Optical Radiation-Induced Eye Injuries

Bruce E. Stuck

ICNIRP Member
bstuck@satx.rr.com

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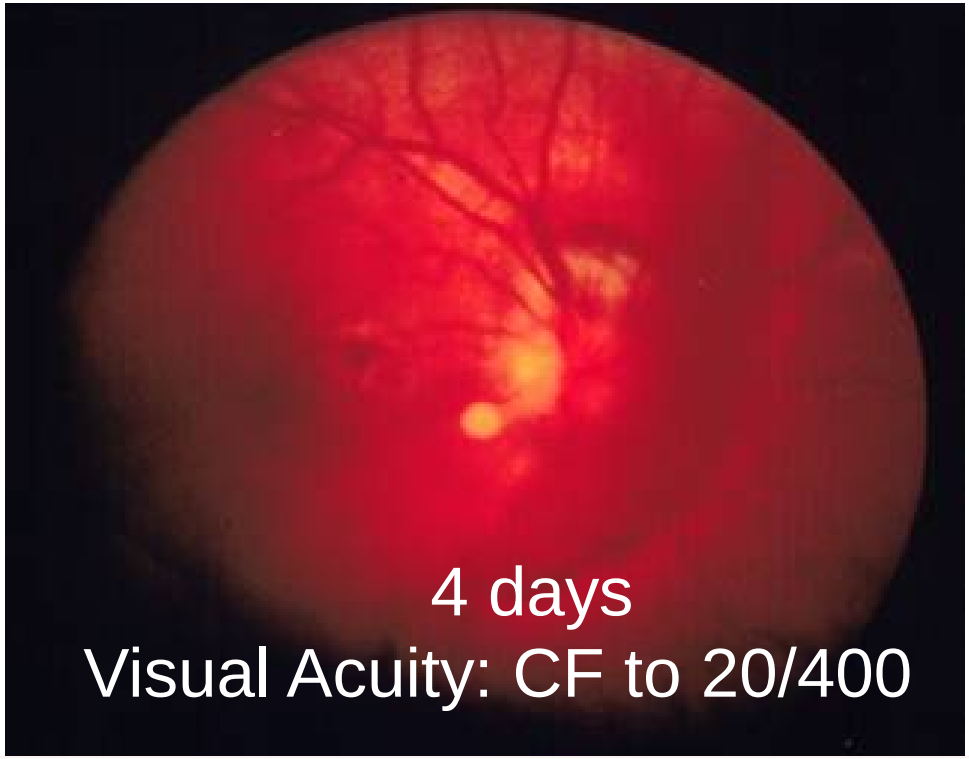
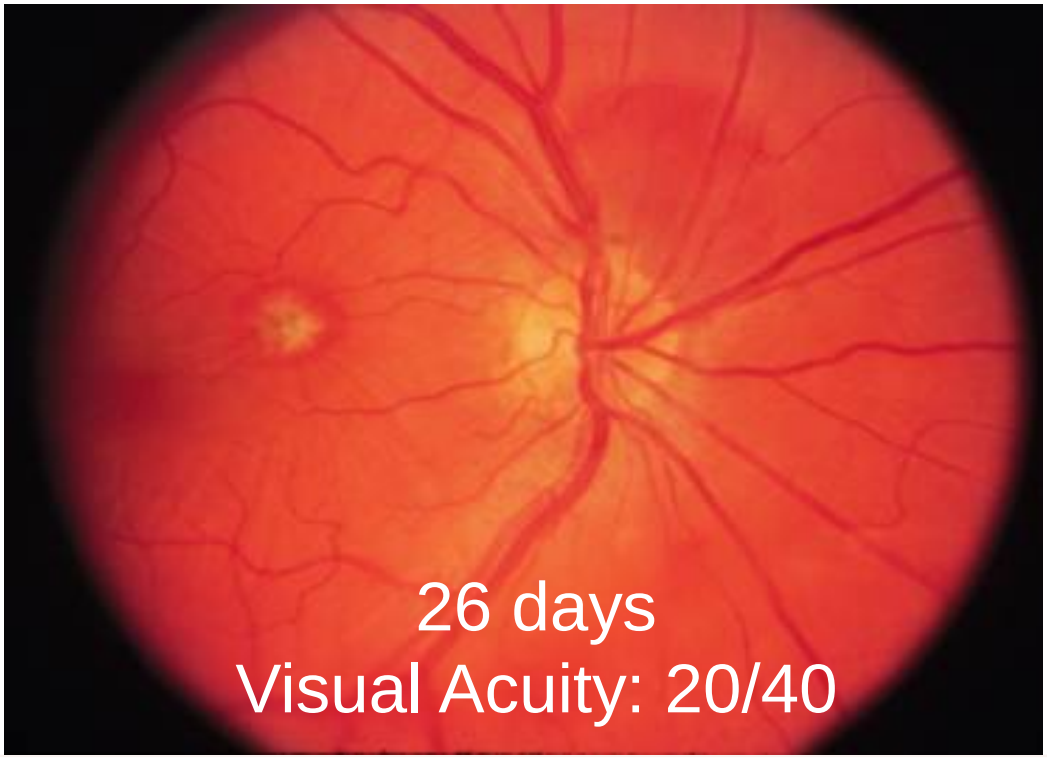
Report of Laser Injury by Dr. CDD

