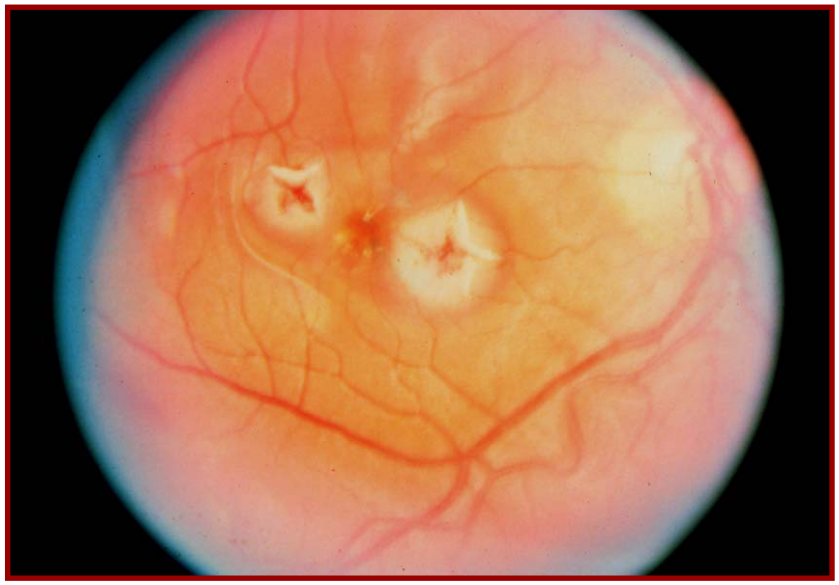
Accidental Laser-Induced Eye Injuries



Bruce E. Stuck

ICNIRP Member

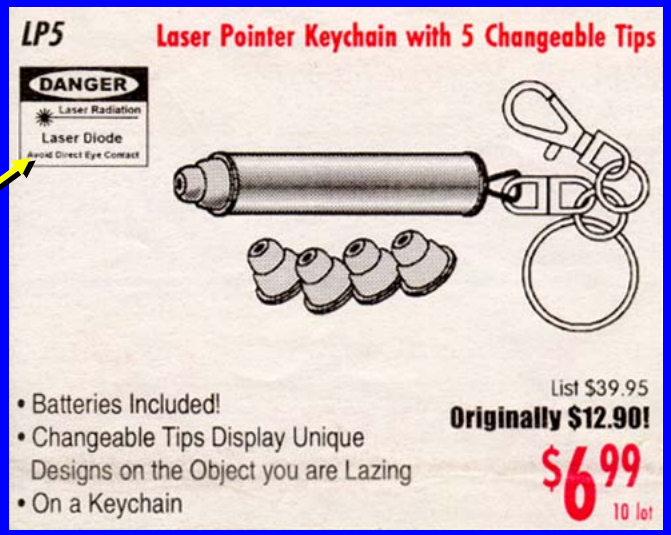
U.S. Army Medical Department

(Recently retired!)

San Antonio, TX, USA

Laser Pointers .....CHEAP!!!

Avoid Direct Eye Contact



Laser Illuminations

- Ocular exposure to laser radiation **with** injury
  - Relatively low number of cases
  - Usually involves misuse
  - Outcome varies – from permanent severe visual dysfunction to nearly complete recovery
- Ocular exposure to laser radiation **without** injury
  - Large number of incidents
    - Commercial airline illumination
    - Sporting events
  - Potentially serious consequences
  - “The bright light experience”
  - Potentially miss diagnosed – R_x ?

Factors affecting Laser Dazzle (Glare/Flash) and Laser-Induced Retinal Injury

- Energy/Power through the pupil
- Pupil diameter (dynamic)
- Wavelength
- Exposure duration (on any given retinal site)
- Retinal irradiance diameter (spot size)
- Adaptation state of eye
- Aversion response
  - Eye and head movement
  - Pupilary constriction
  - Source movement
  - Blink

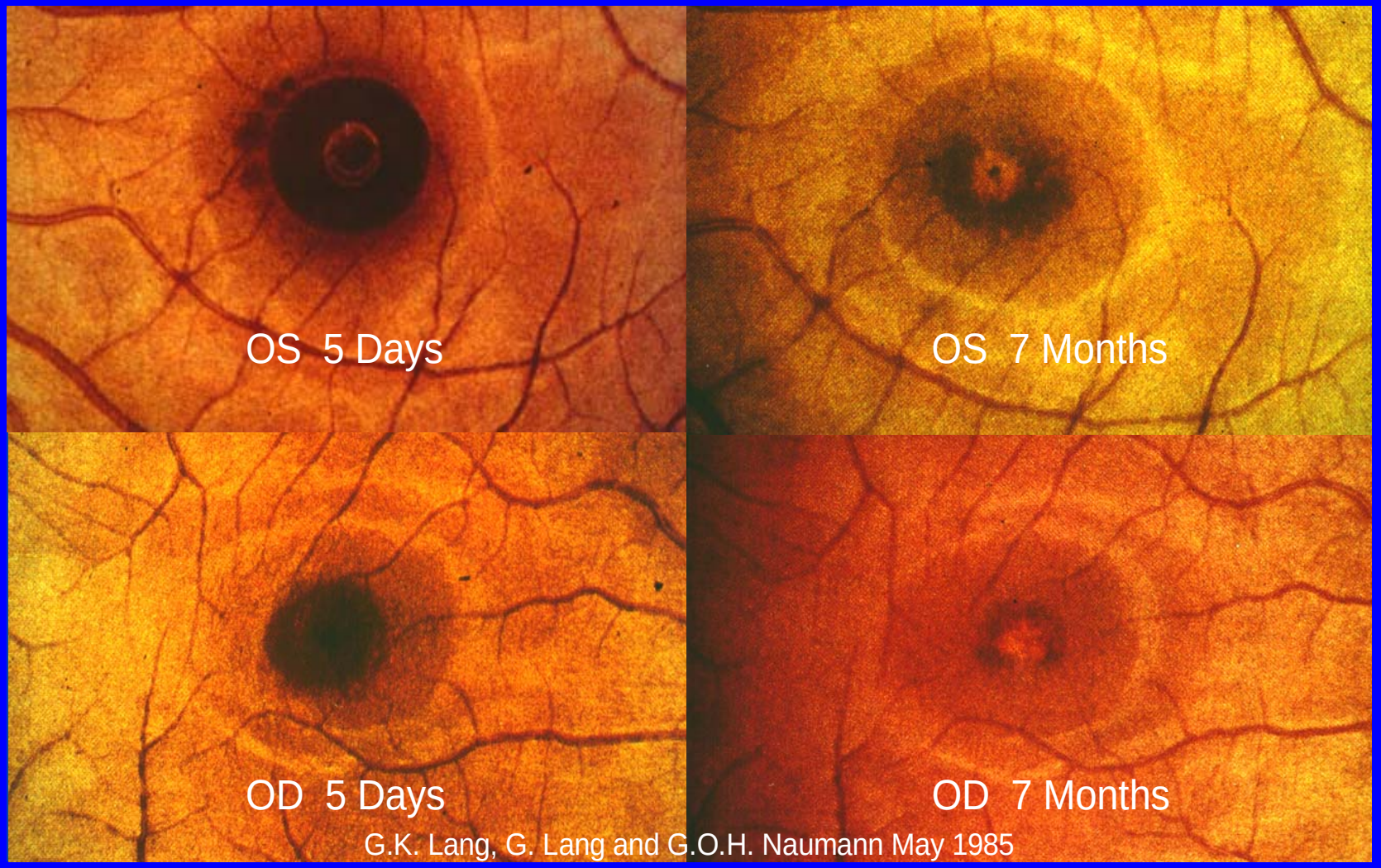
Ocular exposure to laser radiation **with** injury

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 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". (Nd:YAG Laser at 1064 nm, 10 nsec pulse, Estimated, Total Intraocular Energy – 6 mJ)

