Dabney Biography

- Matthew S. Dabney spent 13 years mastering details of optics at Hyperfine, Inc. He fabricated and qualified most of the optics in the Hubble Space Telescope and other space flight optics. Matthew brought his optics and engineering experience with him to the National Renewable Energy Labs (NREL) National Center for Photovoltaics in Golden, CO, where he currently is an optical engineer. During his 14 years at NREL as an engineer, he was encouraged to pursue first a Master's and then a PhD in materials science at Colorado School of Mines, while working full time on optical processing of materials for photovoltaics. He also served as the LSO for NREL from 2013-2016.

Laser Optics 101

Matthew Dabney, PhD, CLSO

September 28, 2016

My Optics Background

- 13 years high end Spaceflight Optics Design/Manufacturing/Testing
- Hubble Telescope/Ground Based Scopes
- Telecom/Communication
- Lasers
  - Holography
  - Metrology
  - Products
- 14 years laser processing research

Optics 101 - Overview

- Researcher interactions
- What to look for in an Optics lab
- Notoriously hazardous Optics
- How laser users select Optics
- Engineering controls/Eyewear
- Examples

One Laser to rule them all!

Researcher Interactions
The Plan

1. Break the Us vs Them mentality

2. Best Friend/Good Parent approach

3. Confidence vs Competence balance

1. Be prepared - requirements/goals

2. Partner

Researcher Interactions
In the Lab

1. Ask Questions – they are the expert usually

1. Explain the requirements/goals

2. Explain what you plan to do to help

3. Come to a mutual plan forward

4. How do they mentor a balance Confidence vs Competence

5. Expedient, Organized, set tasks and timelines

Discussing Requirements

- Discuss key hazards (example: periscopes)
- Explain the Requirements
- Discuss best methods for meeting requirements
- Example question: What could we do to improve the system if we had the resources?
- Brainstorm with them on how to get those resources.

Do's and Don'ts in Optics Labs

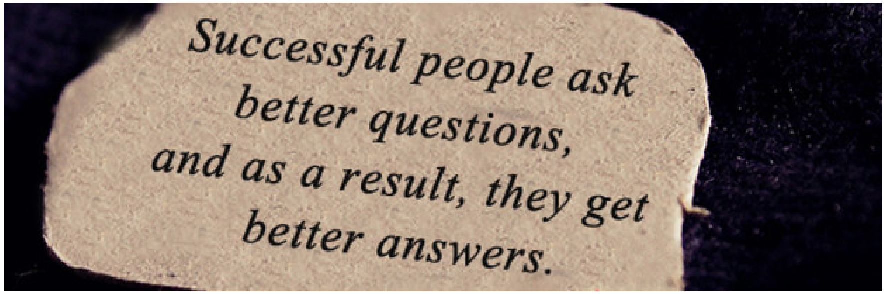
1. Put your hands in your pockets!

You will be tempted to touch something….

DON'T Touch Anything!!!

Ask Questions

2. They want to tell you what they are doing.



Let them!

If they don’t, work on the us/them mentality and be watchful of possible mentoring issues.

What to look for in Optics Labs

General Lab Layout

Follow the Beam-line

Critical pieces of the laser interaction

General Lab Layout

Safe Approach?

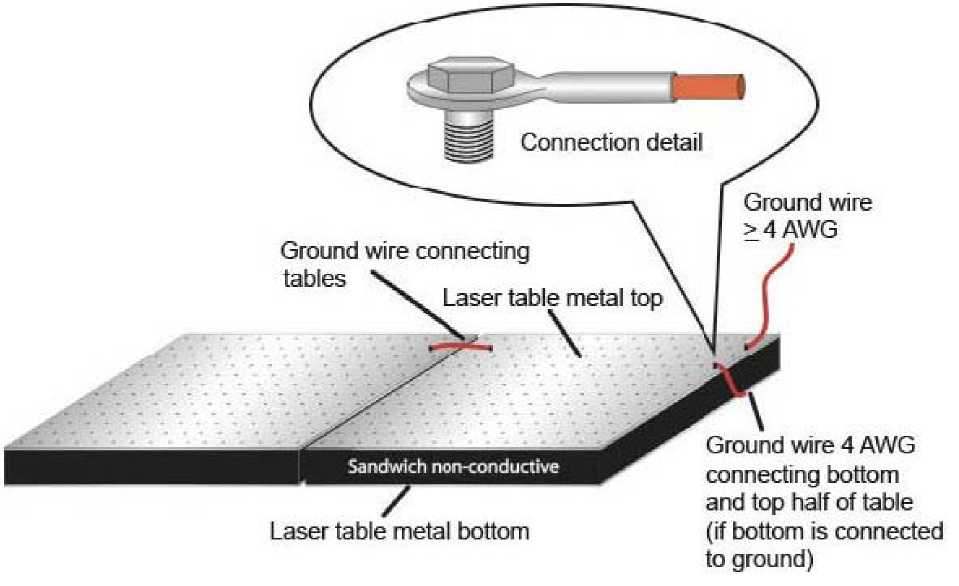
Optical tables Electrically Grounded?

Clean and Orderly?

Optics and Eyewear storage?

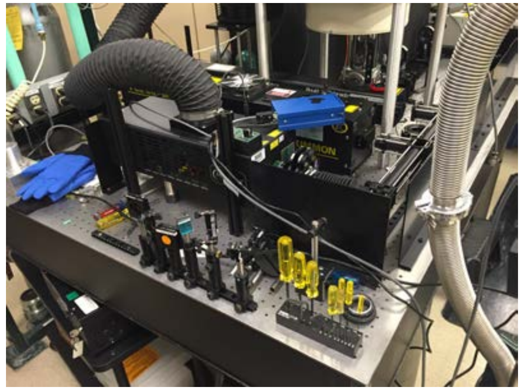
Grounding of Optical tables

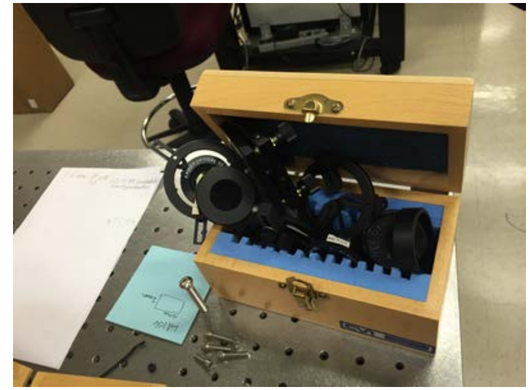
- Most laser fatalities
- NFPA requirement



