

Reliability Test of the Actively Tunable Filter

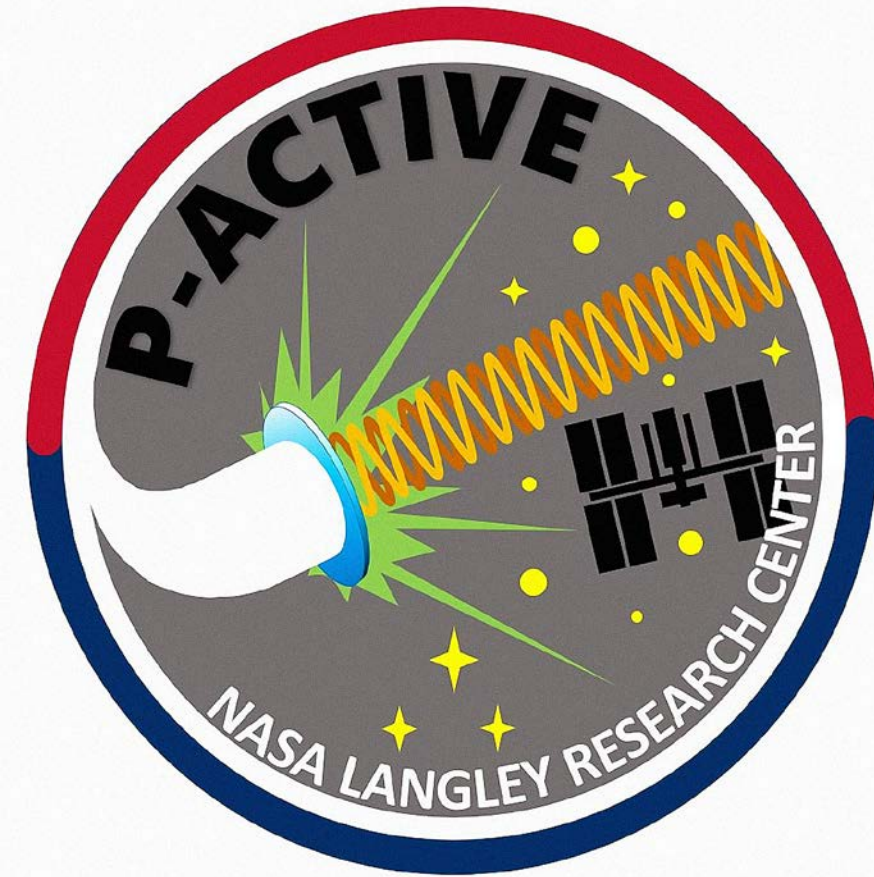
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Advanced Measurements and Data Systems Branch (AMDSB)

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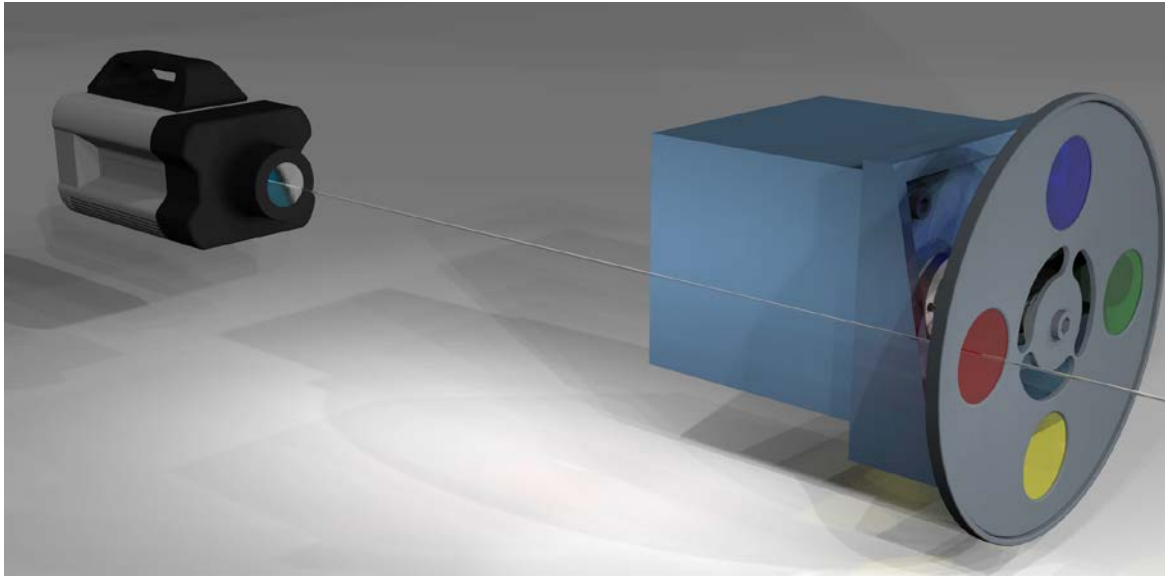
Introduction

