NREL
NATIONAL RENEWABLE ENERGY LABORATORY





# Contributing Causes and Lessons Learned from NREL's Recent Laser Accident

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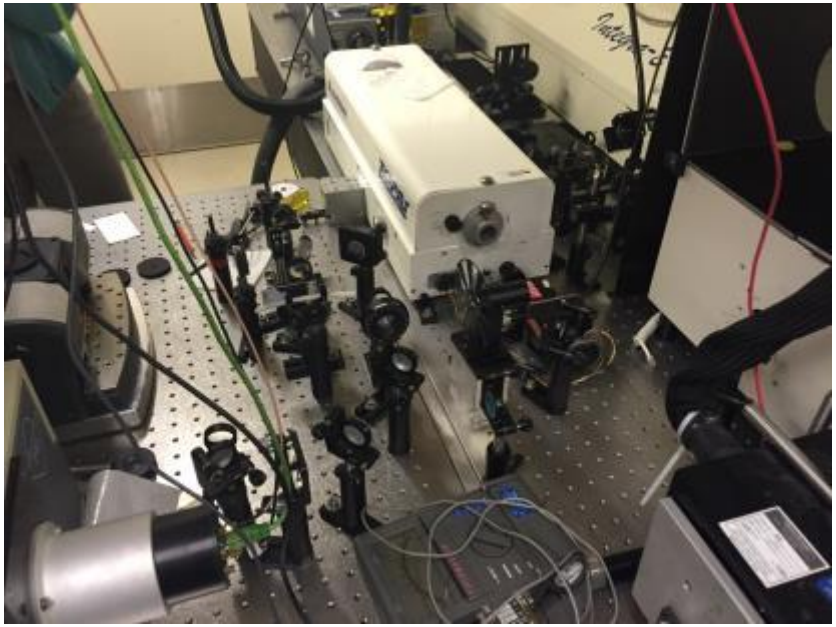
September 27, 2016

# Common Denominators in Many Laser Accidents

- Wavelength and type of Laser?

# Common Denominators in Many Laser Accidents

- Wavelength and type of Laser:
  - Ti:Sapphire 800 nm, repetitively pulsed Class 4 laser



# Common Denominators in Many Laser Accidents

- Common task being performed during accident?

# Common Denominators in Many Laser Accidents

- Common task performed during accident:
  - Beam alignment

# Common Denominators in Many Laser Accidents

- Essential control method that was not in use?

# Common Denominators in Many Laser Accidents

- Essential control method that was not in use:
  - Laser Protective Eyewear

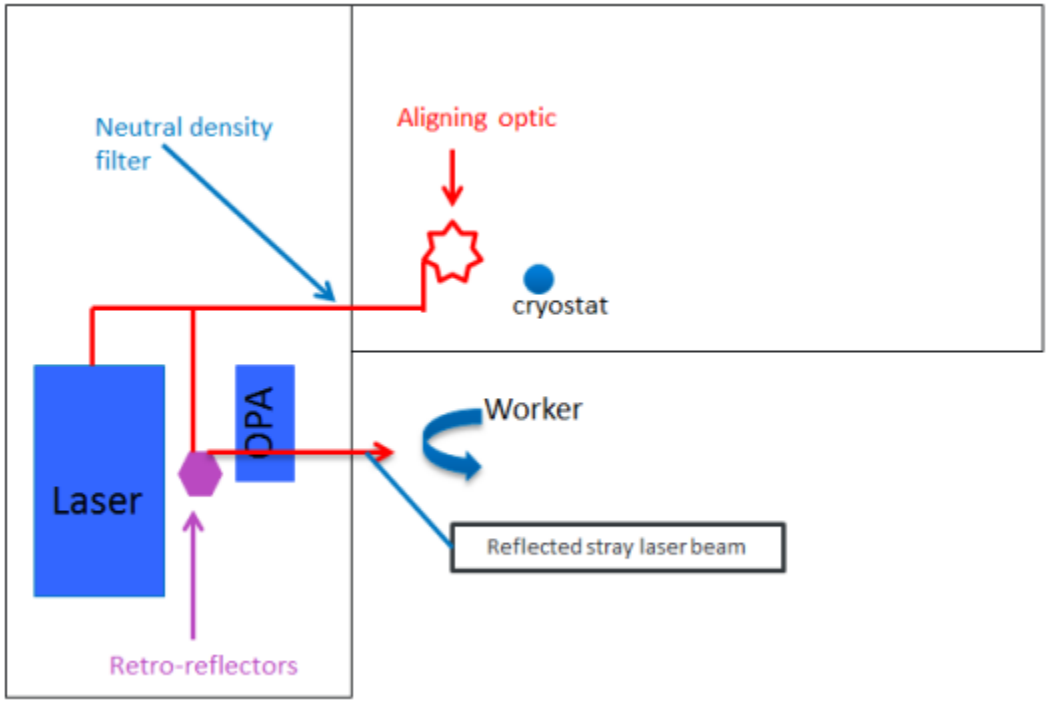
# Common Denominators in Many Laser Accidents