Typical Storage Issues

- Optics

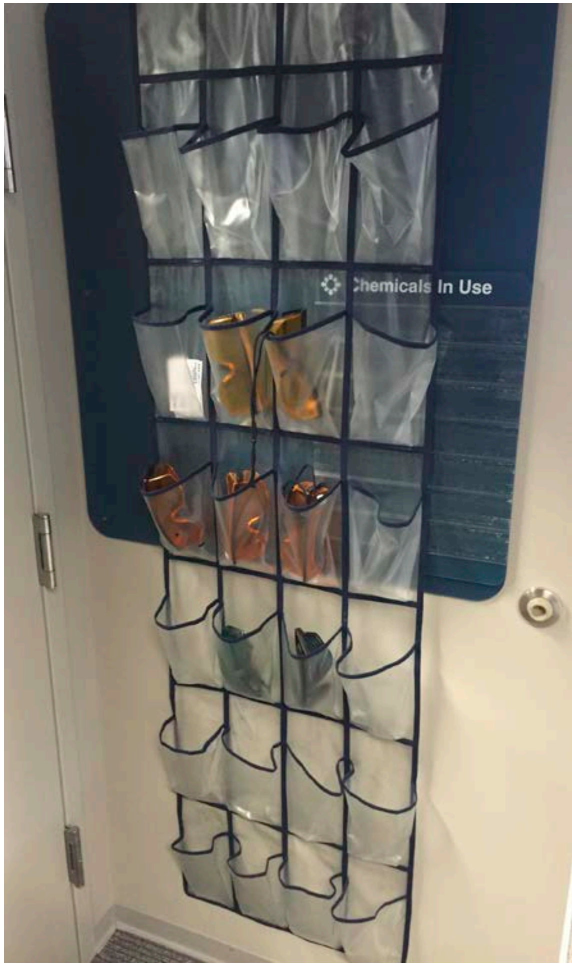


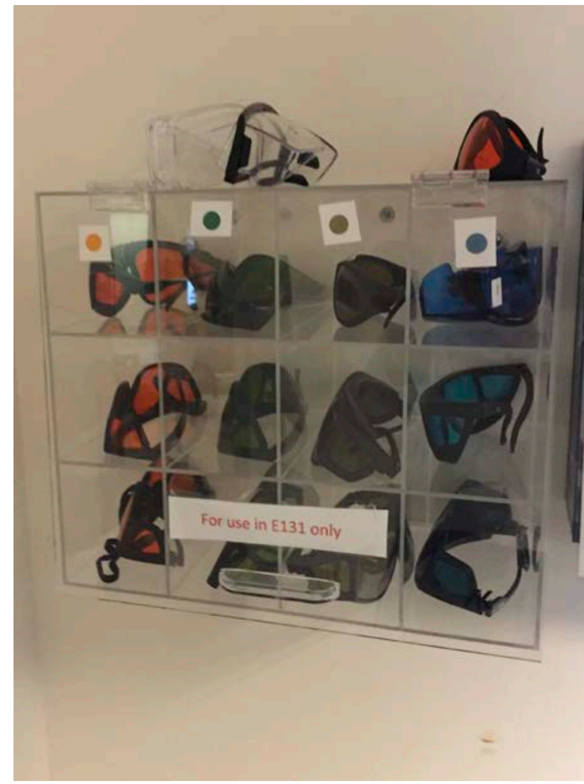


- Eyewear in drawers or on table

- Crowded Optical table

Good Eyewear storage

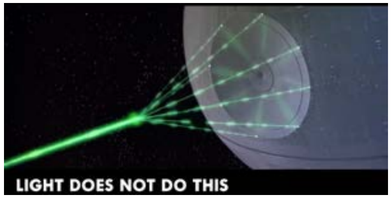




Good Optics storage

Following the Beam-line

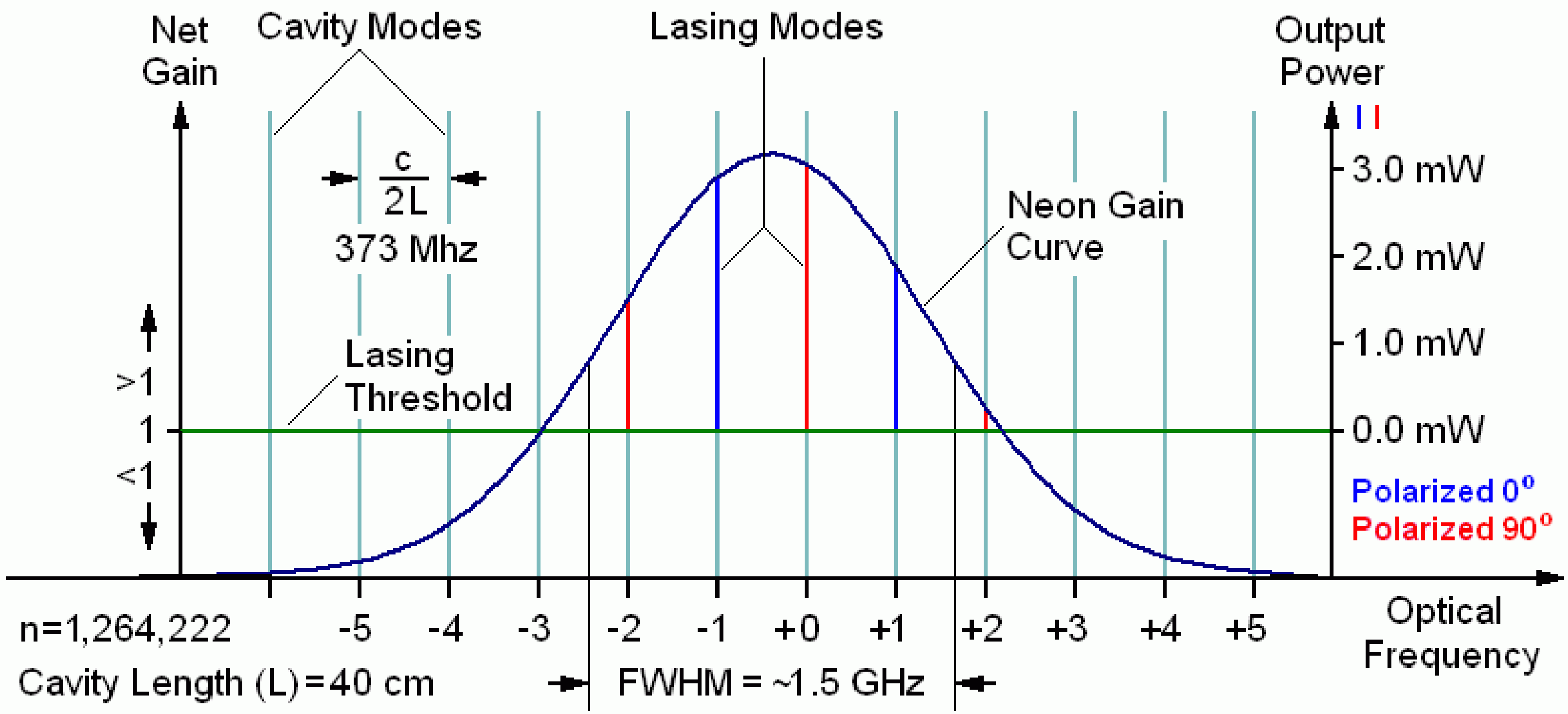
- Ask Researcher to walk you through the system
- Ask if there is any Wavelength changing/mixing?
- Ask what they consider the most worrisome parts?
- Ask what are normal/frequent adjustments?
- Where will the beam go if deviation occurs?
- Look for reflectors close by
- Look for notorious optics



Why do things need adjusting?

- World of Peanut Butter and Rubber

Other Contributors - Thermal drift



Longitudinal Modes of Typical Random Polarized 8 mW HeNe Laser

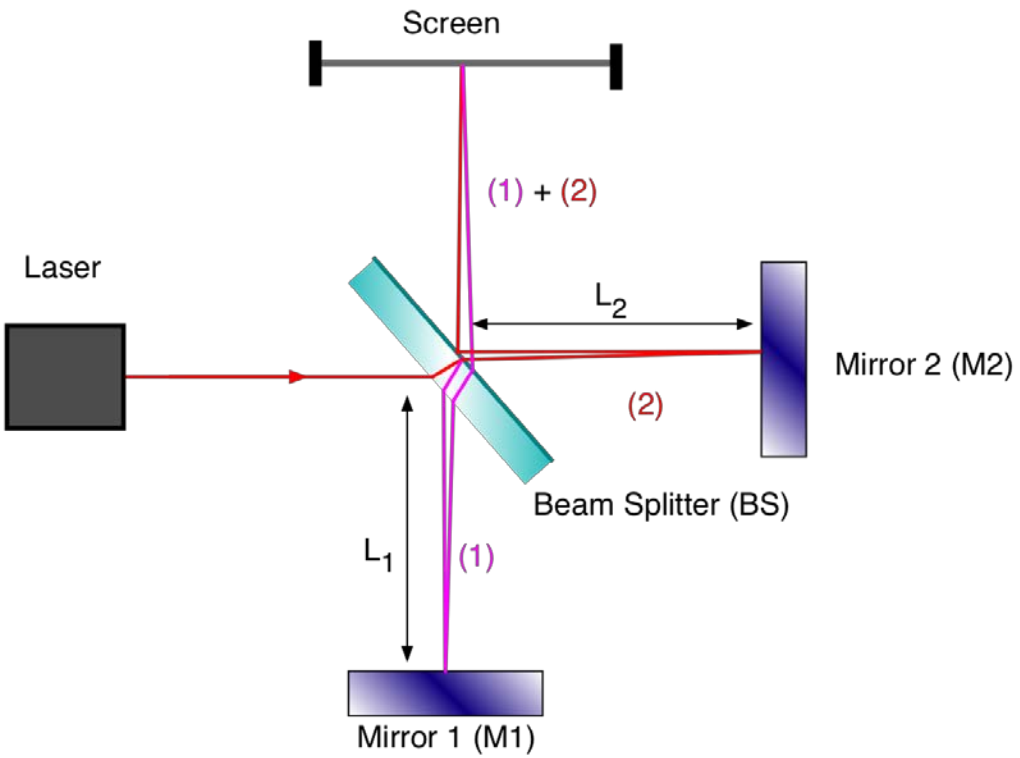
Other Contributors - Vibration

- HVAC can cause vibrations
- Motors/generators
- Traffic
- Gravity Waves

How sensitive are lasers systems?

How Sensitive? (Interferometry)

- Half wavelength sensitivity in single pass
- Gravitational wave measurement
- Microscopy scalable (<1Å)

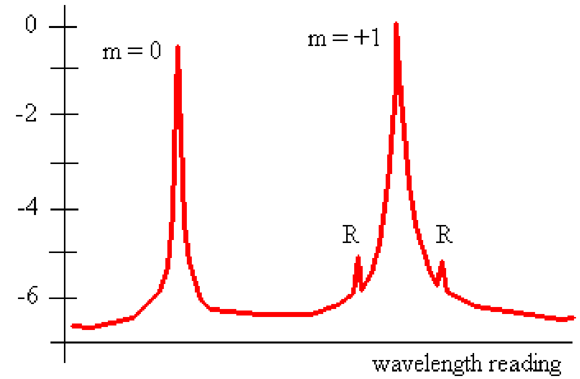


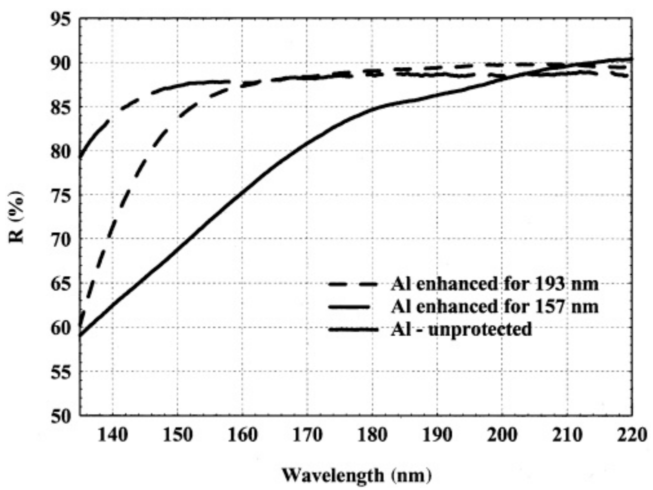
How laser users select optics

- Function
- Material Selection
- Grade/finish
- Wedge
- Reflectivity/Transmittance
- Wave front
- Signal to Noise
- Wavelength
- Irradiance
- Power
- Pulse width