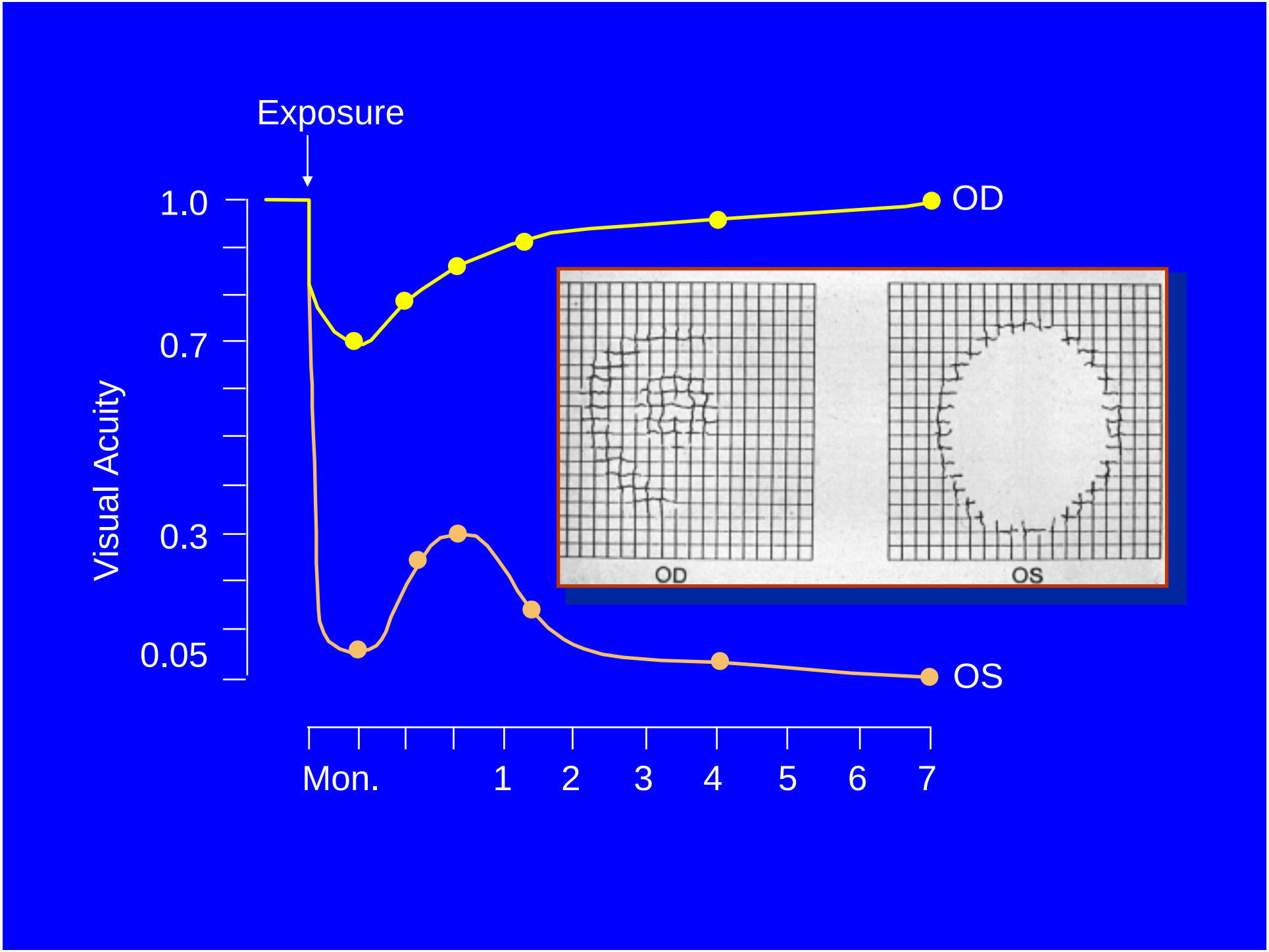
Laser Focus, April 1982

Accidental Bilateral Asymmetric Maculopathy Caused by Ruby Laser

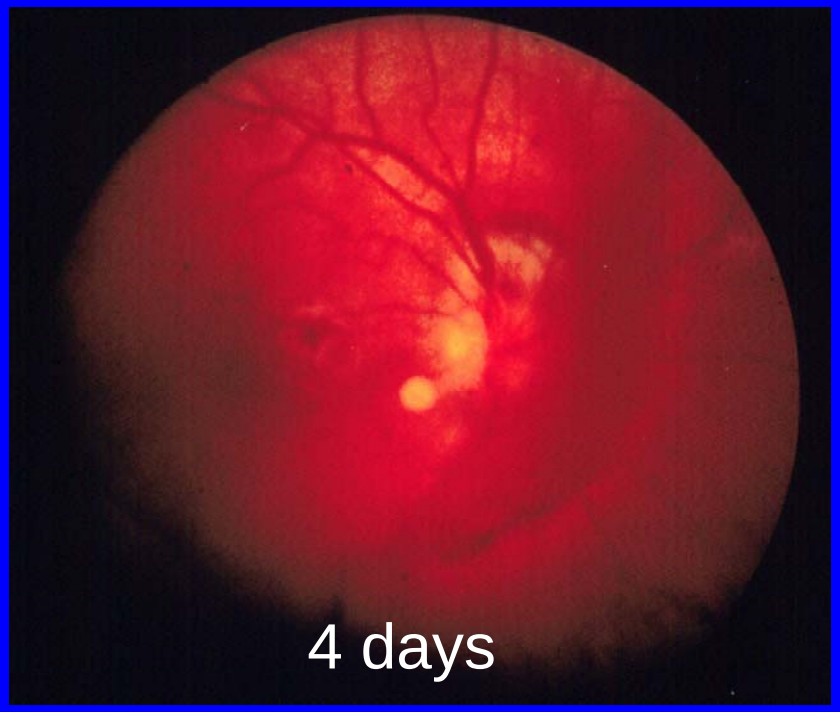


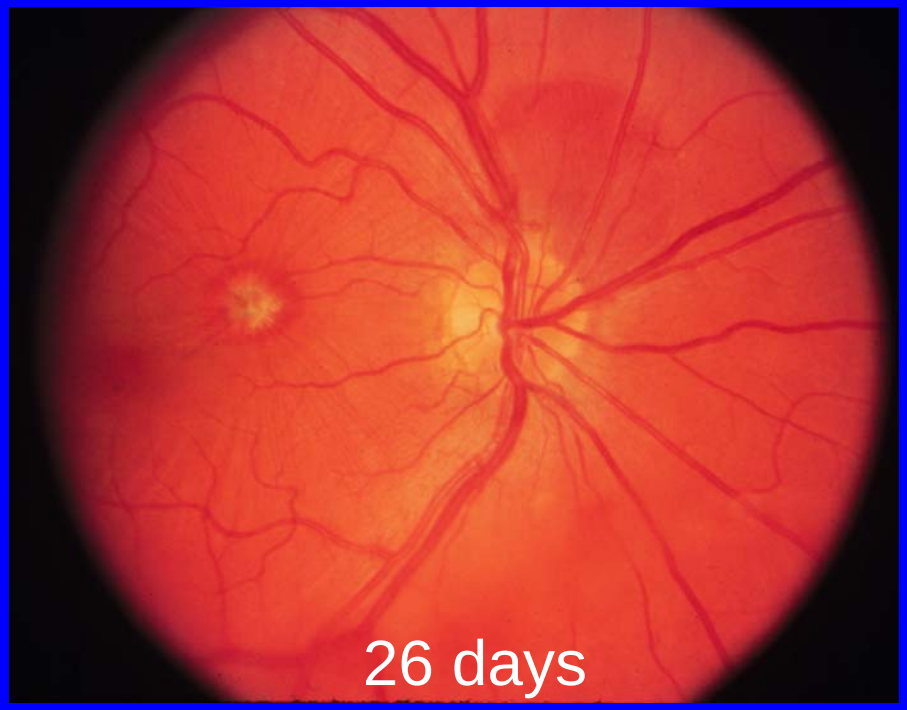
G.K. Lang, G. Lang and G.O.H. Naumann May 1985

Slides courtesy of Professor Naumann


Exposure
1.0
0.7
0.3
0.05
Visual Acuity
OD
OS
OD
OS
Mon.
1
2
3
4
5
6
7

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





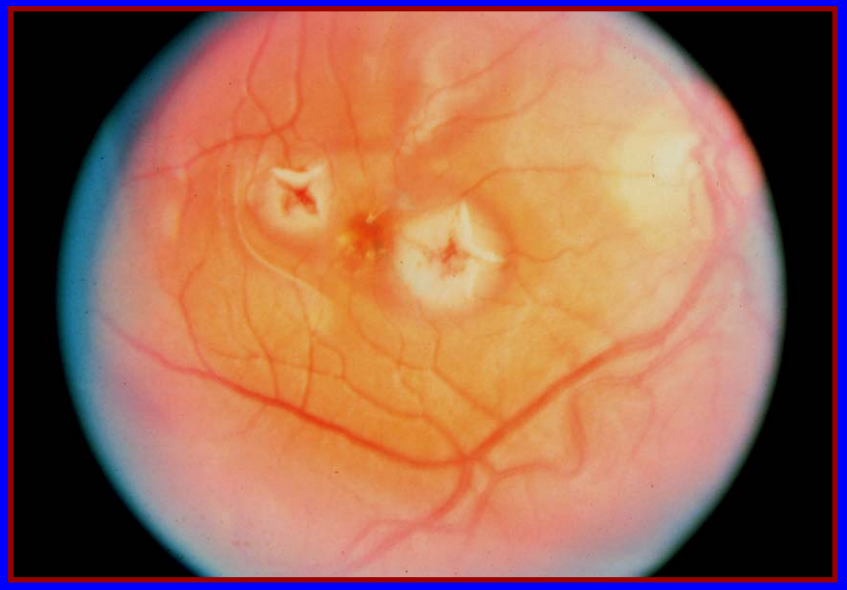
Visual Acuity: CF to 20/400

Visual Acuity: 20/40

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

AJA

ANGVS-5 Laser Rangefinder Accident



FOUR DAYS

TWO MONTHS

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

Case 1 (AP)

Situational Assessment: A fire-control technician, performing a maintenance procedure on a Ground Laser Locator Designator (GLLD) in an indoor test facility, momentarily looked into the exit aperture of the GLLD while activating the laser. The technician reported "seeing two or three yellowish flashes" and immediately sought medical assistance. The size of the exit aperture shown with respect to the separation of the eyes permitted simultaneous bilateral exposure (right photo). The pupil diameter was estimated to be 4 mm for the indoor test environment.

Treatment: A steroid treatment regimen was initiated six hours after the exposure. An initial dose of 80 mg methylpred-nisolone sodium succinate (Solu-Medrol$_{tm}$) was administered intravenously (IV) over a 30 minute period. This was followed by 250 mg every 6 hours (Q6) for the next 72 hours. The dose was tapered over the next two weeks from 80 mg (Q6) to 40 mg (Q6).