"When the beam struck my eye I heard a distinct popping sound, caused by a laser-induced explosion at the back of my eyeball. My vision was obscured almost immediately by streams of blood floating in the vitreous humor, and by what appeared to be particulate matter suspended in the vitreous humor. It was like viewing the world through a round fishbowl full of glycerol into which a quart of blood and a handful of black pepper have been partially mixed. There was local pain within a few minutes of the accident, but it did not become excruciating. The most immediate response after such an accident is horror. As a Vietnam War Veteran, I have seen several terrible scenes of human carnage, but none affected me more than viewing the world through my blood-filled eyeball. In the aftermath of the accident I went into shock, as is typical in personal injury accidents." (Note: Nd: YAG Laser operating at 1064 nm, 10 nsec pulse. Estimated Total Intraocular Energy: TIE = 6 mJ. ED_{50} = 18 μJ. ICNIRP EL = 0.8 μJ)

Laser Focus, April 1982

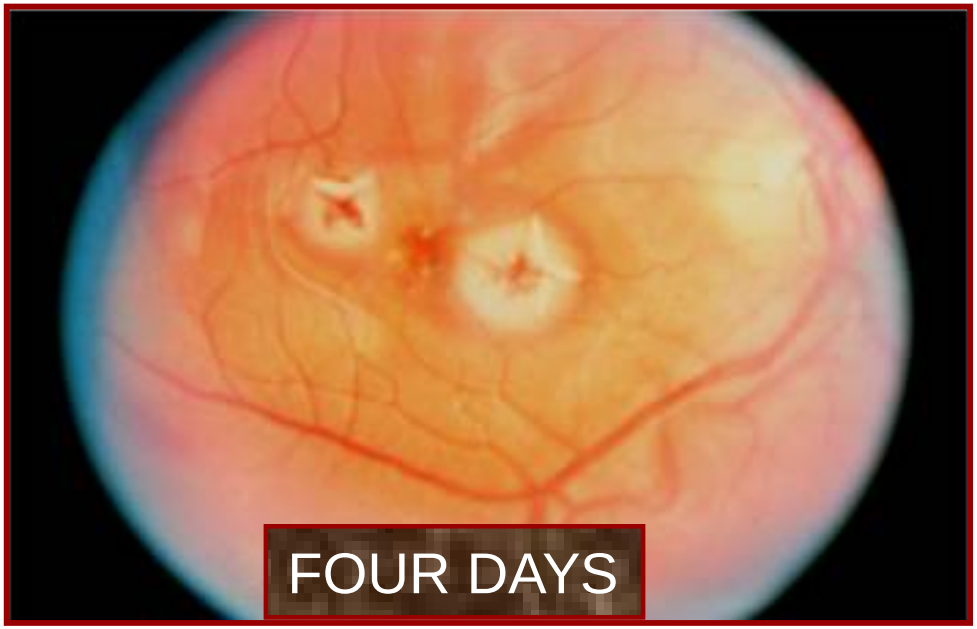
Nd:YAG Laser Exposure Incident 1064 nm at 10 pulses per second





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

Multiple Neodymium Laser Rangefinder Exposures



Visual acuity OD at 3 years < 20/200
Visual acuity OS – 20/20 w/o correction
Medical disability – 30%

Case FC2

Situational Assessment: A 21 year old male received a bilateral macular injury from a Q-switched Nd:YAG laser rangefinder (LRF) operating at 1064 nm with a 6 ns emission duration and total emitted energy per pulse of 15 mJ. The exit beam diameter was 11.5 mm. The incident occurred in the bright midday sun at close range when connecting the LRF to a vehicle battery. Each eye was exposed independently resulting in unequal but bilateral vitreous hemorrhage from the macula.

Treatment: None until 18 months after exposure. The OD injury was complicated by epiretinal membrane and retinal hole formation requiring surgical intervention at 18 months.