Laser User Optical Concerns

- Signal to noise
- Wavelength specific
- Ghosts
- High energy optics (Heat)
- Degradation



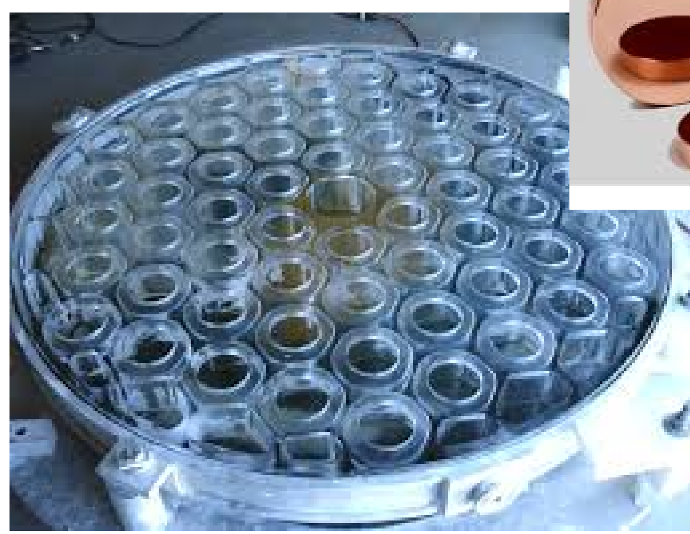


Optics Manufacturing Mini-tutorial

- Materials selection
- Specifications
- Manufacturing process
- Shaping
- Grinding
- Polishing
- Coating

Material selection

- Glasses
- Metals
- Crystals
- Lightweight



Optical Manufacturing Specifications

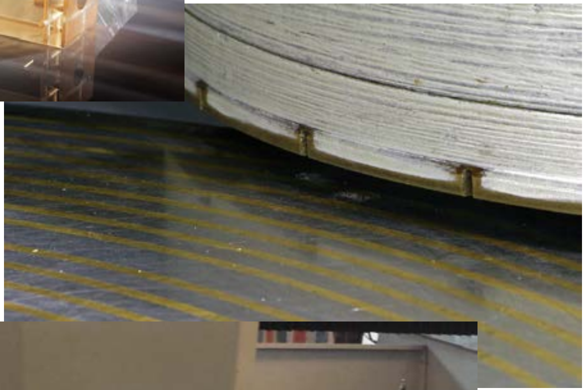
- Wavefront – thickness for stability
- Roughness
- Scratch and Dig
- Bevels
- Wedge
- Reflectivity/Absorption

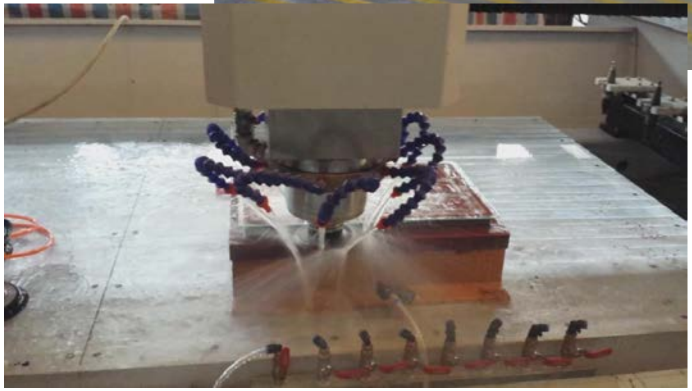
Optic manufacturing processes

- Shaping
- Bevels
- Grinding
- Polishing
- Post-polishing/coating

Shaping

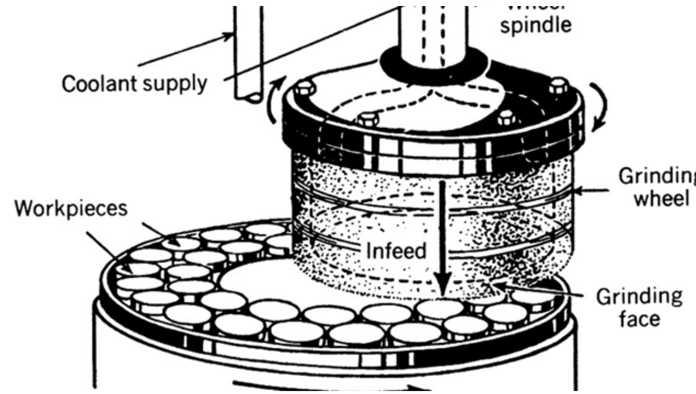
- Raw cut material
- Cast
- Blanchard
- Drilling
- Saws – wire, dicing…
- Milling
- Lathes

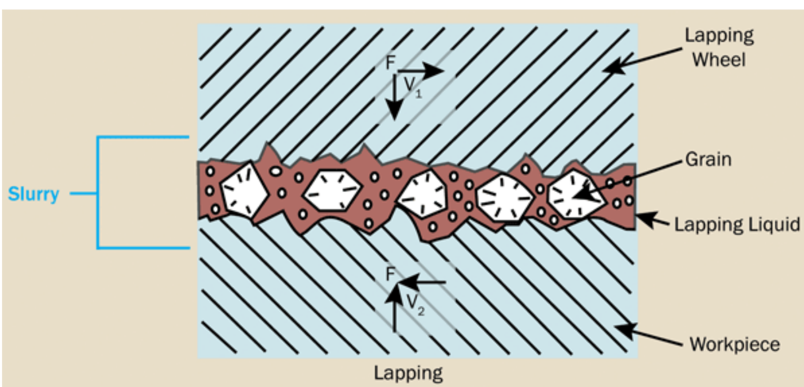




Grinding

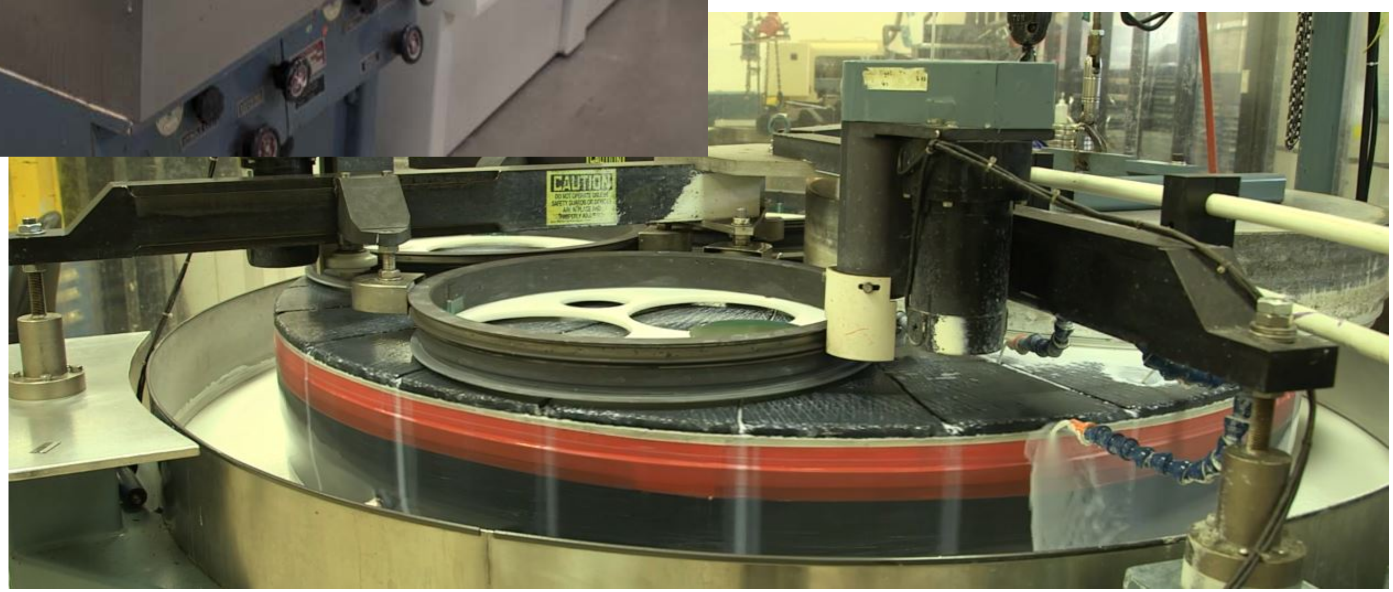
Grit size usually starts at 40 um
finishes at 5-10 um





