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LiveWebcast

Safety Concerns in Fiber Optic Systems

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Your instructor today is

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Director and Founder of Light Brigade

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Some Housekeeping Issues

First, for your convenience, this presentation will be available on demand within 24 hours after we conclude today at www.lightwaveonline.com

I encourage you to ask questions using the "Ask a Question" box that you should see on the left-hand side of your screen. To keep a consistent flow we will answer those questions at the end of the presentation.

If you have a tech support issue, you can alert us through this question box as well.

The Light Brigade

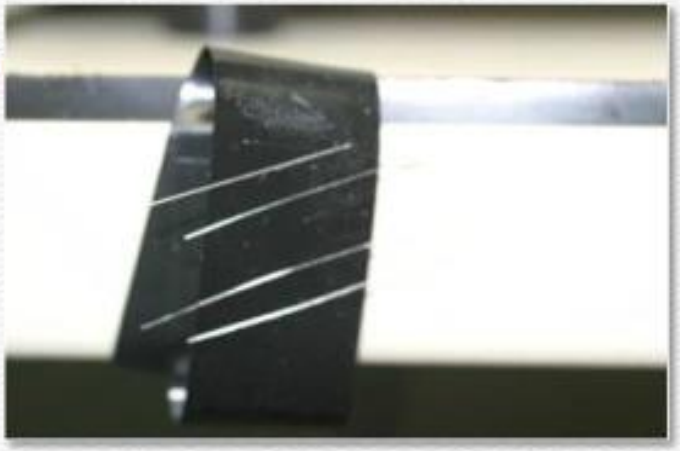
- Founded in 1986.
- Over 45,000 trained in fiber optics since 1987.
- Strengths.
  - Staff.
  - Content.
  - Equipment.
  - Experience.
- Technology based.

Fiber Optic Safety Concerns

Lasers

Optical amplifiers

Fiber



Personal protective equipment

Fiber Optics is "Eye Safe"

- We have all heard or will hear that claim.
- What does it really mean?
- To answer that question ones needs some background information.
- Lasers can produce photons over a wide range of wavelengths.
- Different bands of wavelengths effect the eye in different ways.
  - Eye safety will depend on wavelength one is exposed to.
  - How one is exposed, meaning direct, specular, or diffuse.
  - The power or irradiance of the exposure.
  - Length of the exposure.

Safety Issues

- Wide variety of hazards.
  - Laboratory.
  - Manufacturing.
  - Installations.
  - Operation.
- Occupational Safety and Health Administration (OSHA).
  - Develops and enforces workplace safety in the United States.
- Center for Devices and Radiological Health (CDRH).
  - Regulates lasers in the United States.
  - Through the CDRH, the Food and Drug Administration releases Federal Laser Product Performance Standard 21 CFR Part 1040, product safety rules for all laser products sold in the United States.
- Developing the attitude for safe work.
- National and international safety standards.

American Laser Safety Standards

- The U.S. safety standard for fiber optics is ANSI Z136.2-2012, *Safe Use of Fiber Optic and Free-space Optical Communication Systems Utilizing Laser Diodes and LED Sources*.
  - ANSI Z136.1 defines laser classifications.
- The OSHA standard for laser safety is STD-01-05-001, Pub 8-17.

A Closer Look at ANSI Z136.2-2013

- Safe Use of Optical Fiber Communication Systems Utilizing Laser Diode and LED Sources
- Sections
  - 1 General (sets scope and purpose)
  - 2 Definitions
  - 3 Hazard Evaluation (classification)
  - 4 Control Measures
  - 5 Safety and Training Programs
  - 6 Medical Examination
  - 7 Non-beam Hazards
  - 8 Criteria for Exposure of the Eye and Skin
  - 9 Measurements
  - 10 Revisions and Codes
  - Appendix A-E

International Laser Safety Standards

- The international standard for optical fiber communication systems is IEC 60825-2, *Safety of Optical Fiber Communication Systems*.
  - IEC 60825-1 defines laser classifications and identifies three independent mechanisms to ensure automatic power reduction (APR) allowing class 1M safety classification.
  - Detection of magnitude of amplified spontaneous emission (ASE) power created by Raman outside the signal band, e.g., in the C-band.
  - Detection of pump back-reflection.
  - Detection of optical supervisory channel (OSC) modulation.