- The middle-wavelength infrared (MWIR) waveband is considered the “**spectral fingerprint**” for many chemical species.
- MWIR: 3 – 10 μm wavelength range.
- MWIR imaging devices are important for multispectral imaging, thermography, chemical spectroscopy, surveillance, automotive safety, and astronomy.
- Tunable optical properties are desired to increase the amount of information that is detectable.
- $\text{Ge}_2\text{Sb}_2\text{Te}_5$ (GST) is a chalcogenide phase change material (PCM) that has the potential to be used as a compact, solid-state, fast-switching tunable optical filter.



Strategies for Multispectral Imaging

Filter Wheel (Current Strategy)



- Slow response times, limited spectral resolution (depending on the number of filters), bulky, and contains moving parts.

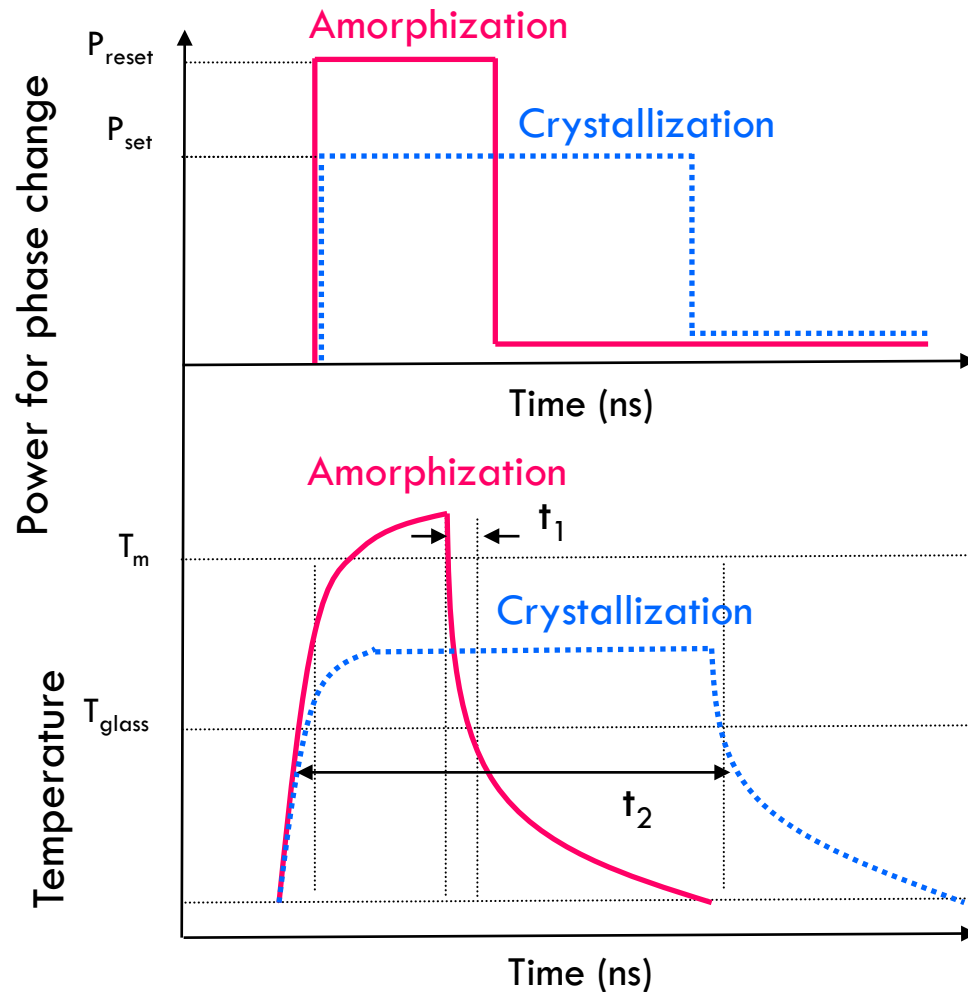
Actively Tunable Solid-State Filter (Emerging technology)



