Senior Design-II – CREOL Showcase Competition [CREOL Showcase Project Summary Form]

CREOL, The College of Optics and Photonics

Project Summary

Page limit: 1

Project Title: OpenSense V3 - Simplifying Sensors for Educational Experimentation

Team/Group number: 1

Team members' names and majors: Brandon Collins (CE), James Eyler (CE), Daniel Gonzalez (CE), Noah Wilfond (EE/PSE)

Senior design advisors (if any)**:** Dr. Borowczak, Dr. Maddox, Dr. Parto

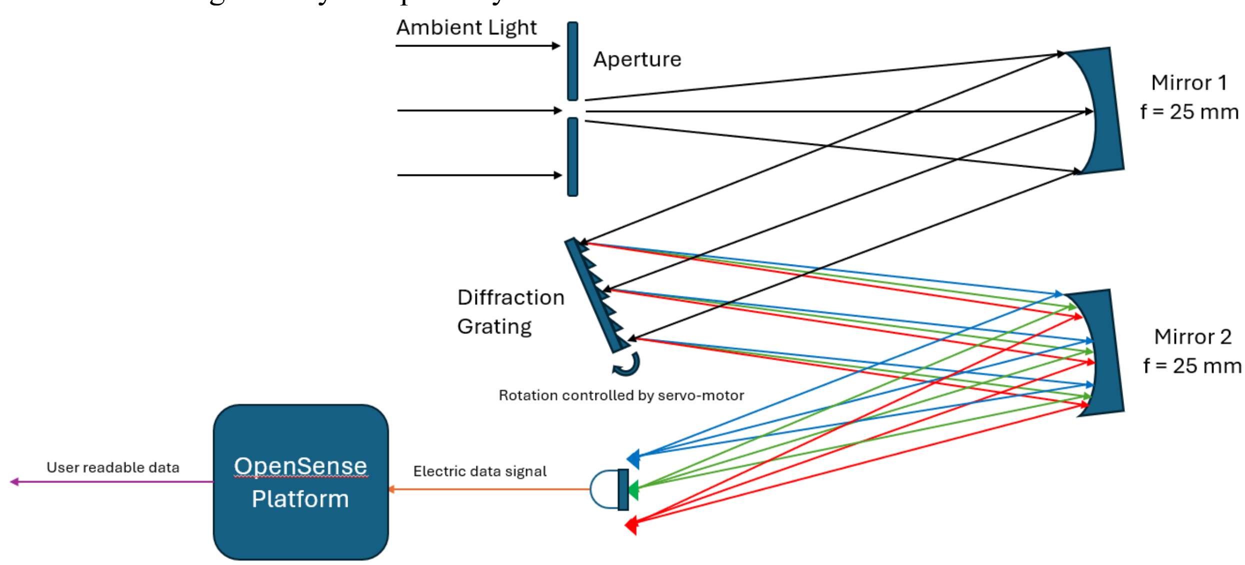
Sponsor of your project (if any): D.R.A.C.O Lab @ UCF

You may invite your advisor(s) and sponsor(s) to the Showcase Competition.

Project Summary (300 words maximum, Times New Roman Font, Size 11, Single space): State the project goals, objectives, optical designs that you have done to build your system, applications of your system, and how your system is better than the existing products used for similar applications.

OpenSense v3 is an open-source, low-cost, and customizable sensor platform designed to solve a major problem in education and prototyping: most commercial sensor systems are expensive, closed-source, and limited to pre-defined configurations that conceal internal logic and restrict customization. Our goal is to provide an accessible, transparent, and extensible alternative for students, educators, and developers to build, configure, and understand real-world sensing systems. The platform is built around an ESP32-WROOM microcontroller, and supports up to five sensors simultaneously, including both I2C and analog devices, at 3.3V operation with two ports also offering a 5V source. The system features onboard microSD data logging in CSV format, wireless connectivity, and a browser-based user interface for configuring sensors, viewing live data, and downloading measurements. A key advantage over commercial platforms is the hybrid driver model, which allows users to integrate new sensors through parameterized configuration without modifying core firmware. To demonstrate the platform's capabilities, a Czerny-Turner reflective optical monochromator was developed targeting a 300–800 nm spectral range with a resolution of ≤ 5 nm. The optical design uses concave mirrors for collimation and focusing, a 1200 lines/mm holographic diffraction grating to disperse incident light, and a servo-driven grating rotation to scan wavelengths sequentially. A PIN photodiode and transimpedance amplifier convert light intensity to a readable voltage, with angle-to-wavelength mapping derived from the grating equation. The resulting spectral and position data are transmitted to the OpenSense platform over I^2C, where the parameterized sensor driver maps each intensity reading to its corresponding wavelength to reconstruct the full optical spectrum. This integration highlights how the platform's architecture can support sophisticated, domain-specific sensing applications. These qualities make OpenSense v3 a compelling tool for K–12 STEM education, university labs, field data collection, and rapid prototyping, helping users understand how sensing systems work while encouraging hands-on innovation.

