# THz Emission and Amplification for Transient ion Emission

*Location: Groupe de Physique des Matériaux (GPM), Saint Etienne du Rouvray (France)*
*http://gpm.univ-rouen.fr/fr*
*Duration : 36 months, starting autumn 2026*

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The Atom Probe Tomography (APT), the laboratory's flagship technique, enables the 3D reconstruction of the chemical distribution of a nano-object, with spatial resolution close to the atomic scale, using field evaporation of ions from the surface. In laser-assisted APT, commonly used to study metals, insulators and semiconductors, evaporation is triggered by an ultrafast laser pulse in the near ultraviolet (UV) range . The energy of the UV pulses is absorbed by the sample and its heating degrades the instrument's performance in terms of spatial and chemical resolution.

Remarkable progress has been made using sources in the terahertz (THz) range, which has enabled the analysis of metallic materials as well as ceramics and oxides. In addition, it has been shown that the emission process assisted by THz pulses minimizes heating effects. An important parameter for SAT analyses is the repetition rate of laser sources. High-frequency sources (>100kHz) enable large volumes to be analyzed using SAT. However, in the THz domain, high-frequency sources are less energetic than low-frequency sources. This can reduce their effectiveness when used in SAT.

Initial high-repetition-rate results show that THz pulses can be used to analyze metals with performance superior to that of commercial SAT. However, for semiconductor or insulating materials, high-repetition-rate THz pulses of a few hundred kV/cm no longer reach the intensity required for SAT analysis.

This project aims to explore original approaches to overcome the current limitations of THz pulse-assisted SAT. The first way focuses on the development of a new, more intense THz source, while the second focuses on amplifying less intense sources by metallizing the sample.

THz Source:
Today, we use two approaches to generate THz pulses: optical rectification in a nonlinear crystal for the high-repetition-rate source, and two-color filamentation-induced plasma generation in air for the low-repetition-rate source. The latter requires high-energy, millijoule-class lasers, which are only available at low repetition rates. Recent studies show that replacing the filament with a microplasma significantly lowers the THz generation threshold while preserving the spectral characteristics of the THz source and, at the same time, amplifying its intensity. This opens up the possibility of operating at high repetition rates with broadband sources. This project therefore aims to exploit these new THz pulses, which have sufficient amplitude to enable the atomic layer-by-layer evaporation of non-electrically conductive materials using SAT (Scanning Atom Probe Tomography).

THz Amplification:
Another strategy we will investigate involves amplifying the THz pulse through the sample itself, via its metallization. We plan to test different metal deposition techniques as well as different types of metals. Preliminary encouraging results have been obtained with chromium metallization on silica and germanium samples, but the adhesion of the metal layer and the quality of the deposition still need improvement.

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**Work Program:**
In the first year, we will primarily focus on designing a new experimental setup for generating high-amplitude THz pulses via microplasma, using femtosecond pulses in the near-infrared range. We will use an existing low-repetition-rate amplified laser source already installed and available at GPM. Initially, we will select the optical components to be used and, if necessary, design custom optics for collecting and characterizing the THz radiation across the entire spectral band. In parallel, the PhD student will test metal deposits, particularly silver—chosen for its high electron mobility—on silica samples (continuing the work started during Matteo De Tullio's thesis) as well as on semiconductors such as Ge and Si (continuing the work initiated during Michella Karam's thesis).

By the end of the first year and into the second year, we will implement microplasma-based generation and initially work on maximizing the THz signal. We will then focus on controlling its characteristics in terms of polarization, phase, and spectrum. This work will be supervised by Dr. Jonathan Houard, whose expertise in ultrafast optics and THz optics will be invaluable for making technical choices and implementing this new generation setup.

Once the microplasma source is validated, we will transfer the generation setup to the high-repetition-rate laser source at the CORIA Optical and Laser Department or possibly at GPM, if the source is purchased. This source, operating at a repetition rate 100 times higher, will allow us to validate high-amplitude, high-repetition-rate THz generation via microplasma. Finally, the new high-repetition-rate THz source will be coupled with SAT for compositional and structural analysis of materials already studied with metal deposits, particularly silica, germanium, and silicon.

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**Collaborations:**
This study will be conducted in collaboration with Prof. Stelios Tzortzakis' team at the University of Crete, as part of the Ingenium consortium, and with the Optical and Laser team at the CORIA laboratory

Skills:

- Knowledge in optics, non-linear optics and laser-matter interactions
- Previous experience in development of THz sources will be highly appreciated.

- Previous experience with atom probe microscopy is highly desirable.

- Technical skills required in non-linear optics and/or electron microscopy and/or atom probe tomography
- Independent work
- Team work

**Application:**

The PhD student will be supervised by Prof. Angela Vella.

Interested candidates should send a CV, a letter of motivation and the names of 2-3 references to:

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