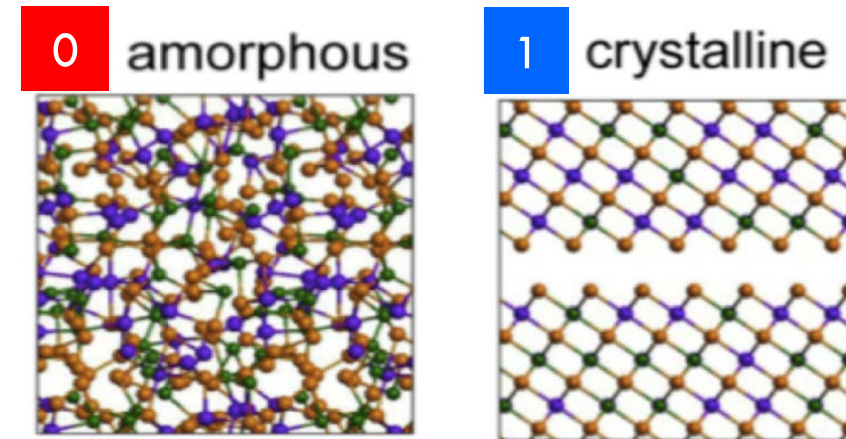
- Compact, fast-switching, has no moving parts.

Amorphous and Crystalline Phase Change

Enables multispectral imaging through repeated heat-triggered switching.



- Heat can be transferred with electrical or laser power.
- Switching can occur on the nanosecond (MHz) timescale.



