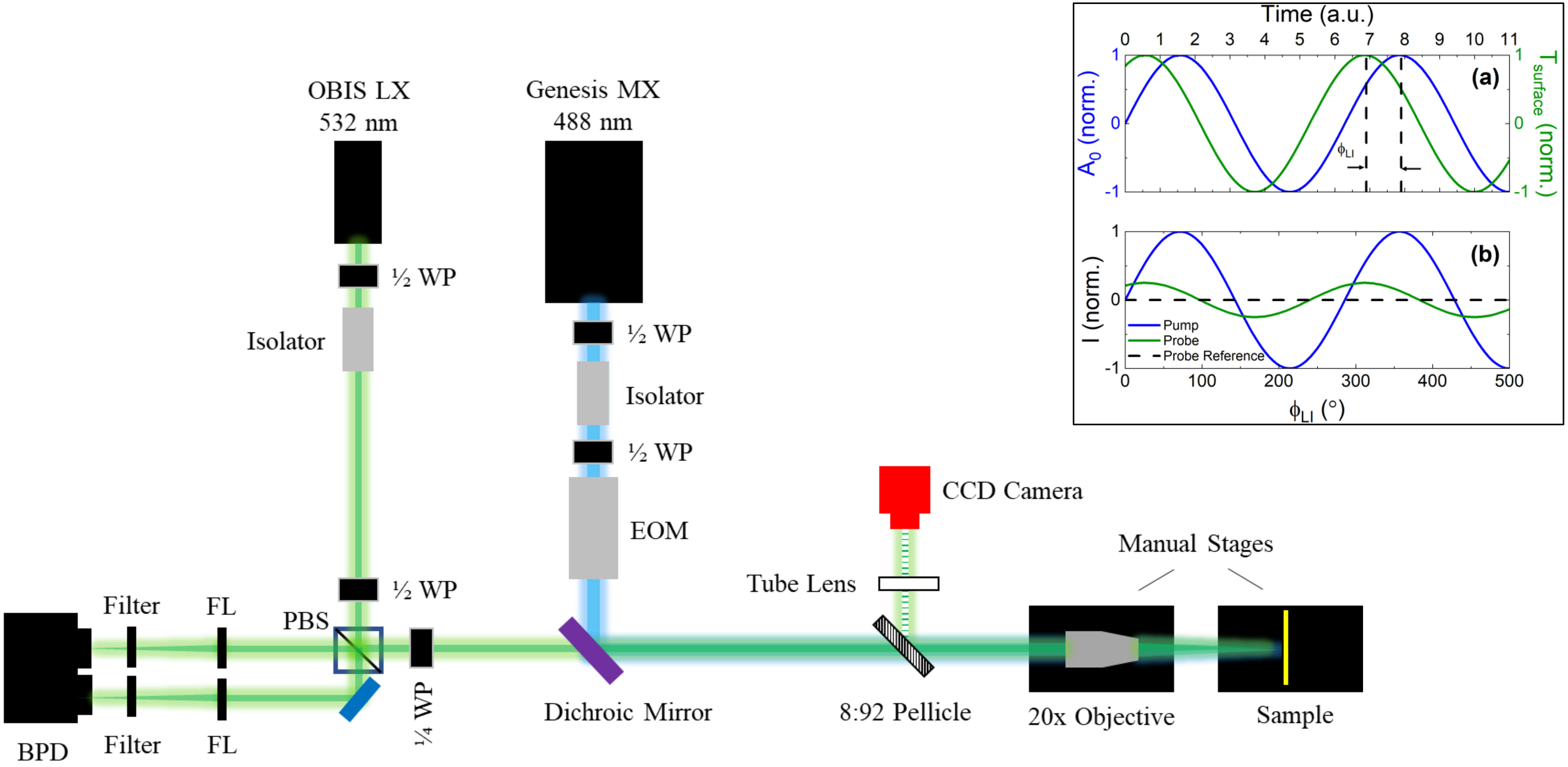
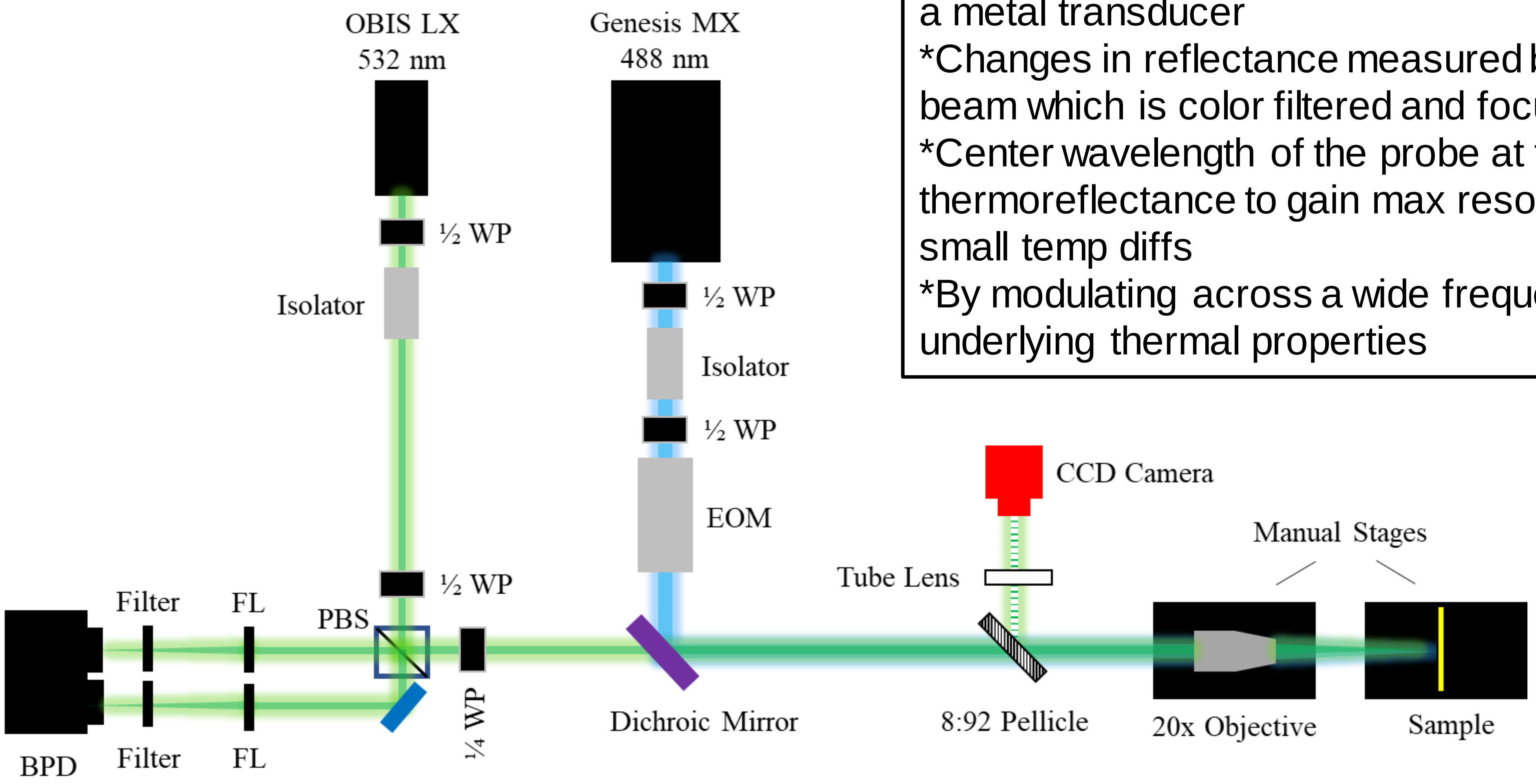
Frequency-domain Thermoreflectance Layout and Overview

