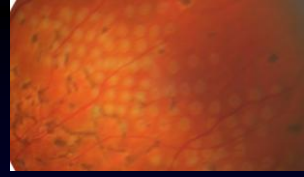


LASERS
shots in the dark…

Robin D Hamilton

Moorfields Eye Hospital, London, UK

L ight

A mpified

S timulated

E mmision

R adiation

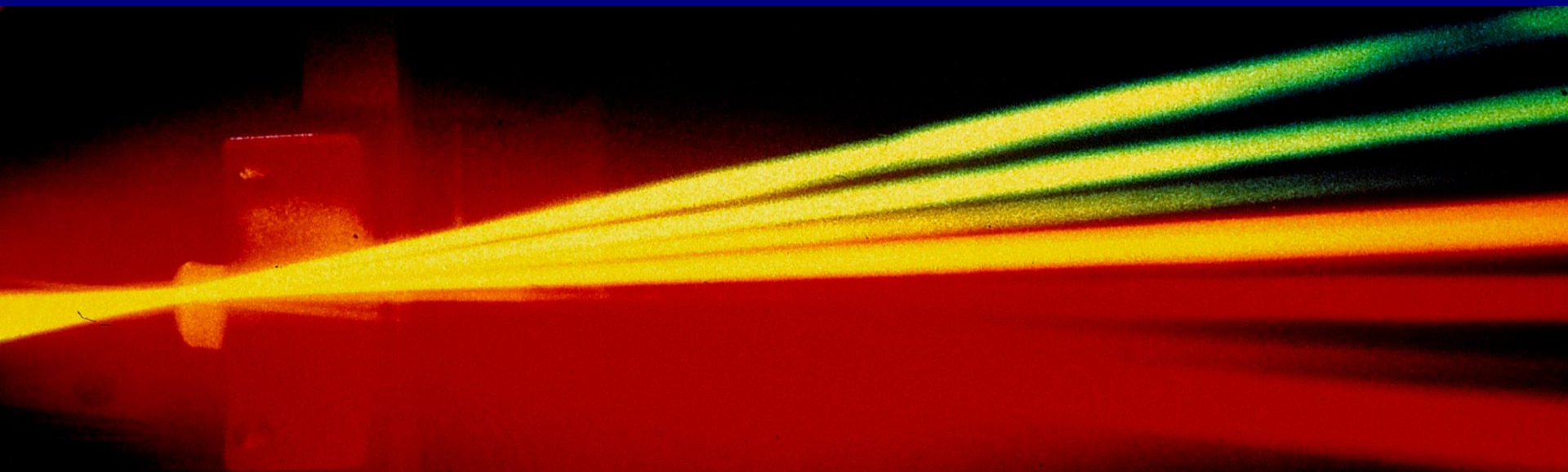
L ucrative

A cquisition

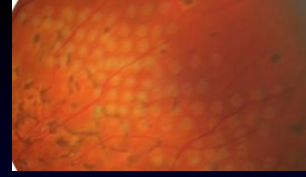
S cheme

E xpensive

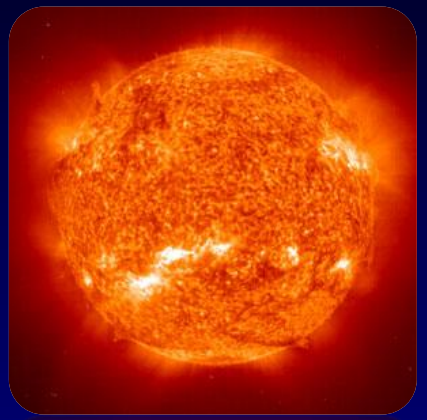
R esearch



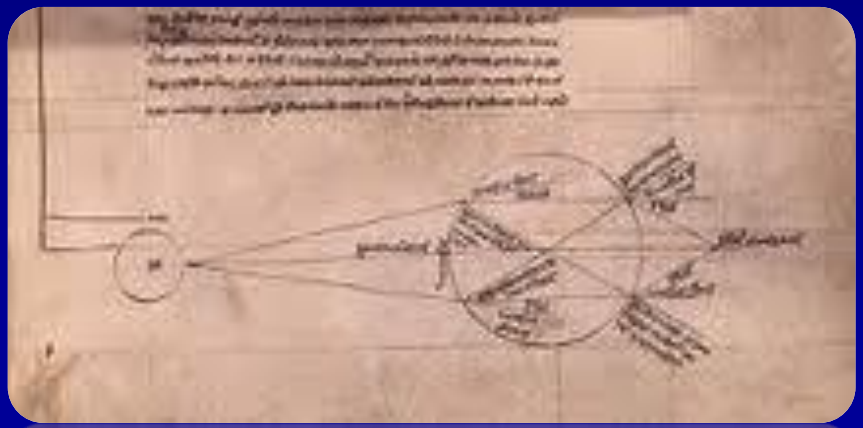
L.A.S.E.R.



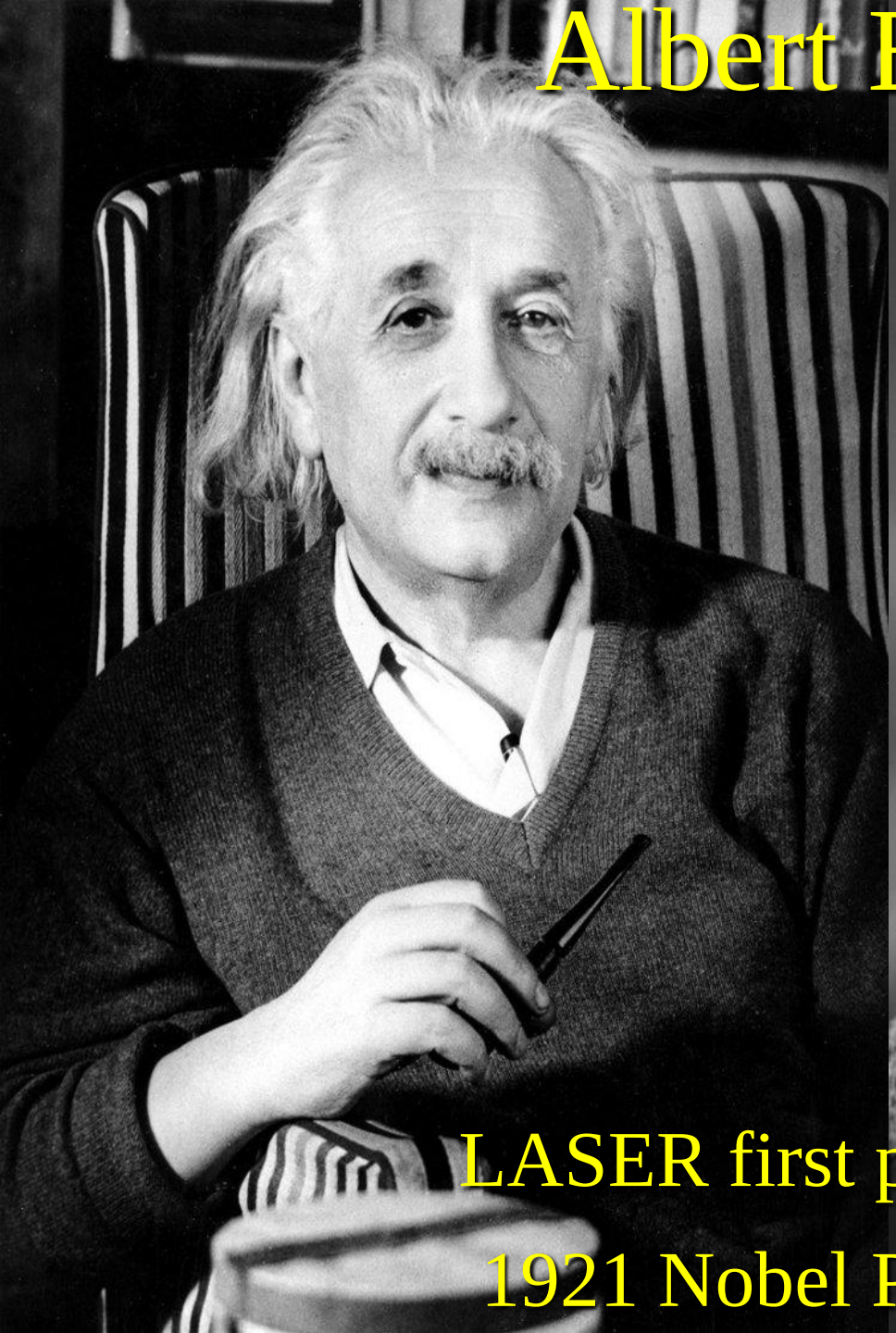
Light **A**mplification by **S**timulated **E**mission of **R**adiation

