INDUSTRIAL AUTOMATION IN LASER MANUFACTURING

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ABSTRACT OF THE THESIS

Industrial Automation in Laser Manufacturing

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With the rapid development and proliferation of PLCs and other software technologies, manufacturing in industries has changed drastically from manual to automation. The following report shows one such effort of fully automating a laser-manufacturing machine that assembles and tests the laser diodes at lower costs. This includes development of hardware and software for a laser testing equipment, which completely eliminates the human error and increases the product manufacturing efficiency. In developing such fully automated system a 3-axis Cartesian Robot is used with the help of LabVIEW and some other sensors& actuators. The code written in LabVIEW to control Robot provides solutions to use LabVIEW as main interface for any automation project. The developed algorithms for testing and pick & place provides the project with the needed time and cost effectiveness.

Acknowledgements

First and foremost, I would like to thank my adviser Dr.Hana Godrich for all the support and help provided during the research. Secondly, I would like to thank Dr.Greg Charache director of Equipment Development of Trumpf Phtonics Inc. for the support provided during my internship and helping me in the research. I would like to thank my family and friends for providing me moral support in hard times of my life.

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Introduction

Industries, nowadays, are plagued with high demand of goods and services, which they are not able to satiate with adequate supply [1]. Hence, in recent years a shift from manually managed operations to fully automated facilities is visible in many industries. Automation is a set of technologies that facilitates in operation of machines and systems without significant human intervention and achieves performance superior to manual operation.

The usage of feedback controllers and PLCs in manufacturing plants has drastically increased the efficiency of production over the past few decades[2]. Additionally, with the implementation of SCADA(Supervisory Control and Data Acquisition) in manufacturing industries enabled a remote method of capturing data and events (alarms) for monitoring processes [3]. Over the past few decades Lasers have emerged the forefront of industries, been utilized in various applications such as manufacturing jobs (cutting, welding), in medical devices, spectrometers ad printers to name a few. Laser-manufacturing industries involves handling of precision items (mirrors, lens, semiconductor wafers) and the process of building and testing the lasers is monotonous and time taking for humans [4]. Usage of robots to handle all the precision materials has helped in reducing human errors but there is still scope to increase production by automating the process[5].

Automation systems can be categorized into Fixed Automation, Programmable Automation, Flexible Automation, and Integrated Automation based on the flexibility and level of integration in manufacturing process operations [6]. In Fixed Automation the set of operations are fixed whereas in Programmable Automation, they can be changed according to a sequence. Human operator can change the high level commands by identifying the product and its location. In all the above automation techniques, a human operator is needed whereas Integrated Automation denotes complete automation of a manufacturing plant, with all processes functioning under computer control. It includes technologies such as computer-aided process planning, computer numerical control machine, and automated material handling systems such as robots and also database connectivity for data upload and retrieval. This thesis focuses towards implementing an Integrated Automation system in the Laser manufacturing Industry where precision is highly required.

The objective of this thesis was to design and implement an Integrated Automation routine in the Laser manufacturing industry that helps in reducing labor, material and energy requirements, by improving quality as well as productivity and achieve Industry 4.0 [7]. The following report documents the efforts of developing a complete automation routine for testing of bulk laser diodes. The report also documents how SCADA is achieved with LabVIEW.

In the effort of achieving such automated routine, LabVIEW is used as the primary control software and a robot with different sensors and actuators are used along with LabVIEW. The problems in establishing the communication between LabVIEW and Robot are discussed and a solution is proposed. Different testing algorithms and a feedback control algorithm for pick and place are discussed in the following report.

Chapter one starts with the brief introduction about LabVIEW, Laser, Robot and its Controller, different sensors, testing equipment and relays. Chapter two states about the construction of the testing equipment and the schematics are produced in Appendix 1. Chapter 3 discusses about the testing algorithms implemented in achieving the automation.

Chapter 4 explains the communication problems between Robot and LabVIEW and proposes a solution. Chapter 5 discusses about the feedback control algorithm of Robot for pick & place and finally chapter 5 produces the results and states how this automation routine comes under Integrated Automation with cost & time effectiveness and ,how this helps in establishing Industry 4.0

Chapter 1

Introduction on Hardware and Sofware used

1.1 LabVIEW

LabVIEW (Laboratory Virtual Instrument Engineering Workbench), a product of National Instruments, is a powerful software system that accommodates data acquisition, instrument control, data processing, and data presentation. LabVIEW which can run on PC under Windows, Sun SPAR stations as well as on Apple Macintosh computers, uses graphical programming language (G language) departing from the traditional high level languages such as the C language, Pascal or Basic. All LabVIEW graphical programs, called Virtual Instruments or simply VIs, contain a Front Panel and a Block Diagram. Front Panel has various controls and indicators while the Block Diagram consists of a variety of functions.

Figure 1.1: NI 9215 AI module.

The execution of a VI is data dependent, which means that a node inside the Block Diagram will execute only if the data is available at each input terminal of that node. By contrast, the execution of programs such as C language program, follow orders in which the instructions are written.

Figure 1.2: NI 9472 DO module.

The Analysis Library offers the user a comprehensive array of resources for signal processing, statistical analysis, filtering, linear algebra and many others. LabVIEW also supports the TCP/IP protocol for exchanging data between server and client. LabVIEW also supports dynamic-link libraries (DLLs), that can be called using constructors and use all the methods and objects of the called DLL. It also supports database connection and can upload the data to database with ease. LabView supports data acquisition, communication with the hardware like sensors (flow, pressure, temperature sensors), actuators and other third party appliances using the COM ports. For acquiring data and controlling instruments, LabVIEW supports IEEE-488 (GPIB) and RS-232 protocols as well as other D/A and A/D and digital I/O interface boards. In this project we use a Compact DAQ USB Chassis for data acquisition and also to send the analog and digital signals to the hardware. CDAQ contains 8 slots for the modules in it where we use NI 9215 AI (Analogue Input) and NI 9472 DO (Digital Output) modules. NI 9215 is an analogue Input module where we can log four analogue signals simultaneously at a rate of 100Ks/sec.

1.2 Adept Ace

The software used to control the Robot is Adept Ace which is provided by the Robot manufacturer (Omron Adept).

The Adept Automation Control Environment (ACE) software is a PC-based software package that contains a collection of tools for configuring, programming, controlling, and monitoring Adept equipment in a work cell. These tools are accessed through the Adept ACE graphical user interface (GUI), which provides a user-friendly, point-and-click environment [7].

The Adept ACE software provides a core framework of functionality in a library that runs on the PC, as shown in the following figure.

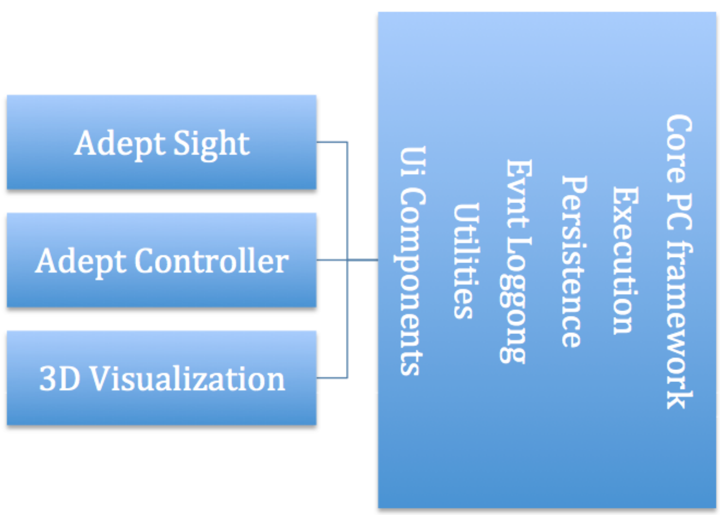

Figure 1.3: Framework of Adept Ace

These functions include the ability to: Save and load workspace data (persistence) , Run applications , Log events , Run various utilities Base Framework and Extensions Communication between the Adept ACE software and the Adept controller is supported over Ethernet. A custom user program (typically written in Visual Basic, C Sharp, or C++) can run in a process or on a PC that is independent from the Adept ACE application, and make remote calls to the Adept ACE Framework API.

Programs (called modules) are written in V+ language (combination of assembly and C++), which has its own functions and methods to talk to the robot. Modules should be executed in a specified task and the robot controller can run 20 different tasks at a time. The main module running on the Primary task (Task 0) calls different modules that runs on different tasks. Adept Ace also gives the option to control the I/O of the robot controller, which are generally used to actuate the gripper and move some linear stages.

Adept Ace can talk to the Robot Controller using Ethernet communication and LabVIEW structures the automation code, acquires the data, saves the results, and talks to all the different hardware. But for fully automated testing equipment there should be a communication between LabVIEW and Adept Ace which is necessary to control the Robot using LabVIEW. A specific DLL is written in C Sharp and called in LabVIEW to establish the communication between LabVIEW and Adept Ace which is discussed in later sections

1.3 Robot

A 3 axis Cartesian robot called the Adept gantry robot is used for pick and place of laser diode, as shown below. The Robot is controlled by a smart controller, which can load different workspaces (contains code to control robot for different tasks) on the Robot. The smart Controller has a number of I/O modules that are used to drive solenoid valves and to stop the robot when an external alarm is activated. The I/O modules are also used to open and close the gripper of the robots Pick Up Tool (PUT), as shown in figure, and also control the linear stages on the testing equipment. The robot also has an emergency stop to kill the mobility of the robot under danger situations. This E-stop can be controlled both by hardware and software.

The Robots 3rd joint is attached with two linear motion pistons with fingers that can be moved between two points with the help of pressurized air. One of them is used to pick up the laser device and the other to pick the trays and lids, in which the laser

Figure 1.4: 3 axis Gantry Adept Robot

diodes are placed.

1.4 Laser Device (ILLASCO)

The diode Under test (DUT) is a semiconductor laser diode, which is mounted on a Micro channel cooler (MCC) manufactured by ILLASCO. Hence the laser diode are called Illascos. The semiconductor is a product of TRUMPF Photonics 5th generation lasers also called GEN5. This laser operates at high currents (up to 300 A) and low voltages, so the chip must be cooled down simultaneously. For the process of active cooling, water is circulated through the MCC whenever the laser diode is powered on.The MCC is stacked with 7 tiny layers of copper sheets through which water is circulated uniformly. Illasco can emit either 23 or 27 emitters of 10 watts each. So, One laser diode can emit a laser beam of 230 watts or 270 watts of energy. Two DC power supplies rated at 3000W (150A, 20V) are used in parallel to get the maximum current of 300A, are used to energize the laser diode. Electricity is supplied through the P and N contacts of the laser chip located on the top of the chip as shown in the figure.

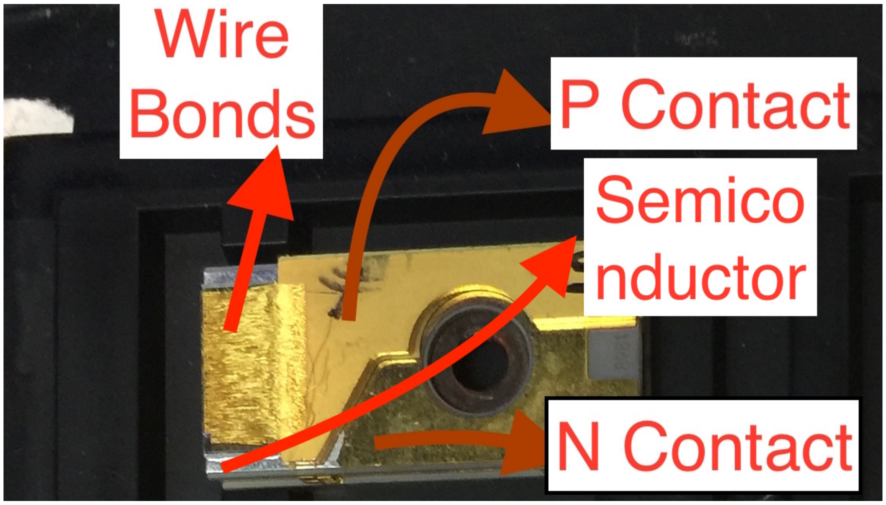

Figure 1.5: Front View of Laser diode.

Connection between the P-contact to the p side of semiconductor is made by thousands of gold wire bonds and the connection between the n side of semiconductor and N-contact is made with the solder metal. The MCC has two tiny holes with O-rings on the back that circulates water through it to cool the laser as shown below.

