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College of Engineering
Department of Electrical and Computer Engineering

Silicon Chip Cleaving Tool

Project Report

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Table of Contents

Executive Summary

In the Problem Definition section, the goals and constraints of the design are discussed. The goal of this project is to design and build a relatively inexpensive, semi-automated tool to cleave small Silicon chips which are roughly 1 cm in size, in a precise way, with a precision well below 1 mm. Motorized motion components and computer control will be used as much as possible to optimize accuracy.

In the Functional Analysis section, an analysis is done on the basic functions required for this project. The basic purpose of this project is to break a silicon chip in half, where the break occurs across the feature on the chip. To break a silicon chip, two primary steps are employed. The first is to score the chip, using a diamond scribe, and then break the chip across the resulting fault.

In the Alternative Evaluations section, alternative versions of the design are explained in detail. There are three different components to the project, the stationary platform, the scribe, and the clamping arm. Three different versions of each are conceptualized, and are designated numbers. The alternatives are scored and the highest scoring alternative for each component is chosen for the final apparatus.

In the Project Planning section, the planning process of the project is documented. A risk analysis evaluates potential risk items in the intended design. A mitigation strategy is then drawn to address any of the risks above the threshold line drawn from the risk analysis. The responsibilities of the design team are detailed and illustrated on a timeline for each listed responsibility.

In the Concept Development section the decisions made for the final product are described in detail. The concept design explains each selected component in detail. The highest

scoring component is chosen as the selected component. The concept design is then evaluated through interviews and revisions are made based on feedback. A design convergence is completed to join all the ideas from the concept design and evaluation criteria sections.

In the System Architecture section, the system architecture of the design is covered. The system architecture plan covers how the system operates. The system is split into four sections: mechanical, electrical, human and software. Given the nature of this design, majority of the operation is by the user.

In the Detailed Design section, everything that is required to build the product is displayed. This includes layout drawings, bill of materials and product lifecycle. This section links with the mechanical drawings from the layout drawings section and shows where each specific part goes.

In the Test and Analysis section, the statistics of the product are discussed. Statistics are classified as failure modes, effects, and cost analysis. In the physical testing section, the success rate of this product is discussed. The precision of the product is shown by the smallest feature size on the chip that has a 95% or more chance of being broken through. Finally, in the cost analysis section, the cost of the product is calculated.

I. Problem Definition

Introduction:

In the semiconductor industry, large wafers are divided into smaller chips containing individual devices. One approach is to "cleave" the chip, which is to score the surface with a very sharp tool, namely a diamond scribe, and break the chip along the resulting fault. Advanced robots for high-volume production already exist for this purpose. However, in a research lab, similar tools are needed, but on a much smaller scale and for flexible tasks.

The goal of this project is to design and build a relatively inexpensive, semi-automated tool to cleave small Silicon chips which are roughly 1 cm in size, in a precise way, with a precision well below 1 mm. As much as possible, motorized motion components and computer control will be used, while minimizing the cost of both building and operation. The team will be required to optimize the design for high performance, low cost, and ease of use.

Needs Description:

There is an abundance of silicon wafer cutters, but most are not precise enough to cleave through smaller wafer chips. With the development in technology, chips, and their components, are getting smaller and the need for a more precise cleaver increases. In a research lab, there is a need for flexibility in the use of this cleaver, due to varying sizes of the chips used.

The intent of this design is to cleave a silicon chip with a high amount of accuracy. A standard cleaving process includes scoring the chip with a very sharp tool and breaking the chip along the resulting fault from the score. This is the method that we are choosing to follow in order to cleave a silicon chip as it is simple and it fits the goals that we have for this design. The entire cleaving process needs to be controlled with a high degree of accuracy in order to achieve our goal of cleaving the chip with accuracies on the order of several hundred microns. We are on a budget for this design so we want to get the highest degree of accuracy out of the design while staying within budget. We also desire the cleaver to be relatively light-weight and not take up a large amount of area.

There are many variations of chip cleavers/dicers in the market currently. The goal of a chip cleaver varies on a needs basis but most of them are used for bulk wafers and multiple chips and are not necessarily expected to have the same amount of accuracy that we want to achieve with our design. The desire for most current chip cleavers is to separate individual chips from others on entire wafers and the accuracy desired is enough so that individual chips are not damaged when being separated from the wafer. We are not necessarily trying to bridge a technology gap among silicon chip cleavers. We simply want to very accurately cleave a single silicon chip through a patterned feature on the chip. There are several methodologies in place in order to cleave silicon chips including using diamond saws, diamond scribes, water jets, lasers, etc. Many of the aforementioned technologies are very expensive and take up a large amount of room. The following pictures are examples of current cleavers/dicers used in industry.

DYNATEX, DX-III

$21,500

ALLIED HIGH TECH - TECH CUT

$5,250

There is a need for our design not only at MSU-Bozeman but there is a need in research labs across the country for a flexible, accurate, low cost and easy to use silicon chip cleaver. The user of our silicon chip cleaver will be able to very accurately cleave silicon chips with ease and without taking up a large amount of real estate in the lab. We know that several professors and their research assistants at MSU-Bozeman are interested in our design and have a need for a highly accurate and flexible silicon chip cleaver. Our design will be easy to use for any user without much prior knowledge of the design and will be able to cleave silicon chips with a high degree of accuracy. There are many students and professors performing research in the Montana Microfabrication Facility (MMF) at our campus and chip cleaving is a relatively common task in the device fabrication process. Our design will be able to fulfill that need for them.

Stakeholder List:

1) Research labs researching related fields

- The target client for this project is mainly for research labs that require precise and flexible silicon wafer cleavers, and only need it in a much smaller scale than that of industries.
- Low cost of production and operation means that funds can be diverted elsewhere

2) Chip producing companies

- With further development of technology, chip get smaller and smaller. If this project is successful, it can be developed further into a larger scale and can increase production and reduce costs for these companies.

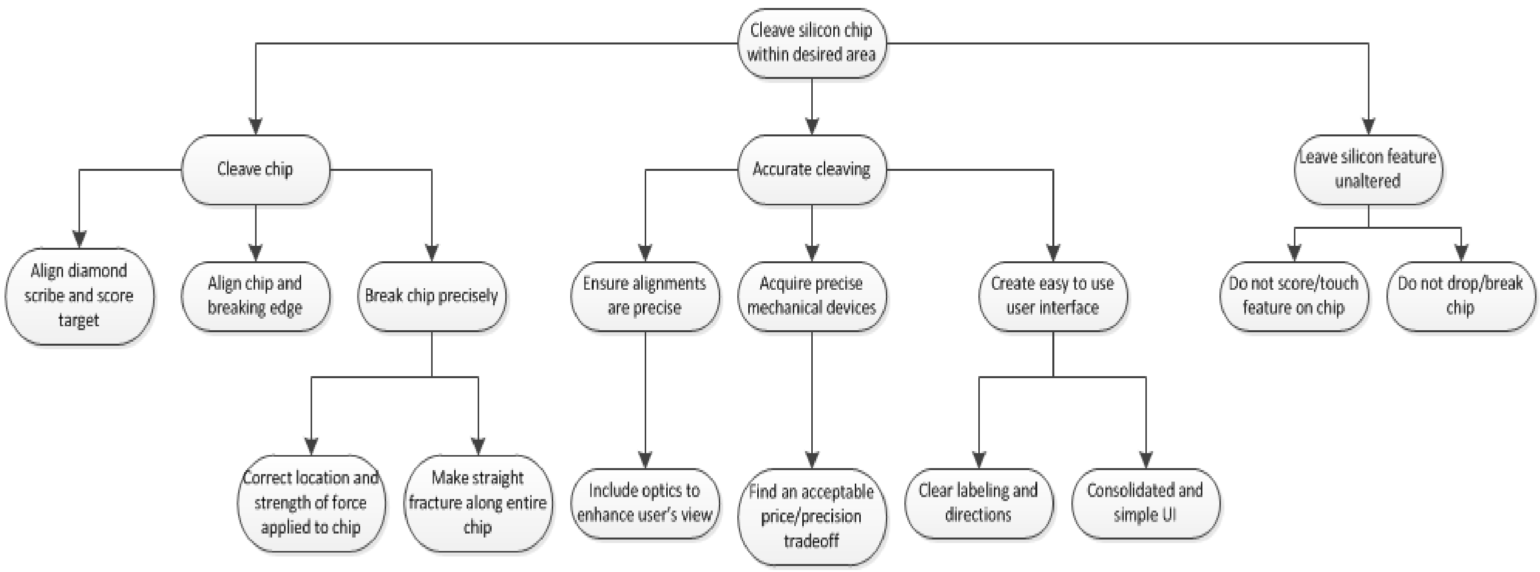
3) Research Assistants

- Less tedious to cut silicon chips. At the moment, such processes are done manually, and can be time consuming and not within the precision requirements. With production of the cleaver, research assistants can save time doing such tedious processes and reduce the risk of breaking the silicon chip at the wrong places.

Project Goals:

Our high-level project goals can be found in the objective tree below. We want to and plan to fulfill all of the objectives that are listed out in the objective tree.

Objective Tree



Objective tree can also be seen in attached “Objective Tree” Microsoft Visio document.

Project Constraints:

1) Low cost

- Cost of the entire silicon chip cleaver design is desired to be within the named limit, which is about $500-$1000.

2) Precision

- We must be able to cleave the chip within a certain area of precision. This area of precision has to be between the best case of 300um by 300um and the worst case of 1.0mm by 1.00mm.

3) Size

- Size of design must be small enough that it does not take up a large amount of bench space and is relatively easy to move around if necessary.

4) Weight

- Weight of design must be low enough that it can be moved if necessary.

5) Ease of use

- The design must be easy enough to use so that people somewhat familiar with the design can utilize it to its full potential.

6) High performance

- The design must be able to quickly, efficiently and precisely cleave silicon chips. If it cannot complete this task better then manually cleaving by a human then there is no point for the design.

7) Flexibility

- The design must be flexible to cleave various size chips with varying amount of accuracy.

II. Functional Analysis:

Introduction:

In this section, an analysis will be done on the basic functions required for this project. The basic purpose of this project is to break a silicon chip in half, where the break occurs across the feature on the chip. A degree of precision is required given the size of the feature, and it was decided that by using as much automation/motorization as possible, the chance of human error is reduced. To break a silicon chip, two primary steps are employed. The first is to score the chip, using a diamond scribe, and then break the chip across the resulting fault. The brittleness of the chip requires that the appropriate amount of force at the correct location is used while scoring without breaking the chip, as well as when clamping the chip to ensure accuracy. Also, the score needs to basically be orthogonal to the surface used to break the chip in order to ensure accuracy in terms of the break itself. Because of this, alignment has to be relatively precise, and use of motorized platforms and a high quality camera is required in order to reduce human errors. After the chip is broken, an apparatus is required to catch the overhanging piece from an appropriate height, so as to not further damage or break it.

Black Box Model:

Input: 1cm x 1cm silicon chip with feature

↓

Silicon chip Cleaver

↓

Output: 2x cut chips with break across feature

Functional Specifications:

The silicon chip cleaving tool needs to be able to cleave a silicon chip with a desired amount of accuracy without destroying, damaging or altering the feature on the silicon chip or the chip itself. There are commercial products that serve this functionality, however, in a research lab, similar tools are needed but on a smaller scale and for flexible tasks. As much as possible, motorized motion components and computer control will be used. The tool basically has two major functions in order to be able to cleave a silicon chip. These two primary functions are scoring the chip and breaking the chip along the resulting fault. There are also several intermediary steps and sub-functions between these two major functions that will be explained within this section. Accuracy is also an important feature of the tool that needs to be carefully thought about throughout the entire chip cleaving process.

The first major function of the chip cleaving tool is to score the silicon chip. A flat surface and a very sharp tool are needed for this function to be completed. The chip needs to be held tightly at an adequate distance from the feature printed on the chip so that the chip does not move during the scoring process but at the same time the chip and feature do not get damaged, broken or altered. The sharp tool needs to be able to very accurately score a specified edge of the silicon chip. The accuracy needs to come from some sort of automation or computer aided assistance as the precision that needs to be achieved cannot easily be done manually by a person. This means that we need a simple and concise user interface so that a person with very little knowledge about the tool can use it to its full potential. The amount of pressure that is applied on the silicon chip from the sharp tool needs to be controlled with a relatively high degree of accuracy. The chip needs to be scored with enough pressure so that it creates a proper fault to break along later but not too tight so that the chip is damaged or broken.

The second major function of the chip cleaving tool is to break the silicon chip along the resulting fault from the score. A very sharp edge of a flat surface and an object to place pressure on the silicon chip is needed. The scored silicon chip needs to be transported from the flat surface where it was scored to a very sharp edge of a flat surface where it will be broken. The chip still needs to be held tightly at an adequate distance from the feature printed on the chip so that the chip does not move during the breaking process. The score from the sharp object needs to be aligned very accurately with the edge of the flat surface in order to obtain a desirable break. The alignment process will also most likely need to come from some sort of automation or computer aided assistance. The amount and location of pressure that is applied on the overhanging edge of the silicon chip from the object also needs to be controlled with a relatively high degree of accuracy. The object needs to apply enough pressure at the desired location so that it breaks the chip straight along the fault that was created by scoring and not shattering or undesirably breaking the chip. The silicon chip needs to be immediately caught by some apparatus so that it does not drop so that the feature printed on the chip or the chip itself are not damaged, altered or broken.

Design Metrics:

Silicon chip surface area: 1cm x 1cm

Feature Size: <1mm

Precision of break: 300um-500um

Cost: $500-$1000 (not inclusive of existing parts in the lab)

III. Alternatives Evaluation

Introduction:

In this section, alternative versions of the design will be explained in detail. There are three different components to the project, the stationary platform, the scribe, and the clamping arm. Three different versions of each have been conceptualized, and have been designated numbers. Each component should be compatible with any of the other different components, (i.e. Alternative #1 Platform works with Alternative #2 Clamp and Alternative #3 Scribe, or any other combination of the three components). A general user operation explains and describes the general things the user has to do to maximize efficiency of the design. Finally, a design matrix scores each component alternative based on the project constraints mentioned in the problem definition section of this report. The scores are then totaled and the highest scoring alternative for each component is chosen for the final apparatus.

Design Alternatives:

All of the alternatives described below are centered on three main components: the platform, scribing apparatus and motorized clamping arm. The drawings for each alternative are attached in the Appendix.

<u>Alternative #1:</u>

The platform of this alternative is a stationary flat surface with three sliders and a metal flap that flips up to secure the chip on all four sides. The idea behind this alternative is that the silicon chip will be completely on the stationary platform while it is scribed and then it will be moved using the sliders so that the score mark is aligned with the platform edge for the breaking process later. The sliders are there to make the platform work for variable size silicon chips. The two sliders opposite each other will have a groove taken out of them so that the sliders do not become a problem when scribing takes place. These two sliders are mostly there for alignment and stability while scribing. The metal flap that flips up is embedded in the platform in order to stabilize the chip when needed and can move the chip to the edge of the platform for breaking. The slider opposite the embedded metal flap is there for stability and to be able to move the chip to the edge of the platform after the scribing takes place.

The scribing apparatus is a metal arm connected to a translational mechanical stage which is attached to a one-axis rail. The pressure applied on the silicon chip for scribing comes from the spring at the top of the arm. There is a slight angular metal extrusion in the metal arm so that the diamond scribe remains stable while it is exerting force on the silicon chip. The diamond scribe should be at about a 45 degree angle to the chip when scribing takes place. The mechanical stage will be able to be adjusted on the vertical axis also. The mechanical stage will be moved manually along the rail in order to create the score mark on the silicon chip.

The motorized clamp is a two-axis motorized stage with a metal arm and mechanical clamping hand connected to it. The hand will be able to grasp and open mechanically sort of like an adjustable crescent wrench. The hand will be used to both grasp and break the silicon chip. It will first be used to grasp the chip to load it on the stationary platform for scribing and then the top half of the hand will be used to put pressure on the end of the chip that is hanging off of the stationary platform in order to break the chip. The shape of the top half of the hand is angled because it should be able to break the chip more precisely compared to just being flat. The bottom half of the hand will be used to catch one half of the silicon chips after breaking.

<u>Alternative #2:</u>

The platform of this alternative is a combination of a stationary flat surface with a spring clip attached to it for holding and/or moving the silicon chip and a translational stage for supporting the overhanging half of the chip. The idea behind this alternative is that the desired scribe point on the silicon chip will already be aligned with the edge of the stationary platform so that minimal, if any, adjustments will have to be made to realign the chip to the platform edge for the breaking process later. The spring clip will be used to secure the silicon chip to the platform and will be able to move the chip along a single translational axis if necessary. The translational stage will be used to support the overhanging end of the silicon chip during the scribing process and then will be moved away for the breaking process. The motorized clamp will most likely be used for the translational stage.

