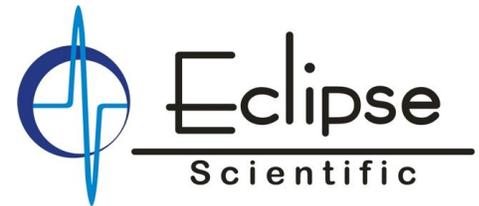
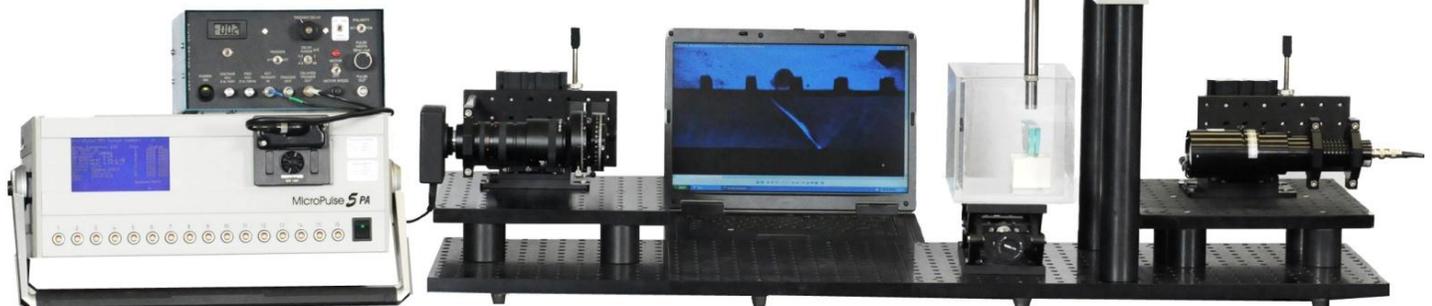
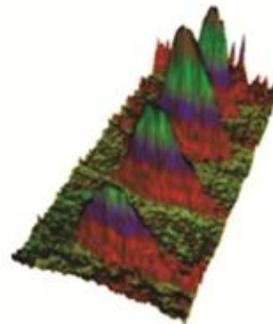
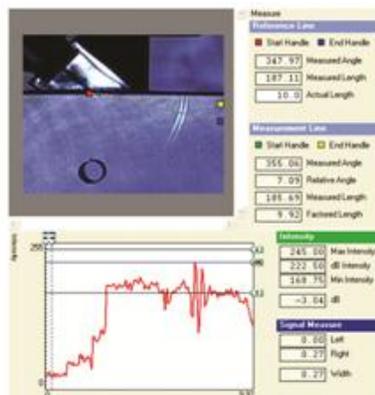
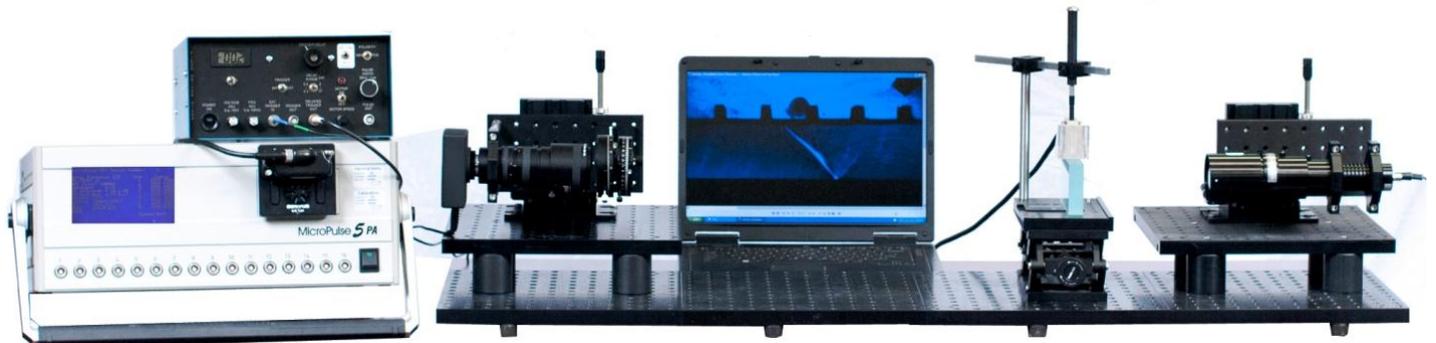


ESPHOTOELASTIC



Ultrasonic Photoelastic Visualization System Data Sheet

Eclipse Scientific Model: ESPI



Rel. 1.0

Head Office & Training Center
97 Randall Drive, Unit 2
Waterloo, Ontario, Canada, N2V 1C5
Phone (800) 490-1072 • Fax (519) 886-1102

Western Operations
3-11 Bellerose Drive, Suite #353
St. Albert, Alberta, Canada, T8N 5C9
Phone (780) 449-4078 • Fax (530) 239-8408

Accounting & Software Engineering
1260 2nd. Avenue East, Unit 4
Owen Sound, Ontario, Canada, N4K 2J3
Phone (519) 372-1831 • Fax (519) 372-2039

Groupe Solutions Avancées
2800, rue Louis-Lumière, Suite 110
Québec, Québec G1P 0A4, Canada
Phone (418) 933-9992

eclipsescientific.com

Contents

Copyright Information	3
Introduction to Ultrasonic Photoelastic Visualization	4
Image Processing Software	9
Camera Settings Tips.....	10
Application Software.....	10
Image Intensity Analysis Software	11
Image Scaling	16
Image Intensity Analysis	16
Suggested Experiments.....	20
Compression Wave using a Normal Beam Probe	20
Shear Wave using a Refracted incidence of a Compression Wave Probe	20
Using Other Ultrasonic Instruments	21
Video Imaging with the ESPhotoelastic system.....	21
Camera Settings for video.....	22
Optional Components for the ESPhotoelastic	23

Please Note:

The purpose of this manual is to provide information for product mechanical aspects and parts ordering only. It is not intended as a guide for use, NDT procedures, techniques, data collection or data interpretation.

It is the responsibility of the end user to use this product in a safe manner and in accordance with any local or regional safety legislation.