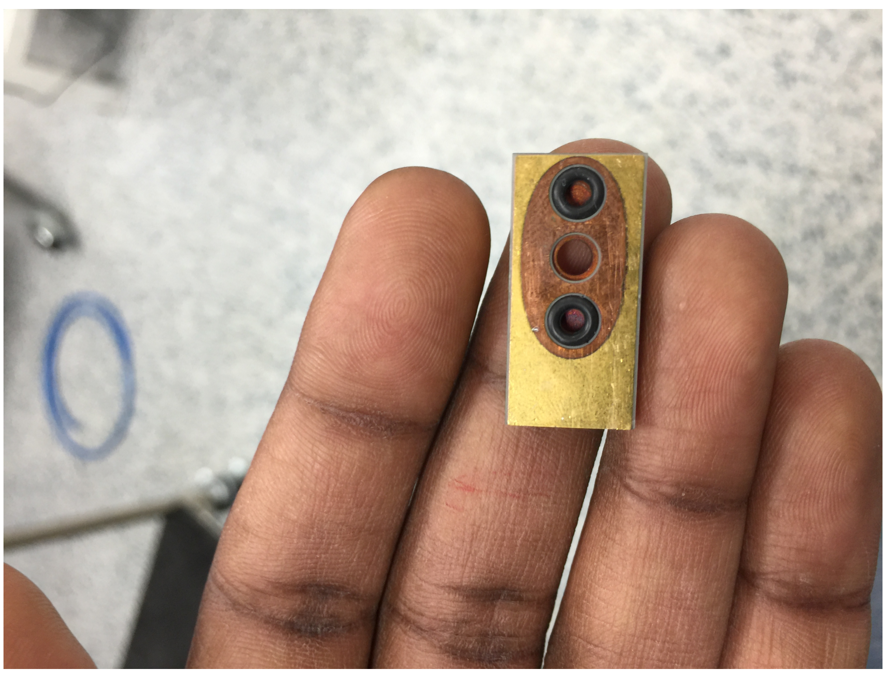

Figure 1.6: Rear View of Laser diode.

Water sent through this should be maintained at constant temperatures as the water gets heated up when the laser is ON. So, a water chiller named THERMORACK is used to pump water at a certain pressure and temperature, which is discussed in later sections.

1.5 Thermorack

ThermoRack is a 19-inch rack-mount thermoelectric recirculating liquid chiller manufactured by Solid State Cooling Systems, which provides precise, quiet and reliable temperature control for a wide variety of applications. It can pump up to 3.5 liters per minute (LPM) at a pressure of 30psig and temperatures ranging from 10 to 40 degrees. Chiller should be operated at 1.2lpm and temperatures ranging from 25 to 28 degrees based on the recipe chosen. The ThermoRack has digital PID controls for

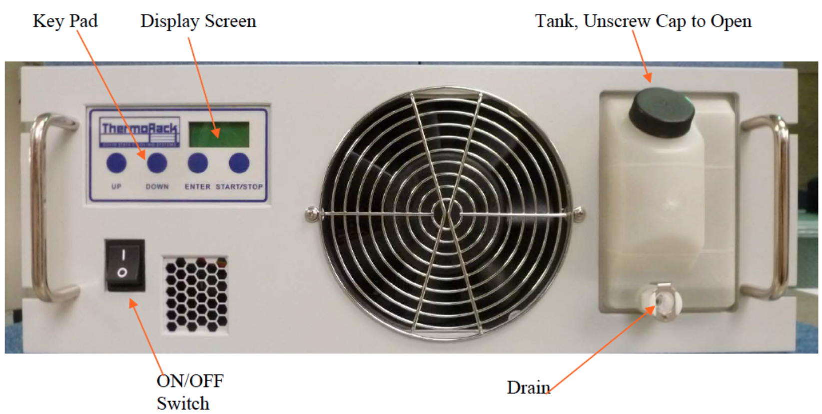

Figure 1.7: Front View of ThermoRack.

heating and cooling and has pumps that operate at 2lpm @ 15psig or 3lpm @30psig. It has a tank of 1-liter capacity and the water should be circulated back to chiller for continuous flow. ThermoRack can be communicated to PC through USB interface and can signal an alarm whenever the tank is low or any pump failure. This feature is used to prevent the laser diode from frying when tank is low or during a pump failure. Water is circulated from the ThermoRack to the laser diode and is circulated back to chiller through a combination of solenoid valves.

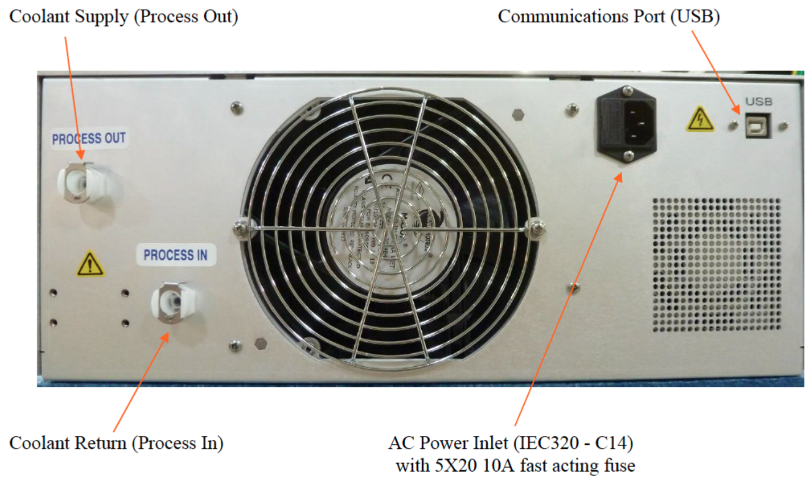

Figure 1.8: Rear View of ThermoRack.

1.6 Lumina Power Supply

The laser used in this automation requires a High Power Diode Laser Driver, which can give 300A dc supply. So, LDD-6000 manufactured by Lumina Power. INC. was chosen to drive the laser chip. LDD-6000 takes any 3Phase AC input from 200VAC to 480VAC, 50/60HZ. Upon applying the mains, the fans start and the safety relays of the power supply close after a delay of a few seconds if the power supply is healthy and ready to operate. The output inverter is a state-of-the-art zero voltage switching (ZVS) inverter, which permits very high frequency power conversion with minimum losses. The ZVS inverter is the most modern high frequency/low loss/low noise topology utilized in power electronics today.

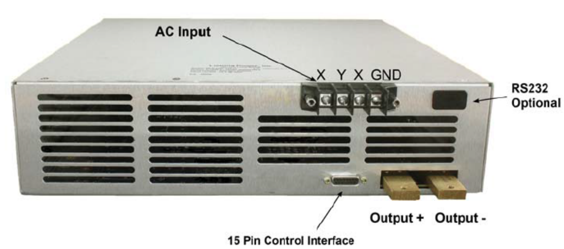

Figure 1.9: Rear View of LDD-6000

LDD-6000 also has a 15-pin D-sub Female interface that can be connected to PC and controlled by LabVIEW. The interface has Current control (Iprogram), Interlock, Ground, Current and voltage monitor, Pulse control and Enable pins. All these pins are controlled and connected to PC by using LabVIEW DAQ Chassis. Current and Voltage monitors are connected to the AI module and Enable, Iprogram are connected to the AO module and Pulse control and Interlock is connected to DO module of the DAQ chassis. The Interlock function can be connected to external interlock switches such as doors or over temparature switches. A thermal switch is gated internally to protect the power supply against over temperature . The Enable function turns the output section of the power supply ON and OFF. When the power supply is enabled, current is delivered to load as programmed via Iprogram. Rise times resulting from Enable are approximately 25msec. Applying a TTL 0 to Pulse Control may pulse OFF the output.Amplitude of the output current pulse is determined by the current level programmed. As a diode laser driver, the LDD-6000 power supply acts as a current source and delivers constant current based on the input program signal, Iprogram , which is normally 0-10V in which 0 is 0A and 10V is 300A.

1.7 Chuck

Chuck is a piece of aluminum block that seals electrical contacts and supply water to the laser diode.

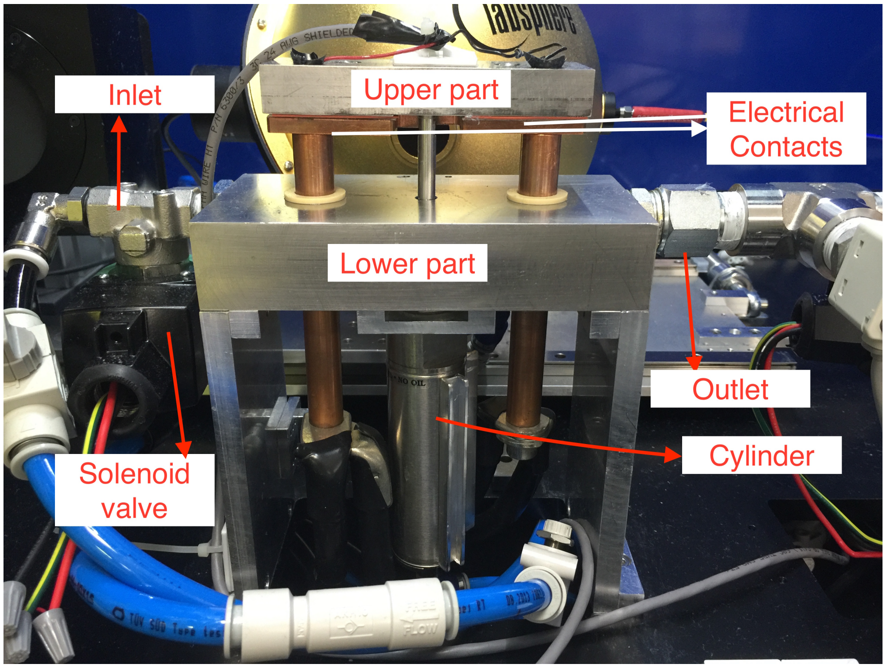

Figure 1.10: Layout of Chuck.

Inlet and Outlet water/air hoses are connected to lower part of the chuck to let the water/air in. The surface of lower part of the chuck has two tiny holes just like the MCC specified above.

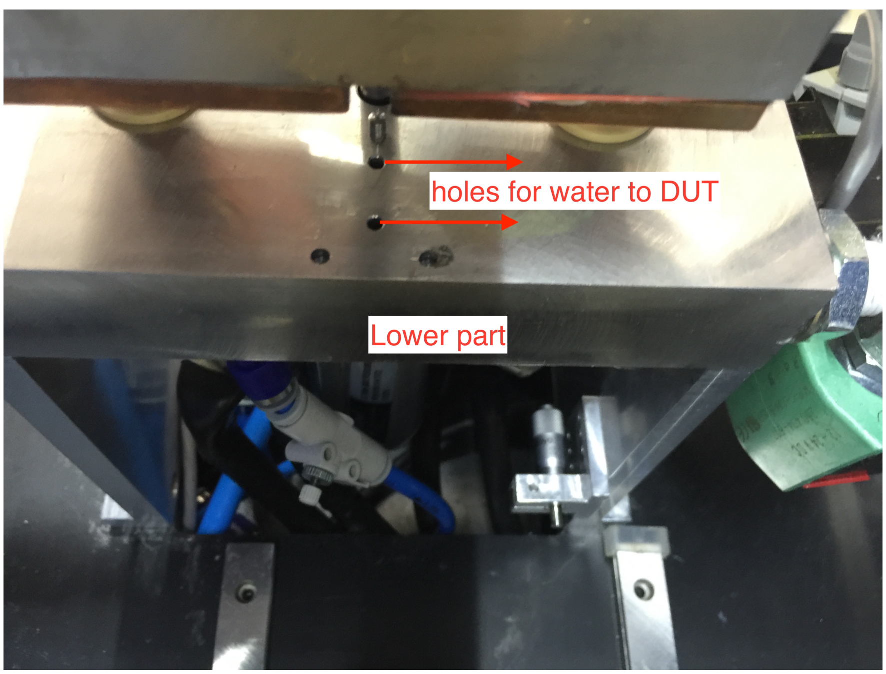

Figure 1.11: Surface of the chuck .

Laser diode is placed on the surface of the lower part of chuck such that the two tiny holes on the MCC and on the matches and are sealed by O-rings without any leak. Upper part of the chuck has electrical contacts that seal up with the p-n contacts of the laser diode with help of a cylinder controlled by Robot I/Os. Upper part of the chuck acts like a linear stage that goes up and down to create a gap for inserting a laser chip and supply electricity contacts by closing the contacts down. The linear stage is driven by pressurized air and controlled by the Robot.

1.8 Solenoid Valves

In this project, the DUT is regularly changed so there is a need to start and stop water flow from chiller and also completely eliminate water from DUT by purging (sending pressurized air to eliminate the water). Also there is a need to check for any leaks by sending air through DUT and record the air pressure by a pressure sensor. Therefore, Solenoid valves are used to switch between air and water, to start and stop the stream of water, to purge the water remains, to detect the leak and to bypass the water between DUT and chiller.

Three Normally closed 3-way solenoid valves are used in this project for the operations specified above. The solenoid valves have three ports and two orifices. When one orifice is open, the other is closed. The pressure of fluid in the valves must not exceed 35psig as the valves are rated not to operate over that pressure. The valve has 3 terminals, two for the 110V AC power supply and the other for control. The valves are controlled by USB relay, which is discussed in later sections.

Solenoid valve 1 switches water between chiller bypass circuit and DUT. As mentioned in previous sections that Chiller tank capacity is 1 liter, there is need of a bypass circuit for circulation of water through chiller output and input through solenoid valve. Valve 2 decides whether water or air should go through the DUT based on the operation. Valve 3 is used to block pressurized air on output side of DUT to do the leak checks. The schematic of the entire water circuit is shown here for clear understanding.

Figure 1.12: solenoid valve.

