

Multi-Angle Low Cost Ultrasound Camera for NDT Field Applications

Author(s):

Mr. Robert Lasser, Dr. Marvin Lasser,
Mr. Jack Gurney, Mr. John Kula, Mr. David Rich
Imperium, Inc.
1738 Elton Road, #218
Silver Spring, MD 20903
Phone: 301-431-2905

Abstract:

Imperium has developed and patented a hybrid microelectronic array and camera that can generate ultrasound images over an area at 30 frames per second. The array is made up of two components, a piezoelectric material that is deposited onto silicon readout multiplexer. The energy that strikes the piezoelectric material creates voltages that are read out by the multiplexer, identical to a CCD imaging array.

The array is responsive over a wide range of ultrasound frequencies, typically between 1 MHz and 10 MHz. A large unfocused ultrasound beam and an acoustic lens are used to image in pulse echo geometry. The use of a lens provides a simple and inexpensive alternative to allow beam forming on a small sensor region. The user simply focuses by adjusting the lens while looking at the image on a monitor. The resultant pressure wave strikes the target and is scattered. The acoustic lens collects the scattered energy and focuses it onto the ultrasound sensitive array. The result is high resolution imagery in real time.

In this paper, our presentation includes the technical development of the sensor, its evolution and its NDE applications for composites and metals, including real time imagery of delaminations, voids, and cracking. A multi-angle camera will be reported on to describe the technique for shear wave imaging.

Keywords: Imaging, Real-Time, Ultrasound,

General

We are reporting on the latest developments of a real time ultrasound camera system. The basis for the system is a novel patented two-dimensional imaging system that creates real-time, high-resolution images of subsurface structures. Imperium has developed and patented a hybrid microelectronic array that is capable of generating ultrasound images with standard video presentation at video rates. The system can be operated to detect ultrasound energy received in either a through-transmission or pulse-echo modes as shown in the block diagrams in Figure 1.

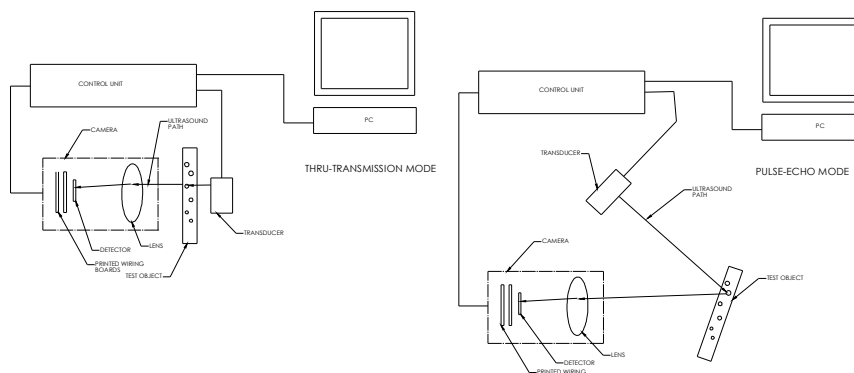


Figure 1: Functional Block Diagram

The system operates by exciting a large area unfocused ultrasound transducer (used only as a source) that generates a collimated plane wave. The resultant pressure wave strikes the target and is scattered. An acoustic lens collects the scattered energy and focuses it onto an ultrasound sensitive detector array. As shown in Figure 1, the process can be used in either the through transmission or pulse echo modes. With some camera designs, the face of the camera is placed in intimate contact with the test object by means of a special acoustic coupling gel or compliant pads or membranes. The camera housing is water filled.

The detector array is made up of two components, a custom Read Out Integrated Circuit (ROIC) and a piezoelectric material that is deposited onto the ROIC. The array is 12 mm on a side made up of 120 x 120 pixel elements (14,400) with 100 micron center-to-center spacing. The energy that strikes the piezoelectric material creates voltages that are

multiplexer, similar in operation to a standard video CCD imaging array.. The array is responsive over a wide range of ultrasound frequencies, although most imaging is done between 1 MHz and 10 MHz.