- Experience level and job status of operator?

# Common Denominators in Many Laser Accidents

- Experience level and job status of operator
  - Grad students and Post-docs

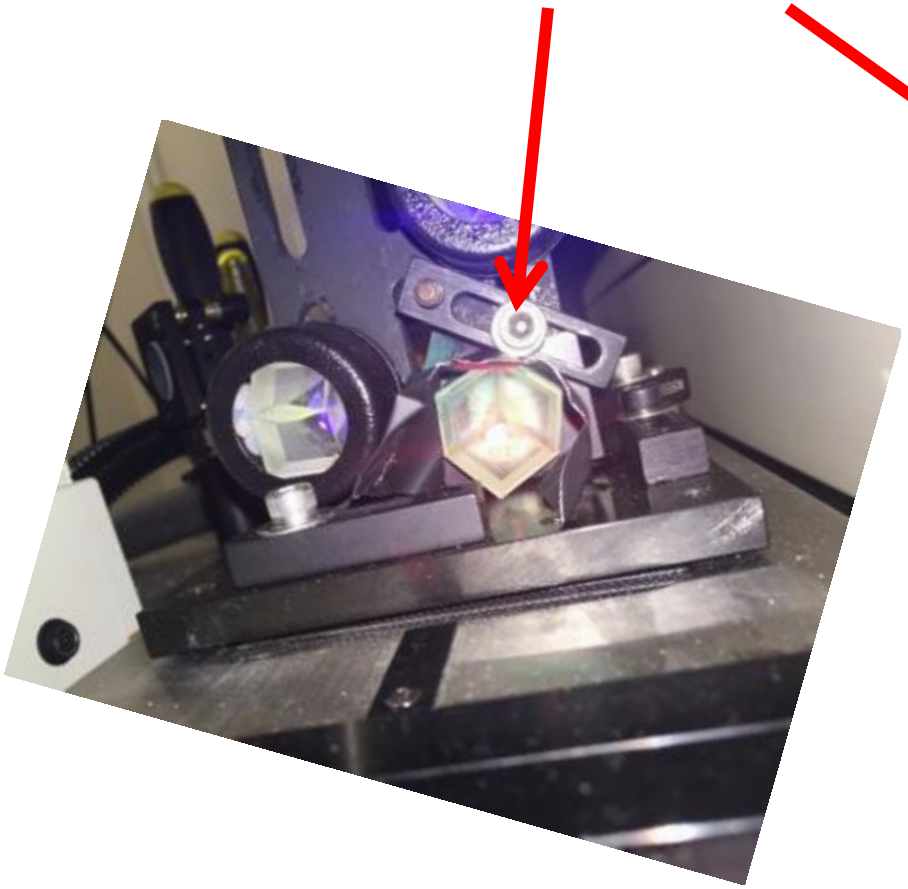
# Incident Overview



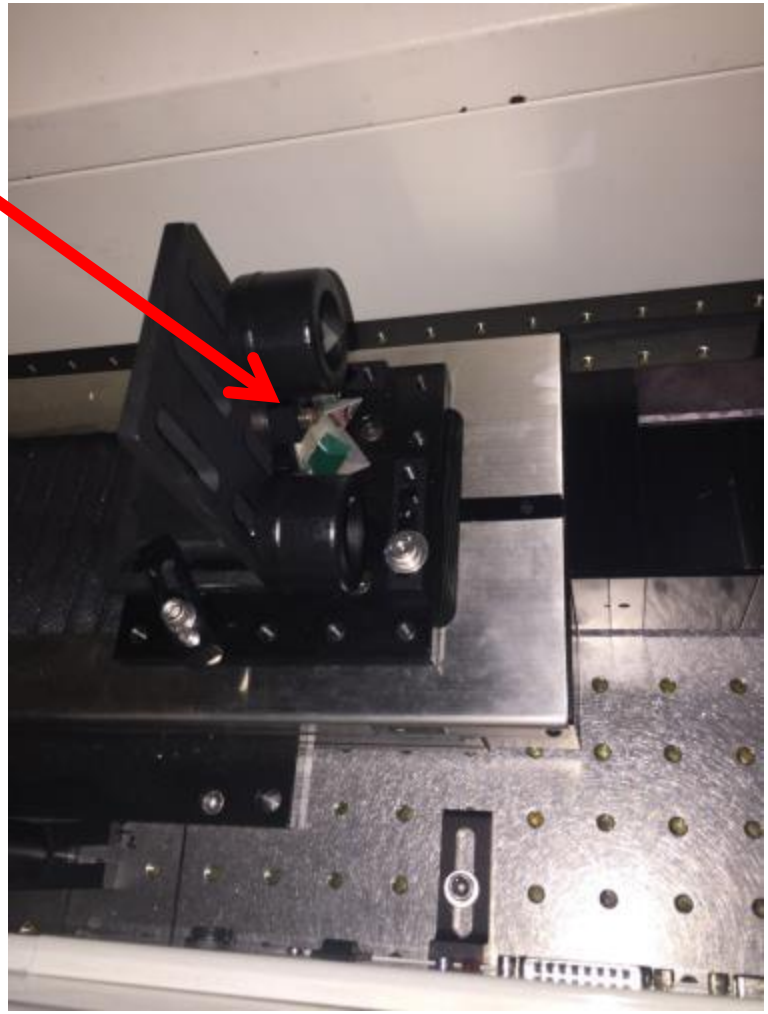

- New NREL postdoctoral worker performing high precision alignment of optical component on Class 4 laser system
- Worker lowered eyewear to view beam with naked eye instead of using IR viewer or viewing cards.
- Received strike to eye from stray beam reflected from optical component