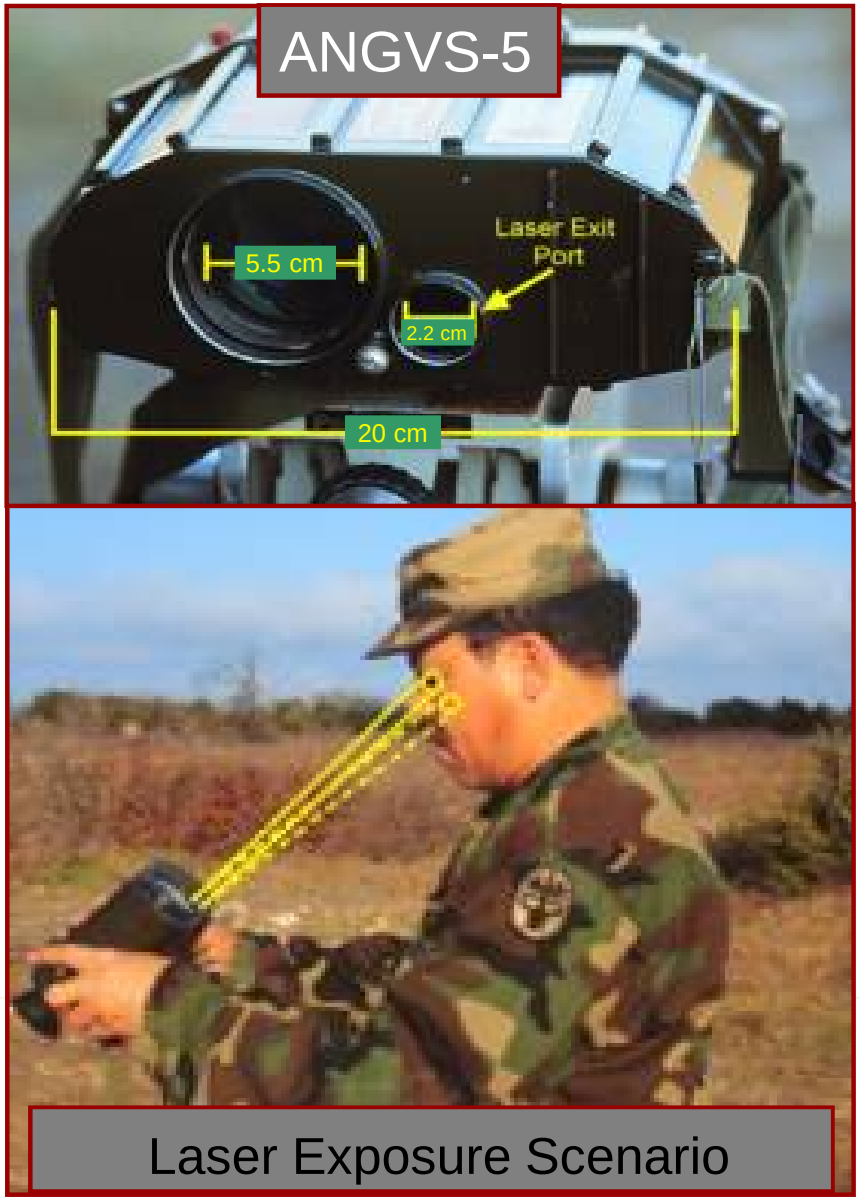
Dose Estimate: Radiant exposure at corneal = 11 mJ/cm^2 . Total intraocular energy through a 3 mm pupil = 1 mJ (or less).

Visual Acuity: (See adjacent panel)

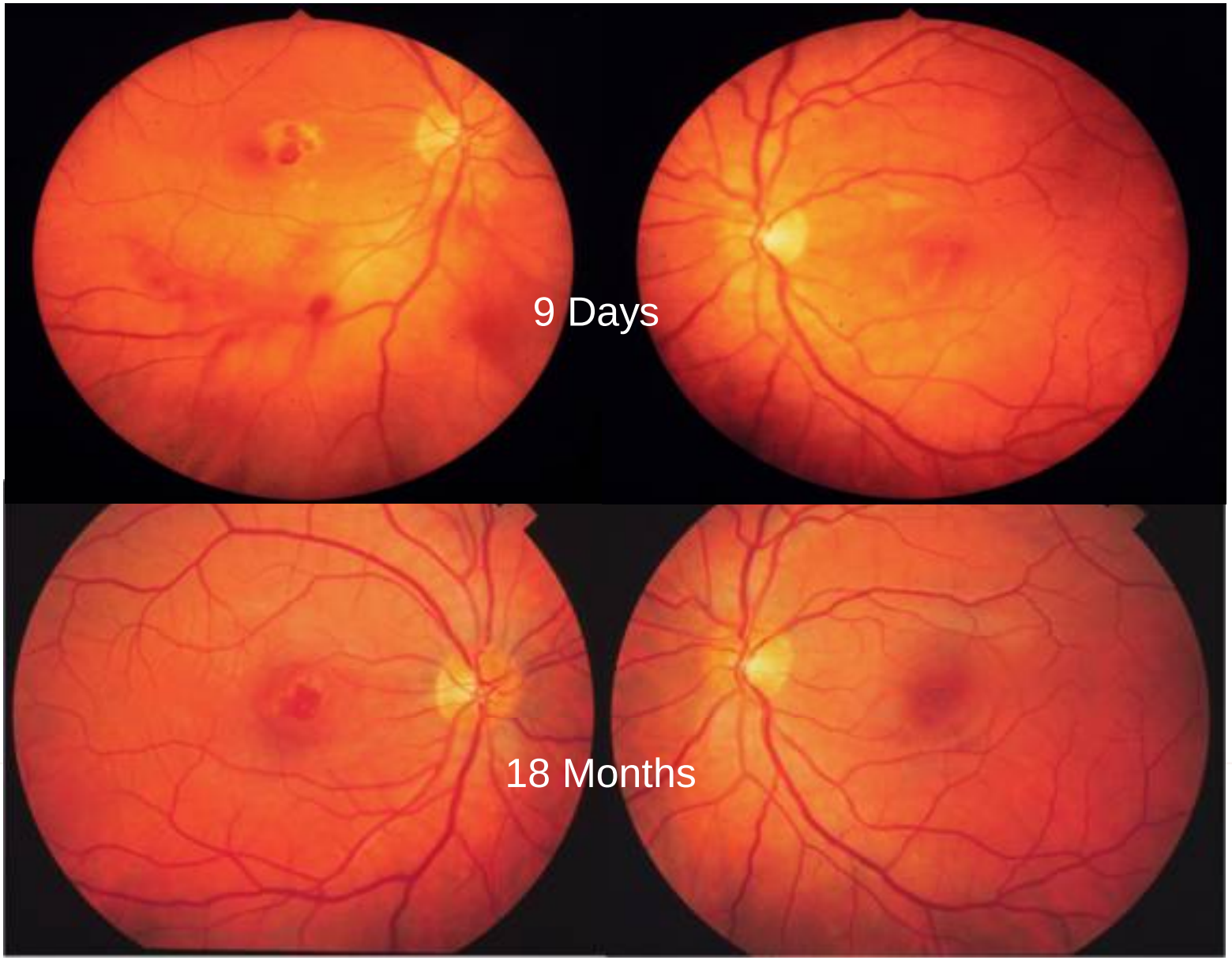
24 hours : OD-20/50; OS-20/200

18 months: OD-20/400; OS-20/17

Disposition: Disability compensation.



