Remote Microscope for Polymer Crystallization WebLab

by

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Submitted to the Department of Electrical Engineering and Computer Science
in Partial Fulfillment of the Requirements for the Degree of
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Abstract

The Remote Microscope for the Polymer Crystallization WebLab was developed at MIT as part of the iLab Project. The purpose of the iLab Project is to build web-accessible remote laboratories that allow real-time experiments from anywhere at any time. The Remote Microscope WebLab allows users to operate and view in real time an actual microscope. Some of the benefits that the WebLab will bring students are that it will allow them to access high-end pieces of equipment, it will allow them to have more flexibility to run the experiments over a wide range of hours, and when it suits their own schedules, and will give them the opportunity to repeat the experiment as many times as they want.

The Remote Microscope System consists of a motorized light microscope, a digital camera and an XY stage, all controlled via a web-enabled client interface that can be run in any browser or platform. The client interface is able to display real-time images, video and status messages, and is able to control and change hardware settings. To do this the client must be connected to a server process running on a Windows PC. This server process is able to communicate with the hardware through several implemented software controllers. Currently only one client can connect to the server at any given time, since no more than one client should be controlling the microscope at any given time.

Thesis Supervisor: Gregory C. Rutledge

Title: Associate Professor of Chemical Engineering

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I will also like to thank Titi and Guille, who are not only my sister and brother but are also my friends. They have always been there for me, and even though we are apart most of the time, we have managed to remain close. I will also like to thank my friend Edixa Jimenez, who from the day I met her four years ago, has always cared for me, supported me, and encouraged me when I most needed it here at MIT. She helped me through the toughest last days of this project, always encouraging me and reassuring me. Furthermore, I will like to thank my roommates Shalini and Jen who saw me through the ups and downs of this project and who were always there to encourage me.

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Chapter 1

Overview

The main purpose of this thesis is to set up and develop the necessary hardware and software to setup a Remote Microscope to conduct Polymer Crystallization Experiments via a web-enabled interface. This project is part of the iLab research project at MIT that aims to develop a new framework for science and engineering education. The goal of iLab is to build web-accessible remote laboratories that allow real-time experiments from anywhere at any time. The underlying educational principle of the iLab project is the conviction that students are more motivated and learn better if they conduct experiments, compare reality with simulations, collaborate with each other, and are allowed to explore a physical system following their curiosity [2].

The Polymer Crystallization experiment is a standard experiment in polymer science, but it has rarely been offered at MIT because of the limited availability of polarized light microscopes, heating stage, and photographic equipment. In addition it has been hard to schedule group of students to work with a single microscope at the same time. The students will benefit from having this lab online because it will allow them to access a high-end piece of equipment such as a light microscope and heating stage. They will have more flexibility to run the experiments over a wide range of hours, and when it suits their own schedules. The students will also have the opportunity to repeat the experiment as many times as they want, after data of an earlier experiment is analyzed, to encourage learning through iteration. In addition, with the online setup, the experiment

could easily be demonstrated in a lecture setting.

The Remote Microscope System is the first big step towards the completion of an entire Polymer Crystallization WebLab. The Remote Microscope System consists of a light microscope, a digital camera and an XY stage, all controlled via a web-enabled interface. In future releases of the project the system will have a heating stage controlled via a web-enabled interface as well. The current system allows the user to remotely control and view a microscope over the Internet. The system consists of a graphical user interface client that can run in any browser or platform. Figure 1 shows what the graphical user interface looks like. The client is able to display images that are captured by the digital camera; it displays real-time video, and is able to display real time status messages. In addition the user is able to do autofocusing of an image remotely, and change a number of the microscope settings.

The overall software system consists of a client application that can connect to a server process running on a Windows PC. This server process is able to communicate with the hardware through several implemented software controllers. Currently only one client can connect to the server at any given time, since no more than one client should be controlling the microscope at any given time.

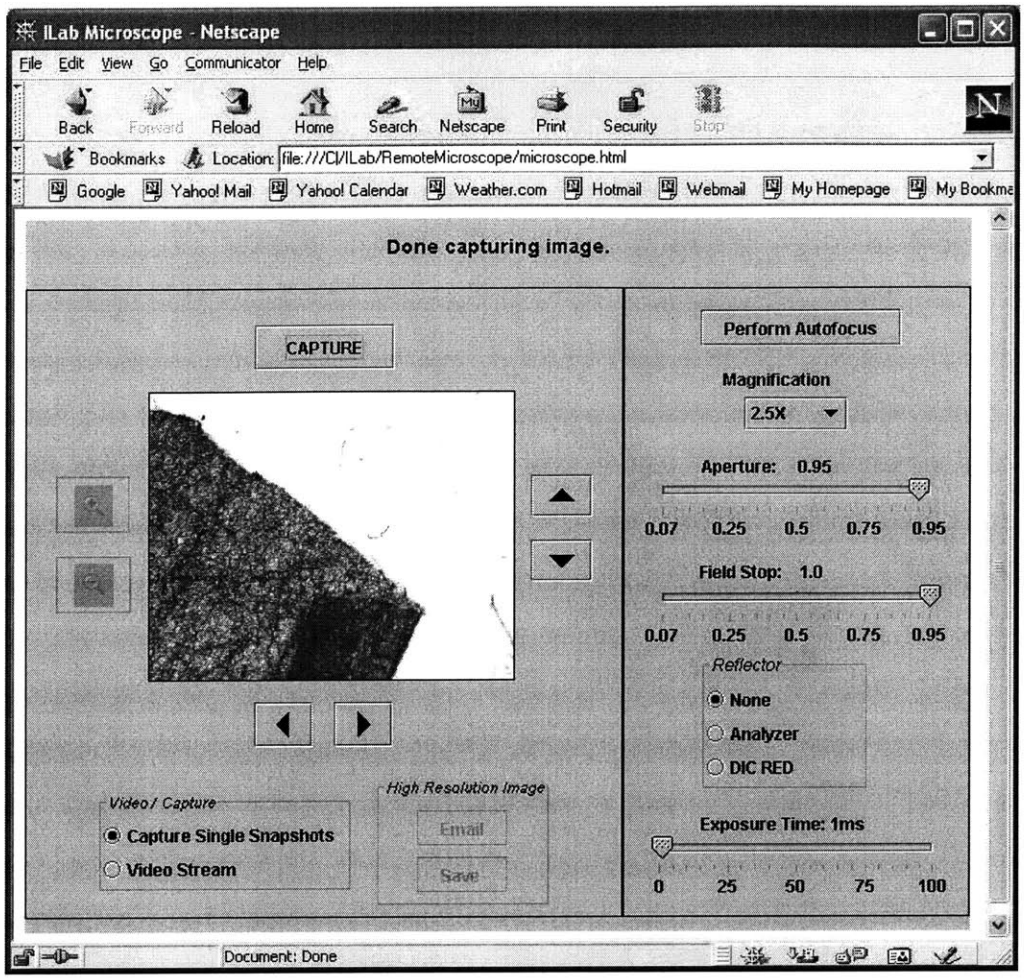


Figure 1 – Remote Microscope GUI

Chapter 2

Background

This chapter will cover background information relevant to the Remote Microscope. It will start by describing the experiment intended to run with this Remote Microscope System. It will then go to describe existing remote microscope systems, and will later describe the related Framework Project. A brief overview of the programming tools used in the system will also be given at the end of the chapter.

2.1 Polymer Experiment Overview

The polymer crystallization experiment lends itself particularly well for an online real-time experiment. The experiment is such that, once the sample is set up in the microscope, the experiment can be cycled repeatedly without operator intervention. The aim of the experiment is to measure the rate of crystallization and relate this to polymer crystallization kinetics, as well as to measure the rate of volume transformation and to determine the Avrami exponent of thin film crystallization. The experiment consists of a polymer sample that is raised above its melting temperature. Then it is dropped to different levels of cooling, where the polymer will start to crystallize. The student will be able to see the growing crystallites, and will have to record the rate of growth of the

spherulites.

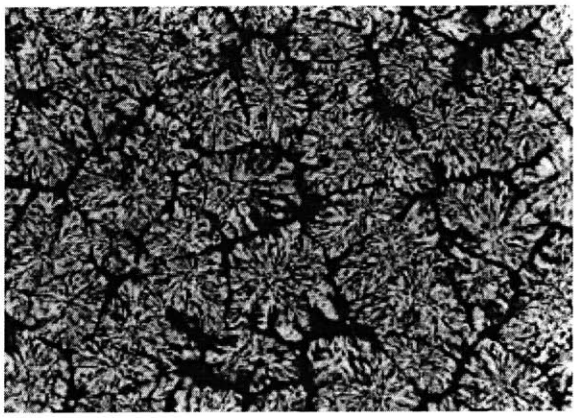


Figure 2 - Poly(ethylene oxide) crystallized at 55.5 C [9]

2.2 Existing Remote Microscopes

A remote microscope was developed here at MIT by James Kao [3] as part of the Computer Integrated Design and Manufacturing project to help in the remote fabrication of integrated circuits. It allowed users to operate a microscope, and view a static image of the circuits remotely. It also allowed multiple users to view the same image at the same time for conference inspection. This microscope system was later extended by Somsak Kittipiyakul, which added complete automation of the microscope [4]. Currently the microscope is no longer running, but there is considerable amount of literature from which we were able to learn from for our own design.

In addition there is open source code of a server and client for a Remote Microscope implemented by Andrew Kuchling for the MEMS Exchange project[1]. The MEMS Exchange has deployed this fully automated and remotely controllable microscope that is used for semiconductor inspection. It allows MEMS designer to view wafers after critical processing steps from any location having an Internet connection.

