Journal of Physics: Conference Series

PAPER • **OPEN ACCESS**

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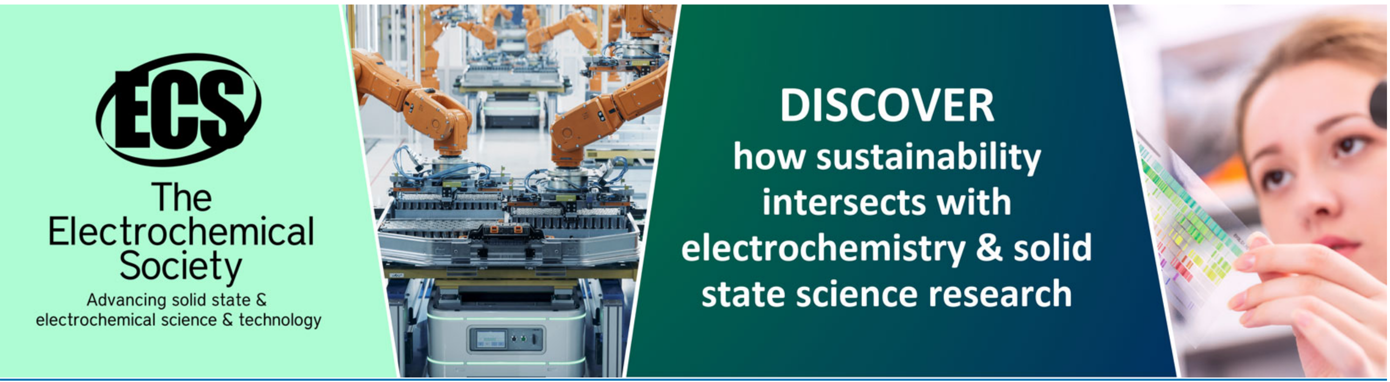
To cite this article: Gang Yang *et al* 2021 *J. Phys.: Conf. Ser.* **1732** 012133



Study on magneto-acousto-electrical tomography based on laser-excited ultrasound

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Abstract. A new laser induced ultrasonic transducer (LIU-T) based on photoacoustic effect was presented. Compared with traditional piezoelectric transducers, Liu-T reduced electromagnetic interference and improved the sound pressure signal. Firstly, Liu-T was made and its sound field characteristics were characterized. The experimental results have shown that the sound pressure of this transducer can reach 3.9MPa and the frequency range was 2.5MHz-7.9MHz. Then an experimental platform for magneto-acoustic-electrical tomography(MAET) based on Liu-T was designed and built. Furthermore, B-scan images of abnormal copper plates were obtained by B-scan, which further indicated that LIU-T would play an important role in the field of NDT and biomedical imaging.

1. Introduction

Magneto-acousto-electrical tomography (MAET) technology has been widely used in medical imaging and nondestructive testing. As a new tomography method, it has the advantages of high resolution of ultrasound imaging and high contrast of electrical impedance imaging [1]. In 1998, Han Wen et al. from the University of Maryland proposed a tomographic imaging technology with electrical parameters as the imaging target parameters and built an experimental platform with Bacon as the target body, which was then called Hall effect imaging[2]. In 2013, Salim MIM et al. detected the MAE signal of beef in vitro with electrodes and obtained b-scan MAET, but the signal to noise ratio was very low [3,4].

MAET is mainly composed of static magnetic field, ultrasonic transducer, weak electromagnetic receiving unit and image reconstruction. The traditional piezoelectric ultrasonic transducer and the static magnetic field act together as the excitation of the imaging target. It is worth noting that under the action of a strong static magnetic field, the piezoelectric ultrasonic transducer will be subject to electromagnetic interference, which requires that the transducer be placed outside the static magnetic field, resulting in that it must be placed at a distance of 3-5cm from the imaging body[1]. In order to solve the interference of ultrasonic transducer by strong magnetic field, LIU-T based on carbon nanocomposite was proposed. The principle of LIU-T is simply described as: laser excitation of carbon nanocomposites to produce ultrasonic signals. The laser excites carbon nanocomposites to produce ultrasonic signals. Carbon nanocomposites are composed of carbon nanomaterials and polydimethylsiloxane (PDMS) with high thermal expansion coefficient [5,6]. Carbon nanomaterials include carbon black (CB)[7], carbon nanotubes (CNT)[8], carbon nanofibers (CNF)[9], candle soot (CS)[10], reduced graphene oxide (RGO)[11,12], etc.