IEC

IEC 60825-2

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Safety of laser products –
Part 2: Safety of optical fibre communication systems (OFCS)

Sécurité des appareils à laser –
Partie 2: Sécurité des systèmes de télécommunication par fibres optiques (STFO)

INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

CT

Classification Limits

- Class 1.
  - No eye or skin hazard.
- Class 1M.
  - Expanded beam , invisible.
- Class 2.
  - 1 mW, aversion reflex.
- Class 2M.
  - Expanded beam, visible.
- Class 3R.
  - 1-5 mW, safe for momentary exposure.
- Class 3B.
  - 5-500 mW-CW.
  - Cannot produce 125 mJ in less than 0.25 seconds .
- Class 4.
  - >500 mW-CW.
  - 125.J/pulse in less than 0.25 seconds.

Requirements by Laser Classification

Class	Procedural & Administrative Controls	Training	Medical Surveillance	LSO
1	Not Required	Not Required	Not Required	Not Required
1M	Required	Application Dependent	Not Required	Application Dependent
2	Not Required	Not Required	Not Required	Not Required
2M	Required	Application Dependent	Not Required	Application Dependent
3R	Not Required	Not Required	Not Required	Not Required
3B	Required	Required	Not Required	Required
4	Required	Required	Not Required	Required

Laser Safety Terms

- There are a number of terms used in laser safety worth your time to know and understand.
- MPE = Maximum Permissible Exposure.
  - Easiest way to think of it is as the exposure speed limit.
  - Exposure below and up to that limit will not cause injury.
- Definition.
  - Maximum level of exposure to laser radiation without hazardous effect or adverse biological changes in the eye or skin.
- Used to determine:
  - Nominal hazard zone (NHZ).
  - Optical density (OD).
  - Accessible Emission Limit (AEL).

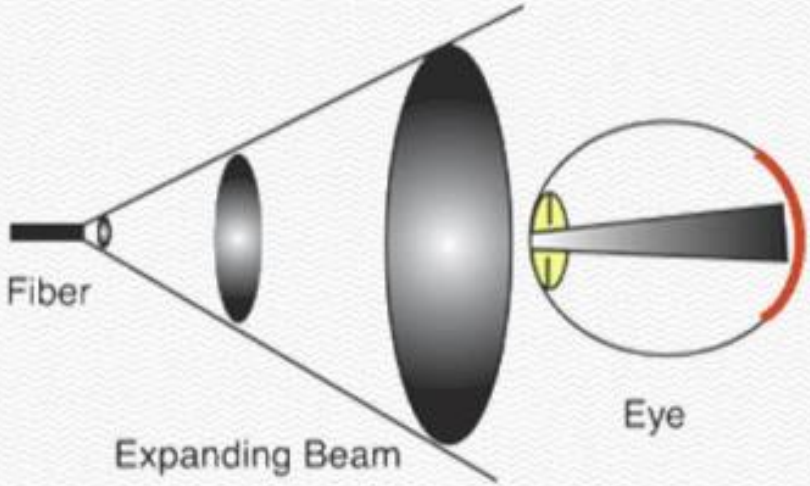
Optical Density

- The protective goal of laser eyewear is such that if laser radiation strikes the lens portion of the eyewear, the lens will completely block or reduce any transmitted radiation to below the Maximum Permissible Exposure (MPE) level.
- This filtration or protection level is called optical density (OD).
- Log ratio of incident beam versus transmitted beam.
- One can think of OD similar to SPF for sunblock.

OD	Attenuation	Transmission
1	10	0.1
2	100	0.01
3	1000	0.001
4	10,000	0.0001
5	100,000	0.00001
6	1,000,000	0.000001

Nominal Ocular Hazard Zone (NOHZ)

- The distance along the axis of the unobstructed beam from a laser, fiber end, or connector to the human eye beyond which the irradiance or radiant exposure is not expected to exceed the MPE.
- Meaning the start of the safe zone.
- Think of it as the diameter of a circle.