[1] http://www.mems-exchange.org/software/microscope/

They currently have five Remote Microscopes deployed. Their system consists of an optical microscope (Leica INM200 or INS1000), a server, and a Python/Tk client that displays the client interface.

The system described in this thesis is based on the ideas developed by Andrew Kuchling in his implementation of the server of the Remote Microscope. One of the additional challenges that this project faces is that in order for students to see the growth change of the spherulites in the polymer crystallization experiment, they need video streaming, not just snapshots of images like the remote microscopes described above. In addition, the experiment needs a temperature control, which means the additional challenge of adding a heating stage that works with the whole system.

We found that the existing remote microscopes have implementations specific to the application of the microscope. In our project a great deal of focus was placed on the extensibility of the system, so that the same software architecture could be used for different applications of the system. Chapter 8 discusses in detail the extensibility possibilities of the system.

2.3 I-Campus Framework Project

The Framework Project is part of this iCampus initiative, a research alliance between Microsoft Research and MIT that aims to enhance University education through information technology. The focus of the Framework project is on creating Web service modules to support other iCampus projects, such as iLab. They are currently working on building "lab controllers" that provide the basic authorization, resource allocation, event notification, and collaboration services required to deploy on-line laboratories in a way that can be scaled across multiple laboratories at multiple institutions. The work currently being developed by them will complement the efforts of the system described in this thesis, by making use of such events as logging, user identification, and scheduling of students for equipment use.

2.4 Development

This section provides an overview of the programming languages used for the implementation of the Remote Microscope System.

2.4.1 Java

The client module is built entirely in the Java programming language. Java was developed by Sun Microsystems Inc. The Java language is a high-level and portable language. The great advantage of Java is that it allows programmers to develop platform independent applications.

Java is an Object Oriented Programming language. In brief, this means that all the code is contained within objects known as classes. Each class has its own set of variables and methods, and objects in a system will interact by calling other object's methods.

One of the great advantages of Java is that it enables the programmer to write programs called applets that can run embedded into Internet Web Pages. An applet is an object in java that allows Java code to be downloaded over the network and run within a Java Virtual Machine (JVM), which nowadays is part of all web browsers [8]. Therefore, by using a Java applet, users would not need to download any extra software to run a program. All they need to do is connect to the appropriate URL using a web browser.

2.4.2 Python

The server and hardware modules are implemented in Python: an interpreted, interactive, object-oriented programming language, which is often compared to Tcl, and Perl [11]. Guido van Rossum, who is currently employed by the Corporation for National Research Initiatives (CNRI), first developed Python in 1990. The home page for the language is at *www.python.org* and is hosted by CNRI.

Python is very simple and powerful. One of the advantages of Python is that it has an interactive mode, where the programmer can enter expression one line at a time. This

mode allows the programmer to try ideas quickly and cheaply, testing each method as it is written. Python also makes parsing strings very easy, and has built-in high-level types such as lists and dictionaries, which help in programming and usually mean writing less code.

To some extent Python is also platform independent. The core language and standard libraries are identical across Windows, Unix and Macintosh platforms, although each platform offers its own dedicated extension.

Chapter 3

Hardware Overview

This chapter describes the hardware setup of the Polymer Crystallization WebLab. It describes in detail each hardware component, and explains its features. The second part of this chapter gives an overview of the vendor software that can be used to control certain hardware components from a PC.

3.1 Hardware Setup

3.1.1 Zeiss Axioplan 2 Imaging

The Zeiss Axioplan 2 Imaging is a motorized light microscope. It is a flexible microscope system that can be tailored to several applications. It is currently setup for polarized and transmitted light only, but if needed the reflected light module could be purchased in the future as well. The microscope can be manually controlled or computer controlled.

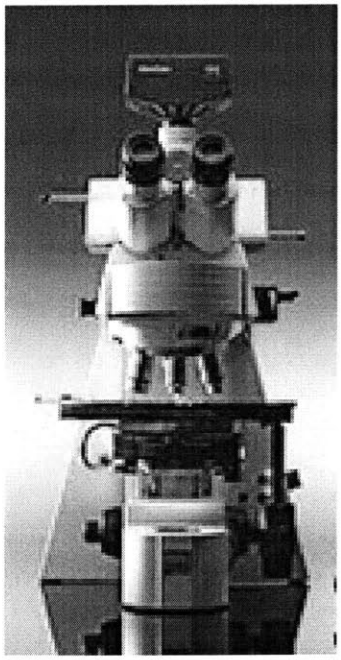


Figure 3 – Zeiss AxioPlan 2 Imaging

3.1.2 Zeiss AxioCam MRc

When the Zeiss Axioplan is combined with the AxioCam it provides a real digital imaging workstation. When the AxioCam takes pictures the images are available immediately on the PC screen. It is a color camera that has a resolution of up to 1300 x 1030 pixels. It creates a fast live image, and has adjustable ROI (Region of Interest) and binning.

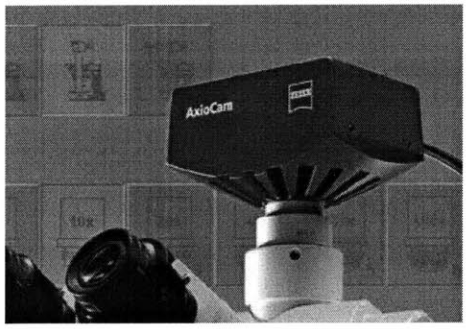


Figure 4 – Zeiss AxioCam MRc

3.1.3 Ludl XY Stage

The XY stage is manufactured by Ludl Electronic Products. The stage is a BioPrecision stage that is designed for applications where speed, repeatability and accuracy are required. The stage is coupled with the MAC5000 controller module, and joystick that can control the stage. The MAC5000 allows efficient communication between PC and stage via a serial port. For specifications on the set of commands that the controller accepts see the Ludl manual titled "MAC 5000 Programming".

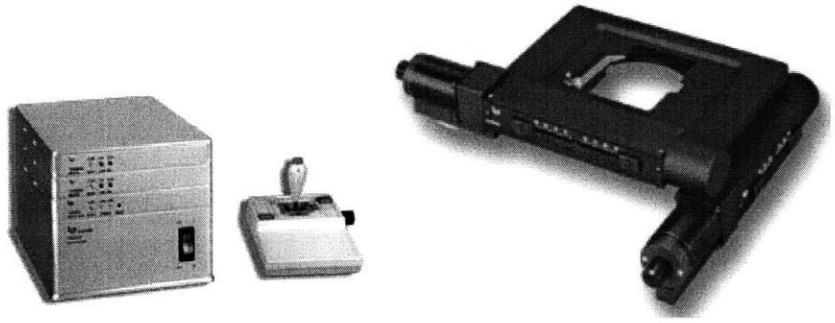


Figure 5 – LUDL XY Stage System with MAC5000 and Joystick

3.1.4 Linkam LTS 350 Heating Stage

The fourth component of our system is the Linkam LTS 350, which is a large-area heating stage. The TMS 94 is the temperature controller used with the heating stage. The TMS 94 can be programmed to control heating rates of 0.01°C - 130°C/min. and cooling rates of 0.01°C - 100°C/min. Like the MAC5000, the TMS 94 provides RS 232 computer interface, so that communication via serial ports is possible. For specifications on the set of commands that the controller accepts see the Linkam User Guide called: "Serial Communications Manual for T92, T93, T94 Series Programmers".

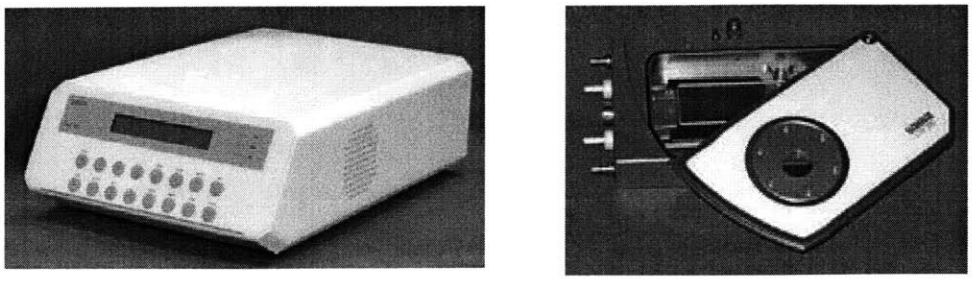


Figure 6 - Linkam LTS 350 Heating Stage with TMS94

3.2 Vendor Software Overview

3.2.1 KS Software

The KS Software can be used to control the Axioplan and AxioCam. This software was developed by Zeiss. It allows easy capture, processing and saving of an image. In addition it provides additional tools such as autofocus, light manager, and setting of manual controls. The great advantage of the KS Software is that it has a variety of image analysis tools that can be used to measure and evaluate areas of an image.

3.2.2 Linksys Software

Linksys software can control the Linkam heating stage system. It connects to the TMS 94 via a serial port connection. It has a very simple user interface that allows the user to set the rate of temperature, the target temperature and the amount of time to remain on the target temperature (hold time). It also allows for the temperature ramp to start and stop, while viewing the real time temperature and status on the screen. Linksys is basically a reflection of what you can see and do with the TMS 94 hardware.

Chapter 4

System Architecture

In the previous chapter we discussed the various hardware components of the Remote Microscope. This chapter gives an overview of the software system architecture. Chapters 5, 6, and 7 will describe in more detail the exact implementation of each software component. The purpose of this chapter is to familiarize the reader with the client and server applications, as well as the underlying client/server communication protocol.