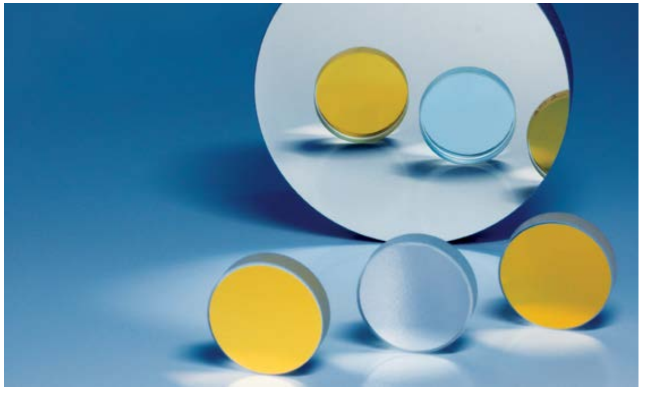
Polishing

Slurries: CeO, colloidal silica, diamond powder



Coatings

- Mirror
- Anti-reflection
- Strengths/Weaknesses
- Cleaning



Notoriously Hazardous Optics

- Mirrors
- Beam Splitters/Polarizers/Windows
- Periscopes
- Retro-reflectors
- Diffraction Gratings

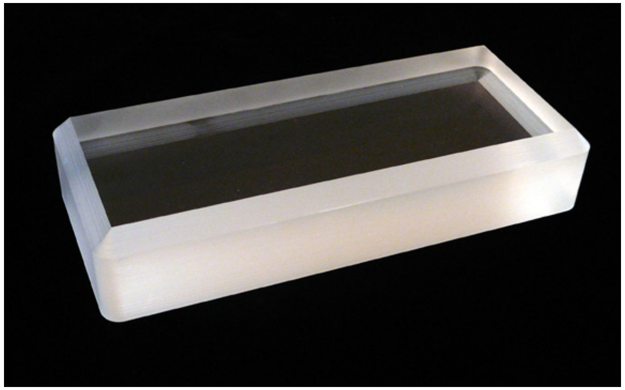
Assume everything is trying to get you!
How would you protect a 12 year old!?!

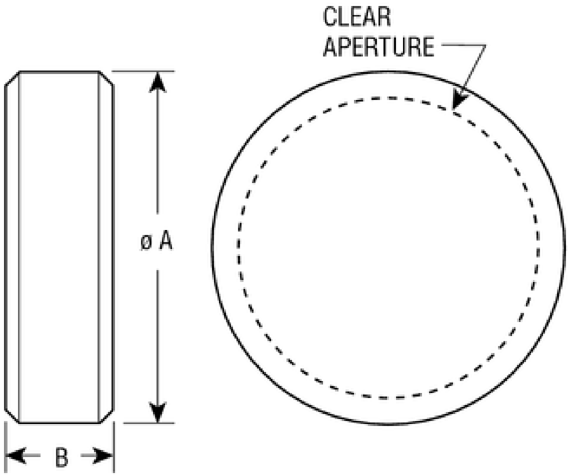
Mirrors

- Coatings – dichroics/metallic/dielectric
- Sheres - Focusing/de-focusing
- Aspheric
- High energy
- Rastering

Mirror hazards

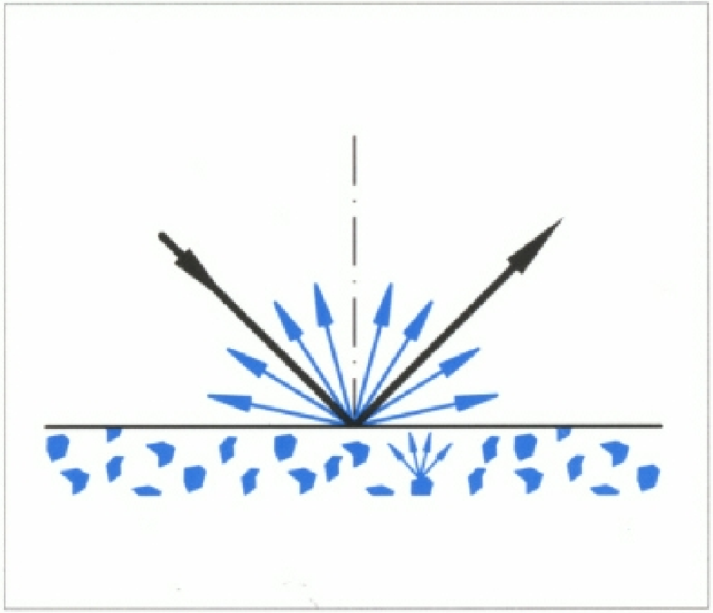
- Bevels can be polished
- Unexpected beam direction change
- Unrecognized transmission
- Failure mechanisms

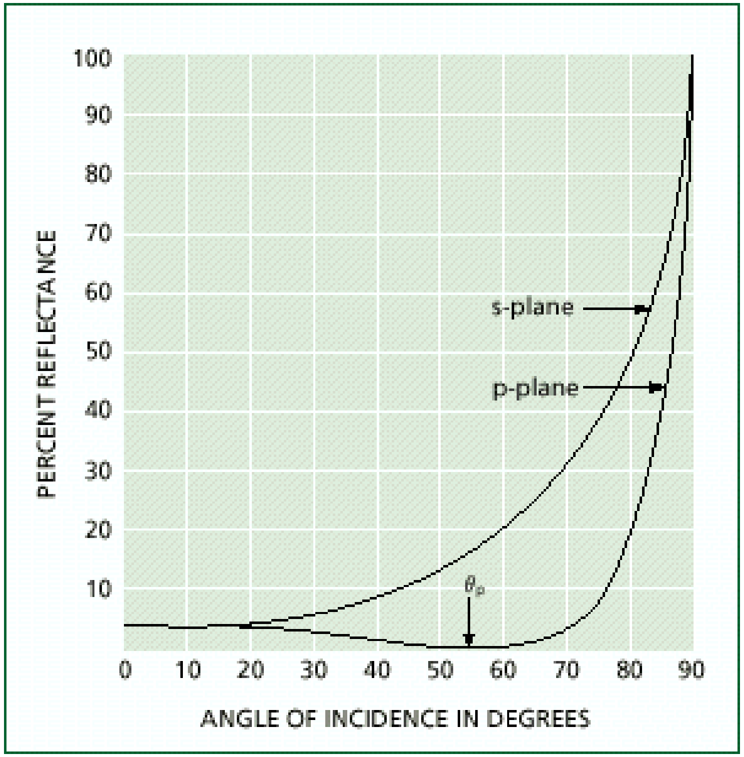




Brewster's Angle can make everything a mirror!!!

Brewster's Angle makes almost everything a Mirror





Beware Brewster's angle
and
Increased High angle reflectivity

Brewster's Angle Example

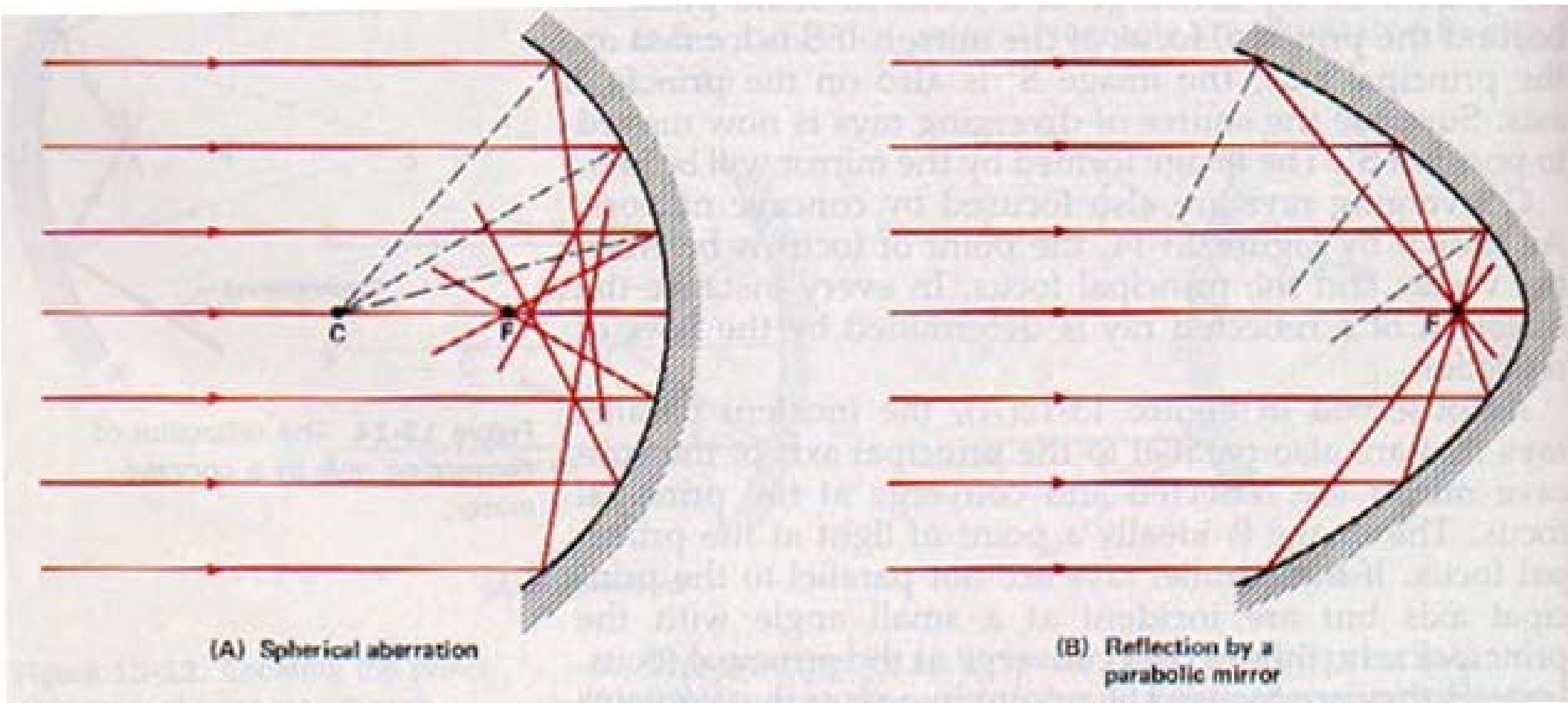
Brewster's Angle Example

Brewster’s Angle Example
(It’s complicated)