The scribing apparatus is a metal arm connected to a translational mechanical stage which is attached to a one-axis rail. The pressure applied on the silicon chip for scribing comes from the spring hinge at the top of the arm. The diamond scribe should be at about a 45 degree angle to the chip when scribing takes place. There is a stop connected to the back of the diamond scribe so that once the scribe has scored the chip the scribe will not be damaged by striking other objects. The mechanical stage will be able to be adjusted on the vertical axis also. The mechanical stage will be moved manually along the rail in order to create the score mark on the silicon chip.

The motorized clamp is the same concept as in alternative #1 except for the fact that the bottom or top half of the hand could be used as the translational stage part of the platform component of the design as mentioned in that section above.

Alternative #3:

The platform for this alternative is just a flat surface with another piece slightly raised above the surface to hold the chip down. The upper surface is translational on two axes mechanically and will be controlled by the user. This platform does nothing during the scribing process, but after the chip has been scored, and the score mark has been aligned with the edge of the platform, the upper part has to be moved to hold the chip down. The locking mechanism will ensure that the chip is secure during the breaking process.

The scribing apparatus is basically a spring-loaded arm with a locking mechanism on the spring so as to prevent damage to the scribe itself or the surface the chip will be on. The arm is able to move at many different angles, offering more flexibility in terms of the angle of the scribe. The spring mechanism can be locked after the scribe has been placed on the chip so the scribe does not scratch the surface, damaging both the surface and the scribe. This apparatus will be mounted on a translational rail in the direction of the desired scribe line for the scribing process itself. This rail will be manually controlled to make the score mark.

The clamp will operate on a motorized two-axis platform, and a motorized rotational bar. This clamp will work alongside a mounted camera, and will be clamping the chip throughout the entire process up to the breaking of the chip. It will use the image taken by the camera to automatically place the chip in the desired position for scribing, then moving the chip to align the score mark made by the scribe with the edge of the platform. The lower part of the clamp will be lowered, and with the chip held by the platform, the upper part of the clamp will be lowered to break the chip. The piece that is not resting on the platform will then drop to the lower part of the clamp.

Client/User Operation:

The first thing the user needs to do is to have the chip prepared. Once that is done, the user has to place the chip onto the clamping arm. Although the alignment is automated, having the chip at a proper alignment is preferable. The clamping arm will then move the chip onto the platform. The scribing process will then begin.

The scribing process begins with the user using the camera to zoom in to the feature. The camera will then capture an image of the feature, and will upload it to the computer. A program will then align the chip to the appropriate position for scribing. Once the chip is aligned, the user then has to lift the diamond scribe, and move the scribing apparatus via the translational ramp to the desired length of the score. Once the position is determined, the scribe is lowered by the user onto the chip gently, so as to avoid too much force being applied on the chip. Excessive force would result in breaking or even shattering the chip, so extreme caution has to be taken in this step. The user then has to move the apparatus across the translational ramp, away from the feature, to score the chip. Again, caution has to be taken. If the user moves the apparatus too fast or too slow, there is a risk of causing cracks through the score marks, reducing the precision of the break greatly. This is because the break is dependent on creating weak points on the crystalline structure, via these score marks. By having cracks on these score marks, there is a risk of the chip following any one of the cracks rather than the score mark, reducing precision. Once the scribing is done, the apparatus can be moved away to begin the breaking process.

With the scribing process complete, the breaking process begins. First, the score mark has to be aligned to the edge of the stationary platform. This is automated, so all the user has to do is begin the process. The camera will recapture an image of the chip, with the feature and the score mark, and the clamping arm will align them to the edge of the platform. Since the breaking will be done by the clamping arm, a form of clamp is preferable on the stationary platform, if only for this section. This should be done after the chip is aligned with the edge of the platform. With the chip secure, the clamping arm can release the chip, by lowering the lower “jaw” to a depth sufficient enough for the chip to bend enough to cause it to break, while not being too deep as to not be able to catch the broken off piece well enough. The clamping arm will then be entirely lowered, with the upper "jaw” pushing down one side of the chip. The upper “jaw” is made in such a way that the corner nearest to the score mark will experience the most force, making the break more precise. With the other side of the chip clamped to the stationary surface, the chip should break once sufficient force is applied. The lower “jaw” will catch the broken off piece. Once this happens, the user then has to remove both halves of the chip from their respective positions, and the process is complete.

Decision Matrix:

A decision matrix is the tool used to determine which of the concepts explained above will be the selected one that will be proceeded forward with. Each constraint is scored on a scale of 1 to 10, 1 being the worst and 10 being the best. The scores are then totaled for each alternative component and the highest is the one that will be used in the final product. Green denotes the highest scoring alternative.

	Alternative #1	Alternative #2	Alternative #3
	Platform	Platform	Platform
Low Cost	6	8	8
Precision	9	4	6
Size	8	6	6
Weight	7	7	7
Ease of Use	6	8	6
High Performance	N/A	N/A	N/A
Flexibility	9	5	7
Total	45	38	40
	Alternative #1	Alternative #2	Alternative #3
	Scribe Apparatus	Scribe Apparatus	Scribe Apparatus
Low Cost	8	9	7
Precision	5	8	9
Size	7	7	7
Weight	7	7	7
Ease of Use	6	6	8
High Performance	6	7	8
Flexibility	7	7	7
Total	46	51	53
	Alternative #1	Alternative #2	Alternative #3
	Motorized Clamp	Motorized Clamp	Motorized Clamp
Low Cost	4	4	4
Precision	6	6	8
Size	7	7	7
Weight	5	5	5
Ease of Use	7	7	7
High Performance	8	8	8
Flexibility	7	7	8
Total	44	44	47

IV. Project Planning

Introduction:

In this section of the report documents the planning process of the project. A risk analysis evaluates potential risk items in the intended design. These risks can be broken down into meeting times, design malfunctions, time constraints, project report revisions and human resources. A mitigation strategy is then drawn to address any of the risks above the threshold line drawn from the risk analysis. By doing this, there is a reduction of occurrence to the listed risks. Next, a work breakdown structure is written to display the main areas that work that needs to be performed in the project. These were identified to be the webpage, the identification of the required parts, the building of the product, the design of the user interface, the testing of the product, writing of the project report and user manual, and the demonstration and presentation of the final product. A responsibility matrix then describes the responsibilities of the design team, as well as the individual responsibilities of each member. Finally, a Gantt Chart illustrates a timeline for each listed responsibility.

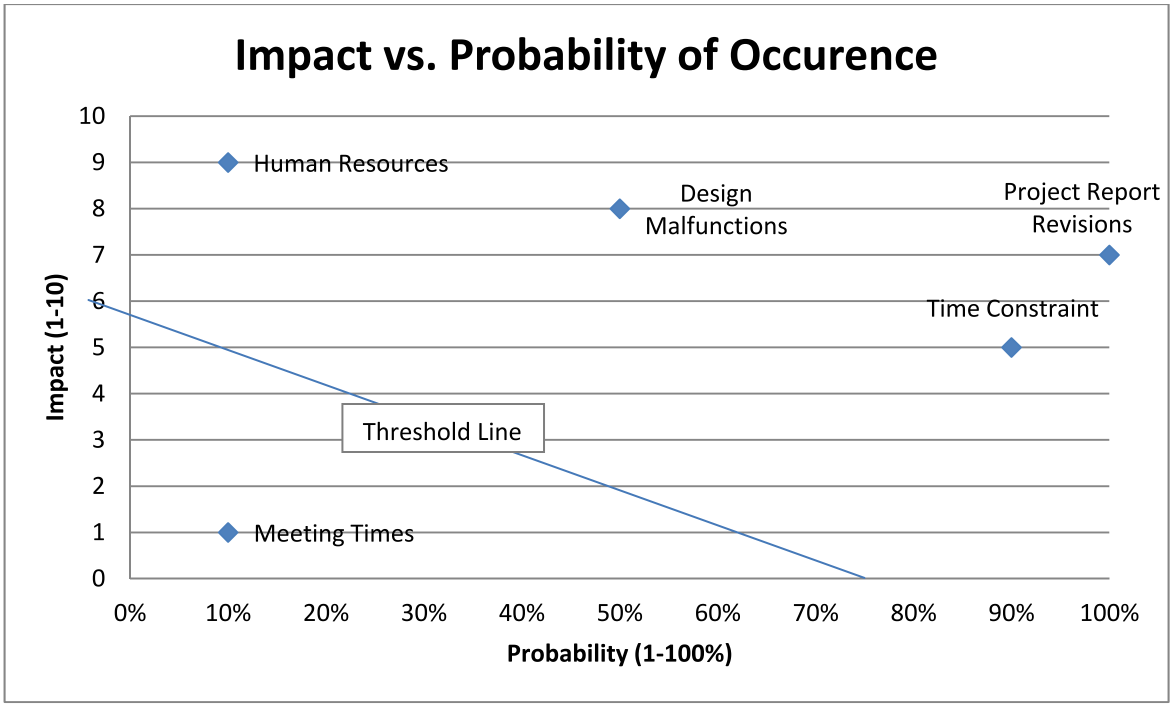
Risk Analysis:

- Meeting Times
    - Our group has limited times that we can all meet outside of our own class and personal schedules in order to work on our project. We need to be able to find time to meet and collaborate on the tasks at hand in order to complete the design and project report.
- Design Malfunctions

- Once we are ready to build the design there is bound to be errors and oversights that we failed to notice earlier in the design process. These design malfunctions have a potential to be a large problem for our design depending on the severity.

- Time Constraint
    - We have a limited amount of time (i.e. the end of the semester) in order to complete our design and all of the work that comes with it. We must have enough time to allow us to assemble and complete the design from when we order and receive parts. We also must be able to assemble/build the design before the design fair and complete our project report before it is due.
- Project Report Revisions
    - Project report section revisions consume time that could be used towards progressing with the project. This unplanned time consumption could throw us off of our design schedule and consequences could come with that.
- Human Resources
    - A human resource may become unavailable due to illness, injury, etc. A human resource could potentially not deliver their assigned task on schedule.

Identified Risks	**Probability of Occurrence**	**Impact**
	(1-100%)	**(1-10)**
Meeting Times	10%	1
Design Malfunctions	50%	8
Time Constraint	100%	7
Project Report Revisions	90%	5
Human Resources	10%	9



Mitigation Strategy:

- Meeting Times
    - Do as much individual work on the project as possible and try to manipulate our existing schedules to find time to meet.
- Design Malfunctions
    - Build a mostly functioning prototype and perform as many tests and simulations on prototype design components before building the final design. Spend as much time as possible thinking about the design and potential pitfalls of design components.
- Time Constraint
    - Get as much work done, either individually or as a group, and try to meet as a group as much as possible throughout the semester. Order parts for both the prototype and the final design as soon as possible.
- Project Report Revisions

    - Try to do as well as possible on the original project report sections so that revisions will be as simple and easy as possible.
- Human Resources
    - Spread work evenly between members to reduce the risk of one member becoming overloaded with work or irreplaceable towards the project completion.

Work Breakdown Structure:

- Webpage
    - A webpage is required to introduce the project team and have a description of the project design goals, a summary of the engineering constraints, and any other relevant information.
- Part Identification & Ordering
    - Parts needed for the project need to be listed so as to identify what needs to be bought. This relates to the cost analysis and also dictates if any parts need to be ordered and needs to be done in a timely manner so as to reduce time constraints.
- Building the Design
    - A prototype of the final design needs to be built for presentation at the Engineering Design Fair to better illustrate the usage of the product. Having a physical representation allows the potential user to better understand the product.
- User Interface
    - A user interface for the operation of the project (i.e. control of the clamping arm, etc.) needs to be designed so as to simplify the usage of the project. A more graphical interface makes the project more user friendly, which is one of the aims of this project.

- Design Testing
    - The prototype has to be tested to ensure that it works and meets the project requirements. This will be done in the workspace provided.
- Project Report
    - A project report has to be written to document the entire design process, the building and testing process, and final product.
- User manual
    - A user manual needs to be produced so a new user would be able to operate the final product without any reference to the product designers. This, combined with the simplification of the design through the user interface, is one of the goals of the design project.
- Design Demonstration & Presentation
    - A demonstration and presentation of the final product will be done at the Engineering Design Fair.

Responsibility Matrix:

The design team consists of Daniel Chern and Michael Martin. Both team members are seniors in the Electrical and Computer Engineering program at MSU-Bozeman. Both will be responsible for the building and testing of the project. Both members are responsible for meeting various deadlines throughout the design process this semester.

Daniel Chern: Responsible for Parts Identification, writing of User Manual.

Michael Martin: Responsible for webpage construction and design, User Interface design

Project Schedule:

The Gantt Chart can be found in the Appendix.

V. Concept Development

Introduction:

This section will describe in detail the decisions made for the final product. The concept design will explain each selected component in detail. Since some of the components are combinations of alternatives, modifications have been made to them. The dominant, highest scoring component is named as the selected component, but will not be fully similar to the alternatives mentioned in the previous sections. An evaluation criteria then shows interviews performed with potential users of this product. They mention what they like and dislike about the design, and also provide alternatives or modifications that should be made to make the product better, and a score is given to the overall design. A design convergence is then done to converge all the ideas from the concept design and evaluation criteria sections into a final product. Finally, contingency plans for each of the components are made in the event of failure of the final design.

Concept Design:

From the Design Alternatives, a final decision was made on each component of the final product. Detailed descriptions of the selected components will be discussed in this section. The concept drawings can be found in the Appendix.

Platform: Alternative #1

The platform selected has sliders on it to secure the chip in place. However, the number of sliders was reduced to 2, since the alignment processes requires the chip to have a degree of freedom. Also, since the angle of the feature on the chip is not always in its ideal 90 degree angle, a degree of freedom for rotation is required. Since the sliders' main purpose is to prevent slip, a cylindrical shape can be used. For the breaking process, the clamping arm will not be securing the chip. Therefore, one of the sliders needs to serve this purpose.

Clamping Arm: Alternative #3

The clamping arm will work on a 2-axis motorized stage. This increases the precision of the positioning of the chip onto the platform. It will also operate on a precise, to the micron, rotational axis. This is due to the aforementioned inaccuracies of the feature on the chip.
The clamping arm will work in sync with the camera for the alignment of the chip. The camera captures an image of the feature on the chip, and the computer interface will display the positioning changes needed to be applied. The user inputs these numbers into the motorized stage controller interface to align the feature to these coordinates.

The clamp itself is user operated in that the user has to load the chip onto the clamp, and secure it using the screw controlled clamp. After the chip is scribed, the user has to un-secure the chip and lower the lower "jaw" for the breaking process. The clamp is then lowered to break the chip. The upper "jaw" has a raised surface on one side that applies force onto the side of the chip that has been scored. The lower "jaw" has to be long and wide enough to catch the broken off piece.

Scribe: Alternative #3

The scribing apparatus involves the diamond scribe being mounted on a spring loaded swivel that rotates on a single axis and has a locking mechanism that ensures the scribe does not hit another surface after scoring the chip. This mechanism is then mounted on a single axis translational rail that will be operated by the user to score the chip.

Operation:

To operate, the user is to load the chip onto the clamping arm, and initiate the loading process onto the platform via the computer interface. The clamping arm will then move to a pre-set height and load the chip onto the platform below the camera. This allows the user to see the feature on the chip via the camera and set the position and angle of the chip. After the chip has been aligned, the user uses the clamp on the platform to hold the chip in place on the platform.

The user then needs to load the scribe and place it on the desired point to start the scoring, and engage the locking mechanism after. After locking the apparatus, the user has to move the apparatus across the rail to score the chip. After the scoring process is complete, the apparatus is moved to a position that will not interfere with the rest of the processes.

The user then unclamps the clamping arm, lowering the lower “jaw”. Since the chip is clamped to the platform, it will still be secure. The user then initiates the breaking process on the computer interface, and the clamping arm will lower and will break the chip. The broken off piece will be caught in the lower “jaw”, while the other half remains on the platform. The user then can remove both halves of the chip.

Evaluation Criteria:

Interview #1: Stephen Teh (Chemical Engineer, worked in Fabrication Lab in Montana State University)

The design looks good for a small scale operation, for example in a research lab in MSU. In the fabrication lab that I worked in, the chips tended to not break in straight lines, and resulted in many wasted chips. The precision offered by this design would reduce that. However, I am not a fan of the scribe being on a ramp. One of the reasons behind the breaks not being straight lay in the accuracy of the scribing. Other than that, the rest of the design looks like it would greatly help anyone working in a fabrication lab, and the learning curve is simple enough for someone who is relatively new to fabrication and its processes.