1.9 Testing Equipment

The main motive of this project is to automate the testing of the laser diode. Following tests should be conducted on each laser diode that is placed on the chuck.

- LIV -power , current and voltage curves
- Spectrum measurement
- Emitter count

In order to do the above tests special hardware is needed that can grab the raw data. A spectrometer is used for calculating the spectral power vs wavelength, a camera is used to count the number of emitters emitted by the laser and a photodiode is used to measure the power. In order to prevent all the testing equipment from burning due to high power laser, a Labsphere is placed in between the laser chip and the testing equipment to diffuse the illumination of laser. National Instruments DAQ chassis is used to record the Current and voltage at the laser chip for LIV measurements. An Integrating sphere manufactured by Labsphere was used to distribute light at all points. Light hitting the sides of the sphere is scattered in diffused way. Only light that has been diffused in the sphere hits the ports or detectors used for probing the light. Basically its like a diffuser, which preserves power but destroys spatial information.

Figure 1.13: Labsphere .

National Instruments DAQ chassis is used to record the Current and voltage at the laser chip for LIV measurements.

1.9.1 Spectrometer

Spectrometer named USB4000 manufactured by Ocean Optics was used in this project. The USB4000 Spectrometer connects to a computer via USB port or serial port. When connected to the USB port of a PC, USB4000 draws power from the host PC. LabVIEW drivers are provided by Ocean Optics such that spectral measurements are directly loaded into LabVIEW and integrated with other tests.

A reference and dark measurements (without laser) are stored to correct for instrument response variables. Light from the laser is transmitted through the optical fiber to

Figure 1.14: Ocean Optics Spectrometer .

the spectrometer. The spectrometer measures the amount of light and transforms the data collected into digital information. Here the integration time has to be specified to let the spectrometer collect light sample for a specific period of time. If the integration time is very high, the spectrum gets saturated and if it gets too low, the spectrum readings does not give exact value. So, the integration time for each currents allowed in through the laser chip are calculated based on a binary search algorithm, which is discussed in later sections. In the Spectral measurements, Centroid of the wavelength where the power is maximum and power in a specific band of wavelength is found out for other tests.

Chapter 2

Project Structure

2.1 Introduction

The main idea of the project was to automatically test a large quantity of laser diodes according to the given test conditions from the recipe. The following chapter explains about the Project Layout and procedure involved in testing the laser diode.

2.2 Project Layout

All the hardware discussed earlier with the Robot is enclosed in a closed chamber, which is, laser safe and has different brackets that holds the hardware.

Figure 2.1: enclosure for the setup

Apart from the robot, Labsphere, chuck, distance sensor and solenoid valves, and all the hardware are kept in the bottom sections of the enclosed chamber. The robot is mounted on the side of a big metal board called breadboard inside the enclosed chamber. The chuck where the DUT is placed for testing is placed in the center of the breadboard. The Labsphere attached with photodiode, camera are placed on the back of the chuck where in the laser emitted is pointed towards them. The chucks electrodes are connected to the output of the Lumina. A big aluminum plate with attached guide rails is placed in front of the Chuck for holding the trays and lids. This plate is divided into 7 different pallets as stated below and as shown in the figure.

- Input pallet
- Pass pallet
- Fail pallet
- Not Tested pallet
- Input lids pallet
- Spare lids pallet
- Spare trays pallet

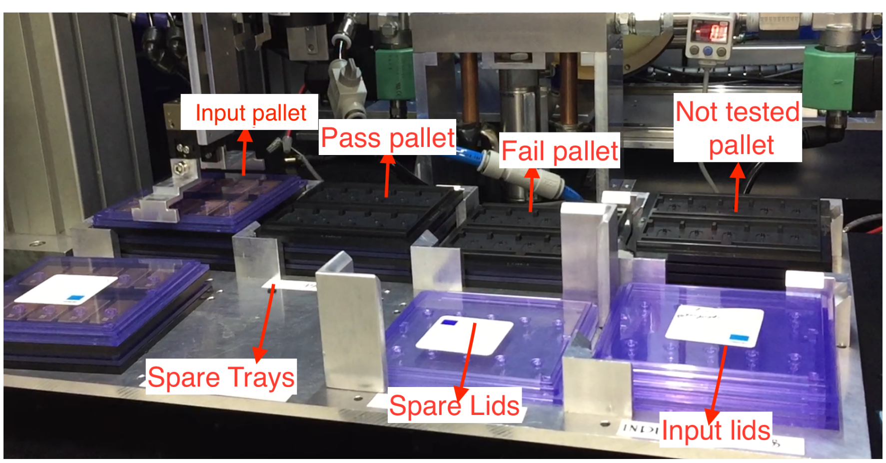

Figure 2.2: Tray plate with trays and lids

Each and every pallet is surrounded by guide rails made of aluminum to give support to the trays and lids so that the robots PUT can pick up the diode , tray or lid successfully.

Input pallet contains a number of trays stacked with laser diodes that are to be tested. Each tray has 10 laser diodes and is covered with a lid and the robot has to pick the lid first before picking the diode.

Pass, Fail and Not Tested pallets have an empty tray at the beginning of the test and are filled eventually with the laser diodes that are passed, failed and not tested respectively. A diode is marked as not tested when it fails the leak check or when any program interruption occurs during automation. Input lids pallet holds the lids picked by the robot from the Input pallet. This pallet is needed because the Input lids are marked with a Work Order (WO) number and the Pass pallet trays must be closed only with the marked lids. When the pass pallet tray is filled with the diodes, the robot picks a lid from the Input lids pallet and places it on the failed tray.

Spare lids pallet holds the spare lids that are used to close the filled trays in the Failed and Not Tested pallets. Spare trays pallet holds the empty trays, which are used to place a new tray on the Pass/Fail/Not-Tested pallets and also to remove an empty tray from the Input pallet when all the diodes are tested from it.

2.3 Robot PUT

The Robot is equipped with two Pick Up Tools, one to pick up the trays and lids and the other to pick up the laser diode from the tray. Each PUT is fixed on the 3rd arm of the Robot with the help of a linear stage that allows the PUT to move up and down.

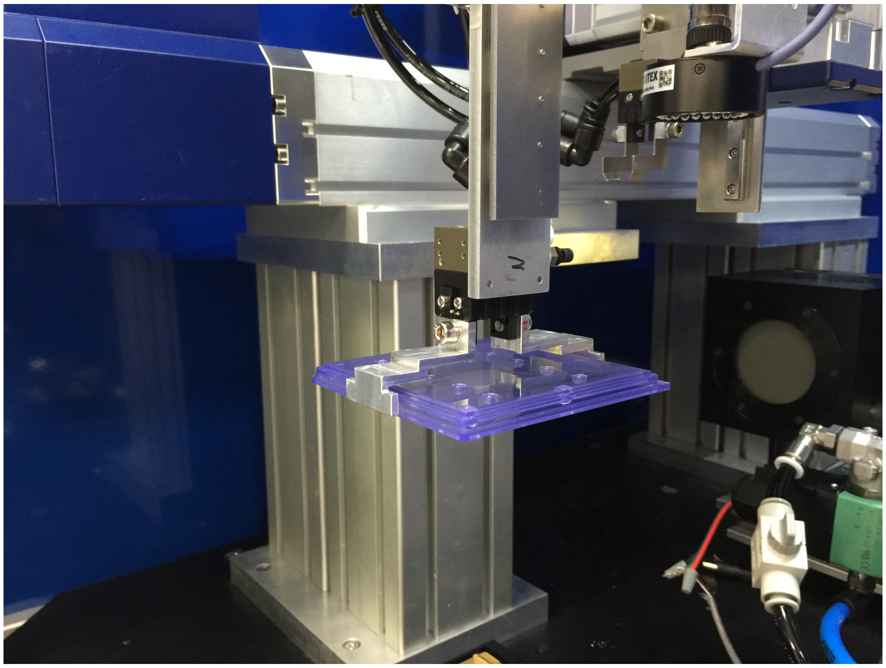

Figure 2.3: Lid/Tray Pick Up Tool

Pressurized air is used to drive the linear stage and fingers of the PUT. Solenoid valves are used as switches to control the flow of pressurized air to fingers and the linear stage and the valves are controlled by Robots I/O.

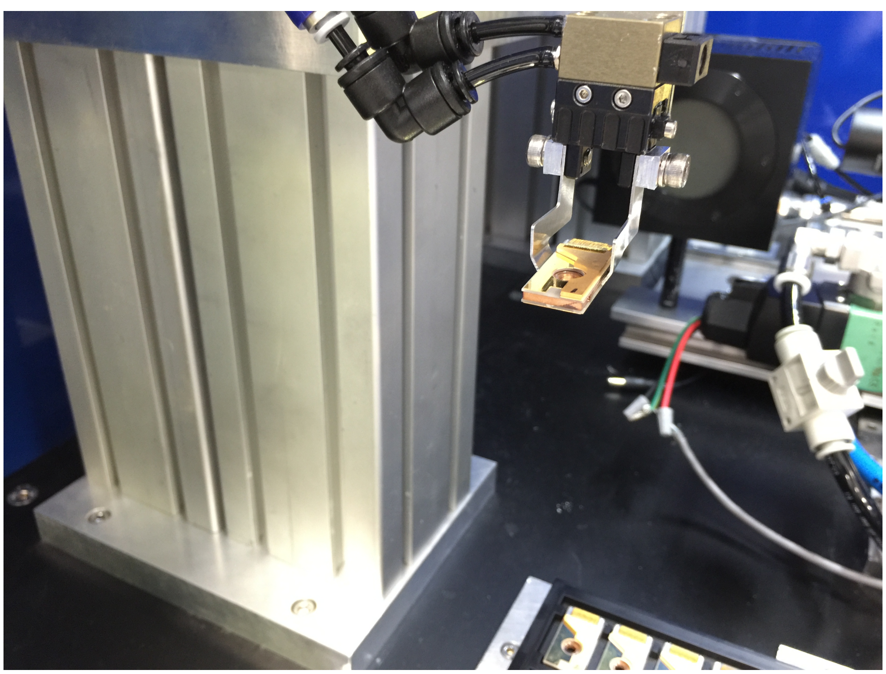

Figure 2.4: Diode Pick Up Tool

2.4 Test Procedure

The entire test procedure is divided into two phases

- Robot Phase
- Labview Phase

And the test procedure is alternated between these two phases.

2.4.1 Robot Phase

In Robot Phase, laser diode is picked up from the input pallet and is placed on the chuck for testing. Once the testing is done, it is again picked by the robot and placed it in the Pass/fail/not-tested pallets according to the results produced by LabVIEW phase

2.4.2 LabVIEW Phase

This phase deals with implementation of all tests needed to be conducted on the laser diode after it is placed on the chuck. This phase also deals with analyzing the results and uploading data to the database. Sorting the DUT that was tested into the pass/fail category is also done in this phase. The following tests are conducted in this phase.

- Leak check
- Spectrum measurement
- emitter count
- LIV -power , current and voltage curves

In this Phase LabVIEW is actively connected with all the hardware and sends or gets information from them for controlling, processing and analyzing.

2.4.2.1 Leak Check

Once the DUT is placed on the chuck, a leak check is conducted by passing pressurized air through the hoses and the pressure is recorded by the pressure sensor attached in between the chuck and the solenoid valve3. Pressurized air at 35psi is sent through the DUT for 5 seconds and the solenoid valve3 is close such that no air escapes through the hoses. Pressure sensor values are recorded by the DAQ and LabVIEW determines the leak when the recorded pressure is less than 33 psi. A signal is sent to the robot to pick up the DUT and place it in Not Tested pallet when it fails the leak check. Other tests are conducted only if the DUT passes the leak check by passing water through it. The reason for conducting this test is to not send water when there is a leak in the system preventing water getting leaked on to the test bed.

2.4.2.2 Spectrum Measurements

Spectrum measurements are taken to check wavelength of the power emitted and also to see if the diode is getting heated up. Diodes temperature directly affects the wavelength of the light emitted []. Laser light is sent from the Labsphere to the spectrometer through an optical fiber and spectral values are recorded in LabVIEW. The data is then analyzed and used as a factor in determining whether the diode has passed the test.

2.4.2.3 Emitter Count

As stated in previous chapter, a laser diode emits 23 emitters when it is energized. The diode must be sorted to fail pallet if there are any missing emitters. As an emitter has 10w of power and a missing emitter results in the reduction of overall performance of the laser diode. So, a camera is attached to the Labsphere with a couple of mirrors and lens in between the camera and lens to check the emitter count.

As the light falls on the camera, it takes a monochrome snapshot of the laser beam and feeds the raw data to LabVIEW. LabVIEW, using Image recognition algorithm checks for a missing emitter and fails the diode if there are any missing emitters.

2.4.2.4 LIV analysis

This test is conducted to check the power efficiency of the laser diode at different excitation currents. Light is collected by Photodiode attached to the Labsphere and is converted into power readings by means of the described power meter. Analog Output module of the DAQ is used to collect the voltage and current values from the power supply and the overall efficiency is calculated. LIV is calculated at currents in the increment of 10A till 300A. The algorithm written to conduct the above tests are discusses in the following chapters.

