# OptoCheck

## Automated Optical Inspection of Laser Components

### ELECOMP Capstone Design Project 2019-2020

***Iradion Laser is continuing their support of the Program for the 3rd consecutive year:***

*https://web.uri.edu/elecomp-capstone/project-details-by-team/iradion/*
*https://web.uri.edu/elecomp-capstone/project-details-by-team-2018-2019/iradion-autolase/*
*https://web.uri.edu/elecomp-capstone/project-details-by-team-2018-2019/iradion-lasimo/*

***(Team Lasimo won the 4th Prize at the Summit on May 10, 2019)***

## Sponsoring Company:


**Iradion Laser, Inc.**
1 Technology Drive, Uxbridge, MA 01569
http://www.iradion.com


## Company Overview:

Iradion Laser, Inc. is focused on the design and manufacturing of patented, RF excited, ceramic core $CO_2$ lasers. The technology is derived from sophisticated military, aerospace and atmospheric monitoring systems and has been commercialized to serve the wider industrial laser market. Iradion's $CO_2$ laser products are available with power ranging from 30 to 250 W. Applications include direct materials processing (cutting, welding, marking, coding and drilling) as well as select processes in the medical and semiconductor fields. Iradion distributes products worldwide through direct sales and representative organizations. Iradion Laser, Inc. is incorporated in Delaware, USA with corporate headquarters and manufacturing facility in Uxbridge, MA, USA.

## Technical Director:

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## Project Motivation:

Laser light is produced by stimulated emission of photons within an energized medium. Mirrors positioned at opposing boundaries of the medium are used to provide optical feedback, which is required for stimulated emission. Together, the energized medium and end mirrors form a laser resonator, or laser cavity, that can produce an extremely bright and well collimated beam of light. Optimal laser performance can only be achieved, however, when the mirrors are positioned and aligned to within a few microns of the design dimensions. Errors in mirror position or alignment will degrade power, mode quality and operating reliability of the laser.

Iradion manufactures thousands of industrial $CO_2$ lasers per year. Price competition in the market means the laser components must have minimal cost, and this precludes designing in fine-tuning mechanisms for mirror position and alignment. Therefore, the manufacturing process and fixtures must provide sufficient precision and accuracy when building mirror assemblies to achieve the micron level requirements. In-process inspection is critical to checking mirror assembly quality, but it must be performed quickly, easily, and with high fidelity.

The aim of this project is to implement an optical inspection technique, i.e. a 3D scanner, to quantify mirror assembly errors during manufacturing of Iradion lasers. The effort will include defining the inspection criteria (resolution, field of view, etc.), selecting a cost-effective instrument, and creating a user-friendly software program to compare scanned parts to SolidWorks models of the assemblies. Critical dimensions must surpass pass/ fail criteria for each part to move forward in production. Ultimately, the product of this effort will be a functional inspection tool for Iradion's manufacturing staff.

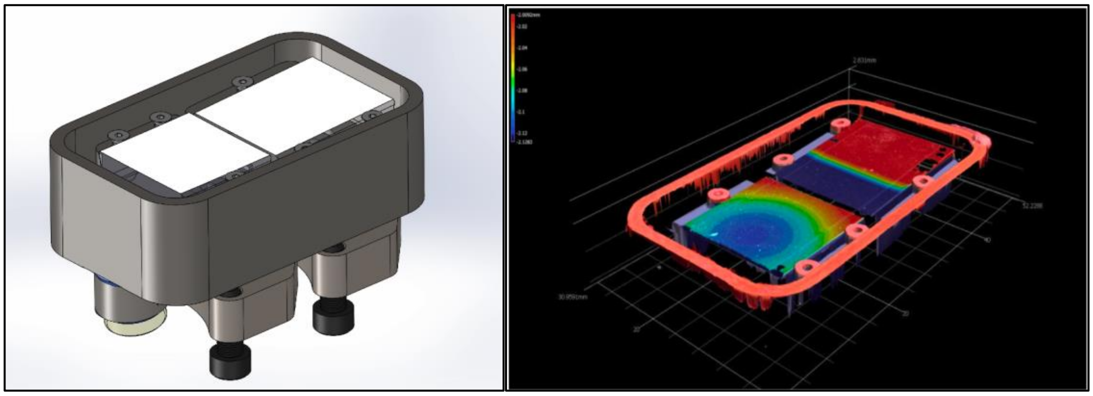
## Anticipated Best Outcome:

