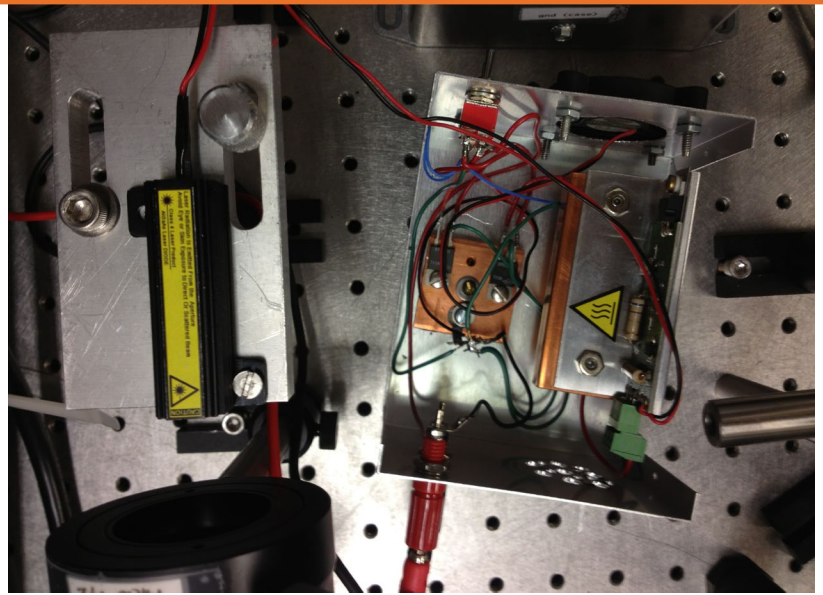
ELECTRICAL SAFETY FOR THE LSO

DOE LSO Workshop 2026

Presenter: Dr. Simon Lappi

Lightwave Safety

Date: May 21, 2026



Question

What do think electrical safety means?

Shock prevention?

Fire prevention?

Death prevention?

CONTENT OUTLINE

Session Overview

01 **Electrical Hazard Basics**

Voltage, current, resistance — what actually kills

02 **Improper Device Use**

Wrong tools, wrong ratings, wrong contexts

03 **Connection & Wiring Failures**

Loose connections, wrong gauges, poor terminations

04 **Overloading & Thermal Hazards**

Overloaded circuits, daisy-chaining, heat buildup

05 **Extension Cords & Power Strips**

The most misused devices in any lab or facility

06 **Laser System-Specific Risks**

HV capacitors, pulsed supplies, grounding faults

07 **Interlock & Bypass Hazards**

Why defeating safety systems creates cascading risk

08 **LOTO & Correct Procedures**

Proper isolation, verification, and documentation

HAZARDS OF ELECTRICITY

ELECTRIC SHOCK

Current through the body — can stop the heart at 50–150 mA.

THERMAL BURNS

Contact with energized parts causes deep tissue burns.

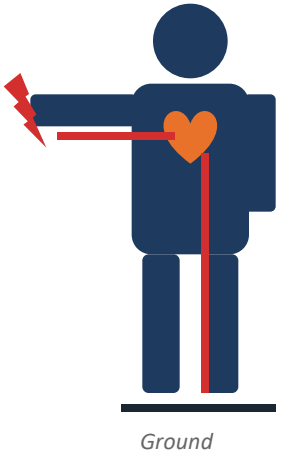
ARC FLASH

Explosive release of energy — extreme heat, light, and pressure.

SECONDARY INJURY

Falls, dropped tools, and reflex reactions following a shock.

Path of Current Through the Body



- 1 mA — Perception
- 5 mA — Painful
- 10–30 mA — Can't let go
- 50–150 mA — Fibrillation
- 1–4.3 A — Fatal
- ≥10 A — Cardiac arrest

CURRENT EFFECTS ON THE HUMAN BODY

1 mA — Perception Threshold

Faint tingle; the smallest current most people can feel. No injury, but indicates contact.

5 mA — Maximum 'Safe' Current

Painful shock, but the person can still let go of the conductor. UL/OSHA practical safety ceiling.

10–30 mA — Let-Go Threshold

Sustained muscle contraction; victim cannot release the source. Breathing may become labored.

50–150 mA — Likely Fatal

Severe pain, respiratory arrest, onset of ventricular fibrillation. Often fatal without rapid defibrillation.