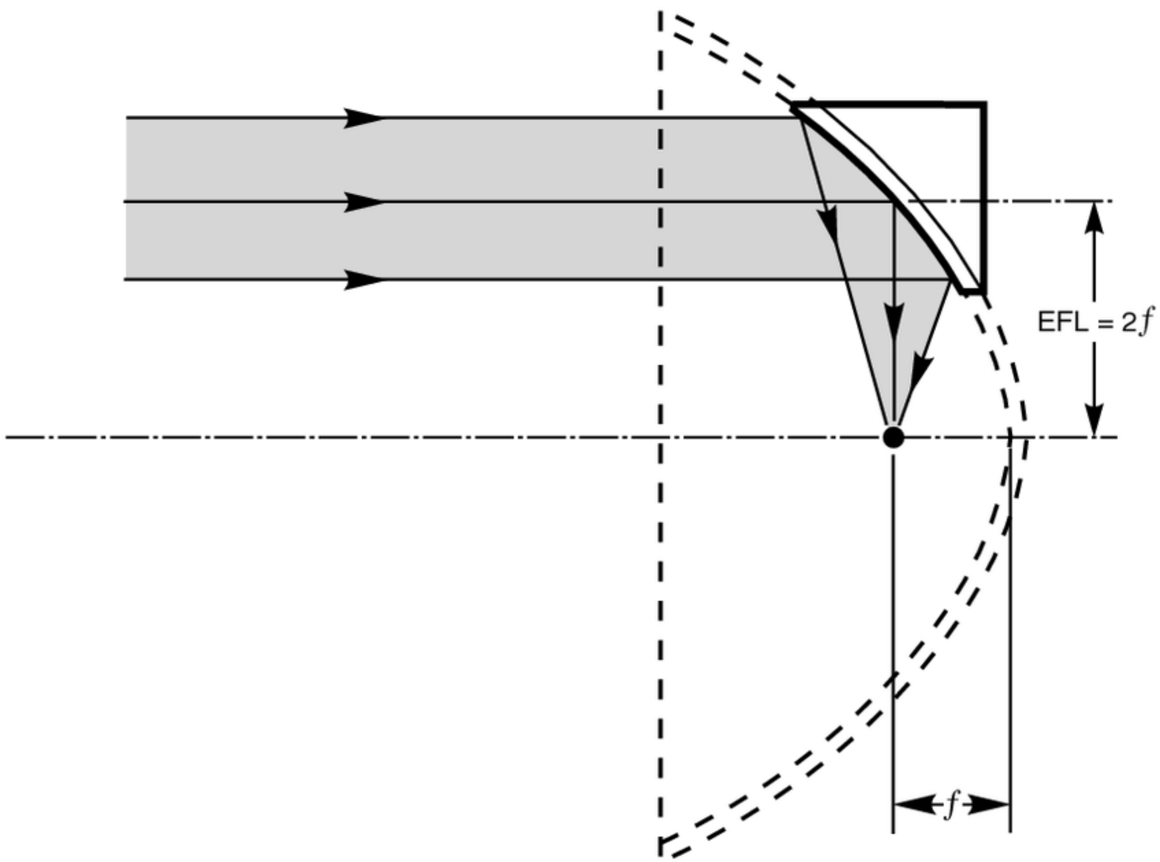
Discussion Question?

Why is the reflection blurry?

Spherical vs Aspherical mirrors



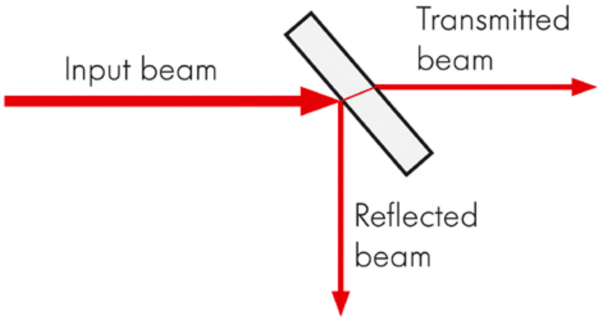
Off axis Aspherical mirrors



Periscopes

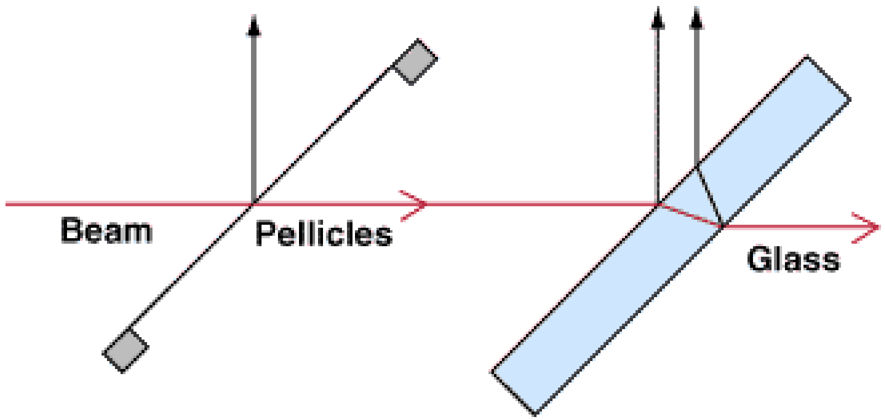
Periscope Hazards

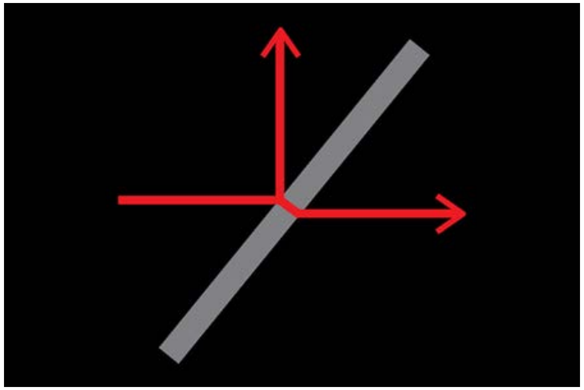
- Vertical redirection of the beam
- Transmission
- Mirror removed

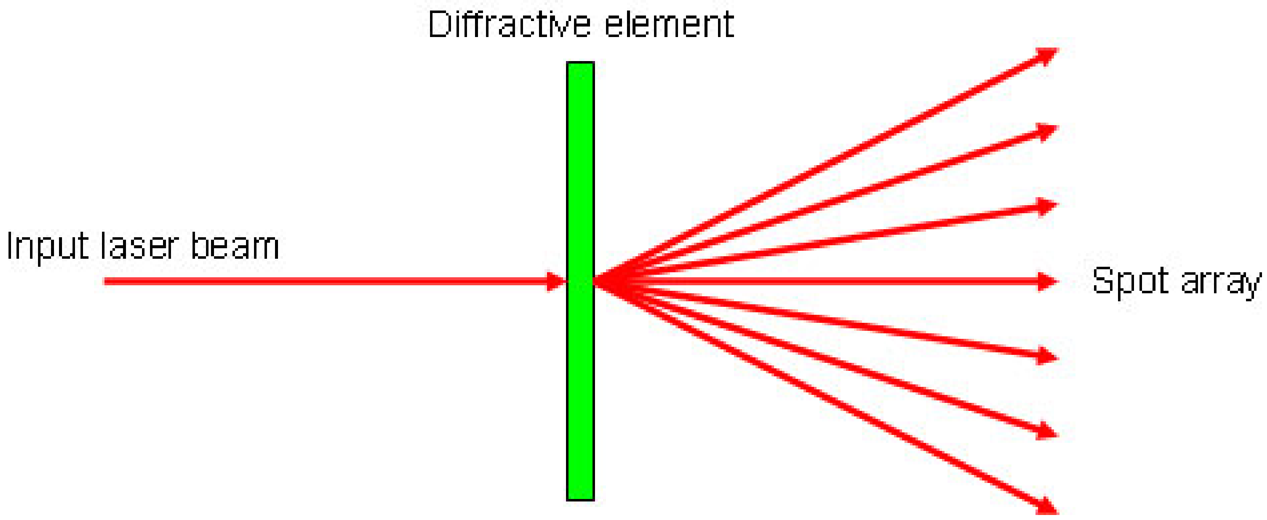


Beam Dumps are important!