Case FC2



What about laser pointers?

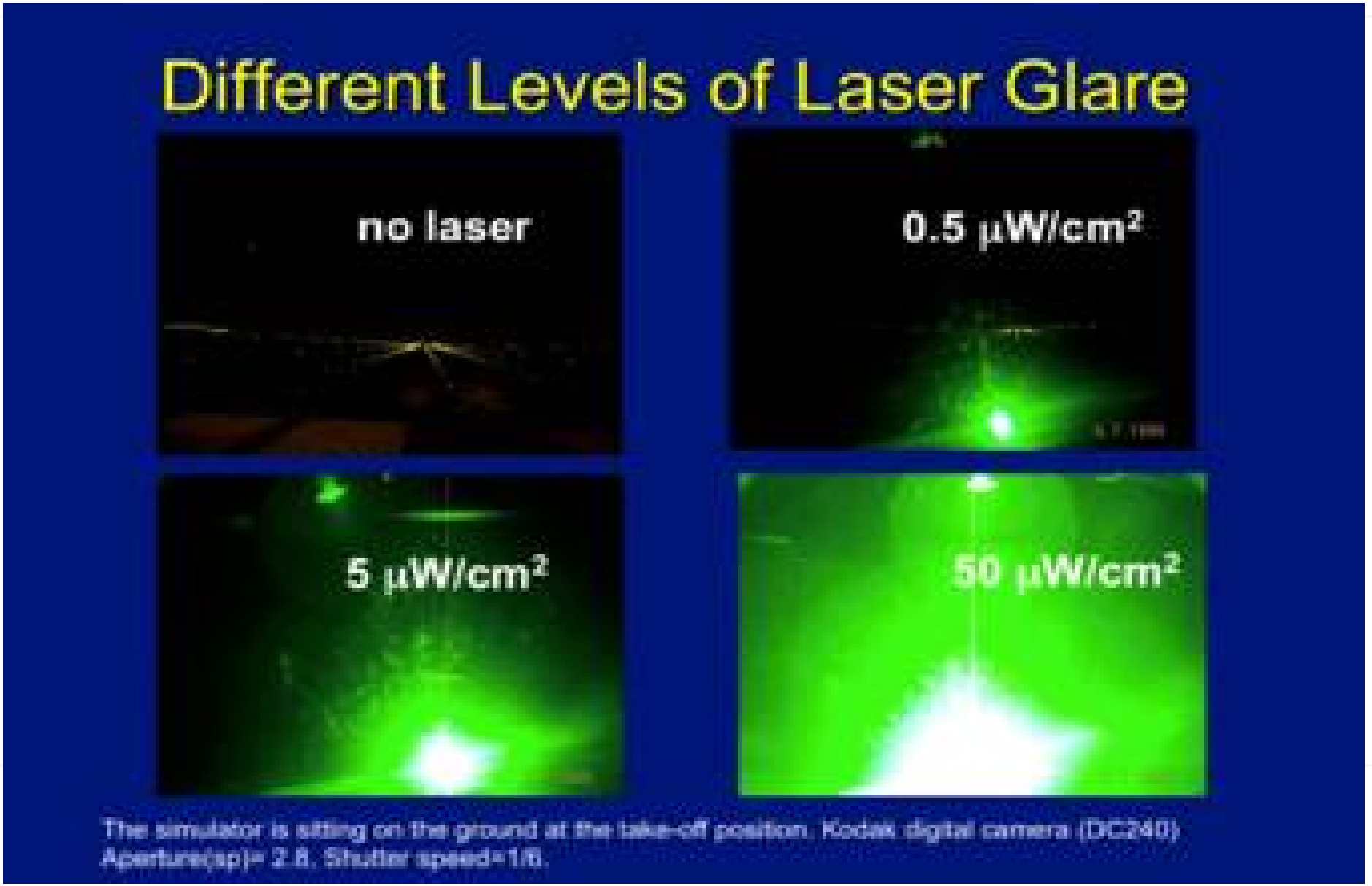
1 milliwatt
3 milliwatt
or ?

Thousands of aircraft illuminations each year in the U.S.

Few (if any?) laser-induced eye injuries.

Las Vegas Hotel Laser "Blinds" Southwest Pilot

- **Incident:** Southwest Airlines Flight departs McCarran International Airport near Las Vegas at 2012 hrs on October 30, 1995. About 3 miles into the flight while in an ascending right turn at an altitude of 3,000-4,000 feet, the pilot was exposed to a bright blue-green flash and experienced sudden, painless decrease in vision OD, requiring the other pilot to "grab the controls."
- **Pilot:** "When the laser hit my eye, time stopped for me. Of course, the airplane was still flying at 250 miles per hour. Had it hit me and the other pilot simultaneously, I shutter to think what would have happened."
- **Medical:** Pilot was evaluated at Brooks AFB on 7 November. There were no findings that could be associated with the exposure incident. Corrected visual acuities were 20/20 or better (OS, OD, OU, near & far).
- **Estimated Irradiance:** 10 - 100 $\mu watt/cm^2$ (MPE = 1000 $\mu watt/cm^2$ for 10 sec exposure)


Different Levels of Laser Glare
no laser
0.5 μW/cm²
5 μW/cm²
50 μW/cm²
The simulator is sitting on the ground at the take-off position. Kodak digital camera (DC240)
Aperture(sp)= 2.8. Shutter speed=1/6.

