

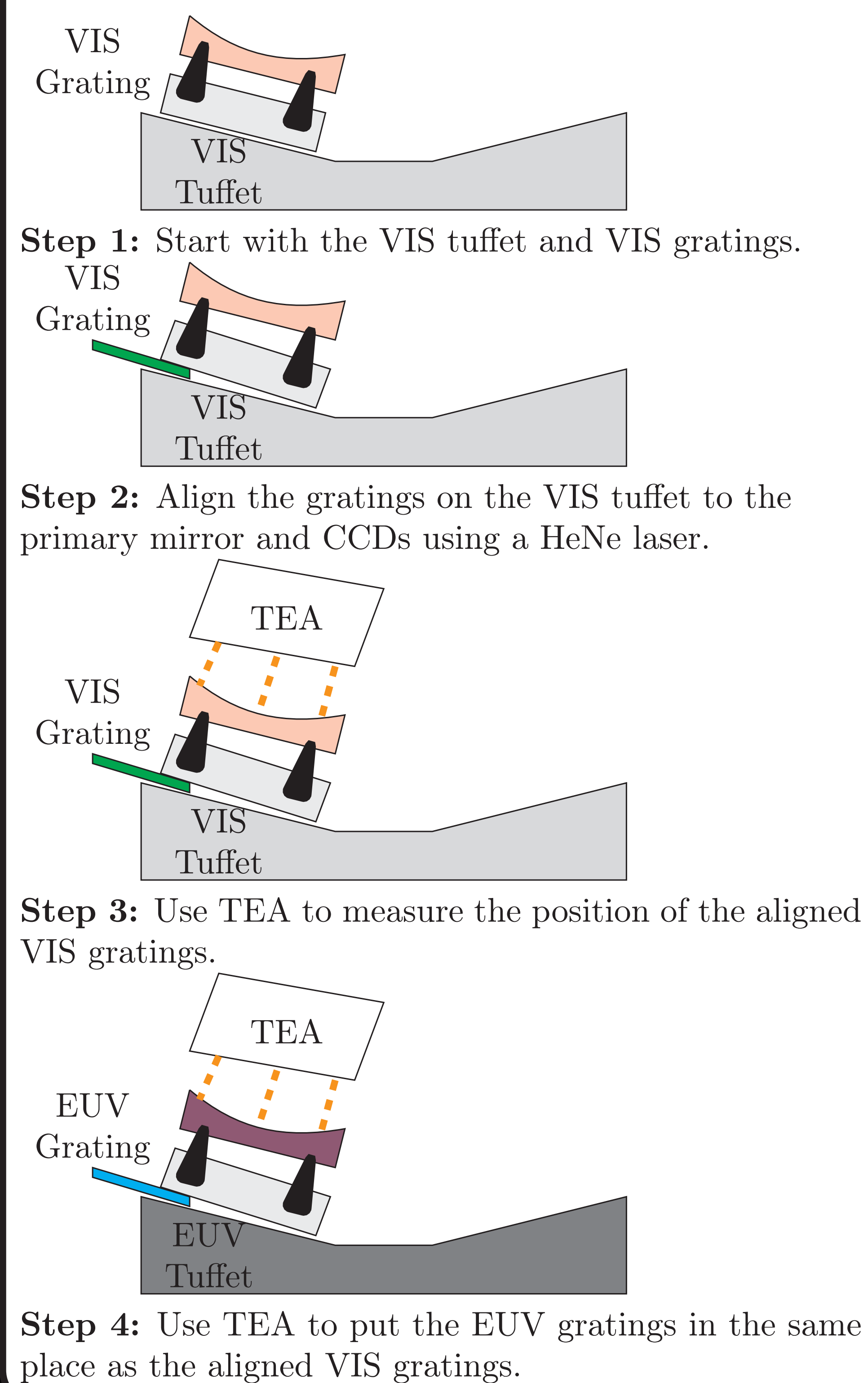
# Confocal Microscopy for Micron Precision Non-Contact Optical Measurements