Provide a schematic diagram of your optical system:



Senior Design-II – CREOL Showcase Competition [CREOL Showcase Project Summary Form]

CREOL, The College of Optics and Photonics

Project Summary

Project Title: Fabric Laser Cutting System (F.L.C.S)

Team/Group number: 2

Team members' names and majors: Jacqueline Harper (PSE), Michael Rodriguez (PSE), Nolphky Nicolas (CPE)

Senior design advisors (if any)**: Saleem Sahawneh, Dr. Peter Delfyett, Professor Maddox, Suboh Suboh**

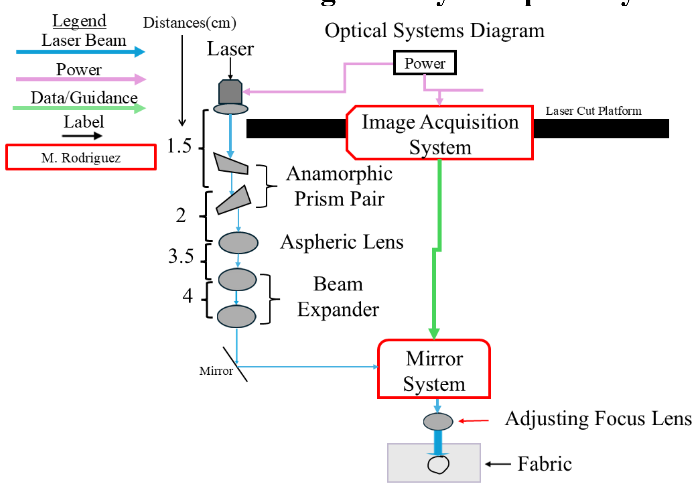
Sponsor of your project (if any): N/A

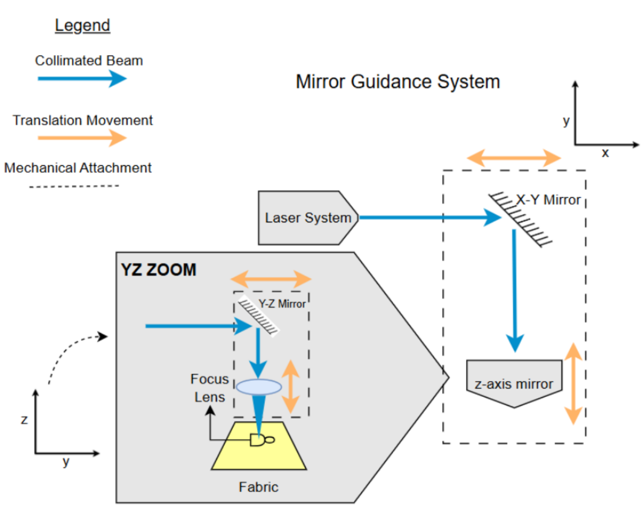
Project Summary :

F.L.C.S. aims to be a solution solver. This project proposes the design and implementation of an accessible, highly reliable fabric laser cutting system intended to transform how individuals or small organizations approach textile fabrication without the need for technical knowledge. Unlike other laser cutters on the market, ours uses an image acquisition system to identify hand-drawn shapes on the fabric to cut out and keeps the laser stationary, opting to use a mirror system to direct the beam instead of moving the laser. Our system will be able to identify lines drawn on fabric within 1 minute of the fabric being shown. We aim to cut fabric with a kerf width size less than .5 millimeters by manipulating the beam via a lens and a mirror system. The lens system will correct the beam shape and expand the beam prior to reflecting off of highly reflective dielectric mirrors in the mirror gantry system and the final aspheric lens, focusing the light into a small spot on the fabric. The lens system is composed of an anamorphic prism pair and 3 lenses, two of which create a beam expander.

Our project also features an easy to use touchscreen that allows users to choose whether they would like to cut white lines on dark fabric or black lines on light fabric. The touchscreen will also feature preset settings that correspond to different types of fabric such as felt, cotton, and denim.

Provide a schematic diagram of your optical system:

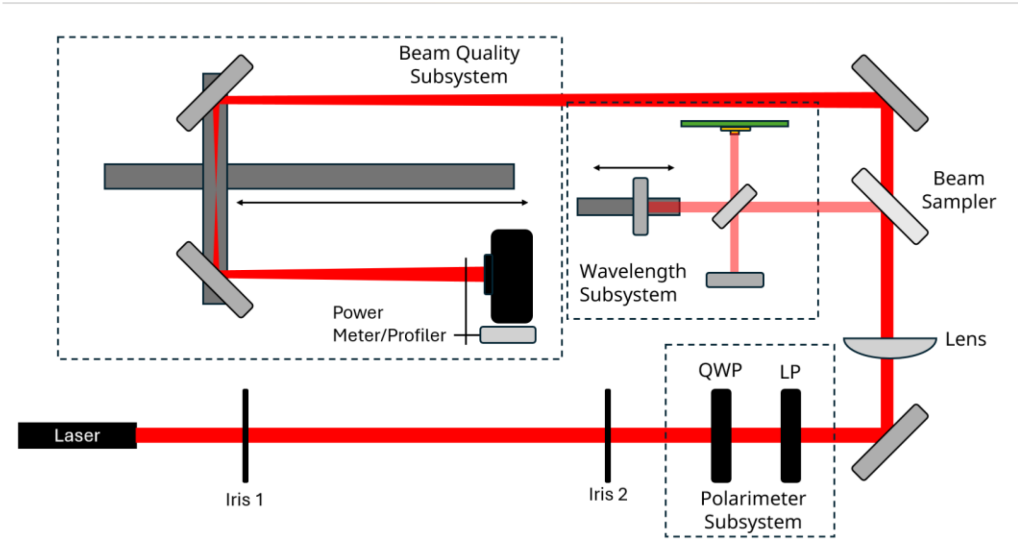




Project Title: Automated Laser Beam Characterizer
Team/Group Number: 3
Team Members:
Zachary Andreasen (PSE & EE)
Thomas Cunningham (EE)
Lynzie Smith (CpE)
Advisors: Dr. Aravinda Kar & Dr. Saleem Sahawneh

