Broadband, sensitive, and fast time-domain THz spectroscopy

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Scientific instruments are often built with the main purpose of testing a theory. Another motivation, which is often forgotten, is our inner desire to explore unknown territories, which not only contributes to satisfy our scientific curiosity but can also lead to the discovery of new phenomena and technologies. One famous example is the laser, now well-known and broadly used for many applications, but originally described by his inventor as a "solution seeking for a problem". The laser and other familiar photonics instruments, such as the microscope and telescope, have clearly demonstrated that boosting performances of optical instruments can fuel scientific research and contribute to high-impact discoveries.

Motivated by this history of technological developments leading to scientific success, my research group has recently made progress improving state-of-the-art photonics instruments, notably as a mean to tackle intriguing phenomena with a different set of experimental tools. More specifically, we are interested in designing and demonstrating new terahertz (THz) devices. THz is an active field of research and development focusing on photonics technology operating around 1 THz in optical frequency, which corresponds to wavelength of 300 µm. Although THz generation and detection techniques can sometimes appear cumbersome, they enable new technologies allowing the creation of images through seemingly opaque materials, the identification of molecular compounds from their low-energy vibrational resonances, and the monitoring of quasi-particles dynamics in condensed matter systems. However, many of these applications are currently limited by a lack of efficient or affordable THz systems. In this presentation, I will show our recent progress on experimentally improving THz time-domain spectroscopy (THz-TDS) systems in terms of bandwidth and sensitivity, notably by relying on ideas borrowed from the fields of nonlinear optical propagation in photonic crystal fibers and nanopatterned semiconductor crystals [1-4]. Finally, a single-pulse THz spectroscopy scheme will be presented as a mean to explore fast and non-reproducible phenomena in materials [5].

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[2] A. Halpin, W. Cui, K. M. Awan, K. Dolgaleva, J.-M. Ménard. Enhanced terahertz detection efficiency via grating-assisted noncollinear electro-optic sampling. Physical Review Applied 12, 031003 (2019)

[3] W. Cui et al. Broadband and tunable time-resolved THz system using argon-filled hollow-core photonic crystal fiber. APL Photonics 3, 111301 (2018)

[4] A. Halpin, N. Couture and J.-M. Ménard. Optical pulse structuring in gas-filled hollow-core kagomé PCF for generation and detection of phase-locked multi-THz pulse. Optical Materials Express 9, 3115 (2019)

[5] N. Couture et al. Single-pulse time-resolved terahertz spectroscopy of sub-millisecond time dynamics. arXiv:2207.11766