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## Introduction

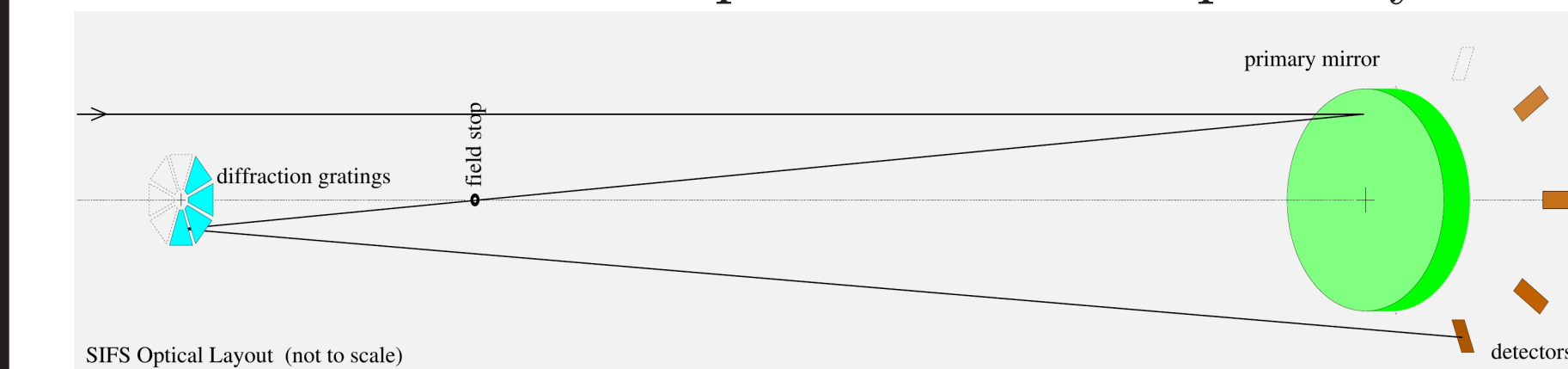
The EUV Snapshot Imaging Spectrograph (ESIS) is a slitless, tomographic imaging spectrograph for observing the solar transition region in extreme ultraviolet (EUV) at 63 nm wavelength. An array of concave diffraction gratings re-image from the telescope prime focus to our CCD detectors. The instrument is aligned and focused in visible light, using substitute diffraction gratings ruled for the red HeNe laser line. To transfer precise alignment and focus of the visible gratings to the EUV gratings, we have developed a miniaturized measurement system, TEA (Transfer ESIS Alignment). TEA locates the grating surface using confocal microscopy, with three independent channels scanned together on a single stage, to specify the position and orientation of the spherical surface. Challenges for this measurement include the size and shape of the ESIS gratings, diffraction effects, the alignment of tiny optics within TEA, and the mechanics used to repeatedly mount the gratings. Our testing shows that the intrinsic repeatability of our measurement apparatus is approximately  $2 \mu\text{m}$ , but the system error is dominated by the grating mounting subsystem, which introduces  $12 \mu\text{m}$  differences between subsequent runs.

## Alignment Plan



## Motivation

ESIS uses a novel optical design for the tomographic imaging of spectral line profiles as a function of skyplane position, for the strong 63 nm line of O v. Sunlight comes into ESIS, and is brought to focus at a field stop by a  $\sim 150$  mm diameter parabolic primary mirror with 1 m focal length. After passing through the field stop, the diverging light encounters a radially symmetric array of concave diffraction gratings. Each grating re-images at  $4\times$  magnification from the prime focus to a corresponding CCD camera, located off axis just outside and behind the perimeter of the primary mirror.