The information provided by Eclipse Scientific is believed to be accurate however Eclipse Scientific accepts no responsibility for the use of this product, nor any patent infringement or other rights of third parties. Eclipse Scientific reserves the right to change specifications without notice. Please contact Eclipse Scientific for the most current product information.

Copyright Information

1st Edition 2012

Ownership: Eclipse Scientific Inc.

Authors: Ed Ginzel

Published by: Eclipse Scientific, 97 Randall Drive, Waterloo, Ontario N2V 1C5, Canada

Copyright by Eclipse Scientific Inc. 2012

This book and the information it describes are protected by the Copyright Act of Canada and international laws. You are permitted to use these materials only for your personal study and research. Use of the materials for any other purposes including reproducing or distributing in whole or in part, whether for sale or not, without express permission of the copyright owner, will infringe copyright. The copyright owners may take action against you for infringement.

Eclipse Scientific, 97 Randall Drive, Unit 2, Waterloo

Ontario, N2V 1C5

Canada

Toll free (800) 490-1072

Phone: +1 (519) 886-6717

Fax: +1 (519) 886-1102

www.eclipsescientific.com

The information contained in this document is subject to change without notice.

File Name: Ultrasonic Photoelastic Imager Data Sheet.docx

Introduction to Ultrasonic Photoelastic Visualization

A picture is worth a thousand words.

Principles of photoelastic imaging of ultrasonic pulses are relatively simple. However, the parameter controls involved and the effects of bandwidth (both light and sound) make hardware requirements and associated electronics somewhat elaborate.

The photo-elastic technique of visualization overcomes problems associated with the older Schlieren method of visualization. Photoelastic visualization has the added benefit of being able to visualize the shear mode in solids. Schlieren visualization relies on the change in refractive index of a material that results with volume changes. This occurs as a result of density changes in the medium under test. But Schlieren visualization of the shear mode is not possible since by definition, the compression mode (longitudinal wave) is an energy transfer that results in a volume change of the lattice structure whereas the shear wave transfers energy by a non-volumetric change in the lattice structure.

Initial studies in the photo-elastic technique seem to have been in 1937 with Heideman and Hoesch¹ observing the stress field from a quartz transducer in a glass block. Essentially, the “nulled” condition of cross-polarized light passing through a transparent material is locally altered by a change in pressure caused by the ultrasonic pulse. This rotates the polarized light so that the null condition is not maintained and passage of light through the second polarizer (also referred to as the analyzer) occurs. A quarter-wave plate is inserted after the polarizer to change the linearly polarized light to a circularly polarized light. This has proven to provide an effective means of adjusting the contrast when imaging the effect. **Figure 1** shows the basic set-up for the photo-elastic system including the delay circuit for timing and delay of illumination with respect to the pulse.

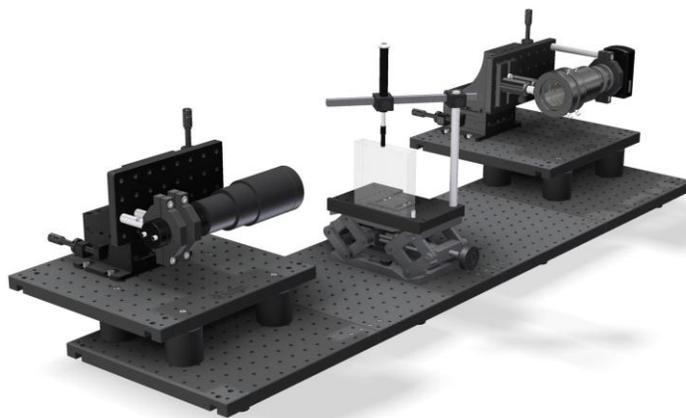


Figure 1 Set-Up for the ESPhotoelastic

¹ E. Heidemann and K.H. Hoesch, Z. fur Physik, Pages 104-107, 1937

In the late 1960s Dr. P.D. Hanstead² and his associate R.C. Wyatt developed a system using a spark gap controlled by a high voltage thyatron. This provided a white light of high intensity with relatively short pulse duration. With the appropriate pulse voltage to the probe and suitable timing delay circuitry, it was easy to image pulse interactions in a test piece once the polarization planes had been optimized for the conditions under test.

In addition to being able to visualize shear waves the photoelastic system has a distinct advantage in resolution. The light pulse duration for the thyatron unit is approximately 50ns with a 2ns rise time. This, along with the intense irradiance allows wavelength resolution with the technique. This has provided wavelength resolution of even high frequency pulses (e.g. 7.5MHz pulse in glass has a shear wavelength of 0.49mm and is clearly resolved).

The ESPhotoelastic system deviates from the design by Hanstead and Wyatt and takes advantage of the high intensity light provided by new LEDs (light emitting diodes). Total beam output is determined by the combination of pulse duration and the number of pulses per second. Although the LED output is much less than the spark gap the difference can, to a great extent, be compensated for by using a higher repetition frequency. To obtain the required viewing intensity at the imaging location (camera with CMOS or CCD elements) the peak power output must be suitably high to compensate for the losses during the non-illumination periods including rise and fall of intensity as the light is switched on and off during the timed pulsing.

The ESPhotoelastic has the same main features as the older spark pulse unit but in a compact modular form. A component layout drawing is indicated in **Figure 2**.