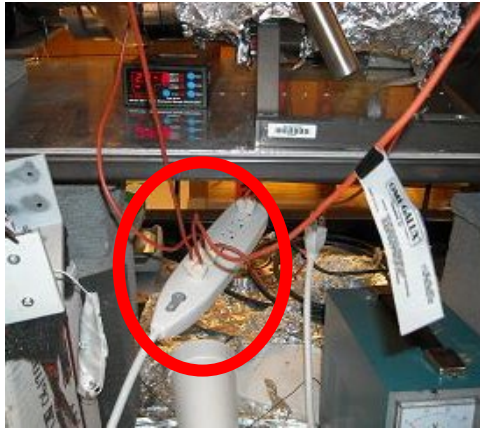
1–4.3 A — Fibrillation Certain

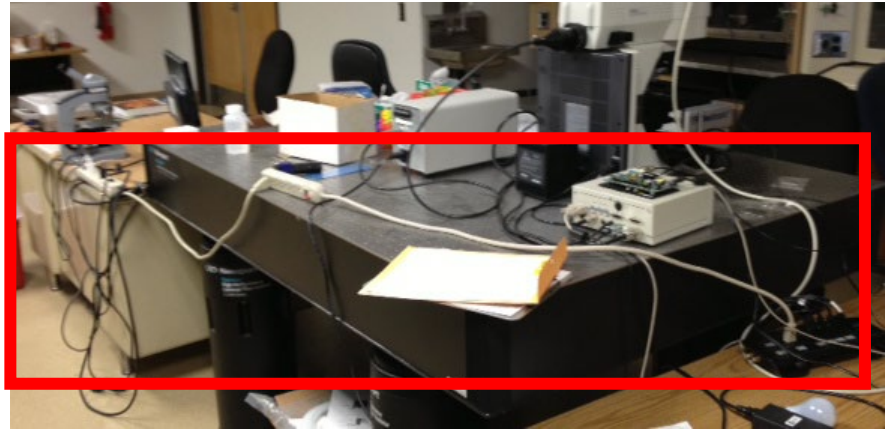
Ventricular fibrillation, nerve and tissue damage. Survival rare.

≥10 A — Cardiac Arrest

Heart stops, severe internal/external burns. Almost always fatal.

IMPROPER DEVICE USE





IMPROPER USE OF ELECTRICAL DEVICES

Rating Mismatch

✗ WRONG — Using a 15A-rated power strip on a 20A circuit feeding a laser chiller, pump, and controller simultaneously

✓ RIGHT — Match strip/outlet rating to total load; use a dedicated 20A circuit for high-draw equipment

Voltage Mismatch

✗ WRONG — Plugging a 240V laser PSU into a 120V outlet via a physical adapter — 'it fits so it should work'

✓ RIGHT — Verify supply voltage against nameplate before energizing; use a multimeter, not the power button

Covers-Off Operation

✗ WRONG — Running a laser during scheduled PM with covers removed because 'the test will only take a second'

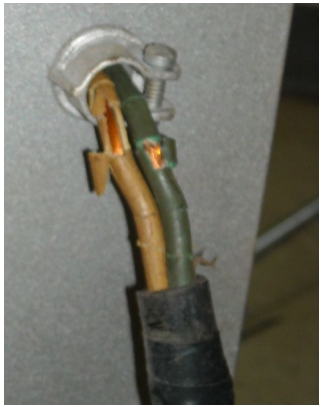
✓ RIGHT — Any maintenance access requires full LOTO — partial de-energization is not de-energization

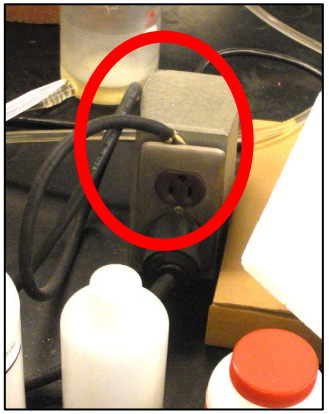
Undersized UPS

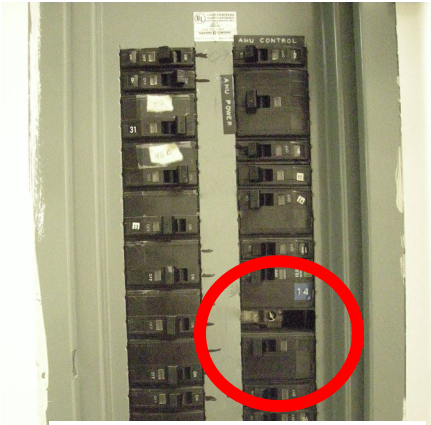
✗ WRONG — Using a consumer-grade 120V/600W UPS as ride-through for a 3kW laser power supply

✓ RIGHT — Size UPS for 125% of continuous load; verify output waveform is compatible with the connected load

CONNECTION & WIRING FAILURES







CONNECTION & WIRING FAILURES

03 — How Bad Connections Cause Fires & Failures

🔩 Loose Screw Terminals

A loose terminal on a laser PSU input increases resistance, causing localized heating, insulation melt, and arc fault. Torque to spec; re-check after first thermal cycle.