FDTR Basics

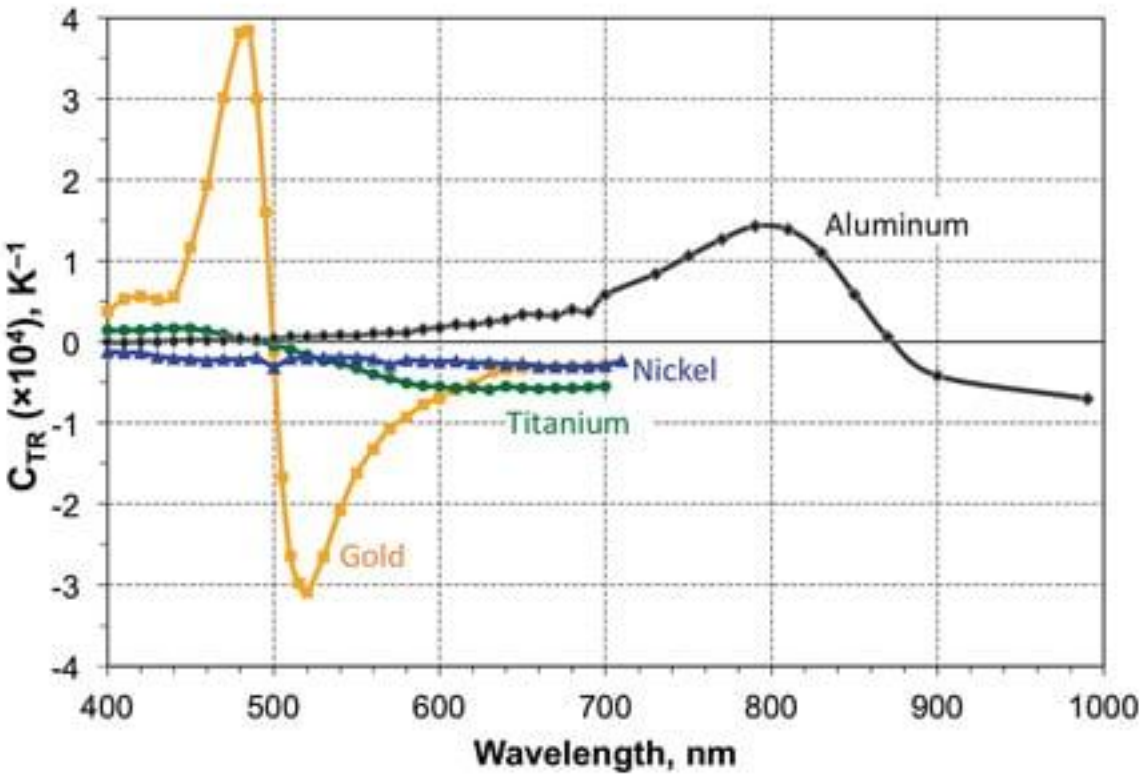

OBIS LX
532 nm
Genesis MX
488 nm
½ WP
Isolator
½ WP
Isolator
½ WP
EOM
CCD Camera
Manual Stages
Tube Lens
½ WP
Filter
FL
PBS
¼ WP
BPD
Filter
FL
Dichroic Mirror
8:92 Pellicle
20x Objective
Sample
Time (a.u.)
(a)
A_0 (norm.)
$T_{surface}$ (norm.)
ϕ_{LI}
(b)
I (norm.)
Pump
Probe
Probe Reference
ϕ_{LI} (°)

FDTR Basics

*Like any other characterization technique, rely on heating a sample and measuring its temperature
*Pump beam establishes a modulated heating event on the sample surface
*To absorb pump light & convert it to thermal energy, use a metal transducer
*Changes in reflectance measured by separate probe beam which is color filtered and focused into BPD
*Center wavelength of the probe at the max coefficient of thermoreflectance to gain max resolution and resolve very small temp diffs
*By modulating across a wide frequency range, can obtain underlying thermal properties



FDTR Basics – Coefficient of Thermoreflectance



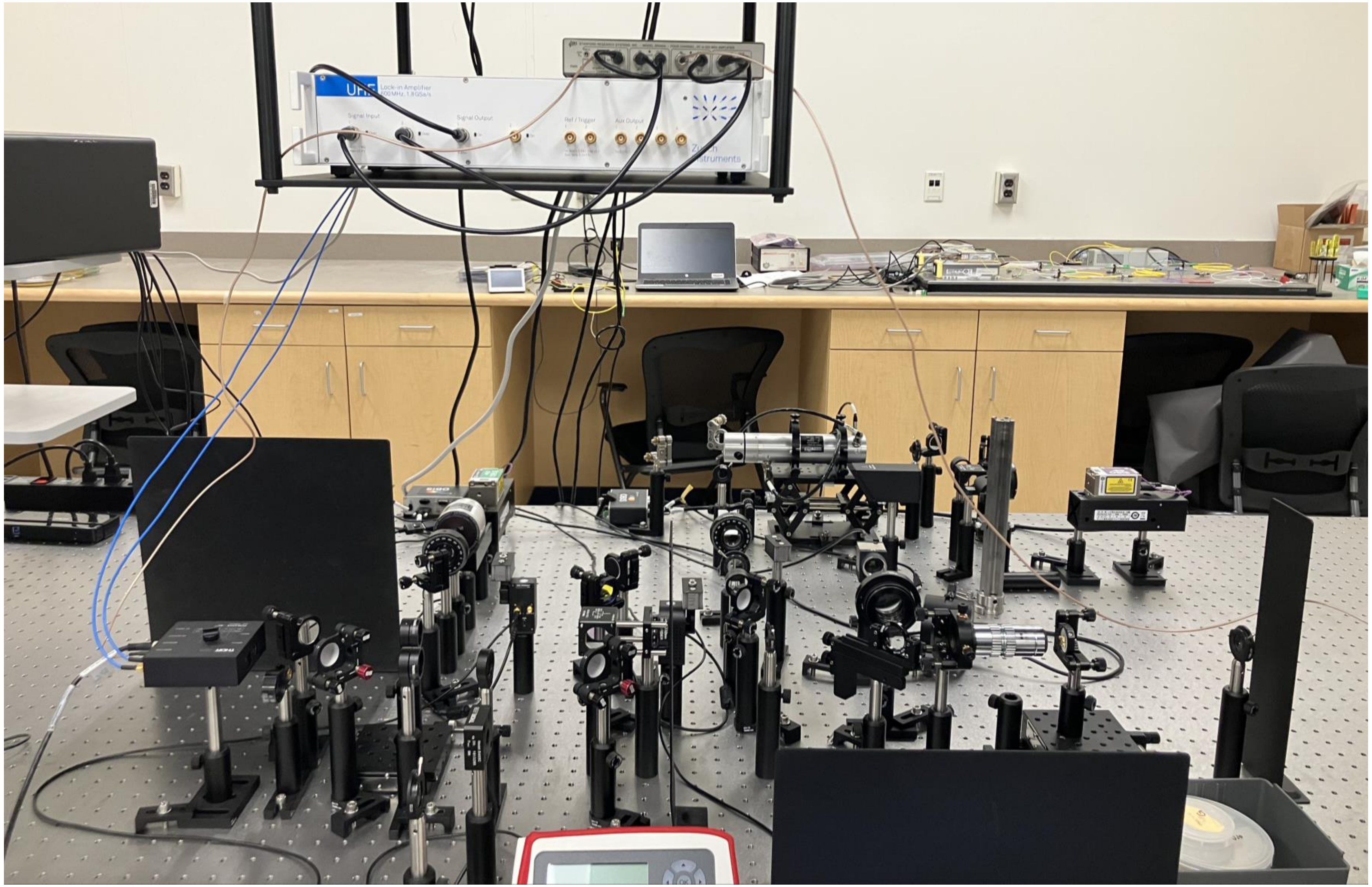
- We use a transducer to:
  1. Convert photonic energy to thermal energy
  2. Measure changes in reflectivity at the sample surface with time or frequency of a heating event
     - Metals have well-known relationship between temp and reflectivity