In this paper, the preparation process of LIU-T was first described, and then its ultrasonic performance was characterized. Finally, a magneto-acousto-eletrical tomography experimental platform was built based on this LIU-T, and copper b-scan imaging experiment was conducted to verify the feasibility of LIU-T

2. LIU-T preparation and characterization

When the carbon nanocomposites were irradiated by pulsed laser, and the high frequency and high pressure ultrasonic signals were generated by the instantaneous endothermic expansion of the composites. In order to obtain high amplitude photoacoustic signals, composite materials with good light absorption and high thermal expansion coefficient are usually selected. CNT-PDMS composite was selected in this paper. For known materials, the photoinduced damage coefficient determines the upper limit of sound pressure, so it is necessary to characterize their properties. The schematic diagram of liu-t is shown in figure 1. Liu-t is composed of glass substrate, laser highly absorbent material CNT and thermal expansion material PDMS[13,14,15].

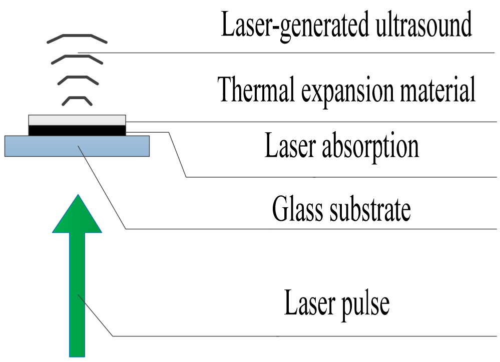

Fig. 1. Schematic diagram of the LIU-T.

Then the performance of LIU-T is characterized, and the experimental schematic diagram is shown in figure 2. The laser beam with 55mJ/pulse emitted by the laser is directly irradiated to Liu-T after collimator. And the ultrasonic signal generated by LIU-T is received by the focused ultrasonic probe, which is located in the center of LIU-T and receives ultrasonic signals at a distance of 3cm from Liu-T. As shown in Fig. 3, the delay time from the trigger signal to the received signal is 21μs, the propagation velocity of ultrasonic wave in water is 1500m/s, and the calculated distance is about 31.5mm, which is consistent with the actual distance. Fig. 4 shows that the positive and negative sound pressure is 3.9 MPa and -2.3 MPa respectively. The band width of -6db is shown in figure5, and the ultrasonic frequency range is 2.5Mhz-7.9Mhz.