International Laser Safety Standards

- ITU-T Series G Supplement 39, *Optical System Design and Engineering Considerations*.
  - Describes engineering and design considerations.
    - Single and multichannel (WDM) systems.
    - Unamplified or amplified.
    - PDH, SDH, and OTN signals for single-mode spans.
  - Best practices, including viewing fibers, signage, alarms, viewing equipment, terminations, and cleaning of connectors and optical amplifiers.

International Laser Safety Standards

Series G Supplement 39 Considerations

- Viewing.
  - Fiber end faces should not be viewed with unprotected eyes or with any collimating device not approved by the operating organization this includes viewing aids such as filtered or attenuating viewing aids.
  - Any single fiber or ribbon fibers should be covered with a material appropriate (e.g. splice protectors or tape) for the wavelength and optical power when being worked on. Sharp ends should not be exposed and end caps should be placed over unmated connectors. Ribbon fibers cleaved as a unit may exhibit a higher hazard level than of a single fiber.
- Test cords.
  - The optical power source should be the last to be connected and the first to be disconnected.
- Fiber bends.
  - Excessive bending of the fiber can form a risk of failure due to bending stress (macrobend) or as a local heating point high power transmission.

International Laser Safety Standards

Series G Supplement 39 Considerations

- Follow the maintenance instructions approved by the operating organization for the system when being worked on.
- Do not make any unauthorized modifications to any optical fiber communication systems or associated equipment.
- For equipment which uses control keys, these should be placed under the control of a person responsible for safe use, storage and overall control.
- Reporting of damaged or missing safety labels.
- Area warning signs are required for locations exceeding hazard level 1M.
- System alarms, especially those that identify that automatic power reduction (APR) and other safety system is inoperable should be responded to so that the repair takes place within a specified time.

International Laser Safety Standards

Series G Supplement 39 Considerations

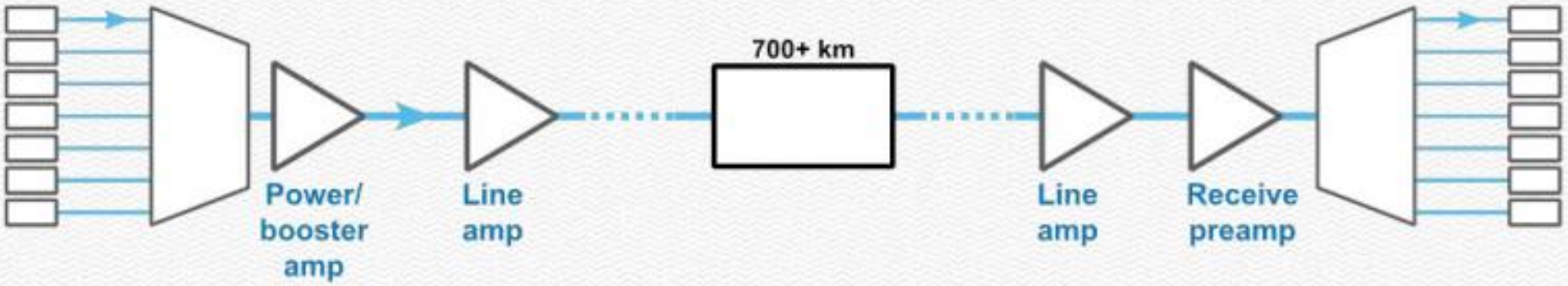
- Raman amplified systems.
  - These systems operate at high powers than can cause damage to fibers or other components.
  - Before activating the Raman power:
    - Calculate the distance to where the power is less than 150 mW.
    - If possible inspect any splice closures to assure that no bends less than 20 mm diameter exists.
    - If inspection is not possible use an OTDR to identify the location.
    - Connectors must be clean. Metallic contaminants are particularly prone to causing damage.
    - Be careful of reflective sites when Raman power is increased.
  - When Raman power is present bending losses increase the absorption and increase the heating with amplified systems when a carbon layer is formed a runaway thermal reaction can occur that produces enough heat to melt the fiber that blocks all optical power.

