AutoLase II

Automatic Laser Optimization and Production

ELECOMP Capstone Design Project 2018-2019

Sponsoring Company:

Iradion Laser, Inc.
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Iradion Laser is continuing their support of the Program they initiated last year
https://web.uri.edu/elecomp-capstone/project-details-by-team/iradion/

Team Iradion won 1st prize at the 2017 December ELECOMP Capstone Symposium and 1st prize *again* at the 2018 May ELECOMP Capstone Summit

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.

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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. Assembling a laser resonator with the required precision, however, can be a major challenge. The mirrors must be aligned with micrometer position accuracy and microradian angular accuracy. Even small errors in alignment will degrade key laser performance attributes, such as the power output from the laser and its spatial beam quality.

Currently, the mirrors in Iradion production lasers are adjusted for optimal power output and spatial beam quality by using long screwdrivers to turn a series of screws on the back of the mirror mount. Even for our simplest laser resonator designs, this task has proven to be tedious and prone to deficiencies. For our more complex resonators, the alignment process can take a full day, *or even multiple days*, to optimize the power output and spatial beam quality of the laser. This process is a **major bottleneck** in our manufacturing work flow.

The aim of this project is to design and implement a production-ready workstation (hardware and software) to automate the process of adjusting mirrors for optimal laser attributes. The workstation will furthermore automatically align resonator mirrors at the global maxima in laser performance parameter space.

Anticipated Best Outcome:

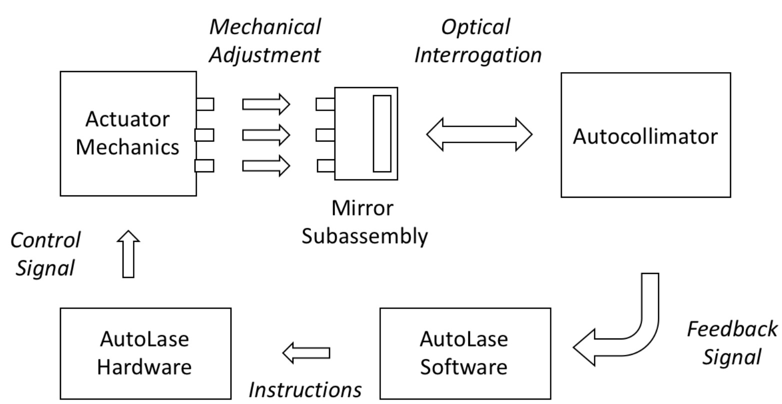
The anticipated best outcome would be to advance software and hardware into a production-ready workstation that will automate the alignment of mirrors such that (i) power output and (ii) spatial beam quality of the laser beam are optimized to their global maxima.

Project Details:

The concept for the project is to automate and advance a process for aligning laser resonator mirrors for Iradion production lasers. AutoLase, the initial project executed during 2017-18, successfully developed a prototype apparatus and control system to align mirror subassemblies using an autocollimator. AutoLase II, the present project, will achieve two primary goals:

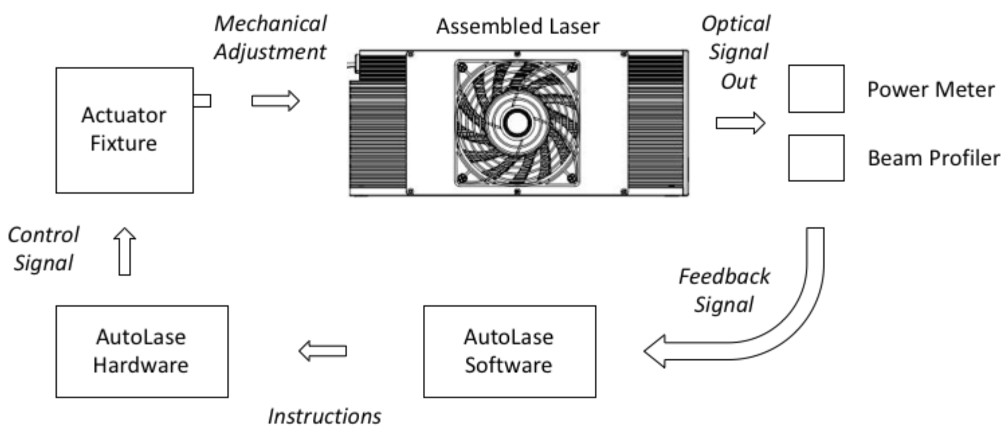
1. Develop a production-ready version of the mirror subassembly alignment set up.
2. Advance the concept to function for full laser optimization.