The software architecture consists of two main components: a server and client. The server and client communicate via TCP/IP socket interfaces, using a simple but well-defined message protocol that can send or receive messages from server to client and vice versa. A third component is the hardware control. The hardware controllers are modules that contain specific methods that communicate with the hardware to set certain settings and to get the hardware status. Figure 7 shows how the software components interact in our remote microscope system.

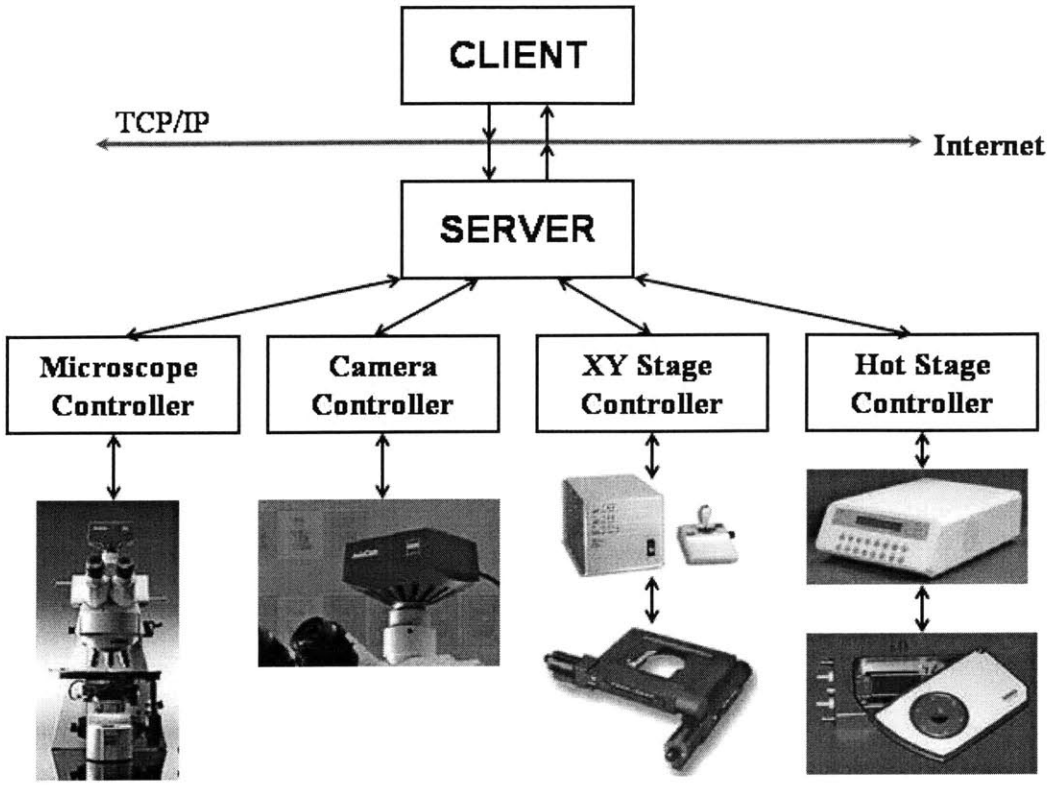


Figure 7 – System Overview Diagram

4.1 Client Overview

The primary function of the client module is to display the graphics for the control panel that runs remotely through a web browser, and accept user requests to modify the state of the microscope. The client accepts input from the user to change settings of the microscope, camera, and XY stage. The client then sends requests to the server to change these settings. In return the client receives digital images and video from the microscope, which it then displays on its image panel for the user to see.

Upon starting the client application, it attempts to connect to the specified server. After the client is authenticated, it will then be able to send and receive commands and data from the server. The connected client will then have the ability to control the state

of the microscope, stages and camera.

To create the Graphical User Interface (GUI) and display the graphics on the web a Java applet was used, which is described in more detail in Chapter 5. The user interface is designed for student's use, which restricts the type of commands they can send to the microscope server, and only allows those necessary for the experiment. It is important for the student user interface to be adequate for educational purpose, and easy enough to use, so that it facilitates the learning and the experiment analysis.

4.2 Server Overview

The server is responsible for relaying messages from client to the appropriate hardware controller, and keeping the state of the system. It receives and parses client request messages, and then forwards these messages to the corresponding controller module. In addition the server is constantly listening for new client connections. Due to the specifics of the experiment, the server does not allow more than one client to connect to it at a time, and sends messages of "No Connection Possible" to other clients trying to connect.

In conjunction with the microscope server, there is also an HTTP server running. The HTTP server acts as the network server for the client. It allows the client browser to interact with the server using the standard HTTP protocol. Both the microscope and HTTP servers are written in Python. For the server implementation details see Chapter 6.

4.3 Hardware Controllers

The controller modules are in charge of handling all interactions between the software and the actual hardware. For example, when a client requests a change in XY position, the server will forward this request to the XY Stage Controller. Then the XY Stage Controller will communicate with stage over the serial port to make the desired changes. It will then inform the server when it is done.

Controllers are also in charge of maintaining their own state. Each controller stores the present values of the settings it controls, which is then used by the server to maintain the entire state of the system. For the controller implementation details see Chapter 7.

4.4 Client/Server Protocol

The server and client communicate via TCP/IP socket interfaces, using a simple but well-defined message protocol that is based on Andrew Kuchling's remote microscope implementation for the MEMS project [6]. The advantage of this messaging abstraction is that it is very easy to update and change the individual client and server modules without having to make a change on the whole server system. In addition, we have the flexibility of choosing any programming language for the client or server, as long as they can send messages to each other.

The messaging protocol consists of single lines of ASCII text sent back and forth between server and client. Images are sent in binary form as a series of messages over a separate TCP/IP socket connection.

Messages are designed to be human readable and are sent asynchronously. This means that there is no expectancy of a response after a message is sent by either party. Instead, the client sends a message to server, who then processes it, and may either ignore it, or generate more messages back to the client. Either way the client will not be waiting for a server response after it sends a message. The reason for choosing this protocol is because of the unreliability that the Internet brings. We cannot be 100% sure that the server will receive a message, therefore the client could wait forever for a response, instead of continuing its normal operation.

Messages are single lines of text ending with a new line (\n). The first word of the line is the message name, followed by the parameters required by the command. Parameters are of the form parameter_name=value, where value can be a single word, number, or a quoted string. Command names and parameter names are case-insensitive, and the order of the parameters is not significant. Some parameters are optional, and others are not, but as long as the message ends with a new line, either client or server will

be able to parse the message.

Some examples of messages are:

```
SET magnification=10X x=10 y=10
CAPTURE sizeX=1300 sizeY=1200 mode=RGB
```

4.4.1 Client Commands

The following table shows commands that are sent from the client to the server.

Command	Explanation
AUTH *authtoken*	Request to authorize this client. *authtoken* is a base64-encoded, compressed text string. When decoded and uncompressed it contains a signature and info string used for authentication.
AUTOFOCUS	Performs autofocusing by searching for the best z-focus position.
SET x=*val* y=*val* magnification=*val* lightMode=*val* lightVoltage=*val* aperture=*val* fieldStop=*val* reflector=*val* transFilter=*val* exposureTime=*val*	Changes the hardware settings and status. All parameters are optional. Command can be sent with one parameter, two, or all at the same time. For a list of valid parameter values see the controller's details in Chapter 7.
CAPTURE sizeX=*x* sizeY=*y* mode=*mode* format=*format*	Request an image from the camera with the specified size, mode and format. *mode* and *format* are optional parameters, but *sizeX* and *sizeY* are always required. If mode or format are not specified the default values are mode=L (black and white image), and format=jpg. For more information on the accepted values for these parameters see the camera controller section 7.2
VIDEO_START sizeX=*x* sizeY=*y* mode=*mode* format=*format*	Requests video streaming to start. The arguments are the same as in the

	CAPTURE command above. *mode* and *format* are optional, while *sizeX* and *sizeY* are required.
VIDEO_STOP	Requests the video streaming to stop.
CENTER	Centers the XY stage.
SERVER	Prints out the server information such as threads, port connections, and client connections. This command is usually used only for debugging.
STATE	Print out the server state information. This command is usually used only for debugging.
QUIT	Terminates the client connection. The server will remove the connection and close the TCP/IP socket.

Table 1 - Client Commands to Server

4.4.2 Server Commands

The following table shows commands that are sent from the server to the client.

Command	Explanation
IMAGE *length* \n *binary data*	Transmit image to client as binary data. The message line includes the length of the image data, followed by a new line, and then the image binary data.
SCOPE x=*val* y=*val* magnification=*val* lightMode=*val* lightVoltage=*val* aperture=*val* fieldStop=*val* reflector=*val* transFilter=*val* exposureTime=*val*	Inform clients of the microscope's current settings (current state). For a list of valid parameter values see the controller's details in Chapter 7.
STATUS *msg*	Sends a message to client specifying the status of the hardware (or what operations are taking place).

ERROR *msg*	Sends an error message to client.
OCCUPIED	Message sent upon client initialization to inform the availability of the scope.
AVAILABLE	Message sent upon client initialization to inform the availability of the scope.

Table 2 - Server Commands to Client

Chapter 5

Client Implementation Details

This chapter describes the Remote Microscope client implementation in detail. The client interface is the main program to which the user of the Remote Microscope will interact. The client module has three main tasks. It must first be able to display the graphic controls to the user (including the image display), it must accept input from the user to control the hardware settings, and finally it must parse or process the messages sent from the server.