Beam Splitters







Beam Splitter Hazards

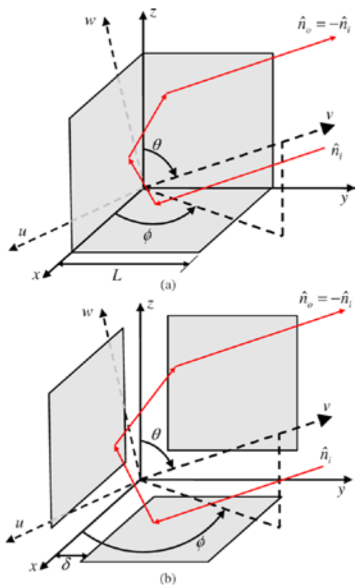
Reflections

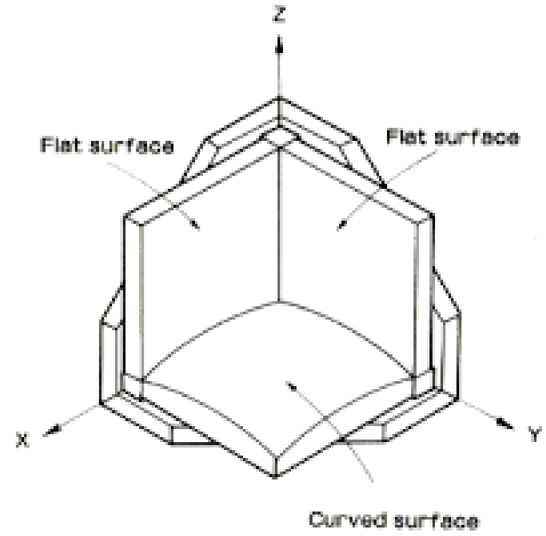
Transmissions

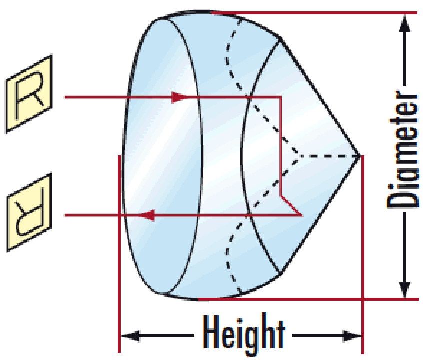
Direction changes

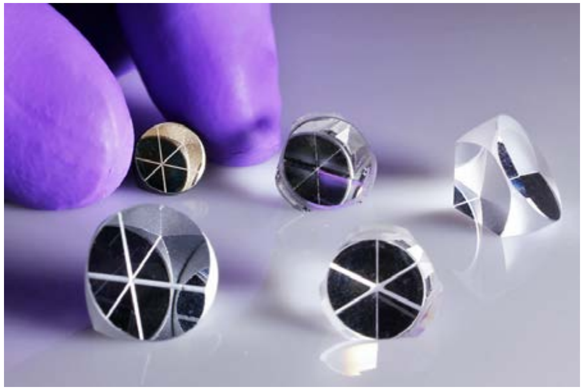
Beam Dumps are your friends!

Retro-Reflectors/Corner Cubes





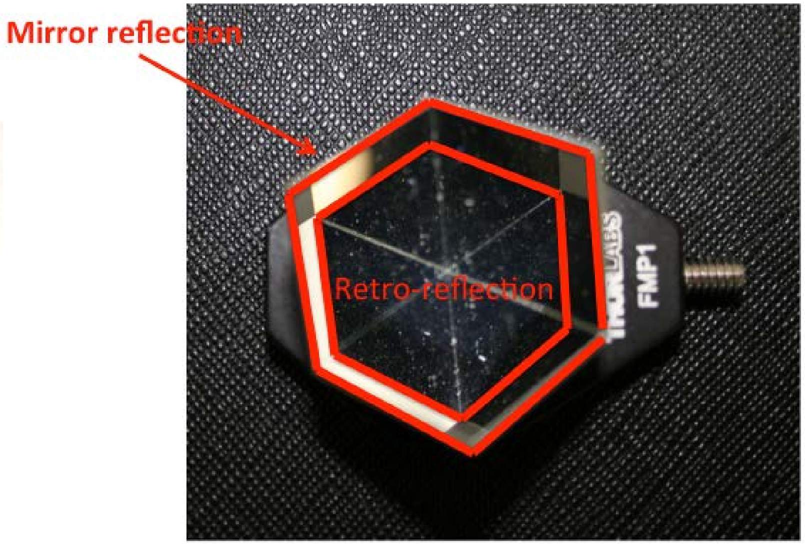




Open/Hollow Retro-Reflector hazards

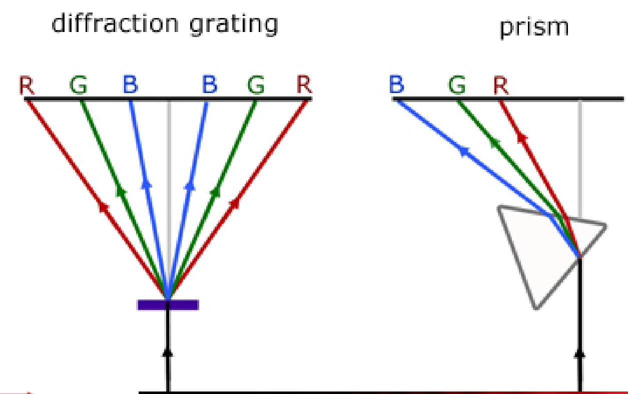
- Functionality change at edges
- Driven to this edge by intended use

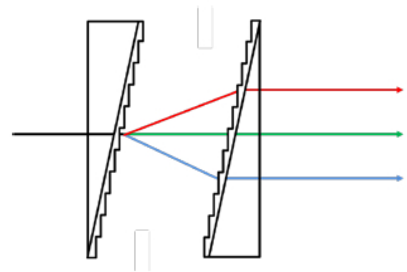
Shields up!!!!

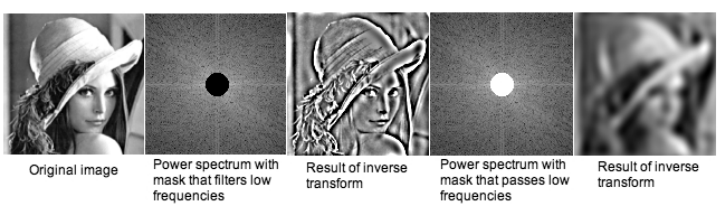


Diffractive Optics

- Gratings
- Prisms/Grisms
- Edges
- Slits
- Spatial filters







Diffractive optics hazards

Multiple beams

Unexpected reflections

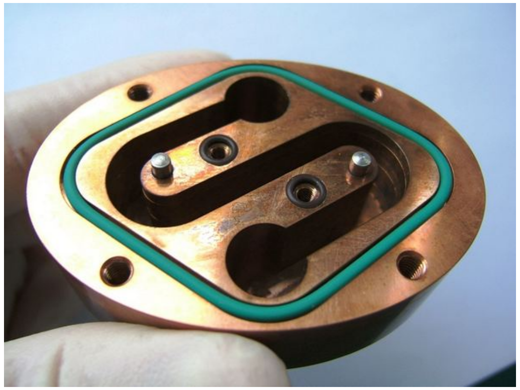
Unexpected beam directions

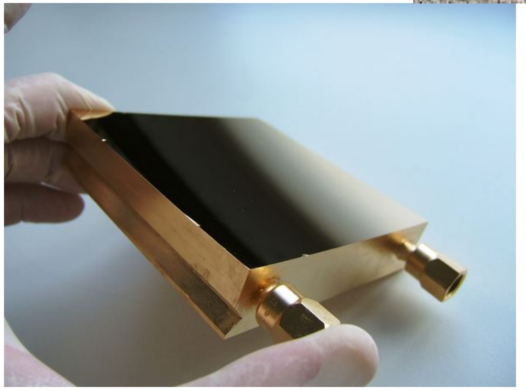
Improper diffraction plane orientation

Beam Dumps are still your friends!