Measured Emission Characteristics and Dose Estimates

GLLD = Neodymium YAG Laser — Wavelength = 1064 nm

Emission duration = 30 ns — Pulse Repetition Frequency = 10 pps

Energy per pulse = 75 mJ; — Exit aperture diameter = 10 cm

*Average radiant exposure = 1 mJ/cm^2 — **TIE = 0.125 mJ

Peak radiant exposure = 2.5 mJ/cm^2 — TIE$_{max}$ = 0.315 mJ

ED_{50} for single pulse minimally visible lesion — TIE = 0.100 mJ

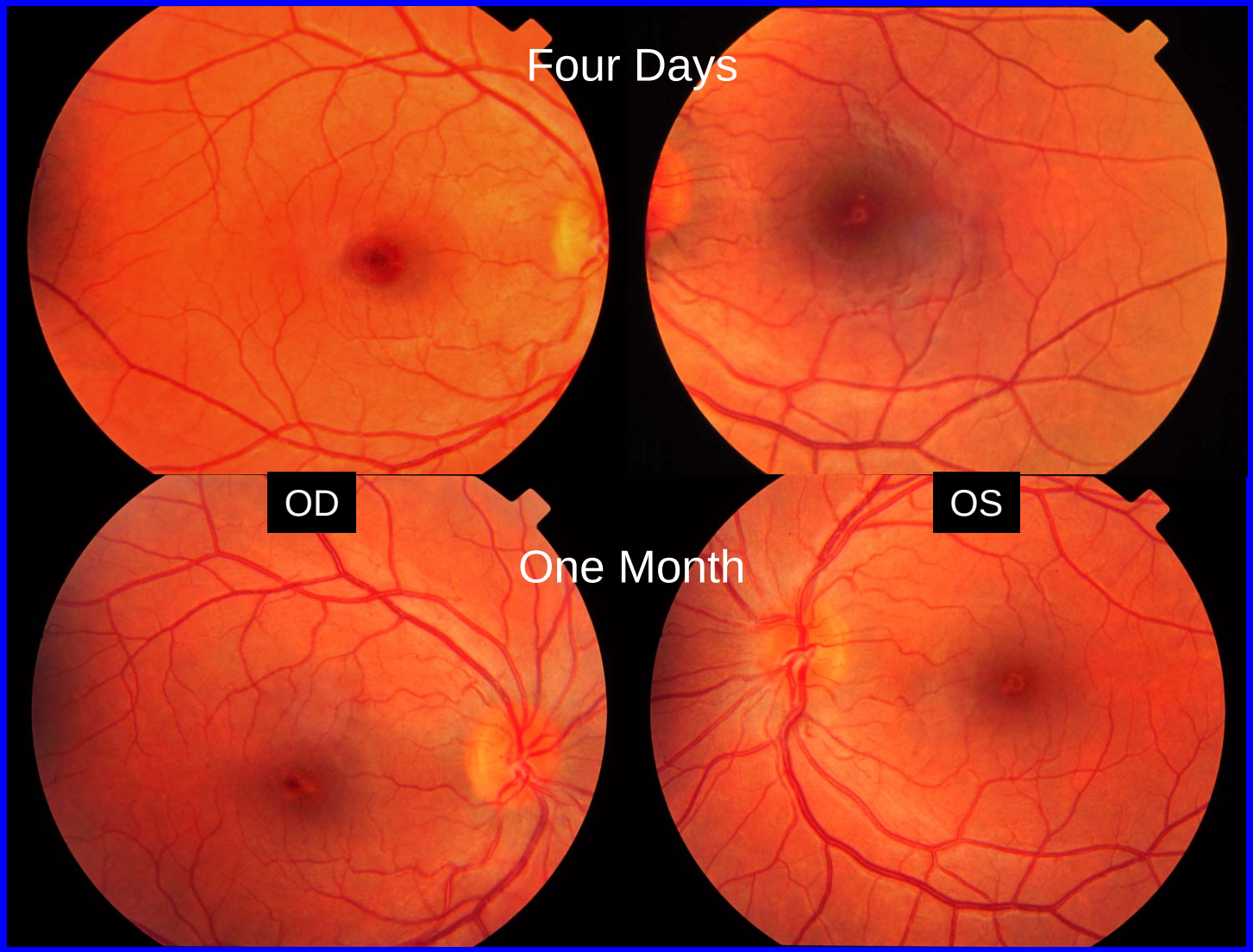
ED_{50} for single pulse vitreous hemorrhage — TIE = 1.0 mJ

ED_{50} for 3 pulses at 10 pps (MVL) — TIE = 0.076 mJ/pulse

*Average radiant exposure = emitted energy per pulse divided by area of exit aperture

**TIE = Total Intraocular Energy through a 4 mm pupillary aperture

Case I



AP

Case 2 (FC)

Situational Assessment: A 21 year old Marine received 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).

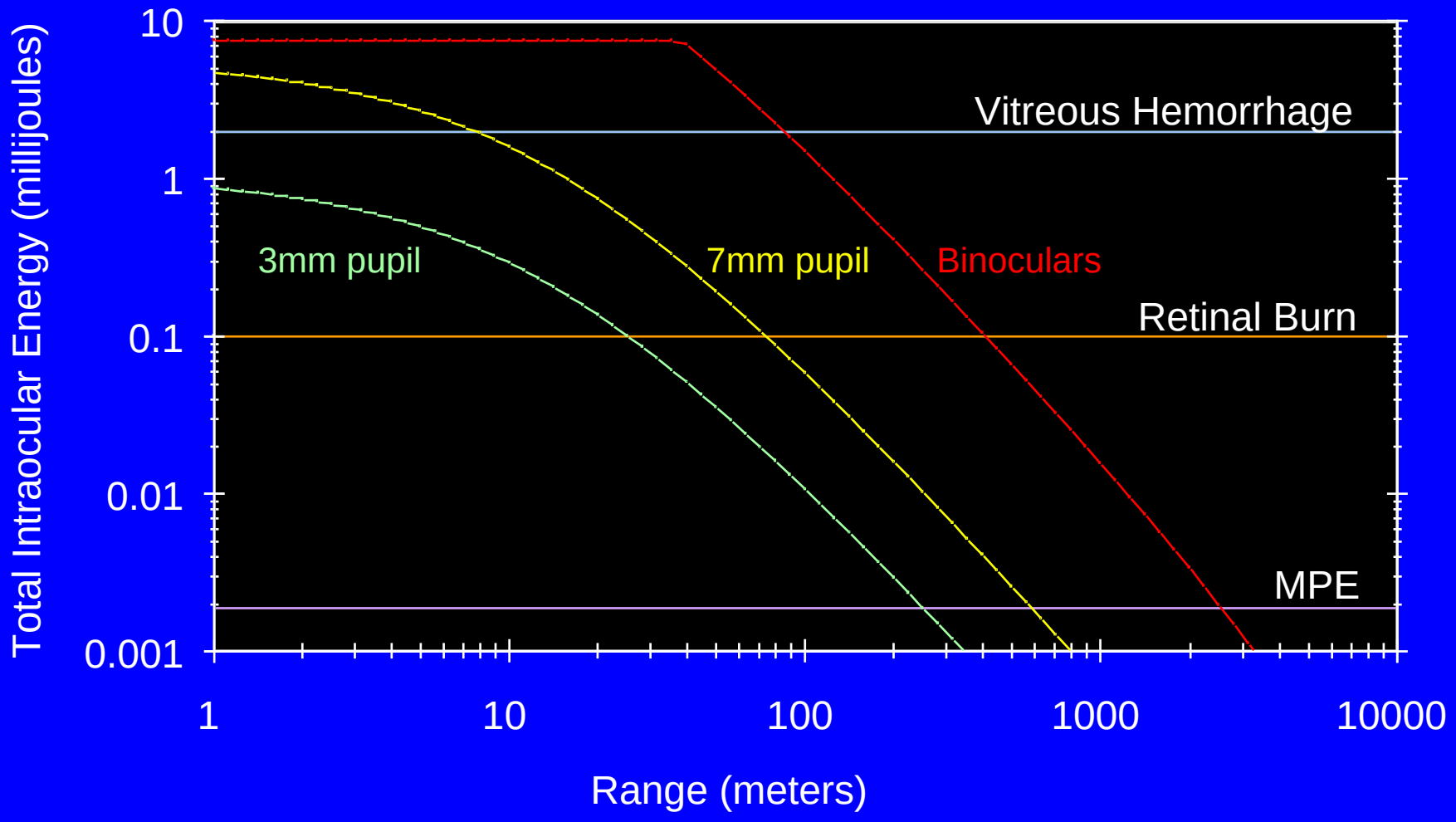
Visual Acuity: (See adjacent panel)