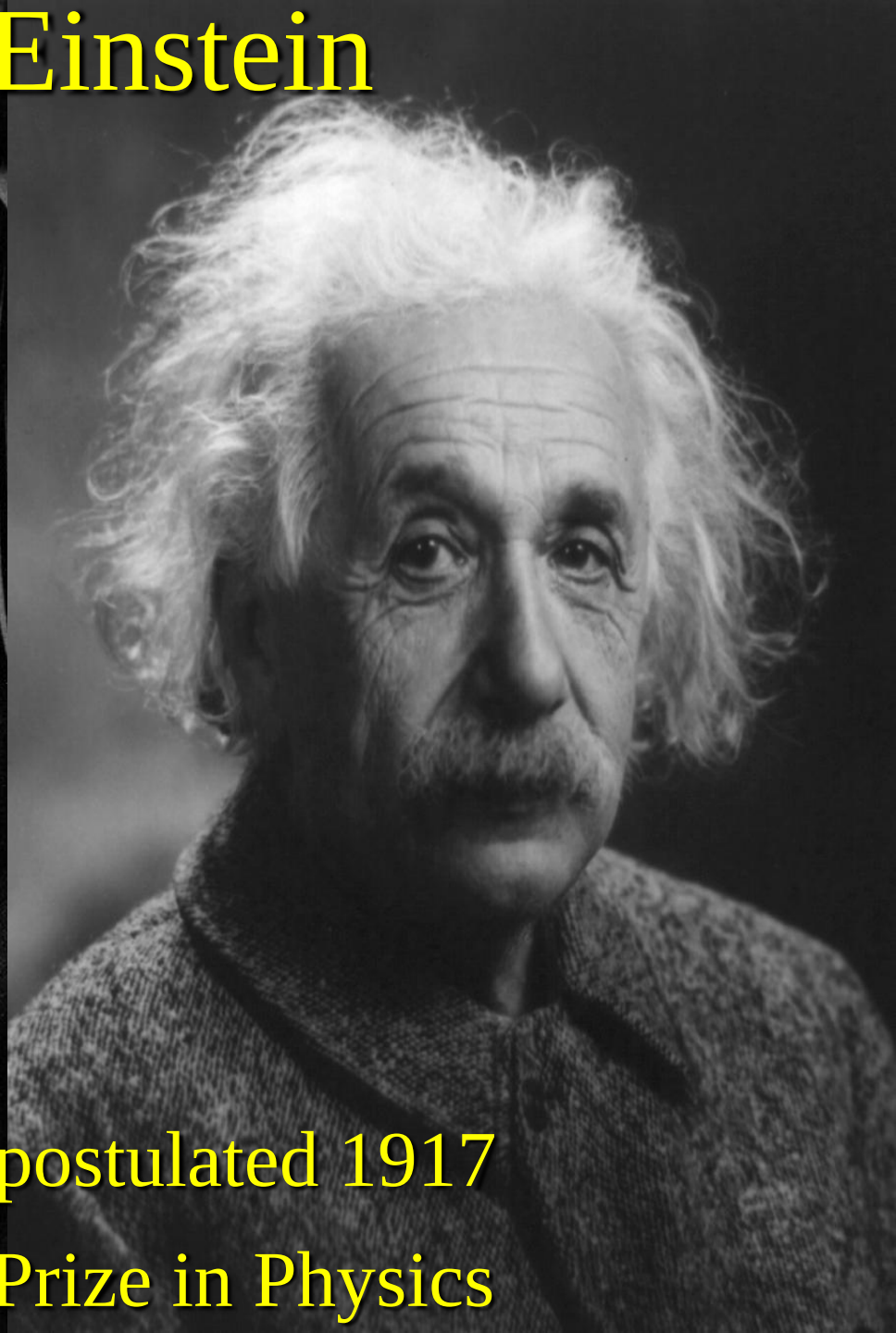


- The effect of solar radiation was well known to humanity since the time of the ancients in China and in the West (Greece)
- Theophilus Bonetus (1620-1689) reported central scotoma (blind spot) following solar burn of the retina