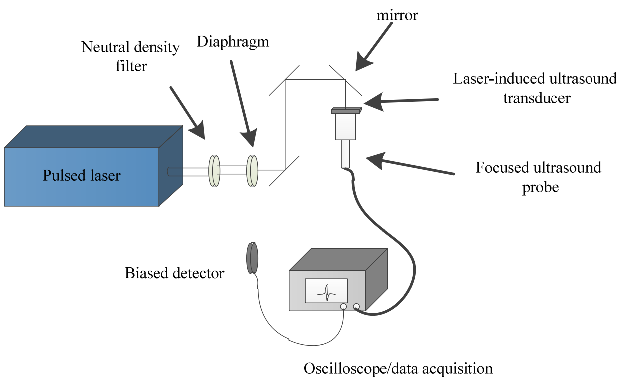

Fig.2. Experimental schematic diagram of LIU-T acoustic characterization

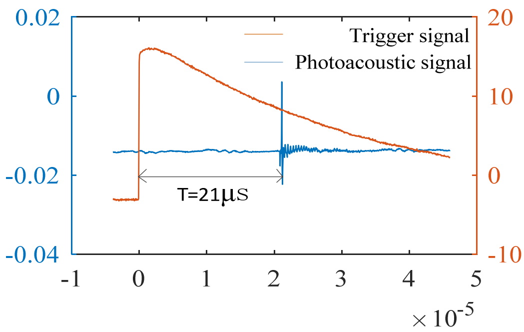

Fig. 3. Trigger signal and received ultrasonic signal

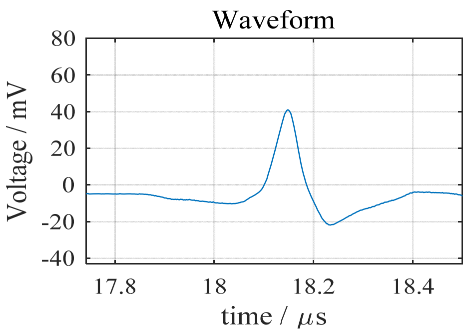

Fig. 4. Ultrasonic signal generated by Liu-T

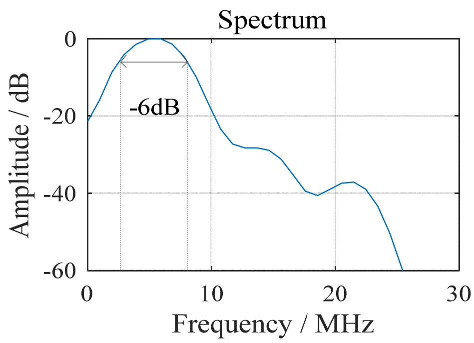

Fig. 5. Frequency domain ultrasonic signal with -6dB

3. MAET experiment and result analysis

As shown in Figure 6, the MAET experimental system was established. The laser source is the Nd:YAG pulse laser (the equivalent wavelength of the laser is 532nm, the pulse width is 20ns, the effective beam diameter is 7mm, the pulse repetition frequency is 10Hz, and the laser energy is 55mJ/ pulse). After the outgoing pulse laser passes through the collimation system, the laser is perpendicular to LIU-T along the Y axis. The target imaging body in this paper is copper, with 6cm long, 3cm wide and 0.1mm thick. The direction of the static magnetic field is y direction, and the direction of the ultrasonic longitudinal wave is perpendicular to the X-O-Y plane. The magnetic field in the effective region of copper foil can be considered constant. The ultrasonic beam emitted by the laser through Liu-T is orthogonal to the direction of the magnetic field, and the voltage signal is collected after filtering and amplification.

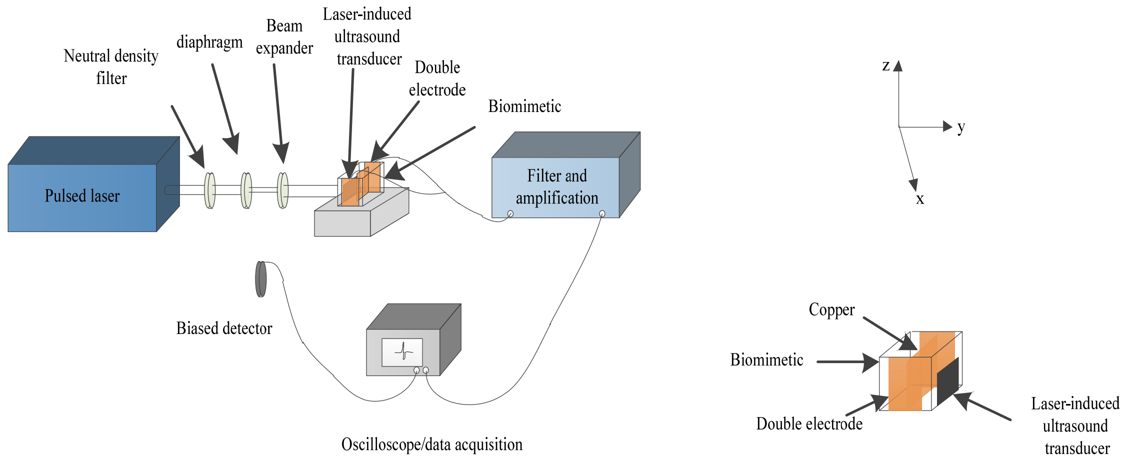

Fig. 6. Schematic diagram of the MAET based on the LIU-T.

The B-scan experiment of MAET is shown in Fig.6. The sound field generated by LIU-T is perpendicular to the measured target body, and the imaging abnormal body in the target body is copper sheet. Ultrasonic scanning was carried out along the scanning direction in Figure 7, and the scanning step size was set to 5mm.

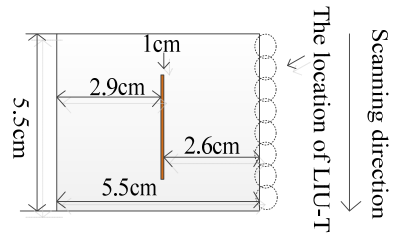

Fig. 7. schematic diagram of B scan

After the scanning is completed, the voltage value of each measurement is recorded, and the image matrix is compiled according to the scanning position. B scanning image is obtained, as shown in Fig. 8. It can be seen from Fig. 8 that there is a certain error between the imaging and the actual copper sheet, which may be due to the non-uniformity of the magnetic field and the divergence angle of the ultrasonic wave.