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

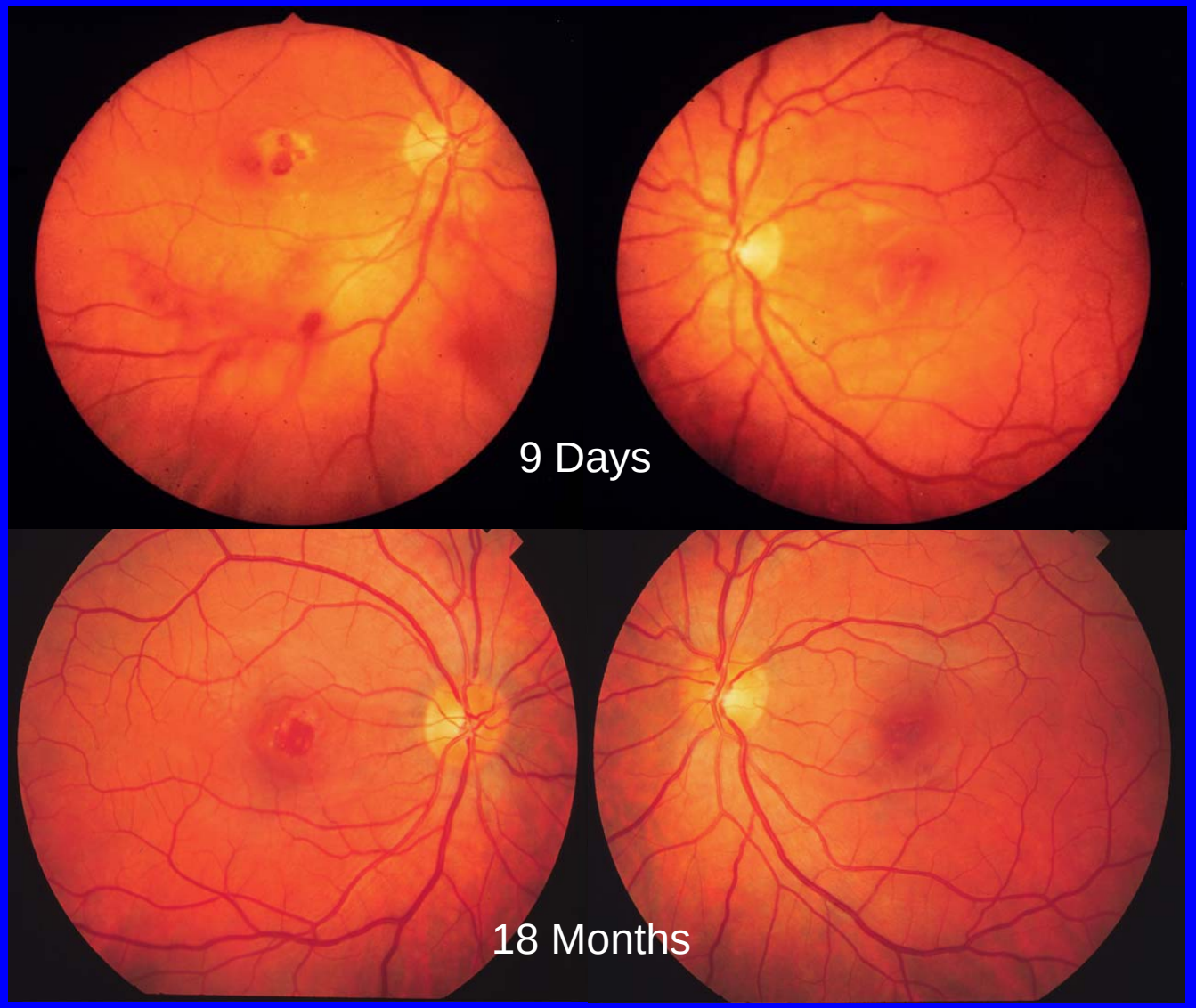
18 months: OD-20/400; OS-20/17

Disposition: Medical board and disability compensation.

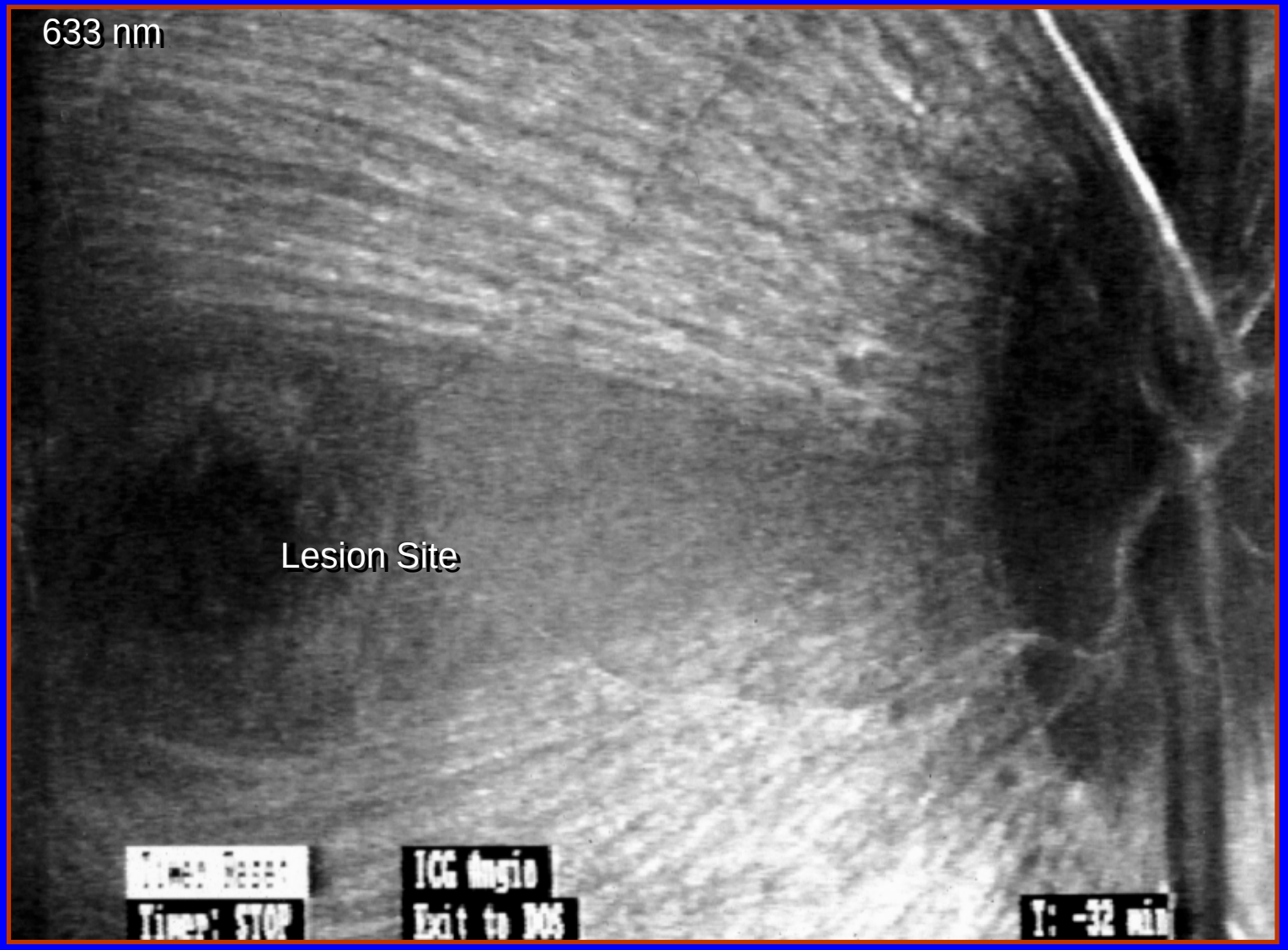
ANGVS5 Laser Rangefinder

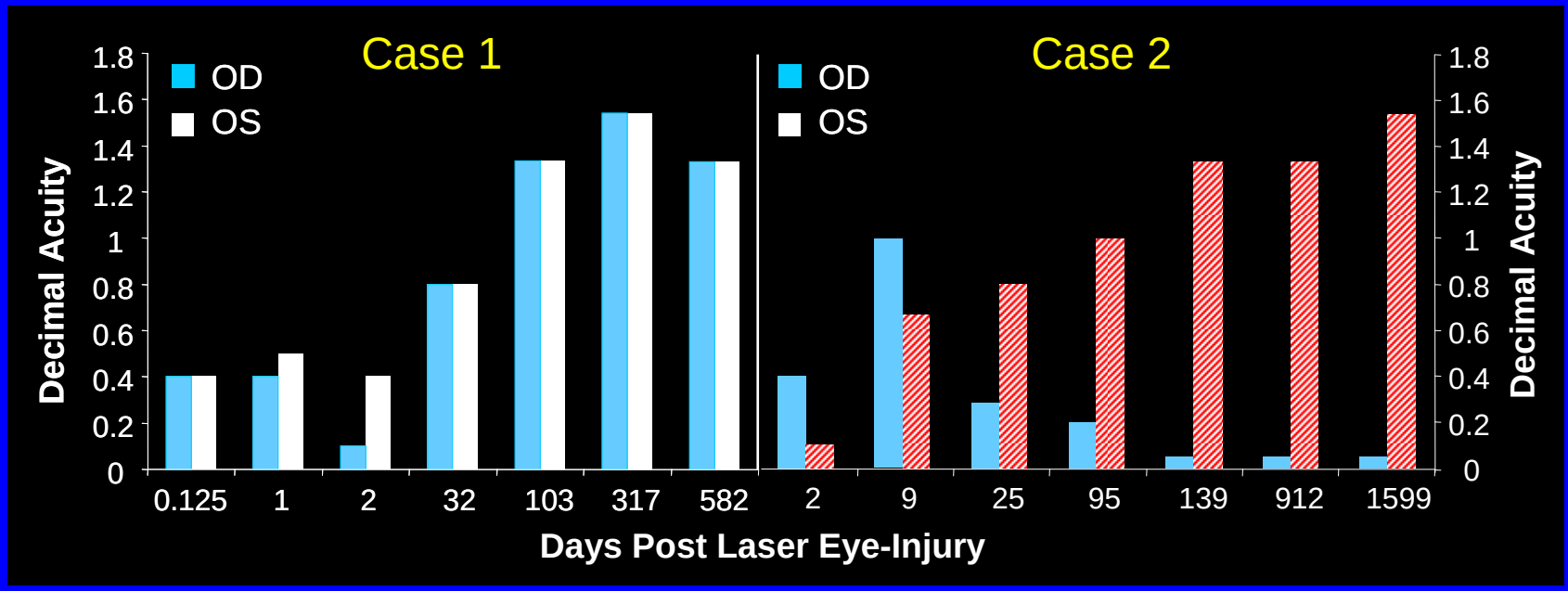


Case 2



FC


633 nm
Lesion Site
ICG Angio



Snellen Visual Acuity: The time course of Snellen visual acuity (VA) changes in Case 1 and Case 2. In Case 1, VA OD was minimal on day 2 which was consistent with the 4 deg. (approx.) dense circular scotoma reported on the Amsler grid. In Case 1 OS, only a relative scotoma was reported with the Amsler grid. Acuity improved in both eyes as the Amsler grid abnormalities diminished. In Case 2, VA OD initially was better than OS (2 and 9 days). A dense 3 deg. scotoma was reported just temporal to fixation. VA OD diminished when the retinal hole encroached on the fovea. VA OD remained at 20/400 or worse after the retinal hole surgery. VA OS improved to 20/15 with a superior temporal PRL (see adjacent panel).