ITU-T G.664

- "Optical Safety Procedures and Requirements for Optical Transport Systems"
- Provides guidelines and requirements for techniques to enable optically safe working conditions on optical interfaces of the optical transport network.
- Includes:
  - Raman amplification techniques in restricted and controlled locations.
  - DWDM systems with large channel counts.
  - Guidelines for automatic power reduction (APR), automatic laser shutdown (ALS), and automatic power shutdown (APSD) for systems employing high power Raman amplifiers.
  - OTN systems using conventional SONET/SDH systems.

DWDM Systems

- How many wavelengths are being transmitted?
  - 50, 100, and 200 GHz spacings.
- Ribbon fiber or single strand?
- What are the optical power levels?
- Are optical amplifiers being used?
  - EDFA, Raman, SOA, or a combination of those.
- Can pose both eye and skin hazards.



IEC/TR 61292-4

- Optical Amplifiers, Part 4: Maximum permissible optical power for damage free and safe use of optical amplifiers.
- Describes fiber damage caused by high optical powers.
- Maximum permissible exposure (MPE) for eyes and skin.
- Connector end-face damage induced by dust/contamination.
- Optical power limits that cause thermal damage.
- Fiber-coat burn/melt induced by macrobends.
- Addresses impact of long haul, high data rate (>40 Gb/s), DWDM, and optically amplified systems.

Erbium-doped Fiber Amplifiers

- Class 3B power levels.
- Optical power levels?
- Can pose both eye and skin hazards.
  - Low to high.
  - Used in DWDM systems.
  - How many lambdas?

Courtesy RED-C

Raman Class 4 Amplifiers

- Pump lasers at both Tx and Rx locations.
- Optical power levels?
- Can pose both eye and skin hazards.
  - Low to high.
  - Used in DWDM systems.
  - How many lambdas?

Courtesy Finisar

Access Levels

Based on Potential for Exposure

- Location types.
- Unrestrictive (Class 1).
  - Domestic premises and premises open to public.
- Restricted (not accessible to public, above class 1).
  - Overhead cables, transmitters in secure spaces.
- Controlled (open beam above class 1).
  - Accessible only to authorized individuals (properly trained).
- Inaccessible, locations normally not occupied.
  - Space more than 6 m (19 feet) above the ground.

Optical Power Measurements

- Is the system live?
  - What is its optical power level?
- Does the optical power meter have the power level range for the systems to be tested?
  - Standard OPM.
  - High power OPM.
- Is laser safety eyewear required?
- Can the laser transmitter be shut off?

Optical Power Levels

- Amplifiers.
  - EDFA.
  - Raman.
  - SOA.
  - A combination of the above.
- Ribbon fibers.
  - MPO/MTP connectors.
  - Up to 12 single-mode fibers.
- Automatic power reduction (APR).
- Automatic power shutdown (APS).

Infrared Viewers

- Handheld instrument that uses a special type of electron tube to collect infrared light and display it visually.
- Shows presence of light as well as divergence of beam.
- Wavelength range from 350 nm to 1550 nm.
- Near-infrared cameras from 400 nm to 2200 nm.

Courtesy University of Rochester via FJW Optical Systems, Inc.

Infrared Sensor Cards

- Made of phosphors that are sensitive to infrared radiation.
- 3/4” x 3/4” active area size: $80.
- 2” x 2” active area size: $130.
- Available laminated or adhesive-backed.
- For best results, the sensors need to be charged with ambient light for about 30 seconds prior to IR exposure.
  - Cool white fluorescent light is best.