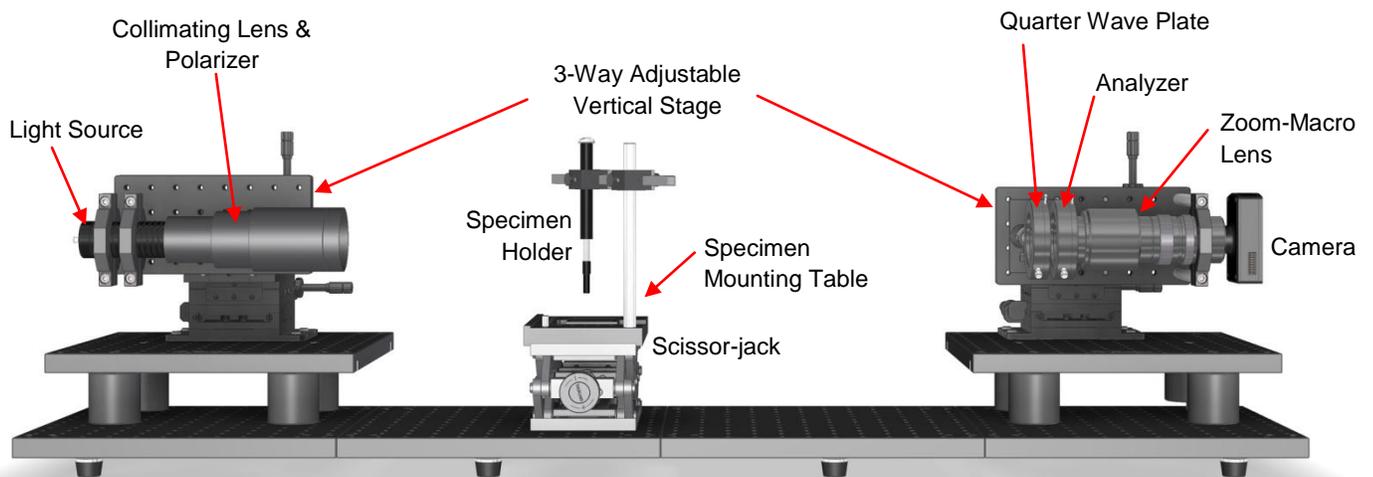


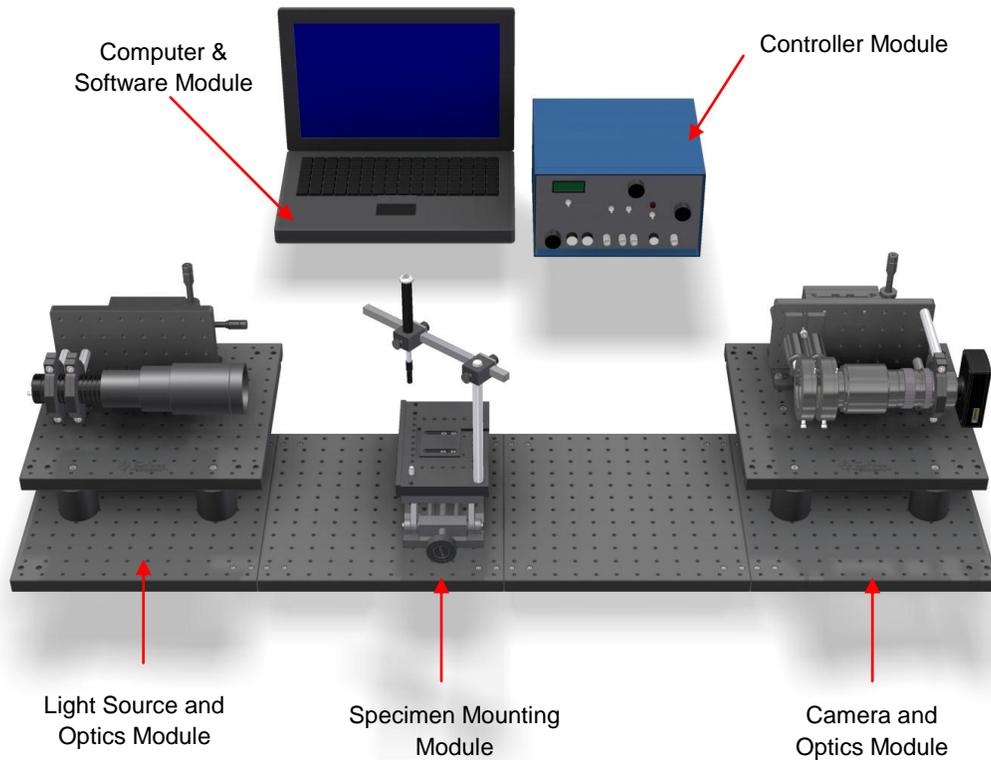
Figure 2 Component Layout of ESPhotoelastic

² P.D. Hanstead, Ultrasonic Visualization, British Journal of NDT, Vol. 14, page 162, Nov. 1972

The specimen mounting area is located along the light path with a nominal 60mm diameter illumination area.

In order that the illuminated image is suitably resolved, a macro focusing lens is mounted on the camera. Although generally located in the longer range of focus, it is possible to place the camera and lens within less than 30cm of the specimen for very detailed imaging.

Software is provided for viewing and analyzing the projected images on a supplied laptop computer.



LED Lamp	
Wavelength (2 LEDs supplied)	LED-5500 350-700nm ('white' light) LED-630 630nm (red light)
Power (peak at lamp) (approx)	1000mW
Pulse rise time	2ns
Pulse duration (nominal)	30ns
Controller	
Input (110V)	110 VAC
Pulse rep rate	0 to 10 kHz
Delay and Clock Output Trigger Pulse	TTL (+5V)
Delay adjustment	200ns to 100 μ s
Ultrasonic Pulsar voltage	Variable 0 - 300V pp
Ultrasonic Pulsar shape	Negative or Positive square wave variable width from 40-250ns
Optics	
Collimator lens with built-in polarizer (PCX)	60mm diameter
Quarter-wave plate with rotary optic mount	42mm
Analyzer with rotary optic mount	50mm
Macro-zoom lens	6-97mm Field of View
Digital camera	12fps USB2 interface
Computer/Software	
Laptop	Windows platform
Image Capture software	Suitable for camera used
Image editing software	Eclipse Scientific IIA

Image Intensity Analysis	Eclipse Scientific IIA
Other	
Glass target samples	Radius Side drilled hole and notch
Mounting boards and hold-down mechanics	(6) Optical boards; (2) XYZ translation stages; (1) Scissor-jack
Ultrasonic transducer and wedges	5MHz with standard 60° and 70° for steel
Carrying case	Impact resistant

Image Processing Software

Two software packages are provided for the image captures. LuCam Capture is the software provided by the camera manufacturer. This will control the camera functions and the image collection. The other software is IIA (Image Intensity Analysis). It is provided to facilitate analyzing the photoelastic images. Both stills and video images may be collected. Analysis includes the ability to display intensity maps and to make beam dimension measurements. Examples of the analysis options are indicated in **Figure 9 to 11**.