Summary Case 1 and Case 2

- Case 1
  - Bilateral injury to the macula
  - Rx within 6 hours – Steroid Pack
  - VA – Recovery to 20/15 (OU)
  - Amsler Grid – persistent defect observable
- Case 2
  - Bilateral injury
  - OD – retinal hole stabilization @ 18 months
  - VA OD < 20/400
  - OS – recovery to 20/15 – Amsler grid defect

Laser-induced Eye Injury

- A 19 year old emmetropic male military weather observer/forecaster was “curious to see the light” from a laser rangefinder and exposed the macula of his right eye (OD) at 1700 hours on 18 March to the emission from the LRR-104 neodymium laser rangefinder
- Visual field (OD) went “blank or dark” for a “few minutes” but vision started returning after 5 minutes - decided not to tell anyone and see if his vision “cleared.” OS was normal.
- Finished his shift at 2300 hrs and drove 20 miles back to base - noting a dark central scotoma with “black floaters” in OD
- Decided to “sleep on it” to see if his vision would recover
- Sought medical assistance the next morning: VA OD = 20/150 with vitreous hemorrhage and retinal hole; VA OS -WNL; No R_X
- VA OD-20/70 (June) with central scotoma and unstable class IV, $\approx$ 100 μm retinal hole.

LRR-104 Mark IV
Neodymium Laser Rangefinder

1064 nm; 7.7 mJ; 12 ns;

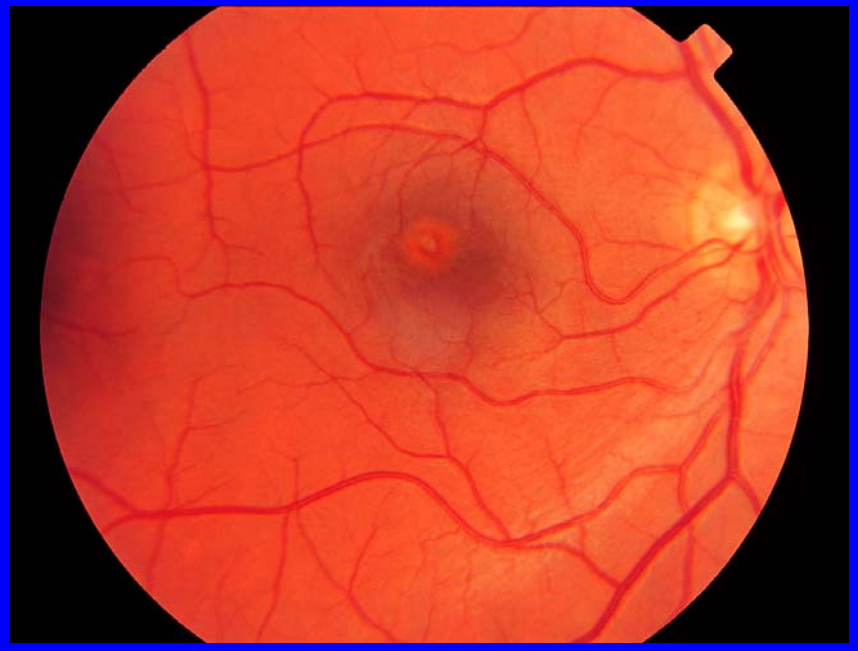
0.65 mrad (1/e), 2.0 mm (1/e)

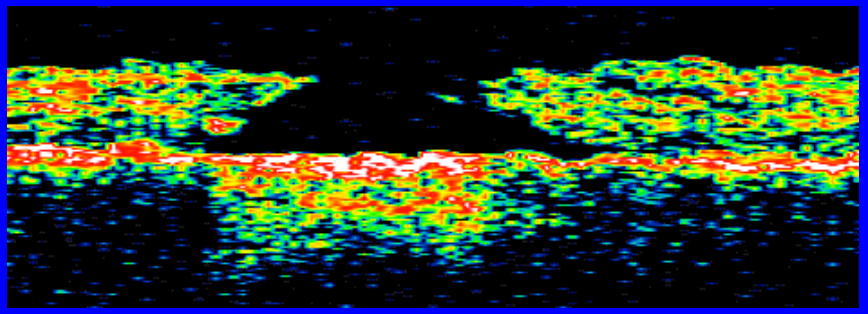
Neodymium Laser Rangefinder Exposure Incident

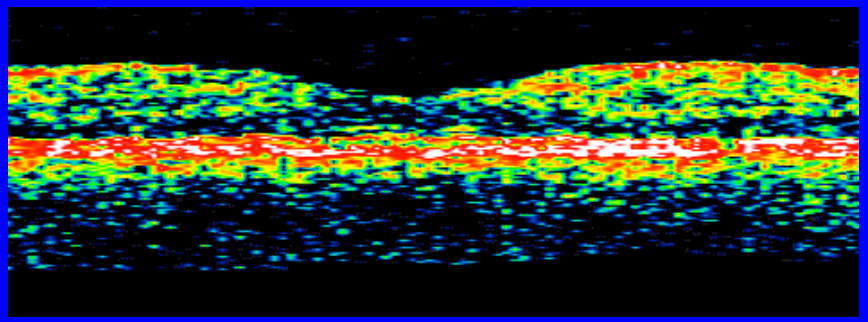
Fundus photograph of the laser-induced retinal hole in fovea of the right eye at 2.5 months post exposure

Optical Coherence Tomography (OCT) showing the retinal hole (right, upper). OCT of normal fovea (right, lower)

Visual Acuity = 20/70 with central scotoma







DS

Ocular exposure to laser radiation **without** injury

Las Vegas Hotel Laser "Blinds" Southwest Pilot

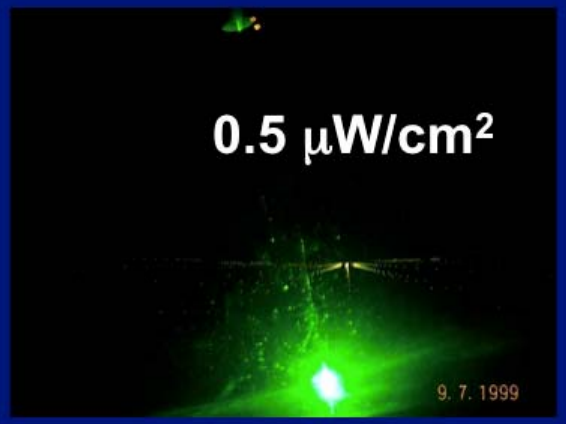
- **Incident:** Southwest Airlines Flight departs McCarran International Airport near Las Vegas at 2012 hrs on October 30, 1995. About 3 miles into the flight while in an ascending right turn at an altitude of 3,000-4,000 feet, the pilot was exposed to a bright blue-green flash and experienced sudden, 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)

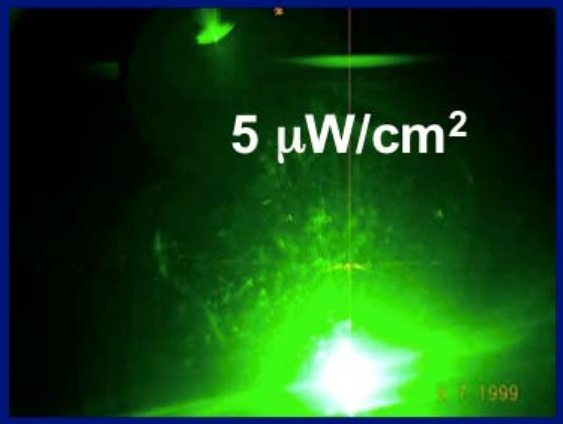
Southwest Airlines Laser Glare Incident

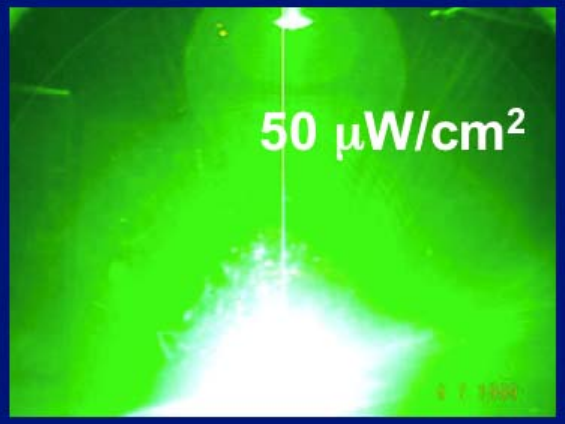
- After viewing the "bright green light, the pilot reported that his inability to see lasted 30 seconds and for an additional 2 minutes, he could not focus on or interpret any instrument indications and was completely disoriented in his spatial relationship to the vertical.
- "Yet, I must stress that the confusion and incapacitation resulting from a laser beam cannot be imagined or anticipated. It is instantaneous and it is dangerous.