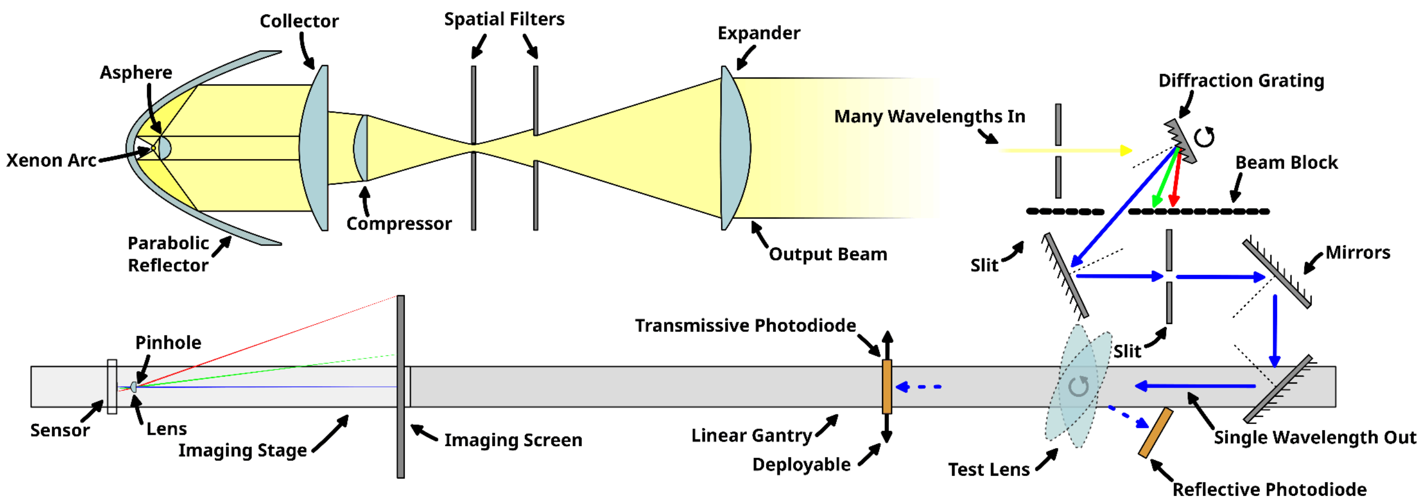
The Automated Laser Beam Characterizer seeks to make the process of collecting data for free space laser beams simpler and more convenient. In any lab that uses a laser, basic knowledge of its characteristics is essential for knowing how the laser will behave in the system. Thus, any laser must be properly characterized before it can be implemented into a certain technology. This system aims to automate this process to make data collection easy and convenient. The system built will measure the laser's wavelength, polarization, M^2 factor, and divergence. There are three main subsystems to this project corresponding to the different measurements to be taken with the M^2 factor and divergence measurements grouped into one subsystem. The first subsystem is a Michelson Interferometer, which will be used to measure the wavelength of the beam. The system will perform this first since many of the other measurements require knowledge of the wavelength of the beam for accurate results. The second subsystem will measure the polarization of the laser using a rotating quarter waveplate, fixed linear polarizer, and power meter to extract the Stokes Parameters. Finally, the M^2 factor and divergence values will be measured by focusing the laser beam with a long focal length lens and performing several knife edge tests along the propagation path of the beam. All these systems are motorized and controlled with an STM32 microcontroller to fully automate the system, providing easy user experience and quick data collection. The goal for this project is to measure wavelength to within 1 nm accuracy, normalized Stokes parameters to within 0.1 accuracy, M^2 Factor within 0.1, and divergence to within 10 microradians.

Below is a general schematic of the system:



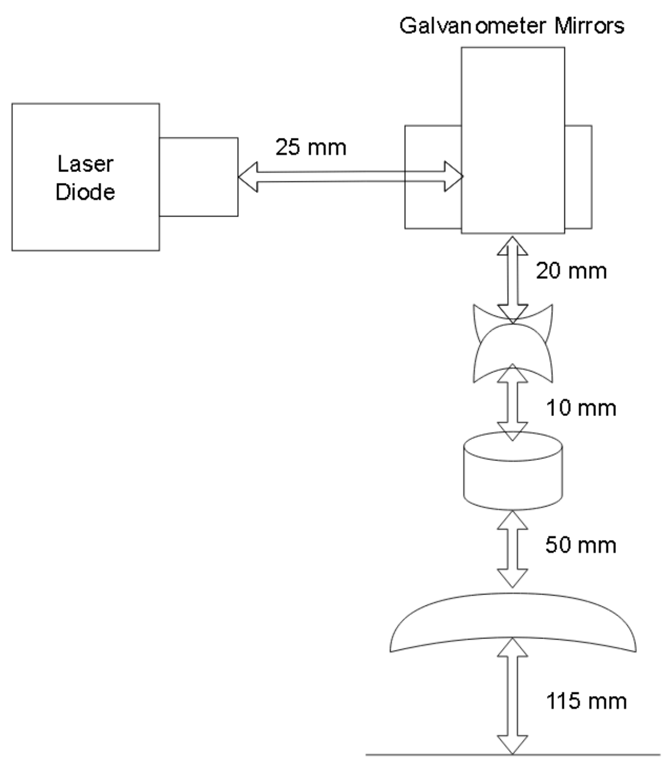
Project Title: Automated Lens Metrology
Team/Group number: 4
Team members' names and majors: Kiva McCracken & Ollie Mueller, PSE, Zachary Kassner, EE, Daniel Gomez, CpE
Senior design advisors (if any)**:** Dr. Aravinda Kar & Dr. Sreeram Sundaresh
Sponsor of your project (if any): N/A