Laser Pointer Injury?

Yiu et al, 2014

Ocular Safety of Recreational Lasers
Yiu et al 2014

- Nine year old boy with bilateral vision loss
  - "Playing" with an adult who directed the handheld laser in his eyes
- Visual Acuity
  - Upon presentation: OD – 20/126, OS – 20/100
  - Two months: OD – 20/25; OS – 20/20
- Immediate vision loss.
- "Good" outcome at two months.
- D_x ?
- R_x ?
- What blue laser?

Recent Laser-Induced Eye Injury Literature

- Glenn Yiu, MD, PhD; Sujit Itty, MD; Cynthia A. Toth, MD. Ocular Safety of Recreational Lasers. *JAMA Ophthalmol*. January 9, 2014. - Duke University Medical Center, Durham, NC, USA
- Naz Raoof; T.K. Johnathon Chan; N.K. Rogers; W. Abdullah; I. Haq; S.P. Kelly; Fahd M. Quhill. **'Toy' laser macular burns in children.** *Eye (Lond)* 28(2):231-4, January 17, 2014. -Royal Hallamshire Hospital, Sheffield, South Yorkshire, UK
- Sulaiman M. Alsulaiman, MD; Abdulaziz A. Alrushood, MD; Jluwi Almasaud, MD; Sultan Alzaaidi, MD; Yahya Alzahrani, MD; J. Fernando Arevalo, MD; Nicola G. Ghazi, MD; Emad B. Abboud, MD; Swanson R. Nowilaty, MD; Mohammad Al-Amry, MD; Saba Al-Rashaed, MD. High-power handheld blue laser-induced maculopathy: The Results of King Khaled Eye Specialist Hospital Collaboarative Retina Study Group. *Ophthalmology* 121(2):556-572, February 2014 - King Khaled Eye Specialist Hospital, Riyadh, Saudia Arabia
- Gosling DB, O'Hagan JB, Quhill FM. Blue laser induced retinal injury in a commercial pilot at 1300 ft. Aerosp Med Hum Perform 2016:8:69-70, 2016.
- Marshall J., O'Hagan J., Tyrer J.R. Eye hazards of laser 'pointer' in perspective. Br J Ophthalmol 100(5) 854-585, 2016

Spyder III Pro Arctic Laser
Yiu et al 2014

Φ_e = 1250 mW

λ = 445 nm

Blue!

Cheap!

Web Videos:

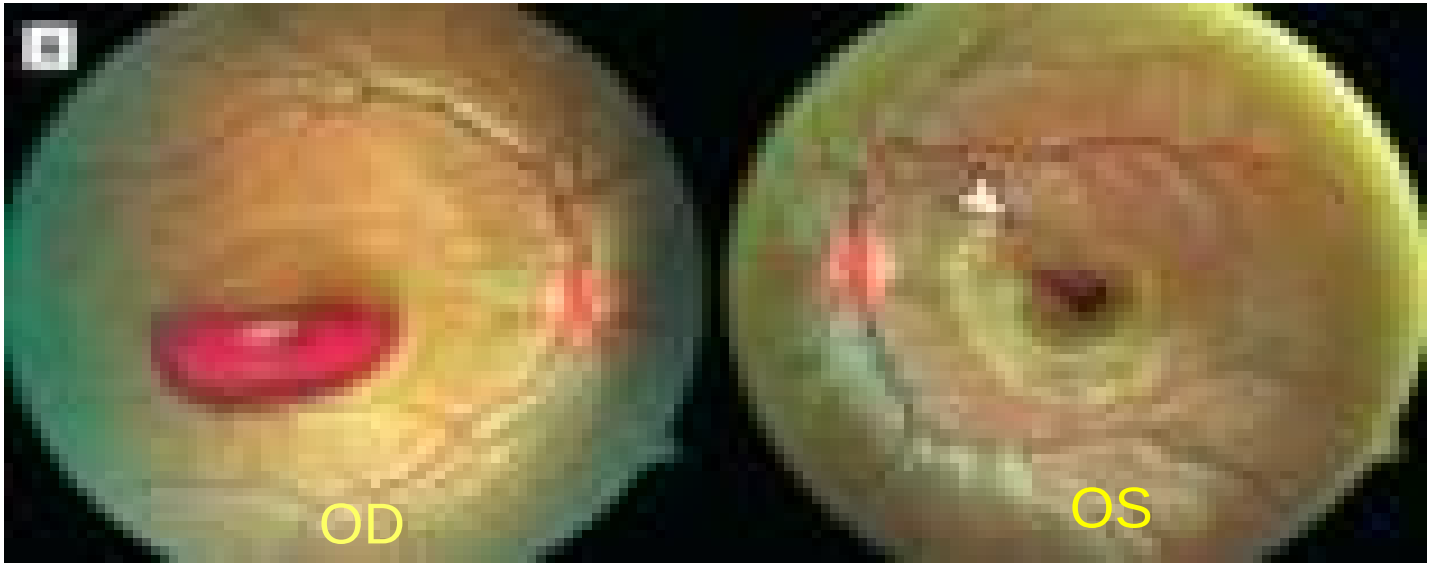
What's in the box?