This chapter will start by giving an overview of the programming tools used to implement the client application. It will then describe the graphical user interface built, and will give specifications of the objects or modules in the client application, and show how they relate to each other.

5.1 Programming Tools

The client application was programmed entirely with the Java programming language. The latest version of Java, Java 2 SDK version 1.4.0, was used. In addition an integrated development environment (IDE) for Java technology called Forte for Java, (Community Edition v3.0) was used for development. This development environment contains various coding, editing, compiling, debugging, and source code management tools. I

believe that the greatest advantage of using this environment for development, other than ease in compiling, editing, and browsing of code, is the GUI Form Editor. The GUI Form Editor provides a graphical development environment to create dialogs, windows, applets, allowing for easy debugging and development of visual applications.

To create the graphical components I used Swing, which is a graphical user interface component kit, which is part of the Java Foundation Classes (JFC). The JFC extends the original Abstract Window Toolkit (AWT) and encompasses a group of features to help people build GUIs. Swing is integrated in the Java 2 platform, and there is no need to download or install it. Swing simplifies deployment of applications by providing a complete set of user-interface elements written entirely in the Java programming language. Swing components permit a customizable look and feel without relying on any specific windowing system [12].

5.2 Graphical User Interface

At the present, the Graphical User Interface (GUI) is composed of three main panels: the Image Panel, the Microscope Panel and the Message Panel. Panels are general-purpose containers for various components that usually don't paint anything other than their background, and border. In the future there will be a fourth panel that will correspond to the display of the Linkam hot stage controls.

5.2.1 Image Panel

The main function of the Image Panel is to display images, as well as enable controls that change the image view or that relates in some way to the capturing of images. Figure 8 shows what this panel looks like.

The main component of this panel is an image icon in the center of the panel that displays a 260x206 image. To the right and bottom of the image icon we find arrows that control the XY stage positioning so that the image will shift in an XY direction. Above

the image icon we have a CAPTURE button that sends a request to the server to tell the camera to capture a new image, so that it can be displayed on the image icon. When a user selects the Video Stream radio button bellow, the CAPTURE button will be disabled, and a stream of images will be displayed. The high-resolution controls and zoom controls remain disabled throughout, as they have not been implemented yet, but could be of great value to future use of the system.

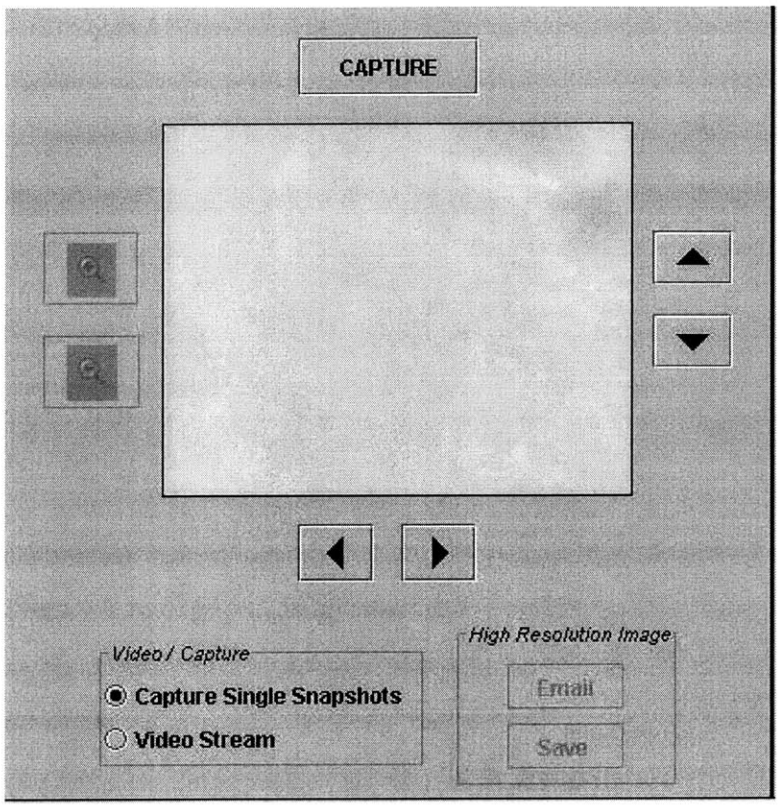


Figure 8 – GUI Image Panel

5.2.2 Microscope Panel

The Microscope Panel contains all the controls that can change the microscope settings. Figure 9 shows what this panel looks like. On the top we have the Autofocus button. This button calls the one-time autofocus function, and returns a new focused image that is displayed on the image panel. The autofocus main purpose is to search for the right z stage position for adequate focusing.

The magnification control changes the objective being used. The possible magnifications are: 2.5X, 5X, 10X, 20X, and 50X. The aperture control changes the condenser aperture setting. This is useful mainly in magnifications greater than 10X, because in lower magnifications the field of vision will be greatly reduced. The field stop controls the light intensity. This control is useful mainly for the lower magnifications of 2.5X, and 5X. In addition we have three possible settings for the reflectors. There is an analyzer, a DIC_RED reflector, and no reflector at all. Finally, we have the exposure time that controls the shutter speed of the camera.

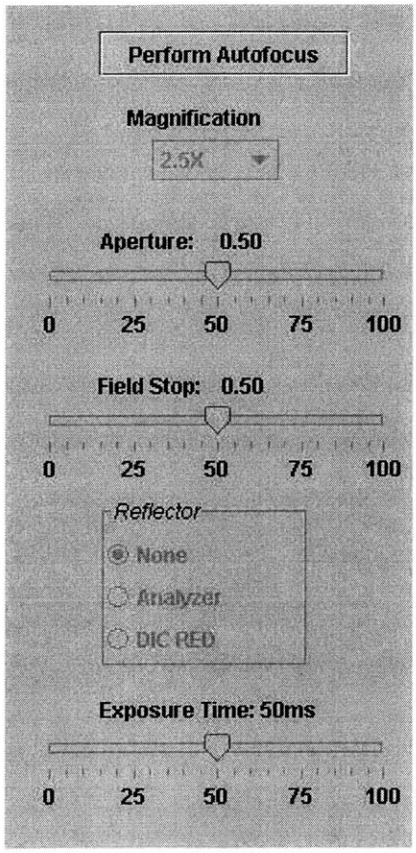


Figure 9 – GUI Microscope Panel

5.2.3 Message Panel

The Message Panel displays two types of messages. First it displays status messages. These messages are sent by the server to inform which operation is being performed at

any given time on the server side. In addition, if any type of error occurs or an exception is thrown on the server side, a message will appear in red on the Status Panel.

Figure 10 - GUI Message Panel

5.2.4 Temperature Panel

The Temperature Panel has not been implemented yet. This panel should include controls to set the temperature rate, the temperature target, and the hold time of the target temperature. It should include a START and STOP buttons to indicate when heating or cooling should start. Finally it should include a temperature display that displays the present temperature in real time.

5.3 Class Specifications

The main class of the client application is a Java Applet class called ScopeApplet. As mentioned before Java Applets are programs that can have compiled code stored in a remote host, and can be run from any Java enabled web browser [7]. Figure 11 shows how the ScopeApplet interacts with all the other components in the client application.

The ScopeApplet class first creates two objects used for communication with the server: ScopeConnection, and ScopeImageConnection. These objects are in charge of creating socket connections with the server, and to send and receive messages to and from the server. In addition the ScopeApplet creates a ScopeGUI object. The ScopeGUI object creates all the graphical control panels and graphical components. The ScopeGUI inherits two interfaces: IScopeControls and IScopeProtocol, and contains a set of event

listeners that are in charge of sending messages to the ScopeConnection object. ScopeApplet reads and writes messages from the ScopeConnection, and reads binary data from the ScopeImageConnection. ScopeApplet processes the messages, and then passes them to the appropriate method in ScopeGUI. The following sections describe in more detail the function of each module in the client application.

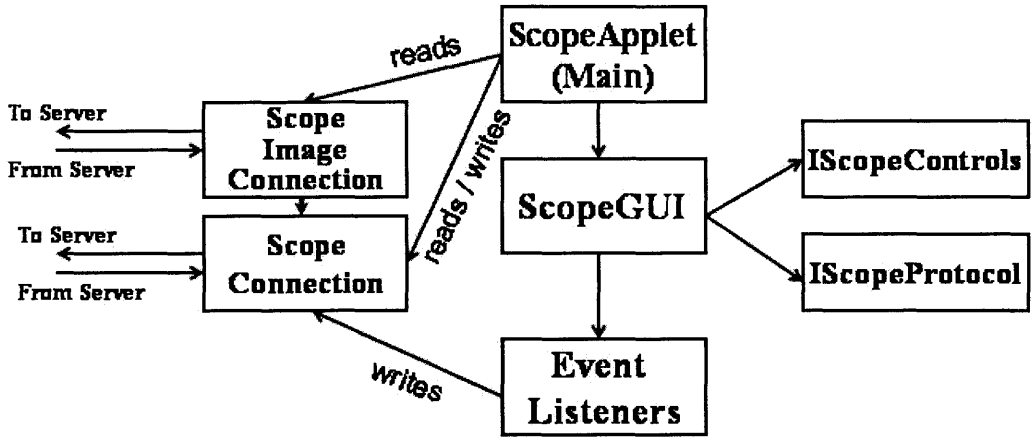


Figure 11 – Module Dependency Diagram for Client Application

5.3.1 ScopeConnection and ScopeImageConnection

The ScopeConnection class is in charge of creating a socket connection to a given host name and port number. The two main methods are *sendMessage()* and *readMessage()*, which allow external objects to write and read text messages to and from the socket connection.