The use of a lens provides a simple, inexpensive alternative to complex beam forming often employed in ultrasound imaging. The user simply focuses by adjusting the lens while looking at the image on a monitor. Furthermore, it provides a means to trade off resolution and area coverage, or zoom in and out. Currently, Imperium uses a 1 – 2 inch Field of View (FOV) in its production model systems and is experimenting with a 3 inch FOV for next generation models.

Test Setup

Imperium established a simple test set-up in our laboratory based upon our approach. All tests were done using a 5 MHz transducer and our handheld device driven up to 700 V. The camera was placed on several samples and images were captured using the frame grabber in a personal computer and a graphical user interface (GUI). A slight amount of gel was placed on the target before moving the probe around the area under study.

Results

Images from the ultrasound camera taken in 1/30 second are shown below.

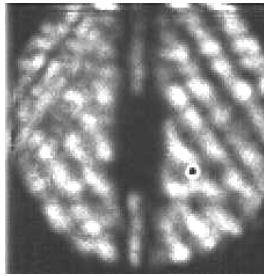


Figure 2: Through transmission image of radius with defect in center



Figure 3: Pulse Echo Image of quarter

System Implementation

Imperium has done further development work in the handheld area through the development of a prototype design that is intended to employ the latest generation detector. This water filled prototype is shown in Figure 4 and incorporates a built-in 2.5” LCD display for viewing of the images.



Figure 4: New Handheld Ultrasound Camera for rapid inspection of materials with LCD

Angle Beam Detection

This alternative method is based upon the well known angle beam techniques used in conventional ultrasound. Here, however, the Acoustocam permits the collection of real time images that permit the rapid evaluation of the results. This contrasts to conventional ultrasound where careful study or post-processing of results is required to obtain similar visual results.

Inspections of this nature could be done by modifying the handheld AcoustoCam with the addition of a newly developed coupling nozzle that inclines the camera at the appropriate angle to the part. This type of modification is shown in Figure 5.

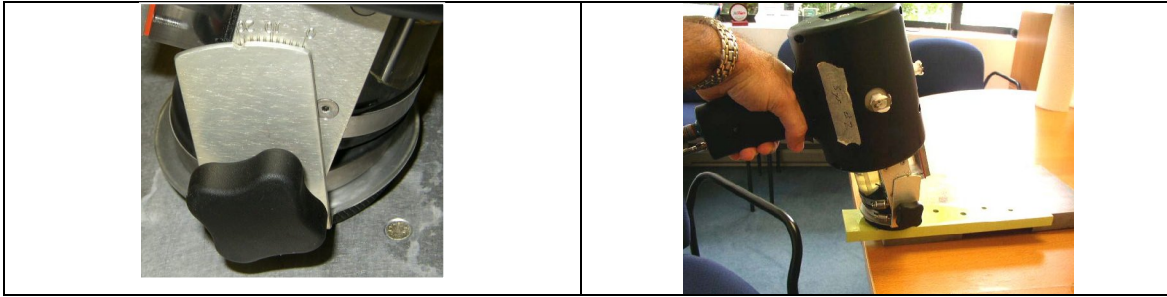


Figure 5. Angle Beam Coupling Camera. Angle can be adjusted from 0 to 20 degrees.

In this test, the same sample plate was inspected. However, this time, the AcoustoCam was inclined at an angle to the plate in order to introduce a shear wave into the plate. Shear waves are particularly sensitive to the detection of cracks and corrosion. In this case, the front side reflection is angled away from the detector and only rear side faults are seen.