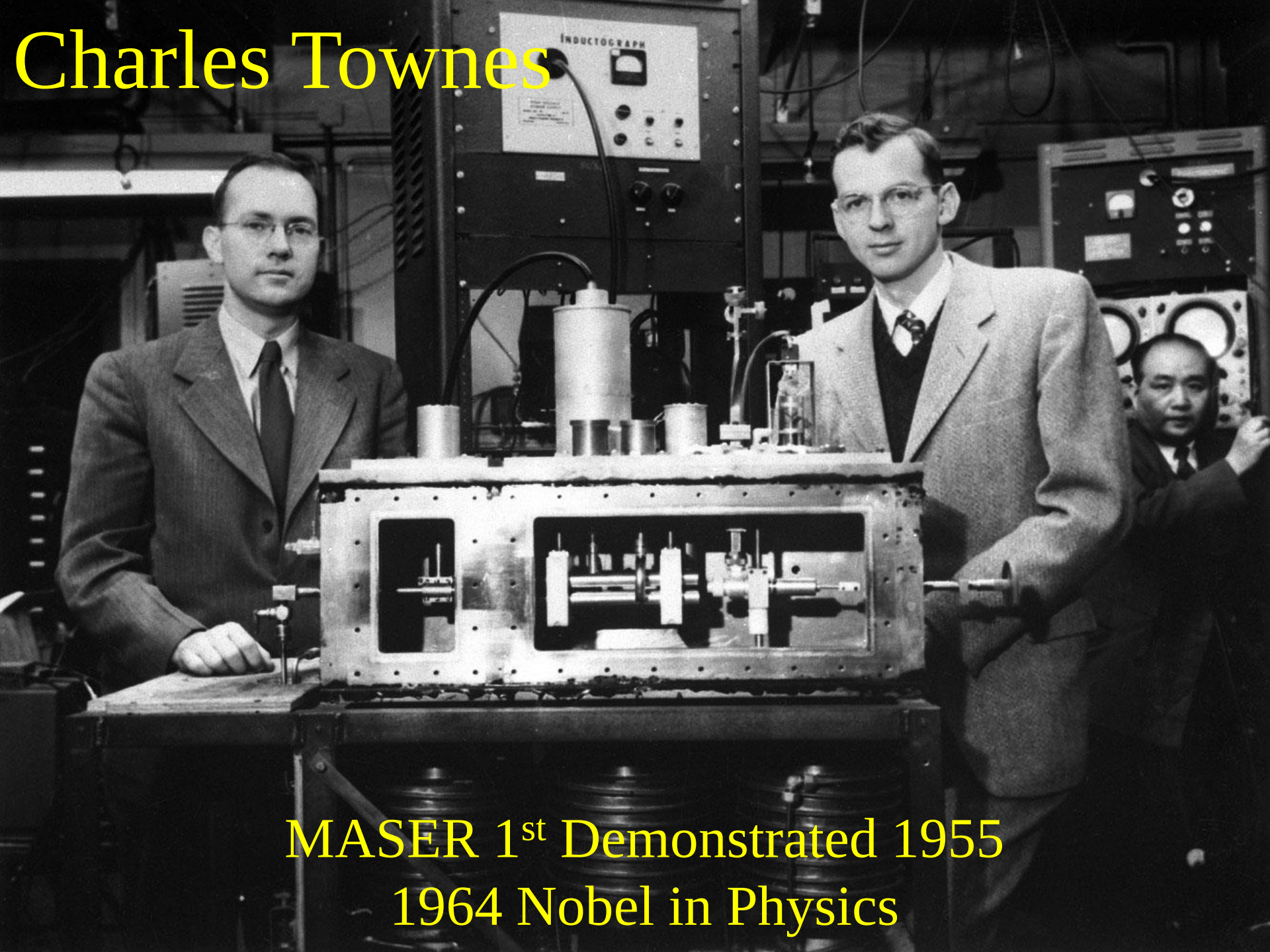
Albert Einstein



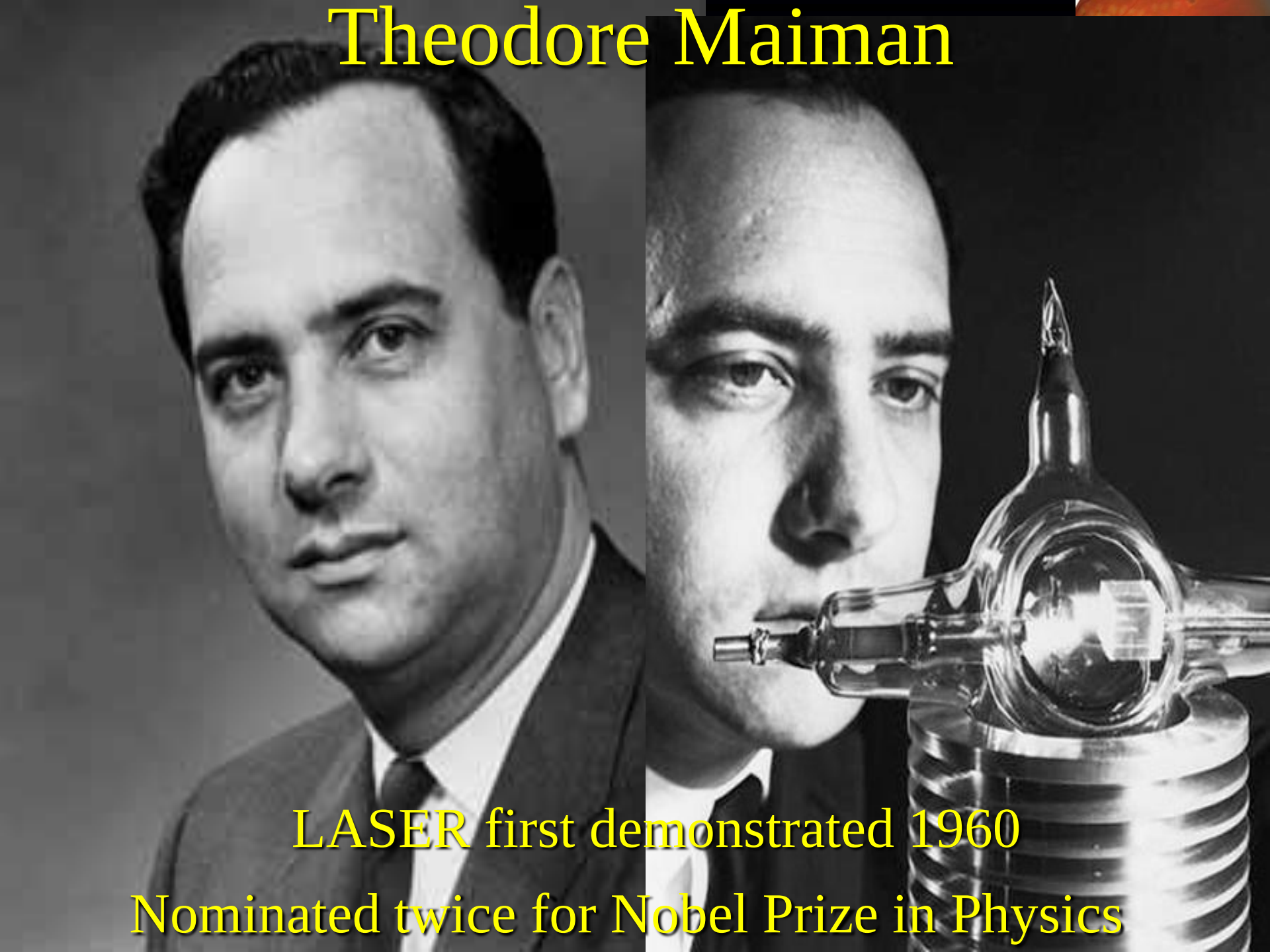


LASER first postulated 1917

1921 Nobel Prize in Physics


Charles Townes
INDUCTOGRAPH
MASER 1st Demonstrated 1955
1964 Nobel in Physics

Theodore Maiman



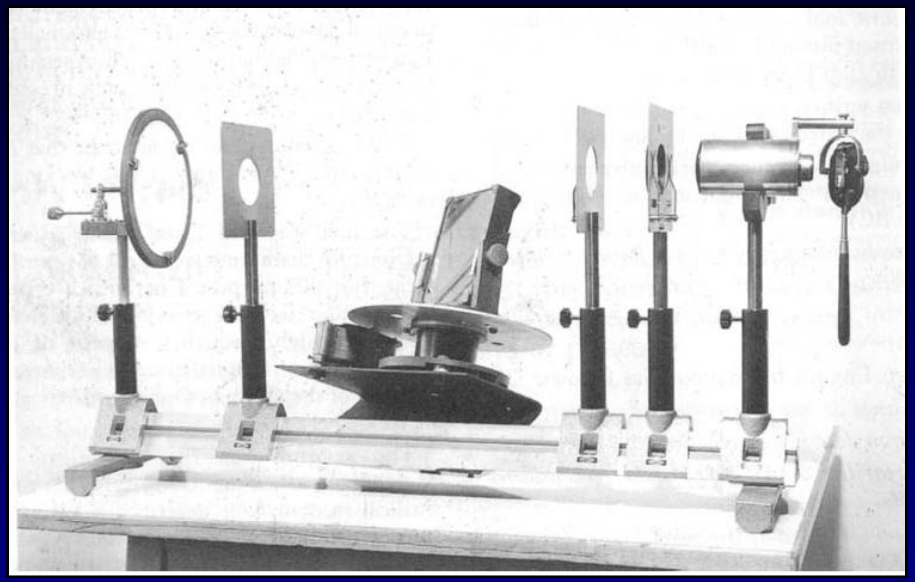
LASER first demonstrated 1960

Nominated twice for Nobel Prize in Physics

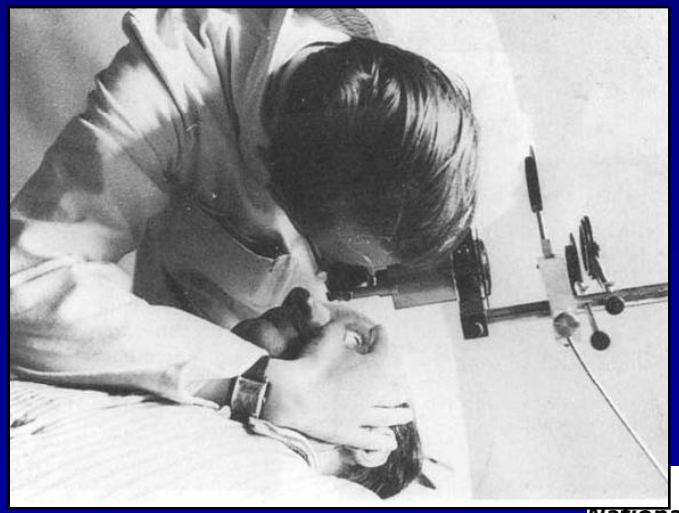
1964

007

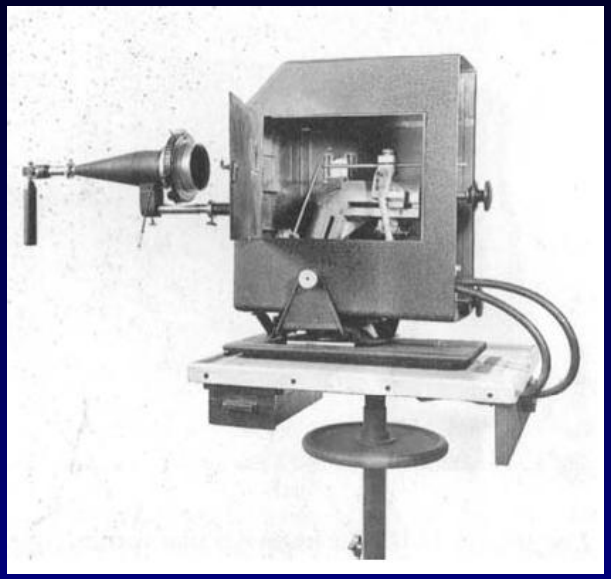
Revolution



Gerard Meyer-Schwikerath
1946



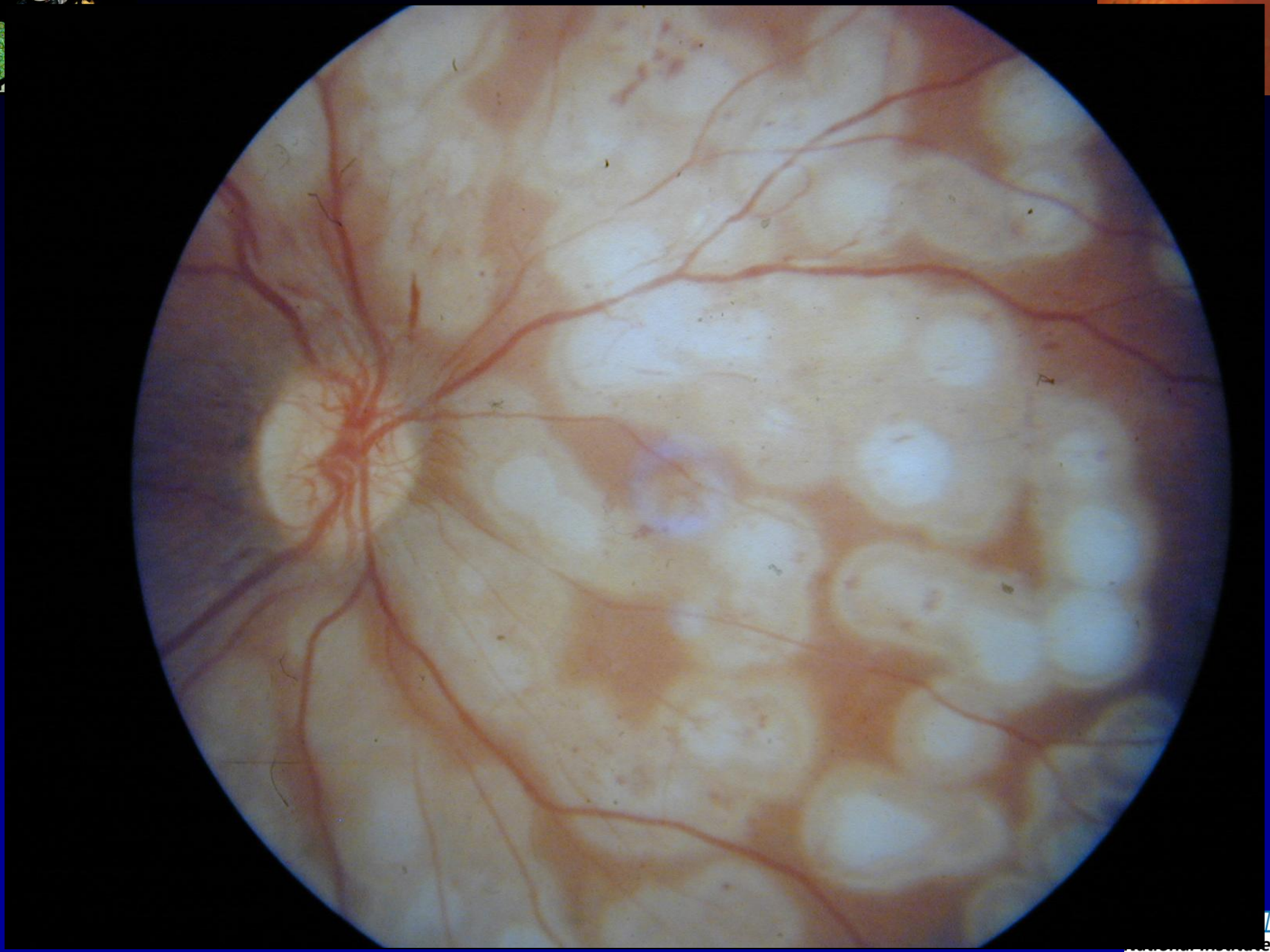
Evolution



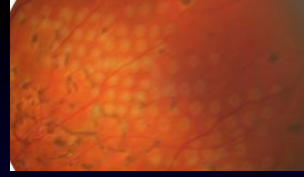
Carl Zeiss Xenon arc lamp

NHS National Institute for Health Research


OISONS

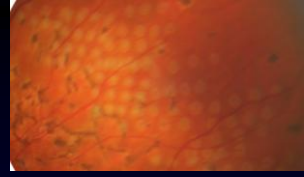


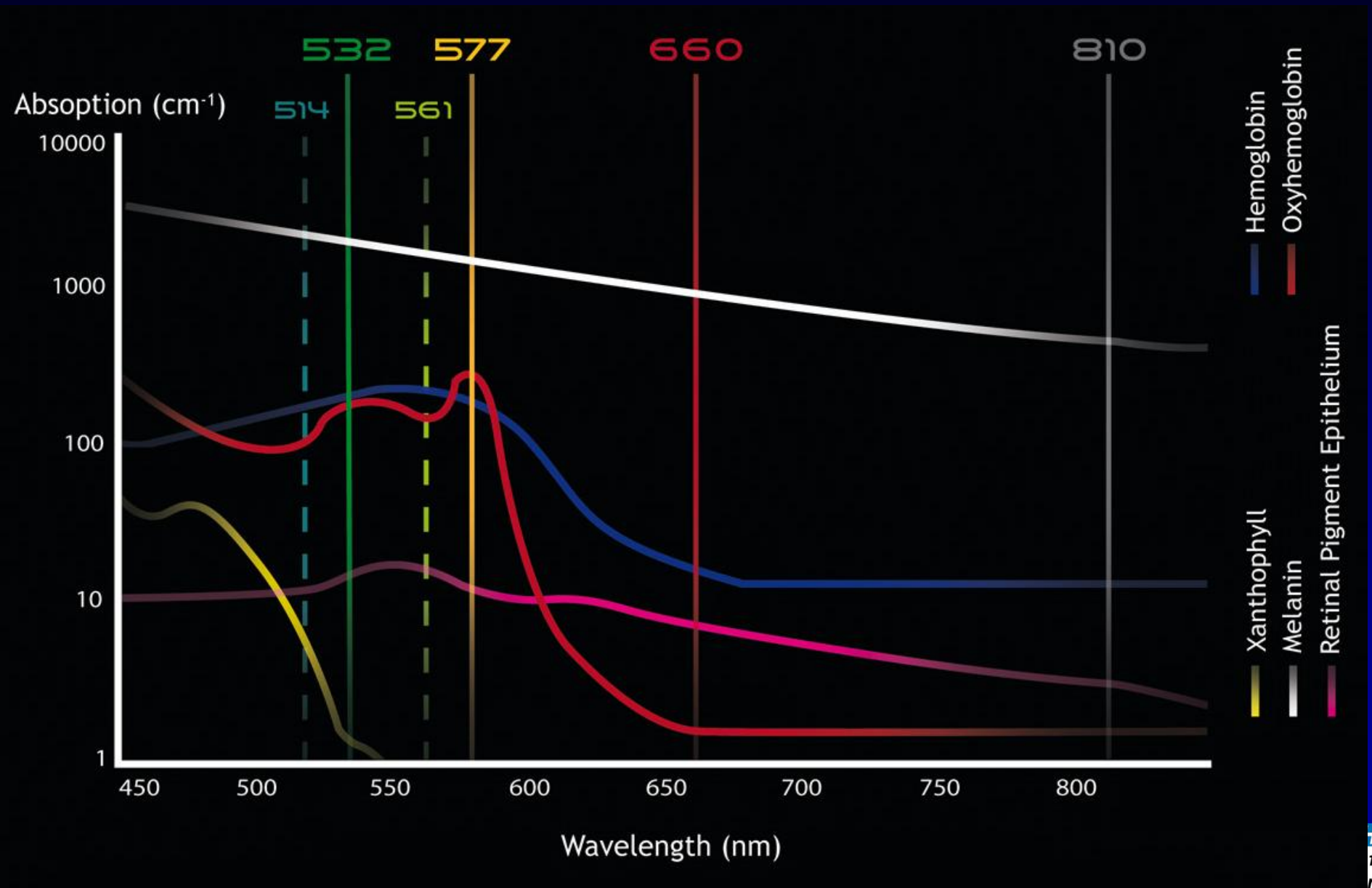

SPECTRA-PHYSICS

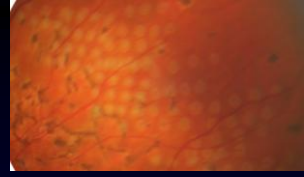


Wavelengths

- Excimer 193 nm
- Argon Blue 488 nm
- Argon green 514 nm
- FD-YAG green 532 nm very high RPE absorption
- Krypton yellow 568 nm
- Solid State Yellow 561nm 577 nm
- Dye Orange to Red 590-630 nm
- Krypton red 647 nm