The anticipated best outcome would be an easy-to-use, table top optical inspection station that provides a go/no-go check of Iradion's production mirror assemblies. The team will use an off-the-shelf optical scanner and simple fixturing to hold each mirror assembly. The team's software must compare scanner data for each part to dimensions from the assembly mechanical model. If all measurements are within tolerances, a "Pass" indication shall be displayed. Conversely, out-of-tolerance parts shall invoke a "Fail" display. All measurements shall be saved to an electronic database. The anticipated best outcome will include demonstrating station functionality and providing training in its operation to Iradion staff.

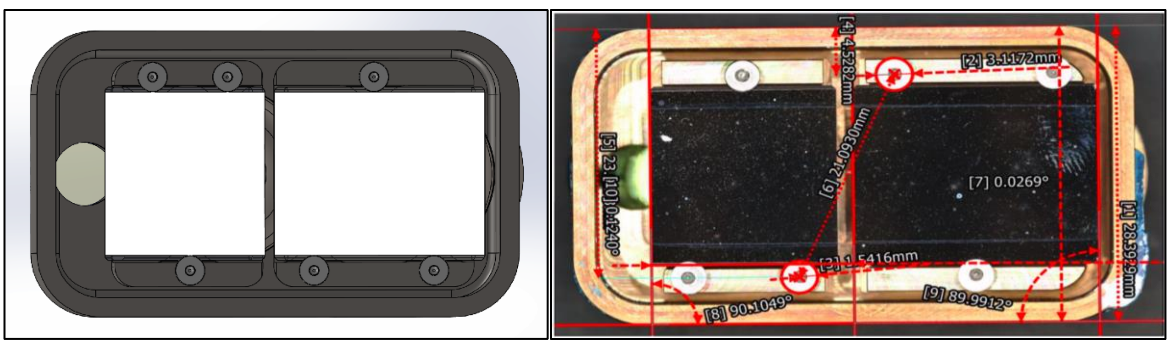
## Project Details:

The concept for the project is to build and program an easy-to-use inspection station for insuring Iradion production mirror assemblies meet mechanical design criteria. The first step will be to define the requirements for the optical scanner and identify candidate instruments to procure for the project. This may require interfacing with instrument makers and participating in their product demonstrations. The next step will be to create a software program that works with the designated scanner and Iradion's mechanical files for the mirror assemblies to perform comparisons of critical dimensions. The software must compute differences between actual part measurements and the mechanical design. Differences that exceed predetermined thresholds shall produce an alert to the user. The final step for the project will be to make the station user-friendly for Iradion manufacturing staff. This will include working directly with staff members and improving the station based on their feedback.

There are existing optical scanners and software packages that can perform the type of inspection tasks we are pursuing in this project. However, these platforms typically cost in the range of $100,000 per station and require customization for each process. The approach with this project is to utilize a much more cost-effective optical scanner along with original software to form a streamlined, dedicated inspection station for Iradion's production line. The figure below shows a SolidWorks drawing of a mirror assembly (left) and a 3D scan of the physical assembly (right) performed using a structured light canner. The assembly has two mirrors (white, rectangular parts) inside a stainless-steel housing (gray). The 3D scan shows the relative depth of the mirror surfaces, using the housing as a reference plane. This information could be used to check the angular alignment of the mirrors against design criteria.



The figure below shows the same part as above when viewing the front face. The 3D scan (right) includes multiple measurements for mirror position and angle relative to the metal housing. The correctly assembled part will have well-defined distance from metal edge to mirror edge, well-defined spacing between mirrors, and no clocking of the mirrors relative to the housing. The software developed in this project should import these dimensions and tolerances from the SolidWorks model, compare the real part measurements to the design criteria, and display an error report.