Chapter 3

Testing algorithms

3.1 Introduction

In any industry , to check the quality of any product, a series of tests must be conducted on the product to determine repeatability and accuracy of product. Laser diode used in this project is subjected to three tests which are specified in the previous chapters. And to perform any tests automatically, there must be an algorithm to perform all these tests. All the algorithms that are used in this project are briefly discussed in this chapter.

3.2 Literature Study

Laser diode needs an active cooling mechanism which involves the leak check and purging the remains of water. To do this, an algorithm for water management was built and implemented in LabVIEW and discussed in the later sections. Laser diode has a cooling channel and it is supposed to be water cooled at 1.2 liters per minute at 25 degrees C . As the project involves pick and place of a large number of diodes, a leak check is mandatory to determine the leaks in the system before supplying water and leak check is done by pressurized air. A pressure sensor to detect the pressure drop in the system, a flow sensor to determine the flow, a chiller to pump and cool the water, solenoid valves to control the water and air flow are used for water management. To check whether the diode is getting overheated, spectral power of laser diode is recorded by a spectrometer and analyzed by checking the shift of spectral power versus wavelength. The spectral power shifts on wavelength by 1nm per 0.3 degree centigrade rise of temperature. To do the spectrum analysis a spectrometer manufactured by Ocean

Optics is used and the data measured is transmitted to LabVIEW for analysis.

To test the efficiency of the laser diode used,laser must be fired at different currents and the data should be analyzed for efficiency.Current, voltage, power and efficiency of the diode are measured at different currents and the readings at the rated current are compared with the golden samples to check for power and voltage failures in the diode. This test is named as LIV test and it needs an algorithm to actively control the current supply and also the measuring devices. A National Instruments NIDAQ, a photodiode with a power meter are used to perform this test.

As explained in the previous chapters, each and every diode emits 23 emitters of 10 watts each, so a test is required to check if there are any dead emitters. This requires a camera to capture the laser image and an algorithm to process it.

3.3 Algorithms implemented

3.3.1 Water management algorithm

When the laser diode is placed on chuck, the diode O-rings are matched with holes of the chuck and clamp of the chuck applies pressure to seal the mechanical contact. It should be noted that the same clamp provides the electrical contact to P and N contacts of diode. Once the contact is sealed, pressurized air is sent through cooler of diode and pressure readings are taken on the outlet of the chuck. The switch from water to air and air to water is performed by Solenoid valves which are controlled by LabVIEW using programmable relays.

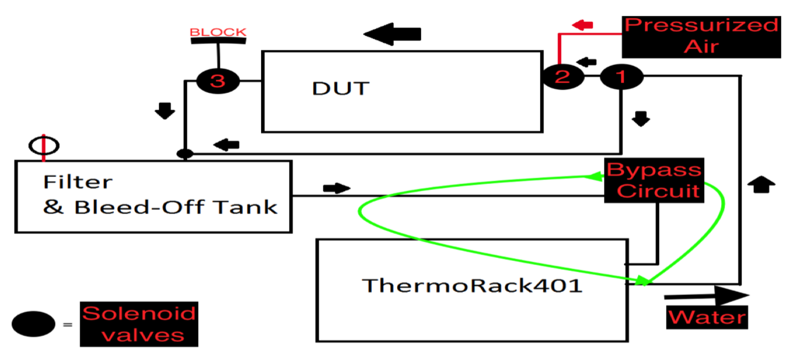

Figure 3.1: Figure showing the water Circuit with solenoid valves

Thermorack is the water chiller chosen and water in chiller is circulated from its it output to input during normal operations(when the system is idle). Water from chiller is bypassed to the chuck by solenoid valve 1 as shown in above figure. Solenoid valve2 sends pressurized air at 35 PSI for a period of 5seconds and valve 3 is closed to seal the air in between the valve 2 and 3 .Pressurized is turned off and pressure sensors readings are recorded by using the Data Acquisition of LabVIEW at 100k samples per second. If the pressure recorded in the pressure sensor is dropped below 33PSI, LabVIEW shows a pop up showing that there is leak. Water is turned on by the valve1 to the DUT if there are no leaks in the system.

When the tests are done, water is bypassed from DUT to the chiller by valve1 and pressurized air is turned on for 5 seconds to remove the water remains in the cooler.

3.3.2 Binary Search algorithm for Spectrum analysis

The spectrometer used in this project has an integration time that is to be set each and every time a spectrum is requested. Integration time is the length of time that the detector is allowed to collect photons before passing the accumulated charge to the A/D converter for processing. The minimum integration time is the shortest integration time the device supports and is dependent on how fast the detector can read out all of the pixel information. If the integration time is too long, the spectral power gets saturated and its hard to get the maximum spectral power readings and if the integration time is too less, the average noise will be greater than the average spectral power. So it is very important to set the exact integration time for every measurement made on the spectrometer. A binary search algorithm is used to find the exact integration time by starting the iteration at a predefined value. The algorithm for the entire spectrum measurements is shown in the flow chart below.

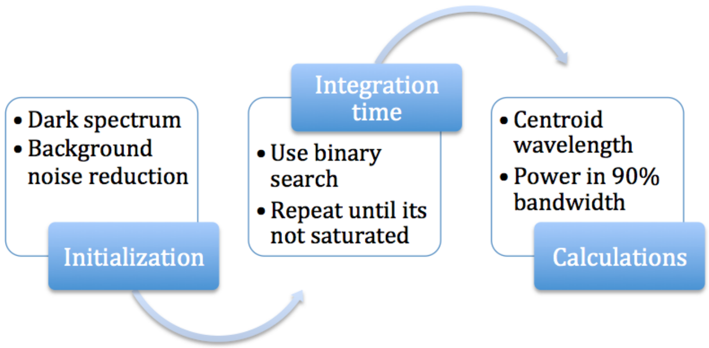

Figure 3.2: FlowChart of the Spectrum analysis

Every spectrometer has a background noise and to eliminate this noise from the actual spectral values, a dark spectrum is recorded before the start of the test and is subtracted from the actual spectral values. A dark spectrum is the set of counts versus wavelength values for a spectrometer at a given integration time when no light is present (either from the sample or from ambient environmental light sources).

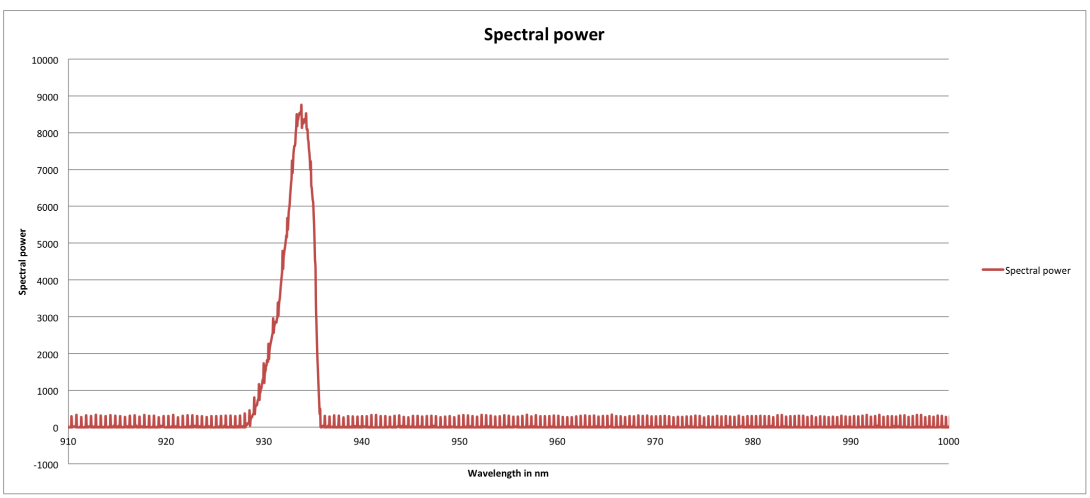

Figure 3.3: Spectral power vs wavelength

The above figure shows a good spectrum taken under a perfect integration time found by the binary search algorithm . The centroid wavelength of the graph shown above is calculated as 934 nm The data obtained from the spectrometer is processed in LabVIEW to find the Centroid wavelength (the wavelength to which the maximum spectral power corresponds to) and used in deciding the Pass/Fail criteria of the laser diode.

3.3.3 Algorithm used to do the LIV analysis

To check the efficiency of laser diode under test, voltage and power(light) readings are taken at different current settings. Voltage readings are obtained directly from the electrodes attached to chuck and given to the Analog input of the NIDAQ to measure the differential readings. Power of laser diode is measured by a photodetector attached to the LabSphere. Photodetector is nothing but a photodiode that detects the light and converts the light voltage readings and readings are multiplied by a calibration factor to get actual power of the laser diode. Current is increased on power supply by means of the NIDAQs Analog output module. Current on the power supply is set by applying a 0-10V on the current program terminal of the power supply.A 0V on NIDAQ refers to 0A on the power supply and if 10V on NIDAQ refers to 300A on the power supply. Power from the photodetector is measured by a power meter which is controlled by LabVIEW for successful synchronization of the data.

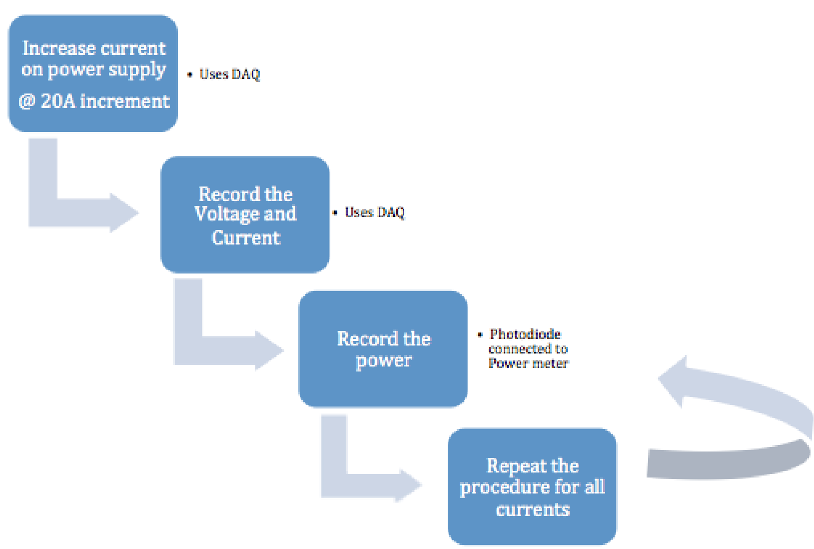

Figure 3.4: FlowChart of LIV analysis

The efficiency of the laser diode is calculated from the available readings and voltage and efficiency at rated current is compared with golden sample specifications for any defects in the diode. The data is automatically plotted and saved into the database at end of the test.

3.3.4 Image processing Algorithm to detect the emitter count

As discussed in the previous sections, the laser diode has 23 emitters of 10 watts each and checking the number of active emitters is one of the main objective of the project. To achieve this, a camera is installed at rear end of Integrating Sphere and laser beam is allowed to project on camera lens through the Sphere. Camera is controlled by LabVIEW and takes a snapshot of laser beam at a specified time. LabVIEW also changes the settings of camera like exposure time, intensity etc., to capture a perfect image for processing.

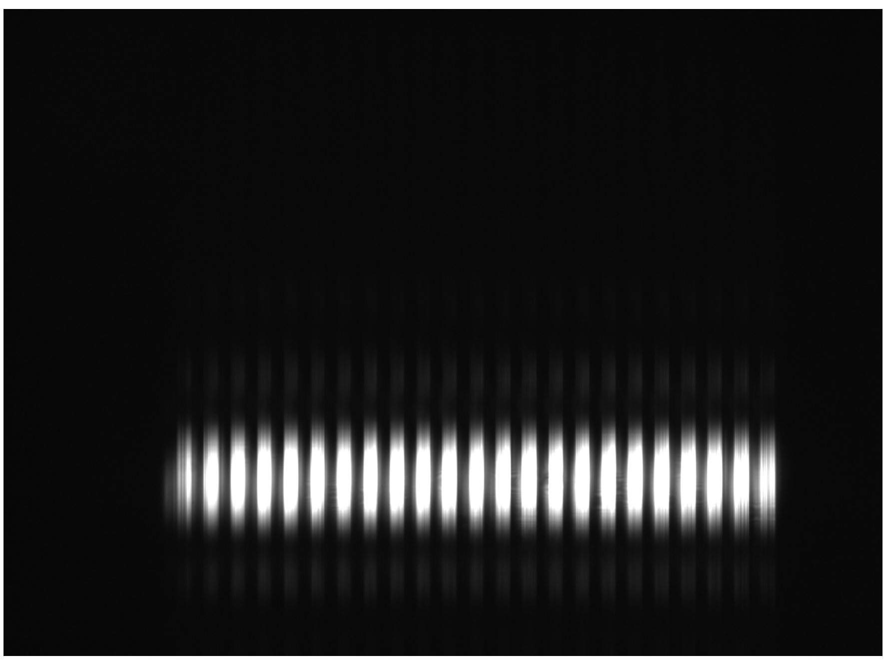

Figure 3.5: Image captured by the camera for emitter count

As shown in the below figure, raw data of image captured is close to a sine wave and a Fourier transform of a signal tells you what frequencies are present in your signal and in what proportions.

