# Laser Stability Project Proposal

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1. **Introduction**

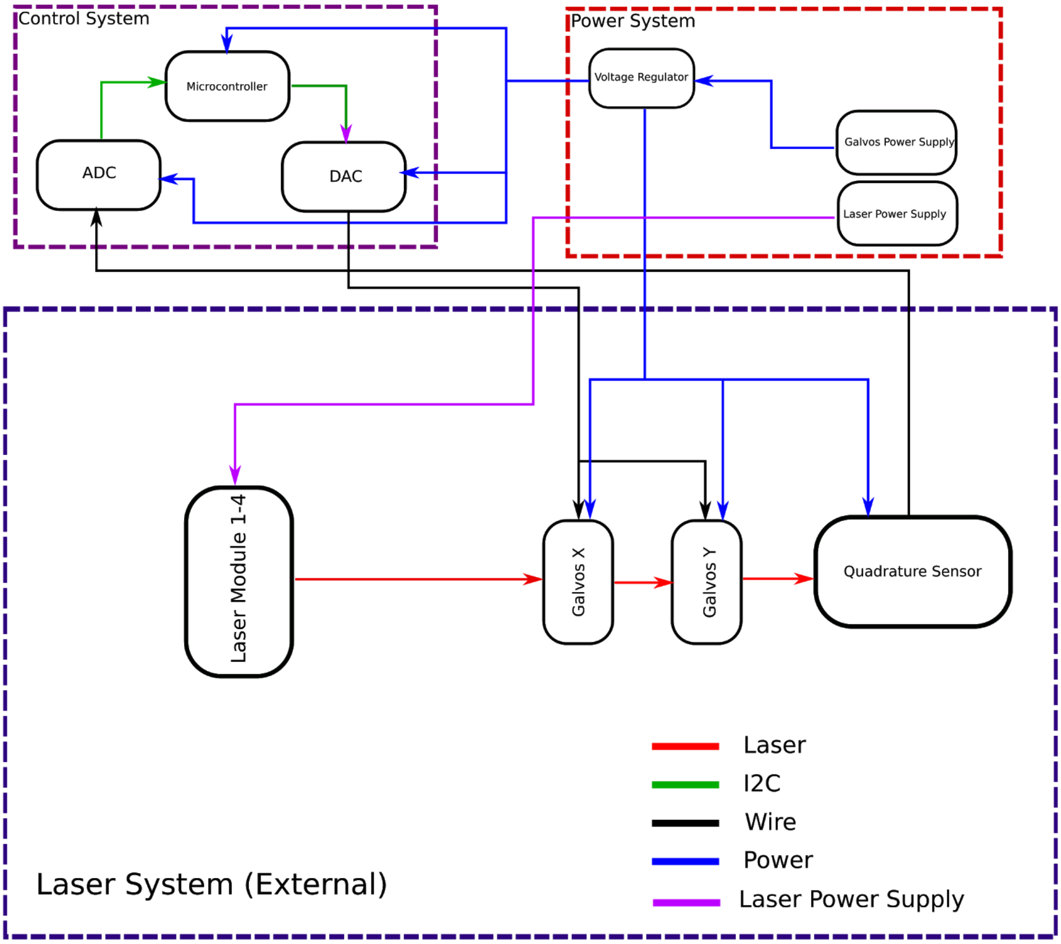
- **Objective:** A closed-loop feedback control system could be adopted to solve this problem. The position information could be obtained from a quadrant photodiode sensor passed to the processing unit. This sensor can generate a difference signal that can be used as the error signal in a PID controller. The microcontroller will then output a voltage to the servo drivers to correct the beam position.

- **Background:** A label-free diagnostic tool used in medical area, infrared microscopy is based on the fact that molecular bonds in tissues and cells have a unique spectral signature in IR. However, the beam pointing could be affected by external factors like the drift of modules or vibration by sound. Because this technique requires a high level of sensibility, it is crucial to maintain the stability of the laser beam. Also, since various QCLs would be used in the technique, they need to be aligned co-linearly with respect to each other.

- **High-level requirements list:**
    1) The design should have high performance as a control unit. For the timing of the operation, this system should have a short restoring time after a sudden drifting of the laser. i.e. The rise time, $t_r$, peak time, $t_p$, and settle time, $t_s$, should be smaller than the overall requirement of the project. We pick the settle time requirement level, at this stage, to be 100ms, which corresponds to half period before the next pulsed wave is generated.
    2) For the accuracy, the overshoot $M_p$ should be smaller enough. The trade-off between the stabilizing speed and max overshoot should be chosen carefully to achieve the best performance of the laser beam. At this moment, we propose the maximum overshoot to be 15% of the laser diameter (4mm), which is 0.6mm.
    3) The design should have all sub-modules compatible with the I/O type of each other, such as their input/output voltage range. For example, the output of the sensor should be able to be recognized by the ADC, which means its analog voltage signal should fall in the voltage range of the ADC I/O. The design should also have all sub-modules compatible with the operating frequency of each other. For instance, the ADC should have enough frequency to detect the change from the photodiode sensor.