- Solid State red 670 nm
- Ruby red 694 nm
- Diode 810 nm 30% RPE absorption
- FD-YAG 1064 nm

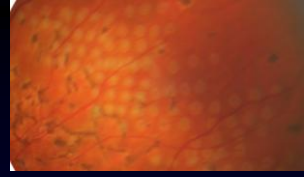



532
577
660
810
514
561
Absoption (cm-1)
10000
1000
100
10
1
450
500
550
600
650
700
750
800
Wavelength (nm)
Hemoglobin
Oxyhemoglobin
Xanthophyll
Melanin
Retinal Pigment Epithelium



Laser Pulse Durations

- Conventional photocoagulation
  - 100 ms
- YAG Laser
  - 3 ns
  - 100 ms = 100 million ns
- Femtosecond lasers
  - 3 ns = 3 million fs
  - One femtosecond is to one second as one second is to 31 million years!



History of photocoagulation

1946/1956 Xenon lamp

1964/1968 Argon lasers

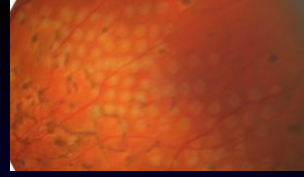
1971/1972 Nd:YAG lasers

1980/1981 Q switched Nd:YAG lasers

2005/2006 First multispot laser

2012 Multispot lasers, micropulses, SRT, 2RT…

2025… ?



Multispot laser technology

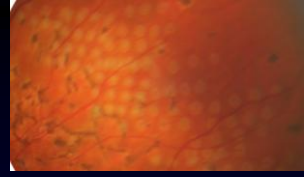

© Rheinmetall Defence

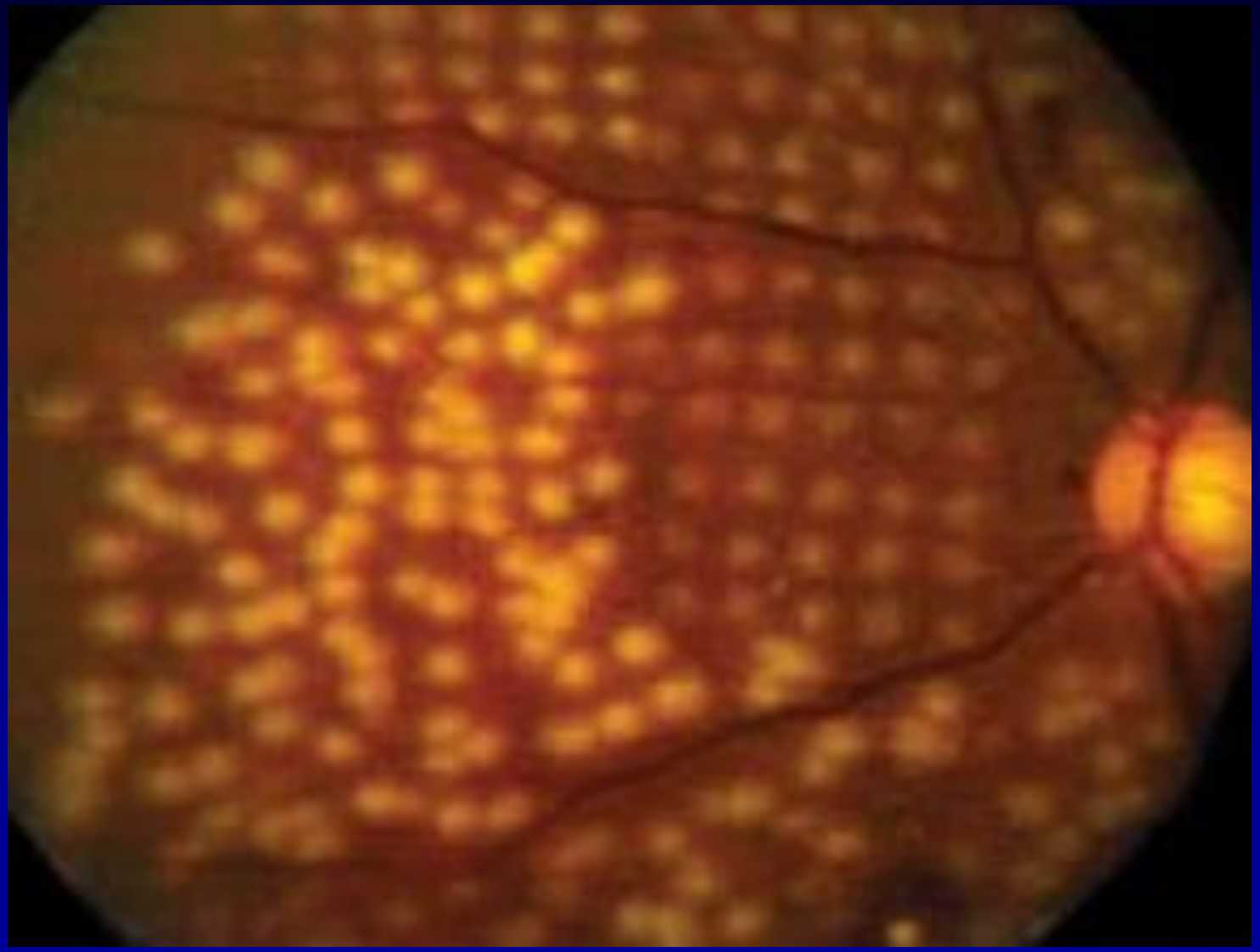
Multispot lasers

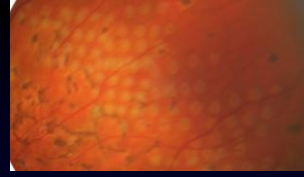
First multispot laser: PASCAL.