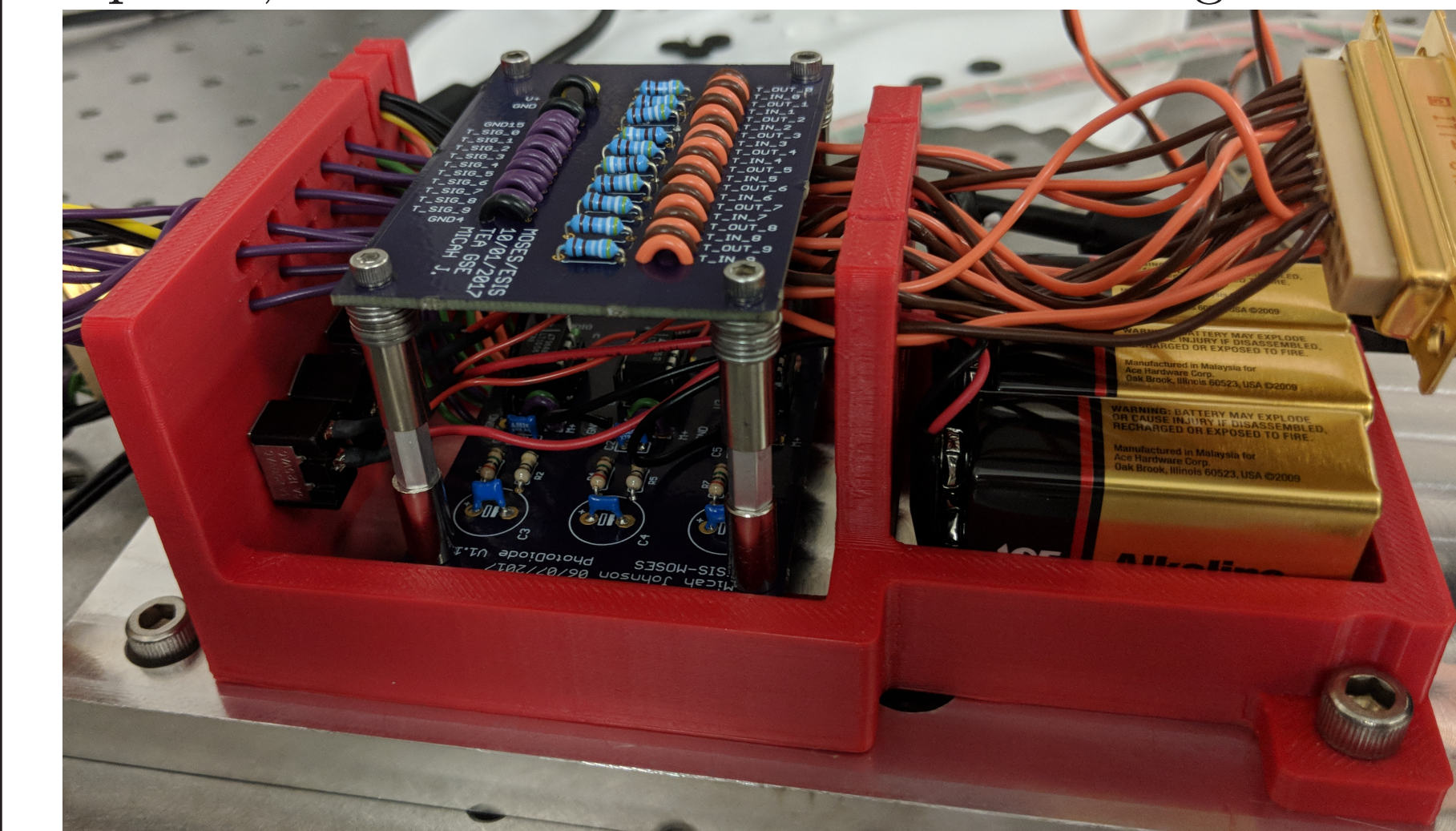
The grating array used in ESIS is mounted to a plate called the tuffet. There are two tuffets. One tuffet holds the VIS gratings, and the other EUV gratings. The VIS tuffet is used for alignment in ESIS, and the EUV tuffet is used for flight after alignment has been transferred from the VIS to EUV gratings.

## Design Goals

1. Be able to detect the orientation of a grating to  $8 \mu\text{m}$ .
2. Do not touch the gratings.
3. Do not use EUV.
4. Do not use vacuum.
5. Be able to complete the alignment transfer in two weeks.

