C L A M
Contact-free Laser Assisted Measurement

Kevin Smith
Christopher Young
Derek Podgorni
Ocean Projects
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ABSTRACT

Byssal threads are small strands that a mussel produces to attach itself to surfaces. There are many aspects of these threads that are of interest to biologists, such as the chemical composition and physical properties. It is necessary to measure the byssal thread without physical contact.

We have designed a tool that will measure the thread by optical sensors. The measurement tool is contact free and uses a monochromatic laser light source to produce a distinct image. The image's width can then be measured by software analysis.

INTRODUCTION

A mussel secretes a fluid into channels in its shell that become solid when in contact with sea water. These become byssal threads which attach the mussel to the surface with which it is in contact with. Biologists wish to measure the diameter of byssal threads in order to correlate it with the environment that the mussel is within. The threads are small enough that physically measuring their diameter would cause the thread to deform and produce an false reading.

Using optical sensors to measure the diameter of the thread can produce high resolution measurements without physically disturbing the subject. Our initial concept was derived from the previous work of Prof. Allen Drake of the Electrical Engineering Department and Binbin Ding, a graduate student working under him. We theorized that it would be possible to calculate the diameter of the byssal thread by measuring the diffraction pattern associated with it when illuminated by a monochromatic light source. Experimental results showed that the subjects we were interested in did not produce a sufficient diffraction pattern. This is due to the fact that the byssal threads are of a much greater magnitude and range than the samples in Ding's theoretical model. We therefore decided to measure the diameter of the byssal thread directly from its shadow.

We constructed the apparatus in two stages, the digital and optical portions.

The optical part consisted of a diode laser, dissecting microscope, polarizing lenses and C-mount adapter for one of the eyetubes of the microscope. The digital components included a CCD camera which was attached to the C-mount adapter. The camera was then connected to a frame capture device which was controlled by a personal computer.

Using the tools in the MAXVision software we were able to measure samples as small as 20 micrometers in width. The upper limit of what could be measured was not calculated but is on the order of 1 millimeter. To measure above this limit it is necessary to change the magnification and calibration of the system.

Technical Discussion

Procedure

In theory, a plane polarized monochromatic light should create a diffraction pattern when it strikes an object. This diffraction pattern is directly proportional to the diameter of the object. It is then possible to relate the distances between the interference pattern to the actual diameter of the object.

To obtain the diffraction pattern, we used various samples and magnifications. The samples included human hair, optical fiber, and 24 gauge wire. All of these samples were within 60 to 200 micrometers. This range is typical of common byssal threads. We tried magnifications from three different microscopes varying from a dissecting microscope up to a compound microscope. A visible diffraction pattern was never evident.

Our failure to produce a distinct diffraction pattern led us to investigate the possibility of measuring the thread by its shadow. No additional equipment would be necessary to explore this prospect. By using the stage micrometer to calibrate the measuring tools in MAXvision, we were able to measure a sample.

Components

Each item within the apparatus was chosen to optimize performance versus cost. The monochromatic light source for our apparatus was the MDL-670-10 by Lasermax. The MDL was selected for its convenient size, single wavelength (670 nm), appropriate power (10 mW), polarized output, and reasonable price ($425). Monochromatic light is important because it eliminates the possibility of chromatic aberrations. A beam expander/collimator was attached to the laser to fill the field of view (1 cm).

The Wild M5 dissecting microscope, with its large stage area, satisfied our need for sample space. It also adequately fulfilled the requirements of magnification. The stage and objective analyzers, C-mount adapter, and light source were easily fitted to the M5 with minimal machine work. The stage and objective analyzers remove all light not associated with the sample when transversely polarized. This removed "noisy" light from our environment. The microscope is on loan from professor Larry Harris.

We chose the Cohu 3315 CCD camera for our opto-electrical interface. This camera provided adequate resolution (510 x 492) and a monochromatic output. Its interface output conformed to the RS 170 standard used by the AT1 Frame Grabber. It was also rugged enough to accept 10 mW output from the

laser. The 3315 came standard with its own step down transformer power supply. The camera had a competitive price of $885.