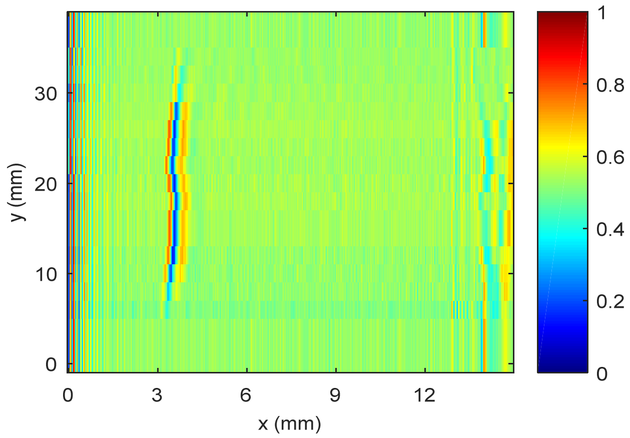

Fig. 8. B scan imaging of copper sheet

4. Conclusion

In order to solve the electromagnetic interference problem of traditional piezoelectric ultrasonic transducers in MAET, LIU-T based on CNT-PDMS composite was prepared and its ultrasonic properties were characterized. The experimental results have shown that the sound pressure of this transducer can reach 3.9MPa and the frequency range was 2.5MHz-7.9MHz. Secondly, the MAET imaging system based on LIU-T was established, and two-dimensional B-scan imaging of copper was carried out to verify the feasibility of LIU-T in MAET.

5. Acknowledgments

This work was supported by the National Natural ScienceFoundation of China (Nos.61771448 & Nos.519370104) and State Grid Technology Project (Nos.520530190008).

References

[1] Guo L, Liu G, Xia H. Magneto-Acousto-Electrical Tomography With Magnetic Induction for Conductivity Reconstruction. IEEE Transactions on Biomedical Engineering, 2015, 62(9): 2114-2124

[2] Han wen, Robert S.Balaban. The Potential for Hall effect breast imaging[J]. Breast Disease, 1998,10(3-4):191-5.

[3] Graslandmongrain P, Destrempes F, et al. Acousto-electrical speckle pattern in Lorentz force electrical impedance tomography [J]. Phys. Med. Biol.,2015,9(9):3747-57.

[4] Graslandmongrain P, Mari J M, Chapelon J Y, et al. Lorentz Force Electrical Impedance Tomography[J]. Irbm,2013,34(4):357-360.

[5] Cox B T, Beard P C. Fsat calculation of pulsed photoacoustic fields in fluids ueing k-space methods[J].The Journal of the Acoustical Society of America, 2005, 117(6):3616-3627.

[6] Shi Y J , Xing D . Study on photoacoustic effect in nanoscale and photoacoustic conversion mechanism of nanoprobes[J]. Chinese Journal of Lasers, 2018, 45(2): 0207026.

[7] Haider S, Hrbek A, Xu Y. Magneto-acousto-electrical tomography: a potential method for imaging current density and electrical impedance[J]. Physiological Measurement, 2008, 29(6): S41- S50.

[8] Baac H W, Ok J G, Park H J, et al. Carbon nanotube composite optoacoustic transmitters for strong and high frequency ultrasound generation[J]. Applied Physics Letters, 2010, 97(23): 234104.

[9] Hsieh B Y , Kim J , Zhu J D , et al. A laser ultrasound transducer using carbon nanofibers-polydimethylsiloxane composite thin film[J]. Applied Physics Letters, 2015, 106(2): 021902.

[10] Wenbin Huang, Jinwook Kim, et al. Candle soot nanoparticles-polydimethylsiloxane composites for laser ultrasound transducers[J]. Applied Physics Letters, 107, 161903 (2015).

[11] Lee S H , Park M A , Yoh J J , et al. Reduced graphene oxide coated thin aluminum film as an optoacoustic transmitter for high pressure and high frequency ultrasound generation[J]. Applied Physics Letters, 2012, 101(24): 241909.

[12] Hyoung Won Baac, Jong G. Ok, Taehwa Lee, et al. Nano-Structural Characteristics of Carbon Nanotube-Polymer Composite Films for High- Amplitude Optoacoustic[J]. This journal is © The Royal Society of Chemistry 2013.

[13] Zou X T , Wu N , Tian Y , et al. Broadband miniature fiber optic ultrasound generator[J]. Optics Express, 2014, 22(15): 18119-18127.

[14] Baac H W , Ok J G , Maxwell A , et al. Carbon-nanotube optoacoustic lens for focused ultrasound generation and high-precision targeted therapy[J]. Scientific Reports, 2012, 2: 989.

[15] Noimark S , Colchester R J , Blackburn B J , et al. Carbon-nanotube-PDMS composite coatings on optical fibers for all-optical ultrasound imaging[J]. Advanced Functional Materials, 2016, 26(46): 8390- 8396.

[16] Zhou Y , Ma Q Y , Guo G P , et al. Magneto-acousto-electrical measurement based electrical conductivity reconstruction for tissues[J]. IEEE Transactions on Biomedical Engineering, 2017, 65(5): 1086- 1094.