Figure 9 Sample Still Image – Unprocessed
Focused shear wave pulse from 7.5MHz phased array

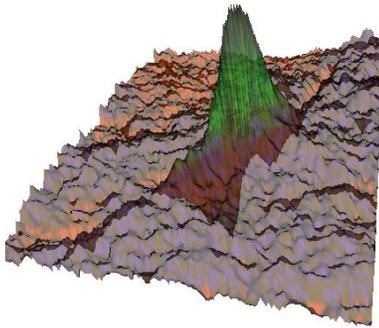


Figure 10 Sample Still Image - Intensity Mapped and Rendered
From image in Figure 9 rendered with 50% transparency and rotated

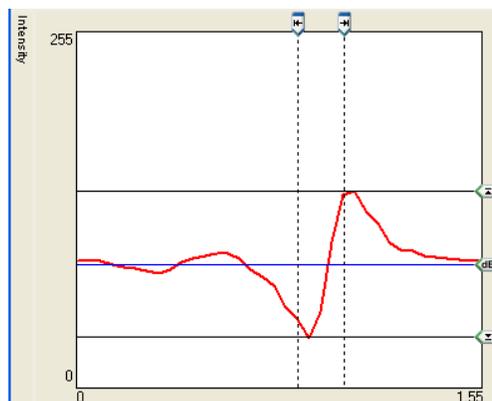


Figure 11 Sample Still Image -
Intensity Beam Dimensions

Cursors in the analysis software allow measurement of distance and amplitudes including the phase effects of pressure differences.

Camera Settings Tips

When working with the LuCam Capture software directly, a capture setup window is provided (see Figure 2-9). The maximum detail (pixel resolution) is the default setting but this can be adjusted to lower settings. For most work with the ESPhotoelastic system the macro lens will require the aperture be open to its maximum (rotated fully to the clockwise position when looking from the camera along the lens).

Having selected a suitable Image size (e.g. 1616x1216) you can then press the “Start Preview” button and a captured image window appears on screen. This is a real-time preview of the video. Exposure time can be adjusted to increase the image intensity or “Gain” can be added for a similar brightening effect. For most photoelastic imaging applications the AEC (Automatic Exposure Control) feature will not be applicable.

Image processing to adjust Gamma and White Balance can also be applied.

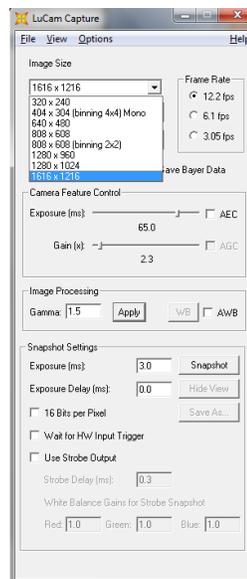


Figure 3 Camera capture menu in LuCam software

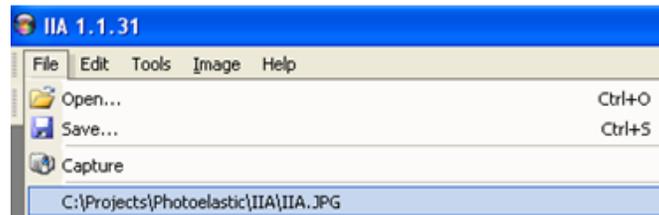
Application Software

Software provided includes two programs. The program used for image capture is “LuCam Capture” and the Image Intensity Analysis software (IIA) for beam dimension determinations. Note, there is an option in IIA to configure the camera capture parameters and observe the captured image while running IIA. IIA also permits captures of stills. In order to capture video images for conversion to we recommend Windows “Movie Maker” software. This will also recognize the camera and allow fast acquisition of video in WMF format.

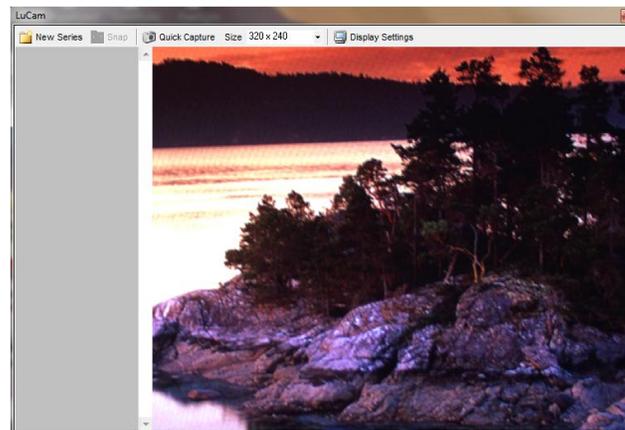
Image Intensity Analysis Software

The IIA (**I**mage **I**ntensity **A**nalysis) software is provided by Eclipse Scientific Products Limited. It has been designed specifically for ultrasonic beam analysis.

Standard image file formats (jpg, bmp and gif) are recognized for analysis. To open an image file click on the Open File and browse to the location where the image is stored that you want to analyze. The five previous files analyzed are available to select from. Once an image has been altered it can be saved with a new name. Direct access to the camera is available via the Capture tab or the video camera icon.



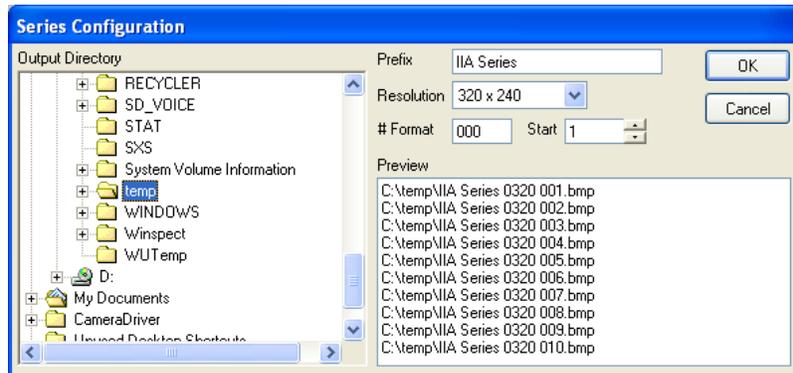
When the capture tab or icon is selected the camera is activated and a window opens indicating the camera view in real time.