The next part of our apparatus was the AT1 Frame Grabber, donated by Professor Richard A. Messner. The AT1 Frame Grabber is a specialized vision processor that enables us to view what the camera "sees" and also provides memory buffers to store images. The user interface with the AT1 is a standard 286 based personal computer. Only computers fully compatible with the IBM AT will be functional.

The software that drives the AT1 is MAXvision by Datacube. MAXvision offers a multitude of imaging tools to process information. For our purposes, we used the image measurement tools. Initially we used the calibration option to define the number of horizontal and vertical pixels. Then the picture scale could be entered by using the stage micrometer as a reference. Lastly, the measure distance function could be used to measure the width of the sample. The MAXvision software automatically calculates the cross sectional width regardless of the angle. These images can then be stored to disk and recalled for future analysis.

Apparatus Setup

Laser mounting - The diode laser is connected to the AC power source and beam expander. The laser is then fitted to the base of the microscope with the machined collar.

Camera mounting - The camera is connected to its AC power supply. The video output is connect to SOURCE 0 on the AT1. The camera is attached to the C-mount adapter, connect to an eyetube.

C - mount adapter - The adapter replaces one of the eyelens in the Wild M5. Two tension screws hold the C - mount adapter to the eyetube.

AT1 Frame Grabber - Interface cable is connected from the AT1 and the controller card within the host computer. The green (B/W) output is connected to the monitor. The green output line contains the vertical sync information.

Polarizing Lenses - The stage lens rests within an adapter ring in the base of the microscope. The objective analyzer fits over the objective lens and is held with a single tension screw.

The orientation of the stage lens should be aligned to provide maximum light output. The objective analyzer's alignment should be perpendicular to the stage lens.

MAXvision Software

Change directory to "C:\MV1>"

Type "MV1" to run MAXvision software.

Initialize MV1.

Focus sample image with microscope.

Under the DEMO menu, use the SNAP Image option to store the picture in the AT1's image buffer (F2).

Type MD to begin Measure Distance procedure.

With the mouse, position pointer at one edge of the sample. Pushing the left button at this point begins drawing the reference line. Draw the line perpendicular to the edge of the sample. Press the left mouse button again on the following edge of the sample. Press the right button to stop measurement.

MAXvision displays the measured distance as the hypotenuse. The units are in micrometers.

Reinitialize and repeat per measurement.

Conclusion

The system accurately measured samples within its operating range. A diffraction was not necessary to measure the threads. Measuring the shadow directly was a sufficient alternative to our original design. We conclude that the diffraction pattern was not visible for the sample sizes and optical path length available in our system.

The system could be improved in a couple of ways. One way would be to have the measuring process automated. Instead of personally running the MAXvision software, a program would run and use MAXvision subroutines to measure byssal thread width automatically. Another possible improvement would be to design a portable camera/microscope unit to gather data remotely and then store for future analysis.

Appendices

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Contact-free Laser Assisted Measurement

Time Line Proposal

Project	Month	Assignment
Basic Design	September	All
Parts Research (Optics)	October	Smith
Parts Research (Laser)	October	Podgorni
Parts Research (Camera)	October	Young
Parts Ordering (Optics)	November	Smith
Parts Ordering (Laser)	November	Podgorni
Parts Ordering (Camera)	November	Young
Parts Received	December	
Basic Software Design	January	Smith/Young
Design Implementation	February	All
Preliminary Testing	February	All
Stage Construction	February	Podgorni
Software Testing	February	Smith/Young
Parts Research (Camera Mount)	March	All
System Verification	March	All
Troubleshoot & Correct	March	All
Final Testing	April	All
Documentation	April	All
Final Report & Presentation	May	All