Later multispot versions: Valon, Ellex, Quantel Medical, Nidek, Zeiss, Lightmed and OD – OS.

Different approaches to the delivery, variable quality of the laser beam, exposure time, parameters stability and number of spots.







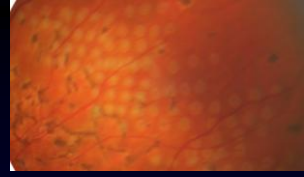
Multi-spot features

Advantages

- Ultrafast
- Painless
- Precise
- Less collateral damage
- Innovative and user friendly
- Versatile

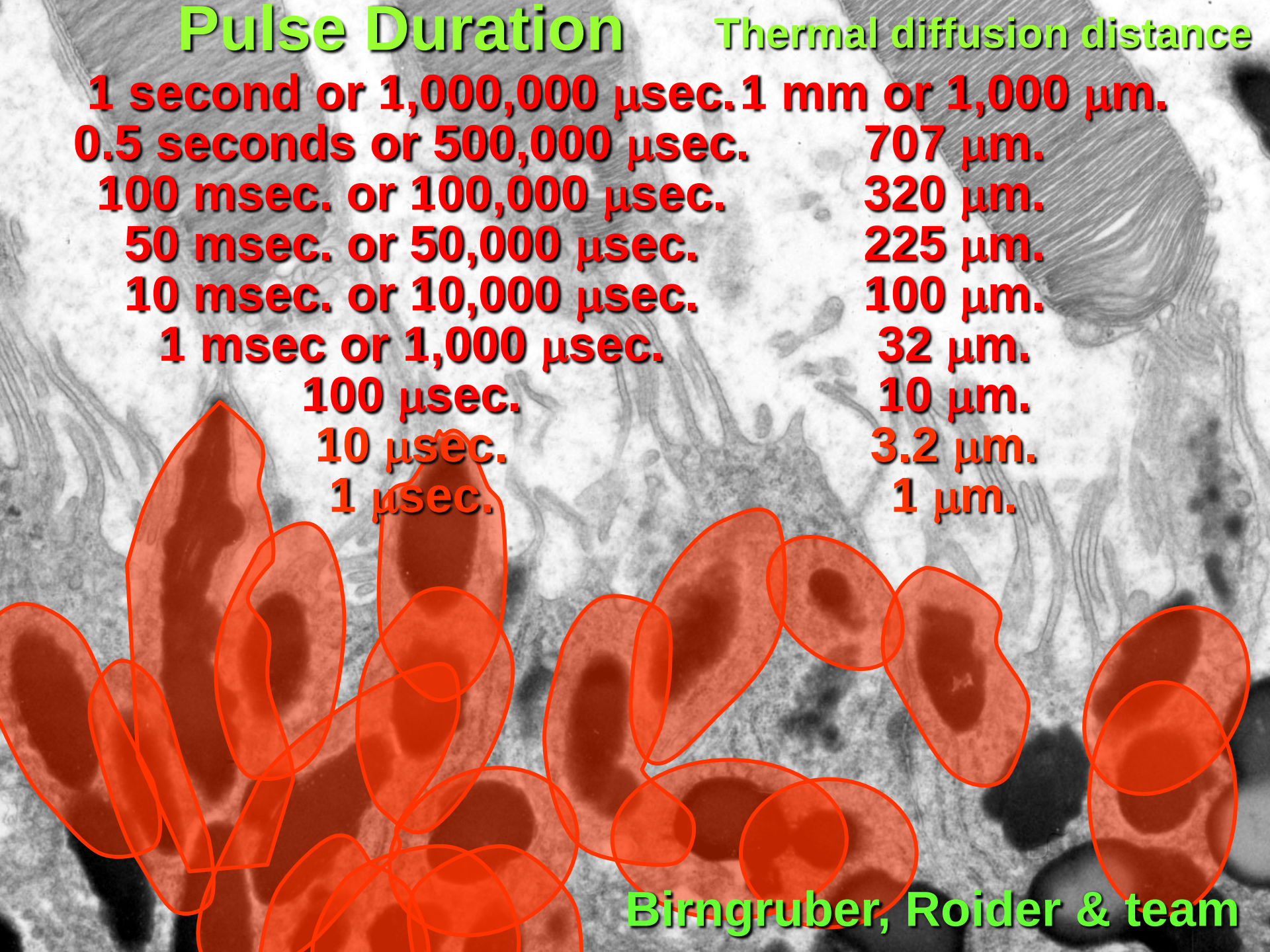
Disadvantages

- Too fast?
- Spot size - preset
- Short pulse
- Less collateral damage?
- Not applicable for OP

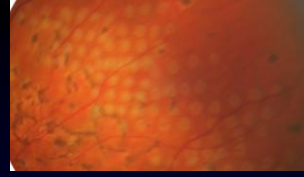


Short pulse duration - advantages

1. No thermal diffusion, vertically nor horizontally
   - Minimal tissue damage
   - Less pain, better patient compliance
   - No risks of macular oedema and other complication
2. Smaller influence of power changes on spot size and intensity (20 msec vs. 100 msec)
3. Full PRP in one sitting (single-session procedure)


Pulse Duration
Thermal diffusion distance
1 second or 1,000,000 µsec.
1 mm or 1,000 µm.
0.5 seconds or 500,000 µsec.
707 µm.
100 msec. or 100,000 µsec.
320 µm.
50 msec. or 50,000 µsec.
225 µm.
10 msec. or 10,000 µsec.
100 µm.
1 msec or 1,000 µsec.
32 µm.
100 µsec.
10 µm.
10 µsec.
3.2 µm.
1 µsec.
1 µm.
Birngruber, Roider & team

