CASE STUDY OF A RECENT FEMTOSECOND LASER INJURY

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Overview

• Introduction
• Ultrashort pulsed injury - Case Study
• Laser Safety
• Summary and Conclusions
Continuous Wave Lasers
Minimum Visible Lesions

1 Hour

24 Hour

Damage Area, 650 nm diode laser

Dose Response Curve (with Fiducial Limits)

- ED<sub>10</sub>
- ED<sub>50</sub>

Outer Nuclear layer
- Outer limiting membrane
- Photoreceptor cells
- Inner and Outer segments
- RPE
- Choroid
Visual acuity at 3 years < 20/200 (OD)
Medical discharge with 30% disability compensation
Nd:YAG Laser Exposure Incident
1064 nm at 10 pulses per second

Initial Reaction: Perceived a brief “pulsating strobe” effect. Patient proceeded to the restroom to “wash the blood out” of his eye.

Visual Acuity: CF to 20/400  Visual Acuity: 20/40
Laser Injury Cases

- Laser pointers can cause severe eye injury, case of a 15-year-old boy

Patient presented in retina clinic in Al-Bahar eye center in Kuwait
- Complaints of decrease in vision following exposure to unknown light


150 mW Laser

High-power laser pointer
Low-power laser pointer
1W Blue Laser Hobbyist Injury

December 6, 2011

• 1 watt, 445 nanometer (blue) laser
• December 6, 2011
• The injury required unspecified surgery, Two days after the surgery, the hobbyist reported a blurry dark circle in his central vision.
• His doctor told him he would always have a small off-center blind spot
• “And just to show that I'm not going to let a little something like blindness in one eye keep me down, I finished the contraption that started this whole mess, except this time using a <100mW greenie instead.”

wickedlaser.com
1W: $299.95
1.2 W: $399.95

Ultrashort Pulsed Lasers

- Very Low Thresholds for damage
- Supercontinuum
  - Damage via nonlinear mechanisms
- Dye-based LEP may have less OD than for longer pulses

Commercially Available Systems sufficient to cause damage/jamming to within 10 km. Primary bands are 700-900nm (Ti:SAP) and 1.55 microns (Er). Nonlinear bands cover entire usable spectrum.

805nm femtosecond laser, 100mJ energy, 10 Hz, at 3.6 meters
Ultrashort Pulse Thresholds for NHP

Visible

Near I R

400 - 700 nm

1.2 µm to 1.4 µm

1.05 µm to 1.15 µm

500 - 700 nm

475 nm

400 - 450 nm

Time (Seconds)

Radiant Exposure at Cornea (J/cm²)
Hazard
800 nm, 100 femtoseconds

• MPE
  – 24 nJ·cm⁻²

• TIE
  – 9.15E-09 J

• NOHD (beam is circular, Gaussian, 0.5 cm diameter, 0.5 mrad divergence) - a very long 29,293 meters, assuming no atmosphere

• Diffuse reflection – viewing laser 1 meter from reflecting surface, viewing angle 90 degrees
  – OD of 1.2 required
Ultrashort Pulsed Ti:Saph Injury Reports


- Kirtland AFB incident, 10 Aug 2012
Kirtland AFB Injury

• Laboratory laser eye injury
• 10 Aug 2012

– TiSaph, ultrashort femtosecond laser retinal injuries in laboratory at Kirtland AFB. The laser reflected off a metallic curved metal plate.

– OCT shows the clear columns of damage in both eyes, on his foveas. He has small spots in his vision. With correction 20/20 acuity, but reported he needed to fixate slightly eccentrically to read the 20/20 letters. He says the deficit is more irritating and noticeable for his distance vision than his near vision.
Both eyes show damage through the retina at the foveas.
• My vision seems to be improving, and I don't even notice the blurry spot unless I think about it. When I do, I analyze my vision by trying to read signs when I am driving. There is still some blurriness around the edges of letters in the center of my vision, but that blurriness is outside of my visual acuity anyway, so it does not affect my ability to read at a distance. The best way that I can describe it, (going back to my last examination) , when I was reading the 20/15 and 20/13 letters on the eye chart, I could see the letters but they were blurry, and the blurry region was approximately the same size as those letters. I base this off of the width of the letters and going up to 20/20 and above, the blurry spot was in the middle of those letters.
Update on vision, 9/6/2013
(1 Year post-injury, 8/10/2012)

• I can no longer detect any holes in my vision.
• I looked at an Amsler grid, and didn’t notice any voids
• “I looked at a $10 bill and with each eye individually, I was able to see unbroken lines in any and all of the thinnest lines on the bill.”
• “A few months back I remembered the incident and I started looking for any hints of the voids and back then I could not detect any voids. So as far as I can tell, my vision has corrected a few months back.”
• He is due for another exam
The Laser

• TiSaph
  – 40 mJ
  – 100 fs
  – The laser was being focused via telescope, onto an aluminum sphere, about 3 inches in diameter.

• LEP
  – UVEX LS 966
  – OD 5+ @ 190-500nm
  – 4+ @ 515nm
  – LS1559 VLT 60%

Wear the proper Laser Eye Protection!

Choose LEP for laser wavelength
Special LEP considerations for ultrashort Lasers

• Laser Eye Protection for ultrashort lasers may in some cases may not provide the OD that is specified by a manufacturer and requires special care in selection.
  – The high pulse density may cause saturation of the absorption and a reduction of the optical density
  – Femtosecond laser pulses have a large bandwidth and a broadband filter may be required
    – The fluence that produces damage of the laser protection materials drops with decreasing laser pulse duration.

• Unfortunately, laser eye protection is not generally provided by manufacturers for ultrashort lasers and measuring their OD requires special techniques.
Laser Safety

• Per ANSI Z136.1, employers have a fundamental responsibility for the assurance of the safe use of lasers owned and/or operated in facilities under their control. For Class 3B and Class 4 lasers and laser systems the employer “shall” provide safety programs and employee training programs.

• The proper LEP should be available, and there should be procedures to assure that the appropriate LEP is worn.

• The lessons that are learned from laser accidents should be incorporated into laser safety practices.
Examination after Exposure

- Personnel exposed, or suspected to have been exposed, to a laser beam with symptoms or at levels above the MPE should be evaluated as warranted.

- Transient visual effects and psychological impacts can be significant

- Include:
  - History
    - Symptoms
    - Laser distances
  - External Examination
  - Near & Far Visual Acuity
  - Amsler Grid Test
  - Pupils
  - Stereopsis
  - Color Vision
  - Retinal Examination – if warranted, include photos, FD OCT, Fluorescein angiography, SLO, AO
**Ultrashort Pulsed Laser Injury**

**Take Home Points**

- Ti:Saph lasers require special safety precautions
- Ti:Saph ultrashort laser injuries have differences with other laser injuries
  - Threshold energy for damage is much lower than longer pulsed lasers
  - All of these patients experienced an exposure to reflected light from an ultrashort pulsed titanium:sapphire laser
  - Bilateral, foveal damage in all these cases
  - Focused ultrashort super-continuum generation may be a mechanism of damage
- Disturbances in the RPE were minimal
  - Minimal retinal laser damage may be difficult to detect with conventional ophthalmological instruments
  - FD-OCT and Adaptive Optics fundus camera, or scanning laser ophthalmoscopy may be helpful
- Wrong laser eye protection or no laser eye protection in all these ultrashort pulsed laser injury cases
- If DoD, report these accidents to the Tri-Service Laser Hotline
  - Rockwell Laser Industries and the FDA also maintain databases of laser injuries
Questions ?