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Inspection Equipment

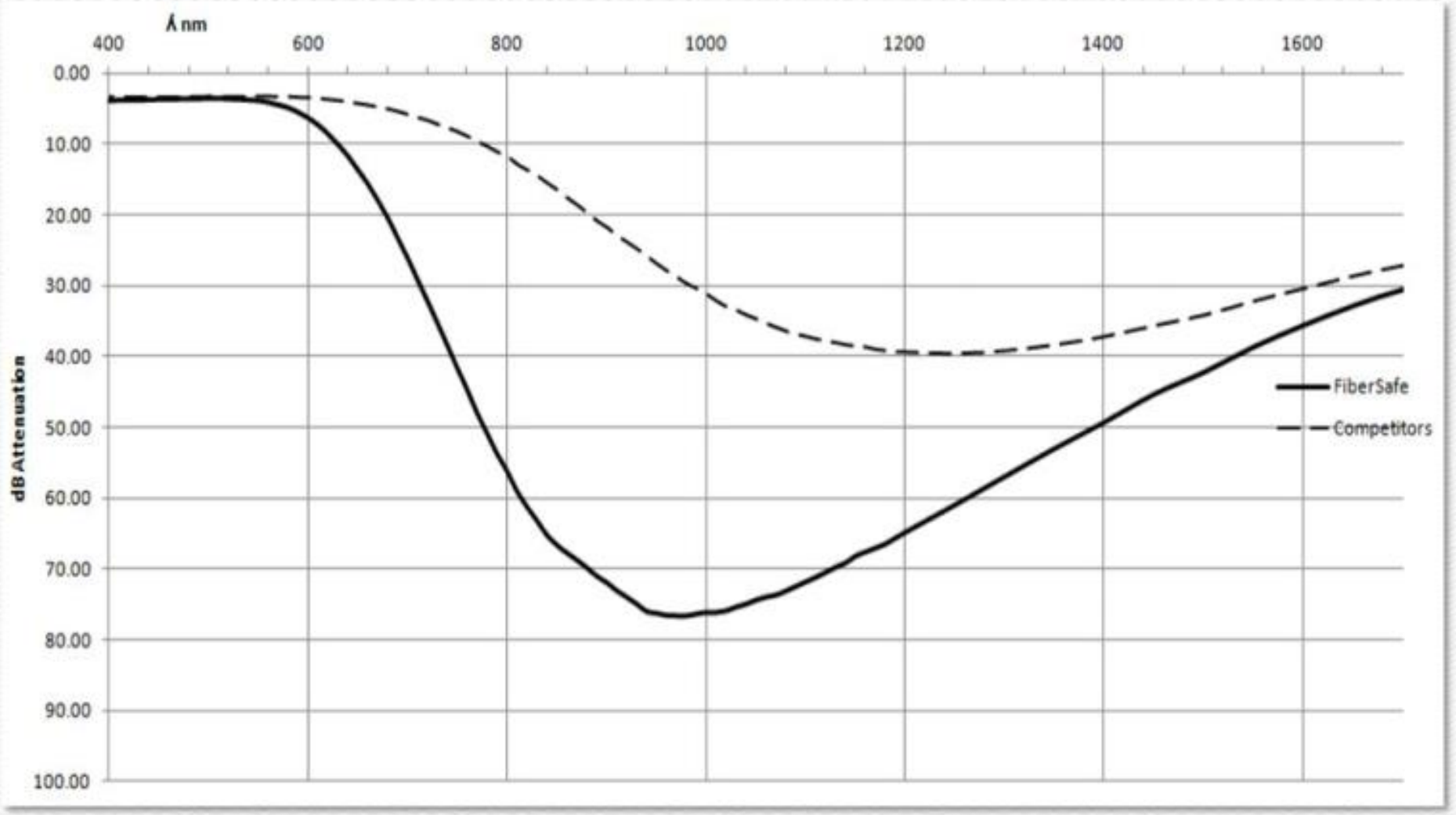
- Microscopes.
  - Does it have an internal safety filter?
  - How much is the optical power attenuated at the specific wavelength used?
- Digital inspection scopes.
  - Image is captured by a camera and shown on LCD display.
  - How much power can the camera receive without damage?

Visual Inspection Equipment

- Used to check connector and fiber endfaces.
- Has intrinsic safety filter.
- Portable.
- 200x to 400x magnification.
  - 200x recommended.

