CLAIMS

1. A method of characterizing one or more layers of a material, the method comprising:

irradiating the material with a THz pulse such that at least a portion of the THz pulse is reflected from the material as a reflected THz signal;

acquiring a first time-domain waveform of the reflected THz signal;

using a neural network on a computing device to map the first time-domain waveform to a second time-domain waveform defined by a superposition of a plurality of peaked time-domain interface waveforms, each peaked time-domain interface waveform comprising a peak corresponding to a reflection from an interface of the material; and

determining one or more proportional thicknesses of one or more layers of the material from a corresponding one or more spacings between adjacent peaks of the plurality of peaked time-domain interface waveforms.

2. The method of claim 1, wherein the neural network comprises a convolutional neural network.

3. The method of claim 1, wherein the neural network comprises a U-Net neural network.

4. The method of any one of claims 1 to 3 further comprising determining relative positions of a plurality of interfaces of the material from the peaks of the plurality of peaked time-domain interface waveforms.

5. The method of any one of claims 1 to 4 further comprising determining locations of the peaks of the plurality of peaked time-domain interface waveforms from the second time-domain waveform by fitting peaks of the second time-domain waveform to peaked functions having predetermined functional forms and determining the locations of the peaks of the plurality of peaked time-domain interface waveforms from parameters of the peaked functions.

6. The method of any one of claims 1 to 5 being configured to determine a total number of layers of the material.

7. The method of any one of claims 1 to 6, wherein a detector measures the time-domain waveform of the reflected THz signal at a plurality of discrete times td, and wherein each peaked time-domain interface waveform comprises a Kronecker delta function $\delta(td,tId)$, tId being a time in the plurality of discrete times that is closest to a time that a signal reflected from an interface of the material is incident on the detector.

8. The method of any one of claims 1 to 6, wherein a detector measures the time-domain waveform of the reflected THz signal, and wherein each peaked time-domain interface waveform comprises a time-domain peaked function having a predetermined functional form and centered on a time that a signal reflected from an interface of the material is incident on the detector.

9. The method of any one of claims 1 to 8, wherein irradiating the material with a THz pulse comprises irradiating the material at a plurality of locations, and acquiring a first time-domain waveform comprises acquiring a first time-domain waveform for each location of the plurality of locations, wherein the method further comprises forming an array of the first time-domain waveforms, and wherein using the neural net to map the first time-domain waveform to the second time-domain waveform comprises using the neural net to map the array of the first-time-domain waveforms to an array of second time-domain waveforms.

10. A method of training a neural network for characterizing one or more layers of a material using a THZ pulse, the method comprising:

training the neural network on a computing device using training data to determine parameters of the neural network, the training data comprising:

input data comprising time-domain waveform data corresponding to at least partial reflection of a THz pulse from each test sample of a first plurality of test samples; and

output data comprising a time-domain output waveform for each test sample of the first plurality of test samples, each time-domain output waveform defined by a superposition of a plurality of peaked time-domain interface waveforms, each peaked time-domain interface waveform comprising a peak corresponding to a reflection from an interface of the test sample.

11. The method of claim 10, wherein each peaked time-domain interface waveform is given at a plurality of discrete times td arranged at an interval ΔT, wherein each peaked time-domain interface waveform comprises a Gaussian centered at the peak corresponding to the reflection from the interface and having a standard deviation in a range of 0.25 to 4 times ΔT.

12. The method of claim 10, wherein each peaked time-domain interface waveform is given at a plurality of discrete times td arranged at an interval ΔT, wherein each peaked time-domain interface waveform comprises a Kronecker delta function $\delta(td,tId)$, tId being a time in the plurality of discrete times td that is closest to a time of the peak corresponding to the reflection from the interface.

13. The method of claim 1, further comprising generating training data for the neural network, the training data comprising input data and output data, generating training data comprising:

determining the input data as time-domain waveform data corresponding to a first plurality of test samples via computer simulation of at least partial reflection of a THz pulse from each test sample of the first plurality of test samples; and

for each test sample in the first plurality of test samples, determining a time-domain output waveform as a superposition of a plurality of peaked time-domain interface waveforms, each peaked time-domain interface waveform comprising a peak corresponding to a reflection from an interface of the test sample, the output data comprising the time-domain output waveform.

14. The method of claim 14, wherein the time-domain waveform data comprises, for each test sample of the first plurality of test samples, a waveform amplitude for each time in a plurality of discrete times td corresponding to detection times of a detector, the waveform amplitude determined from the computer simulation of the at least partial reflection of the THz pulse.