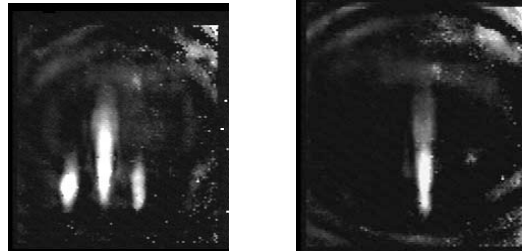


Figure 6. Shear wave images of hole in plate with and without backside cracks taken at 5 MHz. Cracks were 0.080” and the aluminum plate was 1/4” thick.

Using this technique, we have successfully imaged faults in steel more than 5 inches deep.

Comparisons to current ultrasonic inspection

The use of the ultrasound camera provides a significant increase in productivity without sacrificing data quality. As an example, if an inspection is performed of a 10-foot by 10-foot component, with a minimum spatial resolution of 0.5-mm (21 mils) and a scanning rate of 12 inches per second, the difference in scanning time is as follows:

Current C-scan

100 (ft)²
6096 passes

16.9 hours

Real-Time C-scan

100 (ft)²
48 passes

8 minutes

Large Scale Scanning

The camera system offers the capability to inspect not only inspect faster than current scanning techniques, but also with added resolution. Figure 7 below shows a setup of the camera scanning over a composite part. (Images courtesy of ATK Thiokol)

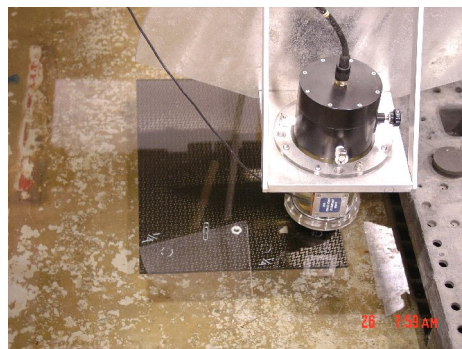


Figure 7: Camera scan

Figure 8 shows a conventional scan using a 2.25 MHz transducer and Figure 9 shows the same scan being performed by the camera.