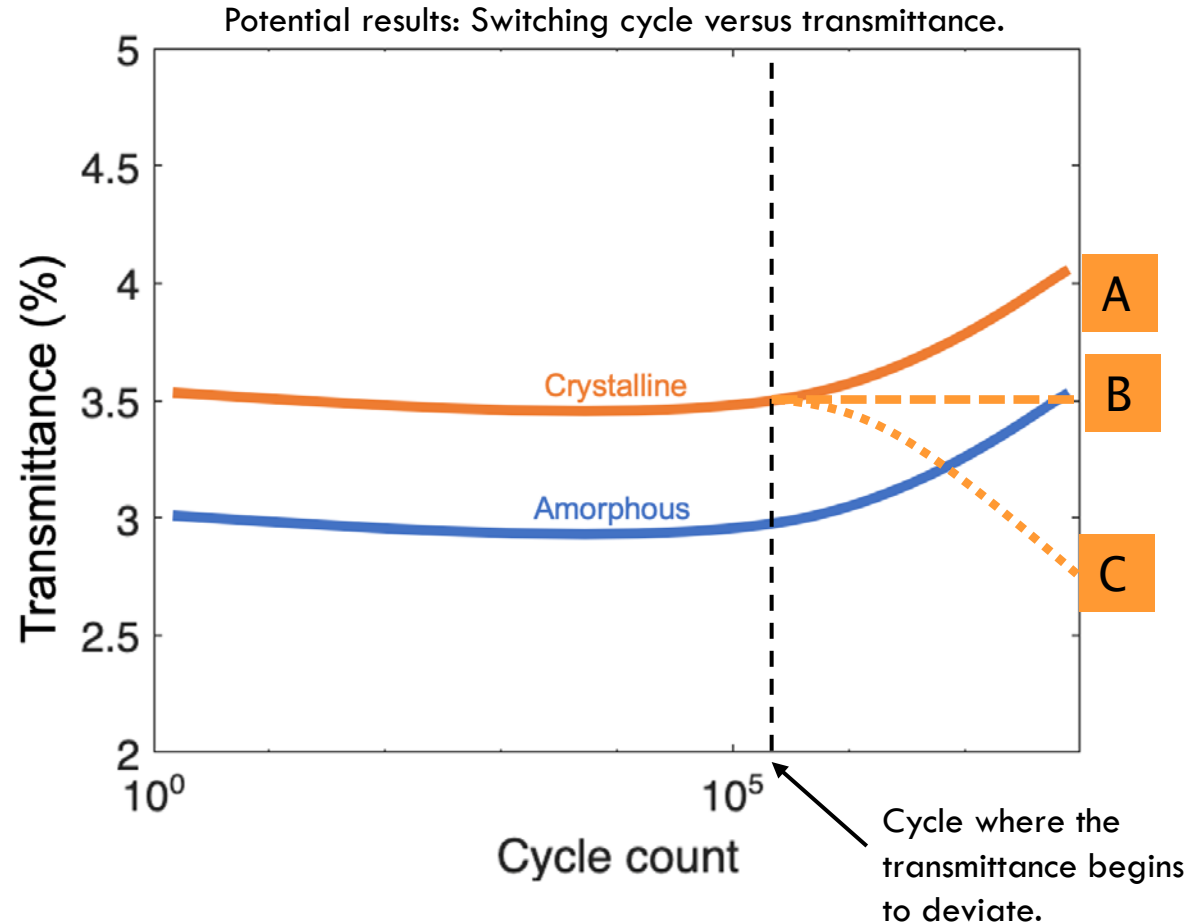


Open Research Questions



- How well does the filter work in real life application?
- How reliable is the filter, i.e. how many times can it switch before it fails?
- In what environments (temperatures and pressures) can it survive?

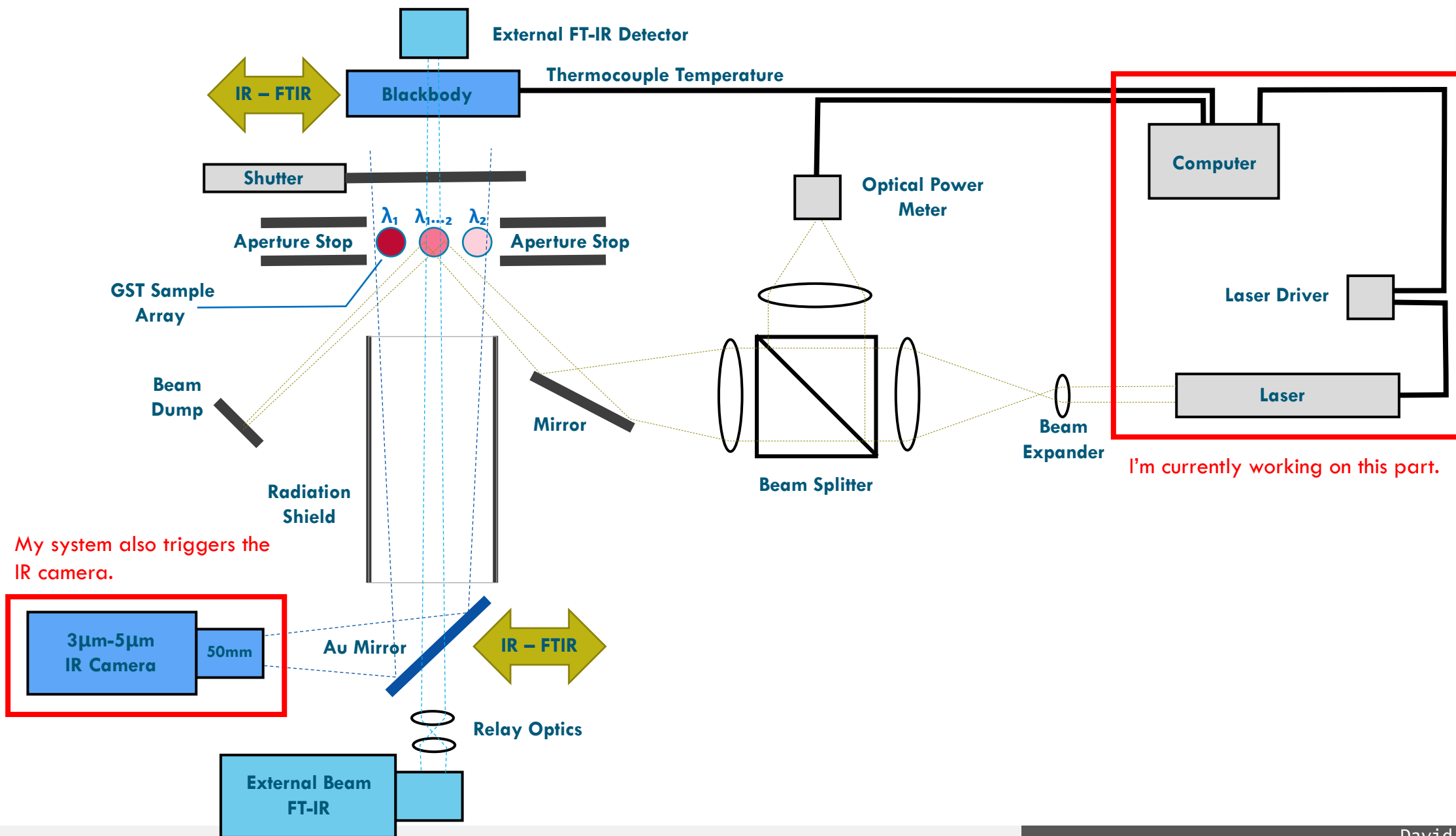
Determining the Failure Cycle of the GST filter.