# Retro-Reflector Cube Corners

Origin of the Stray beam

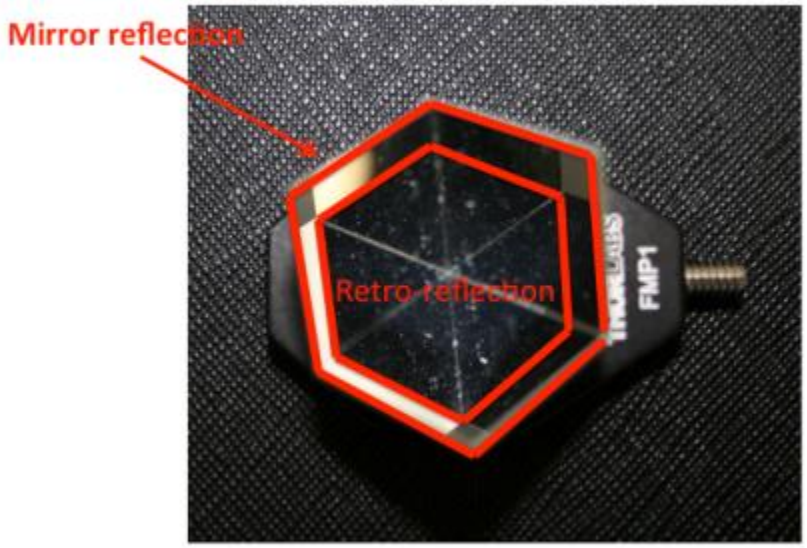


Front view



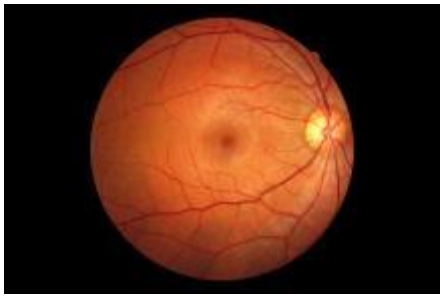
Top view

# Unshielded Retro-Reflector Cube Corners




# Eye Injury

- Initial eye exam revealed potential damage to retina and small blind spot
- Follow-up evaluation by retinal expert indicates no abnormality in the retina
  - Potential measurement artifact with initial exam
- Employee is now able to function normally
- No permanent effect on employee's vision or retina