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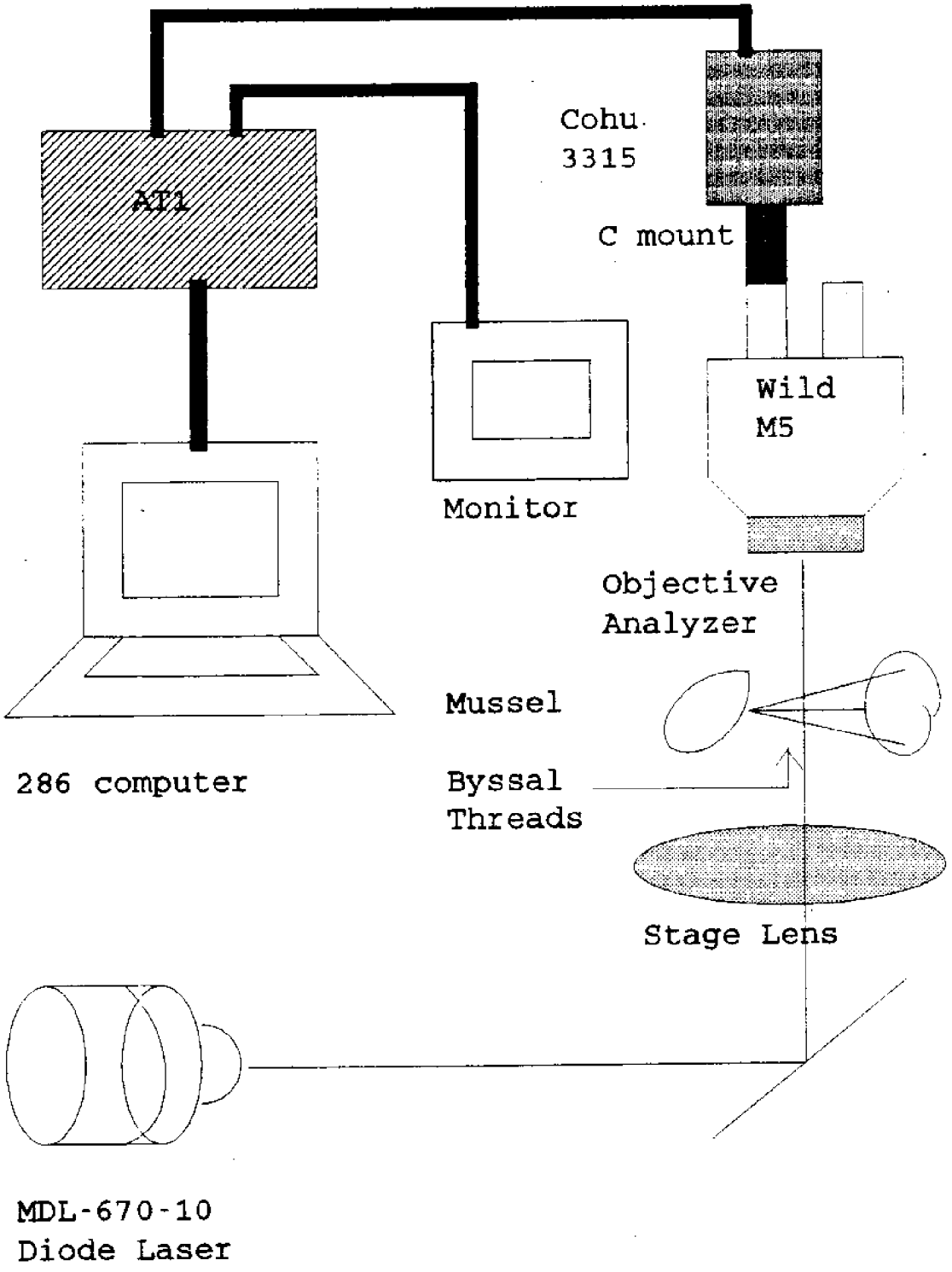
Objective Analyzer	**$260.00**
Laser Polarizing Lens	$195.00
Adapter/Objective	$30.00
M5 Manual	$25.00
MDL Diode Laser 10mW	$425.00
Beam Expander (x10)	$515.00
Power Source 12V	$25.00
3315 CCD Camera	**$885.00**
Telephone	**$125.00**
C-Mount Adapter	$450.00
TOTAL	$3035.00

Revsied Budget for 91-92


Cohu
3315
AT1
C mount
Wild
M5
Monitor
Objective
Analyzer
Mussel
286 computer
Byssal
Threads
Stage Lens
MDL-670-10
Diode Laser