The functional concept for goal 1 is illustrated in the figure below. Today, a trained technician can align mirror subassemblies using graphical feedback from an autocollimator device. The technician will manually turn adjustment screws to align the mirror pitch and yaw angles until the autocollimator display shows coincidence of crosshairs on their target. In contrast, the AutoLase apparatus utilizes feedback signals from the autocollimator to perform calculations and create control signals to direct motorized actuators to adjust mirror pitch and yaw screws.



The AutoLase apparatus demonstrated to-date comprises a prototype version capable of proving the concept. The AutoLase II apparatus shall comprise a production-ready form factor that is easy to use for a qualified operator and sufficiently robust to require only infrequent maintenance and calibration. Defining these requirements in detail will be part of the initial phase of the project.

The concept for goal 2 is displayed in the figure below. In Iradion's standard production workflow, a trained technician will manually turn adjustment screws to align the mirror pitch and yaw angles while monitoring laser power and beam cross section mode profile. The task is iterated until criteria for output power and beam mode quality are simultaneously achieved. It is anticipated that the AutoLase II system will be capable of automating this laser optimization process as well. The system will have to be advanced to utilize alternative feedback signals (power meter and beam profiler).



In addition to working with alternative feedback signals and being compatible with assembled laser form factor, the AutoLase II system will have to incorporate parameters such as torque goals and limits for the adjustment screws and safe tuning ranges for mirror pitch and yaw. These are heuristics that Iradion technicians have learned empirically to avoid damaging components or severely misaligning the laser. They must be distilled down to control algorithms.

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

Mathematical tasks include:

- Model the laser beam and other laser attributes as control system parameters
- Understand the laser attribute interdependencies and trade-offs
- Model the effects of mirror adjustments on each laser attribute

Software tasks include:

- Develop algorithms for screw adjustment to achieve optimized laser attributes and implement in appropriate programming environment
- Develop software interfaces between AutoLaser components, laser control card and metrology instruments
- Optimize software for efficiency and consistency

Hardware tasks include:

- Research applicable components (motors, sensors, etc.) for precise rotary movement of screws
- Build the electro-mechanical apparatus to accept instructions from software and create appropriate pitch and yaw of mirrors
- Validate apparatus in Iradion production environment, e.g. using Gauge R&R analysis

Composition of Team:

Two electrical/computer engineers (double major) who will share the following duties:

- Learning laser physics and laser beam attributes
- Advancing and/or revising the preliminary model for how attributes relate to screw adjustment
- Optimizing and/or revising the alignment algorithms
- Specifying, assembling and testing actuator hardware
- Integrating, debugging and installing the full automated mirror alignment workstation

Skills Required:

Successful completion of this project will require considerable creativity, analytical thinking and resourcefulness. The tasks will be multidisciplinary in nature and will compel the capstone designers to work and communicate effectively with Iradion's laser scientists, mechanical engineers and manufacturing technicians. It is anticipated that many new skills will be developed during the project execution, including how to handle and align laser optical resonators. Nonetheless, the specific skills listed below are necessary for the team to begin the project.

Electrical Engineering Skills Required:

- Knowledge of analog and digital circuit design principles
- Ability to assemble and test PCBs, motors and support equipment
- Discipline to follow general laboratory and production floor protocols for safety and proper use of precision equipment, including working in a Class 10,000 clean room

Computer Engineering Skills Required:

- Solid grasp of algorithms and the fundamentals of computer science
- Competency in C#, FPGA programming and use of serial UART line communications
- Some experience in both object-oriented programming and low-level programming

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

Iradion's current production process utilizes manual mirror adjustment to optimize laser parameters. This process step represents a critical bottleneck that limits our efficiency and scalability of manufacturing lasers. In addition, the manual process imposes some degree of variability in unit-to-unit laser performance.

We anticipate that implementation of the production-ready automated mirror alignment workstation will remove this bottleneck from our manufacturing process, thereby substantially increasing the number of lasers we can produce each year. We furthermore anticipate the automated process will improve unit-to-unit consistency in terms of power and spatial beam quality. Greater consistency is a key competitive advantage in the CO_2 laser market and should enable new customer capture.

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 consistency from CO_2 lasers. We expect that the present AutoLase II project will enable much greater manufacturing efficiency and determinism, thereby reducing the price and increasing the efficacy of these valuable photons. In the long run, we can see a future where CO_2 lasers become accessible to the average home improvement do-it-yourselfer.