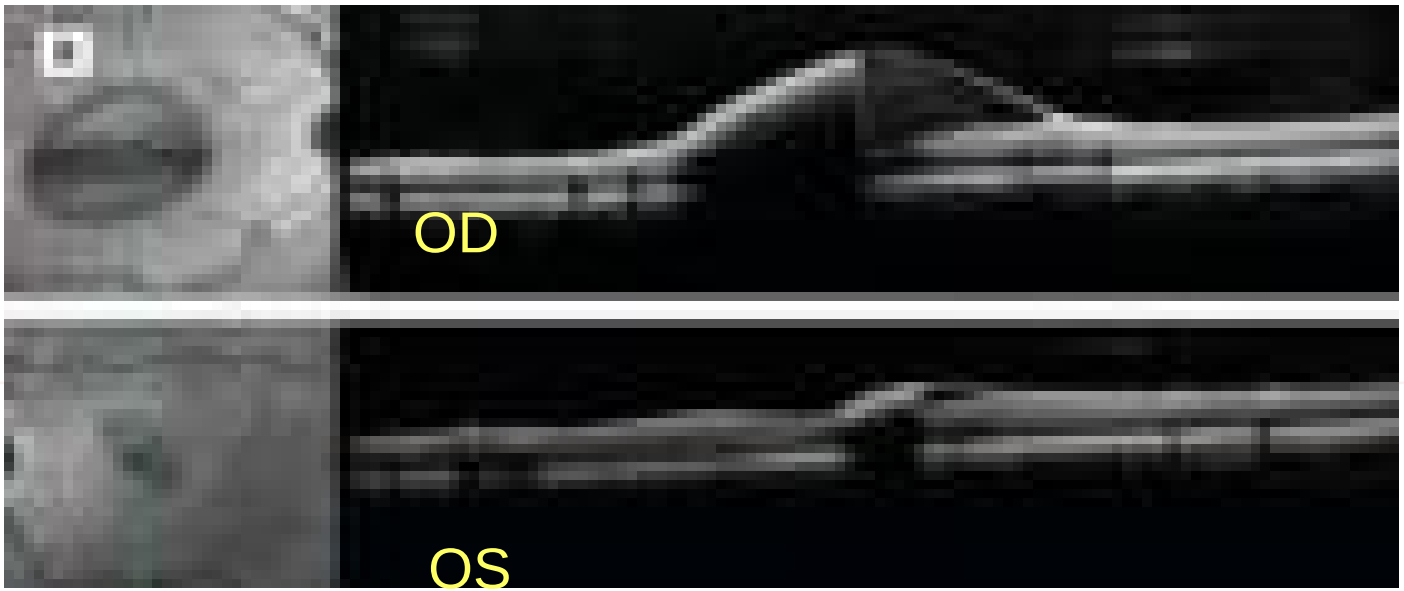
Lighting a match, incense, and a cigarette.

Burning black tape.

Appearance of beam in the dark sky!

Ocular Safety of Recreational Lasers
Yiu et al 2014 (Acute)