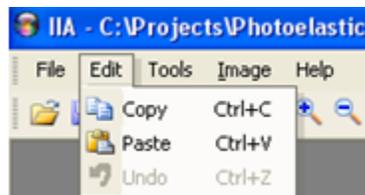
When the "Quick Capture" is clicked the viewed image is captured and sent directly to the IIA processing window for use in IIA. The size of that image (resolution) may be changed (the options being 320x240, 640x480, 800x600, 1024x768 or 1080x1024).

When collecting a series of images with small delay changes between them (as might be done for beam spread analysis) there is an option to collect a series of images that will be sequentially numbered. This is done using the New Series button.

When pressed this sets up a sequenced set of files that you can name and configure using the Series Configuration window. In this window you name the series in the Prefix box, select the resolution for the images and then select the number format (number of digits that will be used) and the starting number. In the example case, the files will be going to the temp directory and all will start with IIA Series. The 0320 indicates the lowest resolution is selected (320x240) and the images will start at 001 with spaces made for 3 as the number format.



The Edit pull-down menu allows for Copy, Paste and Undo previous step.



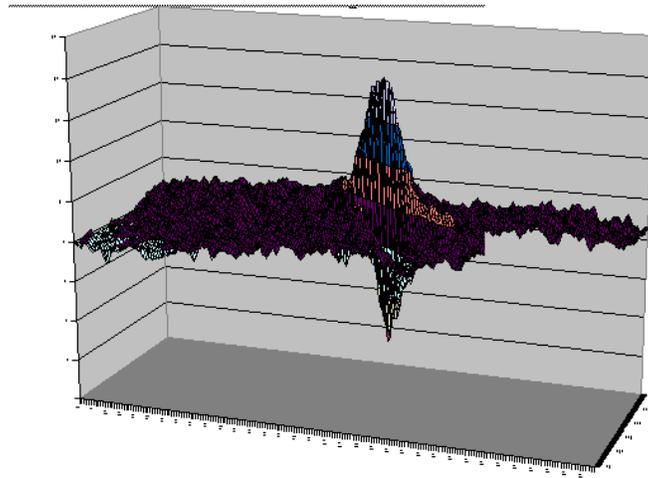
The Tools pull-down menu presents a selection of options for processing the image that has been opened.



Zoom In, Zoom Out and Zoom Fit allow magnification, scale reduction and a 1:1 pixel image presentation of the image.

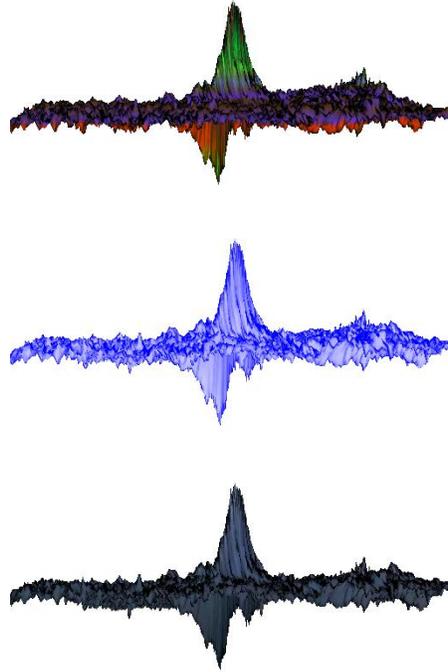
“Measure” is the tool kit that provides the image with two sets of cursors, one for assigning a known distance and angle (Scale Cursor) and the other cursor (Measurement Cursor) is used to make measurements based on the scale indicated by the Scale Cursor.

“Excel” is a utility that converts each pixel to a “bit” value (0-255) and X-Y coordinate. This automatically opens a spreadsheet file in Excel (requires Microsoft Excel to be on the computer). With this spreadsheet data, a graph can be made using the Excel “Surface” graph option.

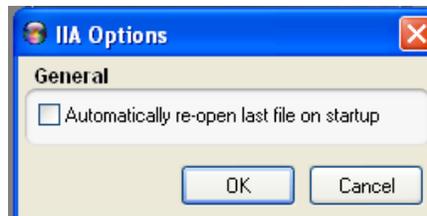


“VR Surface” renders a 3D version (similar to the Excel Surface plot). Options are available within the VR Surface rendering to adjust the colouration and transparency of the image generated. As well, the image may then be spun, rotated and rolled for different perspectives.

Three “colouration” options include Spectral, Lit and Textured Surfaces.



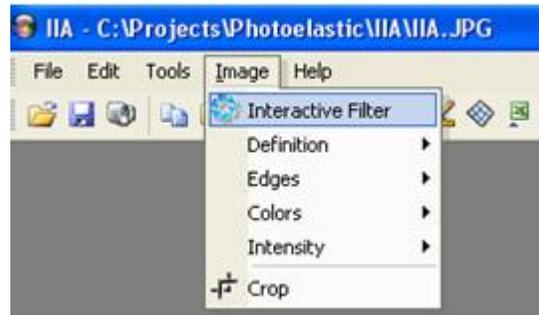
The “Options” button under Tools provides the option to default to the previous image analyzed or not.



The next pull-down menu provides several options for altering the initial image.

Caution is advised when working with these enhancements as the relative intensities can be altered by some of the processes. Several of the image processes are inappropriate for intensity analysis. Some of the processors are simply for image enhancement to aid in the construction of reports or training materials.

The first item on the list of Image enhancement options is the Interactive Filter.



Clicking on this item opens a large window that provides more than 20 methods of adjusting the image. A screen display indicates the original condition of the image before processing and a second display indicates the results of processing with the selected Interactive filter.