Courtesy Kingfisher

Microscope Filter Attenuation Comparison



Personal Protective Equipment

- Safety glasses for eye protection.
  - Working with fibers.
  - Illumination option.
  - Various styles.
    - Goggles.
    - Side shields.
- Laser eyewear.
  - Wavelength.
  - Optical power level.
  - Viewing conditions.
  - Optical density.
    - Base-10 logarithm of the attenuation factor by which the optical filter reduces beam power.

Courtesy 3M

Courtesy Laservision USA

Mid IR

- Laser eyewear for general range of fiber communication lasers has a high VLT.

Working with Optical Fibers

Basic Rules

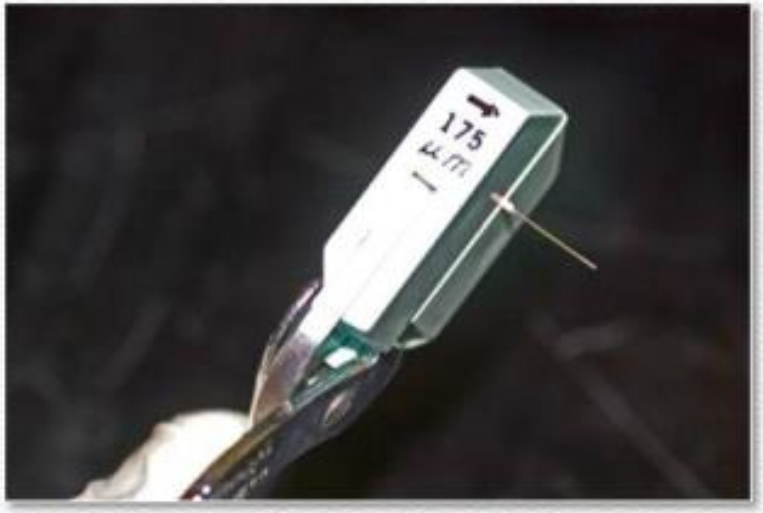
- No food or drinking allowed in areas where fiber work is performed.
- No bare feet in work area or in building due to accidental transport of fiber chips.
- Fiber disposal is not for janitorial staff, unless they are properly trained for the task.

Best Practices to Keep Fibers Damage Free

- When optical fibers are used with high optical power levels the fibers and connectors can be damaged under certain conditions. Due to both the optical power levels and the associated aspects of this safety must be considered.
  - An example of this would be where a fire could start by localized heating caused by an contaminated connector.
- Considerations to keep fibers damage free:
  - Fiber fuse due to high optical powers.
  - Loss induced heating at connectors or splices.
  - Connector endface damage induced by dust/contamination.
  - Fiber coating melting caused by macro and microbends.

Handling Optical Fibers

- Tool handling.
- Eye safety.
- Skin safety.
- Fiber preparation.
- Splice preparation for terminations.
- Cable preparation.
- Clean work area.
- Safe disposal of fiber waste.
- Do not use sticky tape in place of safety containers.



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Safety Gloves

- When working with fibers:
  - Nitrile recommended due to puncture and chemical resistance.
  - Must have tactile sensitivity due to small size of fibers.
  - Textured surface on fingers for holding fibers.
  - Darker colors recommended for best contrast against fibers and debris.
- When working with chemicals:
  - Material must be compatible with chemicals used.
  - Some people have latex allergies.
  - Nitrile recommended due to puncture and chemical resistance.
- When prepping cables:
  - Puncture resistance for strength members and armor.

Fiber Disposal

- Do not use double-sided tape.
- Use approved safety container.
  - Large mouth for debris removal.
  - Seal into large zipper bags and dispose debris off site.
- Cable debris should be removed and then properly disposed of.
- Safety clothing and PPE.