The Automated Lens Metrology system uses a fleet of sensors to measure lens properties not typically found at a glance, namely effective focal length (at different wavelengths), transmissive spectra, and reflective spectra. These properties are used to derive additional parameters and build a datasheet that provides the user with information about the inputted lens. This system is intended for research and educational settings where lens characterization is needed. Automating lens metrology reduces labor for researchers and students, and our system provides satisfactory results at a fraction of the cost of industry-standard metrology devices. The main components of our optical design are a white light source (WLS), a monochromator, and an image acquisition system (IAS). The goals for this project are to measure the focal length of a lens with an accuracy of ± 5 mm and measure the transmissive and reflective spectra of the lens with an accuracy of ± 5 nm. To meet these goals, we have constructed and collimated the WLS to show broad peaks across the visible spectrum. This light is diffracted and selected by our monochromator, which manually tunes the wavelength of light sent to the test lens. The test lens transmits and reflects light into two photodiodes respectively to record the transmissive and reflective spectra in steps of 10 nm. Then, the monochromatic light passing through the test lens forms an image on a screen controlled by a linear gantry. The gantry, screen, and a camera behind the screen form the IAS. The IAS moves along the optical axis to calculate the position at which the minimum spot size is found. The distance between this position and the lens is the lens' focal length. From these data, Abbe number and lens coatings are estimated. Finally, the finished datasheet is presented to the user.



Project Title: Enhanced Laser Inkless Printer (E.L.I.P.)
Team/Group number: 5
Team members' names and majors: Miguelangel Otero (PSE), Jack McCain (EE), Sarah Siverio (CPE)
Senior design advisors (if any)**:** Dr. Aravinda Kar, Dr. Sreeram Sundaresh
Sponsor of your project (if any): N/A

The primary goal of the E.L.I.P. project is to build on the design of the original Laser Inkless Printer (L.I.P.) by incorporating alternative technologies that the previous group had rejected. We utilized a green laser diode that matches the reported output power of the previous design. To improve printing speed and expand the available character set, we used a laser galvanometer to direct the laser over a fixed work area instead of relying on a mobile gantry system. Our software goals include integrating Bluetooth connectivity to initiate print jobs remotely, implementing a microcontroller to control the galvanometer's mirrors, as well as developing safety features that operate before and during printing. These objectives are achieved using C/C++ code programmed onto an ESP32 microcontroller. A custom-designed PCB facilitates communication and power distribution between the optical and software subsystems. Our target character linewidth is 0.9 mm, which we achieve by focusing the laser through a multi-lens optical system. For effective galvanometer scanning, an F-Theta lens is typically required to produce a flat image field and maintain a uniform spot size across the work area. Due to budget constraints, we opted not to purchase a commercial F-Theta lens and instead designed an optical system intended to replicate its flat-field effect. The resulting schematic was developed through technical research, AI-assisted modeling, and faculty review. Compared to the original L.I.P. design, our system has a smaller scanning area due to the absence of a mobile gantry; however, it benefits from reduced mechanical complexity and higher scanning speeds. The E.L.I.P. serves as an environmentally friendly alternative to conventional cartridge-based printers, eliminating ink or toner usage while offering faster operation and improved reliability for small-scale or specialized printing applications.



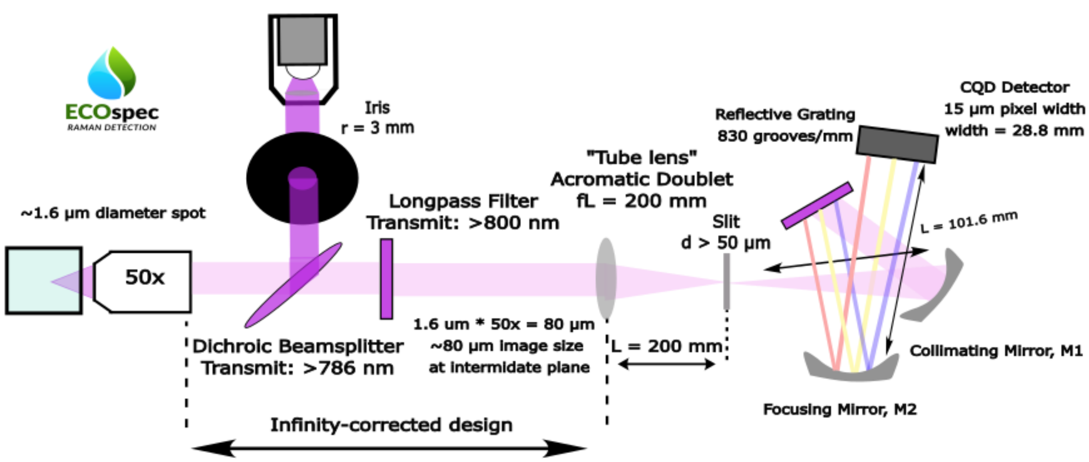
Senior Design-II – CREOL Showcase Competition [CREOL Showcase Project Summary Form]
CREOL, The College of Optics and Photonics
Project Summary
Page limit: 1

Project Title: ECOspec: Microplastic Identification with Raman Spectroscopy
Team/Group number: 6
Team members' names and majors: Sophia Adams (PSE), Landon Morjal (CPE), Logan Sullivan (CPE), Michael Rusinko (PSE/EE)
Senior design advisors (if any)**:** Dr. Aravinda Kar & Dr. Sreeram Sundaresh
Sponsor of your project (if any): N/A

Project Summary (300 words maximum, Times New Roman Font, Size 11, Single space): State the project goals, objectives, optical designs that you have done to build your system, applications of your system, and how your system is better than the existing products used for similar applications.