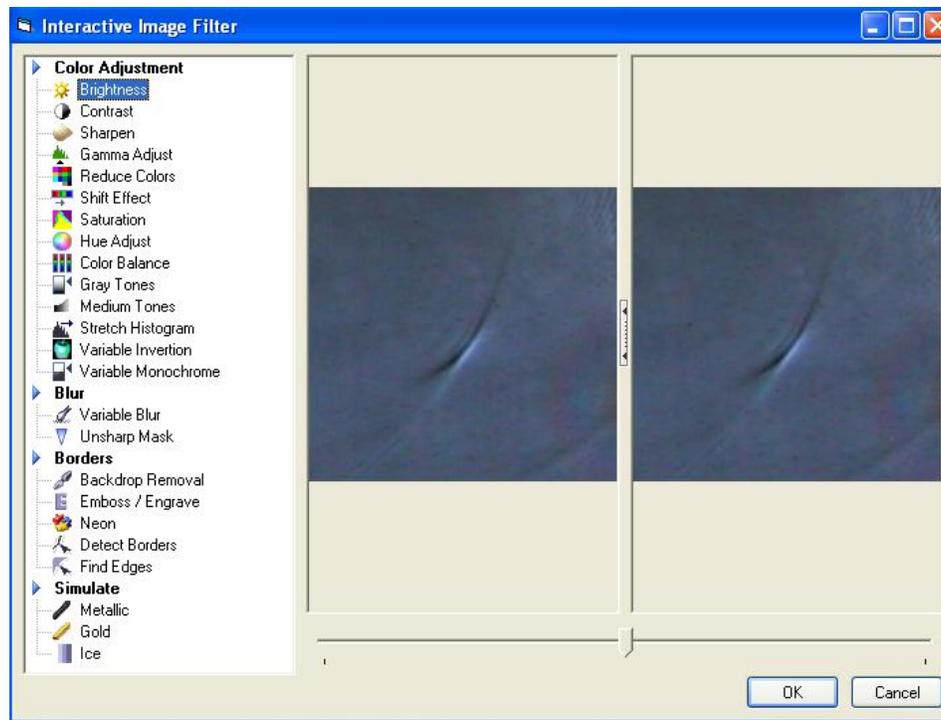


Image Scaling

The original purpose of the IIA software was for quantifying aspects of ultrasonic images. Angle and distance of a pulse as derived from an image presents a problem unless some form of reference can be made. Using the IIA software can provide an effective quantification providing the image starts with some form of reference. This is best accomplished by incorporating a known distance in the original image. Thin lines on the glass, a target such as a hole of a known diameter or the outline of the probe all provide references for this purpose.

The image in figure below is of a standard 6mm diameter 5MHz probe mounted on a polymethylmethacrylate (Acrylic) refracting wedge intended to produce a 60° angle in steel. The image captured shows the entire wedge, the mounting angle (incident angle) and a side drilled hole in the glass specimen.

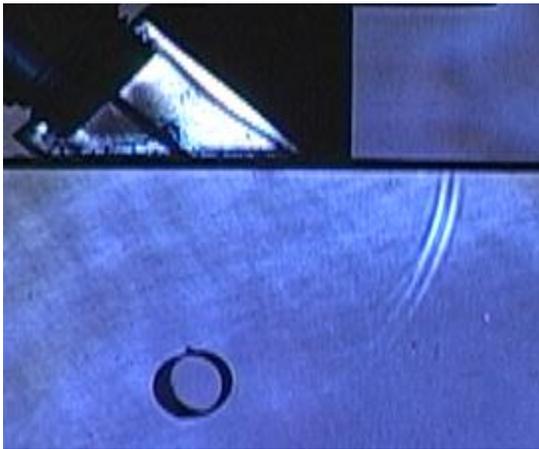
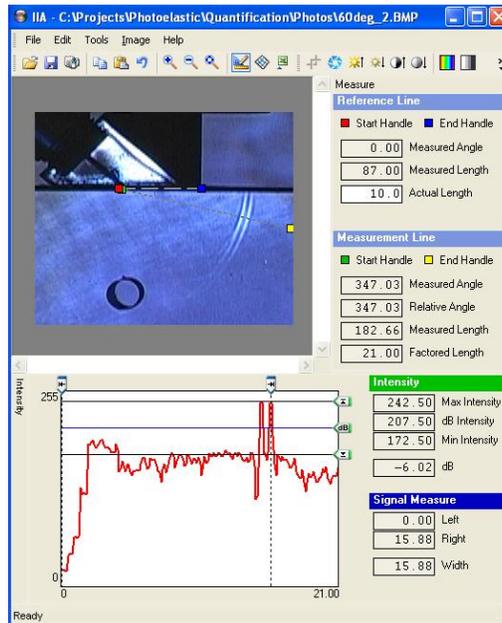


Image Intensity Analysis

After the scaling of the angle and distance has been performed, the signal can be analyzed. This is generally done in conjunction with the image intensity plot.

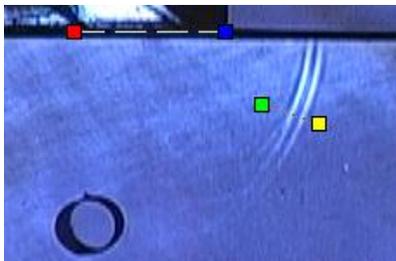
The intensity plot is placed below the image analyzed. A red line indicates the bit value (0-255) of the image intensity at every point the Measurement line. The image shows the starting point where the Green box of the Measurement Cursor starts at the black line made by the exit point marker on the wedge. The Yellow box was then extended to a point beyond the pulse indication and moved so the Measurement Cursor cut the pulse image along the arc made by the pulse until the amplitude of the intensity plot was maximized. This is indicated by the largest positive displacement of the red line on the intensity plot. This is where the intensity of the white arcs from the pulse is the strongest.



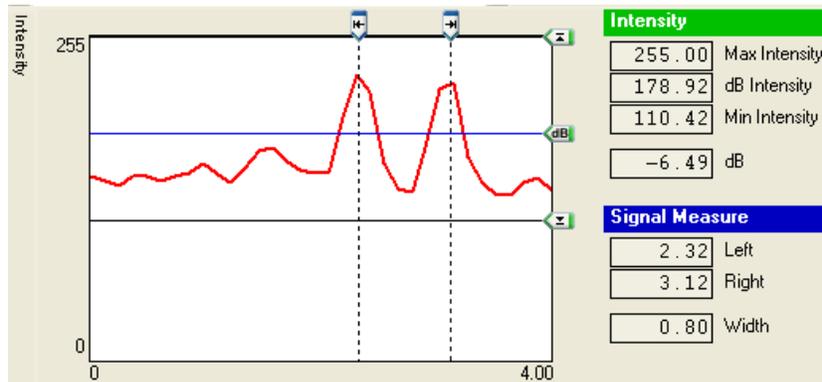
The Measurement Line numeric values indicate that the angle of the Measurement Cursor is 347° . That makes it 13° off the 0° (360°) reference angle. As a refracted angle that is equivalent to 77° . The Measured Length is no longer a straight line so the pixel count is not a whole number but instead the result of the angle formed (282.66). This length when corrected for the scale factor is 21mm.