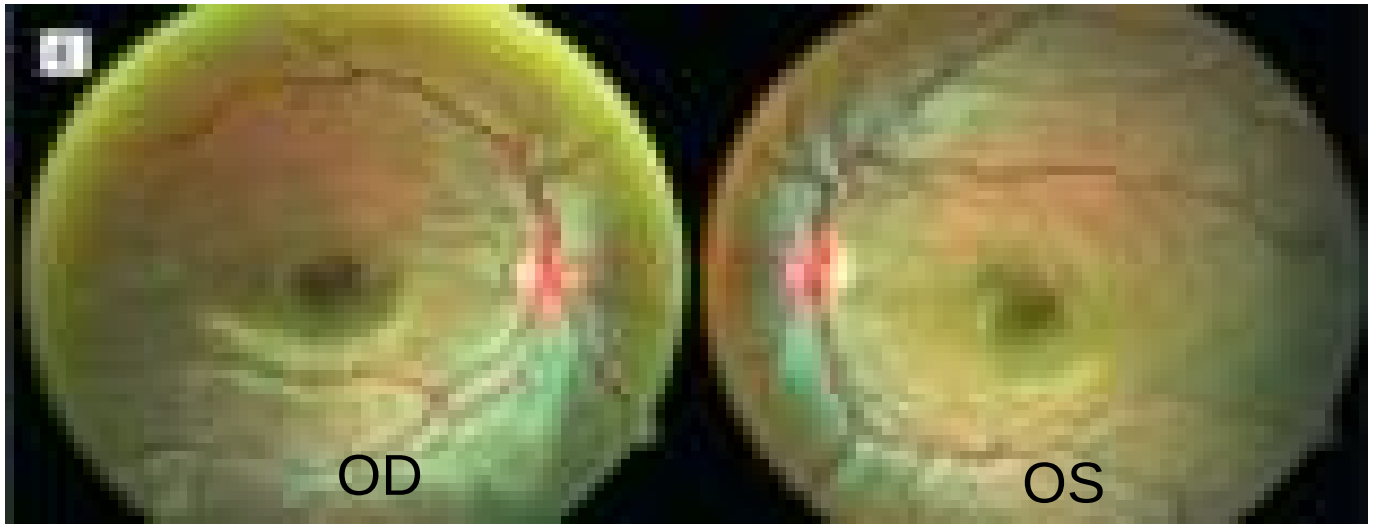
Visual Acuity

OD - 20/126

OS - 20/100

OCT Image

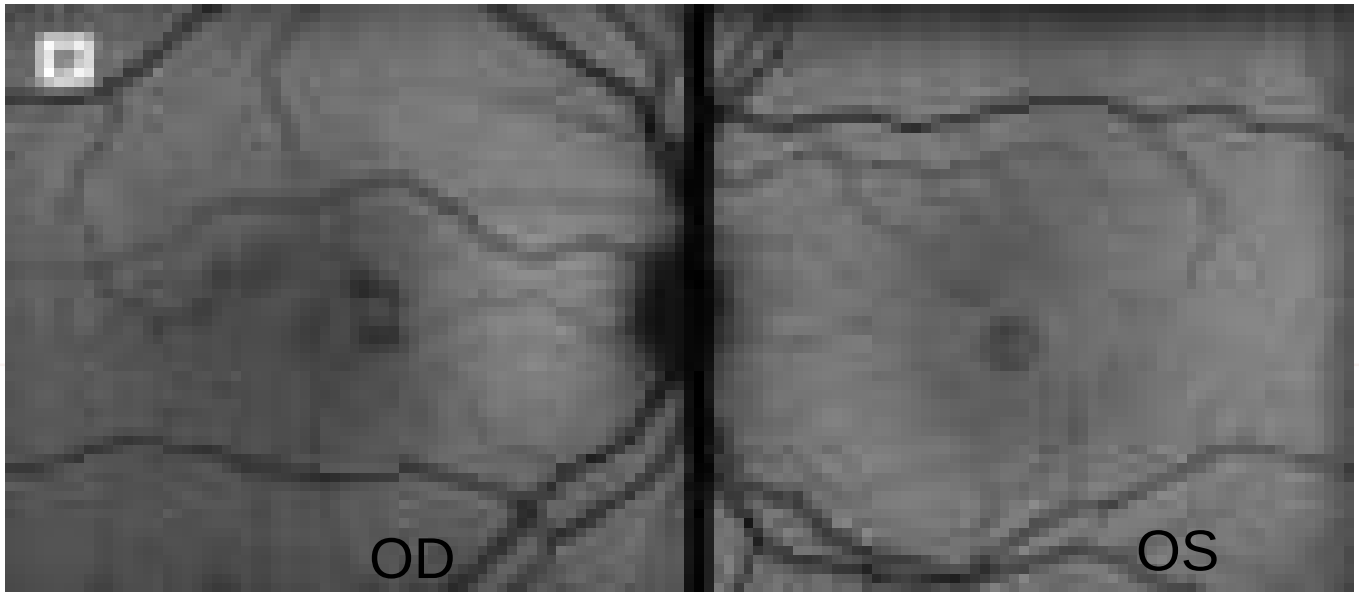
Yiu et al 2014 (2 months after exposure)



Visual Acuity

OD – 20/25

OS – 20/20



Auto Fluorescence (AF) Image

‘Toy’ laser macular burns in children
Raoof et al, 2014

- Report of Five (5) cases - all children - 9-15 years old
- Laser – limited to no detailed information
- Admission of exposure
- Vitelliform-like maculopathy -
- Authors Comments
  - Assessment of alleged laser eye injury requires accurate history and examination.
  - Treatment for such laser retinal injury is uncertain.
  - Oral corticosteroids are sometimes administered.

‘Toy’ laser macular burns in children

Raoof et al, 2014

- Case 1 - 9 yo boy with amplyopia (OD was ‘weak’ eye)
  - Baseline BCVA OS was 6/5 (20/16) - 3 days prior ’vision loss’
- Experienced 24 hours of “painless” vision loss in OS
  - Upon presentation, BCVA OS – 6/15 (20/50) with vitelliform-like maculpathy.
  - SD OCT showed outer retinal layer disruption (RPE) at the fovea in OS.
  - BCVA OD – 6/12 (20/40) and with no apparent pathology
  - Examination at 9 months – BCVA OS was 6/9.5 with SD OCT still showing disruption of outer retina in fovea
- Three lasers were given to the boy for Christmas. Lasers evaluated by the hospital’s Health Physics group:
    - Blue – 405 nm – 57 mW
    - Green – 532 nm – 42 mW
    - Red – 650 nm – 72 mW

High-power handheld blue laser-induced maculopathy

Alsulaiman et al, 2014

- Fourteen eyes of fourteen male patients – 11- 30 yo.
- Patients had a history of exposure to a blue laser (450 nm) with a “power range” from 150-1200 mW.
- All recognized the “blue laser” when shown a picture. Some brought the laser with them.
- Distance from output of laser to the eye – 0.5 to 6 meters
- One case of “self” exposure; the others cases were either purposeful or accidental exposure by others.
- BCVA at presentation ranged from 20/40 to 4/200.
- Four eyes had full thickness macular holes managed by surgical intervention. VA improved after hole surgery in all cases.
- Ending VA improved in all cases.