Microplastic pollution is a growing environmental and public health concern, yet detection remains difficult, time-consuming, and expensive. High quality yet accessible tools are essential for understanding exposure risks, enforcing pollution standards, and evaluating cleanup strategies.
ECOSpec offers an electro-optical solution using Raman spectroscopy to detect and identify microplastics through their unique molecular signatures. A 785 nm laser illuminates pre-prepared samples, producing Raman-scattered light which reveals the material's molecular structure. A spectrometer analyzes this light and compares the resulting spectrum against a database of plastic polymer fingerprints, allowing ECOspec to both detect and identify the sample. The current system is configured for the detection of polyethylene terephthalate, nylon, and polystyrene.
The primary use of this technology is broad- ranging from environmental research, water filtration systems, and regulatory agencies responsible for monitoring pollution and ecosystem health. Target users include environmental scientists, public health and safety professionals, and regulatory agencies. Unlike bulky commercial Raman spectroscopy systems, ECOSpec is compact and more cost effective than conventional metrology devices for Raman spectroscopy, while still offering non-destructive analysis and high chemical specificity. By improving accessibility to microplastic detection technology, ECOSpec could support more widespread environmental monitoring and contribute efforts aimed at mitigating plastic pollution.

Provide a schematic diagram of your optical system:



Senior Design-II – CREOL Showcase Competition [CREOL Showcase Project Summary Form]
CREOL, The College of Optics and Photonics
Project Summary

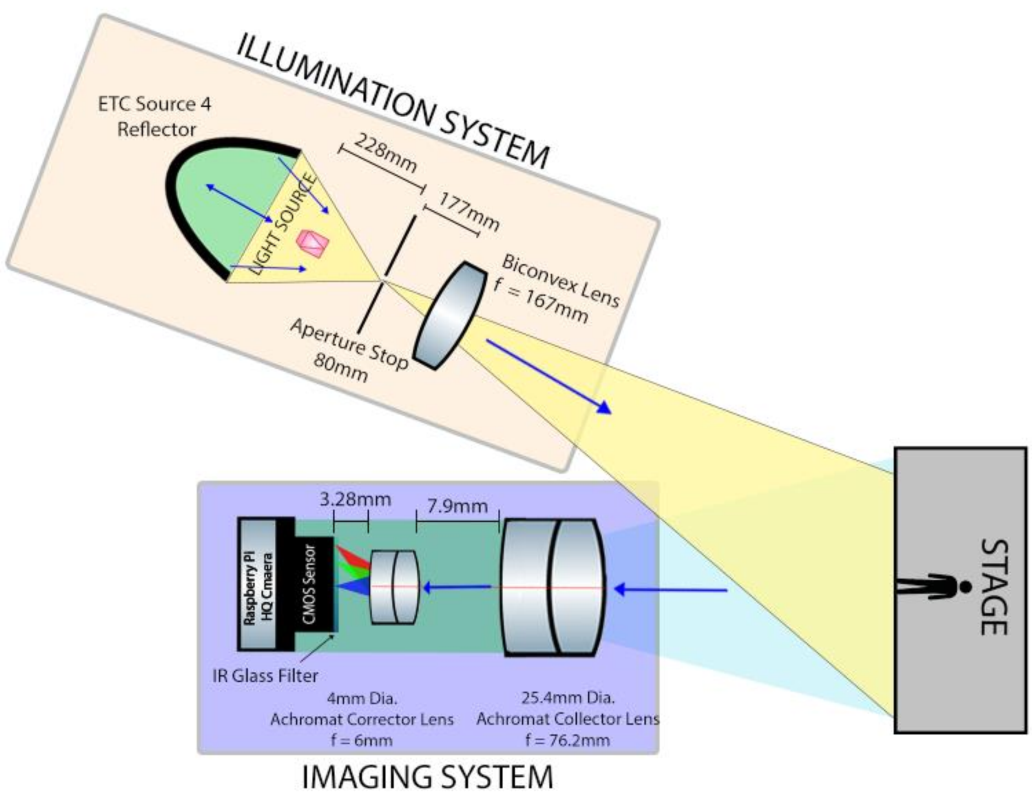
Project Title: S.T.A.R. (Spotlight Tracking with Automated Recognition)
Team/Group number: 7
Team members' names and majors: Gage Anderson (PSE), Travis Nguyen (PSE), Jerison Lau (EE), Lucio Villena (CPE)
Senior design advisors (if any): Dr. Stephen Eikenberry, Dr. Andrew Klein, Dr. Wei Sun, Dr. Jaesung Lee
Sponsor of your project (if any): N/A

The S.T.A.R. system is designed to act as an intelligent stage lighting fixture capable of automatically detecting and tracking a performer while on stage. The primary goal of this project is to combine imaging and illumination systems into a single unit to eliminate the need for manual spotlight operation while improving accuracy and consistency in live performance environments.

S.T.A.R. consists of two main optical subsystems; an imaging system and an illumination system. The imaging system uses a CMOS camera and computer vision algorithms to detect and track human subjects in real time. The illumination system utilizes a high intensity LED source, a cold mirror reflector, and a focusing lens to produce a controlled, uniform beam with an output (full) angle of 19 degrees. Optical design challenges included reflector positioning, imaging lens focal length optimization, and designing precise housings for both optical systems. Additional considerations such as stray light reduction, étendue, and alignment tolerances were incorporated to improve optical performance.

This system has applications in theatre, lecture halls, churches, and any other live events where performer tracking is required. Compared to traditional spotlight systems that require manual operation, S.T.A.R. improves tracking accuracy, reduces workload, and provides more consistent illumination. Other automated spotlight systems are typically not financially viable for smaller venues, as they often require dedicated lighting consoles and control infrastructure, which add significant cost.

Overall, S.T.A.R. presents a cost effective, practical integration of optical design with real-time imaging to create a more accessible and adaptable automated lighting solution to enhance live performance environments.