Comment:
- Psychological effect
- Operational impact for military scenario
- Report to the Flight Surgeon

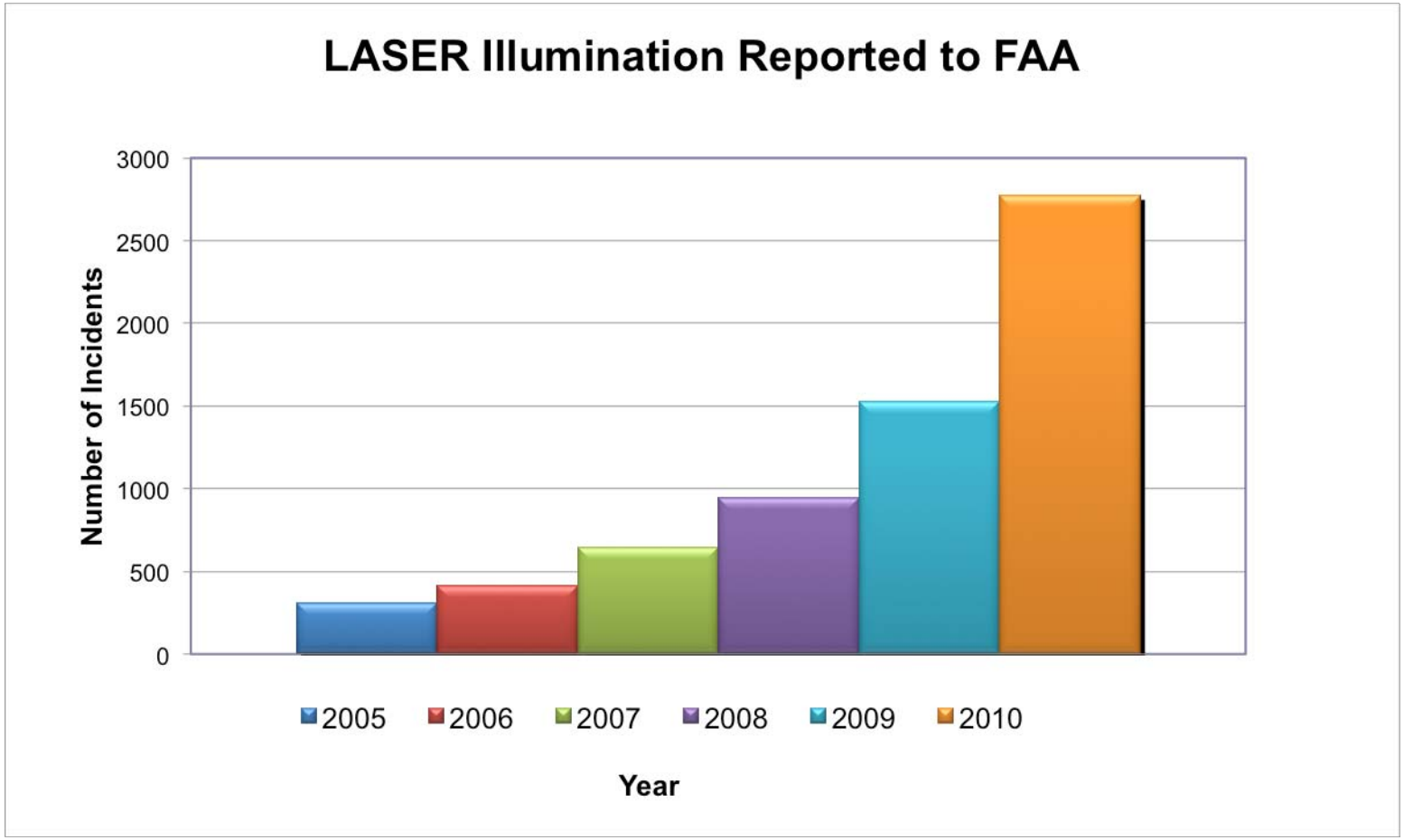
Different Levels of Laser Glare

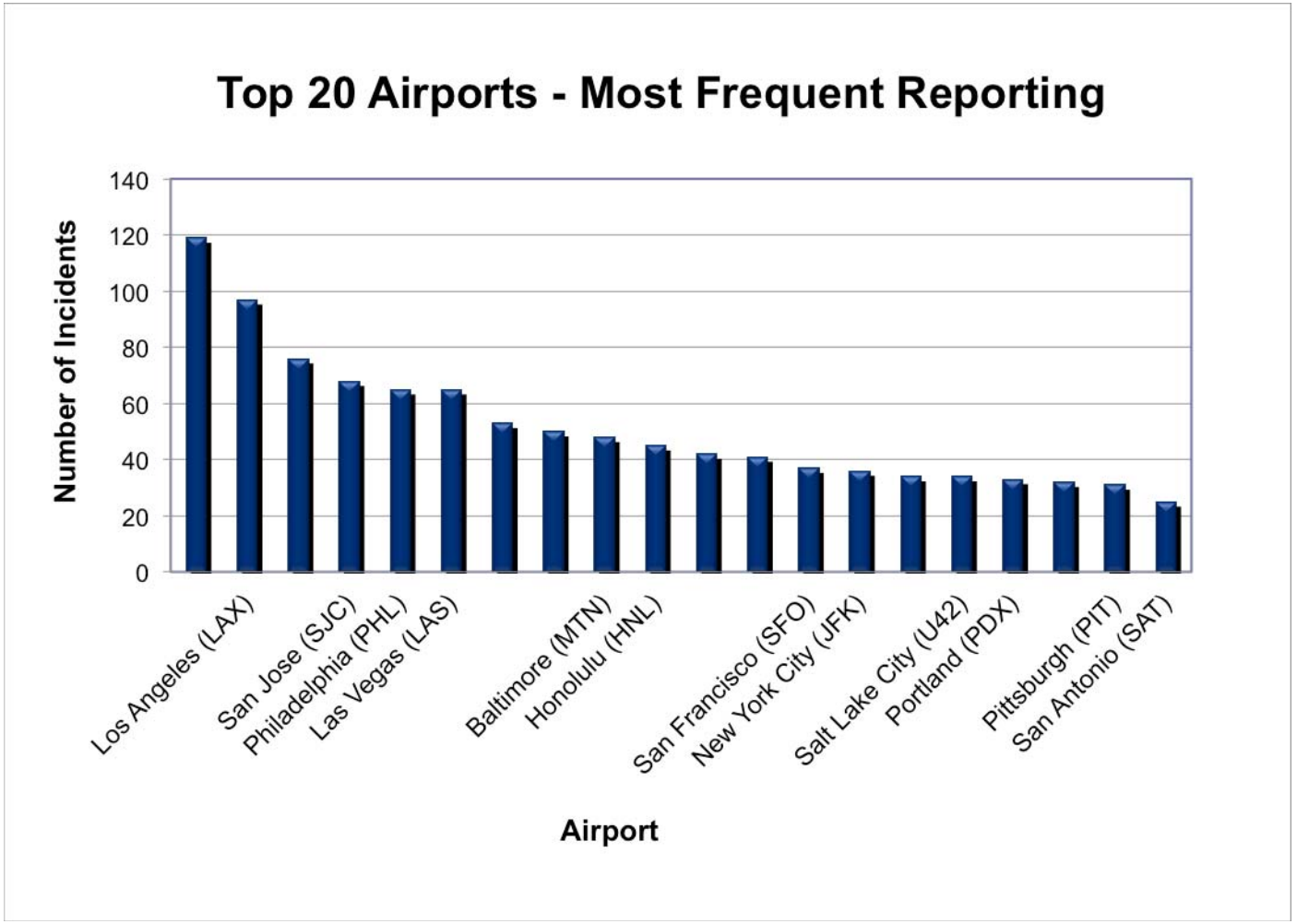






The simulator is sitting on the ground at the take-off position. Kodak digital camera (DC240)
Aperture(sp)= 2.8, Shutter speed=1/6.


LASER Illumination Reported to FAA
Number of Incidents
3000
2500
2000
1500
1000
500
0
2005
2006
2007
2008
2009
2010
Year


Top 20 Airports - Most Frequent Reporting
Number of Incidents
140
120
100
80
60
40
20
0
Los Angeles (LAX)
San Jose (SJC)
Philadelphia (PHL)
Las Vegas (LAS)
Baltimore (MTN)
Honolulu (HNL)
San Francisco (SFO)
New York City (JFK)
Salt Lake City (U42)
Portland (PDX)
Pittsburgh (PIT)
San Antonio (SAT)
Airport