- Type of transducer matters
  - Higher magnitude of CTR produces finer resolution in temperature changes
  - Systems I have built use 532 nm as probe wavelength, and Au as transducer

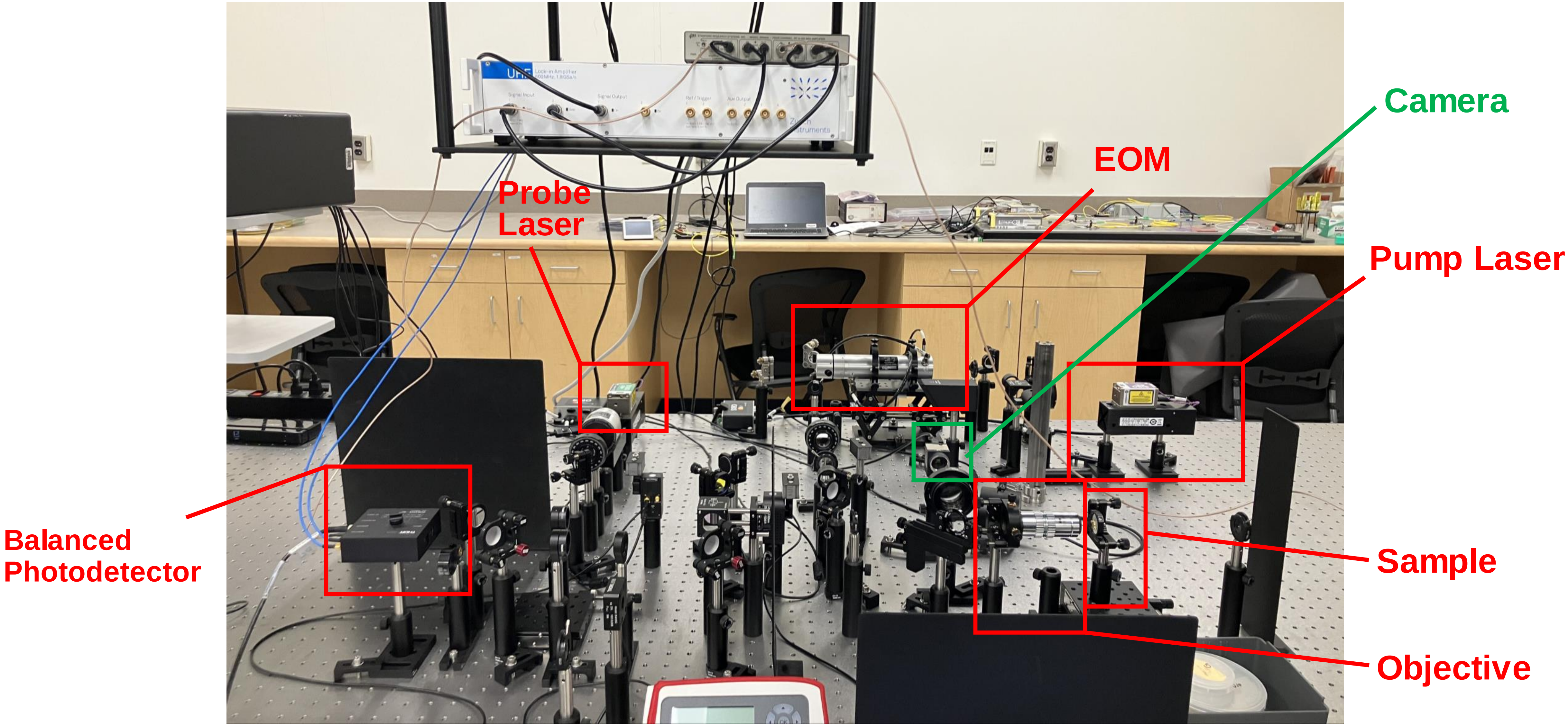
Accessed at (on 11/28/22)

https://www.electronics-cooling.com/2013/03/understanding-the-thermoreflectance-coefficient-for-high-resolution-thermal-imaging-of-microelectronic-devices/