Interview #2: Ethan Keeler (Electrical Engineer, currently works at NanoOptics Group at Montana State University, Department of Electrical and Computer Engineering)

The design helps me with what I am currently working with, which is testing nanostructures. The only thing that worries me is that due to the size of the structures that I work with, there might be some movement on the scribe that might cause some precision issues. If the scribe could be modified to be more stable, it would work better. Also, I have problems seeing where to lower the scribe, maybe a micrometer can be added to help with that? Other than that, I like it. Good job guys!

Convergence Plan:

The main point of contention was the scribe not being stable enough. This shows the importance of the scribing process. As such, the scribe will be mounted on a plate rather than using rods, and will move across a translational stage. The translational stage reduces all wobble that is associated with the translational rail.

Another issue raised is where the scribe would be lowered on the chip. This was solved using a micrometer on the translational rail. This micrometer will control the starting point of the scribe onto the chip, and can be adjusted with an accuracy of 1micron.

Contingency Plan:

Platform: Alternative #3

The final design for the ramp is a combination of #1 and #3. Should the slider design fail, then alternative #3, which simply clamps the chip down to the platform will be used.

Scribe: Alternative #2

All the alternatives for the scribe revolve around running it on a rail. However, how the swivel works for the scribe mount all differ. Alternative #2 is the contingency plan because its stop connection to the back of the scribe prevents damage to the surface or the scribe.

Clamping Arm:

The final design for the clamping arm is a combination of all the alternatives. Modifications made will be done after testing to increase efficiency of the design.

VI. System Architecture

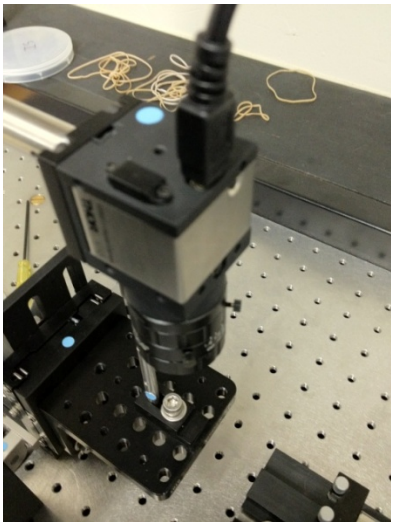
Introduction:

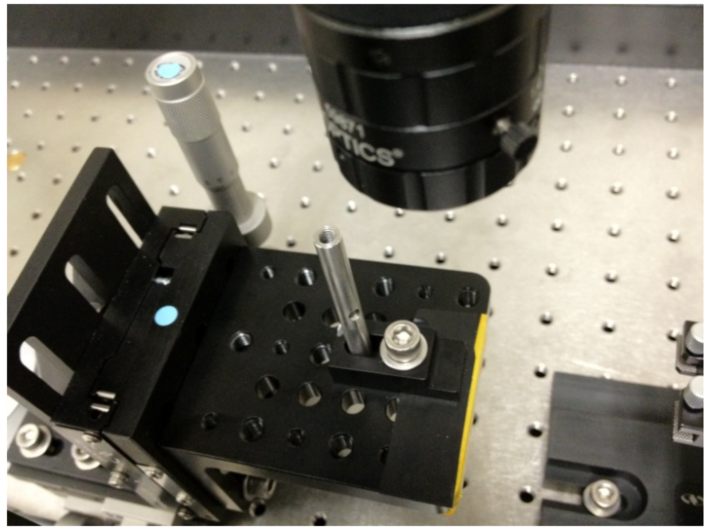
This section will cover the system architecture of the design. The system architecture plan covers how the system operates. The system is split into four sections: mechanical, electrical, human and software. The system interfaces show a flow diagram of the final design and describes it in detail. The sub-system interfaces break down the system interfaces into the four sections of the system architecture plan and how the different components are related to those sections. The user interfaces cover any human factors and ergonomic considerations of the user. Given the nature of this design, majority of the operation is by the user.

System Architecture Plan:

Mechanical

- Mechanical Platform: The mechanical platform will be a 2-axis mechanical translation stage that will hold the silicon chip for scribing and cleaving. The clamp or holder attached to the platform of the stage will be used to secure the chip to the stage itself. The stage is able to be moved by unscrewing it from the work bench if necessary but otherwise it is completely stationary. The stage will be able to move along 2 orthogonal translation axes for alignment with the motorized clamp arm. Each of the 2 axes of the stage is controlled by mechanical micrometers.
- Camera w/ Objective Lens: The camera is able to be moved by unscrewing it from the work bench if necessary but otherwise it is completely stationary.

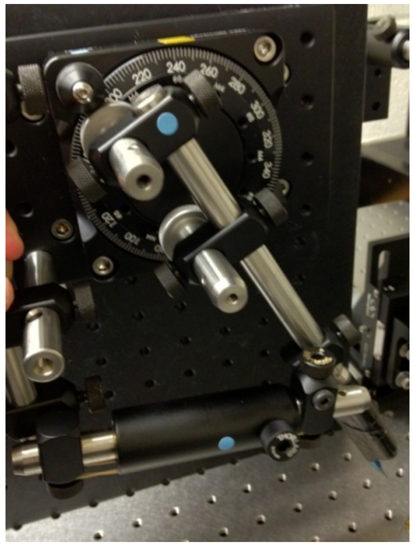




(1) (2)

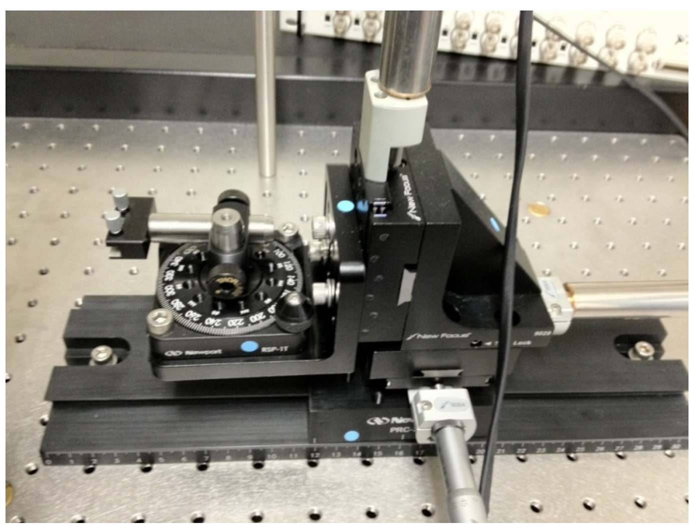
Pictures (1) and (2): Views of Platform

- Scribing Apparatus: The scribing apparatus will be attached to a rotation stage that is attached to a 2-inch travel, single axis mechanical translation stage. The stage is connected to a vertically oriented stationary metal plate. There will be a mechanical arm attached to the rotation stage that will be able to rotate on the pitch axis. Rotation is achieved through the jointed mechanical arm being attached to the rotation stage. The rotation of the mechanical arm will be controlled by a spring mechanism between the two posts of the mechanical arm. The spring mechanism can be made stationary via a screw in the side of the mechanism that will disable the spring movement. The spring mechanism is what allows the scribing mechanism to apply pressure on the silicon chip for scribing. We will also attach several support rods between the stationary metal plate and the jointed mechanical arm in an attempt to ensure stability of the scribing apparatus. A diamond scribe will be attached to the end of the mechanical arm that actually will do the scribing.



Picture (3): Scribing Apparatus

- Motorized Clamp Arm: The 2 motorized and 1 mechanical translation axes of the stage are purchased and there mechanical operation was determined by the manufacturer. The mechanical clamp connected to the motorized stage via rotation stage will be able to clamp the chip via screws pressing against the flat metal surface at the top of the clamp.



Picture (4): Motorized clamping Arm

Electrical

- Mechanical Platform: The mechanical platform does not incorporate any electrical components.
- Scribing Apparatus: The scribing apparatus does not incorporate any electrical components.
- Motorized Clamp Arm: The motors of each motorized translation axis will be powered by a power supply purchased from the manufacturer that made the motors. The controllers of the motors will be connected to a computer via USB cable. The cable will power the controllers and allow it to interface with the computer.
- Camera w/ Objective Lens: The camera will be connected to a computer via USB cable. The cable will power the camera and allow it to interface with the computer.

Software

- Mechanical Platform: The mechanical platform does not incorporate any software components.
- Scribing Apparatus: The scribing apparatus does not incorporate any software components.
- Motorized Clamp Arm: The 2 motorized translation axes are already purchased and include a software package that allows the user to control the motion of each motorized axis. The graphical user interface allows the user to type in distances for each translation axis to move (in mm). The part that we will incorporate to this graphical user interface allows the user to automatically align the center of the feature printed on the chip with the diamond scribe tip and then align the scribe mark with the edge of the mechanical platform for more accurate scribing and cleaving. This will be achieved with the help of the camera graphical user interface.

- Camera w/ Objective Lens: The camera is already purchased and includes a software package that allows the user to see the view of the camera on a computer screen. There are other more complex components of the included graphical user interface that will most likely not be used. The graphical user interface will be used for alignment of the feature with the mechanical platform.

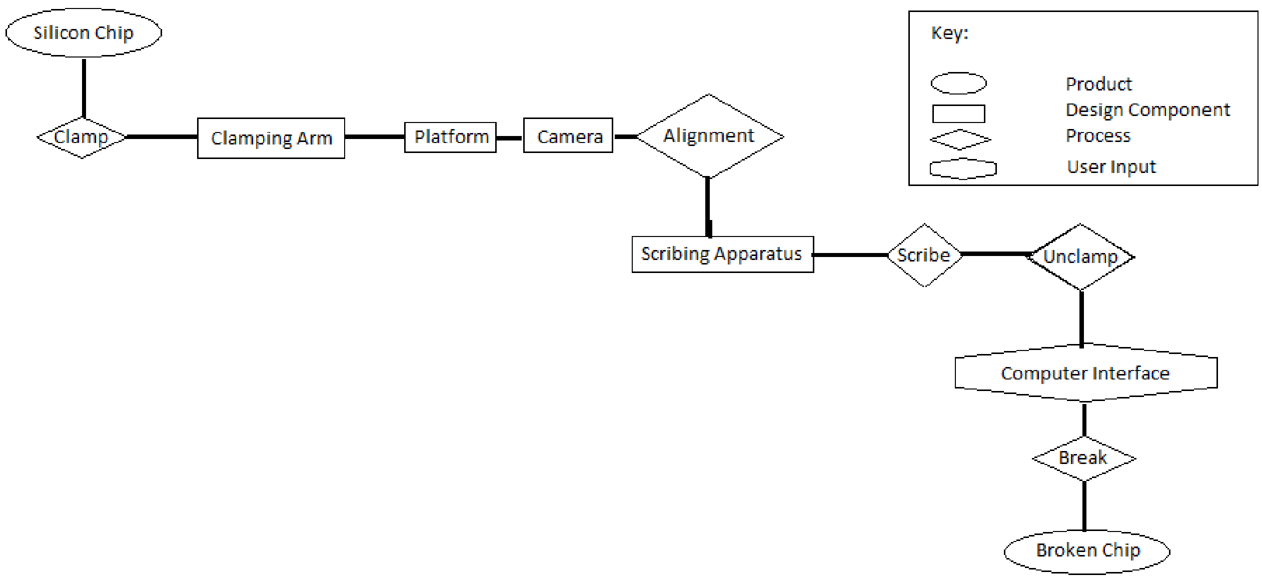
Human

- Mechanical Platform: The holder attached to the mechanical stage will need to be manually manipulated by the user to secure the silicon chip to the platform of the stage. The 2 micrometers that are attached to the stage need to also be manually manipulated by the user. The user will also need to unscrew the mechanical stage from the workbench if it needs to be physically moved.
- Scribing Apparatus: The translation stage of the scribing apparatus will need to be manually moved in a direction perpendicular to the feature printed on the silicon chip in order to scribe the chip. The translation stage will provide the force to scribe the chip and ultimately return the scribing apparatus back to its original position. The mechanical arm will need to be manually rotated so that the tip of the diamond scribe eventually rests on the top surface of the silicon chip for scribing. The screw of the spring mechanism will need to be manually manipulated if the user wants the spring to remain stationary. The user will also need to unscrew the large metal plate from the workbench if it needs to be physically moved.
- Motorized Clamp Arm: The 2 motorized translation axes of the stage will be controlled through a graphical user interface on the computer. The motors for the stage need to be connected to a power supply that has been purchased and the controller for each translation axis needs to be connected to the computer in order to power and interface. The user needs to be able to use a computer with the motor's user interface running on

it. They will also need to know some key features of the user interface, namely the move feature, in order to use our design as intended. The micrometer of the mechanical translation axis that is attached to the stage needs to be manually manipulated by the user. The screws that are used to clamp the silicon chip will be manipulated manually also. The user will also need to unscrew the motorized stage form the workbench if it needs to be physically moved.

- Camera w/ Objective Lens: The camera will be controlled through a graphical user interface on the computer. The camera needs to be connected to the computer in order to power and interface. The user needs to be able to use a computer with the camera's user interface running on it. They will also need to know some key features of the user interface, namely the screenshot feature, in order to use our design as intended. The user will need to be able to obtain a screenshot of the camera view in order to obtain the coordinates of the center of the feature printed on the silicon chip. The user will also need to unscrew the camera from the bench if it needs to be physically moved. The objective lens attached to the camera is simply to allow the user to see a zoomed in view of the chip for better accuracy.

System Interfaces:



Flow Diagram of Chip Cleaver

All processes require that the user give some form of input. The design component parts of the flow diagram show the current position of the chip at that moment. To begin, the user will take the silicon chip and clamp it onto the clamping arm. The clamping arm then moves the chip to the platform. The alignment process takes place using the output from the camera, aligning the chip according to the coordinates from said output. When the chip has been aligned, the scribing apparatus moves into position and initiate the scribing process. Once the chip has been scribed, the chip is unclamped and the breaking process is initiated on the computer interface. Once the break is made the process is complete.

Sub-System Interfaces:

Mechanical

- Platform: The mechanical platform will be a 2-axis mechanical translation stage that will hold the silicon chip for scribing and cleaving. The clamp will secure the chip to the stage itself. The user can move the platform by unscrewing it from the work bench. The stage movable along 2 orthogonal translation axes for alignment with the motorized clamp arm. Each of the 2 axes of the stage is controlled by micrometers.
- Scribing Apparatus: The scribing apparatus will be attached to a single axis translation stage. The rotation of the mechanical arm can be made stationary via a screw in the side of the mechanism that will disable the spring movement. The rubber band is what allows the scribing mechanism to apply pressure on the silicon chip for scribing. A diamond scribe will be attached to the scribing apparatus via tape that actually will do the scribing. This scribe is mounted on a rotational axis.
- Motorized Clamping Arm: The clamping arm is controlled by 2 motorized translation axes, through a computer interface, and a single mechanical translation axis.
- Camera w/ Objective Lens: The camera is able to be moved by unscrewing it from the work bench if necessary but otherwise it is completely stationary.

Electrical

- Platform: The platform does not incorporate any electrical components.
- Scribing Apparatus: The scribing apparatus does not incorporate any electrical components.
- Motorized Clamp Arm: The motors of each translation axis will be powered by a power supply purchased from the manufacturer that made the motors. The controllers of the motors will be connected to a computer via USB cable. The cable will power the controllers and allow it to interface with the computer.

- Camera w/ Objective Lens: The camera will be connected to a computer via USB cable. The cable will power the camera and allow it to interface with the computer.

Software

- Mechanical Platform: The mechanical platform does not incorporate any software components.
- Scribing Apparatus: The scribing apparatus does not incorporate any software components.
- Motorized Clamp Arm: The graphical user interface allows the user to type in distances for each translation axis to move (in mm). The part incorporated to this graphical user interface allows the user to automatically align the center of the feature printed on the chip with the edge of the mechanical platform for more accurate scribing and cleaving. This will be achieved with the help of the camera graphical user interface.
- Camera w/ Objective Lens: The camera is already purchased and includes a software package that allows the user to see the view of the camera on a computer screen. The graphical user interface will be used for alignment of the feature with the mechanical platform.

Human

- Mechanical Platform: The holder attached to the mechanical stage will need to be manually manipulated by the user to secure the silicon chip to the platform of the stage. The micrometers that are attached to each axis of the stage need to also be manually manipulated by the user. The user will also need to unscrew the mechanical stage from the workbench if it needs to be physically moved.
- Scribing Apparatus: The scribing apparatus will need to be manually moved on a mechanical translation stage in a direction perpendicular to the feature printed on the

silicon chip in order to scribe the chip. It will also need to be manually moved back to its original location to prepare for scribing again. The screw of the mechanical arm will need to be manually manipulated if the user wants the arm to remain stationary. The user will also need to unscrew the rail from the workbench if it needs to be physically moved.