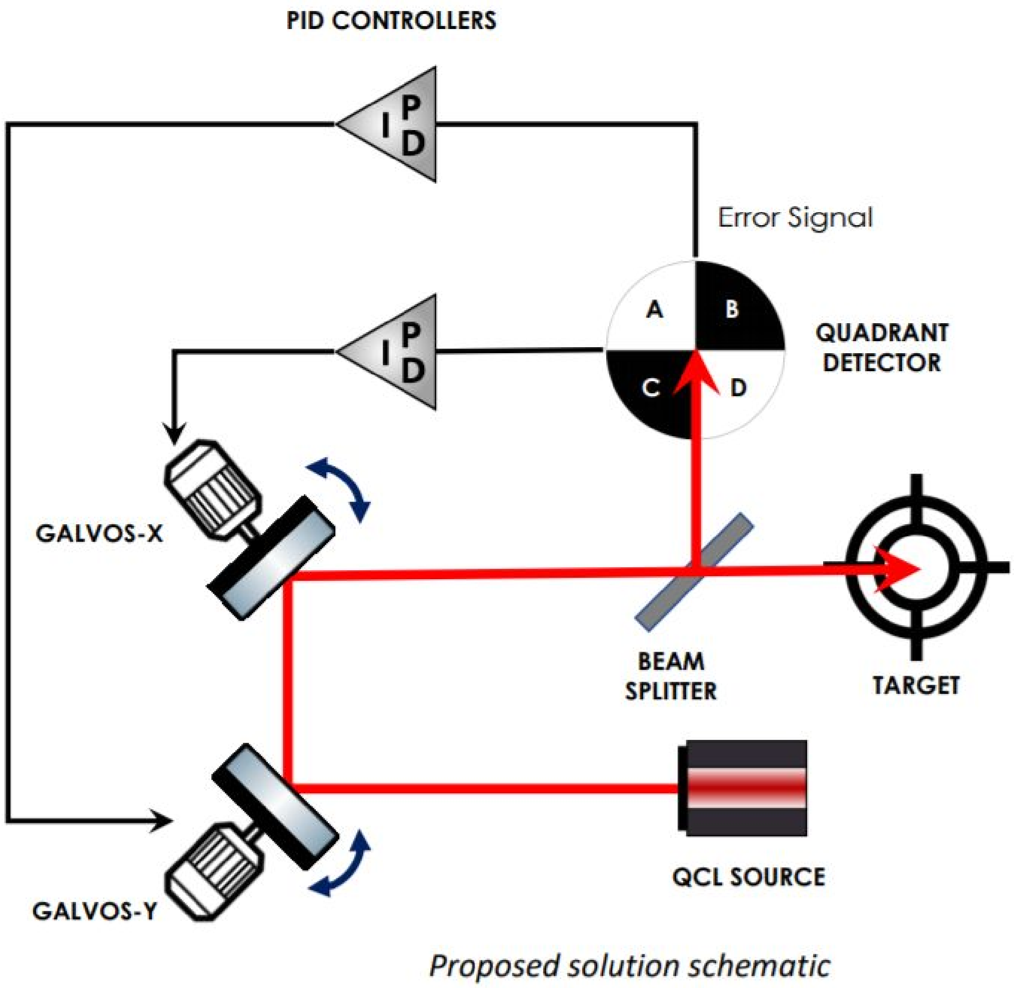
2. **Design**

- **Block Diagram:**




- Figure 1. Block Diagram Model

- **Physical Design :**




- Figure 2. "Proposed solution schematic" by Yamuna Phal

- In Figure 2, the laser used for label-free diagnostic tool goes through a beam splitter, which separates the error signal from the one used for medical purposes. The error signal is then detected by a quadrant detector, which outputs X and Y value of the beam position. The PID control system then process the error signal and generate instructions for the Galvos to adjust angle positions. The Laser beam can thus maintain relatively stable.