- GST has in its crystalline and amorphous phase has distinct values of transmittance intensity.
- A figure with a double y-axis (transmittance of the amorphous phase and transmittance of the crystal phase) based on the x-axis (number of cycles) will be plotted.
- Other useful properties to measure (double / triple y-axis) : center wavelength and full width at half maximum (FWHM).

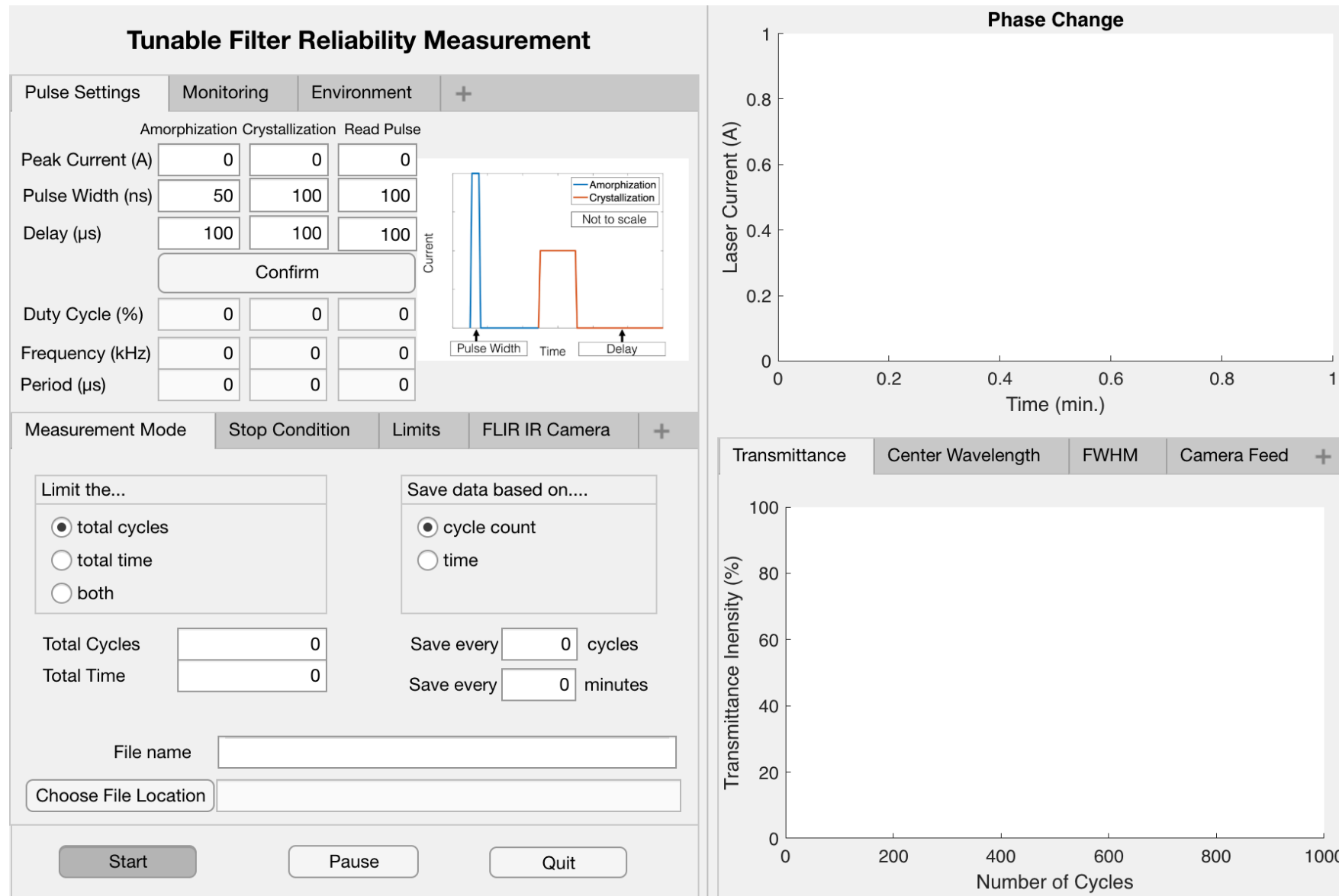


Experimental Setup - Overview



My system also triggers the IR camera.