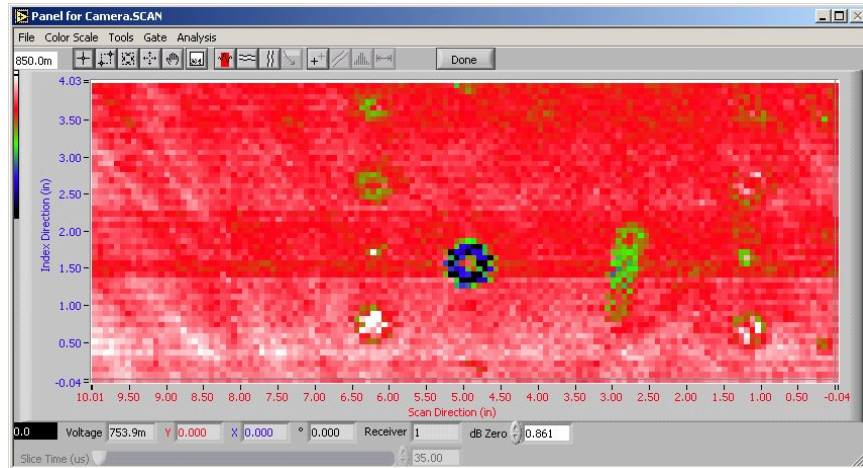


Figure 8: Conventional 2.25 MHz pulse echo scan

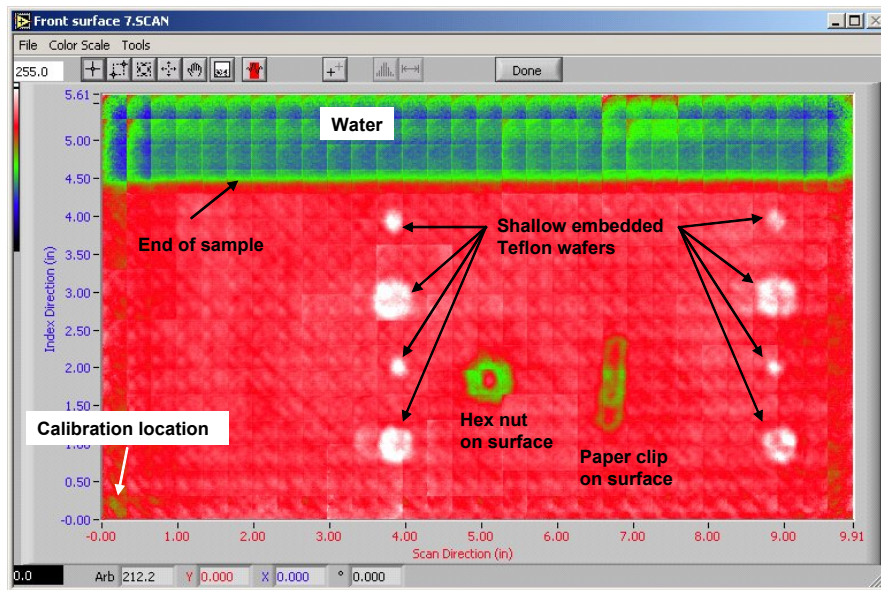


Figure 9: Camera image of same part as Figure 8, also done at 2.25 MHz

Note the added signal to noise and resolution offered by the camera. One reason for the added performance is the averaging that can be performed by covering the same scan area more than once.

Conclusions

Real-time, low cost C-scan technology offers an exciting next generation of ultrasound imaging. The use of semiconductor technology, and standard “optical” techniques such as lenses to create real time imagery means that commercial systems can be delivered at costs less than or equal to today’s slower C-scan systems. For the hand held device, no formal training or certification would be required to observe subsurface faults. For in-service inspections, this technique can be used to quickly quantify very small defects.

REFERENCES

1. Lasser, M., Harrison, G. "A Novel High Speed, High Resolution Ultrasound Imaging System", QNDE Review of Progress In Quantitative NDE, Plenum Press, Volume 17B, pp. 1713-1719 (1997),
2. Plummer, J.D., Swartz, R.G., Maginness, M.G., Beaudouin, J.R., and Meindi, J.D., Two-dimensional transmit/receive ceramic piezoelectric arrays: construction and performance, *IEEE Trans. Sonics Ultrason. SU-25*, pp. 273-280 (1978).
3. Turnbull, D.H., Two-Dimensional Transducer Arrays for Medical Ultrasound Imaging, *Ph.D. Dissertation* (University of Toronto, 1991).
4. Smith, S.W., Trahey, G.E. and von Ramm, O.T., Two-dimensional array transducers for medical u



- Ultrasonic Imaging, 14*, pp. 213-233 (1992).
5. Sandhu, J.S., Wang, H., and Pobek, W.J., Recent Progress on Ultrasonic NDE Using Acoustography, *Second Conference on NDE Applied to Process Control of Composite Fabrication*, pp. 229-237 (1996)
 6. Lo S-C. B., Liu C.C., Freedman M.T., Kula J., Lasser R., Lasser M.E., Wang Y., "Transmission and Reflective Ultrasound Images using PE-CMOS Sensor Array," *SPIE Proc. Med. Img. Vol. 5750*, 2005 (in press).
 7. Lo SCB, Rich D, Lasser ME, Kula J, Zhao H, Lasser R, and Freedman MT, "A C-Scan Transmission Ultrasound Based on a Hybrid Microelectronic Sensor Array and Its Physical Performance," *SPIE Proc. Med. Img. Vol. 4325*, pp. 89-93, 2001.
 8. Lasser, M., Lasser, B., Kula, J., Rohrer, G., "Latest Developments in Real-Time 2D Ultrasound Inspection for Aging Aircraft", 10th Annual AeroMat Conference & Exposition (1999)
 9. Lasser, M., Lasser, B., Kula, J., Rohrer, G., "On-Line, Large Area Ultrasonic Imaging for Composite Manufacturing", American Society for Nondestructive Testing Conference (1999)