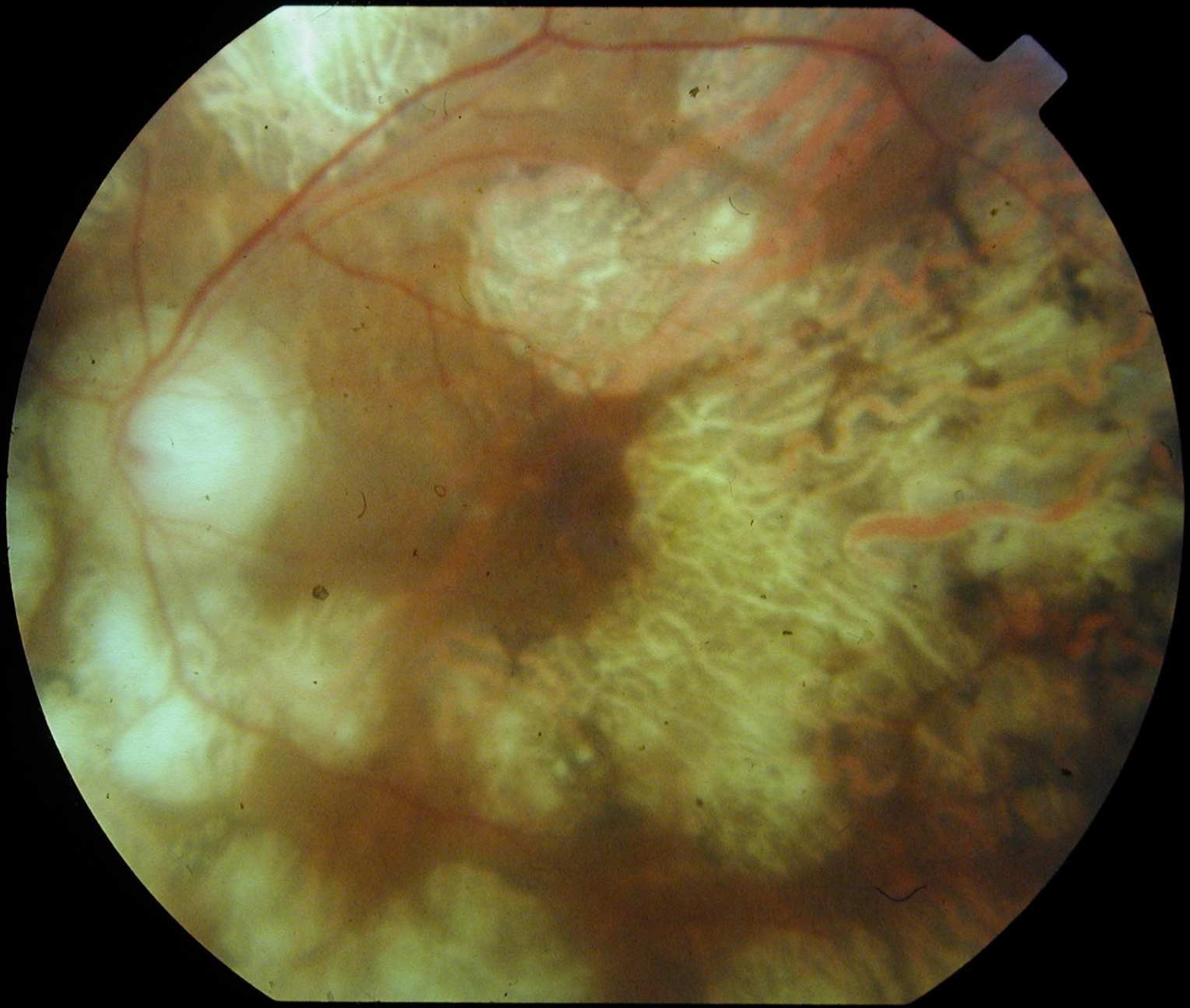

100 μ secs



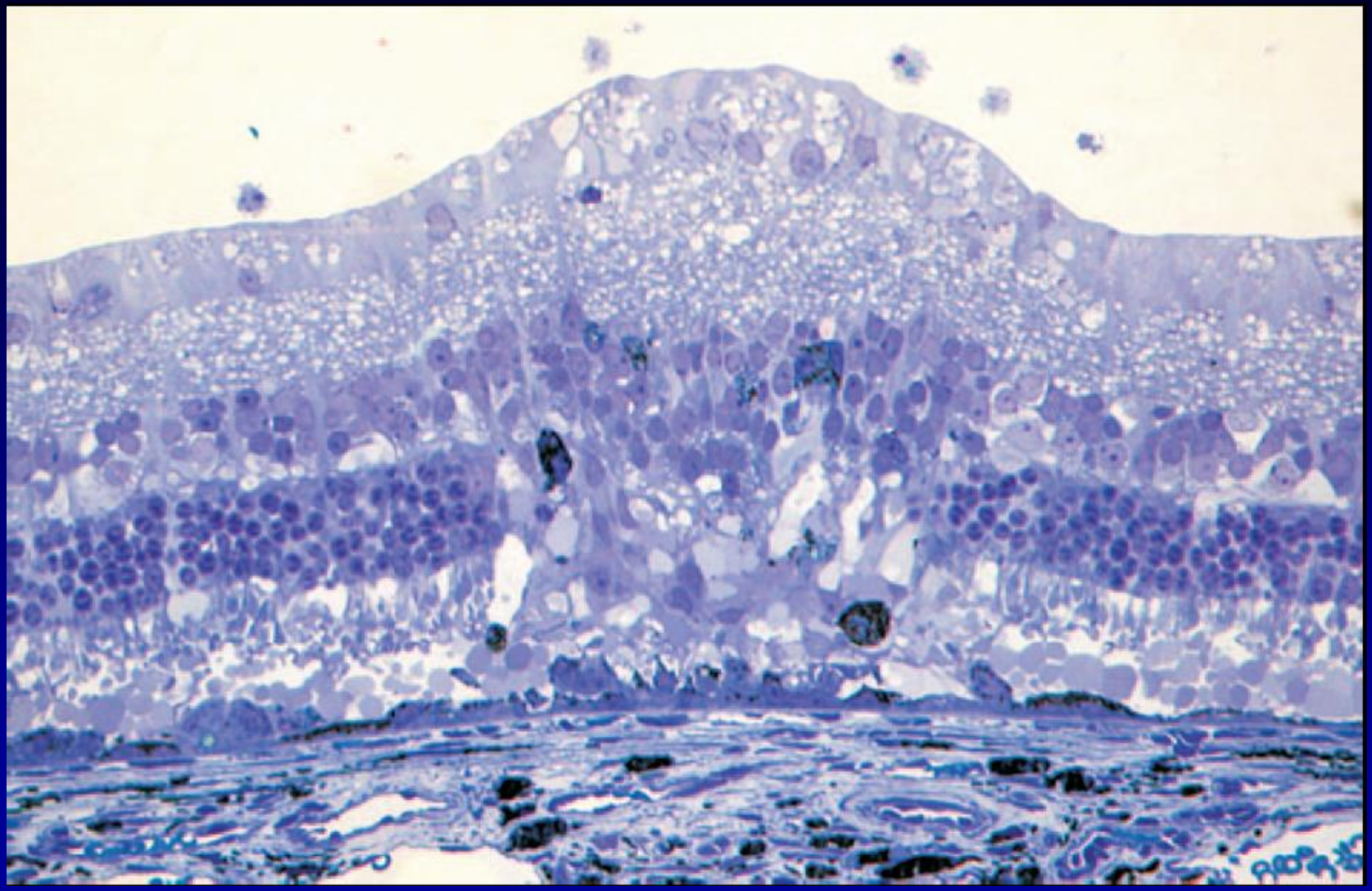
Painless procedure - low energy

Fluence = amount of energy delivered to the particular area

$$\text{Fluence } (J/cm^2) = \frac{\text{Power } (J/s) \times \text{pulse duration } (s)}{\text{Area } (\prod r^2)}$$

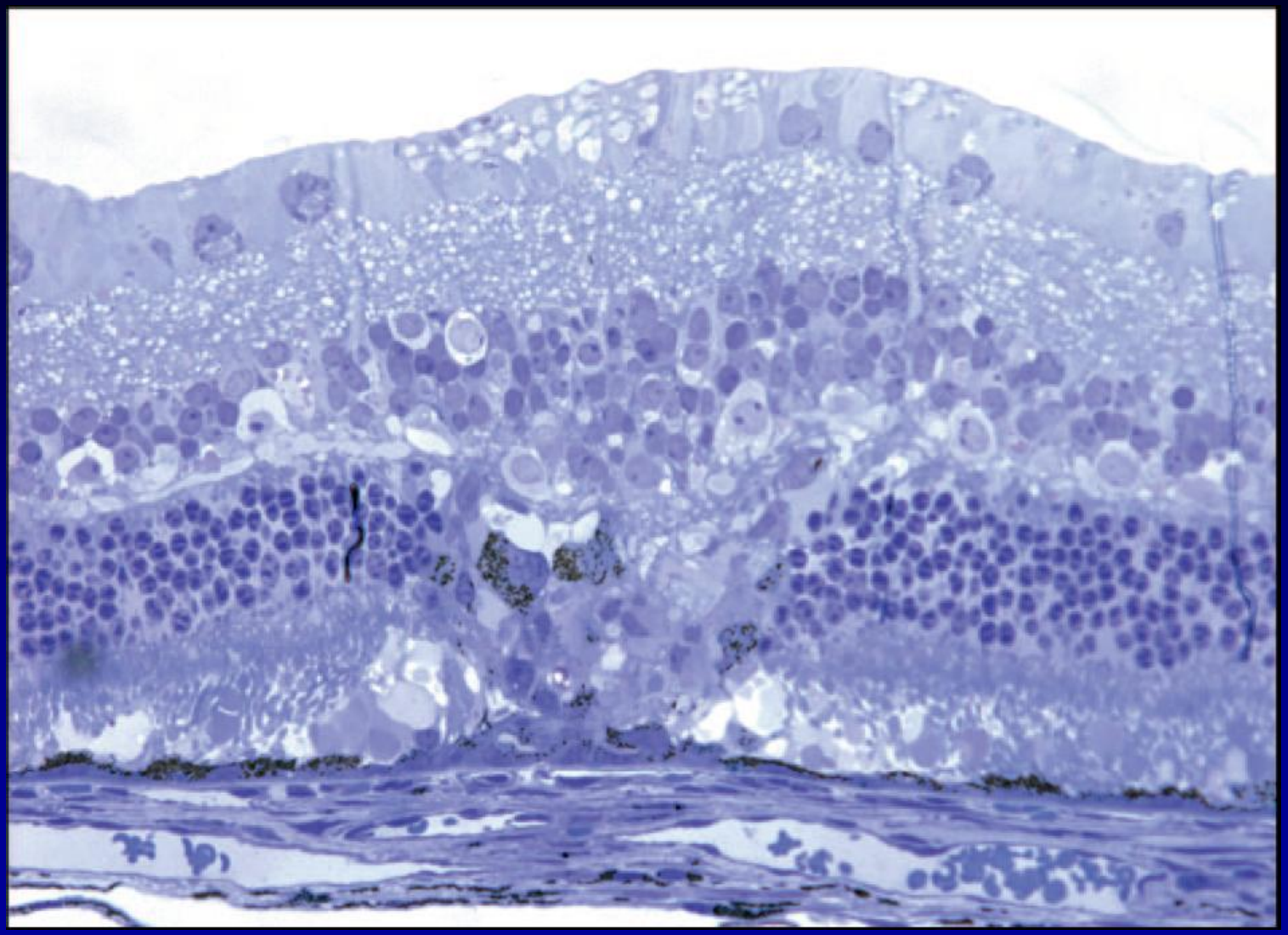


Conventional Photocoagulation



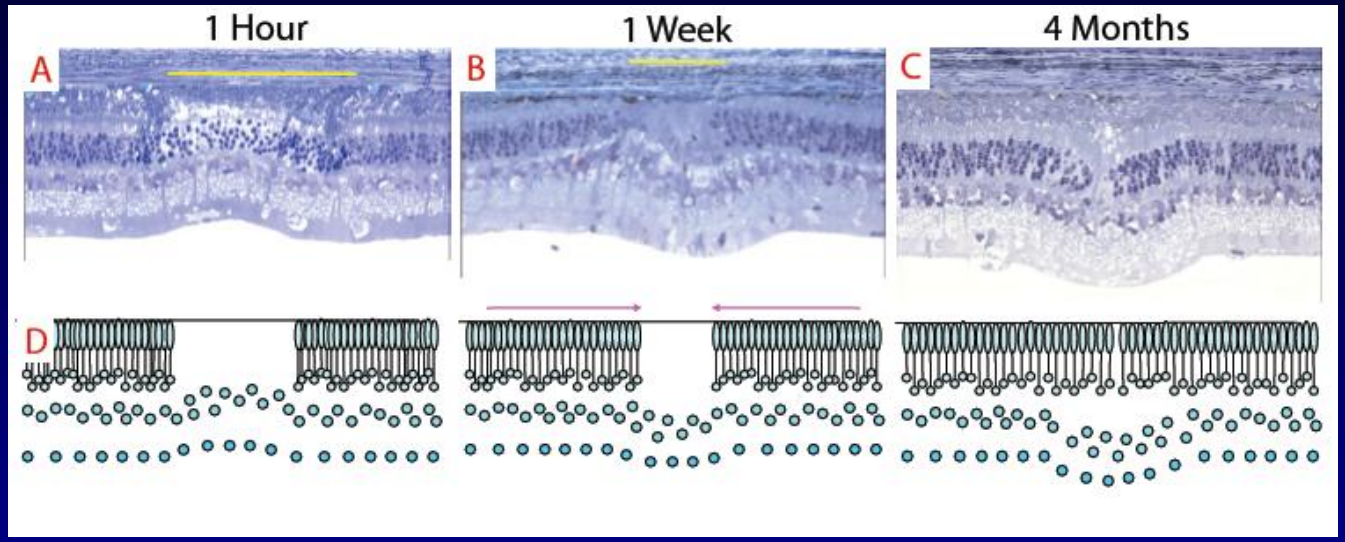
Single retinal lesion 100 millisecond pulse at 60 mW at 1 week (rabbit)

