Standoff identification of concealed explosives under real-world conditions

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Understanding influences such as humidity, standoff distance, and sample roughness is crucial for real-world implementation of terahertz spectroscopy.

Since 9/11 there has been an increased interest in techniques to identify concealed explosives or explosive-related compounds (ERCs). Terahertz (THz) spectroscopy is one of the most promising techniques for ‘standoff identification’ because of its harmless radiation, penetration through clothing, and spectral fingerprints of explosives and ERCs. We have investigated the most important influences on THz spectra to evaluate under which conditions this technique can best be applied in real-world scenarios.

In the past, several groups have demonstrated the identification of explosives using THz spectroscopy in transmission and reflection modes.1, 2 All of these groups used well-prepared samples, short distances between the optics and samples, and a dry air atmosphere to avoid spectral disturbance due to water lines. These are not the conditions we will find in the real world. We have developed an experimental setup where we can adjust several crucial parameters, such as humidity and distance, for standoff measurements. We also investigated the effects of roughness on the spectra using samples with well-defined roughness characteristics. One of the goals of our experiments and simulations was to investigate the possibilities and challenges of THz-standoff identification. We paid special emphasis to humidity in ambient air and sample properties, such as surface roughness and orientation with respect to the incident THz beam.

Water-vapor absorption strongly affects the THz spectra, so numerical simulations can be beneficial. Since the absorption lines are strong and narrow, the calculation must be precise. We have checked models that are well-known in meteorology, covering the IR and microwave regions of the electromagnetic spectrum and achieved an accurate description of the measured THz spectral absorption using the LINEFIT program3 (see Figure 1).

In most realistic cases, the substances that need to be identified by security applications are hidden behind clothing or stored within containers. The transmission characteristics of these outer materials have a strong bearing on the THz spectra. Therefore, we have investigated the effects of different clothing and packaging materials.

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The surface roughness of the sample modifies and limits the bandwidth of the reflected spectra. We used specular and diffuse reflection measurements of samples with different roughnesses to determine the influences of various properties on the reflection spectra. Our calculation is based on the work published by Otolani and coworkers\(^4\) (see Figure 2).

For standoff identification using THz spectroscopy in real-world conditions, it is crucial to understand environmental influences on the spectra. Our results represent an assessment of the feasibility of using THz techniques for this application. Our next step will be to develop software for automated evaluation of THz spectra.

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