Graphical Control Interface



- Made with the MATLAB App Designer
- Modular design with the user of tabs: easy addition or removal for additional functionality.

Pulse Settings

Easily adjustable by the user in MATLAB.



MATLAB

Tunable Filter Reliability Measurement

Pulse Settings	Monitoring	Environment	
	Amorphization	Crystallization	Read Pulse
Peak Current (A)	10	4	1
Pulse Width (ns)	50	100	100
Delay (μ s)	100	100	100
	Confirm		
Duty Cycle (%)	0	0	0
Frequency (kHz)	0	0	0
Period (μ s)	0	0	0

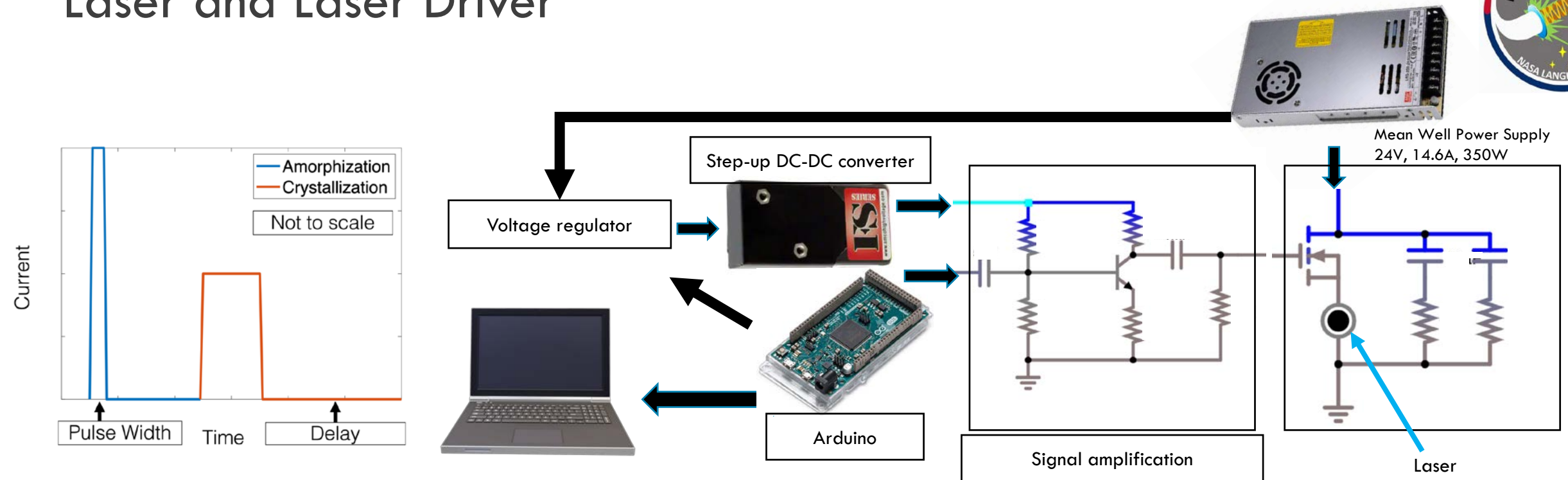
The graph shows two pulses: a blue pulse for Amorphization and an orange pulse for Crystallization. The x-axis is labeled 'Time' and the y-axis is labeled 'Current'. The blue pulse is narrow and tall, while the orange pulse is wider and shorter. A legend indicates 'Amorphization' (blue line) and 'Crystallization' (orange line). A note says 'Not to scale'. Arrows on the x-axis point to the 'Pulse Width' and 'Delay' of the pulses.

Pulse Width (ns) 200

Value must be between 20 and 100

- In this tab, you can control three factors for each phase change: peak current, pulse width, and delay.
- If you try to enter a value out of range, a warning message will pop up and the value will revert to its default.
- Press “Confirm” to calculate the duty cycle and repetition rate.
- The unit of pulse width is ns, while the unit of the delay is μ s.