ScopeImageConnection is a subtype of ScopeConnection. This means that it inherits all of its attributes and methods, but in addition it has some methods that handle reading binary data from a socket connection.

5.3.2 IScopeControls and IScopeProtocol

IScopeControls and IScopeProtocol are both interfaces. Interfaces are essentially a collection of constants and abstract methods. Abstract methods are methods that are declared but not defined. In other words the bodies of these methods are empty.

To make use of an interface you *implement* the interface in a class, and in that class you write the code for each of the methods in the interface. Any constants or attributes that are defined in the interface are also available in the class [1]. The purpose of having an interface is that it can act as a protocol definition between two independent systems that communicate with each other. In our case it serves as a communication protocol between the server and client, and will also aid in the extensibility capabilities discussed in Chapter 8.

IScopeProtocol contains a list of methods called "cmd_<command_name>", where <command_name> are all the possible commands that the server can send to the client. For a detailed description of these commands see section 4.4.2. Bellow you can see what this interface looks like. All methods, with the exception of the image command, take in a String of the arguments to the command. For example, for the STATUS command the *args* String will contain the status message string sent from the server.

```
public interface IScopeProtocol {
        void cmd_scope(String args);
        void cmd_status(String args);
        void cmd_error(String args);
        void cmd_image(byte[] image);
        void cmd_occupied(String args);
        void cmd_available(String args);
}
```

IScopeControls contains a list of methods called "set_<control_name>", where <control_name> are all the possible controls (or settings) that the server can send values for. For a detailed description of these controls see Chapter 7. Bellow you can see what the interface looks like.

```
public interface IScopeControls {
        Hashtable state = new Hashtable();

        void set_aperture(String strValue);
        void set_magnification(String strValue);
```

```
    void set_lightVoltage(String strValue);
    void set_lightMode(String strValue);
    void set_reflector(String strValue);
    void set_transFilter(String strValue);
    void set_y(String strValue);
    void set_x(String strValue);
    void set_exposureTime(String strValue);
    void set_fieldStop(String strValue);
}
```

It is important to note that even if the client does not need a certain control (for example if the GUI does not have a component for the transmission filter control) the following methods still need to be declared in the class that implements this interface, even if they are left empty. The whole point of having declared this interface is because when the command SCOPE is sent from the server to the client it will send the state values of ALL the controls the server can handle. Since the client application calls the *set* methods automatically by their names, "set_<control_name>", if any of these methods fail to appear in the implementation class then an error will occur. The main purpose of the interface is to keep a record and maintain a protocol of which controls the server implements, so that the client knows which methods it has to have.

Another important component to note about IScopeControls is the Hashtable called state. A Hashtable is basically a table that matches key names to values. This state object will be inherited in the class that implements this interface, and will aid in maintaining the state of all the control values. This Hashtable maps the control name to its corresponding value, and should be updated by the class that implements this interface.

5.3.3 ScopeGUI

The main function of ScopeGUI is to create and maintain the components of the Graphical User Interface (GUI). ScopeGUI creates and initializes all the Swing components and panels, and it creates event listeners for each graphical component. These event listeners are discussed in more detail in the next section.

ScopeGUI is also the class that implements the IScopeControls and IScopeProtocol interfaces. Therefore it implements all the methods listed in these two interfaces, and since it inherits the Hashtable *'state'* from IScopeControls it is in charge of maintaining the state of the client.

5.3.4 Event Listeners

Swing components can generate many kinds of events when a user interacts with them, like pressing a button, or selecting an item from a list. In Java each event is represented by an object that gives information about the event and identifies the event source, meaning the component where the event was generated. Each component can have multiple listeners registered, and a single listener can register with multiple components. I chose to have a single listener for each component to keep the handling of events in separate methods. These event listener methods reside in the ScopeGUI class, and whenever an event happens these methods are called.

Event listeners have two tasks. One task is to respond to the component's events by sending requests to the server to change the state of the hardware, or to request an image. This is done by sending text message commands to the ScopeConnection. The second task is to update the *state* Hashtable with a new control value, when the event requests to do so.

5.3.5 ScopeApplet

ScopeApplet is the main class of the client application. ScopeApplet extends the JApplet[2]. In addition to having the capability of an Applet it creates three objects when it initializes. It creates a ScopeConnection (used for reading and writing text messages to and from the server), a ScopeImageConnection (used for reading binary messages from

---

[2] For more information about JApplet or other Java defined classes see: "Java 2 Platform, Standard Edition, version 1.4.0 API Specification," *http://java.sun.com/j2se/1.4/docs/api/index.htm*

server), and a ScopeGUI (used to display the graphical components).

ScopeApplet is also in charge of listening to messages sent from the server, and then processing them. It has a ReaderThread that with the aid of ScopeConnection is constantly listening for text messages sent from the server. When a message is received the message name is extracted from the string. This name is appended to *'cmd_'* to create a method name that is then called with what is left of the message string as argument to the method.

In addition to the Reader Thread, there is a ReaderImageThread that is constantly listening for binary data from the server with the help of ScopeImageConnection. When a binary message is received it extracts the binary information and calls the method *cmd_image*, with the binary data as an argument.

Chapter 6

Server Implementation Details

This chapter will describe the implementation details of the server application. The server runs on the Windows platform PC. The server is responsible for maintaining the overall state of the microscope, accepting client connections, and processing messages sent from client to send them to the appropriate controller module. When the server is run, the application will remain idle until it receives a client connection.

The server implementation was based on Andrew Kuchling's Remote Microscope[3] implementation for the MEMS Exchange project. Kuchling implemented a server written in Python that runs in a Linux machine [6]. His server code was used to aid in the implementation of this server. Many of Kuchling's code structure was maintained, with some changes made to the controller handling, state handling, and some other modifications done so that the server will run in Windows.

Kuchling's server was designed to handle multiple connections to the server, so that one client will act as the controller for the microscope, and other clients could connect as viewers. Even though this was not a requirement for this project, the code is structured in such a way that this feature could be added easily in the future.

---

[3] http://www.mems-exchange.org/software/microscope/

6.1 Programming Tools

The server application was programmed in Python. Python version 2.2 was used. In addition a few Python add-on packages that can be downloaded from the web were used to aid in the functionality of the server. For one, the Python Imaging Library (PIL)[4] was used. The PIL adds image processing and graphics capabilities to the Python interpreter. This package was used to handle the images sent from the camera.

A second package that was used was Win32all[5], which was developed by Mark Hammond as an add-on for the regular Python installer for Windows platform. This package includes Win32 API, COM support and Pythonwin. Pythonwin is an integrated development environment (IDE) and GUI Framework for Windows. Pythonwin was a very helpful tool that allowed the use of Python's interactive window, as well as editing compiling, and running of Python files.

The third package used was the SioModule[6], a serial communication extension for Win32 created by Roger Burnham from MarshallSoft Computing, Inc. This module was used to aid in the connection between controller modules and serial ports.

6.2 Class Specification

The main class of the server application is the *SERVER* class. The server uses various classes or objects to aid in handling users connecting to it, parsing messages, sending messages, and creating devices to be used. In Figure 12 you can see the objects that the server uses. The following sections explain in detail how each of the modules works and the purpose they serve for the server application.

---

[4] http://www.pythonware.com/products/pil/

[5] http://starship.python.net/crew/mhammond/

[6] http://starship.python.net/crew/roger/

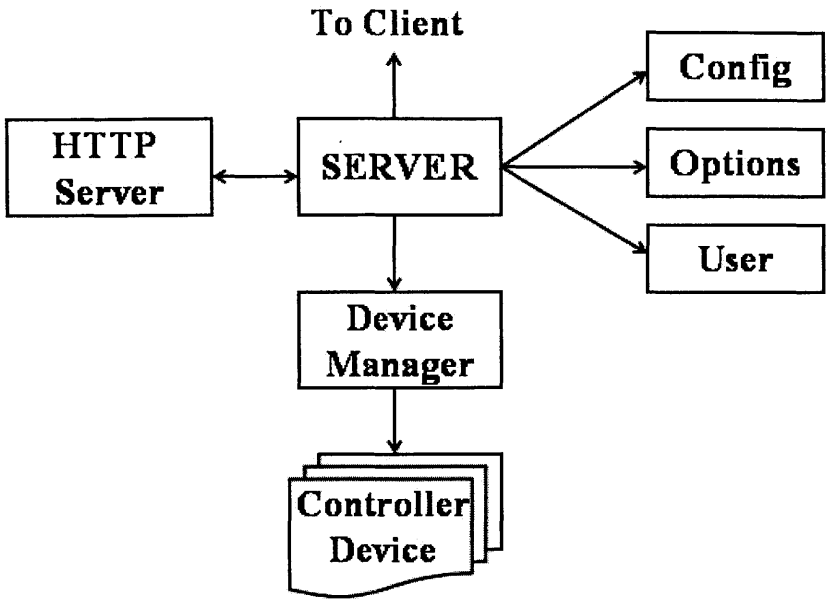


Figure 12 – Module Dependency Diagram for Server Application

6.2.1 Config and Options

The Config and Options classes set certain options and configuration settings to the server when it starts. When the server is launched, it can be initialized with several options. The Options class parses the server initialization command, and keeps a record of the options set, so that the server can knows which options were chosen upon initializing of the server. The options available are:

-c, --center	Center the stage when initializing microscope
-d, --debug	Display debugging trace messages
-f, --cfg <file>	Use specified configuration file
-h, --help	Display this help message
-t, --timing	Display timing trace messages
-v, --verbose	Display verbose activity message

The Config class parses the information given by the configuration file. The default configuration file is called *microscope.cfg*. The information in this file is used by the server to know things like which port number the server will run at, which device

controllers to initialize, and any configurations for these devices such as COM port numbers.