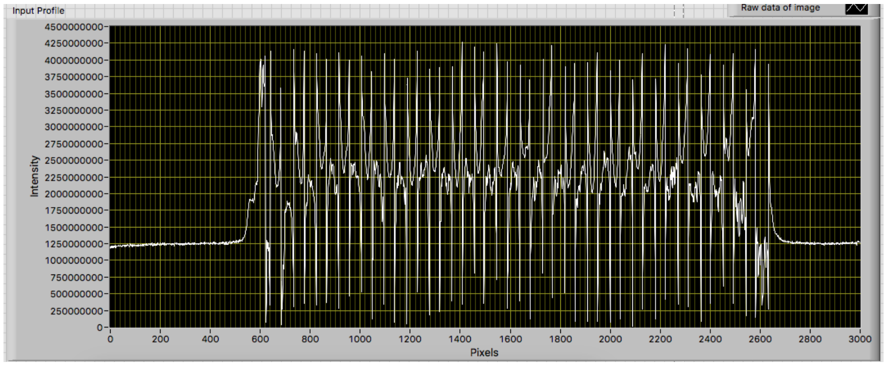

Figure 3.6: Raw Data of the Image Captured (Input Profile)

A Fast Fourier Transform is applied on the captured Image's raw data called Input Profile to determine the peak corresponding to each emitter pitch. Emitter pitch is defined as the width of each emitter on the x axis. The Fourier transform of input profile is shown here and first value of the Fourier transform so called DC term is very high and we neglect that . The DC term represents the average brightness of the entire image. As our Input profile just contains a dark and light lines, the Fourier transform represents a sinusoid and the magnitude corresponds to the contrast of the image.A Fourier transform encodes not just a single sinusoid, but a whole series of sinusoids through a range of spatial frequencies from zero (no modulation, which means the average brightness of the whole image) all the way up to the "Nyquist frequency", i.e. the highest spatial frequency that can be encoded in the digital image, which is related to the resolution, or size of the pixels (3000 in our case).

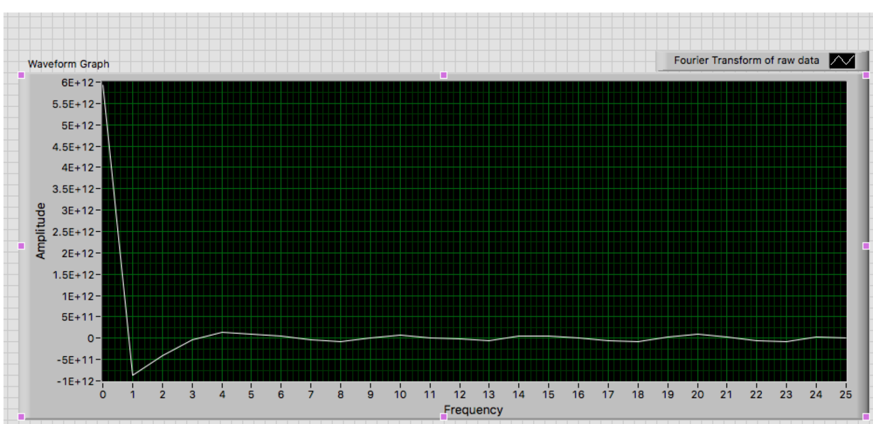

Figure 3.7: First few occurrences of Fast Fourier Transform

So the obtained Fourier transform is a series of sinusoids with the contrast of image at that point as the magnitude as shown in the figure. Hence the second peak of the transform must be the second brightest part on the image (2nd emitter) . From the second peaks corresponding frequency, we can find best pitch(width of an emitter) as follows.

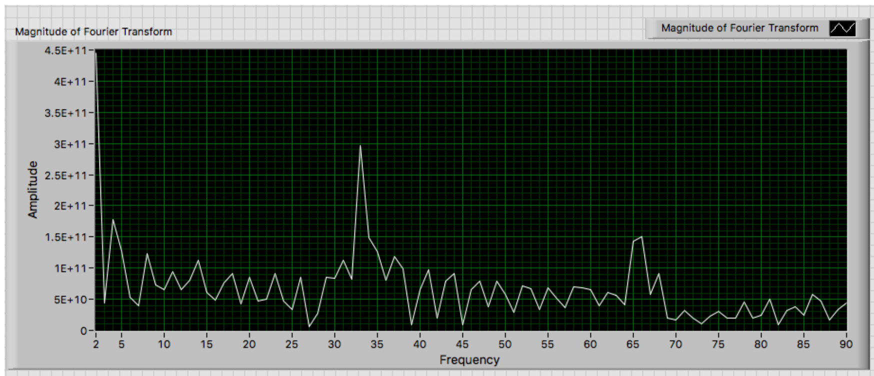

Figure 3.8: Magnitude of the first few occurrences of Fast Fourier Transform

$$BestPitch = InputProfileSize/thesecondpeakscorrespondingindexonXaxis$$

Where

Best Pitch = best width of an emitter on the X axis

Input Profile Size = size of the input array (should be equal to the X resolution of the camera)

Each and every emitter is followed by a dark light (no light), the best pitch gives width of each emitter with noise and entire Input profile is divided into tiny segments of Best pitch width . The summation of the intensity of light in these number of segments is calculated and normalized to 1 for all segments of Best pitch width. If the normalized intensity is greater than Recipe Specified value , it is counted as an active emitter and the total number of active emitters are calculated to determine whether diode has passed the test. The following figure shows the best fit (summation of intensities in each segment of Best pitch width) with a threshold line that determines the emitter count.

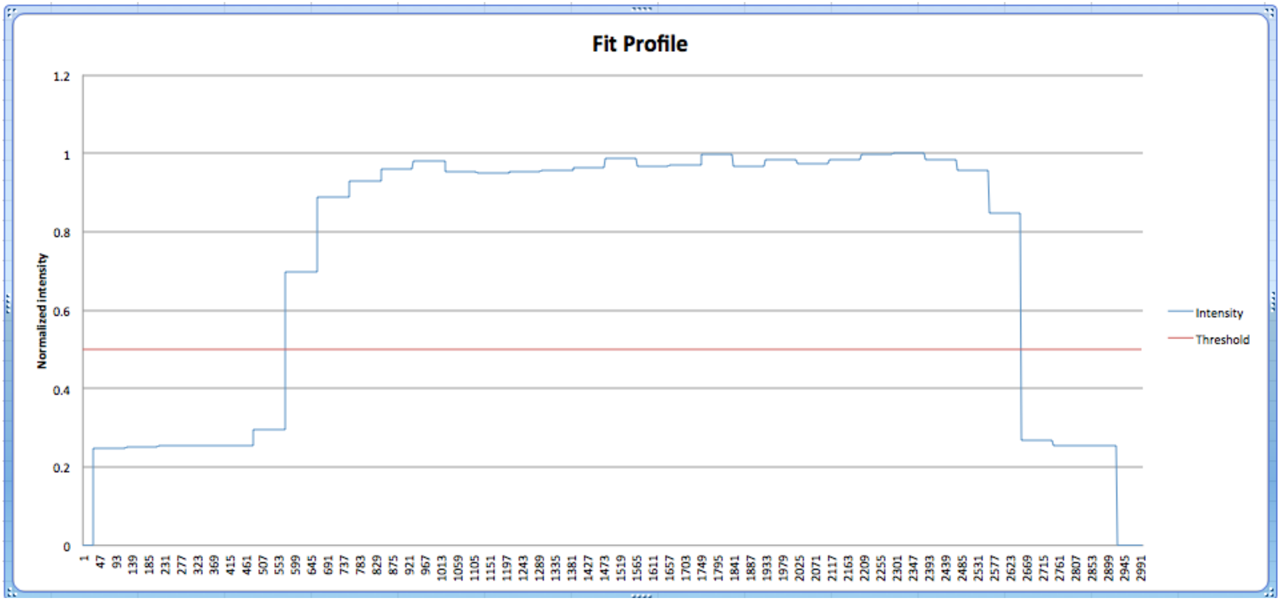

Figure 3.9: Best fit profile of the image captured

The flow chart for the above algorithm including LabVIEWs role is shown in the figure below.

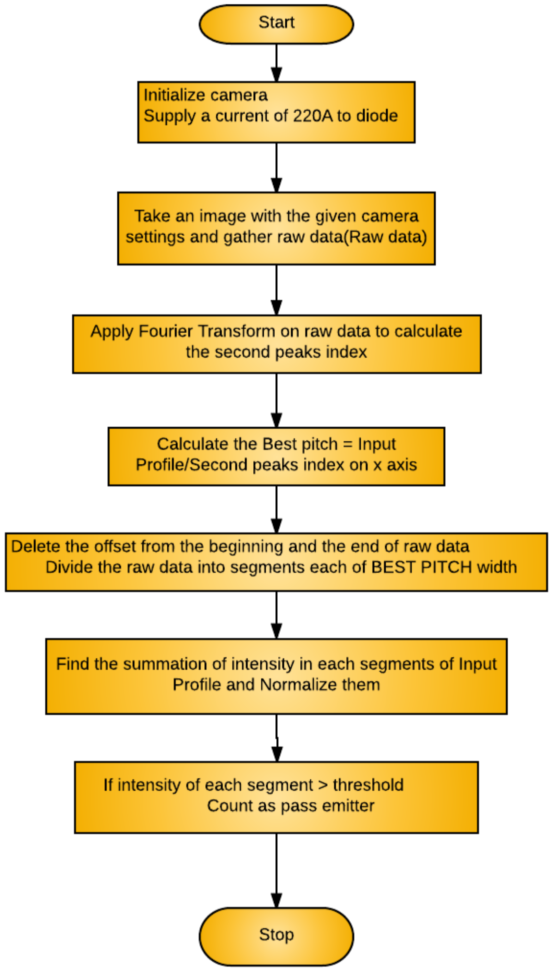

Figure 3.10: Flow chart of the Emitter Count Algorithm

As shown in the above flow chart, LabVIEW initializes the camera with the required settings from the Recipe file and then turns on the laser by supplying current from power supply using NIDAQ. Image is captured and raw pixel values are processed by above algorithm for emitter count. Laser is turned off as soon as the image is captured and the image in jpeg format and best fit profile in csv format are saved in the database for further analysis.

Chapter 4

Communication between LabVIEW and Adept Robot

4.1 Introduction

The communication between LabVIEW and the Robot forms the bases of automation.Following chapter talks about the problems faced in establishing communication and discusses about the proposed solution.

4.2 Literature Study

Robot used in this project is controlled by a smart controller and a number of program modules and control sequences are written in the GUI of the Smart controller.The smart controller can access all the I/O's of the robot and also regulate the speed of the robot.The controller has different task managers and can perform 20 different tasks in a sequence. But,for a fully automated system a single control software is required and a need to control the robot by LabVIEW is mandatory.

The main advantage of a single control platform is that all the hardware used are controlled at a single unit. This project uses LabVIEW as the main automation interface and a method to control the robot controller using LabVIEW is proposed.

In the past, a basic TCP/IP connection was established between the controller and Robot for successful communication but that results in longer delays as there was too much information shared between LabVIEW and Robot. The position of the Robot must be reported to LabVIEW at frequent intervals and individual commands were sent over TCP/IP to control the robot. Commands are sent as numbers from LabVIEW and are decoded into a specific operation on the Robot controller and thus only a limited number of commands were possible to execute. For example, 1 in LabVIEW refers to

"Move robot in X" and 2 refers to "move robot in Y" and so on.

A Dynamic-link library is Microsoft's implementation of the shared library concept in the Microsoft Windows and OS/2 operating systems. These libraries usually have the file extension DLL, OCX (for libraries containing ActiveX controls), or DRV (for legacy system drivers). The file format for the DLLs are same as the Executable files like EXEs and contains code, data and resources. These DLLs can be created in programming languages like C,C++,python,LabVIEW and can be shared to all the programming languages that support DLLs. The code written in a DLL cannot be changed by other users unless the source code is available.

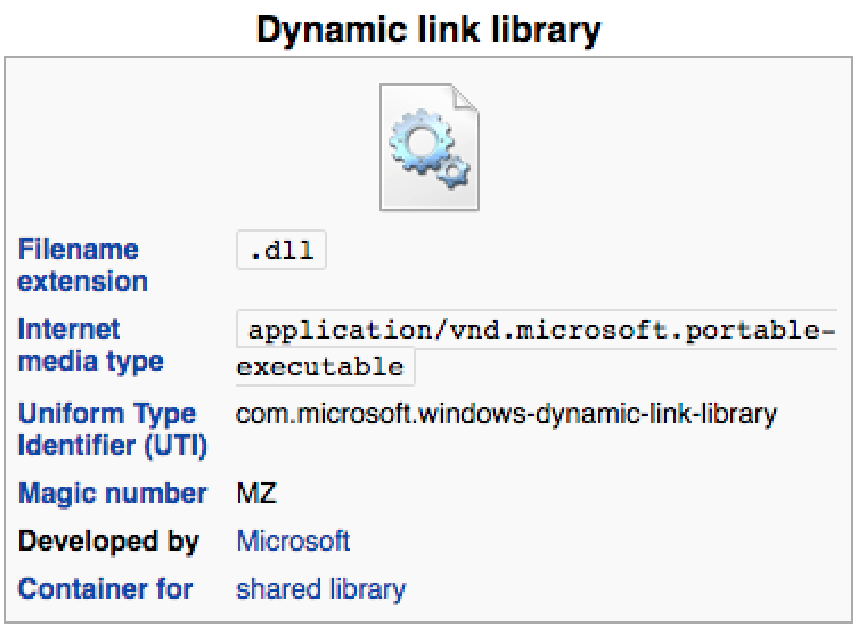

Figure 4.1: Dynamic-link library

These DLLs are called in LabVIEW by a .NET constructor node on the block diagram of the VI.When a node is placed on the block diagram, a menu will be presented , by default it shows you DLLs that LabVIEW is already aware of. The required DLL is saved to the LabVIEWs Project such that it will be shown in the known DLLs. By using the Property and Invoke nodes of the .NET constructor all the methods and functions of the DLL can be accessed.