FDTR Layout

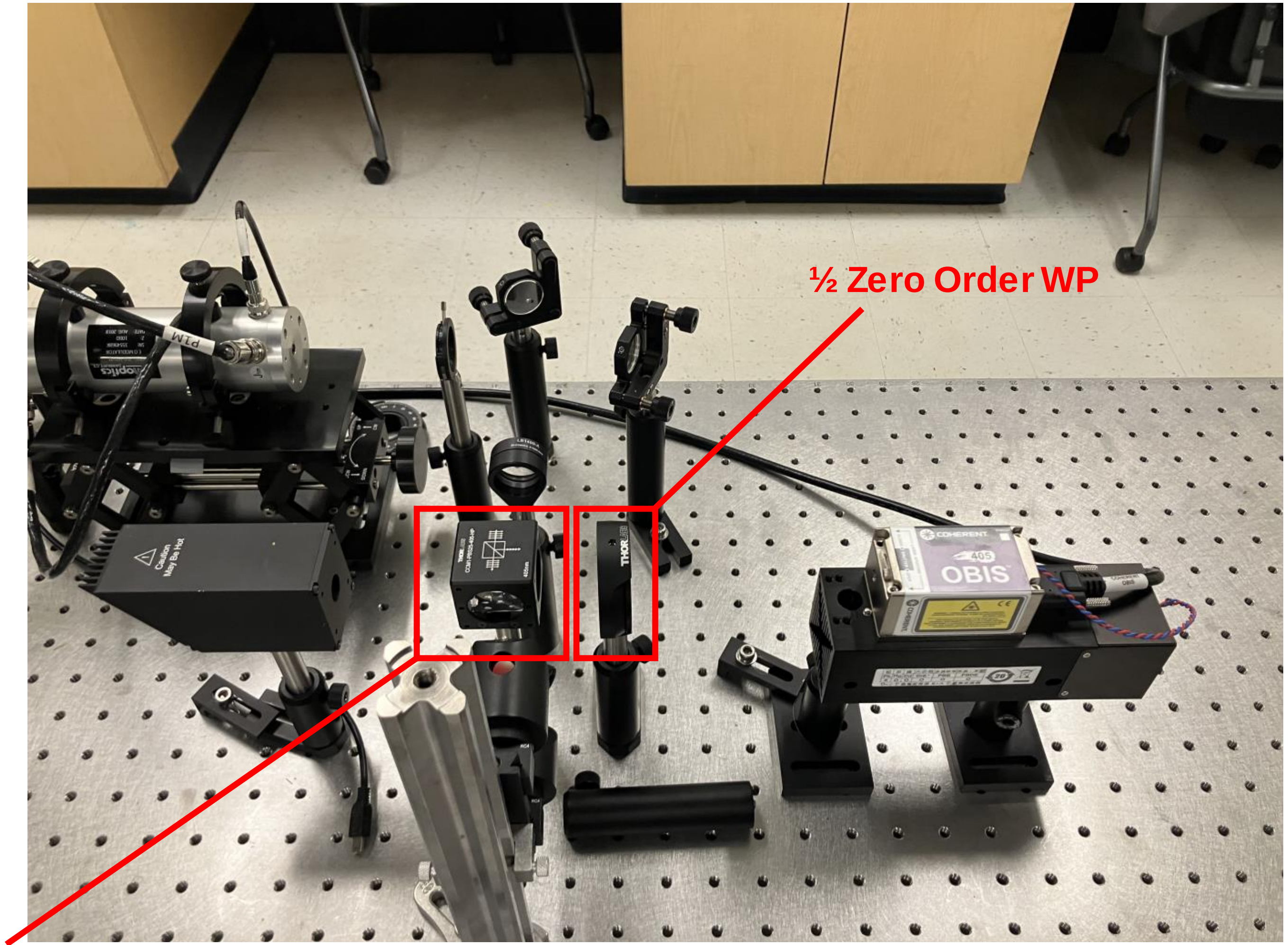


FDTR Layout



Camera
EOM
Probe Laser
Pump Laser
Balanced Photodetector
Sample
Objective

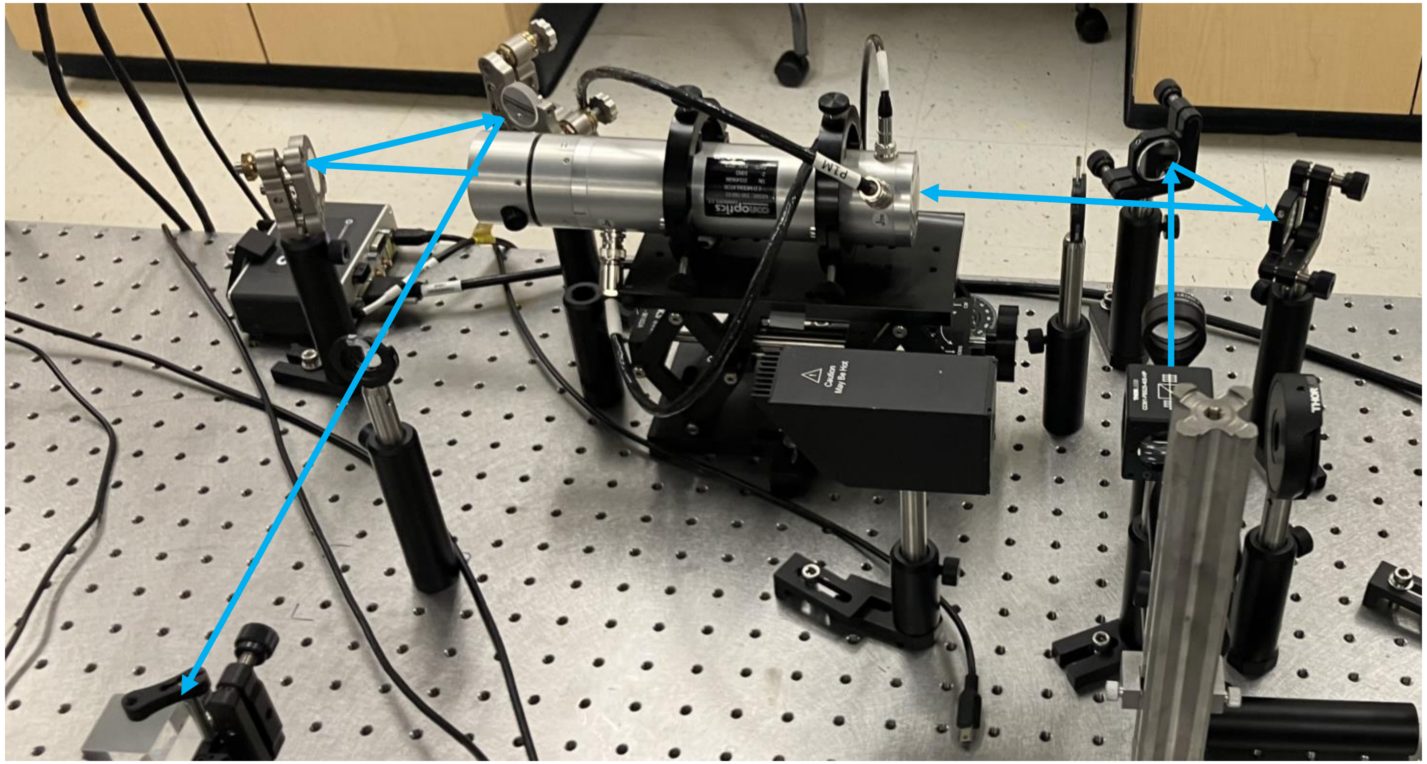
FDTR Layout



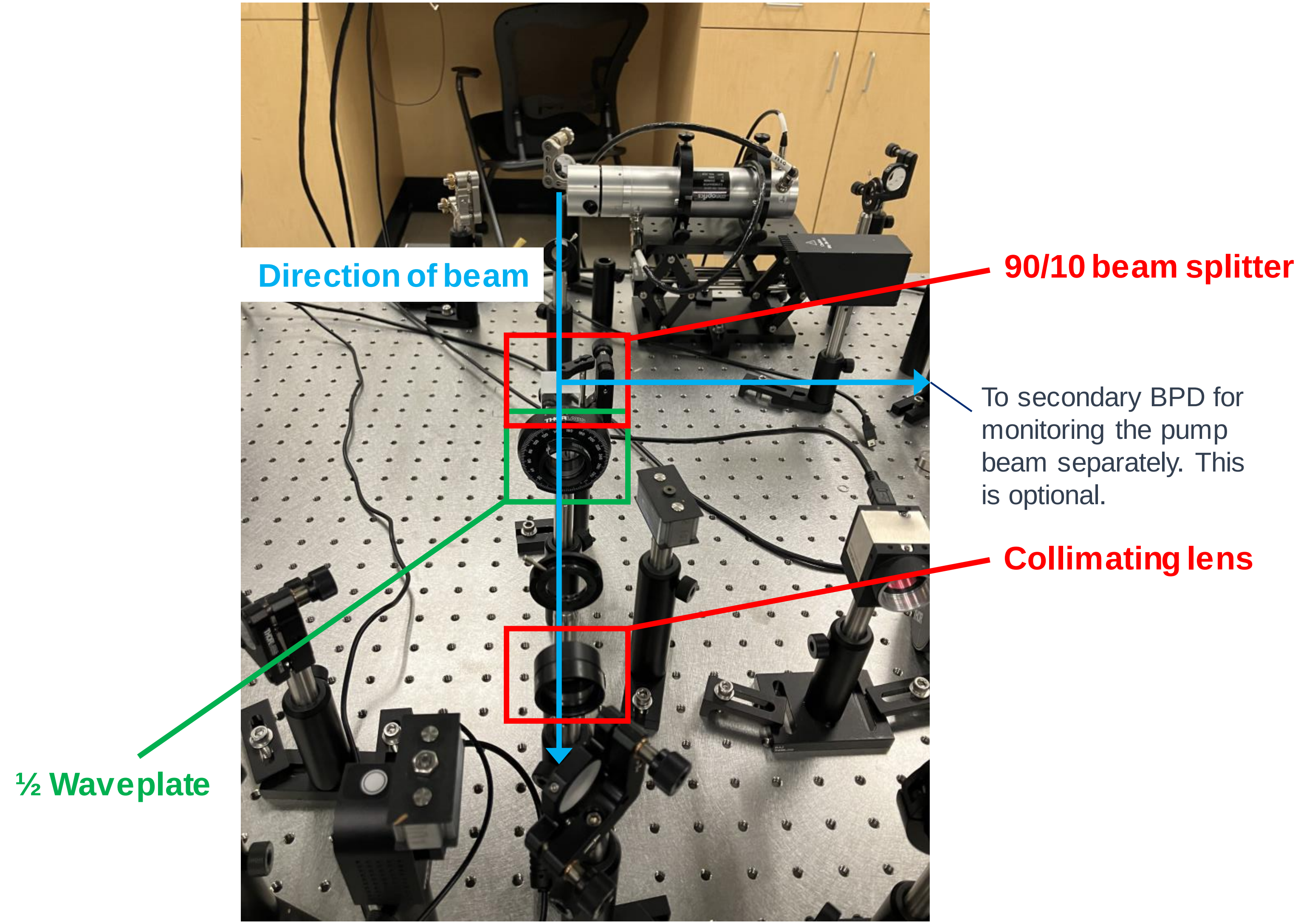
- PBS is used to establish horizontally polarized light ahead of the EOM
- An isolator is put between the ½ waveplate and the laser
  - Was removed in this image for remounting
- A long-distance bi-convex lens is used ahead of the EOM to ensure the beam is small enough to pass through it without clipping anywhere.

FDTR Layout – Aligning through EOM

- [Electro-Optic Modulators – TDTR Short Course (Joe Feser)]
- [EOM Alignment Video Series (Joe Feser)]