The lower numeric regions are identified as the Intensity and the Signal Measure.

In the example below, the Measurement Cursor has been shortened to 4mm length and approximately centred on the pulse.



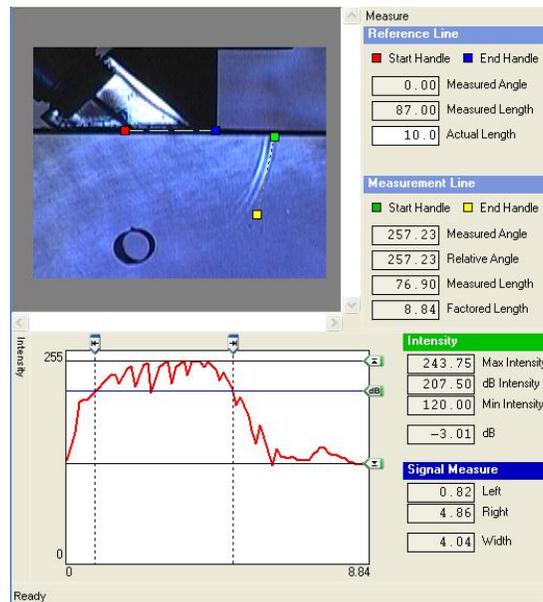
Placing the vertical cursors on the positive peaks of the pulse the wavelength is indicated as 0.8mm



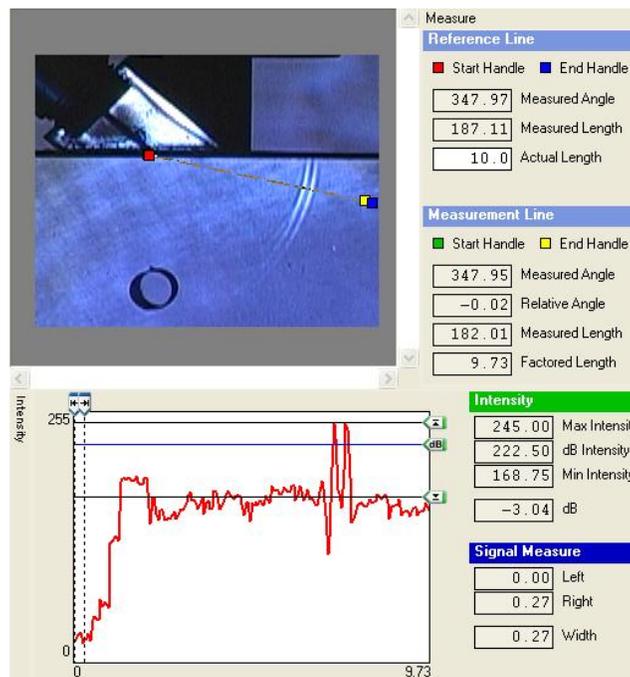
Beam width and divergence angles are also determined using the IIA software. Placing the Measurement Cursor so it cuts across the beam parallel to the wave front the intensity plot can be seen to rise to a peak region in the middle and drop off either side. There is a degree of inaccuracy in this technique for arced wave fronts. This is because some of this drop off is a result of the curvature of the wave front not fitting exactly to the straight line made by the Measurement Cursor. In the image below we see that the Green box must be carefully placed to avoid the dark line made by the test piece edge. The Factored Length reading indicates we have a line of intensity readings 8.8mm long.

Placing the up-arrow at the maximum intensity of the plot and the down-arrow at the background level provides us the range of intensities we are dealing with. Then the dB arrow is located at the 3dB level. Since a photoelastic image is the one-way path of an acoustic pulse, the beam pressure levels we are accustomed to measuring in pulse echo are halved; i.e. the 6dB drop that we normally use to assess beam dimensions is no longer applicable and we must use the 3dB drop to indicate the same region on the beam as we had been assessing in pulse-echo techniques.

Having placed the dB cursor on the Intensity Plot at 3dB below the maximum value we can then place the vertical cursors at the left and right edges of the plot where the plot of intensity crosses the 3dB drop line. In our example, the left cursor is placed at 0.82mm and the right at 4.86mm. The difference in length between these two points indicates a beam width of 4mm.



To assess divergence angle we can use the combination of the Relative Angle indication from the Measurement line and the Intensity Plot in a dynamic mode.



Suggested Experiments

Several experiments are suggested here to familiarize users with some of the equipment features. However, these should not be considered the limits of equipment. Applications of the photoelastic method of visualization will be as varied as the users' imagination. More elaborate experimentation and model verifications can be had by customizing glass models of parts inspected. Depending on the application the user may wish to select glass based on acoustic velocity properties. The main options for glass are Fused Silica, Borosilicate and soda lime float glass. Variations may occur in each of these glasses with "float glass" having the greatest variability.