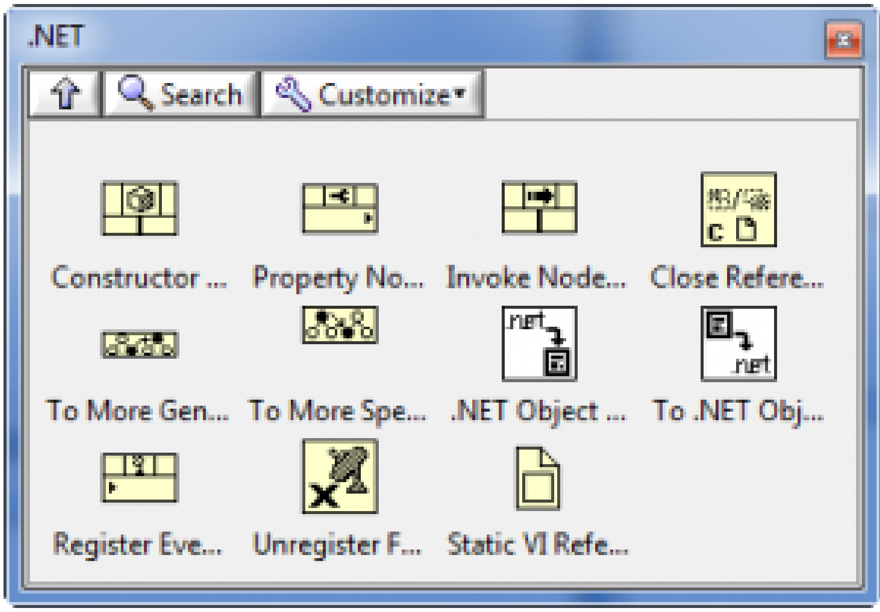

Figure 4.2: .NET constructor and property nodes in LabVIEW

For example we have created a DLL named MyMath with functions MyCos in C-Sharp and this DLL is used in LabVIEW as shown below.

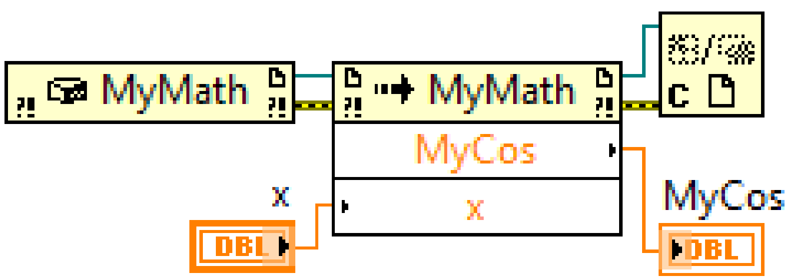

Figure 4.3: LabVIEW calling DLLs

MyMath is the constructor chosen from the list of available DLLs and the MyCos is function chosen by using the invoke node of the .NET constructor . At the end of the program the DLL constructor must be closed by using the close reference block. This closes the reference to the specified class and frees it from the memory.

4.3 Construction of a dll for LabVIEW

To overcome the problems of communication delay and gain the full access of the robot, a new solution was proposed and is discussed here. The robot manufacturer "Adept-Omron Industries" had given a set of drivers written in C to control the robot from Visual basic. The DLLs given by Adept cannot be used in LabVIEW as they were not .NET shared libraries. So the idea was to write a program in C-sharp that can establish the communication with the robot using the shared libraries of Adept.

Adept robot has a smart controller and all the control mechanism occurs through this controller. A connection is established by using RemotUtilityConnection (a function provided by Adept) with the localhost of the computer over a remote port. A command is called to search for the controllers present in the system and the connection is established with the controller found. This entire code is written within a method and if this method is called anywhere in any other software, the connection to the controller will be established.

This code is converted to a shared DLL and it is transferred to the LabVIEWs project folder.

In LabVIEW, DLL is called as a constructor node and the method AdeptConnect is called with port-name, Port-remote and port-callback as input parameter as shown below. A port is always associated with an IP address of a host and the protocol type of the communication, and thus completes the destination or origination address of a communication session. A port is identified for each address and protocol by a 16-bit number, commonly known as the port number.As port number is a 16-bit unsigned integer, thus it ranges from 0 to 65535. As two different ports are used to send and receive, the communication is very fast.

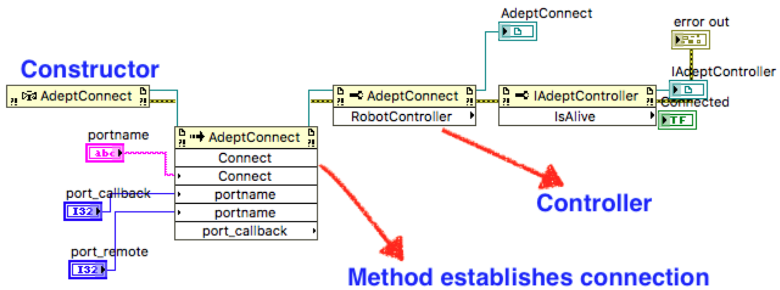

Figure 4.4: LabVIEW establishing a connection with Robot

The controller has a numerous inbuilt functions and methods that can be called in sequence according to the projects need. The functions used in this project are Execute a module, Power on/off Robot, Robot Co-ordinates, Robot IOs and some other .The following figure shows the usage of one such function.

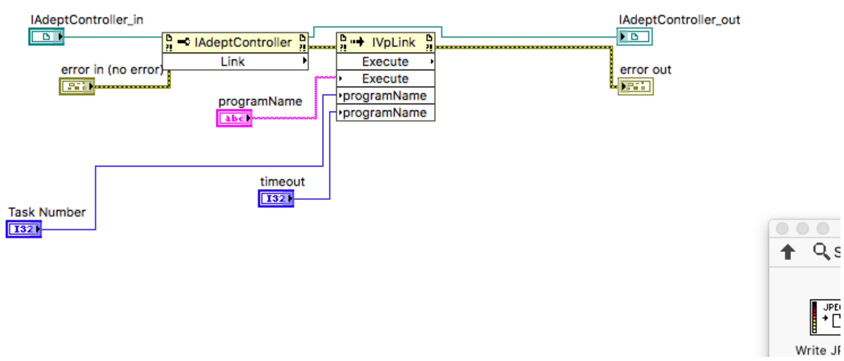

Figure 4.5: Executing a module on robot from LabVIEW

The parameters of the Execute module are program name, task number and timeout. Program name is the name of the module that is to be executed on the Task number x(1-20) and timeout is the amount of time waited to see whether the command is executed.

Separated methods like disconnect the controller from robot are also written in C-sharp using the functions provided by Adept .

4.4 Result

The method proposed in this chapter is very fast as it uses two different ports to send and receive data and very reliable as the connection is Transmission Control Protocol. As individual sub VI's are created with different methods and function in them, controlling the robot was convenient and faster. Robots speed is also monitored and controlled thus making the robot change speeds when precise movements are needed.

Chapter 5

Control Algorithm of the Robot and LabVIEW programming

5.1 Introduction

To control any hardware through an interface, programming is required. A numerous number of hardwares like sensors and measurement diodes are used in this project and all of them need to be controlled and synchronized by a single interface. LabVIEW is the main interface that controls all the hardware including the robot. A number of sub-programs called SubVIs are written in LabVIEW and grouped together to a Main VI. The Robot code is written in its own interface and there was a need to control the robot from LabVIEW for successful automation.

5.2 LabVIEW programming

The Main VI in LabVIEW has three multithreaded loops that perform different functions that are explained below. The first multi-thread loop continuously records all the data from the hardware and sensors and saves them to global variables. These variables are further called in the other threads for retrieving data synchronously. This loop also triggers the alarms and shuts down the entire process if there are any errors in the hardware. The second loop handles the communication between LabVIEW and Robot Controller. It initializes the communication to the Robot and gets access to all the modules available in the Adept Ace workspace. These modules are later on used in the third multi threaded loop. The third loop is the heart of the program wherein all the automation process takes place. It has a State-machine, an action listener, a number of for and while loops, if and switch case structures and SubVIs with algorithms to conduct the tests. The action listener will respond to any button change on the Front panel.

The algorithm used in LabVIEW is described below followed by the flowchart.

Step1 - Initialize all the hardware like sensors, actuators, DAQ, solenoid valves and relays. This happens outside of the multithreaded loops

Step2 - Check whether Robot is Alive (the communication is established between LabVIEW and Robot Controller)

Step3 - Call the Robots Pick and place command

Step4 - Execute the leak check. Solenoid valves connected to USB relay, pressure sensor connected to DAQ are used to perform this operation.

Step4 - If there is a leak then go to step9. If there is no leak, turn on the water flow.USB relay switches the solenoid valves to send water through the DUT.

Step5 - Conduct the LIV test. This is achieved by energizing the DUT with the help of Lumina power supply control. DAQ, Lumina Power supply, Photo diode and Power meter are used. A SubVI is created to calculate the Current steps and record all the data from DAQ

Step6 - Take the Spectrum at different excitation currents. Spectrometer, Lumina Power supply are used in this step. A SubVI is written to record dark spectrum and subtract it from the actual spectrum and another SubVI is written to calculate the Centroid wavelength.

Step7 - Calculate the number of emitters with the help of the camera. An algorithm is implemented to calculate the number of emitters emitted by the DUT. A copy of the image is saved as JPEG in the network folder for further use.

Step8 - Send all data to the Database and plot the results, process the data and save them on the network drive.

Step9 - Call the Robots module ,Pick tested (pallet number), to pick the DUT from chuck and place on the pass/fail pallets/not tested pallet based on the argument, pallet number generated by LabVIEW.

Step 10 - Continue the above steps until all the Input parts are tested and the program is stopped when all the parts are tested.

5.3 Adept Ace Programming

A number of modules are written in Adept Ace to do the pick and place operation of robot. Pallet number and position are parameters for most of the modules. We have 7 pallets on the tray plate and pallet number is decided by robot based on the operation it is implementing. Three parameters are needed for the robot to go to a specific location named X, Y, Z locations as the robot is a 3axis robot. Distance sensor mounted on the robot determines the Z parameter. The robot is made to move in Z-axis on a specified pallet until the distance sensor triggers the I/O of the robot. When the I/O goes on, the robot stops it movement and LabVIEW takes the measurement of the distance sensor. The measured value is added by a predefined offset determining the Z parameter of any pallet. X and Y are fixed parameters for any tray or lid in the tray plate. Tray plate has fixed dimensions and if the robot detects one point on the tray plate, all pallet locations will be found automatically. As the tray contains 10 slots (2 by5) for diodes, the x and y parameters of the location to pick a diode should be calculated at every pick and place operation. The tray slot dimensions are fixed (44.6mm by 26mm) and by a fixed offset of X and Y, the 10 positions for the diode on a specific tray could be found, as trays location is known. For example, location of the nth chip on the pallet m is found in the following way.

Tray m location on the tray with respect to robot = xm,ym,zm

Then the diode position is

(xm+(mod(n/2)44.6) ,ym+(mod(n/5)26),zm)

The location to place the diode on chuck is fixed and it need not to be updated eveytime. A safe location is defined for the robot and robot goes to safe location in between its operations for safety purposes.

There are variables in Adept that gets updated with the program execution and some of them are listed here.