Laser and Laser Driver



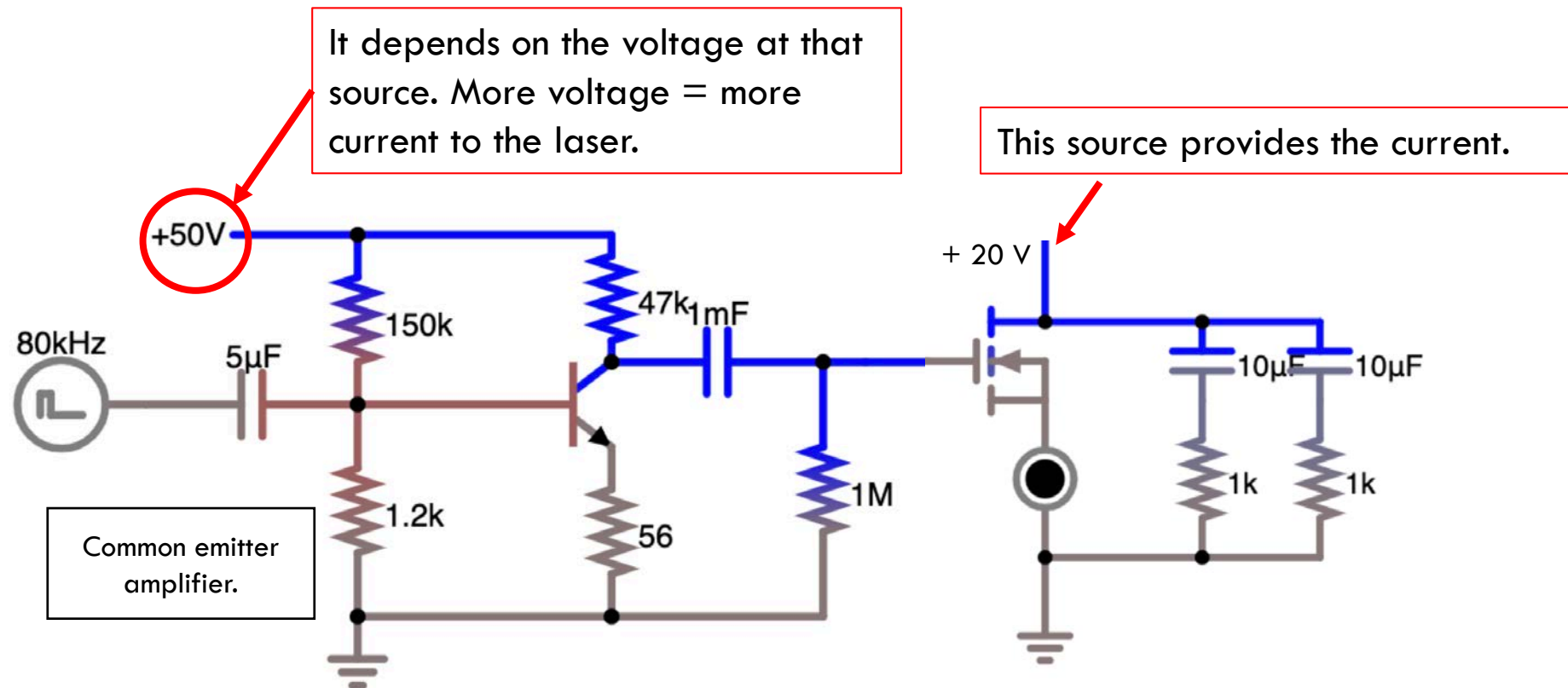
Advantages:

- Low-cost and compact.
- Allows user adjustment of pulse intensity, pulse width, and duty cycle.
- For the most part, uses basic circuit components.
- The Arduino is a microcontroller that functions as (1) a signal generator and (2) an instrument to adjust the output of the voltage regulator.
- MATLAB sends the user's settings to the Arduino at the beginning of the experiment.



How much power can be delivered to the laser?

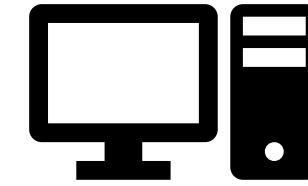
With this configuration, **14 A** can be delivered to the laser.



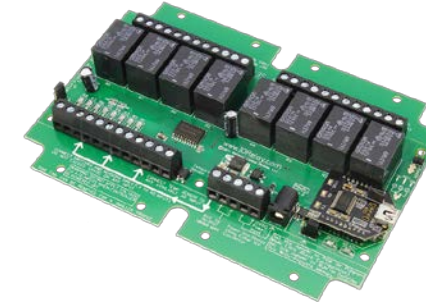
Mid-Wave Infrared Camera (2.5 ~ 5 μm WL)

Needed for measuring the transmittance of the GST.