High Energy Optics

- Thermal Conduction
- Passive Cooling
- Active Cooling
- Coefficient of Thermal expansion
- Failure mechanisms





Engineering Controls Need to Be

Cost effective,

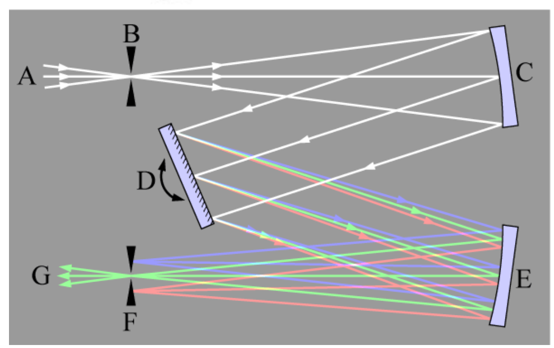
Ideally - simple solutions(Zones)

User friendly

More involved solutions

Engineered protections

- Shields
- Baffles
- Enclosures
- Barriers



- Cost effective, simple solutions
- User friendly

Overcoming Safety Costs

- Huge upfront Capital investment
- Not used much after initial setup

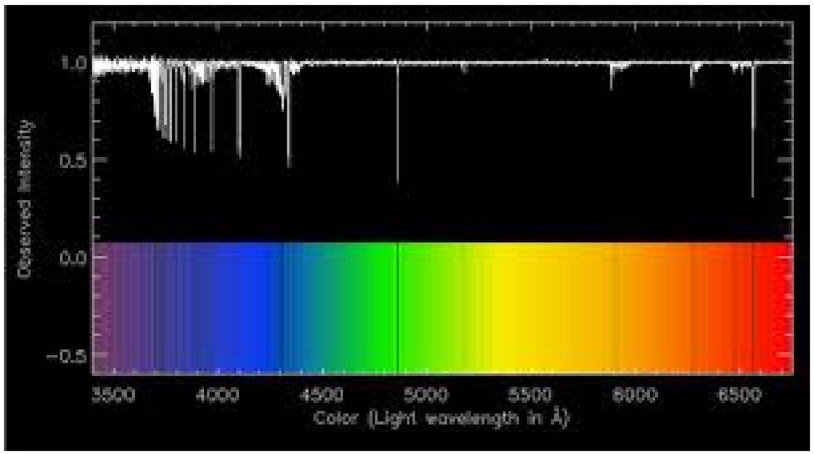
Possible solution:

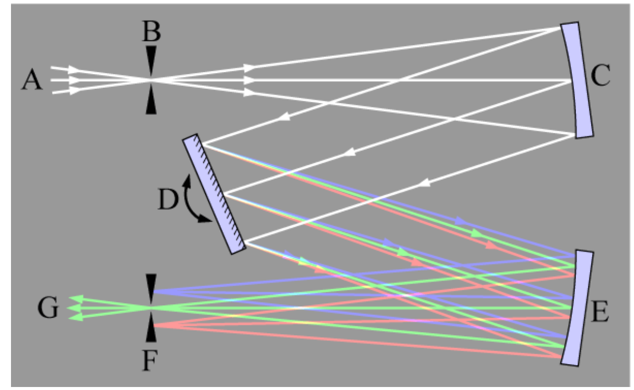
Collective Tool bag?

Laser Protective Eyewear

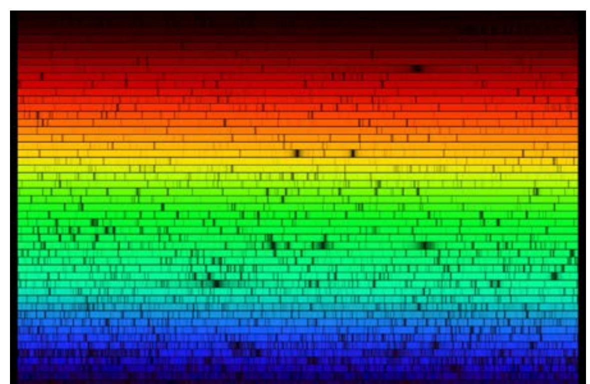
- Non-reflective
- Good condition
- Correct for the application/laser