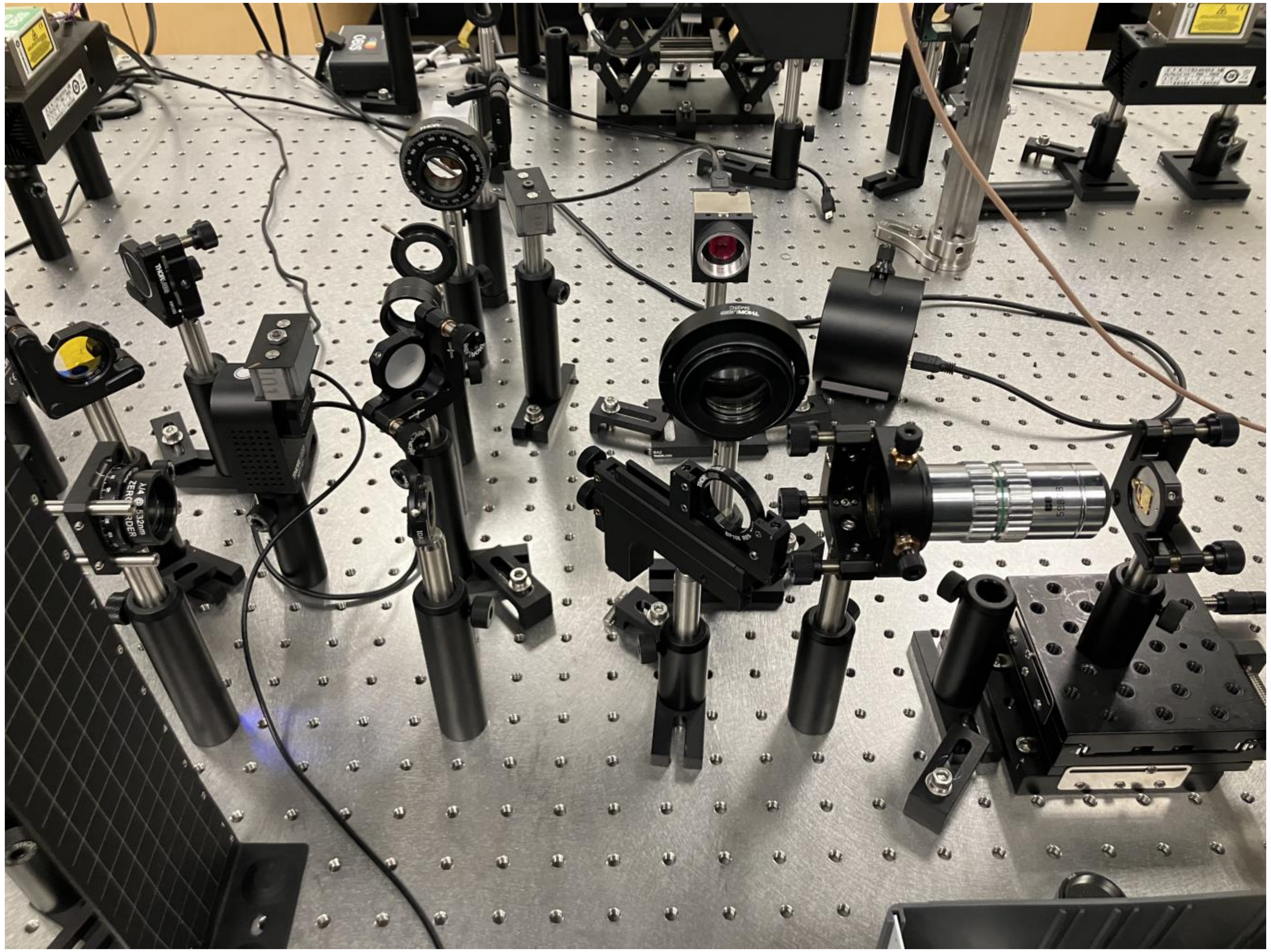


FDTR Layout – Pump Beam Path after EOM



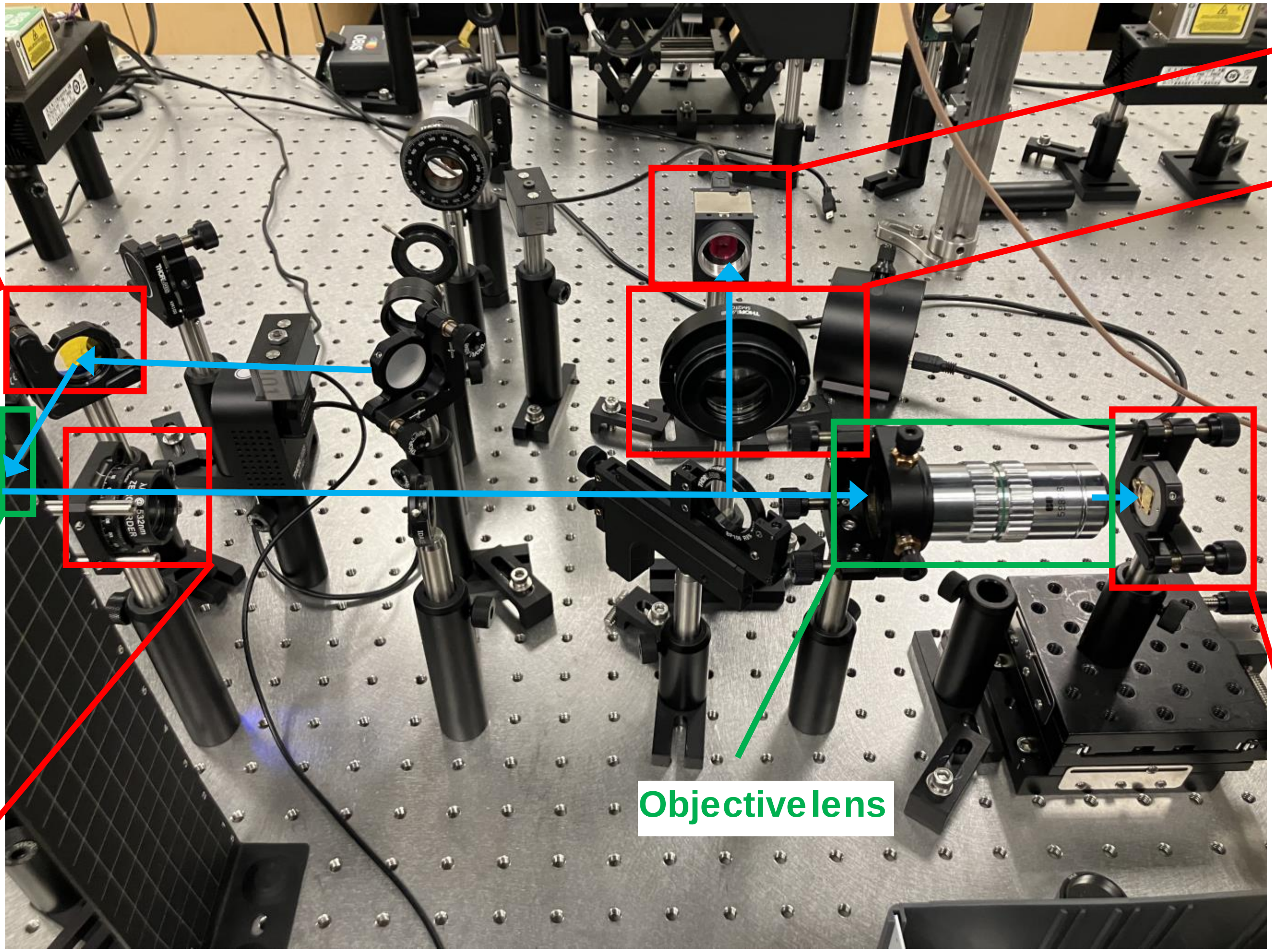
- 90/10 beam splitter is used in a two BPD configuration, where the second BPD continuously monitors pump phase separately (see schematic on next slide)
- ½ Waveplate controls the power of the pump heading to the sample.
- Collimating lens prevents too much divergence ahead of the objective.