# Initial Actions Taken

- Affected system locked out from use
- Safety Pause conducted for all laser users and their managers to overview incident and share initial lessons learned
- Post-doc restricted from working with Class 3B and 4 lasers during investigation
- Lab-wide Extent of Condition conducted to ID locations where unshrouded retro-reflectors were in use
  - Removed 2 unshrouded retro-reflectors from service
  - Removed 4 additional retro-reflectors which were in storage
- Immediately began investigation and causal analysis

# Incident Investigation – Causal Analysis

- Cross-organizational investigation team
- “5 Whys” Causal Analysis
- Barrier Analysis
- 7 Contributing Causes
- 2 Root Causes

# Causal Factors – Contributing Causes

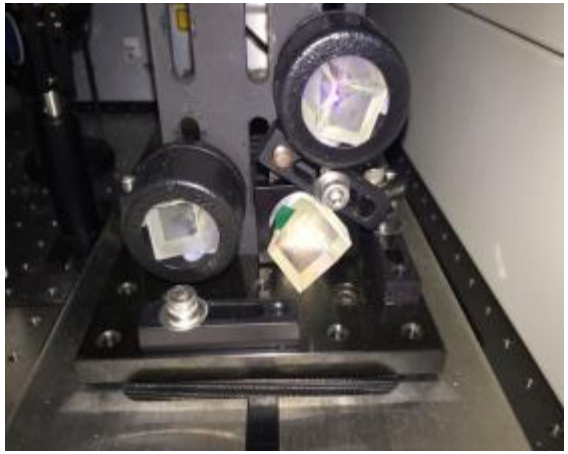
- Individual underestimated the problem by using past event as basis
  - New Post-Doc underestimated risk coming from lax safety culture at university

# Causal Factors – Contributing Causes

- Verbal Communication Less Than Adequate
  - Post-doc knew the requirements for wearing PPE
  - Did not know what to do when he perceived those requirements impacted getting his work done efficiently

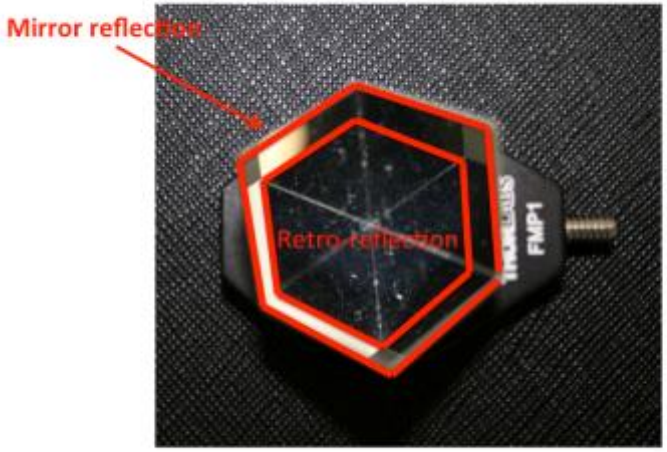
# Causal Factors – Contributing Causes

- Attention was given to wrong issues
  - Post-doc had self-imposed time/efficiency goals
  - To meet those goals he used materials readily available in the lab rather than obtain proper components for system
    - Existing mounting bracket—too small to fit all 3 retroreflectors
    - Unshielded retro-reflector