🎀 Undersized Wire Gauge

18 AWG wire carrying 20A continuous will overheat within minutes. Always verify conductor ampacity using NEC 310 tables before any permanent wiring.

🔗 Wrong Connector Type

Using quick-connect crimp terminals rated 300V on 480V three-phase laser supplies is a code violation and arc-flash initiator. Match connector voltage class to supply.

🛡️ Ground Conductor Omitted

Ungrounded metal chassis on water-cooled laser systems become lethal touch-voltage sources on a fault. Ground continuity must be verified after every service.

#1

Cause of electrical fires in labs: loose connections

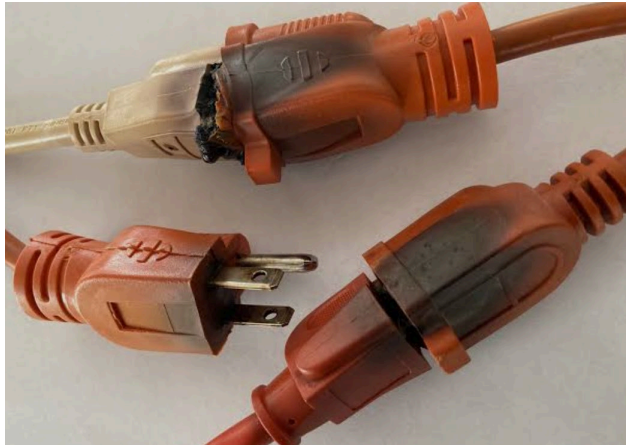
4×

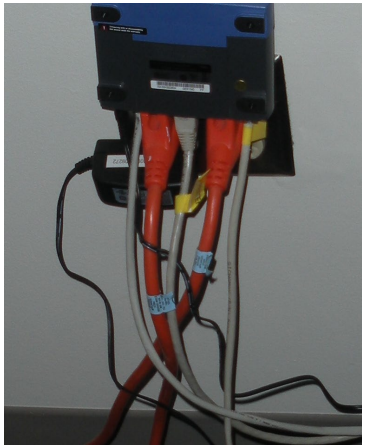
Higher fault risk from one wire gauge undersized

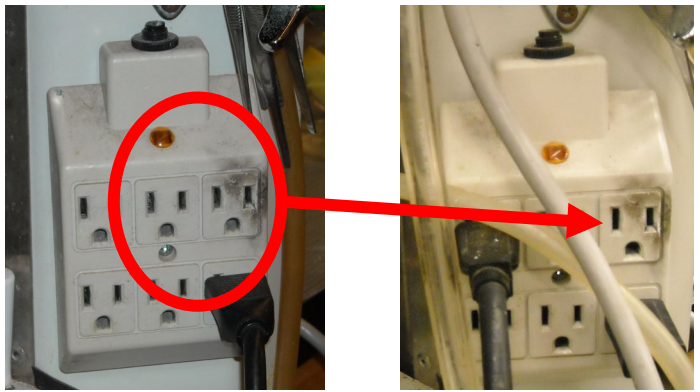
0V

Required at chassis before any wiring work

Overloading & Thermal Hazards







OVERLOADING & THERMAL HAZARDS

Daisy-Chained Power Strips

Stacking strips or extension cords concentrates load on one outlet rated for ~15 A — a classic cause of insulation melt and fire.

Overloaded Outlets & Circuits

Too many high-wattage devices on one branch trips breakers — or worse, overheats wiring behind walls before protection kicks in.

Damaged or Undersized Cords

Frayed, pinched, or under-gauge cords increase resistance, heat up under load, and ignite nearby combustibles.

Blocked Ventilation & Heat Buildup

Equipment covered, boxed in, or run in hot spaces can't shed heat — internal components degrade and arc-fault risk climbs.