- Motorized Clamp Arm: The 2 motorized translation axes of the stage will be controlled through a graphical user interface on the computer. The motors for the stage need to be connected to a power supply that has been purchased and the 2 controllers for each translation axis need to be connected to the computer in order to power and interface. The user needs to be able to use a computer with the motor's user interface running on it. They will also need to know some key features of the user interface, namely the move feature, in order to use our design as intended. The micrometer that is attached to one of the axes of the stage needs be manually manipulated by the user. The screws that are used to clamp the silicon chip will also need to be manipulated manually. The user will also need to unscrew the motorized stage form the workbench if it needs to be physically moved.
- Camera w/ Objective Lens: The camera will be controlled through a graphical user interface on the computer. The camera needs to be connected to the computer in order to power and interface. The user needs to be able to use a computer with the camera's user interface running on it. They will also need to know some key features of the user interface, namely the screenshot and draw features, in order to use our design as intended. The user will need to be able to obtain a screenshot of the camera view in order to obtain the coordinates of the center of the feature printed on the silicon chip. The user will also need to unscrew the camera from the bench if it needs to be physically moved. The objective lens attached to the camera is simply to allow the user to see a zoomed in view of the chip for better accuracy.

User Interfaces:

- Mechanical Platform: The holder attached to the mechanical platform is manually manipulated via an easily accessible screw. The micrometers that are attached to each axis of the stage are also easily accessible and manipulated. Most people are somewhat familiar with a micrometer and there operation is mostly intuitive. The user can easily unscrew the mechanical stage from the workbench with an Allen wrench.
- Scribing Apparatus: The scribing apparatus can be easily and effortlessly moved on the stationary translation stage. The screw that locks the mechanical arm is easily accessible and manually manipulated. The user can easily disassemble the scribing apparatus and remove it from the workbench with an Allen wrench.
- Motorized Clamp Arm: The manual for each motor’s use and graphical user interface is contained on a CD that was included with the motor controllers. We will also include our own user manual that is simpler and more pertinent to our design. The motors are connected to the controllers and the controllers are connected to the power supply and a computer via power cable and USB cable, respectively. Both our user manual and the manufacturer’s manual should allow the user to operate the user interface and our design to its full potential. If they follow our user manual properly then operating our design should be as easy as following directions. The screws that are used to clamp the silicon chip will be manipulated manually. The user will also need to unscrew the motorized stage form the workbench if it needs to be physically moved.
- Camera w/ Objective Lens: There are some helpful webpages for the camera’s use and graphical user interface on the internet. We will also include our own user manual with the camera that is simpler and more pertinent to our design. The camera is connected to a computer via USB cable. Both our manual and the help webpages should allow the user to operate the user interface and our design to its full potential. If they follow our

manual properly then operating our design should be as easy as following directions. The user can easily unscrew the camera boom from the workbench with an Allen wrench. The objective lens attached to the camera should be left that way unless it is necessary that it be removed.

VI. Detailed Design

Introduction:

This section will display everything that is required to build the product. The layout drawings section consists of mechanical drawings of each of the three components, showing all the parts required. The Bill of Materials displays a list of all the component parts. This section links with the mechanical drawings from the layout drawings section and shows where each specific part goes. The project did not required explicit purchases to be made, but the specifications of all parts used are displayed in the Purchased Component Specifications section. All of these are then compiled in the Detailed Design section. Finally, the product lifecycle section discusses the life of the product.

Mechanical Layout:

Mechanical Layout can be found in the Appendix.

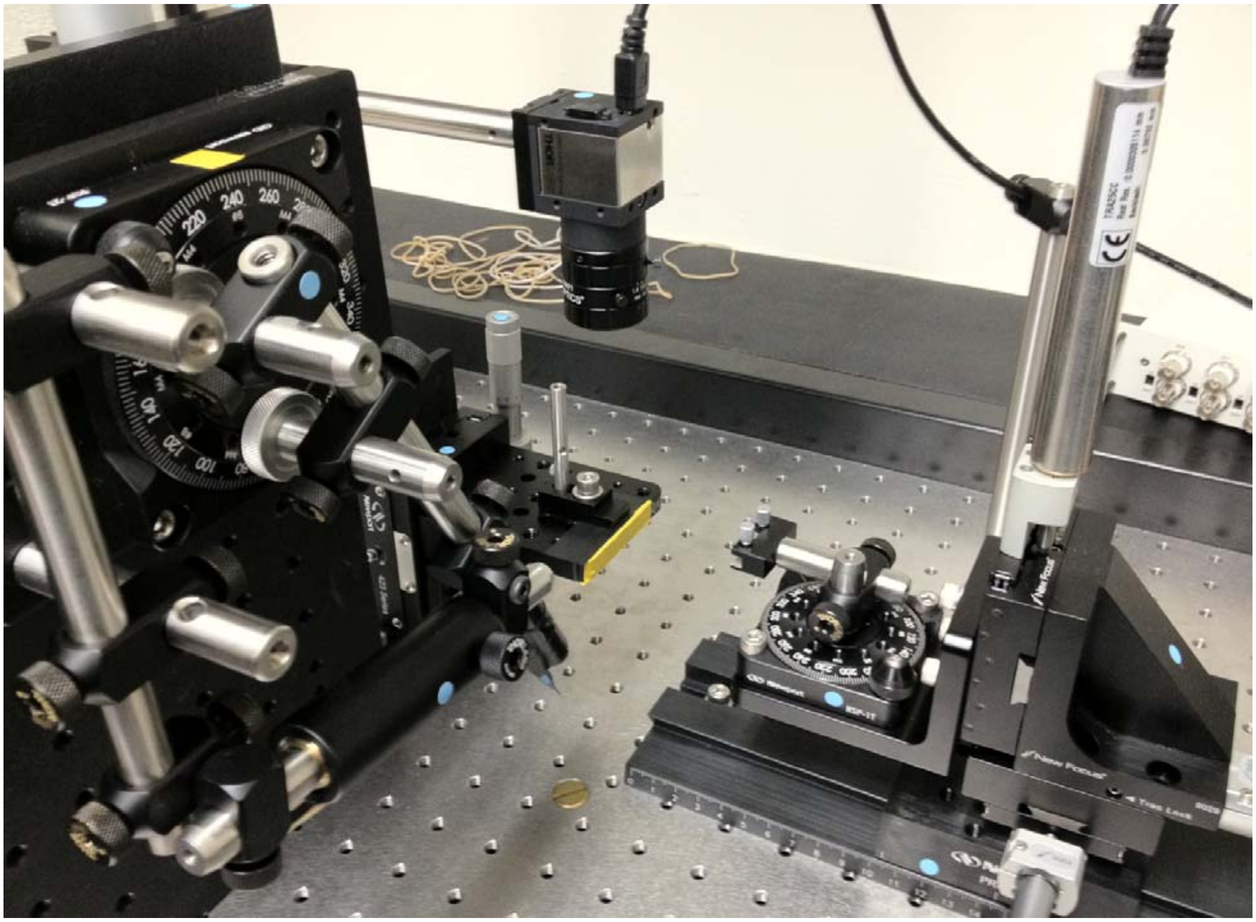
Bill of Materials:

Bill of materials can be found in the Appendix.

Purchased Component Specifications:

As it can be seen in the Bill of Materials, not every part needs to be purchased as most of them are in stock at the laboratory. However, specifications and datasheets for all parts can be found in the Appendix.

Detailed Design:



Final Layout of Product

The picture above displays the final layout of the product. The scribe is aligned to the yellow tape on the platform, and the camera is mounted directly above the where the chip will be clamped. The height of the chip clamp is aligned to the height of the platform.

The flow diagrams for the camera assembly, holding platform, scribing apparatus, user interface and motorized stage can be found in the Appendix.

Product Lifecycle:

The main work in the beginning of the product's lifecycle is proper assembly. All of the parts that need to be purchased are clearly specified in the bill of materials and purchased component specifications sections. The initial construction of the product is very important as we expect a high amount of accuracy from the design and part of that accuracy comes from proper assembly at production. If components or parts are not aligned properly and accurately from the beginning, that leaves a high potential for errors and inaccuracies in the product's performance later in its lifecycle.

There is a certain amount of maintenance that needs to be done with the product in order to keep it in proper working order and to be used to its full potential throughout its life. Most of these maintenance issues are detailed and explained in the user manual that was produced for the product. These maintenance concerns include tape replacement, rubber band replacement, and motorized axes home position reset. Additionally, if any of the parts of the design stop working or break and are unable to be repaired then they need to be replaced or the design will no longer be functional.

We expect a fair amount of recycling to be done with our product at the end of its life. Many of the parts from the design have a potential to be reused unless they fail or break during the product's lifecycle of use. Even if parts do break there is still a potential of salvaging scraps from the parts. The parts that are not able to be salvaged or reused will most likely just be thrown out, as they have little purpose once the product is finally disposed of.

VII. Analysis and Test

Introduction:

This section discusses the statistics of the product. Statistics are classified as failure modes, effects, and cost analysis. The failure mode and effects analysis discusses the potential failures and the effects of those failures. This is done in a table for similar to that of the design matrix. Also in this section is how these potential failures can be corrected. In the physical testing section, the success rate of this product is discussed. Since precision is the best way to illustrate the success rate of this product, test breaks of the chip were performed. The precision of the product is shown by the smallest feature size on the chip that has a 95% or more chance of being broken through. Finally, in the cost analysis section, the cost of the product is calculated. Since most of the product was built using already existing (in stock) parts, this does not illustrate the total cost if a potential client wishes to build this from scratch. Since the target users are mainly people who already work in a similar lab as the one the team used, they should have the required parts in stock as well. The purchased components listed are those that could not be found in the lab.

Failure Mode and Effects Analysis:

In this area, an evaluation of the potential failures and the effects of those failures are explored. This is done using as table format with ratings from the potential failure along with the corrective actions that will be put into place.

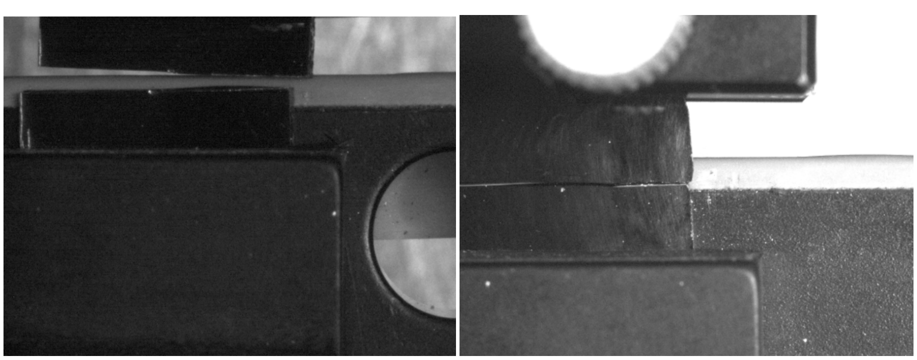
The FMEA table can be found in the Appendix.

Physical Testing:

Physical testing is fully testing for the precision of product, which is defined as how small the feature can be for the product to accurately (probability close to 95%) break through. These tests that we perform will allow us to see the performance reliability for every component of our design. This basically involves breaking test chips that are about the same size as the ones used in the lab. Features are marked on these test chips with varying sizes (1mm, 600 microns, 400 microns and 300 microns) and will be put through the design in order to cleave them. Each test consists of a sample size of 20 chips for each feature size. We figure that a sample size of about twenty will give us a relatively good idea of how our design would perform on a population. A probability will be collated and smallest sized feature with a success probability of 95% or more will be the maximum precision. Based on those results we will continue to try to improve our design for optimal performance. We will take a good look at every component in order to improve our design but the main components that will be under the most scrutiny are the scribing apparatus, clamping arm and camera lens. The ultimate goal would be for us to be able to accurately and reliably cleave a feature size of 300 microns.

Trial	Radius (μm)	Diameter (μm)			Average (including accidental)	Standard Deviation	Minimum Precision
1	107	214			165.395	96.61484451	366
2	107	214					
3	107	214					
4	137	274					
5	107	214					
6	107	214					
7	76	152			Average (excluding accidental)	Standard Deviation	Minimum Precision
8	0	0			149.05	85.23688839	274
9	31	62					
10	76	152					
11	0	0					
12	122	244					

13	76	152					
14	76	152					
15	0	0					
16	76	152					
17	76	152					
18	122	244					
19	76	152					
20	107	214					
21	0	0					
22	76	152					
23	107	214					
24	0	0					
25	122	244					
26	107	214					
27	107	214					
28	0	0					
29	76	152					
30	31	62					
31	122	244					
32	107	214					
33	76	152					
34	31	62					
35	107	214					
36	0	0					
37	31	62					
38	0	0					
39	0	0					
1	107	214					



Test Screenshots.

Cost Analysis:

For this product, one of the main goals was to reduce the cost as much as possible to make it affordable for small scale usage, such as in a school laboratory. The main methodology used by our team was to use parts already existing in the laboratory. The laboratory used was the Montana State University Optical Nanostructures Laboratory run by Dr. Wataru Nakagawa. It was stocked with parts commonly used in optics research, thus providing the necessary equipment with the required precision. As a result, the total cost was reduced considerably. The only pieces of equipment that were purchased are listed as follows:

As it can be observed, many of the components listed in the bill of materials are not listed above. This is because they were not purchased, thus not actually costing the team any money. Since this product is meant to be used in similar labs, it was assumed that they would have the majority of the parts utilized by our team to build our design.

The same can be said for the cost of testing. The chips used for testing were scrap chips that were broken to similar sizes as the ones we would expect our design to be used for and the features were manually marked on the chip. This did not involve any fabrication whatsoever so the cost of testing is negligible.

Conclusion

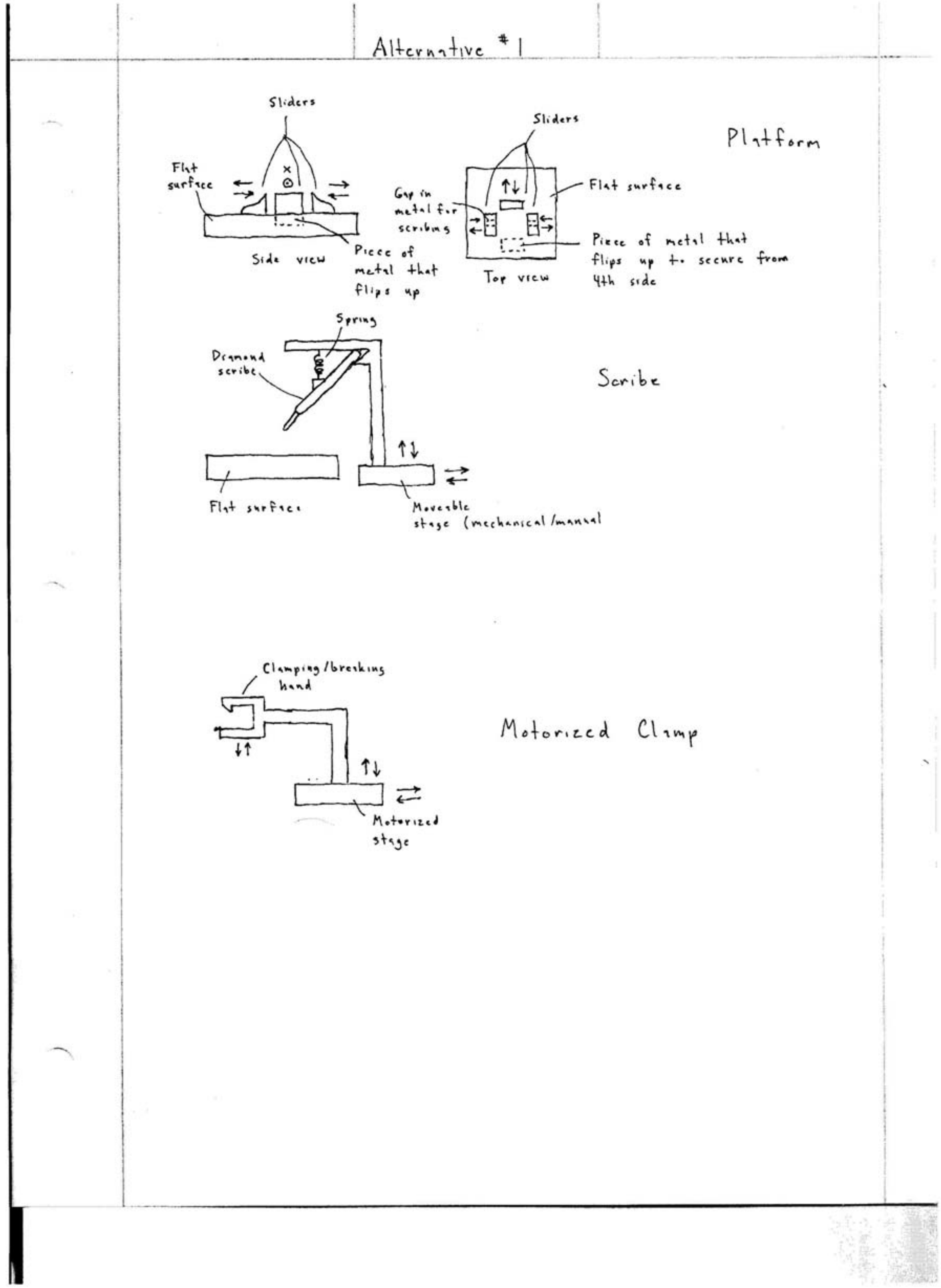
We learned some significant properties about the silicon chip cleaving tool while using it throughout the design process and during the testing phase. We discovered from testing that out of 40 samples we were always able to cleave a feature of at least 274μm. This sets the minimum precision of this tool based on the 40 samples that were taken. This means that the design should be able to cleave a feature size of 300μm^2 with a high degree of reliability. The minimum size of chip that we were able to cleave was determined based on the size of the clamp and scribe access to the chip. The minimum size of chip that we can cleave was determined to be 1cm^2. We speculate that the max size of chip that we can cleave based on design operation observations 2.5cm^2. We ran into some accidental breaks during testing but those are all presumed to be removed through correction of the design. The correction of the design to prevent the accidental breaks was based on what we observed the cause of the breaks to be.