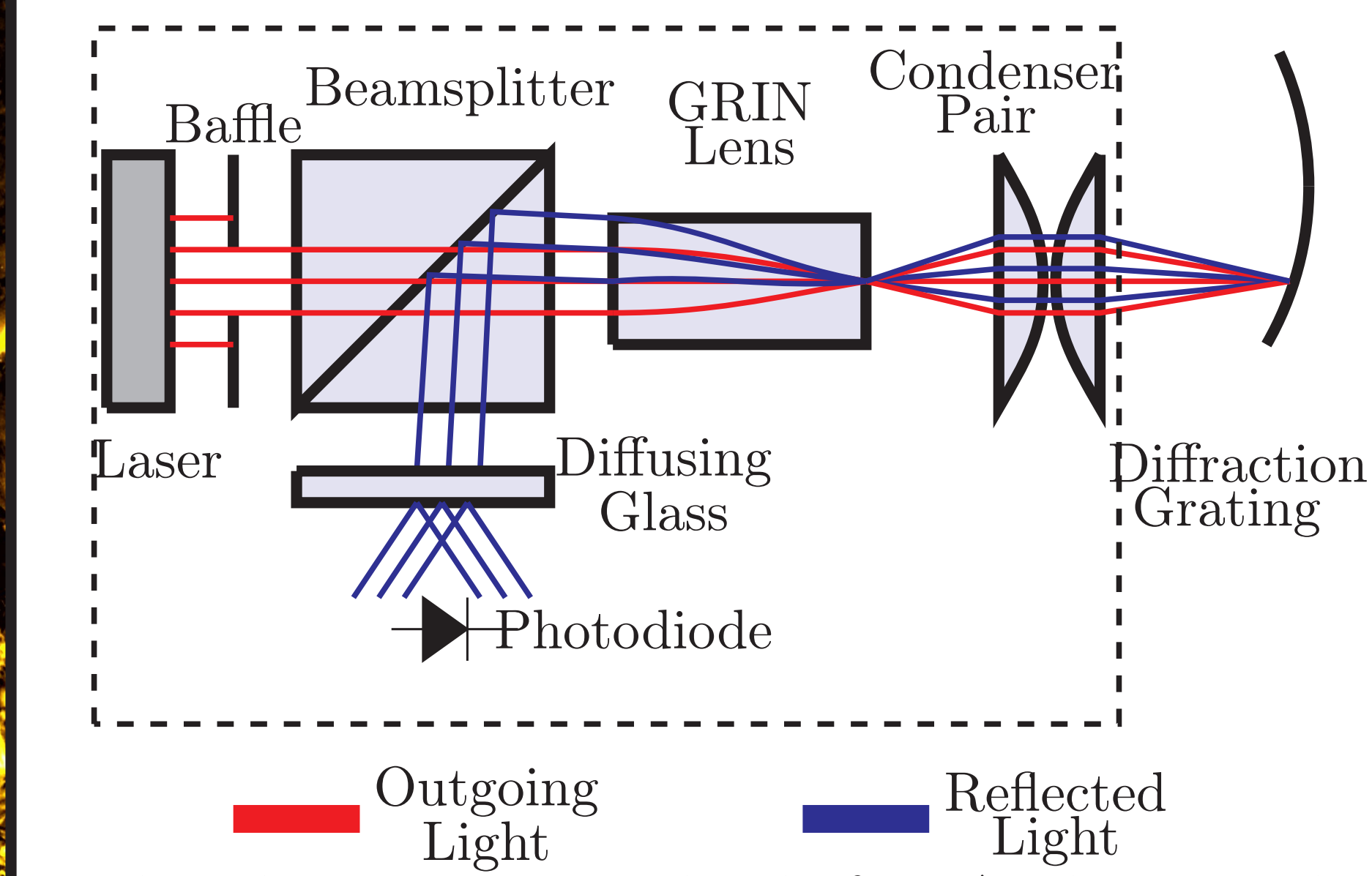
## TEA Electronics

A computer runs an automated stage controller to scan the measurement head. The current from the photodiodes in the measurement head is converted to a voltage in a transimpedance amplifier. The resistance of each thermistor is scaled by a voltage divider. The resulting voltages are measured and digitized by the voltmeter, and acquired as digital data by the computer. The input impedance of the voltmeter is  $1 \text{M}\Omega \pm 2\%$ , which is high enough that buffering was not required for the output filter of the transimpedance amplifier, nor for the thermistor voltage dividers.