Warning Signs

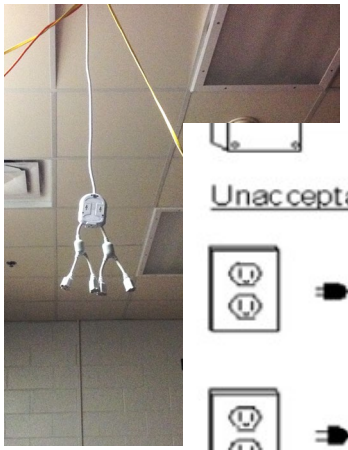
Warm plugs, scorch marks, burning smell, flickering lights, frequent breaker trips — stop using and investigate.

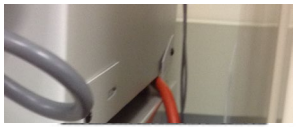
Consequences

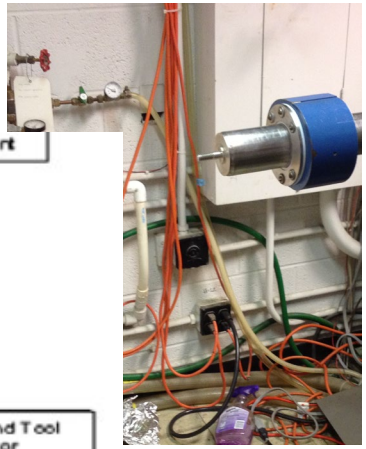
Electrical fires, equipment loss, injury, and downtime — most are preventable with proper load planning and inspection.

EXTENSION CORDS & POWER STRIPS

05 — The Most Misused Devices in Any Facility

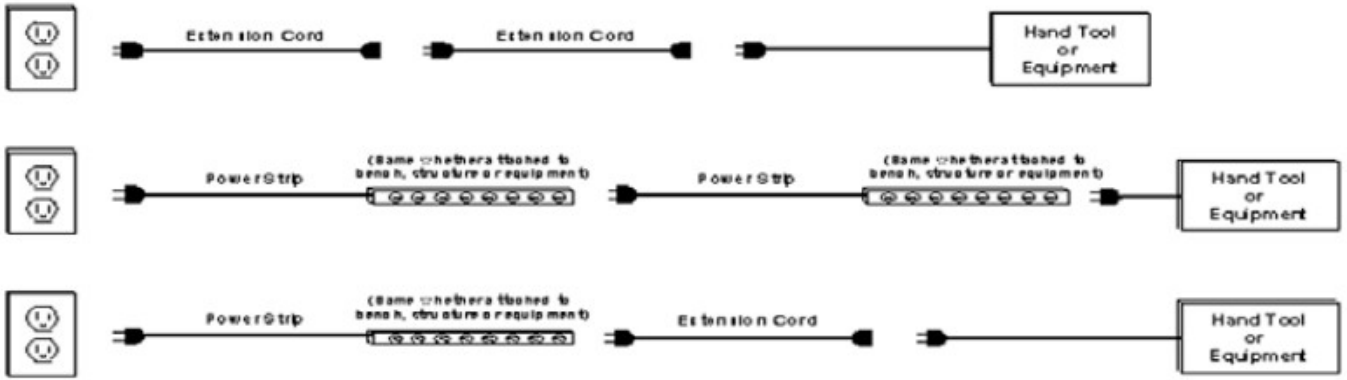


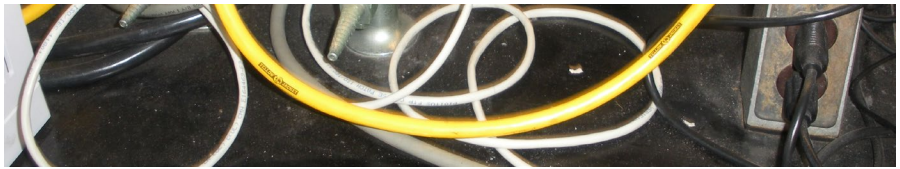




Equipment

Unacceptable (Daisy-chain) combinations of extension cords and power strips.