Glass	Vl (m/s)	Vs (m/s)
Fused Silica	5970	3770
BoroSilicate	5650	3410
Soda-lime float glass ³	5840	3460

Compression Wave using a Normal Beam Probe

Observations to make:

- Edge diffraction effects including divergence and mode conversion
- Backscatter due to incidence on a cylindrical target
- Note the spiral head wave that forms off the curved surface of the cylindrical target after the wave front passes the half-way point across the cylinder diameter
- Observe the intensity distribution with respect to the backscattered angle (compares with published reflection curves)

Shear Wave using a Refracted incidence of a Compression Wave Probe

Observations to make:

- Pulse inside wedge including reflection at wedge/steel interface
- Upper and Lower edge diffraction effects including divergence and mode conversion

³Soda-lime float glass is the variety used in the samples supplied. These velocities are approximate and for accurate assessments should be verified by the user. These velocities for the compressional and shear modes are conveniently "similar" to carbon steels which have velocities for compression mode in the range of 5800-6000m/s and for shear mode between 3140-3440m/s (see Ginzler and Ginzler, Study of acoustic velocity in line pipe steel, Materials Evaluation, May, 1995)

- Backscatter due to incidence on a cylindrical target
- Note the spiral head wave that forms off the curved surface of the cylindrical target after the wave front passes the half-way point across the cylinder diameter
- Observe the intensity distribution with respect to the backscattered angle (compares with published reflection curves)
- Note corner reflection paths at block corner
- Note tip diffraction from a surface notch

Using Other Ultrasonic Instruments

Although the ESPhotoelastic system is supplied with its own pulser, it may be used with other instruments provided they have a TTL in or TTL out capability.

A square wave trigger pulse between +3V to +5V is the normal timing trigger constituting a TTL (Transistor to Transistor Logic) trigger signal.

Some ultrasonic instruments (especially those intended for general laboratory work) are equipped with both input and output terminals. The internal clock controlling the pulse-repetition frequency (PRF) may be used as the “zero time” source, in which case the user connects to the “Trigger Out” (also referred to as Sync out), and it will feed a pulse to the delay circuit. Alternatively, the rate at which the ultrasonic instrument is pulsed can be controlled by an external source such as a sweep generator or basic signal generator. In that case the external “clock” will have a split connection with one connector attached to the Trigger In and the other to the Delay circuit that pulses the light source.

Video Imaging with the ESPhotoelastic system

By adding motion to images provides the user with an understanding of the dynamics of the pulse-echo process that is not available with individual photographs or even a series of still photographs.

The camera provided is equipped with a macro lens that allows the field of vision to be varied so that a reasonable range of sound path can be displayed. When the maximum field is selected the small details of diffraction are not resolved however, the trends of a wide beam and the divergence and reflections that occur along a skip-path can be recorded.

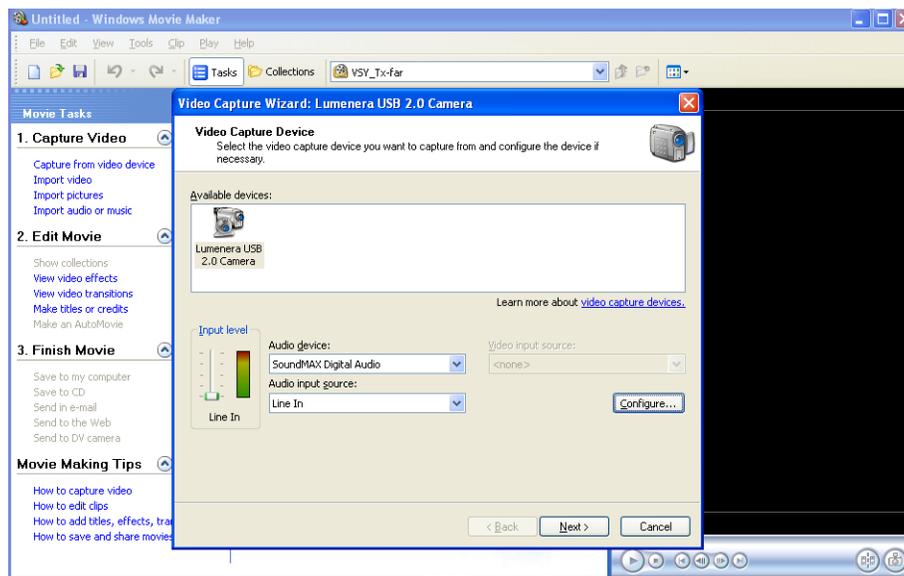
Video recording using the ESPhotoelastic system is accomplished by using the camera in a video acquisition mode while adjusting the light-pulse delay. Provided the user does not spin the delay knob too fast, the camera can record a smooth transition of pulse as its position through the glass is changing.

Camera Settings for video

Video processing by the camera requires that the CMOS camera “capture” the entire array of sensor “pixels” and then send them on to the computer via the USB connector (480Mbits per sec).

The supplied camera has a nominal frame rate of about 12 frames per second when the entire array is used, e.g. 1616x1216. The frame rate can be increased by reducing the resolution. At 640x480 pixels the frame rate can be increased to about 26 frames per second. In order to avoid “jerking” movement of the delayed pulses lower resolutions can be used. For stills or when the ultrasonic pulse motion can be made to move very slowly, the higher resolutions may be selected.

All features of the camera are accessible from the Windows Movie Maker software. Open Movie Maker and click on the first item in the Capture Video section (Capture Video from video device) and the attached camera will be detected (See Figure 17). Selecting the “Configure” will bring up another menu with option to adjust either the Camera Settings or the Video Settings (see **Figure 16**).



Optional Components for the ESPhotoelastic

Transum Immersion System

ESPI-TIS

Converts the imaging stage for use as a search tube immersion system.
Includes stop collar for search tube.



Immersion Search Tube

P_USTB20002

12 in (305 mm) Long x 0.75 in (19 mm) diameter



Immersion Probes

OLN-IPST-19

Probes to fit 0.75 in (19 mm) diameter search tube
(call for information about specific types)



Conventional Probe & Wedge Combination

ESPI-KBA-PWC

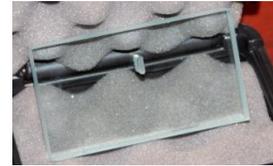


Glass Target Blocks

Special extra clear glass shape with milled targets
(custom shapes possible)

ESPI-GTB-S1

Square Shape-1



ESPI-GTB-S2

Square Shape-2



ESPI-GTB-R1

Square Shape-1



ESPI-GTB-R2

Round Shape-2



ESPI-GTB-S1

Bolt Shape-1



ESPI-GTB-S2

Bolt Shape-2



ESPI-GTB-S3

Bolt Shape-3



ESPI-GTB-S4

Bolt Shape-4



"V" Block Target Holder
with two sizes of V-groove

ESPI-VB-50

50 mm long



Immersion Tank
small tank fits on scissor-jack

ESPI-ITK-150

150 mm x 150 mm

