Modeling of Non-contact Thermoacoustic Imaging

Xiong Wang[(1)], Yexian Qin[(2)], Russell S. Witte[(2)], and Hao Xin*[(1)]
(1) Department of Electrical and Computer Engineering, University of Arizona, Tucson, AZ 85721
(2) Department of Medical Imaging, University of Arizona, Tucson, AZ 85724

Microwave-induced thermoacoustic imaging (TAI) has been actively researched in the past decade and shown to be a promising non-ionizing technology for various applications, such as breast cancer imaging, brain imaging, renal calculi detection, and foreign body detection. TAI develops an image exhibiting internal structures of a lossy sample by exploiting generated acoustic waves from absorbed pulsed microwave energy in the sample owing to thermoacoustic effect (R. A. Kruger *et al*, Radiology, 216, 279-283, 2000).

In conventional TAI setup shown in Fig. 1(a), liquid acoustic coupling medium is needed to couple the generated acoustic waves from the sample to receiving acoustic transducers. But this contacting scheme limits some potential applications of TAI, in which a physical contact with the sample or patient is undesired or impractical. Therefore, developing non-contact TAI modality that senses the thermoacoustic signals through air is beneficial to broadening the application realm of TAI.

In non-contact TAI framework shown in Fig. 1(b), mechanical vibrations (can be at the level of picometer to nanometer) caused by the acoustic waves launched inside the sample can be induced at the surface of the sample. A vibrometer is employed to remotely detect the vibration signals through air. Similar to acoustic pressures signals recorded in the conventional TAI, the obtained vibration signals are another embodiment of the thermoacoustic signals and also bear useful information for reconstructing images of the sample.

The focus of this work is on the modeling of non-contact TAI technique. Both analytical and numerical models specifically for non-contact TAI setup are established to calculate time varying vibration signals subject to the input pulsed microwave signal. Different from the contact TAI modeling in which acoustic pressures are needed, non-contact TAI modeling first acquire acoustic particle velocity and then derive vibrations utilizing the particle velocity at the surface of the sample. One of the most important features of non-contact TAI, the magnitude of the vibrations, is obtained with respect to the input pulsed microwave signal. For a specific sample with an embedded object to be imaged, this parameter indicates how much microwave power and how wide microwave pulse are required to excite a vibration signal stronger enough to be measured by a vibrometer with a specific sensitivity. It is found that spectrum of the vibration signal at the surface of the sample contains signature of the embedding depth of the object in the sample, which can be exploited to form images of the object. An experimental system is also explored and the calculated vibration signals are in good agreement with those measured in experiments.

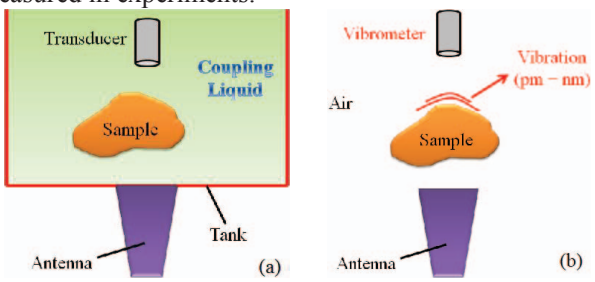

Fig. 1. Schematic setup of (a) contact TAI modality and (b) non-contact TAI modality.