It is also important to keep in perspective the purpose of this tool in the larger scheme. The reason why we were tasked to build this tool was to be able to accurately cleave through features patterned on a silicon chip. The reason why this is needed is so that Wataru's research group is able to inspect the cross section of their nano-scale features. Once they are able to do this inspection they are able to determine if the feature that was patterned on the chip turned out to be what they wanted. Based on the cross section, they feedback information to the people working in the fabrication facility so they may correct deviations or improve their fabrication processes. So this tool is helpful piece in a larger operation to achieve better fabricated features.

There is also future progress that can be done on this design to possibly further increase its capabilities and accuracy. The user interface is not as simple as we would have liked it to be in the end. The ultimate goal would be to have the entire user interface for this design be within one program. This would make the user interface much more useable and user-friendly. The idea we had at this point was to try to implement the user interface in LabView. We would have also liked to find a way to better secure the scribe to the mechanical arm of the scribing apparatus in order to reduce wobble in the scribe. The ideas that we currently had to achieve this were to somehow weld the scribe to the arm or create something similar to a post holder that conforms to the scribe's unique shape and attach that to the arm. We would have also liked to improve the clamp that secures the chip to the mechanical platform. It would have been desirable if the clamp would have included some sort of torque wrench mechanism when securing the chip to the platform. This would not allow the user to tighten and reduce the possibility of an accidental break.

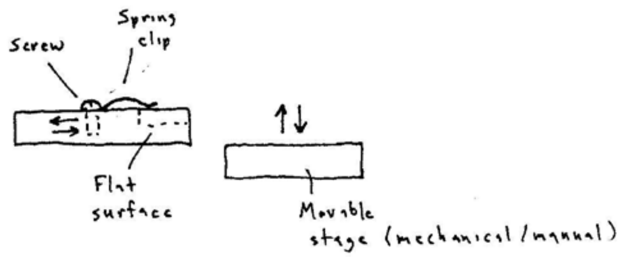
Appendix

Design Alternatives

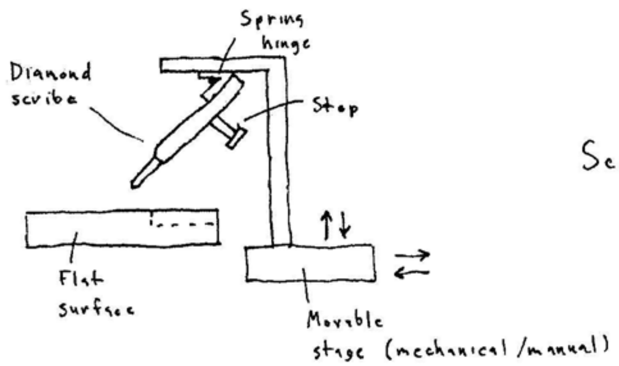


Alternative #2

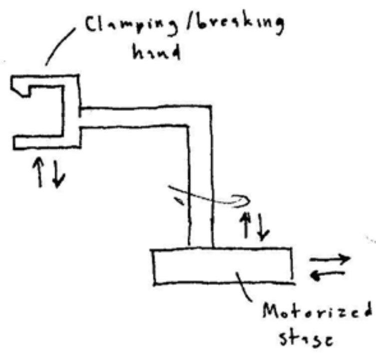
Platform



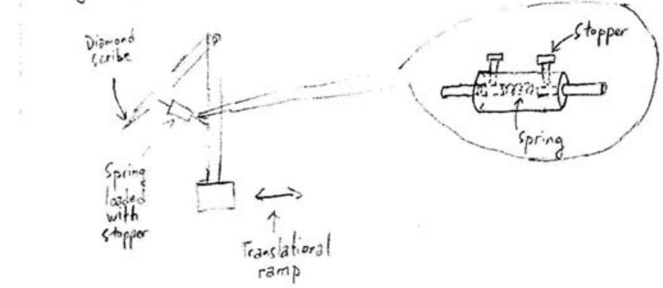
Scribe

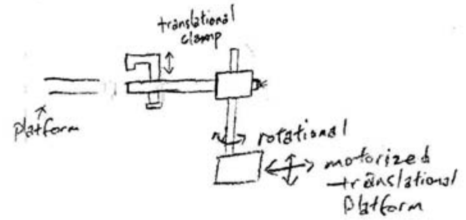


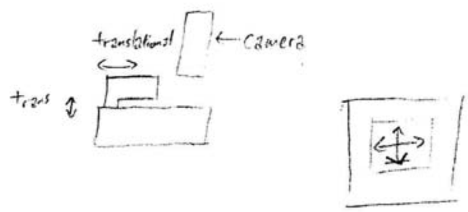
Motorized Clamp



Design Alternatives 3







Gantt Chart

ID		Task Name	Duration	Start	Finish	Predecessors	Resource Names
1		Webpage	6 days?	Thu 9/29/11	Thu 10/6/11		Michael Martin
2		Part Identification	3 days?	Thu 9/29/11	Mon 10/3/11		Daniel Chern
3		Building Design	26 days?	Thu 9/29/11	Thu 11/3/11		Design Team
4		User Interface	26 days?	Thu 9/29/11	Thu 11/3/11		Michael Martin
5		Design Testing	11 days?	Thu 11/3/11	Thu 11/17/11		Design Team
6		Project Report	69 days?	Thu 9/1/11	Tue 12/6/11		Design Team
7		User Manual	36 days?	Thu 9/29/11	Thu 11/17/11		Daniel Chern
8		Design Presentation	1 day?	Thu 12/8/11	Thu 12/8/11		Design Team

Page 1

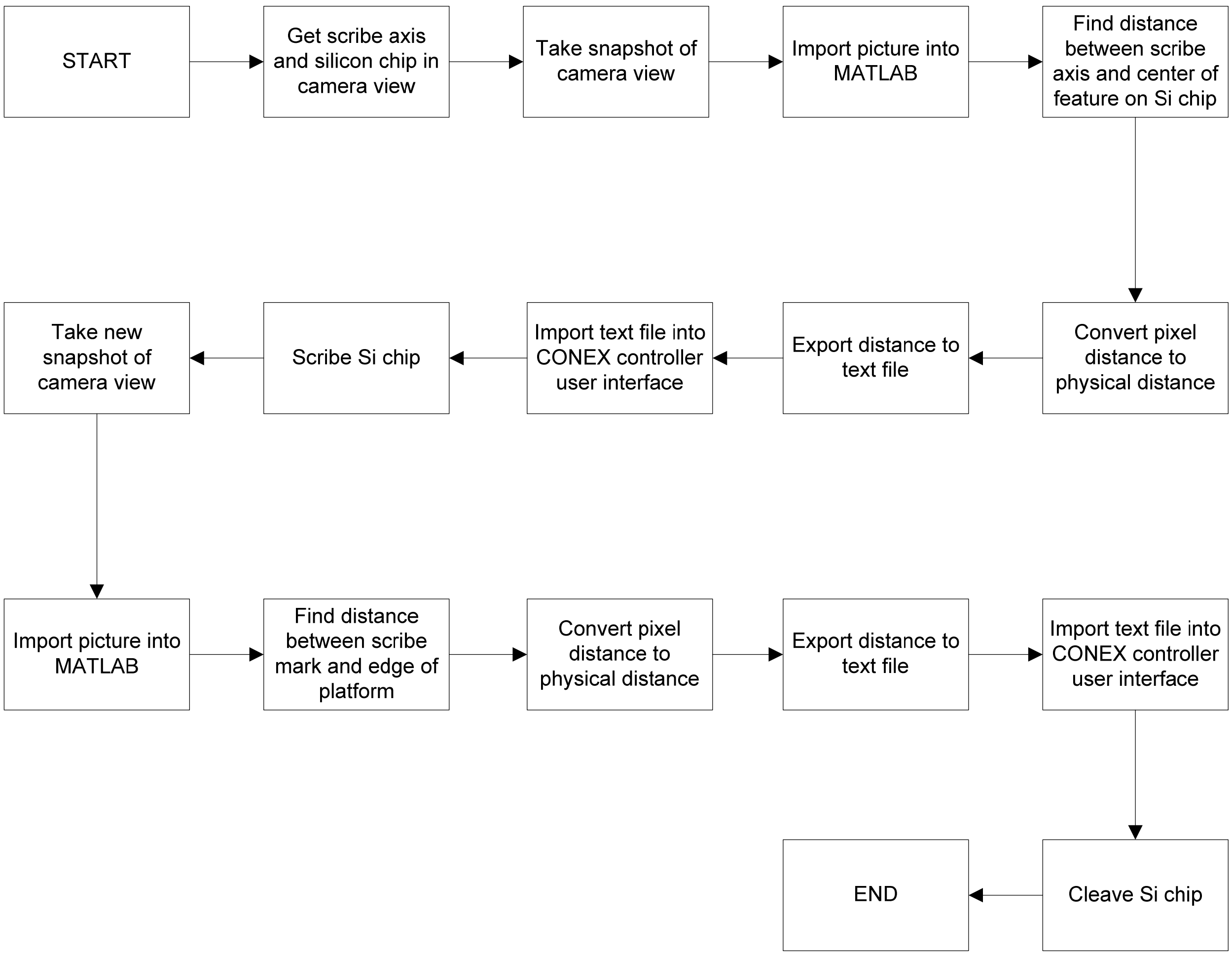

Michael Martin
Daniel Cherm
Design Team
Michael Martin
Design Team
Design Team
Daniel Cherm
Design Team
Task
Split
Progress
Milestone
Summary
Project Summary
External Tasks
External Milestone
Deadline
Project: Project1
Date: Wed 12/14/11
Page 1