Spectrograph Example



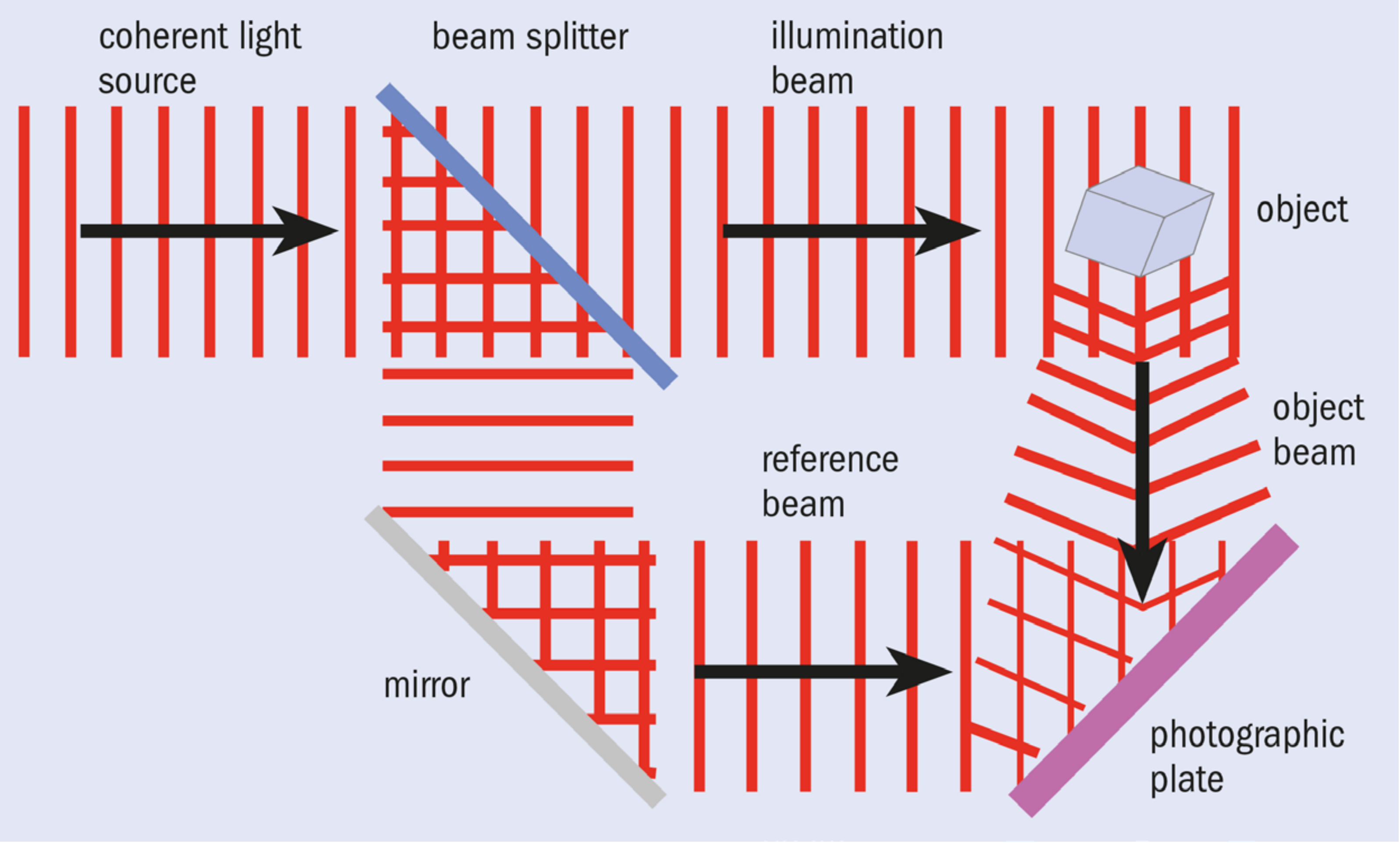


Monochrometer

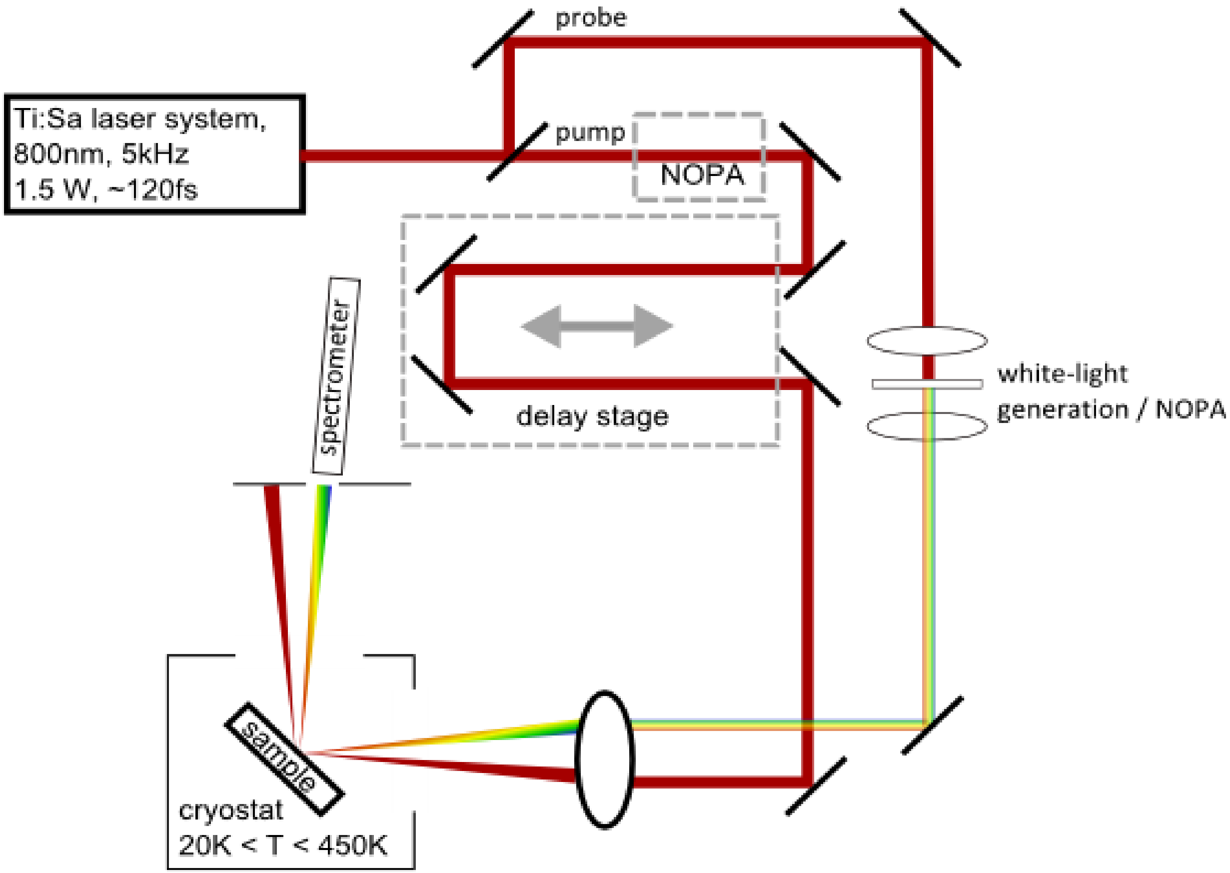


Cross grating Spectrograph

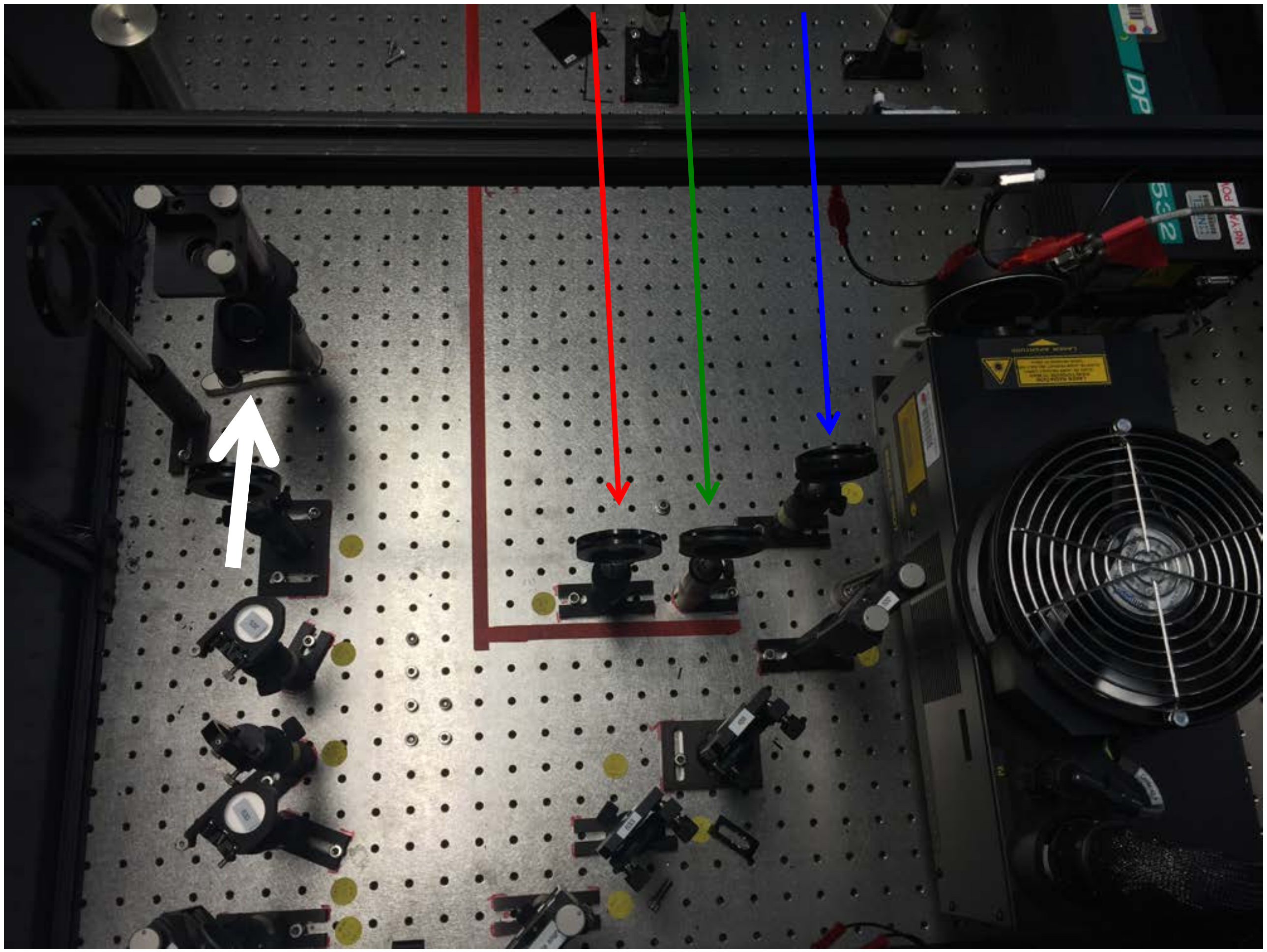
Holography Example



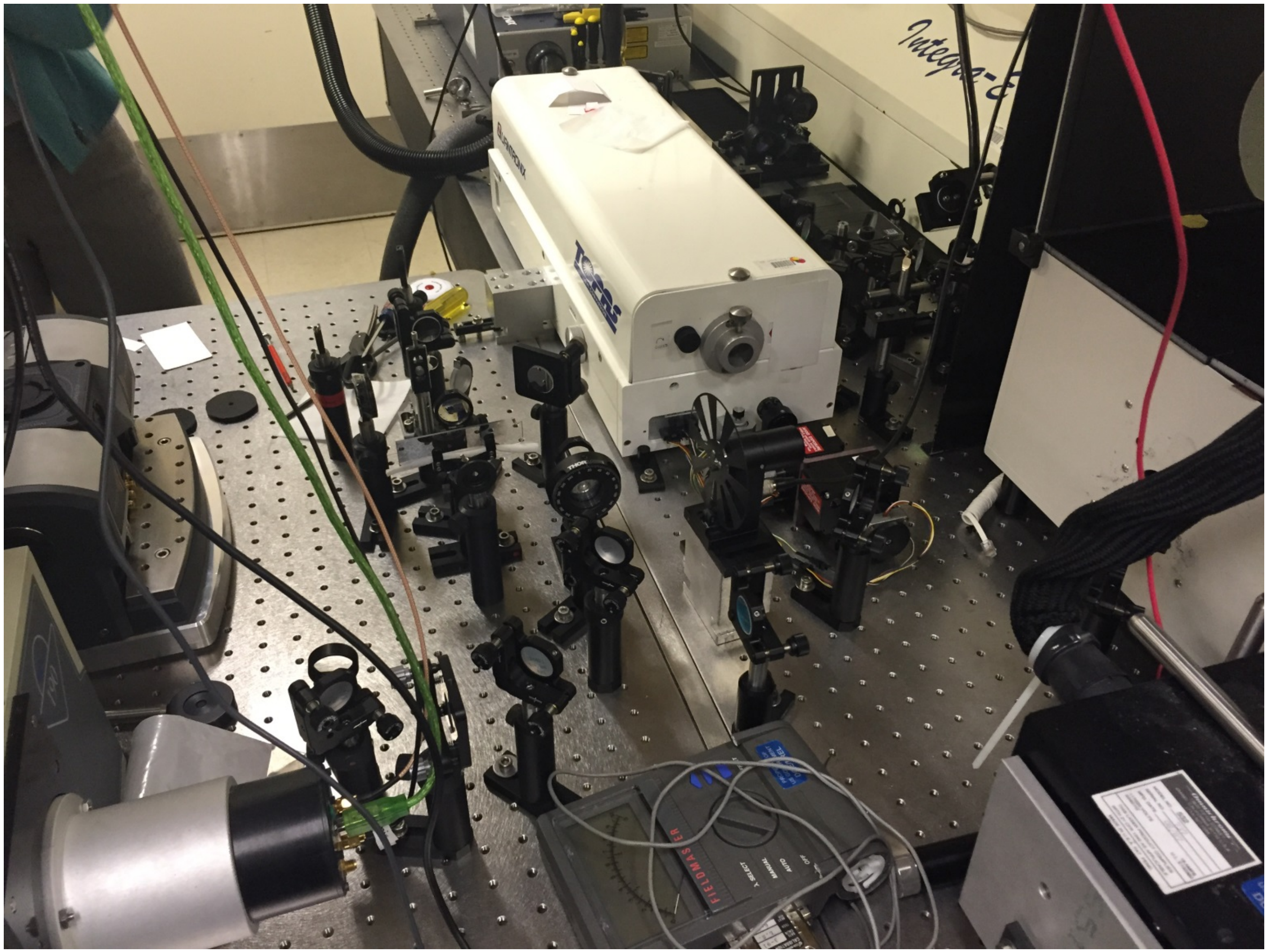
Pump-Probe Example



Example simple beam line



Example moderate beam line



Example complex beam line

Questions/Discussion

YOU MATTER.

Until you multiply yourself times the speed of light squared. Then you Energy.