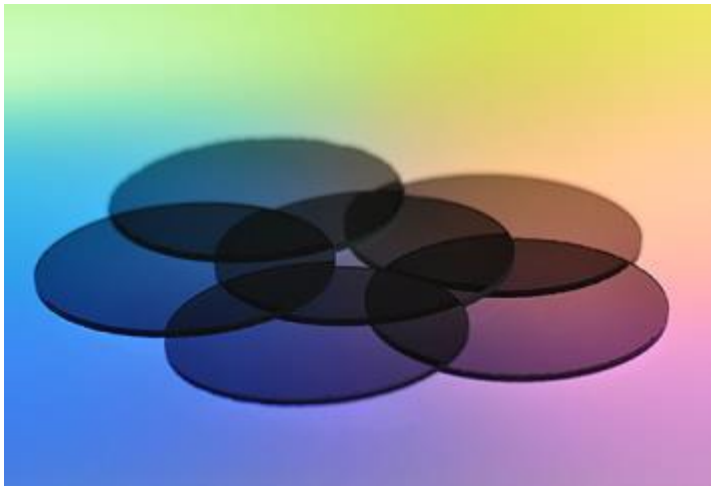
# Contributing Cause - Retroreflector

- An unshielded retro-reflector was used in beam path
- Beam misaligned on outer edge of retro-reflector
- Specular reflection misdirected toward worker



# Causal Factors – Contributing Causes

- Attention given to wrong issues
  - Engineering controls not properly applied
    - Improper placement of neutral density filter
    - Insufficient beam shielding



# Causal Factors – Contributing Causes

- Step was omitted due to mental lapse
  - Checked first few optics in beam path for stray beams
  - Neglected to check retro-reflectors for stray beams

# Causal Factors – Contributing Causes

- Change not identified during task
  - Beam dimensions changed from initial alignment
  - Beam extended to outside edge of retro-reflector causing it to be misdirected towards worker

# Causal Factors – Contributing Causes

- LTA review of alignment task based on assumption that process will not change
  - Laser System Supervisor (LSS) was involved in initial planning and setup of system with post-doc
  - LSS and post-doc performed initial alignment procedures together, and LSS did not anticipate any changes in those methods
  - Post-doc changed alignment method without discussing with LSS

# Causal Factors – Root Cause

- Incorrect assumption that a correlation existed between two or more facts
  - Post-doc observed whole beam was present
  - Section of beam being aligned was at lower power than upstream path due to neutral density filter
  - Post-doc assumed it was safe to lower his eyewear, in spite of knowing NREL requirements

# Causal Factors – Root Cause

- Incorrect assumption that a correlation existed between two or more facts
  - Post-doc used IR viewer and viewing cards for earlier phases of system set-up and alignment
  - Post-doc believed viewing tools were not adequate for precision alignment tasks
    - Granularity and low display quality with IR viewer
    - Prior experience with higher quality tools

# Corrective Actions

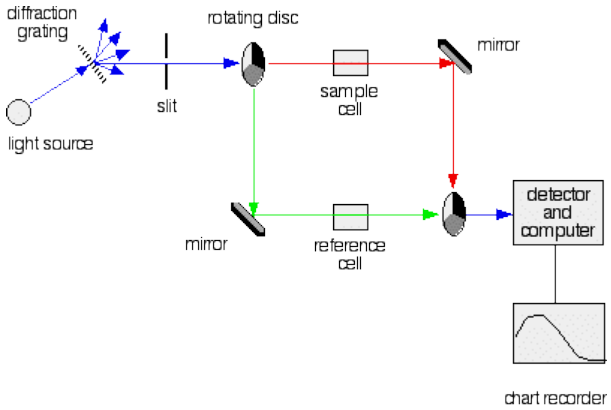
- Communicated lessons learned:
  - NREL's laser community
  - PNNL/NREL database
  - DOE EFCOG Laser Safety Task Group


- Conducted extent of condition for:
  - Use of unshielded retroreflectors
  - Completion of Laser Operator Qualification cards
- Independent subcontractor performed external audit of NREL's laser safety program
- Surveyed and characterized NREL's safety culture
- Implementing hands-on laser use/alignment course
- Evaluating impact of a more formalized lab-wide mentorship program

# Corrective Actions

- Laser Safety Lab Level Procedure revised to clarify when Laser Operator Qualification Card must be completed

- Beam path diagrams to be developed & reviewed by LSO prior to building laser systems




- Updated Annual Lab Safety Refresher to advise workers on how to balance safety and work priorities

# Lessons Learned

- Beware of using legacy equipment

- Shield beams during setup
  - Temporary shields and beam blocks

- Understand properties of optical components in use
  - Retro-reflectors can change functionality

# Lessons Learned

- Have right tools and equipment readily available for job
- Beam alignment may change if beam is expanded
- Always check for stray beams
  - -Don’t assume proper beam alignment

- Place neutral density filters as close to output as possible

# Questions?

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