- **Functional Overview:**

1) **<u>Laser System → Laser Modules 1 - 4:</u>** These are the four lasers that need to be stabilized. They are pulsed lasers that will each fire one-by-one within the 5.7 µm - 12.8 µm range. The laser will hit two mirrors that will direct the laser towards the control system. *Already Provided*
2) **<u>Laser System → Galvos X:</u>** This galvanometer is adjusted by an analog voltage signal between -10V and 10V with a 0.5V/deg change. This will receive a voltage from the DAC. It changes the X trajectory of the laser. *Already Provided*
3) **<u>Laser System → Galvos Y:</u>** This galvanometer is adjusted by an analog voltage signal between -10V and 10V with a 0.5V/deg change. This will receive a voltage from the DAC. It changes the Y trajectory of the laser. *Already Provided*
4) **<u>Laser System → Quadrature Sensor:</u>** This is the sensor that will be measuring the current position of the laser. This quadrature sensor has four voltage measurements that when compared with each other will give an X and Y coordinate of the laser's position on the sensor. This will then output an analog voltage signal that will be read from the control system portion of the project.
5) **<u>Power System → Galvos Power Supply:</u>** This is the power supply that the Galvos need in order to function. We will be tapping into this 24V supply to power the control system as well. *Already Provided*
6) **<u>Power System → Voltage Regulator:</u>** This will take in voltage from the power supply and ensure a near constant 5v for the control system and the servos.
7) **<u>Control System → DAC</u>**: This will take in a signal from the microcontroller based on the PID control and outputs a voltage between -10V and 10V for the galvos.
8) **<u>Control System → ADC:</u>** This will take in the voltage readings from the quadrature sensor and output the corresponding digital signal to the microcontroller.
9) **<u>Control System → Microcontroller:</u>** This will house the software to create the PID controller. This will take in the data from the ADC and convert it into an X and Y coordinate to determine the error between the laser position and what the desired position is. From there, this error signal will be used in a PID controller to correct the position. The controller will then send a data signal to the DAC that will change the output voltage.

- **Block Requirements:**

  The following is a list of requirements that are needed for our control system. The already provided equipment within the block diagram was used to determine the requirements

1. **<u>Laser System → Quadrature Sensor:</u>**
   a. Requirement 1 - It must recognize 5.7 - 12.8 µm wavelength lasers
   b. Requirement 2 - It must handle 4 mm diameter lasers
   c. Requirement 3 - Must handle 10 mW of power from the laser
   d. Requirement 4 - Must have rise time below 150 µs
   e. Requirement 5 - Must output an analog voltage (value doesn't matter since a voltage divider can be used to bring the voltage down to acceptable levels for microcontroller)
2. **<u>Power System → Voltage Regulator:</u>**
   a. Requirement 1 – Must output 5v (± 10%) to the ADC, DAC, and Microcontroller
   b. Requirement 2 - Must output 24v (± 10%) to both of the galvos
3. **<u>Control System → DAC:</u>**
   a. Requirement 1 – Must have at least a 50 Mhz clock (to catch 40 ns pulse)
   b. Requirement 2 - is at least 12-bit resolution for finer tuning of the mirrors
   c. Requirement 3 - Outputs at least 10V (if not will need an amplification circuit)
   d. Requirement 4 - Utilizes I2C or an equivalent
4. **<u>Control System → ADC:</u>**
   a. Requirement 1 – Must have at least a 50 Mhz clock (to catch 40ns pulse)
   b. Requirement 2 - is at least 16-bit resolution to get a more accurate laser position from quadrature sensor
   c. Requirement 3 - Utilizes I2C or an equivalent
5. **<u>Control System → Microcontroller:</u>**
   a. Requirement 1 – Must have at least a 50 Mhz clock however ideally 100Mhz.
   b. Requirement 2 - Has I2C communication or equivalent

- **Risk Analysis:**
  Our biggest difficulty is the systematic errors. For the microcontroller, the output signals could have an inaccuracy in magnitude, which wasn't a problem usually but could be a disaster when dealing with precise control. Similar things could also happen with DAC&ADCs.

  Another possible issue is the timing. This project consists of relatively frequent switching between laser wavelength and Galvo setting, so the sensor should correctly distinguish the stability error signal from the regular operation.

3. **Ethics and Safety**

This project belongs to a research group which is working a developing FTIR and QCL instrumentation for infrared spectroscopic imaging. As a relatively important part of their entire model, IEEE Code of Ethics #10 is applied here, to help and assist their laser pointing stability from an active feedback controller.

Laser safety is a main part in our laboratory, according to IEEE Code of Ethics #9, additional training is required to ensure our eligibility working in this specific laboratory. When working in the lab, it is suggest not wearing expose large amount of skin, when the laser is turned on, safety goggles with corresponding spectrum are required at all time. We also need to be aware that there is no possible reflective medium along the path of any model in the lab, in case of unexpected reflected laser point to any lab personal.

If we successfully accomplish our task, reaches the ultimate goal of this project, IEEE Code of Ethic #5 fits here. As we improve the performance of the model, the closed loop feedback system will adjust the beam and make it stable. we hope this project can have a support on the diagnostic tool as mentioned above, and eventually put on a clinical application if possible.

# References


Yamuna Phal, (27 August, 2019), “Proposed solution schematic”, [online] Available at: https://courses.engr.illinois.edu/ece445/lectures/FA_2019_Lectures/Pitches/Pitch_ECE-445.pdf [Accessed 12, Sep, 2019, ]

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