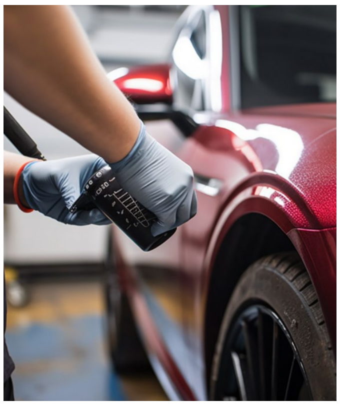
TeraXion
An indie Semiconductor Company

# Ultrafast Lasers for Terahertz Generation

# Application Note


Terahertz (THz) technologies promise advancements in numerous applications due to their unique characteristics. The success of deploying THz technologies heavily depends on the availability of compact, efficient, and affordable THz sources. Femtosecond lasers are crucial tools for generating THz radiation as we will see in this application note.



## THz Applications

- Mail Verification
- Spectroscopy
- Quality Control
- Biomedical
- Pharmaceutical
- Environmental
- Industrial
- Research

## Introduction

Femtosecond lasers offer numerous opportunities, influencing advancements in scientific, medical, and industrial fields. Currently, a wide array of ultrafast laser products is available, emitting at various wavelengths in the near-infrared and visible ranges. In recent years, we have seen the emergence of several alternatives to aging, complex, expensive, and often unreliable ultrafast lasers from established players. In this application note, we discuss how to choose a laser source that best meet the needs and requirements of THz generation.

## THz Technologies

THz radiation possesses unique properties, such as the ability to penetrate various non-conductive materials like plastics, fabrics, and biological tissues, without causing ionization. This makes THz waves useful for detecting hidden weapons and explosives and for non-destructive testing (inspecting materials without damaging them). In spectroscopy, THz can identify molecular signatures, making it useful in chemical analysis, biological research, and pharmaceutical quality control. In life sciences, non-ionizing THz radiation can image tissues with high resolution, aiding in medical diagnostics without the risks associated with X-rays.

MKT-APPNOTE-VINCI-THZ (1.0)

## THz Generation

Over the past twenty years, there has been a growing interest in THz applications which has spurred an ongoing search for brighter and more efficient THz radiation sources. The success of deploying THz technologies heavily depends on the availability of compact, efficient, and affordable THz sources. To achieve efficient THz generation, high-performance femtosecond lasers are required as will be discussed in the next section.

## Femtosecond Lasers for THz Generation

Femtosecond lasers are crucial tools for generating THz radiation due to their ability to produce extremely short, high-intensity pulses. When selecting a femtosecond laser for THz generation, important laser criteria need to be reviewed carefully to achieve efficient THz generation:

### High Peak Power

The extremely short duration of femtosecond pulses results in very high peak powers, which are essential for nonlinear processes like optical rectification and plasma generation.

### Broadband Emission

The short pulse duration corresponds to a large spectral bandwidth, enabling the generation of broadband THz radiation.

### Cost

Large-scale deployment of THz technology will require affordable THz sources. To achieve this, cost-effective femtosecond lasers are of the utmost importance. Although compact femtosecond lasers have become available in the last few years, these lasers still don't quite meet the application requirements in terms of peak power and cost effectiveness.

But a new line of femtosecond lasers from TeraXion was recently released with promising performances. TeraXion VINCI series of fs fiber lasers feature a unique combination of very short pulse duration (50 fs typical) and high peak power approaching 1 MW. TeraXion VINCI-1064 comes in a compact and affordable format, making it a prime candidate for large-scale deployment of THz technology.

## Experimental Results

Several methods are used to generate THz radiation using femtosecond lasers, including photoconductive antennas, optical rectification, or plasma generation. Recently, optical rectification with nonlinear optical crystals such as ZnTe or GaP has been used successfully. As illustrated in Figure 1, TeraXion's new femtosecond laser was used to generate THz radiation with GaP crystals. Two types of crystals were used: 1) 1 mm thick Gap window and 2) 1 mm thick GaP window with a phase grating etched on its surface. THz radiation was measured using a time-resolved spectrometer.

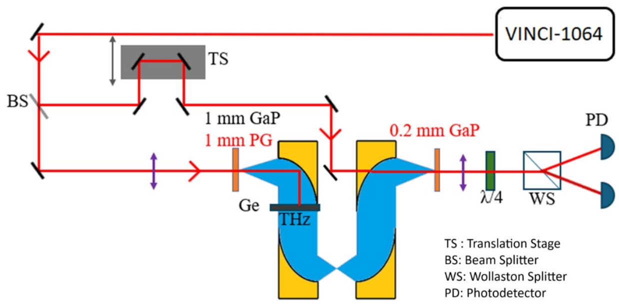



**Figure 1: Experimental Setup of THz Time-resolved spectrometer**

As can be seen on Figure 2 below, short THz pulses were obtained leading to a very large THz spectrum in the frequency domain for both types of crystals used in the experiment.

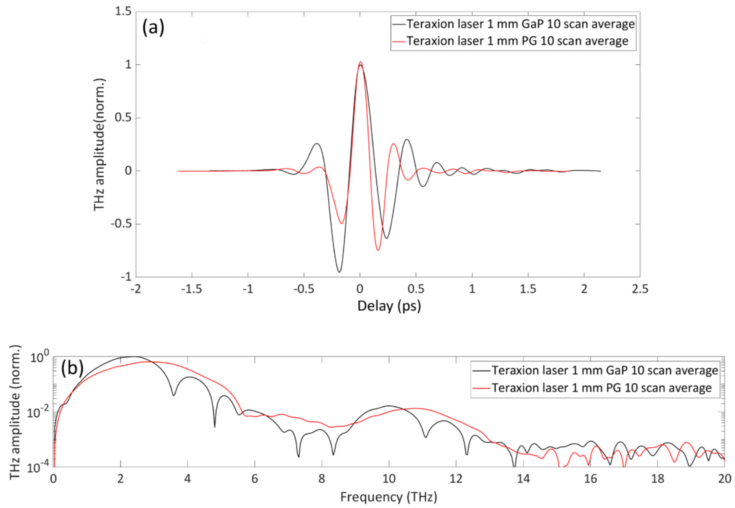



**Figure 2: a) THz pulse signal and b) THz spectrum**

A summary of all experimental results is presented in Table 1 below.

| Parameter | Units | Measured Value |
|---|---|---|
| Terahertz Peak Field | kV/cm | 0.16 |
| Average Terahertz Power | nW | 240 |
| Signal-to-Noise Ratio | | 400 |
| Dynamic Range | dB | 70 |

**Table 1: Summary of experimental results**

As can be seen in the experimental results above, TeraXion VINCI-1064 presents unique advantages for THz Time-Domain Spectroscopy:

- High THz peak field and average power
- THz generation over an extremely broad spectrum (several THz)
- High Signal-to-Noise Ratio
- High Dynamic Range

VINCI-1064 high peak power and large emission spectrum make it a prime candidate for THz generation in THz Time-Domain Spectroscopy applications.

## Conclusion

Terahertz radiation possesses unique properties, such as the ability to penetrate various non-conductive materials like plastics, fabrics, and biological tissues, without causing ionization. The success of deploying THz technologies heavily depends on the availability of compact, efficient, and affordable THz sources. TeraXion VINCI series of fs fiber lasers feature a unique combination of very short pulse duration (50 fs typical) and high peak power approaching 1 MW. VINCI-1064 robust and cost-effective technology make it an ideal candidate for large-scale deployment of THz technology.

Note: Experimental results courtesy of Jean-Michel Ménard from the Ultrafast THz spectroscopy group at the University of Ottawa.