6.2.2 Device Manager

The DeviceManager acts as a proxy, passing along all the parameters to the individual instruments or devices. For example the exposureTime setting goes to the camera, an x setting goes to the XY stage, and so forth. This assumes that all devices can come up with parameter names that won't conflict with the other instruments they're used with.

The DeviceManager is essentially a list of controller devices. The DeviceManager is initialized by the server, and with the information from the configuration file, the server creates a set of controller device modules. These controller devices are explained in more detail in the next chapter. The controller devices are then added to the DeviceManager by the server. The DeviceManager stores them in a list. The server can then use the DeviceManager's single *set* method to set new values to any of the control settings of the existing devices.

6.2.3 User

User is the class representing a user of the microscope. A user will have a unique id for a connection, a name, and two socket connections (one for text messages and one for binary data). A user is initialized with the given client authorization token, which is then validated. The server stores a list of these user objects. In our application the list is limited to length one, but in the future it could be allowed to have more than one user.

6.2.4 Server

The server does the parsing of the messages sent from the client, and uses the DeviceManager to send changes for any hardware setting. In addition the server also

sends text messages to client, and most importantly it also sends binary data for displaying of the image. To do so, the server maintains two socket connections, one for text messages and the other for binary data. The server is also in charge of maintaining the state of the system, and of sending status and error messages to the client informing of the operations being performed, or of any problems that may arise with either the hardware or server software.

The server class is where all the listening, reading and writing threads are fired. Figure 13 shows the threads that run in the server class.

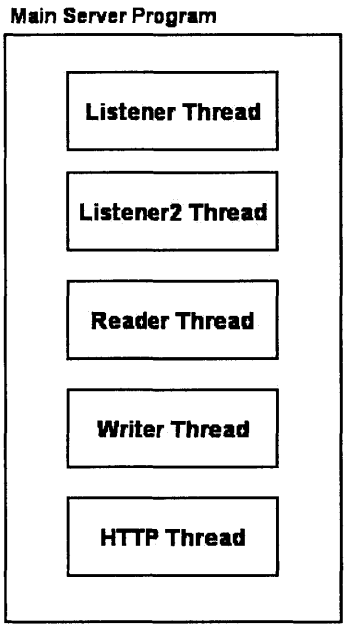


Figure 13 – Server class threads

Listener Thread

Sits and waits for connection requests to arrive. When a new connection arrives, it informs the connection if the microscope is free or not by sending an OCCUPIED or AVAILABLE message. If the microscope is available it adds the socket to the list of client connections.

Listener2 Thread

Listens for connections on the image_socket connection. This socket connection has a different port number than the main socket connection, and that is why we need a separate listening thread.

Reader Thread

The reader thread watches the client sockets for incoming input. When a command comes in, the corresponding method is called: *cmd_<command_name>* automatically. Then this method does whatever it needs to do, usually calling a hardware method with the use of the DeviceManager.

Writer Thread

The writer thread is awoken when messages are added to its outgoing queue, and writes them to all the authorized client sockets

HTTP Thread

The "http" thread runs the http_server that is discussed in the following section.

6.2.5 HTTP Server

Java applets running in a browser have the security limitation that they can only make network connections back to the host from which they came. This means that the client compiled code needs to exist in the same computer in which the server is running. In order for remote running of the applet, the Remote Microscope needs to run an HTTP server that will return the JAR file (compressed file for java files) containing the applet.

HTTP is an Internet Protocol used to exchange data across the network. The HTTP server of the Remote Microscope system is set up to accept connections from client computers, where the client issues a request to read an html file. The HTTP server then locates the content, and sends the data back to the client computer.

6.3 Video Streaming

Video streaming is handled by an additional thread in the server class. When video streaming is requested to start by the client with the VIDEO_START command, the video thread is started. With the help of the DeviceManager, this thread calls the *get_image()* method of the camera controller repeatedly. The thread keeps running until the client sends the message VIDEO_STOP to request the server to stop calling the *get_image()* method so that the video streaming will stop.

Chapter 7

Hardware Controllers

This chapter gives an overview of the implementation details and settings of the hardware controllers. All controller classes are derived from the parent class called Controller. The Controller class has general methods applicable to all type of controllers. Each specific controller has unique attributes and methods specific to the hardware they control. Figure 14 shows the hardware controller's module dependency diagram.

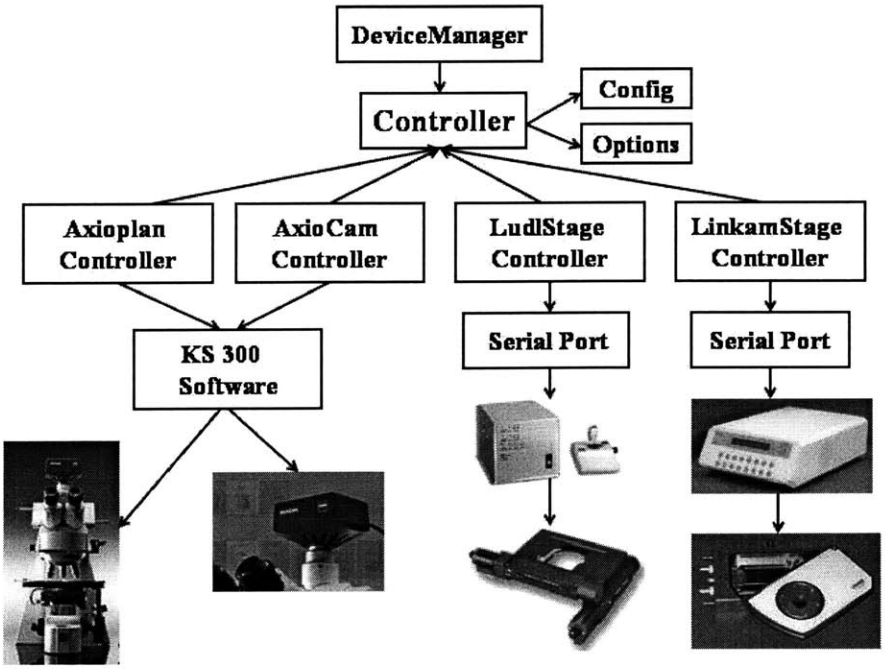


Figure 14 – Module Dependency Diagram for Hardware Controllers

7.1 Controller Class

The Controller class is the parent class for all controllers. All methods specified in this class will be inherited by the controller modules that extend this class. The Controller class has the Options and Config information stored as attributes for use in the implementation of any specific controller. The Options and Config objects are specified as parameters to the constructor of the Controller class.

One important aspect of the Controller class is that it has a *set* method that takes in a control setting name and the new control value. When this method is called, it calls the appropriate *get_<control_name>* method in the specific controller module. This method is very useful for all types of controllers because it handles calls to specific set methods, allowing the programmer to easily add or delete set methods without having to figure out how to handle them. This way the set method can be called through any object of the type Controller.

Another important component of the Controller class is the *settings* attribute. The *settings* attribute is a dictionary that maps control setting names to values. All controller modules have their own *settings* dictionary that stores the present state of the hardware settings it controls.

7.2 Microscope Controller: Axioplan2

The AxioPlan2 controller is the module in charge of handling all operations to the microscope hardware. The AxioPlan2 controller uses the KS Software to communicate with the microscope. When the AxioPlan2 controller is initialized it has to create a connection dispatch to the KS Application, so that it can then send command messages to change the microscope's state.

Table 3 lists all the control settings that the AxioPlan2 controller can manage, along with their types, their accepted values, and the default value given when the server is

restarted. The AxioPlan2 controller contains *set* and *get* methods for each control setting name. All control settings names along with their present values are stored in the Axioplan2's *settings* dictionary, which is updated every time a *set_<control_name>* method is called. The get methods are only used to retrieve the value of a control name. The *set* and *get* methods should always be used for accessing or changing the *settings* dictionary, instead of using the *settings* dictionary directly.

Control Setting Name	***Type***	***Possible Values***	***Default Value***
magnification	String	"2.5X", "5X", "10X", "20X", "50X"	"5X"
lightMode	String	"OFF", "3200K", and "MANUAL"	"OFF"
lightVoltage	float	[0.4 -> 12.2]	5.0
aperture	float	[0.07 -> 0.95]	0.95
fieldStop	float	[0.00 -> 1.00]	1.00
reflector	String	"NONE", "ANALYZER", "DIC_RED"	"NONE"
transFilter	String	"0%", "0.048%", "0.100%", "0.200%", "0.400%", "0.720%", "1.5%", "3%", "6%", "12%", "25%", "50%", "100%"	"12%"

Table 3 - AxioPlan2 Controller Settings

Currently only the *magnification*, *aperture*, *fieldStop* and *reflector* settings can be directly modified by the client interface. The *lightMode* setting is directly controlled by the server application. Whenever a client connects to the server, the lightMode is switched to "3200K" value, and will automatically be set to "OFF" whenever the client disconnects. The reason for giving control to the server instead of the client for this setting is so that the light would not be left turned on after a client disconnects, and is no longer using the microscope.

The *lightVoltage* and *transFilter* settings are currently not being used by the client or server. The setting *lightVoltage* is only used when *lightMode* is set to "MANUAL". This control setting was not added to the client because for image viewing purposes it is

better to have the halogen lamp set to 3200K, and only modify the aperture or field stop settings instead of the light voltage. The *transFilter* setting which controls the transmission filter is a setting that could be added in the future to the client interface, but was not necessary for the present state of the project.