Senior Design-II – CREOL Showcase Competition [CREOL Showcase Project Summary Form]
CREOL, The College of Optics and Photonics
Project Summary
Page limit: 1

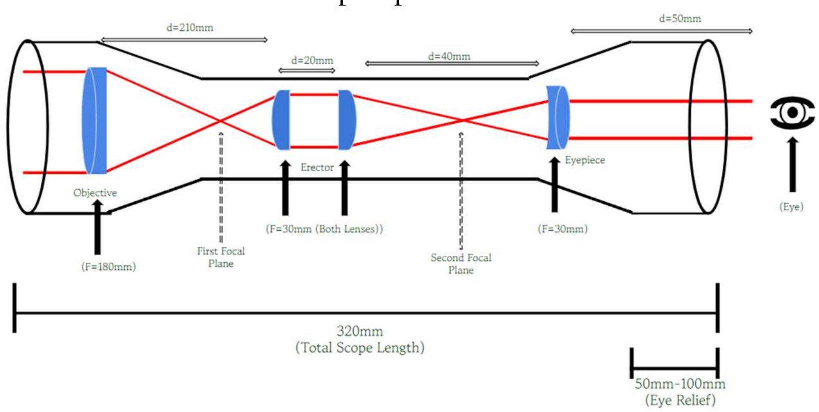
Project Title: Shooting Gallery Simulator
Team/Group number: 8
Team members' names and majors: Mariela Montanez (PSE), Ivanna Socarras (CPE), Zachary Romanoff, (EE)
Senior design advisors (if any)**:** Dr. ChungYong Chan and Dr. Aravinda Kar

The Shooting Gallery Simulator is designed to provide a safe, cost-effective, and realistic training platform for novice and experienced hunters. The primary goal of the project is to improve user accuracy, reaction time, and situational awareness without the risks associated with live firearms. The laser gun and the modular attachments should be able to operate at long distances or approximately 20 meters. Key objectives include developing a laser-based rifle system, an interactive photodiode target board, and integrating advanced features modular attachments such as a detachable rifle scope and a LiDAR rangefinder to enhance realism and usability.

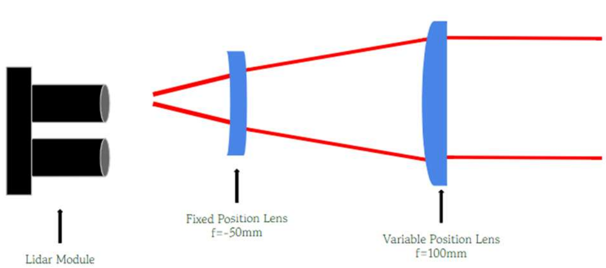
The optical design of the system plays a critical role in achieving these objectives. The barrel of the gun consists of a Keplerian beam expander to enlarge the laser diode beam to ensure reliable detection at long distances, as well as a pair of cylindrical lenses to reshape the laser diode beam. Moreover, the rifle scope was designed using achromatic doublets for the eyepiece and objective lenses, and plano-convex lenses for the erector lenses to minimize aberrations while providing adjustable focus for accurate targeting. Additionally, the LiDAR includes an autofocusing lens system to maintain beam clarity and allow for effective distance measurement.

The system's main applications are in hunting training and general shooting simulation. Compared to existing products such as simple laser training systems, this design offers significant improvements. Unlike traditional systems that only provide basic hit detection, this project introduces dynamic target interaction, real-time performance feedback, and distance measurement through LiDAR. Furthermore, the modular design allows for customization fit to the user's needs and specifications, while maintaining a lower cost than other currently existing systems. Overall, the system provides a more immersive, safe, and versatile training experience.

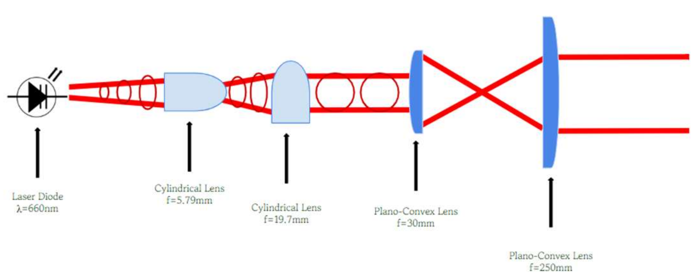
Rifle Scope Optical Schematic



Lidar Autofocusing Lens System



Laser Diode Beam Collimator and Expander



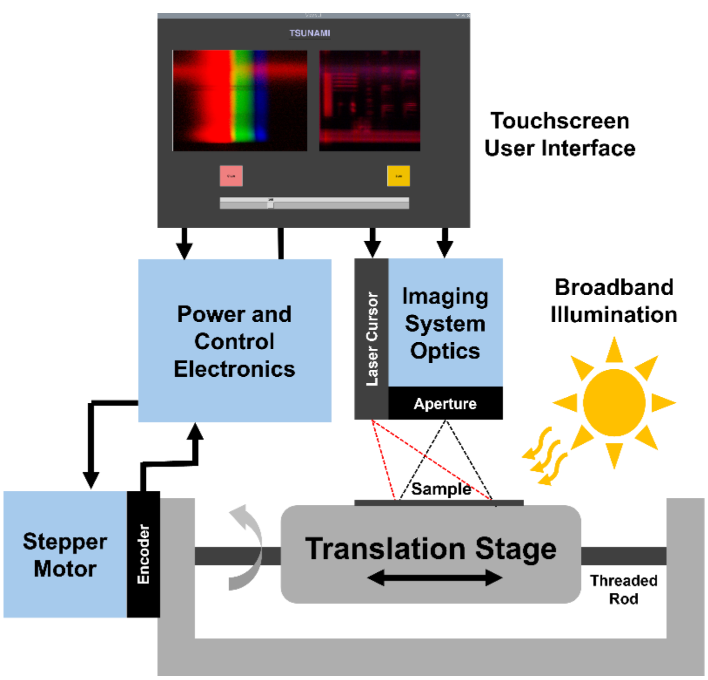
Senior Design-II – CREOL Showcase Competition CREOL Showcase Project Summary Form
CREOL, The College of Optics and Photonics
Project Summary