Semi-Automated Patterned Scanner



Single retinal lesion 10 millisecond pulse at 240 mW at 1 week (rabbit)

Migration of photoreceptors



A By standard toluidine blue stains, nuclei of photoreceptors in the photocoagulation site appear pyknotic at 1 hour, and disappear within 2 days. Inner nuclear layer and ganglion cell layers appear intact but are deformed due to the changes in the photoreceptor and RPE layers.
B By one week, Müller glia fill in the photoreceptor decimated region. The RPE layer appears restored, though hypo-pigmented in the center of the lesion and contracted to 50% of its original size.
C At 4 months, photoreceptor organization in the center of the lesion continues to improve and is distinguished from adjacent normal retina only by a narrow column of Müller glia, and a slight elevation on the vitreal side of the retina.

Photoreceptor morphology within lesions is otherwise indistinguishable from that in the untreated retina and appear to shift from the adjacent areas into the lesion, filling it over time, as schematically shown in D.

Changes of spot size

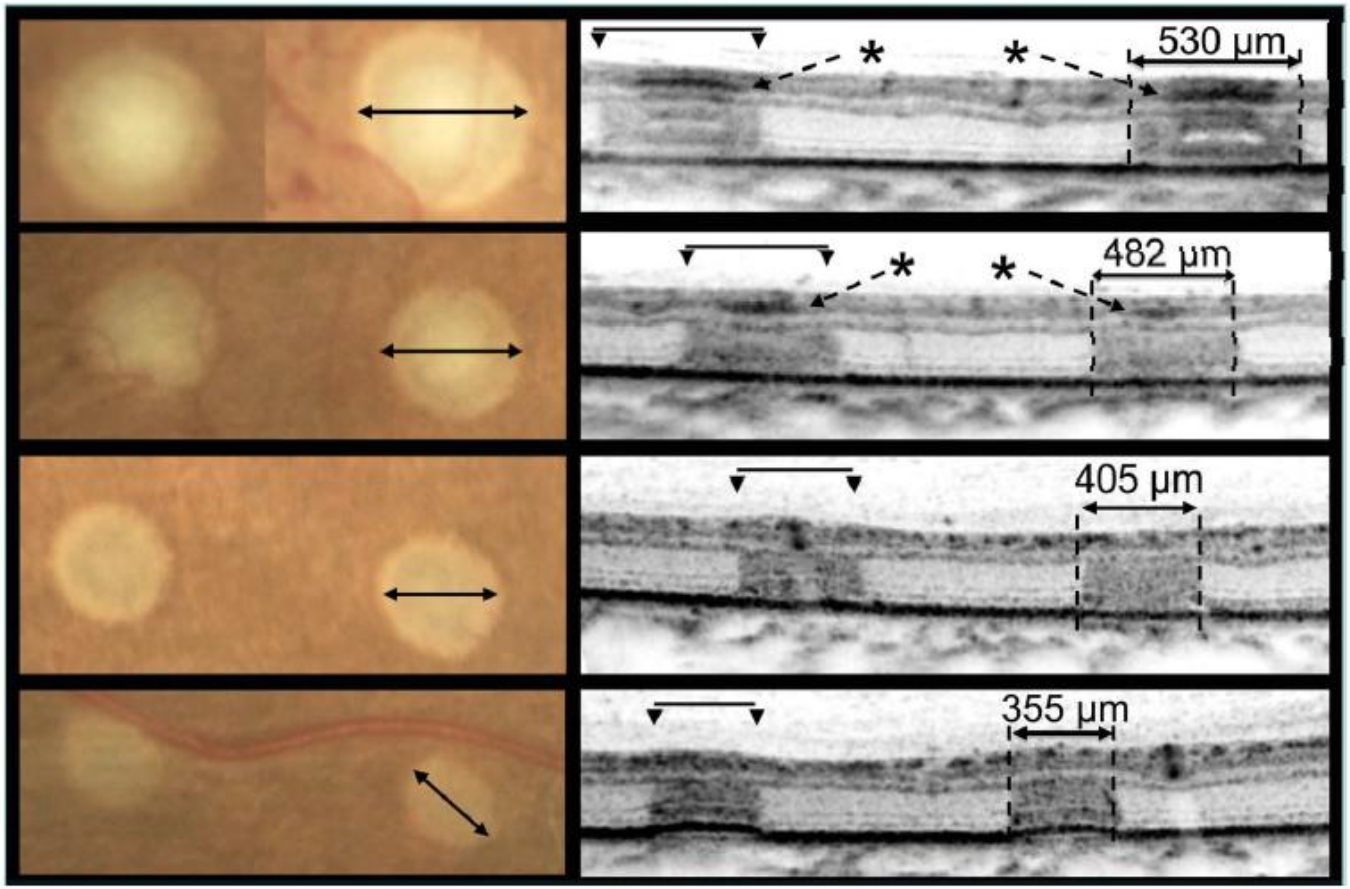
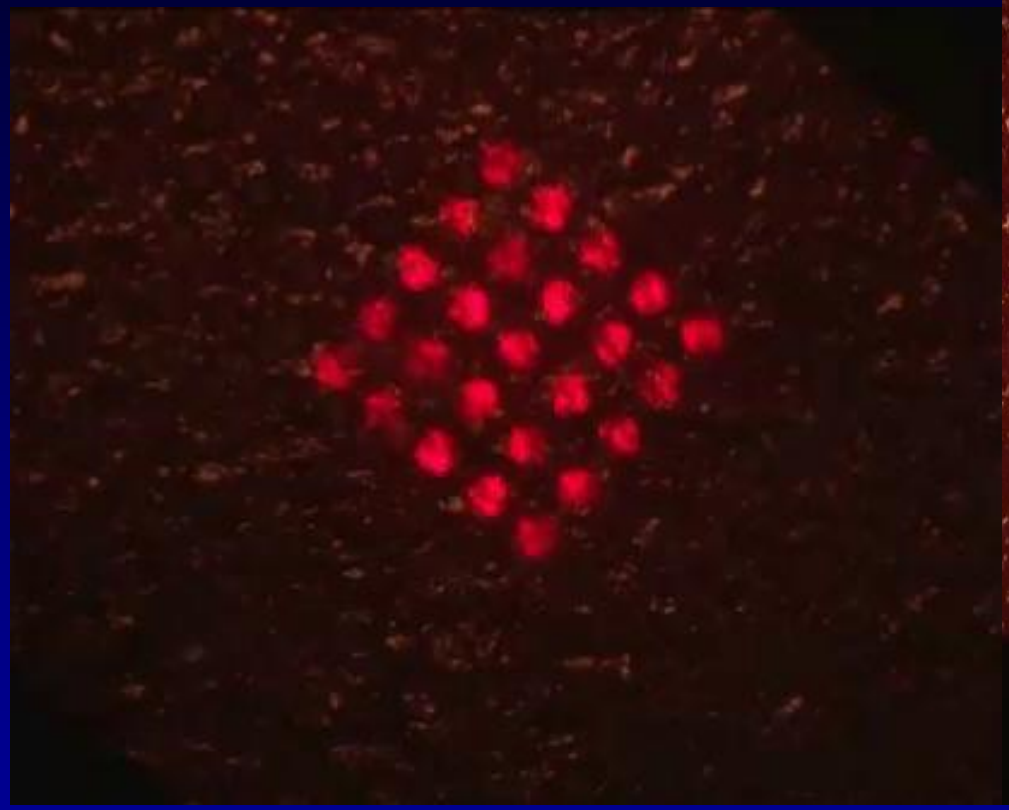
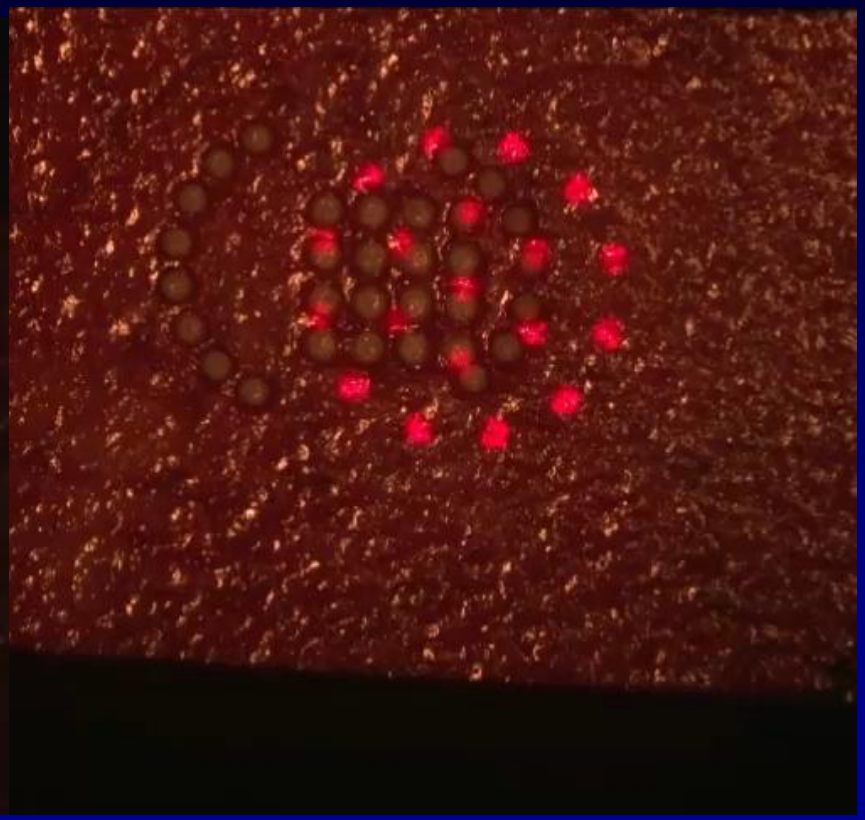
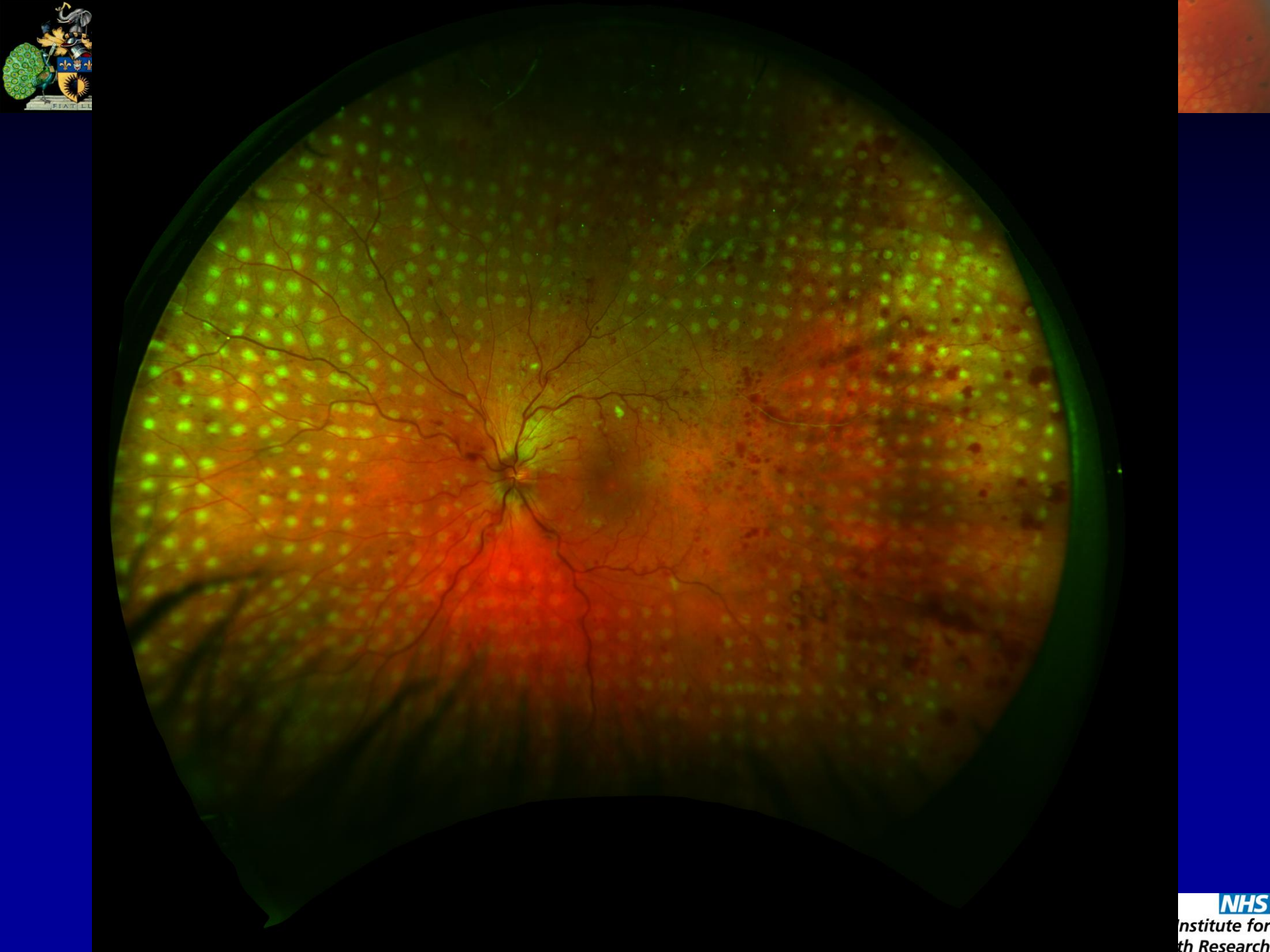