Alsulaiman et al, 2014

Table 1. Patient Characteristics, Interventions, and Outcomes

Patient No.	Age (yrs)	Interval between Exposure and Presentation	Approximate Distance (m)	Diagnosis	Initial Visual Acuity	Intervention	Last Follow-up after Intervention	Last Visual Acuity
1	17	1 week	2–3	Outer retinal disruption	20/40	None	4 wks[a]	20/20
2	30	2 months	≤0.5	FTMH	20/70	PPV + ILM peeling + SF_6 20%	8 wks	20/30
3	11	1 week	0.5–1	FTMH	20/800/PH 20/200	PPV + ILM peeling + silicone oil	10 wks	20/100
4	15	2 days	NA	FTMH	20/400	PPV + ILM peeling + SF_6 20%	7 wks	20/50
5	18	2 months	≤0.5	FTMH	20/200	PPV + ILM peeling + C_3F_8 15%	8 wks	20/40
6	15	3 days	1	Foveal sub-ILM hemorrhage	20/800	None	12 wks[a]	20/20
7	22	9 days	NA	Subhyaloid hemorrhage	4/200	Nd:YAG hyaloidotomy	6 wks	20/40
8	11	7 days	1–3	Subhyaloid hemorrhage	6/200	Attempted Nd:YAG hyaloidotomy	5 mos	20/25
9	18	2 hours	5–6	Subhyaloid hemorrhage	4/200	Nd:YAG hyaloidotomy	8 wks	20/25
10	20	6 days	0.5	Sub-ILM hemorrhage	20/200	None	3 wks	20/40
11	17	8 hours	1	Subhyaloid hemorrhage	5/200	Nd:YAG hyaloidotomy	6 wks	20/25
12	17	1 day	2	Subhyaloid hemorrhage	3/200	Attempted Nd:YAG hyaloidotomy	1 mos	20/70
13	18	2 months	1	ERM with SRF	20/200	PPV + ERM peeling + ILM peeling	5 mos	20/70
14	18	6 days	1–3	Schisis-like cavity with SRF	20/70	None	2 mos[a]	20/20

C_3F_8 = perfluoropropane; ERM = epiretinal membrane; FTMH = full-thickness macular hole; ILM = internal limiting membrane; NA = not available; Nd:YAG = neodymium:yttrium-aluminum-garnet; PH = pinhole; PPV = pars plana vitrectomy; SF_6 = sulfur hexafluoride; SRF = subretinal fluid.
[a]Last follow-up after presentation.

Diagnosis of Alleged Retinal Laser Injury

- Are there ocular abnormalities that could have been caused by a known laser-tissue interaction at the time of the reported incident?
- If “yes”: Have those abnormalities been documented by a reliable technique (fundus photo, fluorescein angiography, OCT)?
- If “yes”: Do findings from ophthalmoscopy and retinal imaging evolve after the incident in a manner consistent with a laser injury?
- If “yes”: If substantial somatic or visual complaints are present, is there any scientific evidence that objective ocular findings could cause the reported subjective complaints?
- If “yes”: If substantial visual complaints are present, is the location of Amsler grid or visual field defects stable and consistent with the location of the retinal abnormalities supposedly responsible?
- If the laser source involved in the alleged injury is available or known, is it capable of producing the observed clinical findings under the reported exposure conditions?

Mainster, Stuck and Brown, Arch Ophthalmol 122, August 2004

Laser Pointer Summary

- With proper use, Class 3R laser pointers will not cause eye injury
- For accidental exposure, exposure to a specific retinal area is limited by:
  - Head and eye movements - primarily
  - Inability to target the pupil
  - Pupillary constriction – reflexive
  - Blink/squint response
- Unintentional exposure to a Class 3R laser pointer will not cause eye injury
- Deliberate or forced exposure for periods of several seconds could result in eye injury and must be avoided.
- Brief exposures during vision critical tasks can be very disruptive and result in accidents
- Easily purchased Class 3B and Class 4 have produced eye injuries in a few milliseconds at close range.

Summary

- ICNIRP optical radiation guidelines are supported by a robust laser bioeffects data base
- Thousands of aircraft illuminations annually but few eye injuries - training and reporting
- High power blue and green lasers from the internet have resulted in eye injuries to your folks
- Exposures resulting in injury exceed the ICNIRP ELs.
- Few laser accident cases
- No apparent long term effects

Blue Light Reading

- David J. Lund, Peter Edsall, Bruce E. Stuck. Ocular Hazards of Q-switched Blue Wavelength Lasers. IN: Proceeding of the SPIE 4621: 44-53, 2001
- David J. Lund, Peter Edsall, Bruce E. Stuck. Wavelength Dependence of Laser-Induced Retinal Injury. IN: Proceedings of the SPIE 5688:383-393, 2005
- David J. Lund, Bruce E. Stuck, Peter Edsall. Retinal Injury Thresholds for Blue Wavelength Lasers. Health Physics 90(5):477 – 484, 2006
- David J. Lund, Peter Edsall, Bruce E. Stuck, Karl Schulmeister. Variation of laser-induced retinal injury thresholds with retinal irradiated area: 0.1duration,514.5 nm exposures. J. Biomed Optcs 12(2):024023-1-7, 2007
- Daniel G. Odom, David J. Lund, Steven T. Schuschereba. Histopathology of Suprathreshold Retinal Lesions Produced by the Alexandrite Laser. Lsrs Life Sci 2(2):113-124, 1988