Project Title: TSUNAMI - Hyperspectral Imager for Chlorophyll Detection
Team/Group number: 9
Team members' names and majors: Emilio Armas (PSE & EE), Jacob Silver (PSE), Xander Kin (EE)
Senior design advisors (if any)**:** Dr. Konstantin Vodopyanov (CREOL), Mark Maddox (ECE), Dr. Chun Yong Chan (ECE), Dr. Aravinda Kar (CREOL)
Sponsor of your project (if any): BEAM Engineering for Advanced Measurements Co. (Dr. Anna Tabirian)

This project centered around an effort to design and fabricate a line-scanning hyperspectral imager for use within the visible/near-infrared (NIR) wavelengths of light. The instrument is able be able to capture an image across a two-dimensional field of view, simultaneously recording an entire spectra per "pixel". Recording an entire spectra per-pixel is a 3D dataset, and naturally with existing imaging sensors being 2D, there must be a way to compromise one metric to enable collecting these data. The method TSUNAMI uses to achieve this goes by limiting a camera's traditional 2D field-of-view to just a vertical line, and translating the sample below along the other spatial axis to capture a strip-image.

A linear incident beam is used, as when it is passed through a diffractive grating, it will form a two-dimensional image on a given plane. This image, rather than containing two traditionally spatial dimensions, now includes only the slit's lateral dimension, with the other now being wavelength. When illuminated onto an image sensor array, this image is now a per-pixel spectral representation of the incident beam into the imager. While the final image cannot be captured simultaneously, with this translating target, a faithful hyperspectral image can be produced, where any selected pixel can have a full spectrum read from it. The entire device is powered via an external AC/DC wall-adapter, hosting an on-board GUI for integrated imaging processing, rendering, and control over all hardware subsystems that run the instrument.

Our primary target is to image the spatial distribution of chlorophyll in plant matter. The concentration of chlorophyll across tissues of a plant (such as a leaf) are a prime indicator for plant health. Being able to image chlorophyll concentration across a particular target directly allows professionals in agriculture, biology and ecology the ability to monitor plant stress and senescence. This can directly improve crop yields.



Senior Design-II – CREOL Showcase Competition CREOL Showcase Project Summary Form
CREOL, The College of Optics and Photonics
Project Summary

Project Title: P.E.G.A.S.U.S. Heads-Up Aviation Display
Team/Group number: 10
Team members' names and majors: Ethan Dill (Photonics Engineer), Luke Anderson (Computer Engineer), Frank Murphy (Electrical Engineer)
Senior design advisors (if any): Dr. Shin Tson Wu
Sponsor of your project (if any): N/A

The Pilot Enhanced Guidance and Augmented Sight Utility System (or "P.E.G.A.S.U.S.") is a compact heads-up display system intended to enhance situational awareness for pilots in general aviation aircraft, such as a Cessna 172 or other comparable private civilian aircraft. By utilizing flight parameter sensor input data, the P.E.G.A.S.U.S. system is able to project it's graphical user interface through a series of optics onto an optical combiner to overlay the HUD onto the forward view of the pilot's environment. The primary goal of this project is to provide an affordable and portable heads-up display solution for the general aviation market.

P.E.G.A.S.U.S. consists of an integrated optical projection system designed to form, condition, and overlay flight data onto the pilot's forward field of view. The system uses a high-resolution TFT micro-display and a Petzval lens configuration, consisting of a positive achromatic doublet ($f \approx 75$ mm) and a negative meniscus lens ($f \approx -500$ mm), to form and magnify the display image while correcting aberrations such as pincushion distortion and field curvature. A reflective optic system is used to compress the optical path into a compact, cockpit-compatible form factor while maintaining alignment with the pilot's line of sight.

The projected image is directed onto a dielectric optical combiner, which overlays the image onto the pilot's external environment while suppressing ghost reflections (double images). A quarter-wave element converts the linearly polarized output of the display into circular polarization, ensuring visibility through polarized sunglasses. Optical design challenges included achieving sufficient image size within strict packaging constraints, managing aberrations with cost-effective optics, and optimizing eye-box and field of view using limited aperture (2-inch) components.

This system has applications in general aviation aircraft, particularly in platforms such as the Cessna 172, where affordable and portable HUD solutions are currently unavailable. Compared to traditional cockpit instrumentation that requires pilots to shift their gaze downward, P.E.G.A.S.U.S. enables continuous forward situational awareness by overlaying critical flight data directly into the pilot's line of sight. Existing HUD systems are typically integrated into high-end aircraft and are cost-prohibitive for smaller or retrofitted platforms.

Overall, P.E.G.A.S.U.S. presents a cost-effective, practical integration of optical design, optomechanics, and embedded systems to create a portable and accessible heads-up display. The system demonstrates how compact imaging optics, polarization control, and combiner technology can be combined with sensor integration and user-interface software to enhance pilot situational awareness in the skies above us.