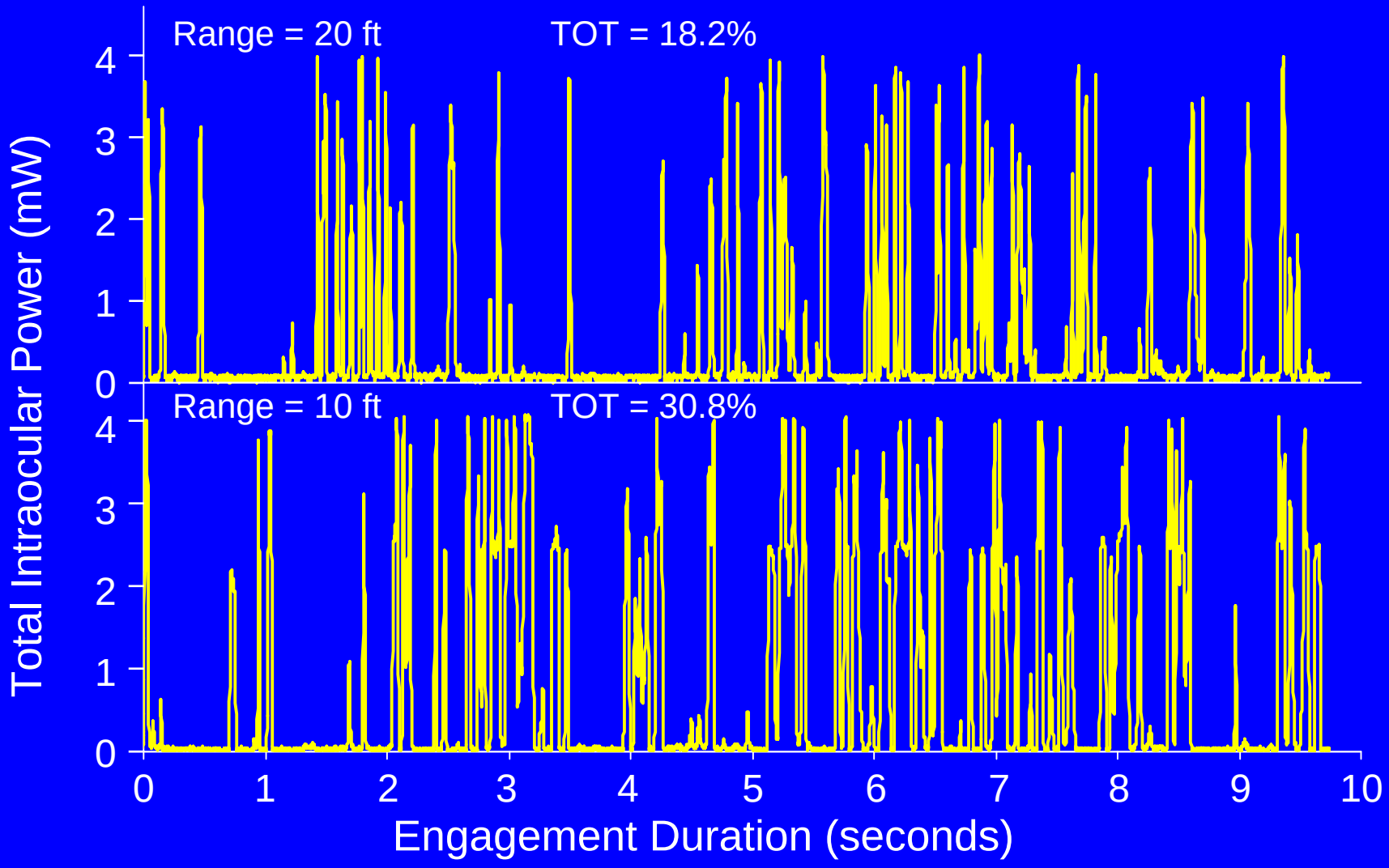
Ocular exposure to laser radiation **without** injury

- Illuminators as signaling devices
  - Numerous eye exams –
  - Few actual injuries
  - Training
- Illumination of commercial aircraft in the USA
  - CY 2011 – approximately 3000 report – no injuries
  - 1Jan -20 Apr 2012 -938
  - FAA Web Site
  - Training