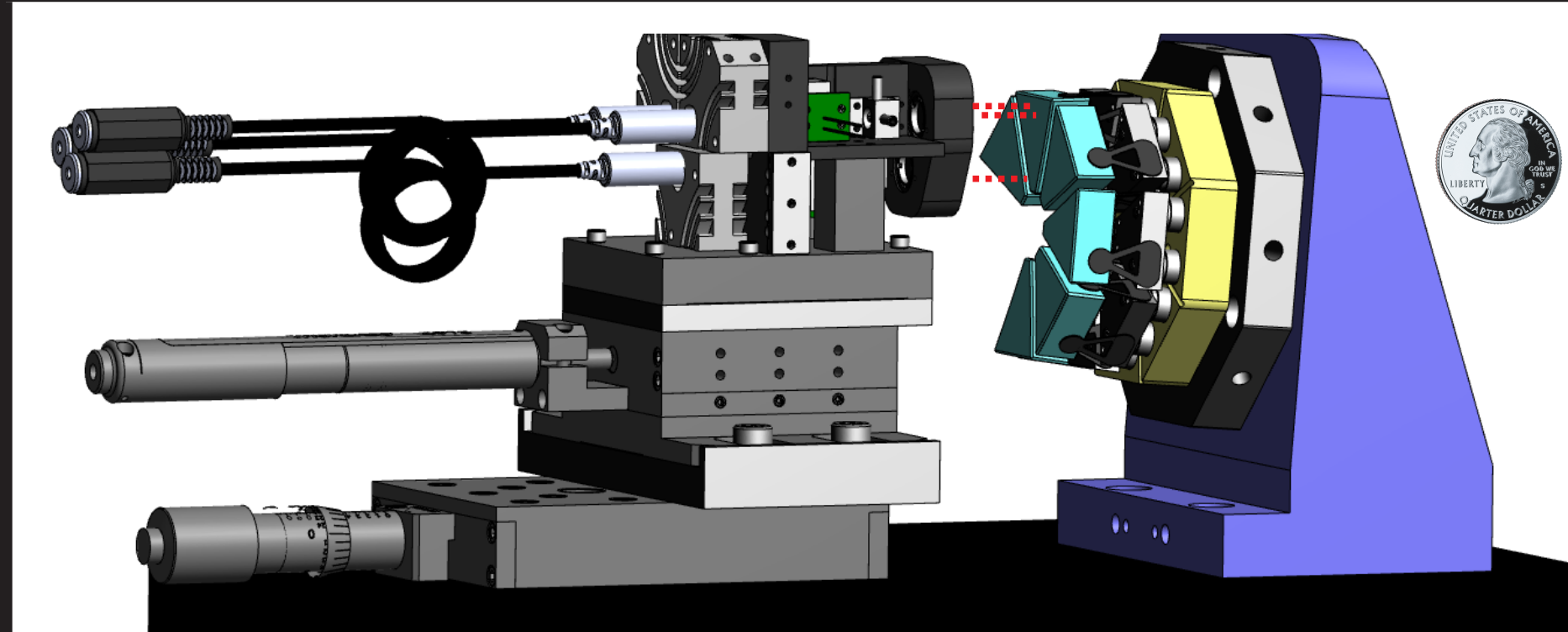
This image shows the circuitry designed for TEA. The top board has 10 independent thermistor channels, while the bottom board contains the transimpedance amplifiers used to measure the photodiode response.