- The USB relay allows MATLAB to trigger the IR camera.
- The GST will be placed on a transparent calcium fluoride substrate.
- An image of only the calcium fluoride will be taken to establish a baseline image that indicates 100% transparency.
- From the subsequent images of the GST in front of the calcium fluoride will transmittance be extracted across the MWIR spectrum.



MATLAB sends numerical command to relay.



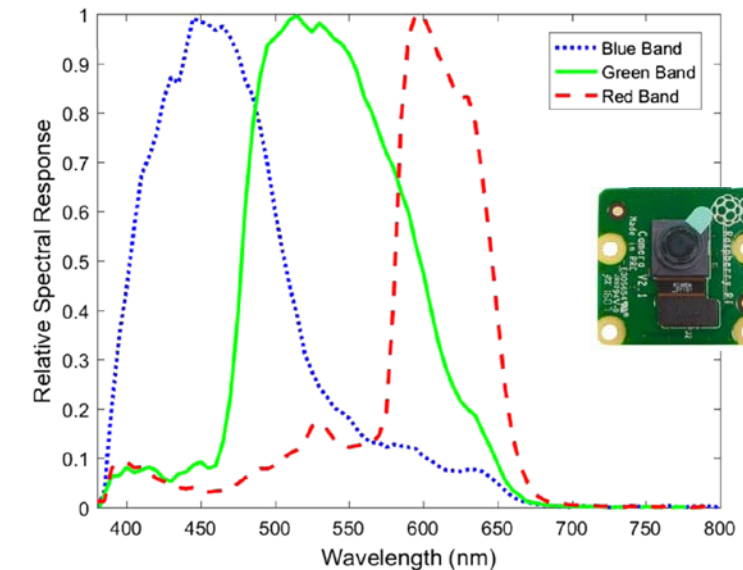
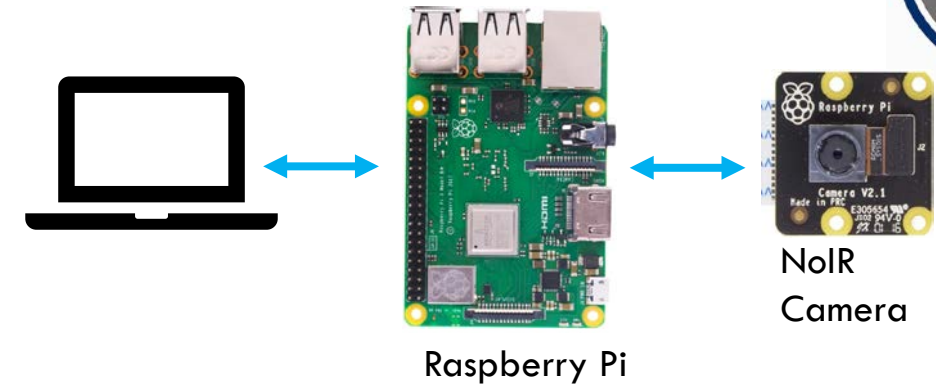
Relay triggers the IR camera.



Raspberry Pi Image Capture

Low-cost alternative to mid-wave IR camera.

- Transmittance intensity of the GST can also be obtained with a low-cost Raspberry Pi camera.
- The Raspberry Pi computer connects to the [NoIR camera](#).
- The Raspberry Pi will be controlled with MATLAB's [Raspberry Pi support package](#).
- The Pi NoIR camera can see beyond the visible range; it is sensitive to **short-wavelength IR** radiation, which is around **880nm** ([Source](#)).



The spectral response of the Raspberry Pi 3 v2 camera.

Source: [10.1117/1.JEI.26.1.013014](https://doi.org/10.1117/1.JEI.26.1.013014).

Summary and Fall Plan



- Designed a system to pulse laser diode with programmatically-adjustable pulse width, duty cycle, and peak current.
- Interdisciplinary project:
 - Electrical engineering: Design the circuit to pulse the laser.
 - Programming: MATLAB user interface and Arduino code.
 - Materials science and optics: Understanding concepts that motivate the design of the system.
- Fall Plan:
 - Continue working on MATLAB user interface and Arduino programming.
 - Improve functionality both Raspberry Pi camera and newly purchase SWIR FLIR camera ($0.6 \sim 1.7 \mu\text{m}$ WL).
 - Submit paper to the [Journal of Open Hardware](#) on the development of system to pulse a laser using low-cost components and open-source software. (progress report add!)

Thank You!

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