FDTR Layout – Pump Beam Path after EOM

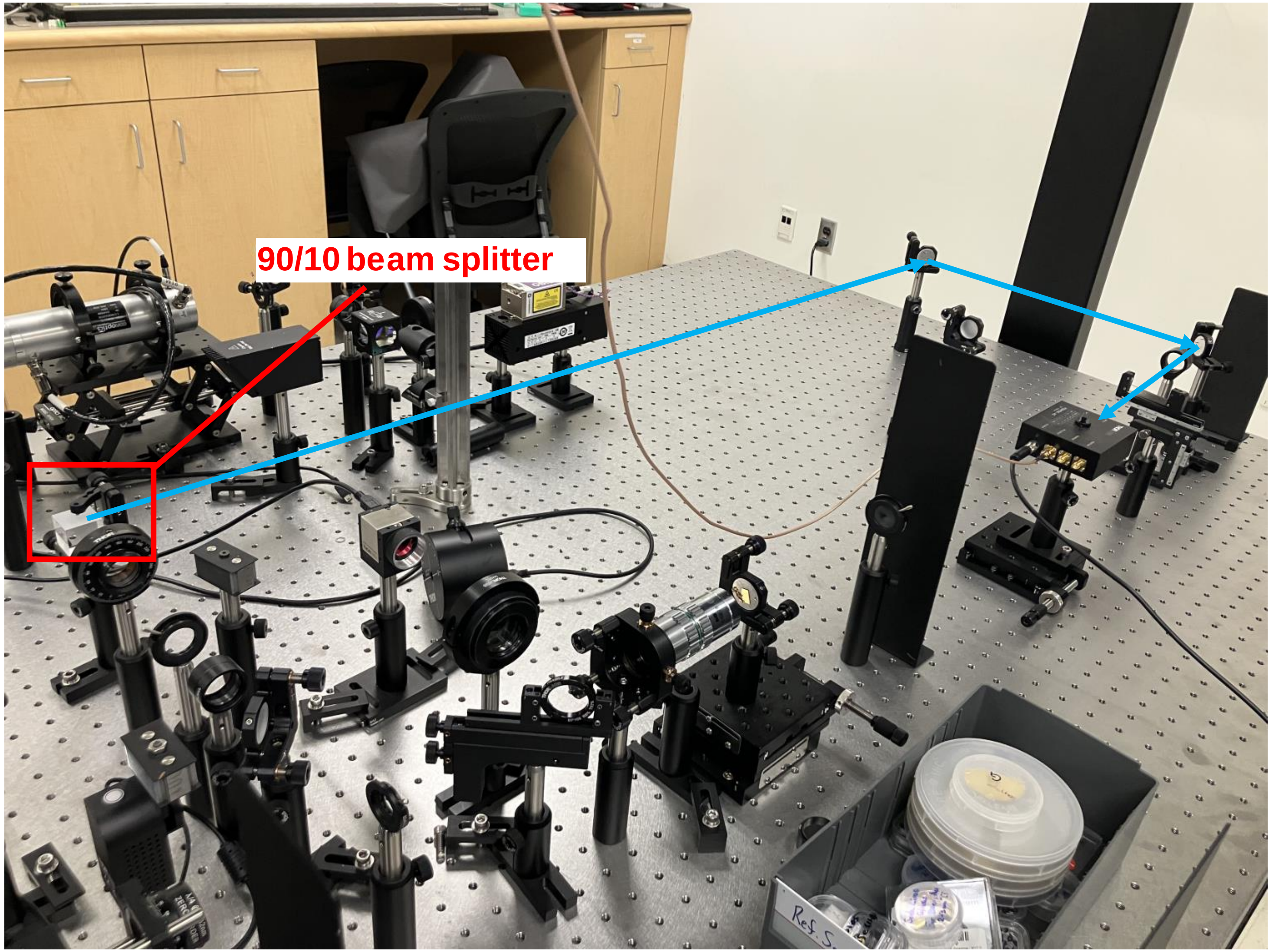


- A Dichroic mirror is used to reflect the blue beam and combine it with the green beam.
- 8/92 pellicle beam splitter used to direct 8% of light returned from the sample and back through the objective into a tube lens, which focuses down onto USB camera
- USB camera is used to make sure that probe light is focused onto the sample surface
  - Sample position is adjusted with x-y manual stages.

FDTR Layout – Pump Beam Path after EOM



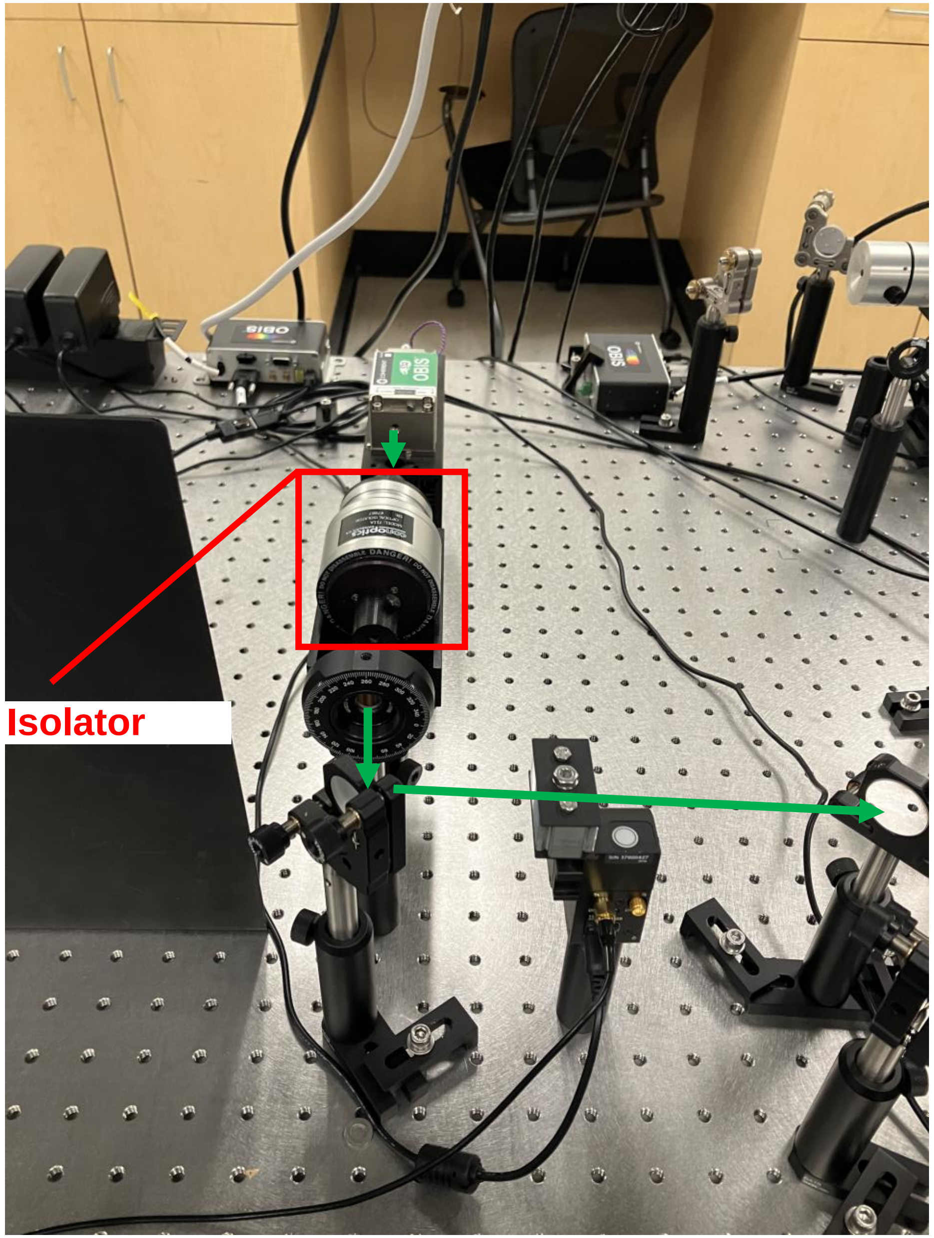
FDTR Layout – Optional Second BPD



- If one chooses, one can use a second BPD to monitor the phase of the pump beam at the same time as the probe beam. We have found that this helps account for changes in phase throughout the day. It also reduces the number of experiments that are required.
- The distance from the 90/10 beam splitter to the second BPD is matched to the distance from the 90/10 beam splitter, to the sample, back to the primary BPD.
    - To do this with precision, you match the phase of the pump beam in each BPD at your highest measurement frequency.

FDTR Layout – Probe path

- An optical isolator prevents back-reflection into the laser cavity.
- 1/2 waveplate is used to control how much power is passed through the PBS downstream (shown on the next slide).