EXTENSION CORDS & POWER STRIPS

05 — The Most Misused Devices in Any Facility

⚠ *Extension cords are temporary devices — not permanent wiring solutions. In laser labs, they are a leading source of overloads, arc faults, and trip hazards.*

❌ Common Violations

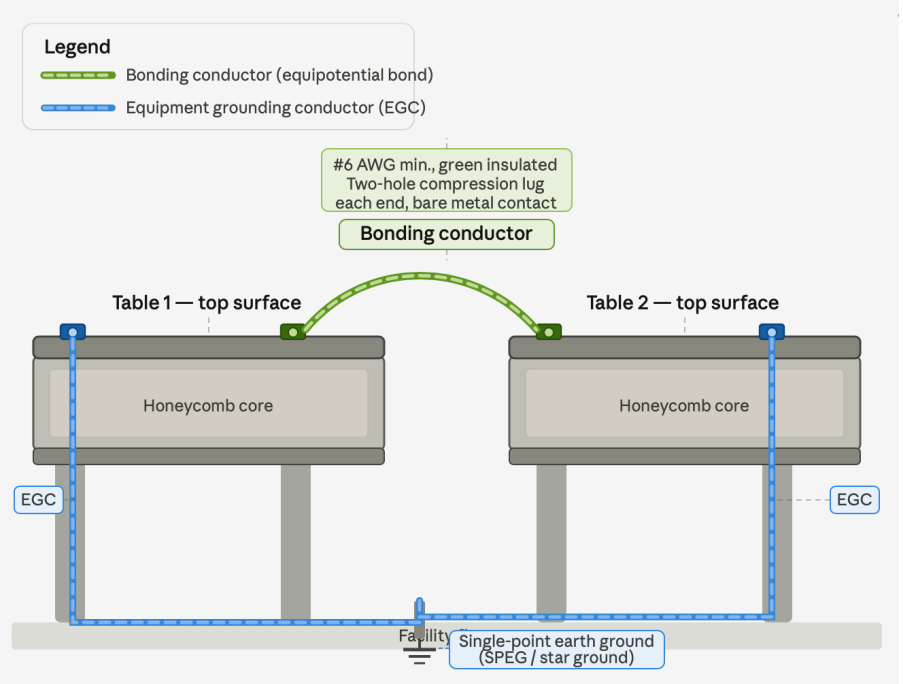
- Daisy-chaining power strips (strip into strip)
- Running cords under rugs, mats, or cable trays
- Using indoor-rated cords in wet or damp areas
- Coiling extension cords while energized — heat buildup
- Using ungrounded (2-prong) cords on grounded equipment
- Taping cords to walls as a 'permanent' wiring run
- Using cords rated below equipment amperage draw

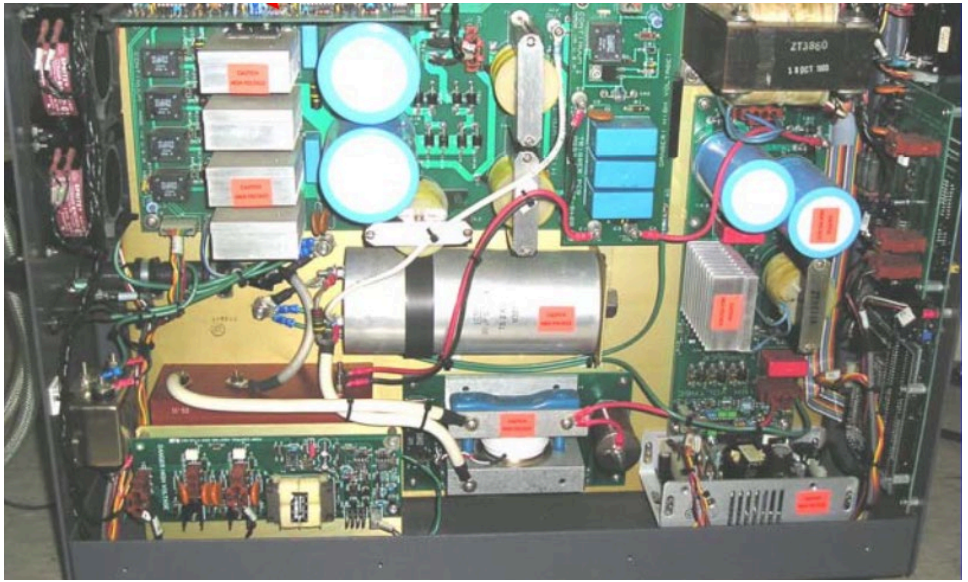
✅ Correct Practice

- Use only for temporary, attended connections
- Match cord ampacity to load plus 25% safety margin
- Never exceed the cord's listed wattage rating
- Uncoil fully before use to prevent thermal buildup
- Use only 3-wire (grounded) cords for lab equipment
- Install permanent outlets where permanent loads exist
- Inspect cord jacket and plugs before each use

LASER SYSTEM ELECTRICAL HAZARDS

06 — High-Voltage & Pulsed System Risks





LASER SYSTEM ELECTRICAL HAZARDS

06 — High-Voltage & Pulsed System Risks

⚡ Capacitor Banks

✗ INCIDENT

Opened a pulsed Nd:YAG enclosure 10 seconds after power-off — capacitor bank at 1.8 kV discharged through the technician's forearm

✓ CORRECT

Wait for bleed-down indicator; verify with CAT III/IV HV meter. Follow manufacturer minimum wait, then measure.