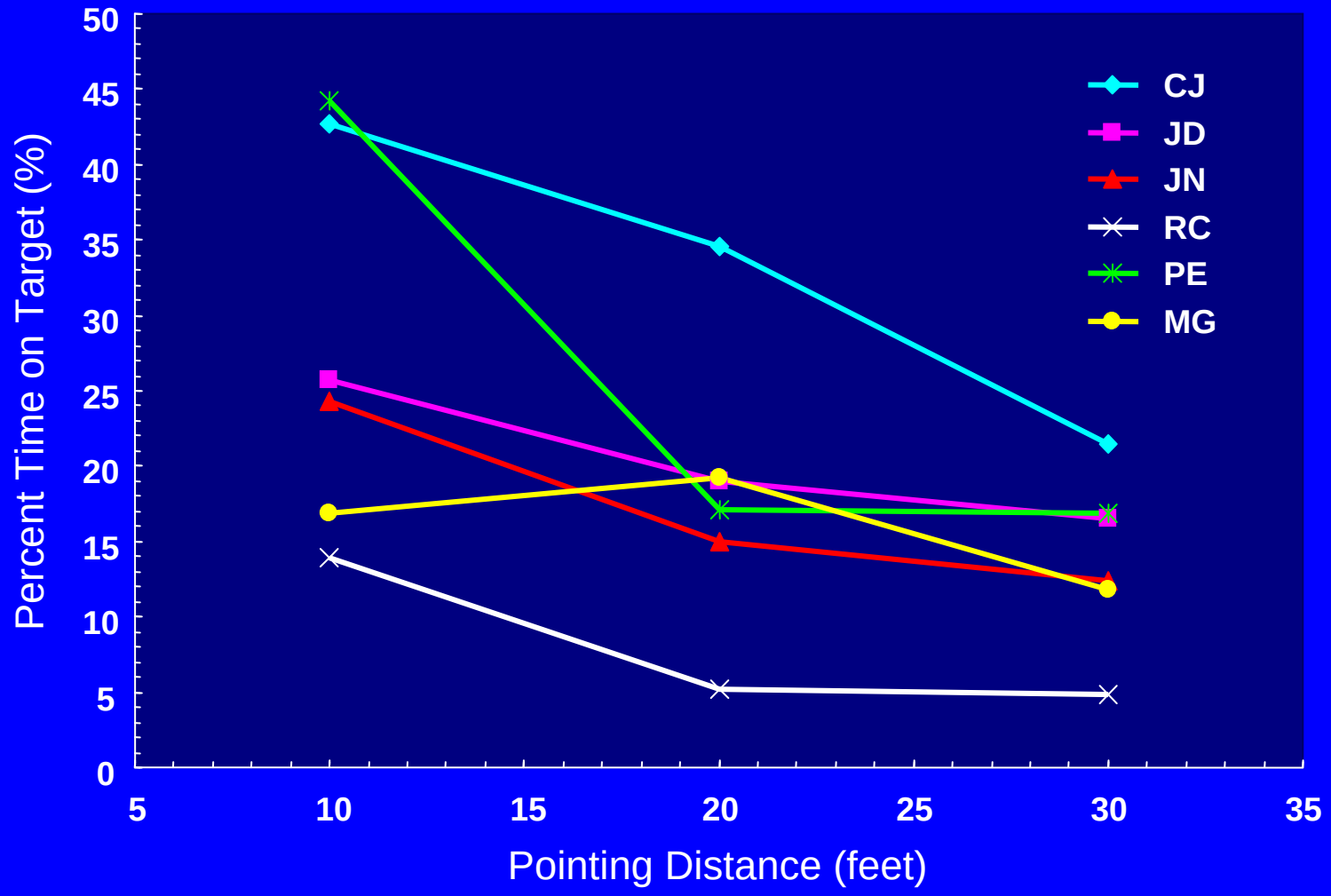

Laser Pointer
with 5 Different Interchangeable Lenses
"Great for parties!"
LASER

Small laser beam and small pupil diameter

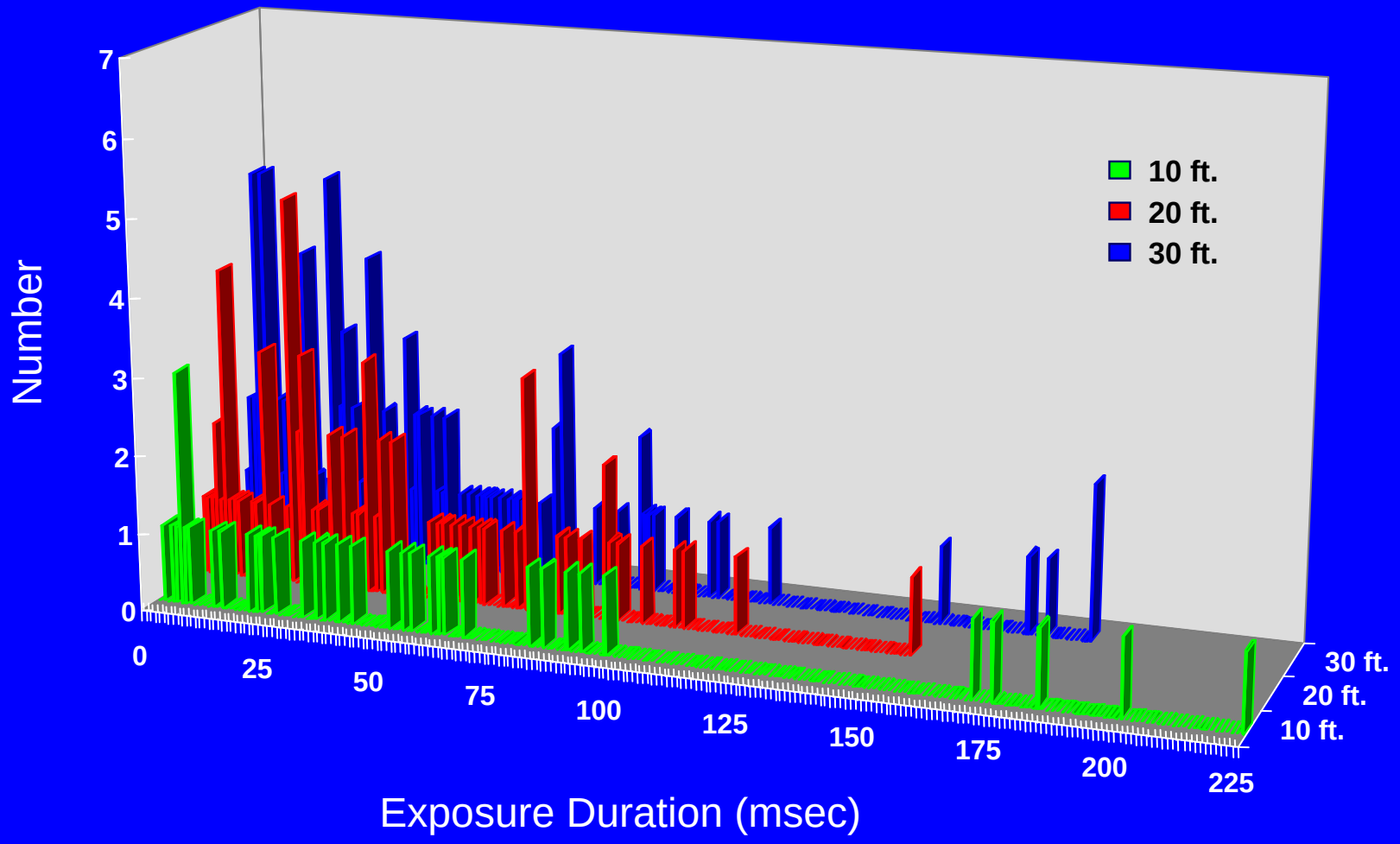
Pointing Accuracy Through a 7 mm Pupil



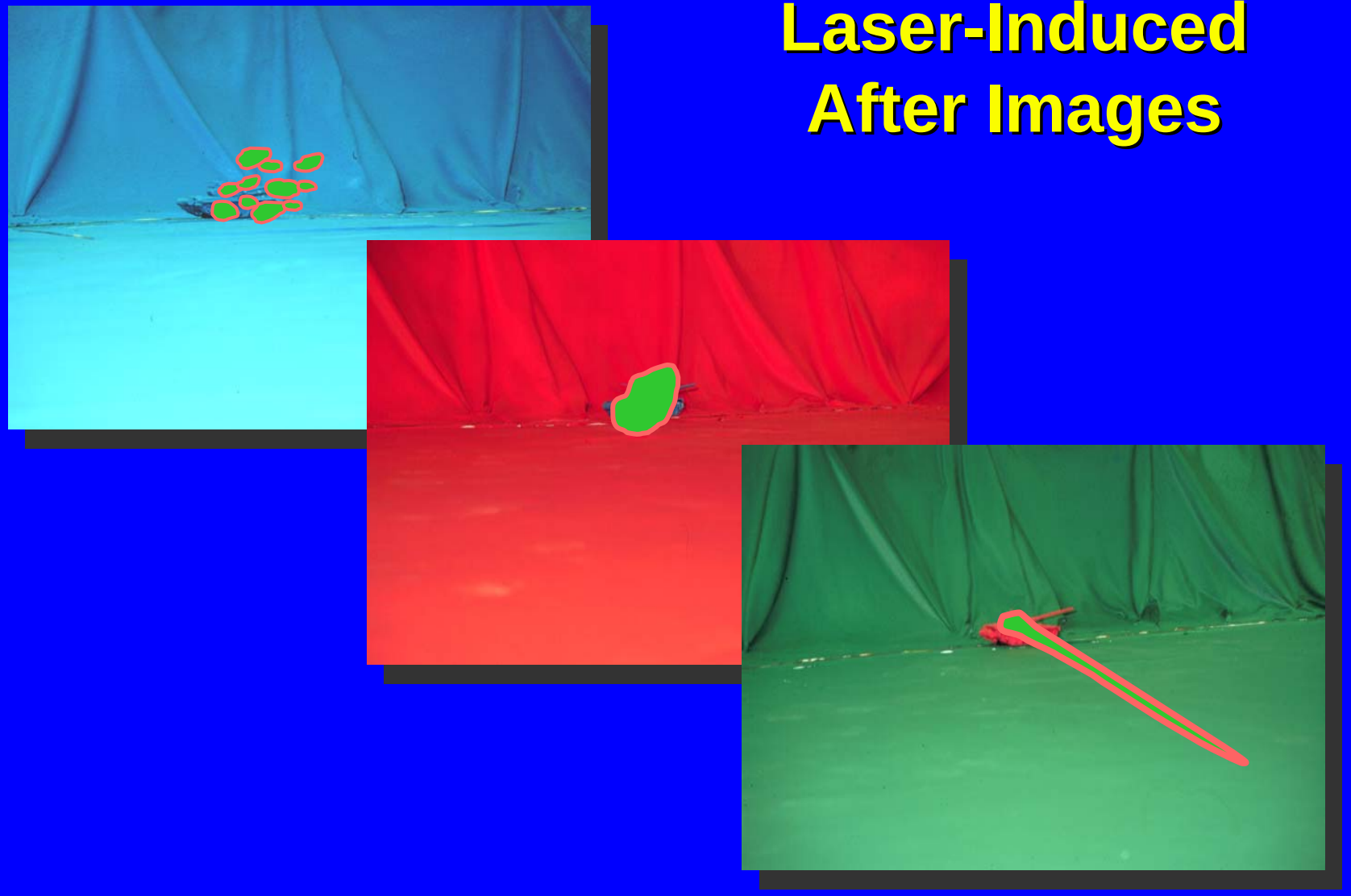
Laser Pointing (7 mm aperture)



Laser Pointer (CJ)



Laser-Induced After Images



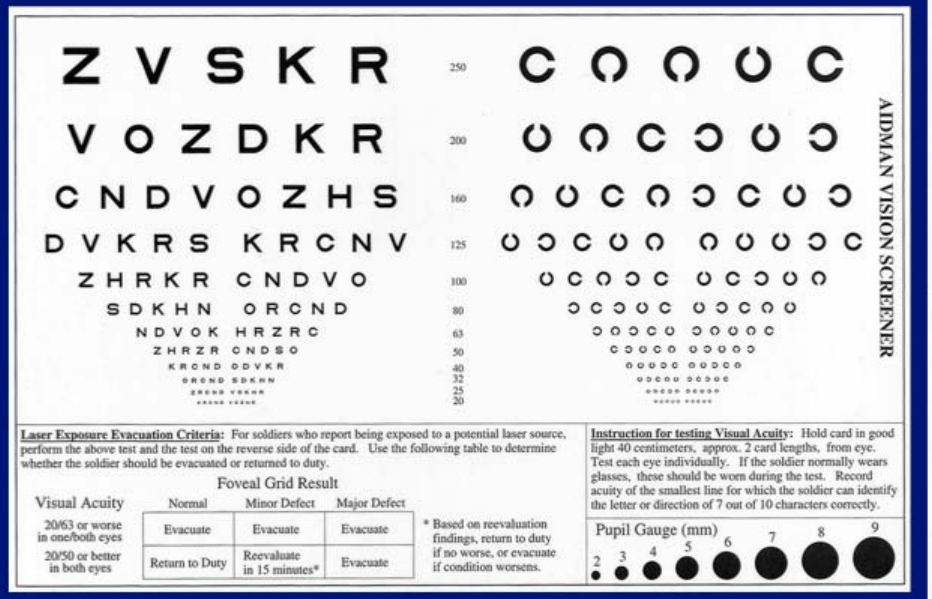
Summary

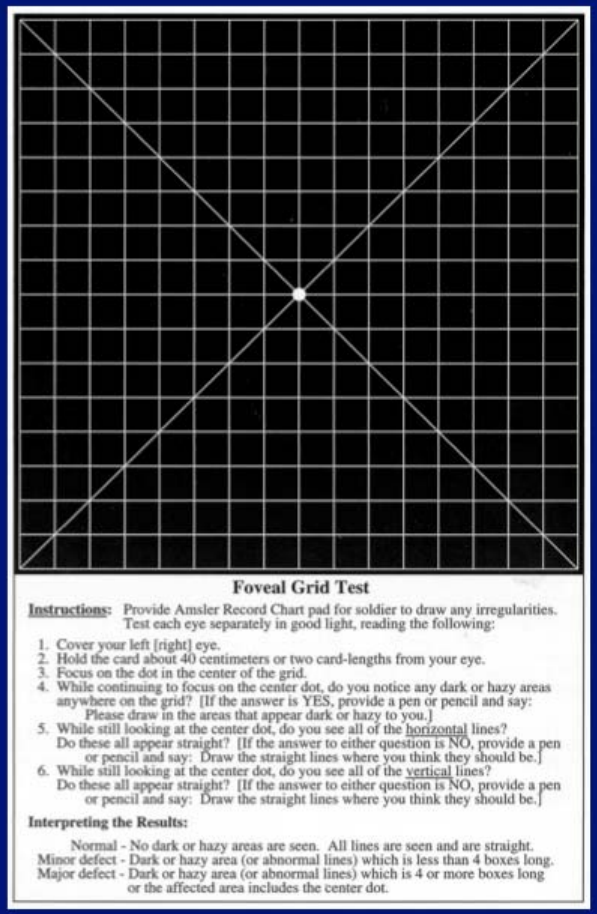
- Serious eye injuries from pulsed lasers
  - Relatively few cases but some quite debilitating
  - Injuries typically involve miss use
- Frequent laser illumination events
  - Most are non injuring
  - Medical or situation assessment is not always straight forward
- Classroom laser pointers
  - Low probability of trans-pupillary exposure
  - Exposure of a given retinal exposure site is brief
  - Purposeful exposure should be avoided

Thank you!

Questions?

Aidman Vision Screener





Amsler Gird