Aside from these settings the AxioPlan2 has an *autofocus()* method that request the KS software to perform autofocusing.

7.3 Camera Controller: AxioCam

The AxioCam controller is the module in charge of handling all operations on the digital camera. Similar to the AxioPlan2 controller, the AxioCam controller uses the KS Software to communicate with the camera. When this controller is initialized it has to create a connection dispatch to the KS Application, so that it can then send command messages for image processing capabilities.

The AxioCam controller has the important method get_image() used to capture an image from the camera. The get_image() method takes in three parameters, two of which have default values. The first one is the size of the image specified in pixels. The second parameter is the image mode. The mode of an image defines the type and depth of a pixel in the image. The KS software supports the following standard modes:

1 (1-bit pixels, black and white, stored as 8-bit pixels)
L (8-bit pixels, black and white)
P (8-bit pixels, mapped to any other mode using a color palette)
RGB (3x8-bit pixels, true color)
RGBA (4x8-bit pixels, true color with transparency mask)
CMYK (4x8-bit pixels, color separation)
YCbCr (3x8-bit pixels, color video format)
I (32-bit integer pixels)
F (32-bit floating point pixels)

The default value for mode is "L" which corresponds to capturing a black and white image.

The last parameter is the image format. This specifies what type of file the image

will be stored at. The possible values for the format are "jpg", "tif", "bmp", and "pcx". The default value format is "jpg" as this is the most compressed image format suitable for image sharing through a network.

In addition the AxioCam has a single control setting to set: exposureTime. This sets the shutter speed of the camera.

Control Setting Name	*Type*	*Possible Values*	*Default Value*
exposureTime	Integer	[1ms - 1,000ms]	1ms

Table 4 - AxioCam Controller Settings

7.4 XY Stage Controller: MAC5000

The MAC5000 controller module is in charge of communicating with the XY stage hardware. The MAC5000 uses the SerialPort class to create a COM port connection, and be able to write and read from the COM port. The settings that the MAC5000 controller handles are the X and Y position of the stage. In addition to these settings, it also has a *center_stage()* method, which calibrates the stage and sets the position to the center of the stage. This operation can be performed whenever the server is initialized or if a client sends the CENTER command.

Control Setting Name	*Type*	*Possible Values*	*Default Value*
x	integer	[-300000 –> 300000]	0
Y	integer	[-30000 -> 220000]	0

Table 5 - MAC5000 Controller Settings

Chapter 8

Extension Capabilities

The Remote Microscope system was designed for easy extendibility and usage with a great sort of devices. It allows new devices to be easily added since each hardware device is encompassed with a single controller module. The system also allows new controls to be easily added to individual controller modules, as well as to the GUI. Furthermore, additional client/server protocol commands can easily be added to the client and server.

8.1 Adding new devices

To add a new device, a new controller module has to be created. This controller module has to be a Python class that *extends* or is of type Controller. Whenever a new device is being created a new Python class file should be placed under the *RemoteMicroscope\hardware* directory. This file should be given a name that describes the hardware it controls such as *AxioCam* or *Axioplan2*. The following figure is a Python file template that shows what the structure of a new controller module should look like. As it can be seen from the class declaration line, the new device class is of type Controller.

```
# <newDeviceName>.py

from RemoteMicroscope.hardware.Controller import Controller
from RemoteMicroscope.hardware.InstrumentException import InstrumentException

class <newDeviceName>(Controller):
    __name__ = '<newDeviceName>'
    settings = {}

    def __init__(self, config, options):

        Controller.__init__(self, config, options)
        if self.options.verbose:
            print "Initializing <newDeviceName> controller..."

        # Set initial settings
            self.set_<setting1>(<initialVal>)


    def set_<setting1>(self, value):

        # Checks to see if the value given is of the correct type
        if (type(value) != type(<typeSetting1>)):
            raise TypeError ("Parameter to set_<setting1> is not of the correct type.")

        if self.options.verbose:
            print "Setting <setting1> to value: ", value

        # Add code that sets hardware setting

        self.settings['<setting1>'] = value


    def get_<setting1>(self):
        return self.settings['<setting1>']


    def close(self):
        if self.options.verbose:
            print "<newDeviceName> controller is closing"
```

Figure 15 - New Controller Module Template

The first step for implementing a new controller class is to replace the name *<newDeviceName>* on the Python file above with the given device filename. Then for each hardware setting that can be changed, the Python file should contain a *set* and *get* method. An example of how these methods are defined and what most be in them are

exemplified above with the *set_<setting1>* and *get_<setting1>* methods. All setting values should be initialized in the constructor (__init__) method, by replacing *<initVal>* with the initial value for the corresponding setting. If this is not done, the setting name will not appear on the *settings* dictionary of the device, and the setting will not be taken into account until the set method is called for the first time.

In addition to *set* and *get* methods, the controller module may have to implement additional methods that do not correspond to changing hardware settings, but that produce an action on the hardware or add additional functionality to it. There is no restriction on how these methods should be implemented, but the programmer should make sure that the server application can call these methods appropriately. In most cases this means adding an additional client/server protocol command that handles these additional methods. To learn how to create a new protocol command in the server side see section 8.4.

After implementing a controller module for the new device, the device name should be added to the configuration file, so that when the server starts it will initialize the new device along with the others.

8.2 Adding new controls to an existing device

To add new control or setting to an existing device is as simple as adding a new *set* and *get* method to the appropriate controller module. The *set* and *get* methods should look like the ones on Figure 15. It is important that in addition to implementing the *set* and *get* methods, the control setting is initialized in the constructor method of the device. This is done by calling the set method within the constructor, with an initial value as a parameter.

8.3 Adding new controls to the GUI

The best way to add a new control to the GUI is by using the Java Forte development environment. Forte lets the programmer visualize the present GUI, easily add new controls by dragging control objects to the GUI form, and automatically generates the necessary code to create these new controls. This way the programmer can save time on figuring out where to add the control code and can observe immediate GUI results without having to run the program. Forte also aids in adding event listeners to controls, and adds the necessary method declarations for each of them. This leaves the programmer having only to fill in the implementation of the event listener for the control. The event listener method usually sends a command message to the server requesting a change in the hardware.

All the GUI controls code is found in the *initComponents()* method of the ScopeGUI.java file. Here is where new controls should be initialized and added to panels. In addition, event listeners are also added here to the controls. A template of how an event listener is added to a control is shown bellow:

```
<controlName>.addActionListener(new java.awt.event.ActionListener() {
        public void actionPerformed(java.awt.event.ActionEvent evt) {
            <controlName>ActionPerformed(evt);
        }
    });
```

In addition an event listener method should be added to ScopeGui.java. This method should then be implemented so that it makes the appropriate request to the server.

```
private void <controlName>ActionPerformed(java.awt.event.ActionEvent evt) { }
```

8.4 Adding new protocol command to server

When adding a new protocol command to the server, we are adding a command that the client can use to communicate with the server, and that will be processed by the server. To add new command to server is as simple as adding the following method to the

server.py class.

```
def cmd_<newCommandName> (self, args, r):
```

This method should contain calls made to the appropriate hardware controller module, which is done using the DeviceManager.

8.5 Adding new protocol command to client

Adding new protocol commands to the client is very similar to adding them to the server side. In the client side the first step is to add the following method declaration to the *IScopeProtocol.java* interface.

```
void cmd_<newCommandName>(String args);
```

Then add the same method name to the ScopeGUI.java class and implement the method in this class.

```
public void cmd_scope(String args) { }
```

Chapter 9

Possible Improvements and Future Work

There are a few ways that the Remote Microscope System can be improved. One major area of improvement is image capturing and video streaming. Currently the image capturing and video streaming is too slow. There is a great delay between when the server requests an image capture to when it actually shows up in the client display. The main reason for this delay is because the AxioCam controller uses the KS software to retrieve images. The KS software is slow, and therefore it delays the whole process. A way to improve this will be to modify the *get_image()* method in the AxioCam controller so that it connects directly to the camera frame-grabber software to get the image from there. This way it will reduce in a great amount the video streaming and image capturing delay.

Another improvement that might be considered is to reduce the delay between when a control is set by the client to when it actually is set in the hardware. The way to do this will be to bypass the KS software. Again the KS software accounts for most of the delay between when a control is requested to be set, to when it is actually set. An alternative to using the KS software is using the DLLs provided by Zeiss. These DLLs provide methods calls that can communicate directly with the hardware. Therefore, there will need to be a way to connect to these DLLs from the Python Axioplan2 controller class so that the appropriate calls can be made.

In addition to improvements, there is still substantial amount of future work left to

be done to complete the WebLab. An integral part of this project is the implementation of the Linkam controller in both the server side and the client side. There is already a template of the Linkam controller in the hardware directory called *tms94.py*, but the methods still need to be implemented. The GUI should also include a fourth panel that includes all the heating stage controls. In addition, the high resolution and zoom controls available in the GUI need to be implemented on the server side, so that the controls can be used.

Furthermore, there is a need for additional controls that manage focusing. Currently only the autofocus control is available. The autofocus control is very useful when having to search for the focus position whenever the stage is lowered and the focus position is lost. This will be necessary when the heating stage is added to the system and the XY stage has to be lowered every time an objective lens is changed to avoid crashing it against the heating stage. In this case autofocus will search for the right z-focus position. In addition to this control though, there is a need for adjusting the z-focus position by small amounts so that the user will have the flexibility to adjust the focusing after autofocus is performed.