## TEA Optical System

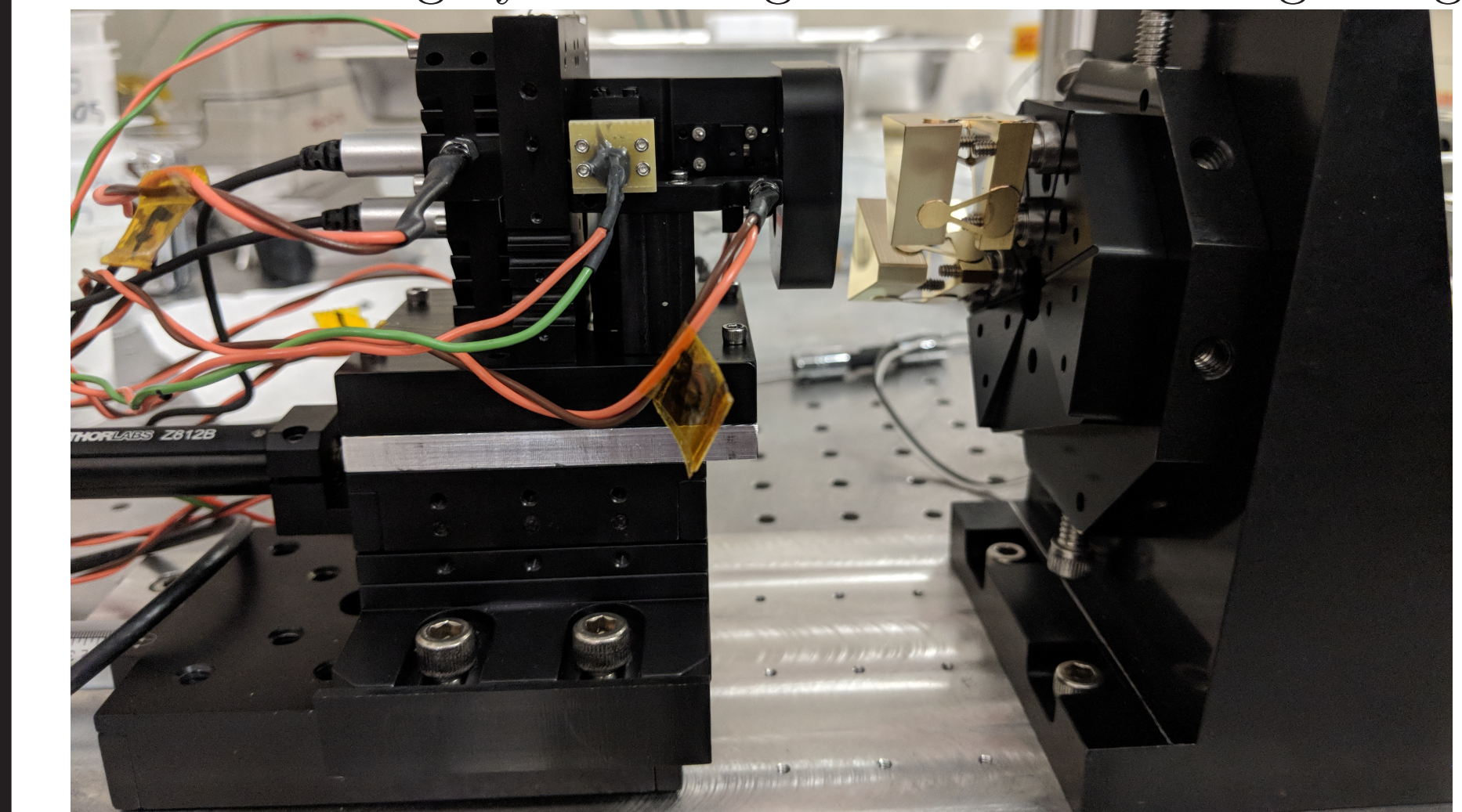


Within the measurement head of TEA, there are three identical confocal microscopes. Each microscope uses a 4.5 mW, 635 nm solid state laser diode module with elliptical beam of  $3.8 \text{mm} \times 1.2 \text{mm}$ . This image shows a ray trace illustration of one of the three microscopes within the TEA measurement head.