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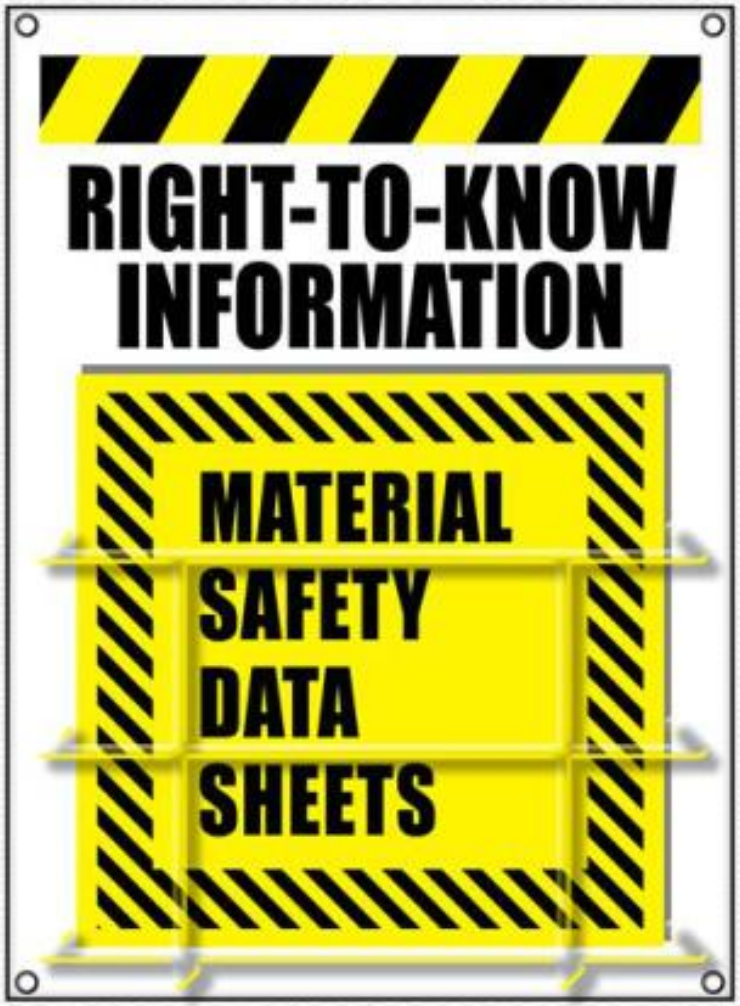
Personal Protective Equipment

- Clothing for manufacturing.
  - Lab coats and aprons.
  - Shoe covers.
  - Face masks, hairnets, and caps.
  - Gloves.
- Clothing for installation.
  - Boots.
  - Hardhats.
  - Gloves for fiber and cable handling.
- Breathing apparatus.
  - Respirators selected for specific particulates and coverage.

Material Safety Data Sheets (MSDS)

- Each chemical requires MSDS to be kept on-site for inspection.
- The employer must make MSDS available for your review. It is your responsibility to read them.
- Just because there is an MSDS does not mean the chemical is unsafe or safe!
- These documents are technical and may be intimidating. If you have questions, ask your EH&S person, nurse, human resources, or contact the manufacturer.



MSDS Example

- Material Name: Optical Fiber
  - Section 1 – Chemical Product and Company Identification
  - Section 2 – Composition / Information on Ingredients
  - Section 3 – Hazards Identification
  - Section 4 – First Aid Measures
  - Section 5 – Fire Fighting Measures
  - Section 6 – Accidental Release Measures
  - Section 7 – Handling and Storage
  - Section 8 – Exposure Controls / Personal Protection
  - Section 9 – Physical and Chemical Properties
  - Section 10 – Chemical Stability & Reactivity Information
  - Section 11 – Toxicological Information
  - Section 12 – Ecological Information
  - Section 13 – Disposal Considerations
  - Section 14 – Transportation Information
  - Section 15 – Regulatory Information
  - Section 16 – Other Information

Courtesy Corning Inc.

Question and Answer Period

- Special thanks to Ken Barat, CLSO with Laser Safety Solutions.
  - lasersafetysolutions@gmail.com
- View our previous safety webinar in Lightwave's Training Webcast Library at lightwaveonline.com.
- Learn more through our Fiber Optic Safety DVD.
  - Only $99 at www.lightbrigade.com with discount code LW2014Safety

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Our next webinar on
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will address
Fiber and Cable Management

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