The system still needs proper authentication and a login page. A feature that will be very useful is to have two distinct clients: one for administrators, and one for students. This way administrator will have access to all the controls of the system, while students will be restricted to only use the ones necessary for the experiment. The administrator and student identities could be identified through the authentication process that will decide which client to launch depending on the username and password provided.

Something for which the KS software could be very useful is for image analysis. Image analysis will be necessary for the WebLab since students will have to measure selected areas of the images they observe. Therefore additional functionality is needed to handle image measurements and other image analysis tools. This functionality should be added to the AxioPlan2 controller that will connect to the KS Software to get information about the image.

Another feature that would be useful for the WebLab is to allow multiple connections to the microscope. This way one client could be the controller that can change the hardware settings, and then multiple clients could be viewing the same image

or video. This will allow collaboration between students. The server application for which the current implementation was based on, already had this functionality, and a lot of the structure for this is still maintained in *server.py*. Therefore it should not be as hard to add this functionality to the system.

Chapter 10

Conclusions

As of now, there is still a lot of room for improvement, but the present project has brought to light many implementation issues that have to be solved in order to have a solid working WebLab. For example, it is very important for the system to be user friendly and targeted to student use. This means also having security filters to protect the equipment from being damaged by the students. Security issues will take more importance when the Linkam controller is added to the system because if not controlled in the right manner the objectives could easily crash into the heating stage.

The Remote Microscope can be a very useful tool for students. It will allow them to run chemistry experiments at their own convenience without visiting the lab. As the I-lab motto says: "If you can't come to the lab... the lab will come to you!". With a one-time hardware investment, the Internet remote microscope will enable students to do real-time experiments and make use of a high-end piece of equipment without having to visit a lab. The remote microscope system is an important tool that we hope will be of great educational value for MIT students, and in the future can also be extended for use in other universities and students. In the future this could be a very powerful, since it could conceivable be used by people who don't have the resources to access such piece of equipment as a microscope.

Appendix A: TA User Manual

The following User Manual assumes that the server is running in the machine called Fujicam.mit.edu, and that the client and server code is found in the C:\ILab\RemoteMicroscope directory.

A.1 Program Requirements

The server application requires *Windows 2000* or *Windows XP* operation system. To be able to run and compile the server application the following packages need to be installed in your PC:

- Python 2.2 : http://www.python.org/
- The Python Imaging Library 1.1.2 (Windows version) : http://www.pythonware.com/products/pil/
- Python Win32 Extension Package for Python 2.2, Win32all : http://starship.python.net/crew/mhammond/win32/Downloads.html
- Serial Communication Extension Package, SioModule : http://starship.python.net/crew/roger/

To run and compile the client application you will need the following installed:

- Java 2 SDK version 1.4.0 : http://java.sun.com/

A.2 Compiling Instructions

For the server application no compilation and linking is necessary because the Python language is an interpreted language that does not requires compiling. Therefore it is as

simple as just making changes to the .py files and saving them.

To compile the client application using the command line:

- Go to the appropriate directory:

  ```
  cd C:\ILab\RemoteMicroscope
  ```

- To compile the code:

  ```
  javac –classpath C:\ILab\RemoteMicroscope client\ScopeApplet.java
  ```

- For a release version of the code you need to create a jar file in the C:\ILab\RemoteMicroscope\client\data directory, which is the directory that the http server can read from. To do this go to C:\ILab\RemoteMicroscope and do:

  ```
  jar cvf client\data\ScopeApplet.jar client/*.class client/images/*
  ```

A.3 Running Instructions

To run the server application:

- Go to the appropriate directory:

  cd C:\ILab\RemoteMicroscope

- Run the starting script:

  startServer.py [options]

- The available options for the script are the following:

-h, --help	Display this message
-c, --center	Center the stage when initializing microscope
-d, --debug	Display debugging trace messages
-f, --cfg <file>	Use specified configuration file
-h, --help	Display this help message
-t, --timing	Display timing trace messages
-v, --verbose	Display verbose activity messages

There are several ways to run the client application.

- One is to use the appletviewer application. On the command line write:

  appletviewer C:\ILab\RemoteMicroscope\microscope.html

- Another way is to use a browser, either netscape or internet explorer, and open the file C:\ILab\RemoteMicroscope\microscope.html

- The third way is with a URL:

  http://fujicam.mit.edu:19001/microscope.html

A. 4 How to add more files to the HTTP server

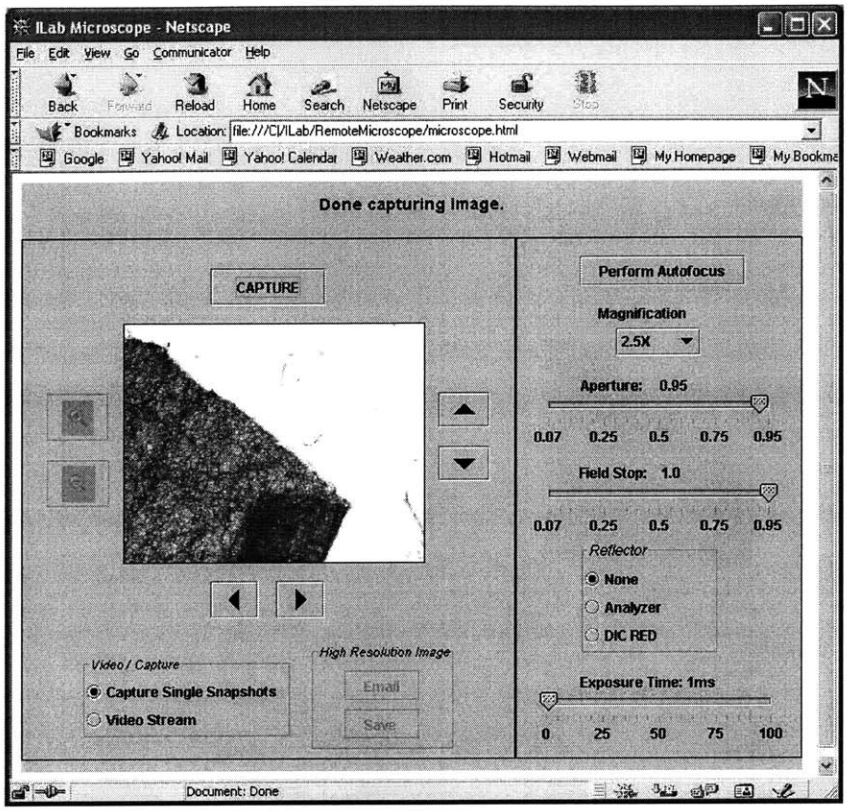
The HTTP server can read files that are located in the following directory:

C:\ILab\RemoteMicroscope\client\data

This is specified in the http_server.py file as the BASEDIR. The http server can only read the files that are listed in its send_head() method. To add more files to the HTTP server, go to the beginning of the send_head() method. There you will find a list called httpFiles where you can add or remove files to be read by the http server.

Appendix B: Student User Manual

This user manual is intended to explain how to use the student client interface. It explain what each graphical component does, and how it should be used.



Capturing Images

To capture microscope images, first the user has to make sure the "Capture Single Snapshots" is selected on the *Video/Capture* control. Then every time the CAPTURE button is pressed an image will be captured and it will be displayed on the screen.

Video Streaming

To start video streaming select the "Video Stream" selection on the *Video/Capture* control. The capture button will be disabled, and a sequence of images will be captured

and displayed on the screen.

Moving the Image

To move the image around use the arrow buttons located to the side and bottom of the image display panel. Whenever any of these arrow buttons are pressed the XY stage moves, and if "Capture Single Snapshots" is selected a new image is captured and displayed on the screen immediately after the stage finishes moving.

Perform Autofocus

The *Perform Autofocus* button calls the one-time autofocus function, and returns a new focused image that is displayed on the image panel. The autofocus main purpose is to search for the right z stage position for adequate focusing.

Magnification

The *Magnification* control changes the objective lens being used. The possible magnifications are: 2.5X, 5X, 10X, 20X, and 50X.

Aperture

The *Aperture* control changes the condenser aperture setting. A condenser has the role of collecting, controlling and concentrating the light from the lamp onto the specimen. The aperture of the condenser serves to control the angle of the cone of light emerging from the top of the condenser. When the aperture is set to the maximum (0.95) the objective provides maximum resolution, but some glare may be present, which reduces image contrast. If the aperture is adjusted to about 0.70 the glare is reduced and contrast is improved, without significant lose of image detail. Lowering the aperture will increase contrast but image detail will be lost.

The aperture setting should only be lowered for magnifications greater than 10X, because in lower magnifications the field of vision will be greatly reduced when lowering the aperture. Therefore, for optimal performance maintain the aperture above 0.70 when using 2.5X and 5X objectives.

Field Stop

The field stop allows you to control the amount of light entering the system as well as the field of view. The field stop is basically a plate with a hole on it placed on the optical axis. This control is useful mainly to control the light illumination for the lower magnifications such as 2.5X, and 5X. For higher magnifications the field stop should be set to the highest value, and only use the Aperture control to adjust brightness and contrast.

Reflectors

With the reflector control you are able to select between an analyzer, a DIC_RED reflector, and no reflector at all. A much higher exposure time is always needed when using the DIC_RED reflector or the analyzer, than when not using a reflector at all.

Exposure Time

The exposure time controls the shutter speed of the camera. The normal setting for the exposure time is 1 ms. If the user is using the analyzer or the DIC_RED reflector then to get a clear image the exposure time has to be increased to around 20 ms.

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