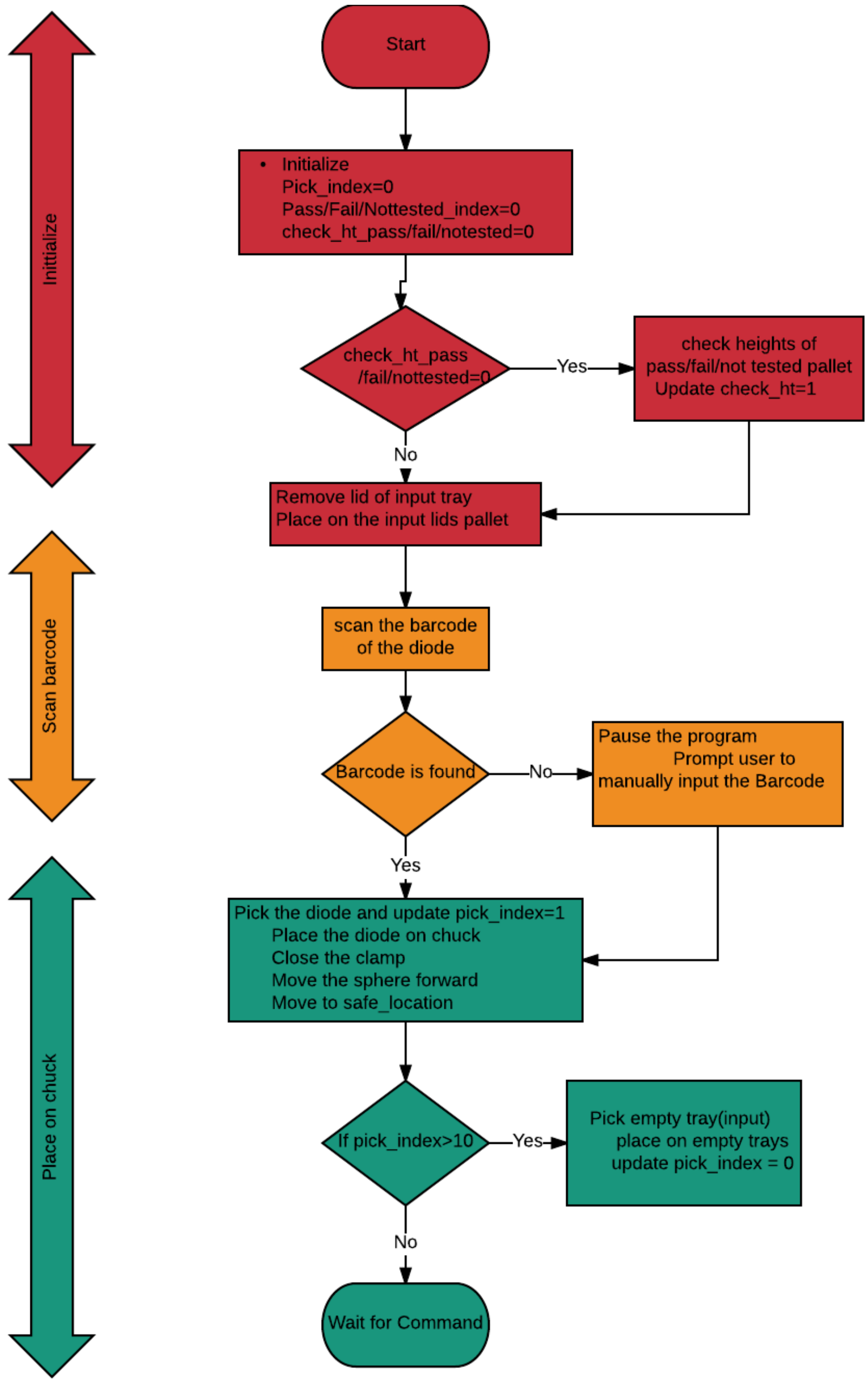

Figure 5.1: FlowChart of the programming in the Robot

Input-Index- Holds the value of the nth diode of the input tray and it is initialized to zero when the robot tests 10 diodes of the current tray. When this variable is zero, the controller asks the robot to pick the empty tray followed by lid from the input tray and place in the empty trays and input trays respectively.

Pass-Count - This variable holds the value of the number of diode placed in the current tray of the pass pallet and is initialized to zero when the robot places 10 diodes in the current tray. When this variable is zero, the controller asks the robot to pick a lid from Input lids and place on the pass pallet and is followed by placing an empty tray picked from Spare tray.

Fail-Count and Not-testedcount - These are similar to the pass-count variable where in the placing happens in the fail and not tested trays.

The modules written on Adept Ace are described below.

rob.init()

Parameters: None

Description: Initializes variables and robot control.

rob.move.safe(current-loc)

Parameters:

Current-loc : String

Description: Moves robot to safe position. If an empty string is passed in the robot will go to the safe location. Otherwise the robot will move to specified location passed in as long as there is a corresponding case provided for it.

rob.pick.init()

Parameters: None

Description: Initializes diode pallet parameters such as the number of slots and their individual dimensions / offsets. It also initializes the Input-Index variable to zero.

rob.pick(Input-index)

Parameters:

Input-Index : Real value used to determine where to place diode on pallet

Description: Picks up diode from diode pallet stack. The input-index value passed in will determine whether the robot will go to a specified index or an automated one. The index value of -1 represents automating the diode pick up routine, and the real values 1-10 represent going to the pallet index values.

rob.place.init()

Parameters: None

Description: Initializes pass, not tested and fail pallet parameters such as the amount of slots and their individual dimensions / offsets. It also initializes the pass-count, not-testedcount and fail-count variables to zero.

rob.place(test-result, index)

Parameters:

test-result : String containing pallet destination based on diode test results

Index : Real value used to determine where to place diode on pallet

Description: Places diode on either a pass or fail or not-tested pallet stack, determined by test results previously acquired. The String test-result can either be pallet2, or pallet3 or pallet4, where pallet 2 represents the pass pallet and pallet3, represents the fail pallet and pallet4 represents the not-tested pallet. The Real value index determines whether the placing process is going to be automated or not. If the index value is -1 then the process is to be automated and the index will increment based on the last automated value, otherwise the diode will be placed at the specified index (1 - 10).

rob.placelid (pallet-number)

Parameters:

Pallet-Number : Real value

Description: Moves to lid stack, picks up a lid, and proceeds to place that lid on a stack specified by the real valued parameter pallet-number.

rob.removelid(pallet-number)

Parameters:

Pallet Number : Real value

Description: Moves to pallet stack specified by the real valued parameter, picks up lid from current pallet on stack, and then moves to and places it on the lid stack.

rob.scan ()

Parameters: None

Description: Moves to the scanning station from the diode pallet pickup location scan the id of the diode to be tested.

rob.checkheight(pallet-number)

Parameters:

Pallet Number : Real value

Description: Checks the height of the specified pallet number by using the distance sensor. If nothing is passed as parameter, the robot checks the height of all the pallets and saves them in their respective location variables

rob.placediodechuck()

Parameters: None

Description: The robot places the picked up DUT on the test chuck wherein the location of the chuck is predefined

rob.updatetrays()

Parameters : None

Description : This module updates manages all the empty trays and lids based on the variables value discussed above. For example, if not-testedcount is equal to zero then the robot picks a lid from spare lids and place on the pass pallet and is followed by placing an empty tray picked up from Spare tray.

rob.pick.tested()

Parameters: None

Description: The robot picks up the tested DUT from the chuck with this command

rob.test()

Parameters: None

Description: A series of modules are called in this module in the following sequence . This is used to pick and place the laser diode on chuck. The sequence of modules are shown below.

rob.checkheight()

rob.updatetrays()

rob. Scan()

rob.pick()

rob.placedidoechuck()

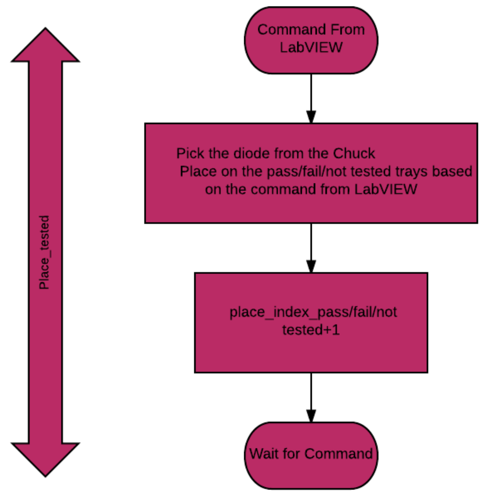

Figure 5.2: Sorting the diodes flowchart

rob.placetested()

Parameters : None

Description : A series of modules are executed for successful sorting of the tested laser diode. The modules executed are as follows:

rob.picktested()

rob.place(test-result)

rob.updatetrays()

Chapter 6

Results

The results of all individual tests and also end result are shown and explained below. Reliability and repeatability of the testing algorithms are also discussed below. When all the tests on a diode are finished, a summary file with Summary-date-times.csv as the name is created and data of all diodes gets updated into this summary file for further analysis.

	A	B	C	D	E	F	G	H	I	J	K
1	2023559_PreBI			Recipe							
2	Upper Limit	N/A	999	2	941	N/A	N/A	12	N/A	30	
3	Lower Limit	N/A	261	0	0	22	25	N/A	0.9	28	
4	ID	EOL Current	Power @ EOL	Volatge @ EOL	Centroid Wa	NF Emitter C	Minimum Leak Check PSI	Maximum Pressure I	Flow Rate	Water Temp	Pass/Fail
5	10031359	300	267.4686536	1.907566219	937.959318	23	28.85877665	6.231095208	1.13235329	29	Pass
6	10030970	300	260.896389	1.931624877	939.986987	23	28.71703747	6.89956401	1.12577253	29	Fail
7	10030978	300	262.5501737	1.934318682	939.671055	23	28.87749344	6.796039386	1.10412799	29	Fail
8	10030971	300	262.2741151	1.935060206	939.32409	23	28.95315491	6.756776207	1.04762597	29	Pass
9	10031357	300	268.3700135	1.916787009	938.523094	23	28.8776781	6.720182627	1.0953365	29	Pass
10	10030972	300	266.8101723	1.924367203	937.637418	23	28.84036362	6.702896436	1.14962779	29	Pass
11	10031356	300	266.8052456	1.94638458	938.469305	23	28.79071398	6.344824733	1.15034756	29	Pass
12	10030973	300	267.1939822	1.920797143	937.079111	23	28.70340826	6.532336429	1.16320061	29	Pass
13	10029138	300	266.7731498	1.925370119	937.380624	23	28.85628264	6.628171916	1.10022066	29	Pass
14	10030977	300	263.6817047	1.944831734	937.879293	23	28.88754523	6.393416066	1.16556558	29	Fail
15	10032575	300	242.9245651	1.926430738	938.268453	21	28.85149778	6.53543807	1.08906421	29	Fail
16	10031343	300	267.1948431	1.915321851	937.99601	23	28.91885457	6.551962715	1.0439757	29	Pass
17	10032576	300	267.4286336	1.920649905	938.853051	23	28.78102245	6.533973921	1.057857	29	Pass
18	10032574	300	266.2875839	1.922314167	936.823856	23	28.56232121	6.568993331	1.06634001	29	Pass
19	10032577	300	258.6878085	1.910976961	939.482479	22	28.78758533	6.405833793	1.180835	29	Fail
20	10032573	300	265.8145341	1.852238697	937.09824	23	28.74873396	6.537345404	1.06947616	29	Pass
21	10032578	300	268.2573515	1.941175188	938.055378	23	28.80164042	6.635156613	1.15132439	29	Pass
22	10032572	300	266.8807894	1.867492652	937.229221	23	28.56666719	6.984047808	1.04279322	29	Pass
23	10032579	300	254.1737862	1.884889435	937.763037	22	28.81697099	6.864867895	1.02366788	29	Fail

Figure 6.1: Summary of the diodes tested

Figure shows the summary of diodes tested and it includes calculations obtained from different tests along with Upper and Lower limits to decide the Pass/Fail criteria.

Summary files, log files and all raw data of different tests are saved in an automatically created folder on the network drive. The whole automation sequence is tested everyday on reference diodes called Golden samples and the data is analyzed for repeatability of the machine.

6.1 LIV result

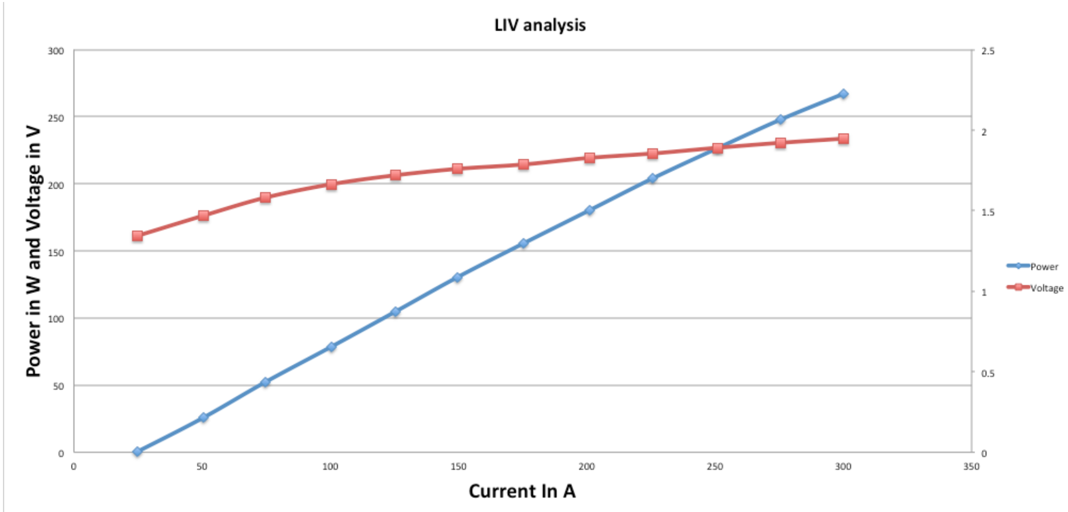

Figure 6.2: Figure showing the graph obtained from LIV test

Above figure shows graph plotted from LIV test . On primary axis , Optical power measured form photodiode multiplied by a calibration factor is plotted and the secondary shows voltage measured across the Diode via DAQ. Efficiency of test is calculated and data is projected to calculate efficiency at End of Life current (I-EOL). The lower limit on the efficiency decides whether the diode has passed the test.