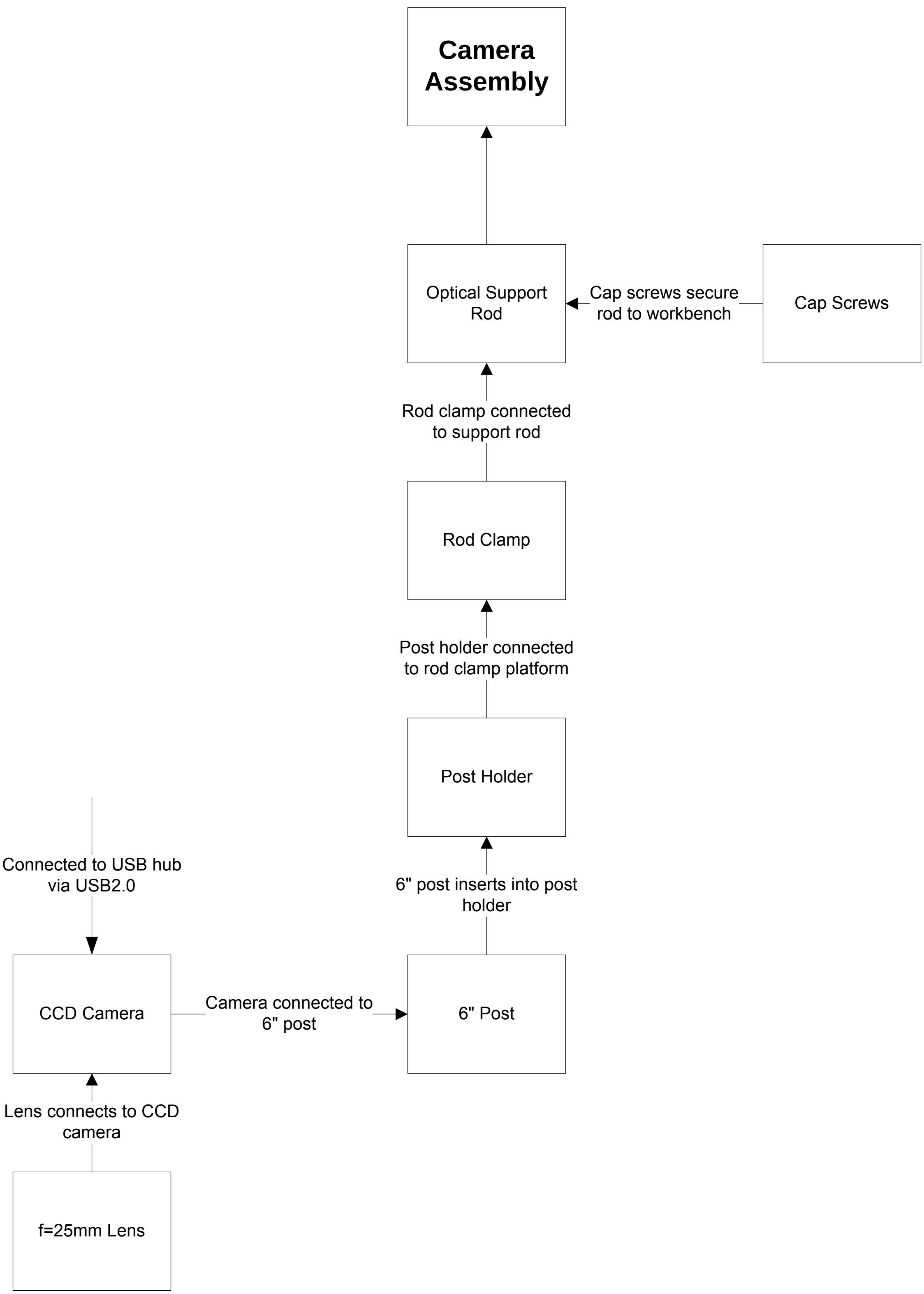
Bill of Materials

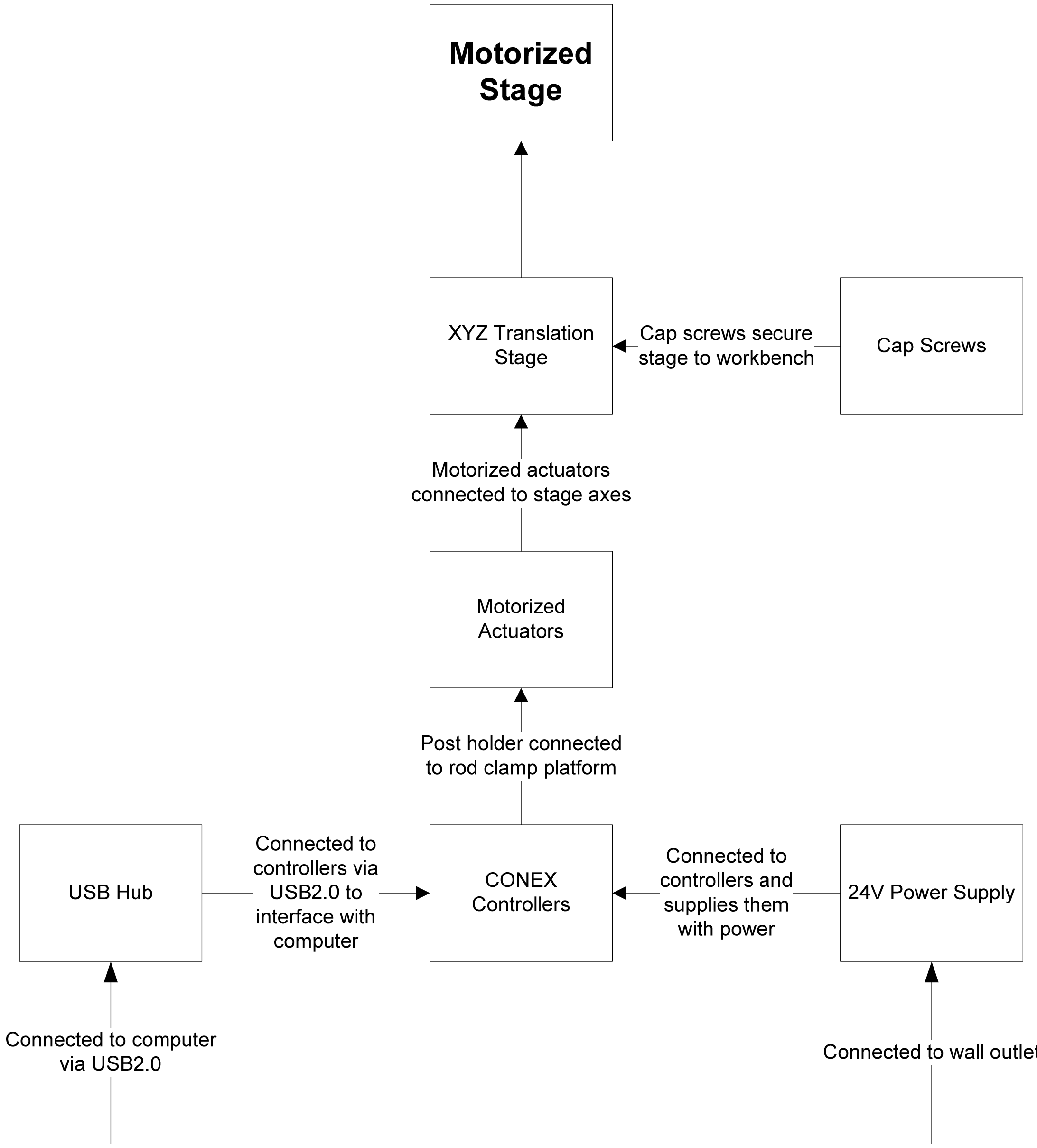
Components List						
Component	**Part Name**	**Manufacturer**	**Part Number**	**Quantity**	**Price per Unit**	**On Hand?**
Camera Setup	USB CCD Camera	Thor Labs	DCU223M	1	$ 1,570.00	Y
	25mm Fixed Focal Length Lens	Edmund Optics	NT59-871	1	$ 295.00	N
	14" Optical Support Rod	Newport	45	1	$ 199.99	Y
	Rod Clamp	Newport	340-RC	1	$ 69.99	Y
	Post Holder	Thor Labs	PH2	1	$ 7.70	Y
	6" Post	Thor Labs	TR6	1	$ 6.77	Y
	8" Post	Thor Labs	TR8	1	$ 8.12	Y
	Right Angle Post Clamp	Thor Labs	RA90	1	$ 9.48	Y
	1/4"-20x3/4" Cap Screw	Thor Labs	N/A	4	N/A	Y
	1/4"-20x3/4" Set Screw	Thor Labs	N/A	1	N/A	Y
	#8-32x1/2" Set Screw	Thor Labs	N/A	1	N/A	Y
Motorized Stage	Actuator with CONEX Controller	Newport	TRA25CC	2	$ 995.00	N
	CONEX 24V Power Supply	Newport	CONEX-PS	1	$ 65.00	N
	XYZ Axis Translation Stage	Newport	9064-XYZ	1	$ 878.88	Y
	1/4"-20x3/4" Cap Screw	Thor Labs	N/A	4	N/A	Y
	1 inch Rotational Stage	Newport	RSP-1T	1	$ 89.99	Y
	Fixed Filter Mount (Used as Chip Clamp)	Edmund Optics	NT54-996	1	$ 39.99	Y
	1.5" Optical support rod	Thor Labs	TR1.5	1	$ 4.99	Y
Platform	1-inch motion Translational stage	Thor Labs	PT1	2	$ 246.00	Y
	90^0 Angle Bracket	Newport	9101NF	1	$ 161.76	N
	90^0 Angle Base Holder	Newport	360-90	1	$ 69.99	Y
	1/4"-20x3/4" Cap Screw	Thor Labs	N/A	8	N/A	Y
	L-Shape General Purpose Table Clamp	Thor Labs	CL5	1	N/A	Y
Scribe	12'x12' Aluminum Breadboard	Thor Labs	MB12	1	$ 161.10	Y
	90^0 Angle Base Holder	Newport	360-90	2	$ 69.99	Y
	2-inch Rotational stage	Newport	RSP-2T	1	$ 199.99	Y
	Rotational stage plug	Newport	RSA-1T1	1	$ 11.99	Y
	3 inch post holder	Thor Labs	PH3	1	N/A	Y
	Assorted Optical Support Rods	Thor Labs	ESK03	N/A	N/A	Y

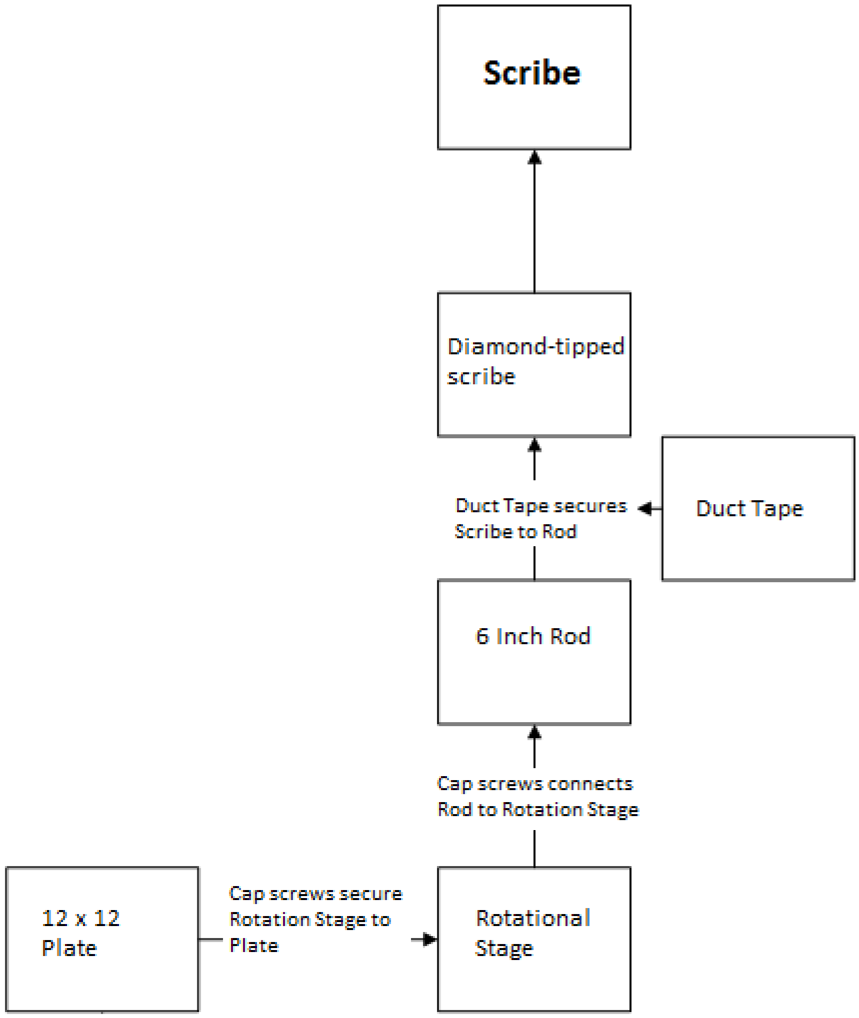
Miscellaneous	7-Port USB2.0 Hub	Macally	TriHub7	1	$ 29.99	N

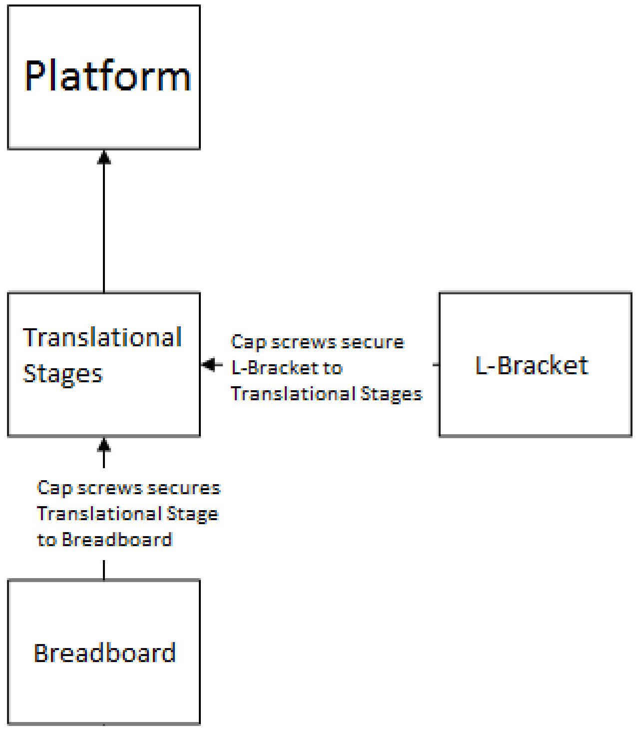
User Interface Flow




Camera Assembly
Optical Support Rod
Cap screws secure rod to workbench
Cap Screws
Rod clamp connected to support rod
Rod Clamp
Post holder connected to rod clamp platform
Post Holder
Connected to USB hub via USB2.0
6" post inserts into post holder
CCD Camera
Camera connected to 6" post
6" Post
Lens connects to CCD camera
f=25mm Lens


Motorized Stage
XYZ Translation Stage
Cap screws secure stage to workbench
Cap Screws
Motorized actuators connected to stage axes
Motorized Actuators
Post holder connected to rod clamp platform
USB Hub
Connected to controllers via USB2.0 to interface with computer
CONEX Controllers
Connected to controllers and supplies them with power
24V Power Supply
Connected to computer via USB2.0
Connected to wall outlet


Scribe
Diamond-tipped scribe
Duct Tape secures Scribe to Rod
Duct Tape
6 Inch Rod
Cap screws connects Rod to Rotation Stage
12 x 12 Plate
Cap screws secure Rotation Stage to Plate
Rotational Stage


Platform
Translational Stages
Cap screws secure L-Bracket to Translational Stages
L-Bracket
Cap screws secures Translational Stage to Breadboard
Breadboard

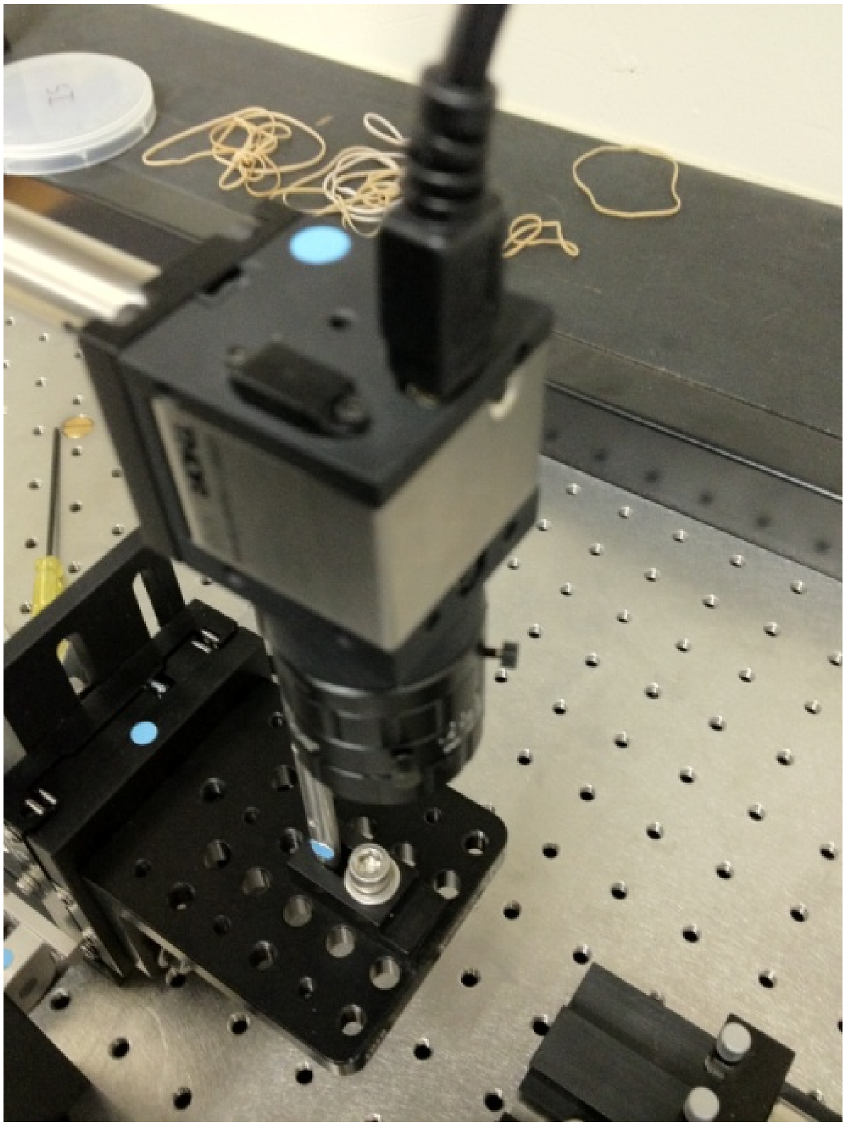
FMEA Table

Project Name:	Silicon Chip Cleaving Tool									
Team Member 1:	Mike Martin									
Team Member 2:	Daniel Chern									
Item or Function	Potential Failure Mode	Potential Failure Effects	DELT	SEV [1-5]	Potential Causes	OCC [1-5]	Detection Methods	DET [1-5]	RPN [1-125]	Required Action
During operation, the design must not drop the chip	Partial failure, chip drops from any elevated object	Dropping the chip could cause complete loss of chip and feature	No	4	Dropping while manually or mechanically handling at any point of cleaving process	3	Visual inspection	1	12	Correct part of cleaving process that dropped the chip so that it doesn't happen again
During operation, the design must not shatter the chip	Complete failure, chip shatters from cleaving	Shattering the chip will cause complete loss of the chip and feature	No	5	Too much or incorrect pressure applied on chip while scribing or breaking	2	Visual inspection	1	10	Correct part of cleaving process that shattered the chip so that it doesn't happen again
During operation, the design must not miss cleaving the feature on the chip	Complete failure, cleave completely misses feature	The objective of the design will not be met	No	5	Design has been disturbed so that it is no longer aligned	2	Visual inspection	2	20	Re-calibrate the design so that it doesn't happen again

During operation, any mechanical components of the design fail to operate properly	Partial failure, any of the mechanical components to operate so that the design cannot be operated	Design will not work properly and chips cannot be cleaved	No	4	Any of the mechanical components fail either through loss of power or malfunction	2	Visual inspection or sensors/visual indicators on some parts	2	16	Inspect components or power source to find problem and correct based on situation
During operation, any user interface components of the design fail to operate properly	Partial failure, any of the user interface components to operate so that the design cannot be operated	Design will not work properly and chips cannot be cleaved	No	4	Any of the user interface components fail either through loss of power or malfunction	2	Visual inspection or sensors/visual indicators on some parts	2	16	Inspect components or power source to find problem and correct based on situation
During operation, the user fails to operate the design properly	Failure level dependent on misuse of the design	Design will not work as intended by the designers	No	3	User is not familiar with design or is negligent of features of the design	2	Visual inspection of design components or cleaving results	1	6	Instruct or inform user on proper use of the design