FDTR Layout – Probe path

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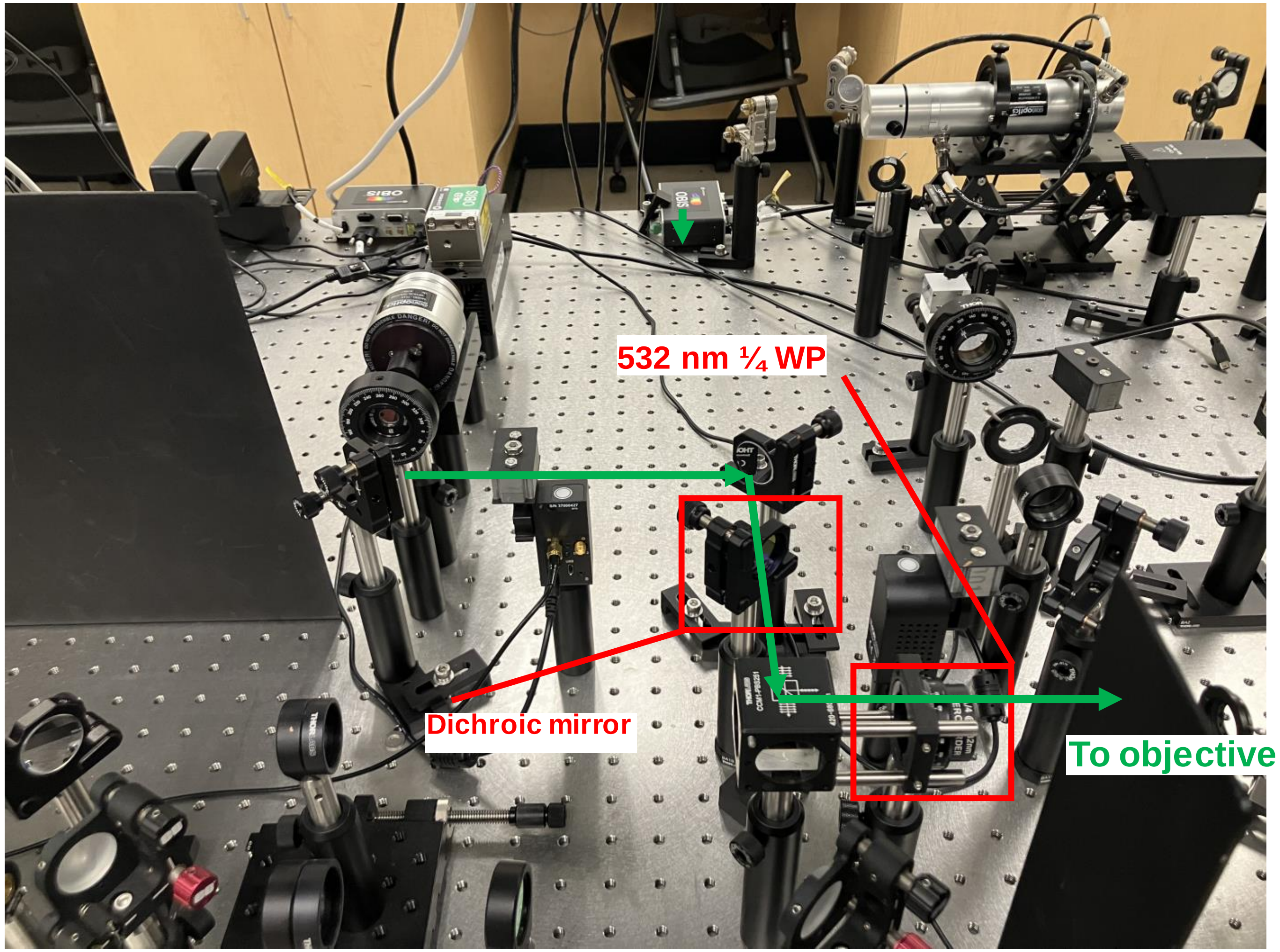
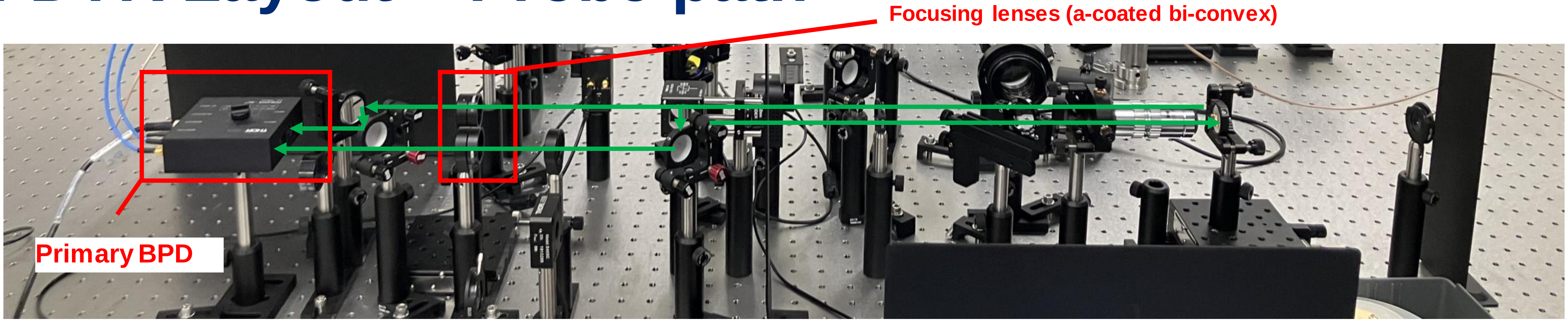
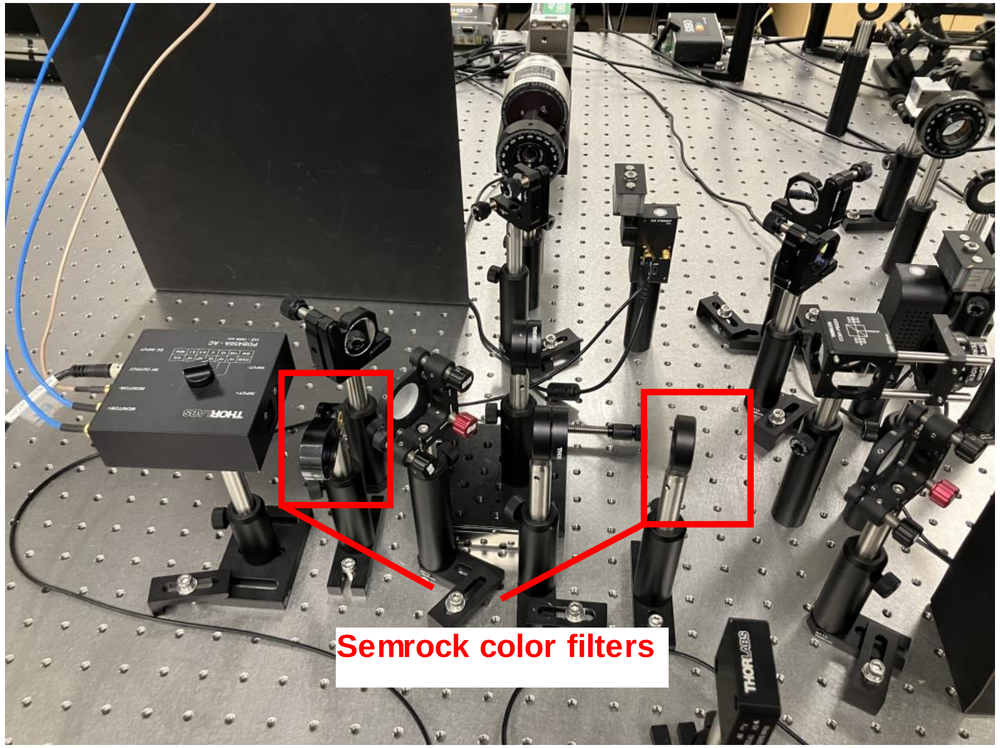


FDTR Layout – Probe path



- PBS directs some light into objective and some light through
  - Light passing through is directed and focused down onto other side of BPD to subtract (principally) low-f noise
  - Light that passes through objective is reflected back through a ¼ waveplate, which has now rotated the beam 180 degrees after passing through it twice so that it passes through the PBS, after which point it is focused down and directed into the BPD



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