices and photovoltaics, where precise control over conductivity enhances device performance and efficiency.

Furthermore, the ability to induce transient changes in conductivity on an ultrafast timescale has significant implications in the field of photonics. By modulating the conductivity of materials using femtosecond laser pulses, it is possible to manipulate the propagation and interaction of light within devices and systems. This opens up new ways for designing integrated photonic circuits, optical waveguides, and photonic crystals with tailored functionalities. The precise control over conductivity provides opportunities for efficient light manipulation, enabling compact and high-performance photonic devices.

2 Experimental results

In this talk, we will show recent advancements in the field of manipulating material conductivity using ultrafast laser pulses, with a specific focus on the interesting phenomenon of photoinduced reduction of conductivity facilitated by the presence of localized states [3].

We will focus on incommensurate crystals, characterized by a lattice mismatch that gives rise to localized states that influence the overall conductivity of the crystal. We will demonstrate that through targeted excitation, electrons can be selectively promoted to occupy these localized states, providing a means to control and reduce the conductivity of the crystal.

To investigate this phenomenon, experiments are conducted employing a pump-probe scheme with femtosecond time resolution. This approach allows for precise temporal characterization of the conductivity changes induced by the laser pulses. Optical parametric amplifiers are employed to selectively tune the wavelengths of both the pump and probe pulses, facilitating the investigation of specific energy transitions and their impact on conductivity reduction.

Through a systematic exploration by this experimental technique, we aim to unravel the underlying mechanisms

*e-mail: Davide.Boschetto@ensta.fr

governing the photoinduced reduction of conductivity in incommensurate crystals. By shedding light on the interplay between localized states, charge dynamics, and conductivity modulation, we can further our understanding of this phenomenon and pave the way for potential applications in fields such as optoelectronics, ultrafast switches, and photonic devices.

3 Conclusions

In summary, our results provide an insights into the progress made in the manipulation of material conductivity using ultrafast laser pulses, emphasizing the role of localized states in the photoinduced reduction of conductivity. The ability to induce transient changes in electrical properties on an ultrafast timescale empowers the ability to develop advanced electronic devices, high-speed optical systems, and integrated photonic circuits with enhanced performance and functionalities. As further advancements are made in this field, the potential for groundbreaking applications continues to expand, driving innovation and progress in various scientific and technological domains.

References

[1] G. Lantz et al., "Ultrafast evolution and transient phases of a prototype out-of-equilibrium Mott-Hubbard material." *Nature Communications* **8**, 13917 (2017).

[2] N. Yoshikawa et al., "Ultrafast switching to an insulating-like metastable state by amplitudon excitation of a charge density wave." *Nature Physics* **17**, 909 (2021).

[3] M. Lejman et al., "Ultrafast photoinduced conductivity reduction by bonding orbital control in an incommensurate crystal." *Submitted.*