With assistance from the Iradion R&D staff, the project team will develop the inspection station and validate efficacy on at least three different types of mirror assemblies from Iradion laser products.

Some specific tasks that are anticipated for the project team are listed below.

**Mathematical tasks include:**

- Develop basic competency in optical inspection techniques, requirements, and limitations
- Apply these skills to specifying the optimal inspection station for Iradion mirror assemblies
- Analyze the results of optical inspection and address systemic measurement errors

**Software tasks include:**

- Develop competency in the 3D scanner operating system and handling image and mechanical model files
- Create the algorithms and write the programs (including GUI) for part measurement and comparison to mechanical model
- Test robustness of the inspection method against anticipated usage scenarios

**Experimental tasks include:**

- Develop basic hands-on 3D scanner operating competency
- Work with Iradion R&D staff to scan mirror assemblies and validate dimensional measurements
- Determine requirement and limitations for the operating environment and usage conditions for the inspection station

## Composition of Team:

2-3 electrical/computer engineers who will share the following duties. (Math minors preferred)

- Learning fundamentals of optical inspection techniques as well as understanding the state of the art in this technology area
- Evaluating 3D scanner options
- Operating the 3D scanner to acquire mirror assembly measurements
- Developing and validating the software that checks assembly dimensions against design tolerances
- Debugging the system
- Training Iradion staff in use of the inspection station

## Skills Required:

Successful completion of this project will require considerable creativity, analytical thinking and resourcefulness. The tasks will be multi-disciplinary in nature and will compel project engineers to work and communicate effectively with Iradion's laser scientists and mechanical engineers. It is anticipated that many new skills will be developed during the project execution, including how to execute 3D scanner measurements. Nonetheless, the specific skills listed below are necessary for the team to begin the project.

**Electrical Engineering Skills Required:**

- Knowledge of fundamental electromagnetism principles, including optical diffraction and interference
- Ability to keep a good laboratory notebook and record and process measurement data
- Discipline to follow general laboratory protocols for safety and proper use of precision equipment

**Computer Engineering Skills Required:**

- Solid grasp of algorithms and the fundamentals of computer science
- Competency in instrument/machine programming environments
- Some experience in creating simple graphical user interfaces

## Anticipated Best Outcome's Impact on Company's Business, and Economic Impact:

Iradion engineers have determined that part-to-part variations in the position and alignment of mirror assemblies are a critical factor in overall laser performance variation. Presently, our only option for inspecting these assemblies is to a primitive microscope and hand measurement tools. This method is both time consuming and prone to measurement error. With today's manufacturing process, mirror position errors are typically discovered once each laser is fully assembled and we observe degraded performance. At that point, it is not possible to rework the assembly to fix errors. This problem has a very real impact on our production yield.

The best outcome of the project will directly impact our ability to make our highest power laser products with predictable yield. We anticipate accelerated market demand for these higher power lasers. Hence, the mirror assembly inspection station will play a major role in Iradion company growth within the next year. It will furthermore automate a process that today is cumbersome and unreliable.

## Broader Implications of the Best Outcome on the Company's Industry:

$CO_2$ lasers are the oldest type of industrial laser, with high power laser cutting, welding and marking systems deployed in global factories for decades now. Nonetheless, we are in a renaissance period of new applications and new markets for $CO_2$ lasers. The emergence of fiber lasers for high power cutting has put performance and reliability pressures on $CO_2$ laser manufacturers. Simultaneously, the far infrared wavelength exclusively provided by $CO_2$ lasers has found broad appeal in brand new markets for lasers, such as high fashion fabric patterning and trimming plastic films for consumer electronics.

Many of the new applications require lower cost and higher power from $CO_2$ lasers. By eliminating variations that obscure other limitations in laser performance, the OptoCheck project will enable faster pace of advancement in laser design and ultimately lead to deeper understanding of fundamental laser performance. These improvements will make the technology more accessible to new applications and types of users. In the long run, we can see a future where $CO_2$ lasers become accessible to the average home improvement do-it-yourselfer.