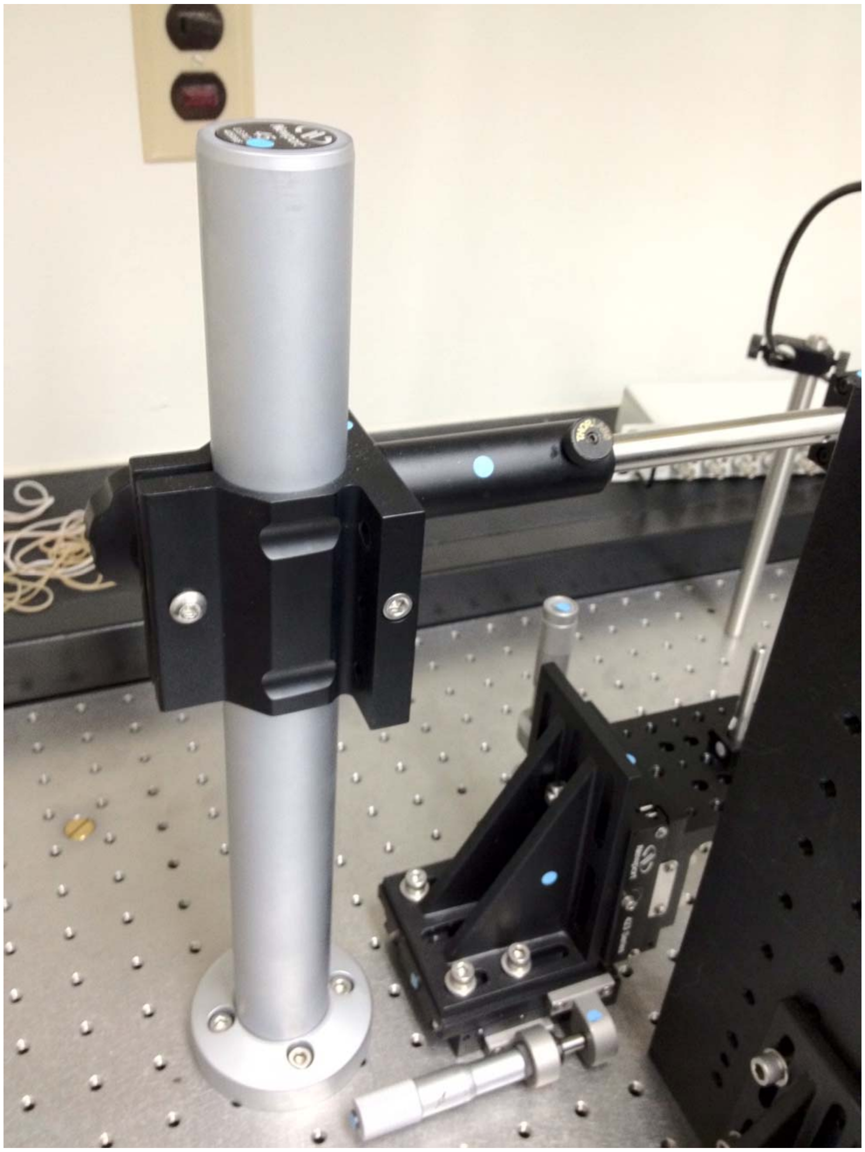
Mechanical Layout

Platform



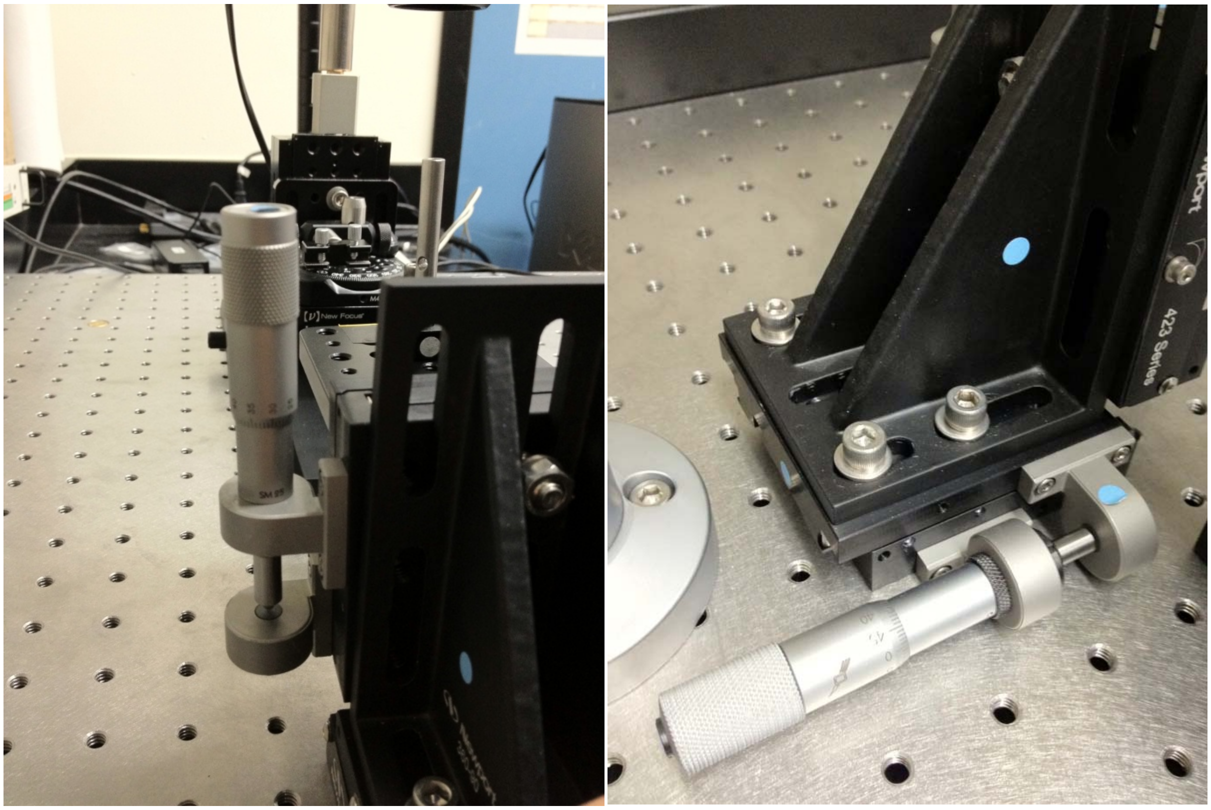
Img P1: Layout of Platform

The platform is mounted on an L bracket which is attached to the base. A 90^{o} plate is used as the platform. The clamp is made using a small base plate that is screwed into 1 of the threaded holes on the platform.



Img P2: Camera Mount

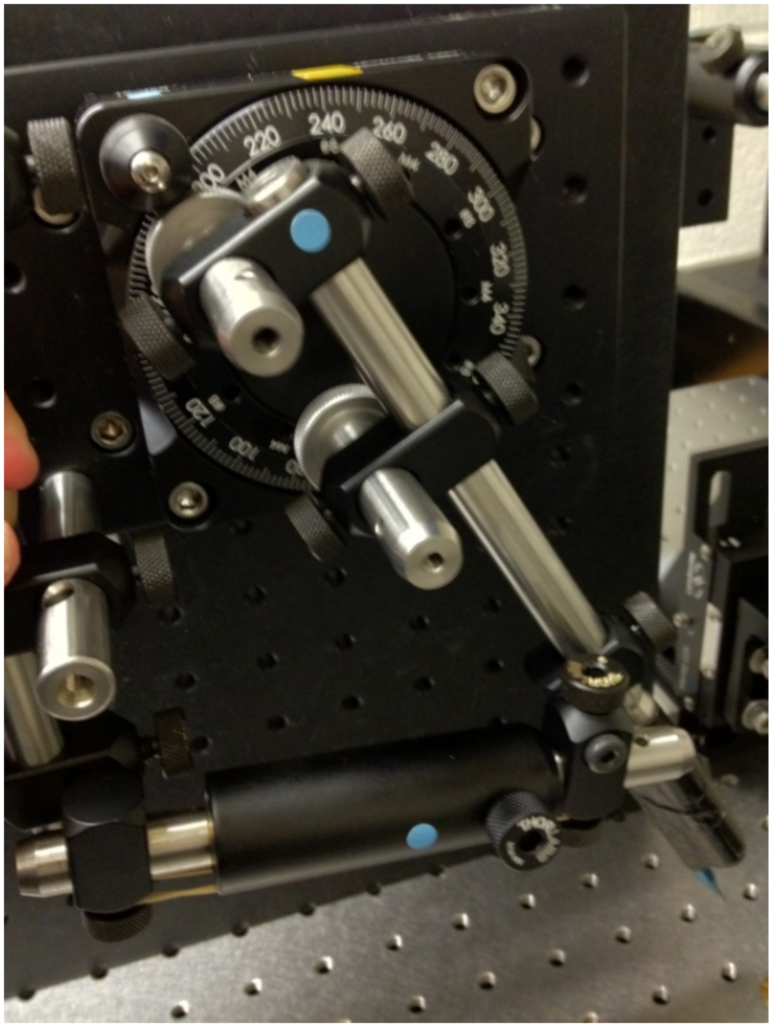
The Camera is mounted on the above post. It is secured to the base behind the platform. This placement was chosen because it allows the user to align the camera to the center of the platform with minimal error.



Img P3: Translational Stages on Platform

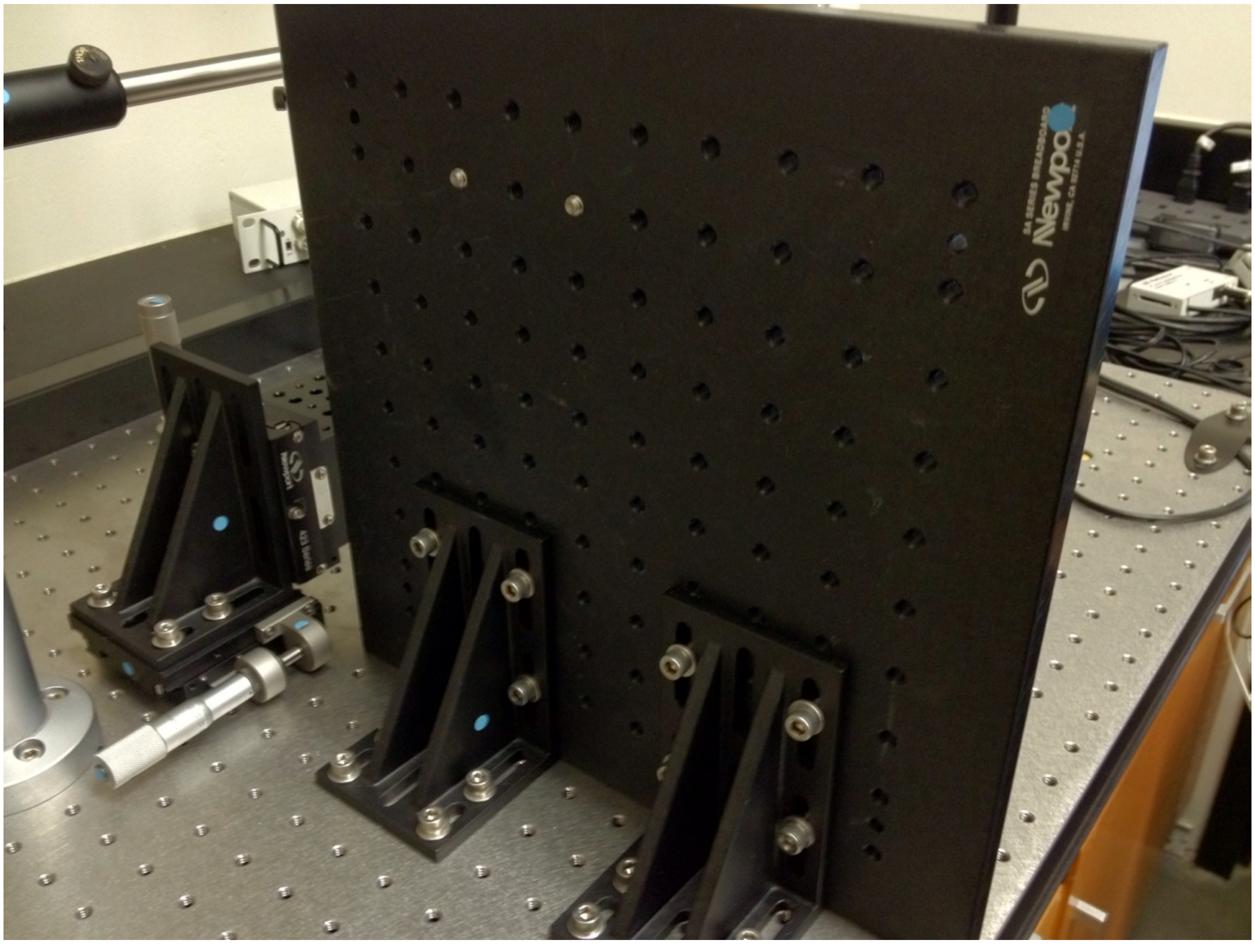
2 translational stages were used on the platform, one for the height axis and one for the length axis. These stages allow the user to align the stage to the clamping arm height and the scribe scribe position respectively. This then reduces the need to move the clamp height or the scribe.

Scribe



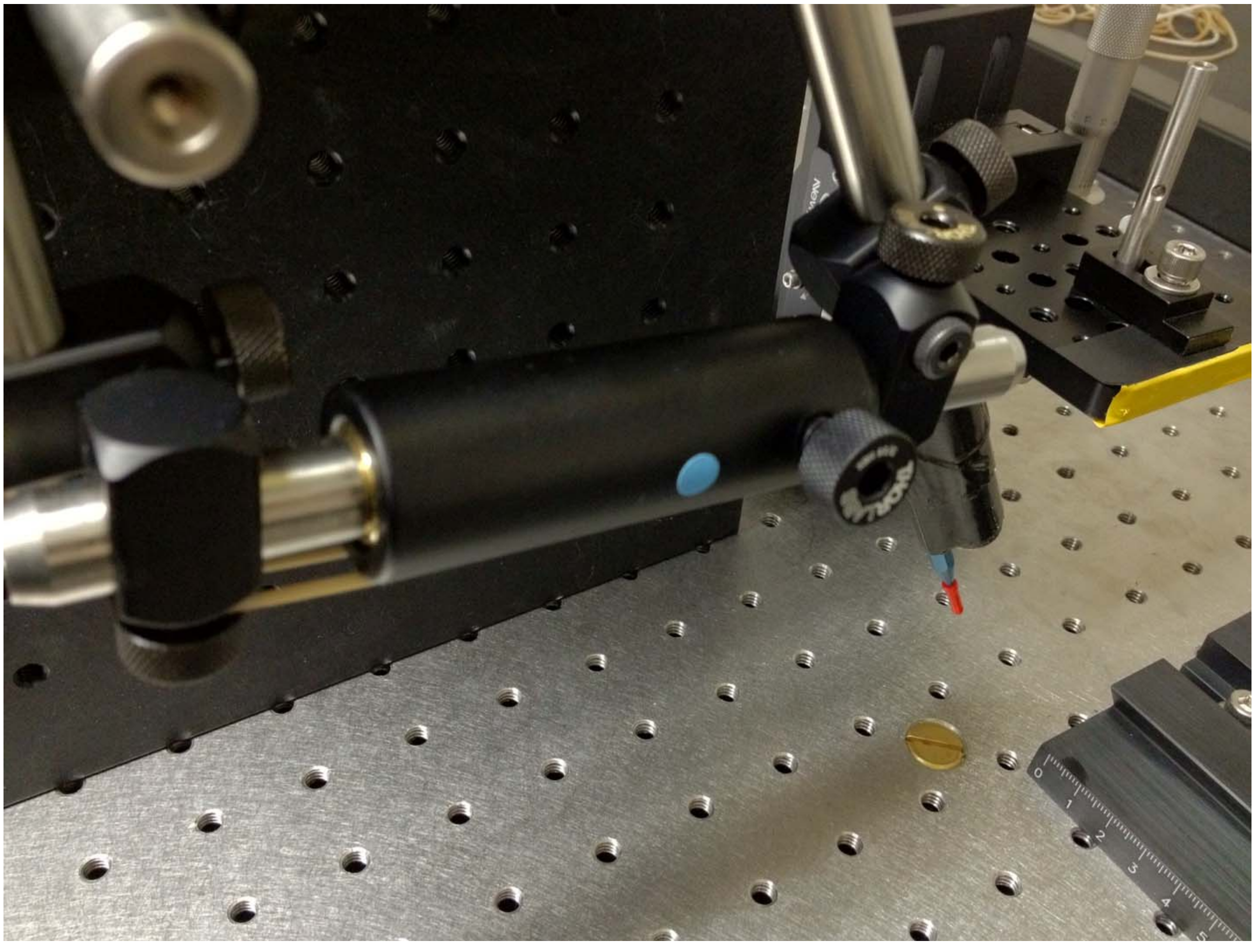
Img S1: Layout of the scribe

The scribe is mounted on a 12 x 12 plate that is secured to the base. The angular motion of the scribe is controlled by a rotational stage. The scribe is secured to the rotational stage using optical support posts and joints. The lateral motion is controlled by a 2 inch motion translational stage. The rotational axis is attached to the translational stage.



