Compressive Sampling for Terahertz Spectroscopy

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Aim

This project aims to investigate whether Compressive Sampling can be utilized to reduce the data acquisition time for Terahertz time domain spectroscopy (THz-TDS).

Backgrounds

What is Compressive Sampling?

Compressive Sampling is a technique that allows a sparse signal to be reconstructed despite failing the conditions set out in the Nyquist Sampling Theorem. It can successfully recover signals from as little as 10% of the data required within the Nyquist regime.

Two steps for Compressive Sampling Reconstruction:
1. Compress under sampled sparse signal

\[ M \times N \text{ measurements} \]

\[ K \leq M \ll N \text{ nonzero entries} \]

\[ \tilde{x} = \arg \min \|x\|_1 \text{ subject to constraint } y = \Phi x \]

(Baraniuk 2007)

2. Decompress underdetermined system:

\[ \tilde{x} = \Phi^{-1} y \]

Significance

If it is possible to reconstruct the THz Spectroscopy with under sampled THz TDS, the acquisition time will be dramatically reduced.

Result

20% ~ 40% compressive sampling gives practicable result

Only used 25% data to reconstruct almost the same result as 100% data!

It can save 3/4 acquisition time!

References


Methodology

2048 full data

25% sampling

25% Wavelet

Fingerprint

Reconstructed TDS

Reconstruction

What is THz Spectroscopy?

Terahertz spectroscopy is an spatial electromagnetic wave propagating at frequencies between 0.1 to 5 THz. It has been widely used in security, medical imaging and material character identification because different materials can absorb different THz radiation. Therefore, it can be considered as a ‘fingerprint’ of materials. There are two special characteristics considered for using Compressive Sampling.

THz TDS acquisition procedure

THz TDS CS is an attractive scheme for THz pulses because

1. THz Spectroscopy is sparse signal (CS is aimed to reconstruct sparse signal)
2. It needs extreme long time to acquire TDS (84 hours for scanning 10cmx10cm item) (Ferguson and Bradley S, 2004)

It was found that THz-TDS pulses are very sparse when transformed to a wavelet representation. So the under sampled THz wavelet coefficients is reconstructed and then transformed back to the time domain pulse for the usual THz-TDS extinction spectrum calculations.