Senior Design-II – CREOL Showcase Competition [CREOL Showcase Project Summary Form]

CREOL, The College of Optics and Photonics

Project Summary

Project Title: Particle Inspector via Darkfield Illumination (P.I.D.I)

Team/Group number: 11

Team members' names and majors: Julian Lopez & Kirolos Kelleni, PSE, Christian Carroz, CPE, Ryan Palumbo, ME

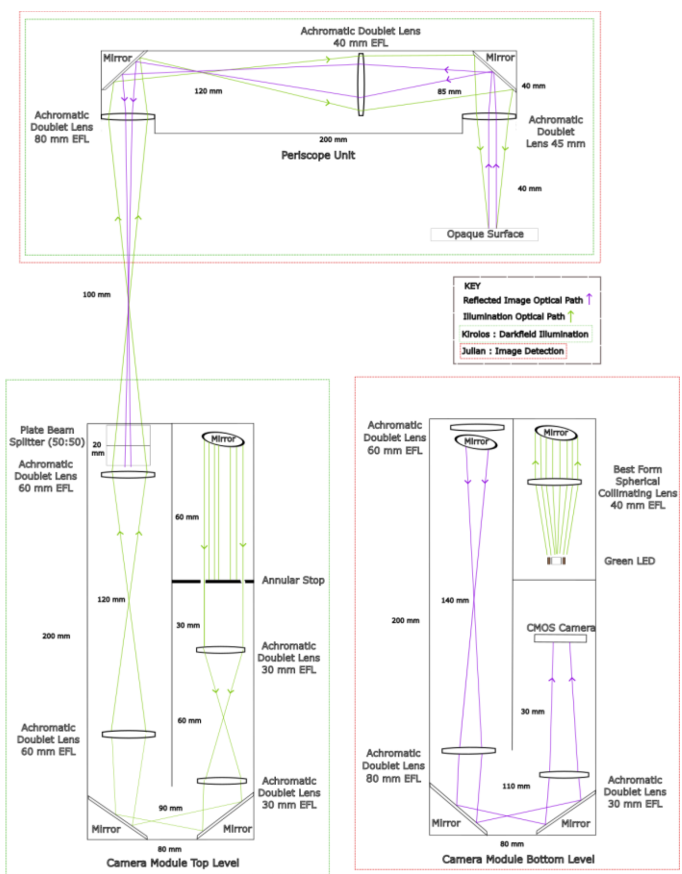
Senior design advisors: Dr. Aravinda Kar & Dr. Chung Yong Chan

Sponsor of your project: ASML

The Particle Inspector via Darkfield Illumination is an imaging system designed to quickly image and detect the presence of contaminants on a reflective opaque surface. The goal of this project is to design and build an optical module, within strict size constraints specified by our sponsor, that can inspect particles of 200 µm x 50 µm in size utilizing darkfield illumination. Additionally, it was our goal to ensure the device was simple to operate, self-aligning, durable, and not exceedingly heavy. To achieve this, we are controlling the system with a touch screen and straightforward custom UI that will capture the result in less than 1 second and detect contaminants in less than two seconds. The device, in total, will also weigh less than 10 kg.

We decided to use a series of six 4f systems to both relay the illumination to the surface and the object to the camera. The tight size constraint also led us to use seven mirrors to maximize the optical path length available. Considering the placement of each lens is dependent on other lenses, the central difficulty with designing this project was not achieving the desired magnification but finding an appropriate combination of optics that did have any components physically overlap. This was not a conceptual problem but an engineering one.

Considering the low tolerances for contaminants required in semiconductor manufacturing, our project is designed to provide a speedy, alternative method for identifying the presence of those contaminants, enabling higher efficiency in manufacturing. Compared to more prevalent contamination detection methods, like brightfield microscopy, our project features stronger contrast around edges, enabling clearer imaging in cases where contaminants have low absorption. With a total cost of nearly three thousand dollars, our system is also more inexpensive than most market-available reflective darkfield imaging systems.



Senior Design-II – CREOL Showcase Competition [CREOL Showcase Project Summary Form]
CREOL, The College of Optics and Photonics
Project Summary
Page limit: 1

Project Title: Fast Polarization Switch
Team/Group number: 12
Team members' names and majors: Michelle Nguyen, David "Austin" Rich, Joshua Hendry
Senior design advisors (if any)**:** Dr. Aravinda Kar & Dr. Chung Yong Chan
Sponsor of your project (if any): ASML

The goal of this project is to design and demonstrate a fast, high-precision polarization-switching system—referred to as the "Poincaré Switch" capable of achieving a polarization extinction ratio (PER) of 1000:1, operating across the visible spectrum, and switching between orthogonal polarization states in under 5 ms. Sponsored by ASML, this system is intended for semiconductor metrology applications where rapid, accurate polarization control is essential.

The system operates by rotating a birefringent calcite crystal whose fast axis is aligned 45° relative to the incoming polarization. This rotation changes the optical path length between the ordinary and extraordinary rays, enabling rapid transitions between orthogonal polarization states. The optical design includes a dual-source combiner using a beam splitter, Glan-Taylor polarizers for high-contrast analysis, a precision-mounted calcite crystal, and a photodiode-based detection system. MATLAB simulations and Poincaré sphere mapping were used to optimize crystal thickness, rotation angles, and expected PER performance.

Applications of this system extend beyond metrology. Because polarization rotation directly modulates transmitted power through an analyzer, the device can also function as a high-speed optical power modulator with extremely high extinction ratios. Its broadband compatibility and mechanical simplicity make it suitable for laboratory optics, imaging systems, and polarization-sensitive sensing.

Compared to existing polarization-switching technologies such as liquid-crystal retarders or bulk rotating waveplates this system offers several advantages. The use of a lightweight calcite crystal and a cross-flexure galvanometer motor enables significantly faster switching speeds with minimal mechanical overshoot. The PER exceeds that of many commercial electro-optic modulators, while the broadband visible-light compatibility avoids the wavelength-specific limitations of coated or resonant devices. Overall, the Poincaré Switch provides a robust, tunable, and cost-effective alternative for applications requiring rapid, high-contrast polarization control