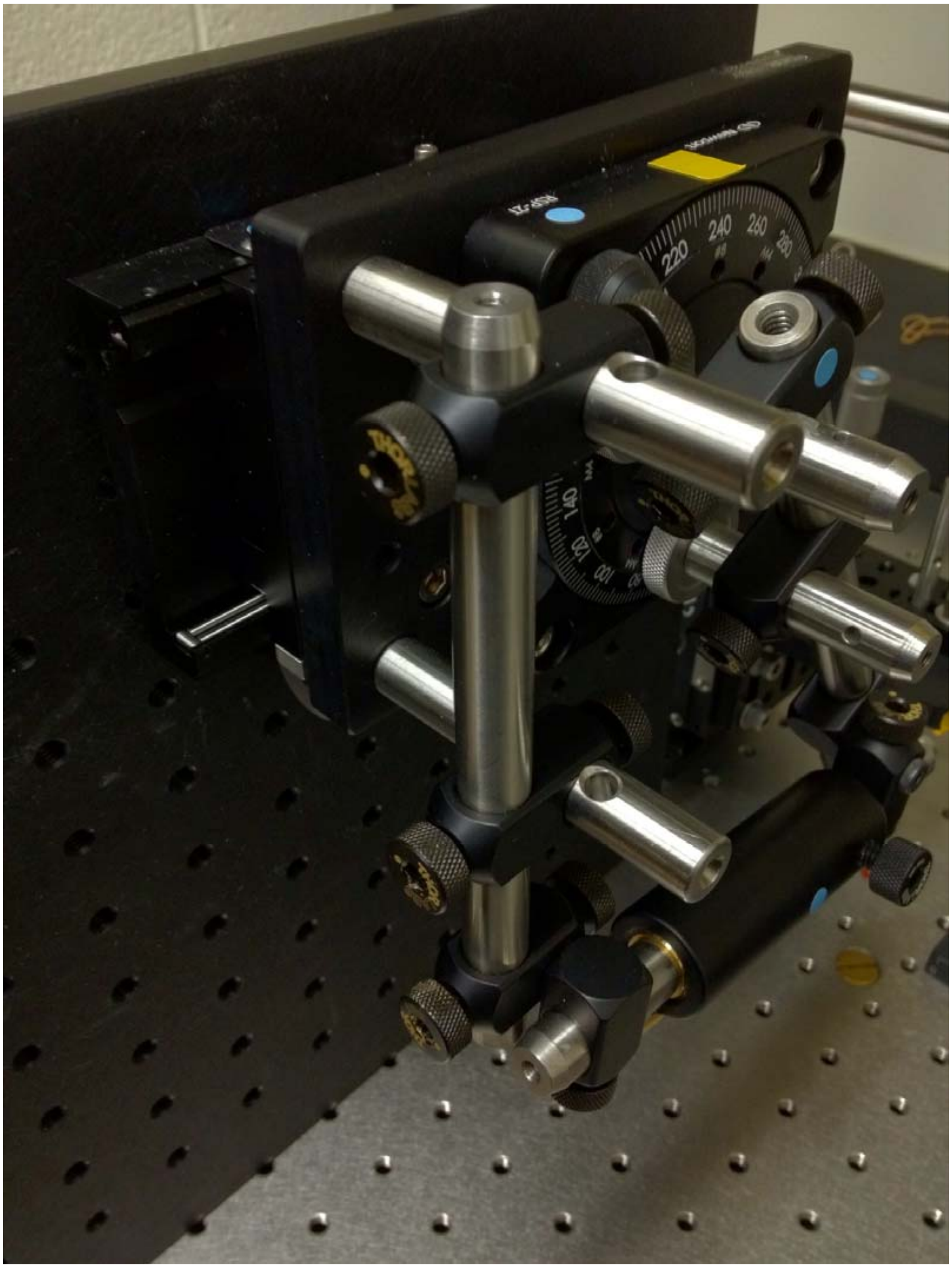
Img S2: Back view of scribe

The plate is attached to the base using 2 base holders and cap screws. These base holders ensure that there is no wobble from the system. The screws on the upper part of the plate show where the translational stage is mounted on it.



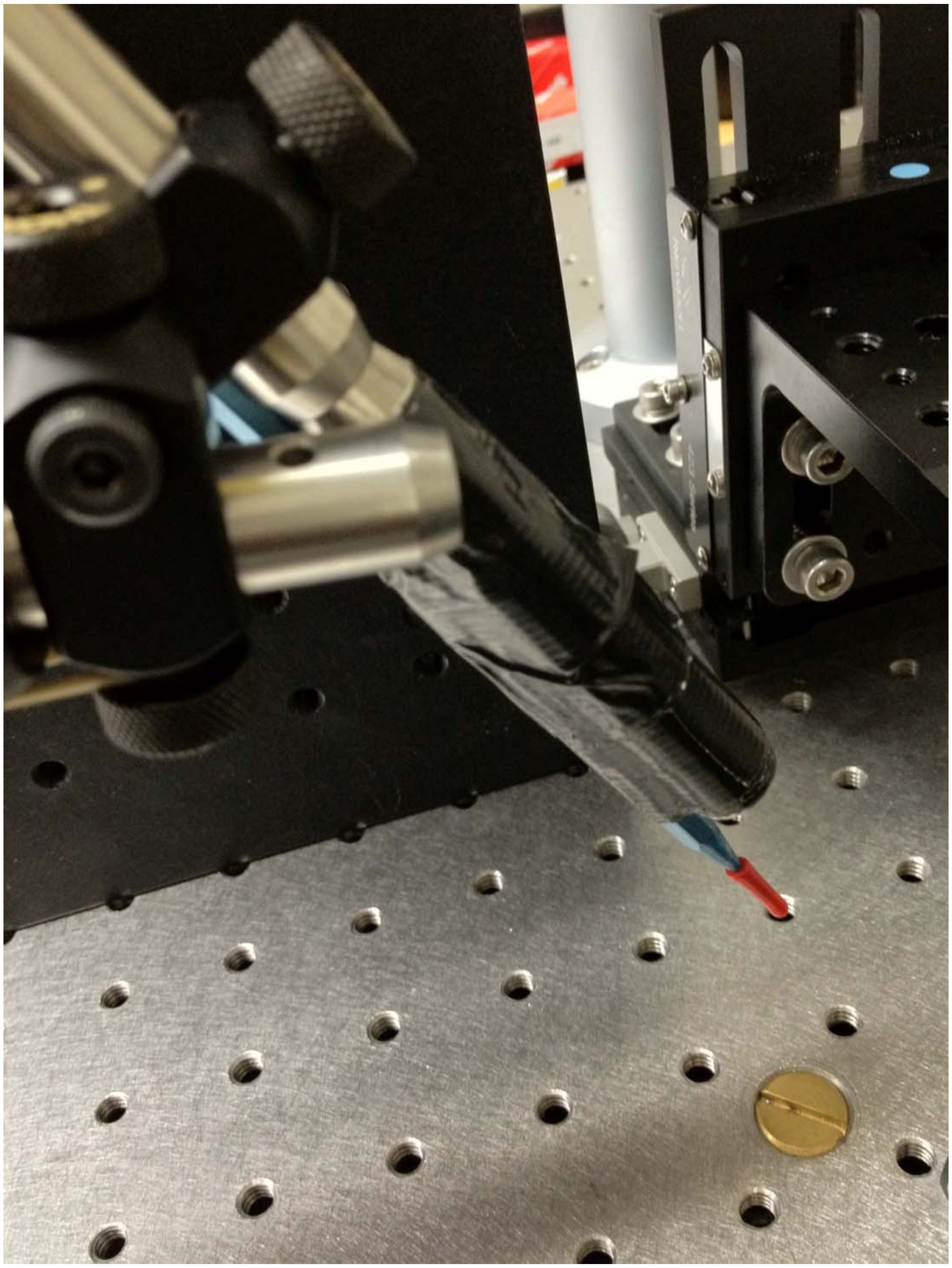
Img S3: Locking Mechanism

The locking mechanism prevents the scribe from hitting the platform after scoring the chip. It was made using a 3 inch post holder with a screw lock. A 1 inch post was attached to the bottom of the post holder. Rubber bands were used to pull the scribe toward the base position.



Img S4: Translational Stage

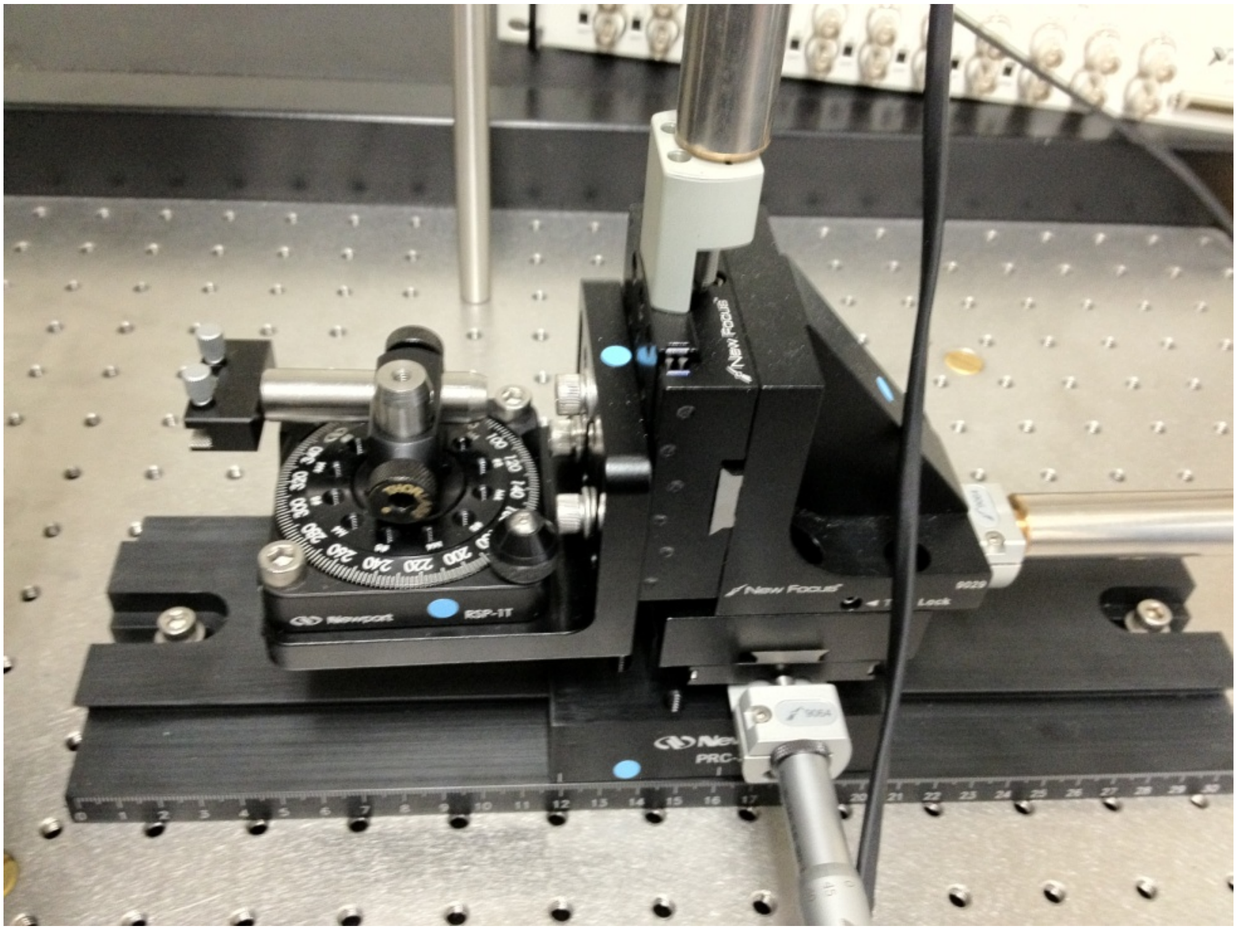
The translational stage holds the entire system for the scribe. The picture above shows how the locking mechanism is attached to the translational stage, as well as the rotational stage.



Img S5: Diamond tipped scribe

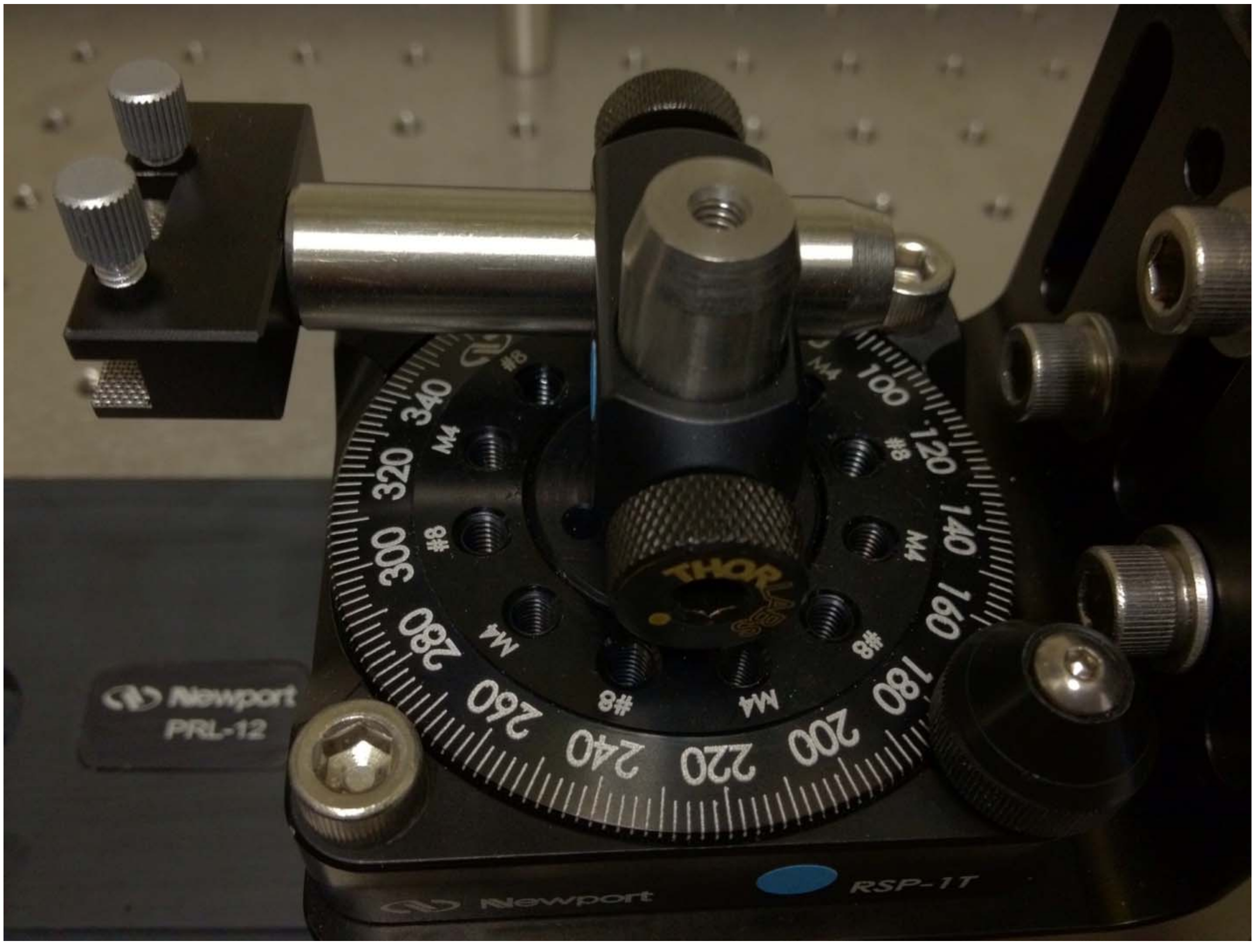
The diamond tipped scribe is attached to the system using duct tape.

Clamping Arm



Img C1: Layout of the Clamping Arm

The clamping arm consists of an XYZ translational stage that is controlled by 2 motorized micrometers on the height and length axes, and a manually controlled micrometer on the final axis. These stages are mounted on a translational rail so that it is easier for the user to mount the chip onto the clamp. The clamp is mounted on a rotational stage that is mounted on a 90^{o} base.



Img C2: Chip Clamp

The chip clamp is mounted onto a rotational stage. This was done using a rotational stage plug to match the screw size, and suing 2 optical support posts and a joint to mount it.