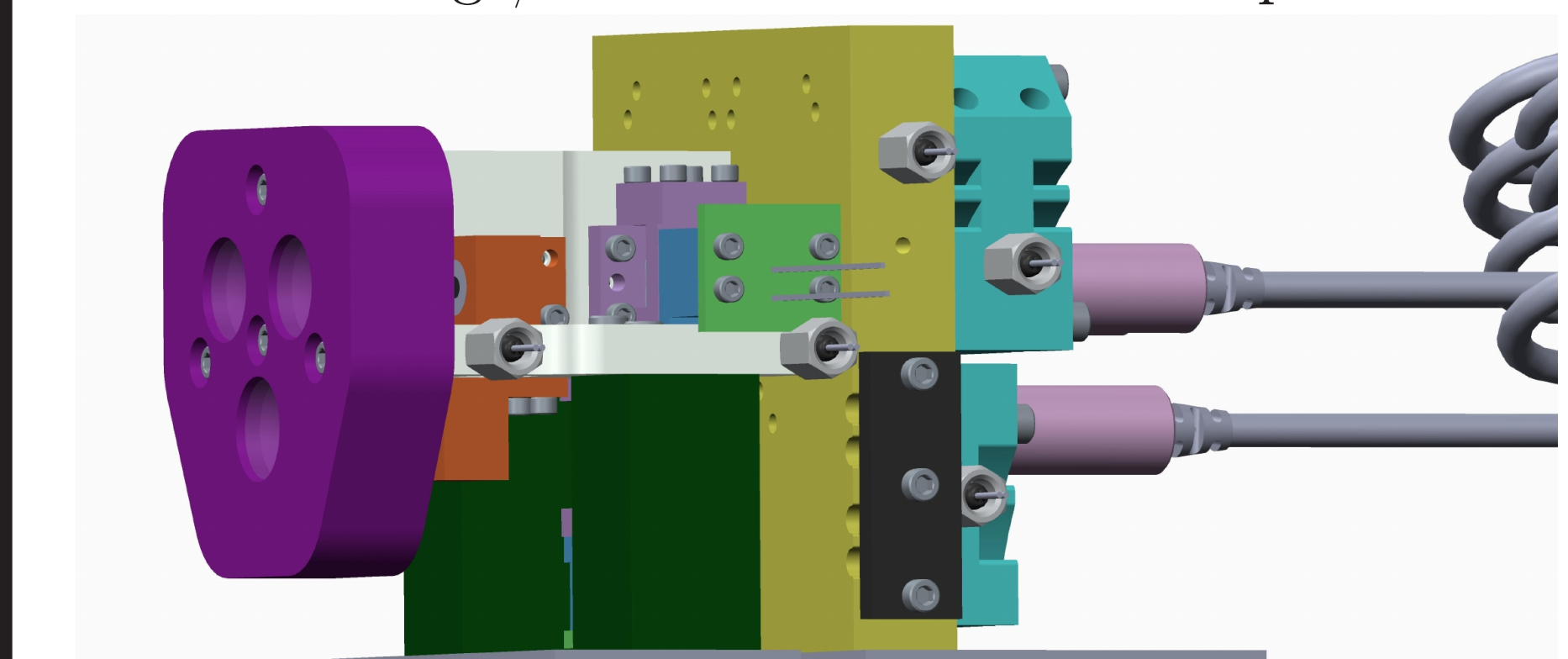
## TEA Mechanical Buildup



Solid Model for TEA, with quarter, for scale. Dashed red lines show roughly where light focuses on the gratings.



