Detecting Biomarkers in the Icy Worlds by means of Teraherz Remote Sensing

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Introduction

Terahertz (THz) radiation, located between traditional microwave and visible light, consists of electromagnetic waves within frequencies from 0.3 to 3 THz (1 THz = 10^{12} Hz). Recently, THz technology has made tremendous progress and many applications have been developed. One of these applications is remote detection of biomolecules in the THz region. Interestingly, many biological compounds exhibit distinct spectroscopic response in THz range.

THz Spectroscopy and Biomolecules

THz spectroscopy (Figure 1) is a promising method for biomolecule detection. The unique rotational, vibrational, and translational responses of biomaterials within the THz range provide information that is generally absent in other imaging frequencies (Figure 2). Over the past years many biomolecules have been studied using THz spectroscopy [1]. In amino acids e.g. α-glycine has absorption features at 2.4 and 2.7 THz and γ-glycine at 1.9 and 2.5 THz (Figure 3). Saccharides, one of the most important biomolecules have also well-resolved spectra.

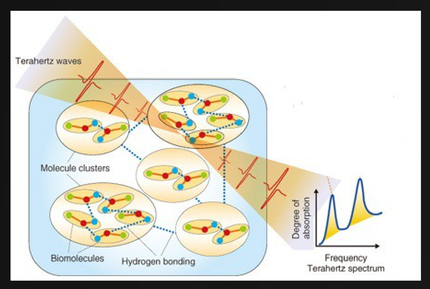

Figure 1. Teraherz spectroscopy [2].

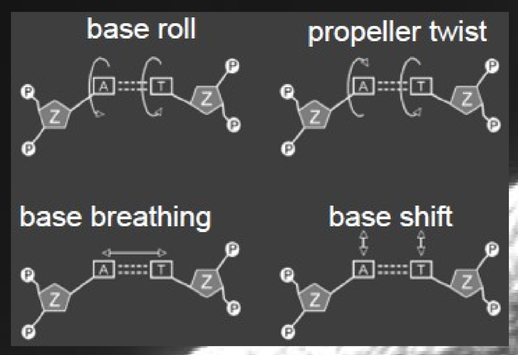

Figure 2. Multitudinous vibration of DNA at THz frequencies [3].

Thz Remote Sensing

Compared to other possible spectroscopic or sample measurements THz remote sensing offers many advantages. THz resonances of biomolecules are repeatable and strong enough that one can estimate their detectability in a remote sensor. Rapid progress in THz technology has already developed some small, light-weight and compact sensors available for space missions (Figure 4). Compared to sample techniques THz remote sensing is relatively simple and reliable method.

Basically there are, just like in the traditional spectroscopy, two THz imaging techniques: passive and active. The great advantage of active remote sensing is the fact that active illumination greatly reduces the sensitivity requirement on the THz receivers.

THz Remote Sensing & Icy Worlds

THz remote sensing is a suitable method for searching for potential biomarkers in the icy worlds, e.g. Europa and Enceladus. Ideally, possible biomolecules would be released from the interior (ocean) of the icy moon as a plume. This could ensure the sensing of pristine biomolecules.

Besides potential plumes, THz could also be used to detect organic matter (e.g. tholins) on the surface of the icy world. This alone could justify the THz remote sensing instrument being aboard on a icy moon mission.

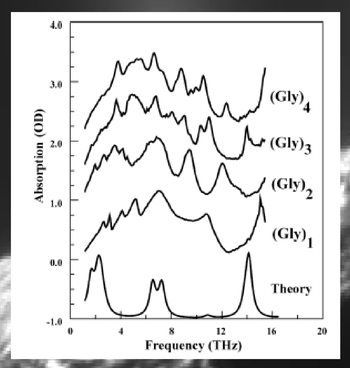

Figure 3. THz absorption spectra of (Gly)n (n = 1 – 4) [4].

Figure 4. 17 cm X 3 cm 557 GHz receiver for space applications (TeraComp).

Challenges

Generally, icy worlds' surfaces are hostile environments for organics and known biomolecules. This can significantly reduce the utility of THz remote sensing. Also plumes are challenging phenomena: questions about timing and location, i.e. when and where plume occurs remain big problems for every attempt to do measurements.

Finally, if there really are biosignatures in the icy worlds, do we recognize them? This is a question whether life could somehow differ from what we know. Could we recognize strange spectra as an extraterrestrial life?

Conclusions

Terahertz remote sensing is a promising method for detecting biomolecules in the icy worlds. It has many advantages that other imaging methods are missing. The main advantage is its capability to detect biomolecules based on their distinct spectroscopic response. It is also the only remote detection method that allows discriminating between common extraterrestrial organic matters from potential biosignatures.

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Enceladus image by NASA.