6.2 Spectrum Measurements

The following figure shows graph plotted from the data obtained from Spectral measurements. Spectral intensity on Y axis is plotted against the wavelength on X axis .

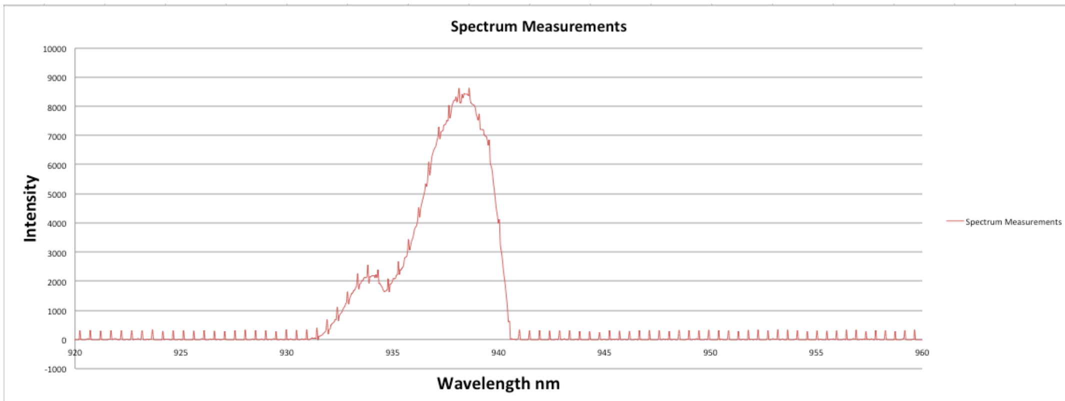

Figure 6.3: Spectrum measurements

The maximum intensity's corresponding wavelength called centroid wavelength is calculated and checked whether it stays in a certain limit . If the centroid wavelength is beyond the Upper limit specification, diode is getting heated due to some reason and the diode fails the test.

6.3 Emitter Count result

The input profile of the image taken by the camera, the best fit calculated by the image processing algorithm discussed in the previous sections along with the threshold are shown in the figure below.

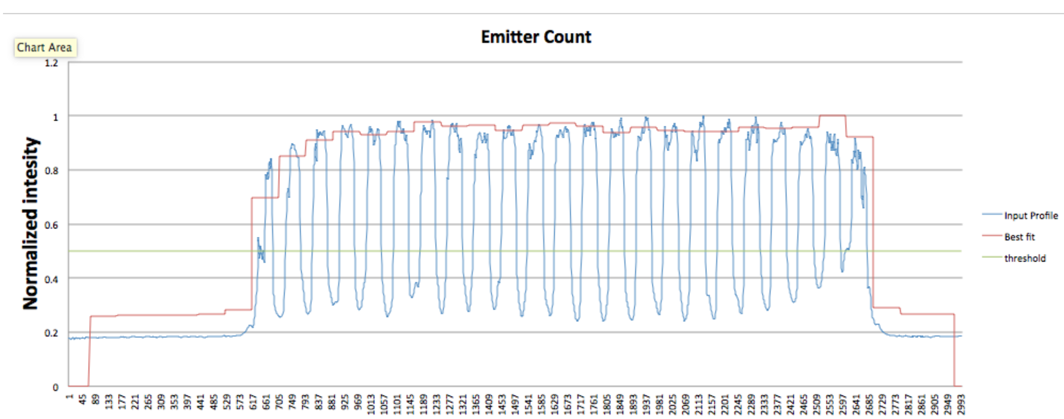

Figure 6.4: Figure showing the Emitter count calculations

If the emitter count obtained from the algorithm is less than the lower limit specification , the diode is failed and sorted into the failed pallet by the robot.

6.4 Performance graphs

The following results shows the repeatability of all the tests conducted.

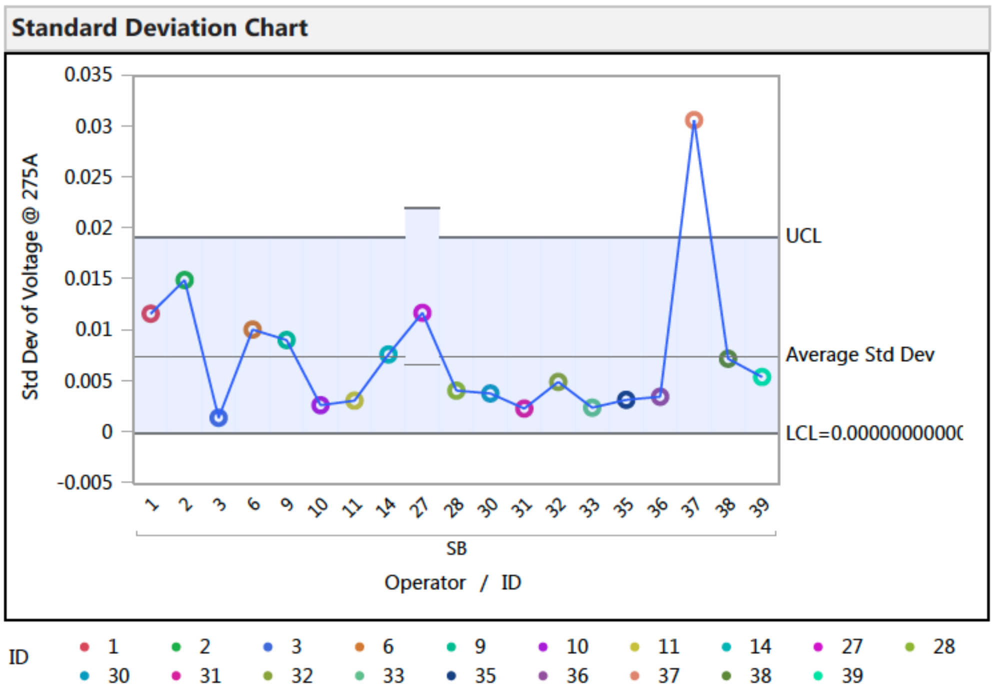

Figure 6.5: Standard Deviation of the voltage measurements

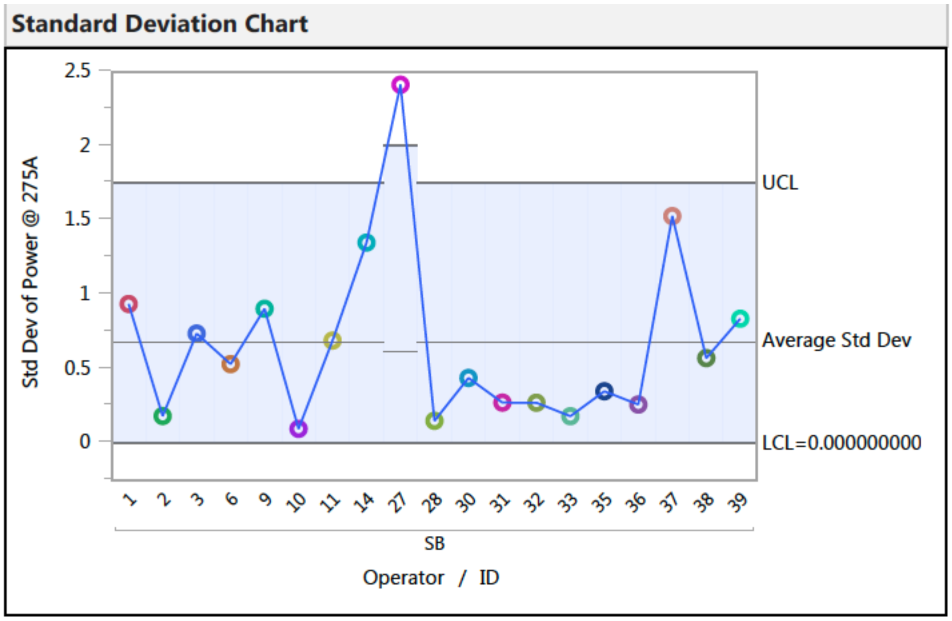

Figure 6.6: Standard Deviation of the power measurements

The graph shows standard deviation of voltage and power measurements of 19 golden sample diodes over a period of time. Golden samples are tested on the machine everyday to check the standard of machine and graphs are plotted from data obtained from daily tests.

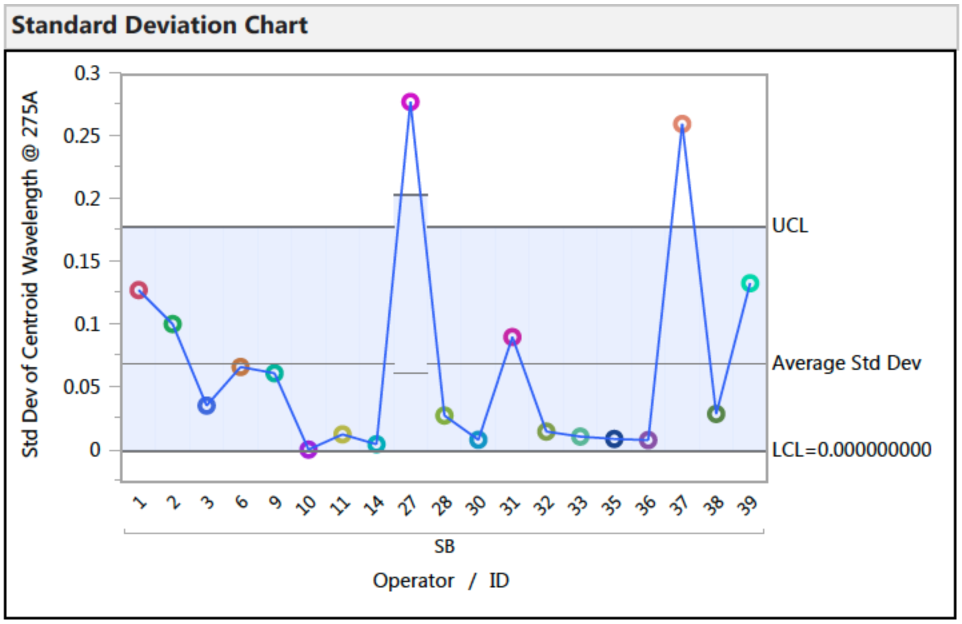

Figure 6.7: Standard Deviation of the centroid wavelength

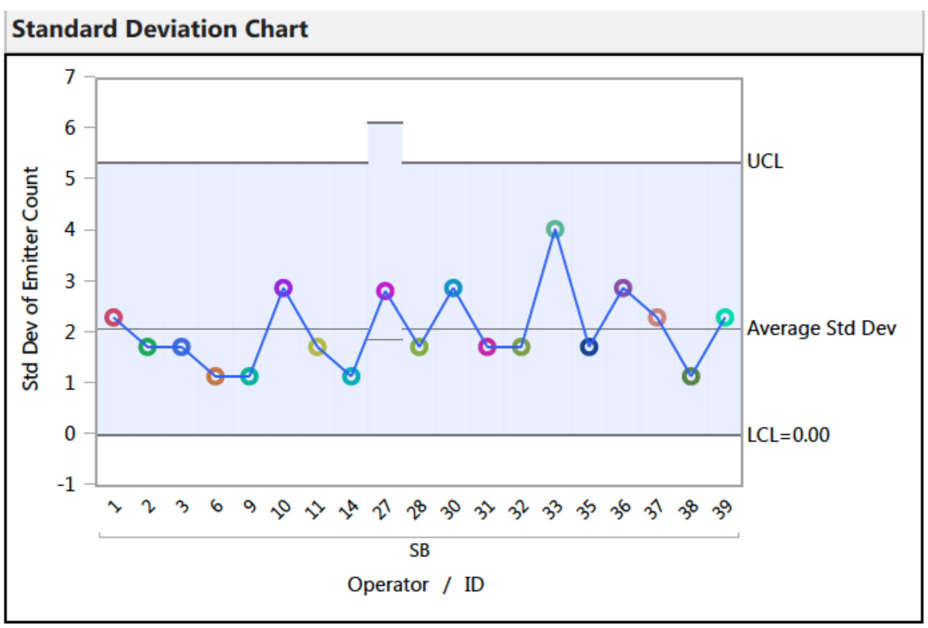

Figure 6.8: Standard Deviation of the Emitter count

Standard deviation of the centroid wavelength and emitter count for 19 golden samples are shown in above figure. The graphs are plotted to check if standard deviation stays in specified cutoff limits.

Chapter 7

Conclusion

An integrated automation routine for laser testing and assembly was successfully tested and implemented. The developed system is cost and time efficient as needed.Interface built in LabVIEW to control Robot opens a platform to build more automated projects in house at lower cost .An image processing algorithm was successfully implemented using Fast Fourier Transforms to detect the emitter count of the diode. The results shown in the previous chapter proves that system is highly reliable and repeatable.

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