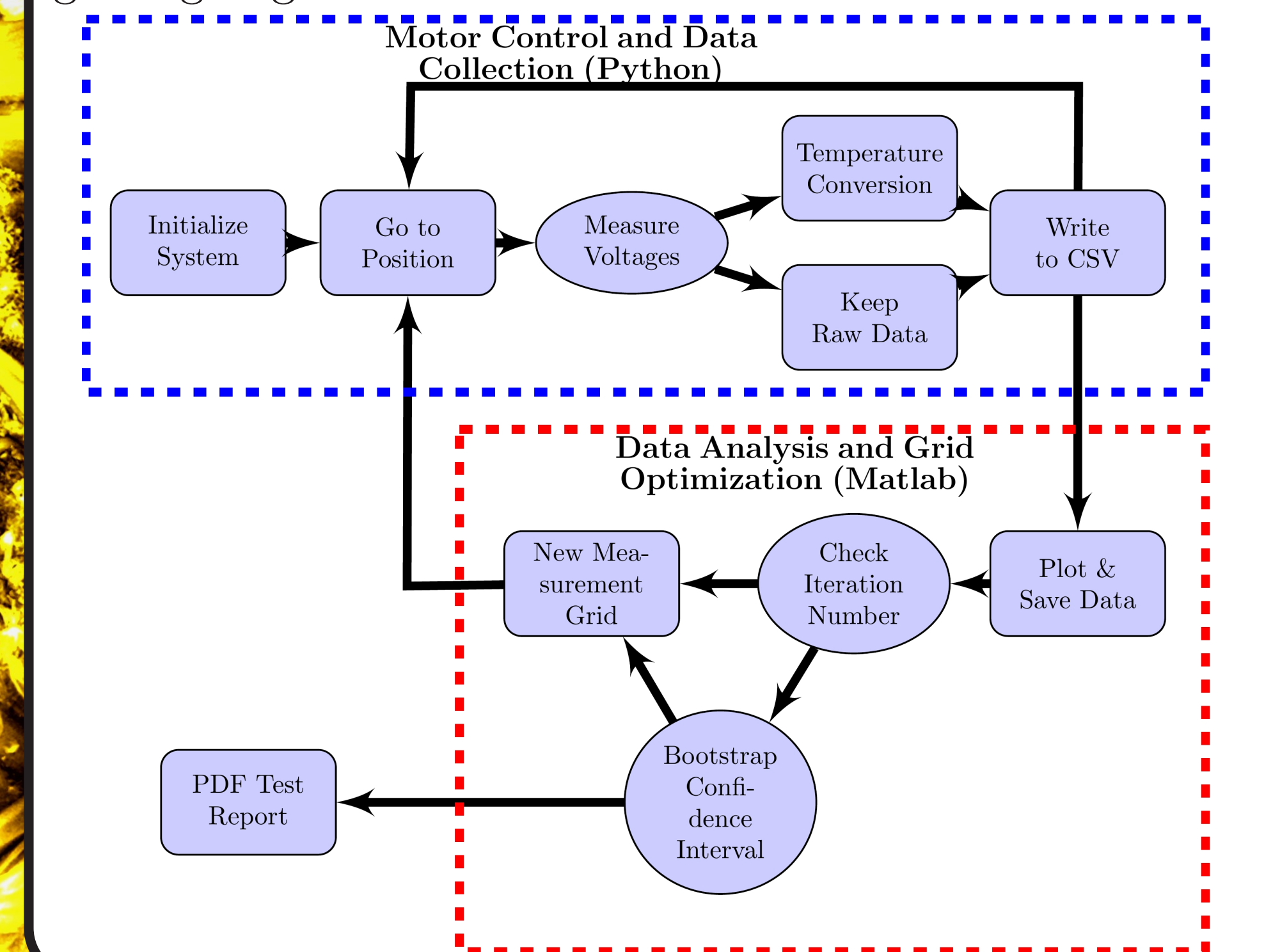
Fully Built TEA. Orange/Brown wires connect to thermistors. Orange/Green Wires connect to photodiodes.



Detailed view of the measurement head, housing the optical systems.

## TEA Software

Many data points are needed to know the location of the gratings to an adequate tolerance. To gather all the data, we developed a software for gathering and analyzing data. The software is split up into two main components: control and analysis. Python is used for control, and communicates with the stepper motor and voltmeter. Matlab runs the analysis part of the software which decides whether more data is needed, or how precisely the grating alignment is known.



## Conclusions

This poster describes a measurement approach that allows us to align an EUV spectrograph in visible light, then transfer that alignment from visible (VIS) gratings to EUV gratings. Our approach uses a unique, three channel confocal microscope measurement head to record the positions of the VIS gratings, and transfer the alignment precisely to the EUV gratings. While coordinate measuring machines and non-contact measurements using a variety of techniques have been in use in optical applications for many years, we anticipate that our alignment transfer technique may have other applications in research and industry. The measurement head can repeatedly determine the orientation of a mirror or grating to  $2 \mu\text{m}$ . The fixtures for holding the optics under test are less repeatable at  $12 \mu\text{m}$ , but this is currently being improved with more precision fasteners, and smaller surface area interfaces between parts.

## Acknowledgments

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## References

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