🔁 Pulsed Power Supplies

✗ INCIDENT

Bypassed a door interlock during alignment — PSU fired at 15 kV during an accidental trigger from a keyboard bump

✓ CORRECT

Interlocks are the last line of defense. Use HV probes, discharge resistors, and always have a second person present.

💧 Cooling System Leaks

✗ INCIDENT

A cracked coolant fitting leaked onto the 480V bus bar on a laser chiller — resulted in ground fault and tripped the main breaker

✓ CORRECT

Inspect fittings and hoses monthly. Route coolant lines away from HV components. Install DI water conductivity alarms.

LASER INTERLOCK AND BYPASS HAZARDS

Interlocks are engineered controls — door switches, shutter sensors, key locks, and emission indicators — that keep a Class 3B or 4 laser from firing when the enclosure is open or alignment is incomplete. Defeating them removes the last barrier between the operator and a hazardous beam.

- **Common bypass methods —** taping door switches, jumpering interlock terminals, propping enclosures open, or using override keys left in the lock. Convenient during alignment, catastrophic during normal operation.
- **Eye & skin injury —** direct or specular reflection of a Class 4 beam causes permanent retinal damage in milliseconds and deep skin burns; invisible IR/UV wavelengths give no blink response or warning.
- **Secondary hazards —** exposed high-voltage power supplies and capacitor banks behind defeated panels, plume/fume release, and ignition of nearby combustibles by stray beam paths.
- **Authorization & controls —** any defeat requires written approval from the Laser Safety Officer, documented procedure, restricted access, and full PPE (wavelength-rated eyewear, barriers, signage) per ANSI Z136.1 §4.6.

08

LOCKOUT / TAGOUT

Safe Isolation Procedures
for Laser Electrical Systems

OSHA 29 CFR 1910.147 • ANSI Z136.1 • IEC 60825

LOTO PROCEDURE — STEP BY STEP

08 — Required for ALL Laser System Maintenance

1 Notify

Inform all affected personnel. Post warning signs at the laser aperture and main panel.

2 Identify Sources

Map ALL energy sources: mains, capacitors, hydraulic, pneumatic, coolant pressure.

3 Isolate

Open all disconnect switches. Close isolation valves. Disable remote-start capability.

4 Apply Locks & Tags

Every authorized worker applies their personal lock. Tag must state name, date, reason.

5 Release Stored Energy

Discharge capacitor banks per SOP. Bleed pneumatics. Drain coolant if required.

6 Verify Zero Energy

Use calibrated CAT III/IV meter. Attempt normal start. Confirm zero-energy in writing.

ARC FLASH HAZARDS

ARC FLASH HAZARDS

What Is an Arc Flash?

A sudden, explosive release of energy when current jumps an air gap between conductors — ionizing air into plasma in milliseconds.

Common Triggers

Dropped tools, loose connections, insulation failure, dust or moisture in gear, racking breakers, and accidental contact during energized work.

Energy & Heat

Arc temperatures reach ~35,000°F — four times hotter than the sun's surface. Incident energy is measured in cal/cm² (NFPA 70E categories 1–4).

Arc Blast & Pressure Wave

Vaporizing copper expands ~67,000×, producing a concussive blast that hurls shrapnel, molten metal, and equipment fragments at high velocity.

Injuries

Third-degree burns, hearing loss, lung damage from hot gases, blunt-force trauma, blindness from UV/IR flash.

Approach Boundaries

Limited, restricted, and arc-flash boundary distances per NFPA 70E — only qualified workers in rated PPE may cross.

KEY TAKEAWAYS

- ⚡ Match every device, cord, and connection to its rated voltage, current, and environment — no exceptions.
- 🔌 Loose connections and undersized wiring are the leading causes of electrical fires — inspect and torque to spec.
- 🔥 Overloading is invisible until it isn't — use a clamp meter to verify actual load before adding equipment to a circuit.
- 🔒 LOTO is non-negotiable for laser system maintenance — capacitors store lethal energy long after power-off.
- 📋 Document everything: LOTO logs, wiring changes, interlock bypass authorizations, and near-misses.