Fig. 1. Typical OCT appearance of the acute retinal lesions produced with a 400-μm aerial beam size using Area Centralis contact lens. Solid arrows show the width of the coagulated zone, with numbers in micrometers. **A.** 100 ms, moderate grade. Dash arrows (*) point at the dark bands indicating some effect in the inner retina. **B.** 20 ms, moderate grade. **C.** 20 ms, light grade. **D.** 20 ms, barely visible grade.

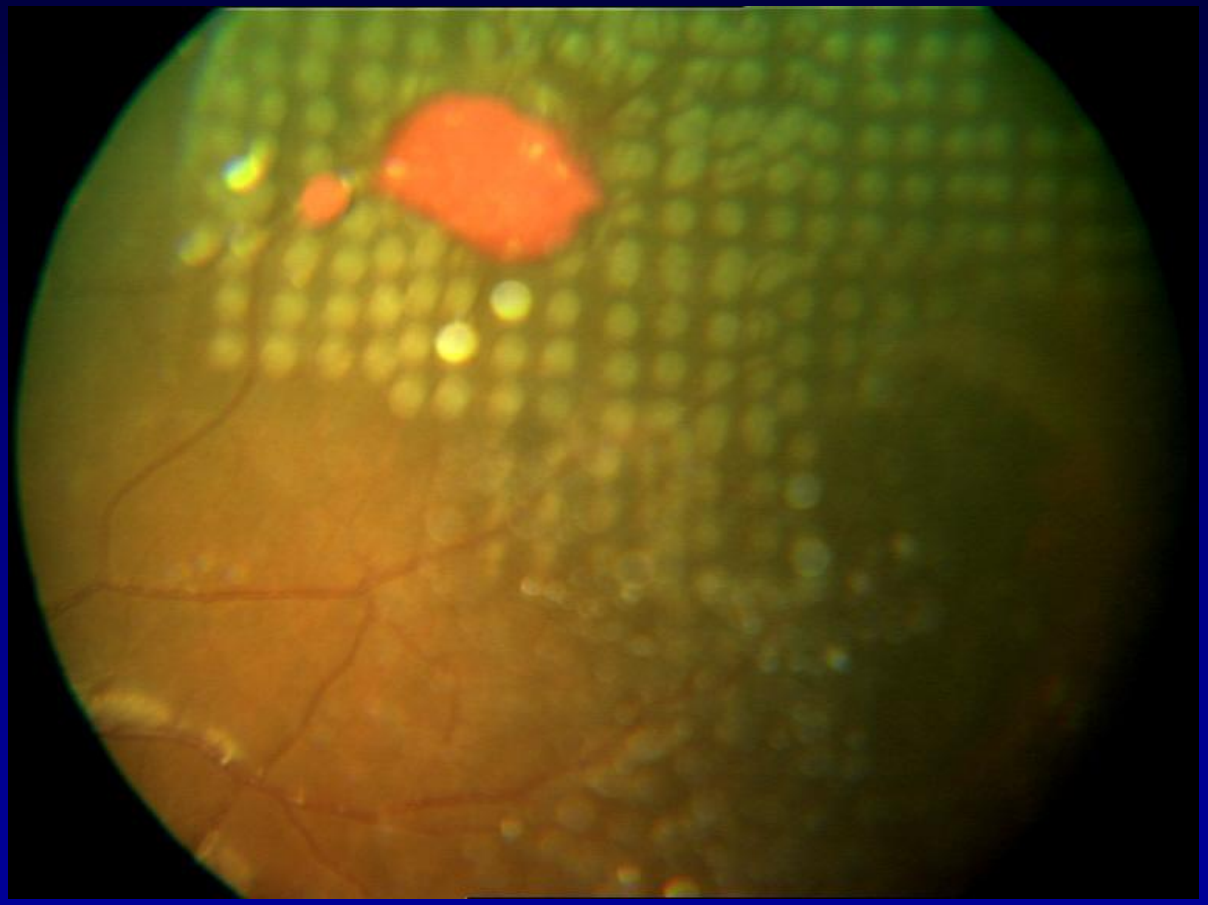
Scanning Patterns







Example PRP for NV and VH



PRP in Sickle Cell Disease

Pattern 4x4,
Settings:
20 msec,
275 mW,
400 microns

Example Macular Grid

Upper half
Long pulse duration, single shot

Lower half
Short pulse duration (10msec), pattern photo-coagulation 200mW

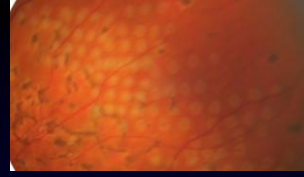
Example Retinal Tear

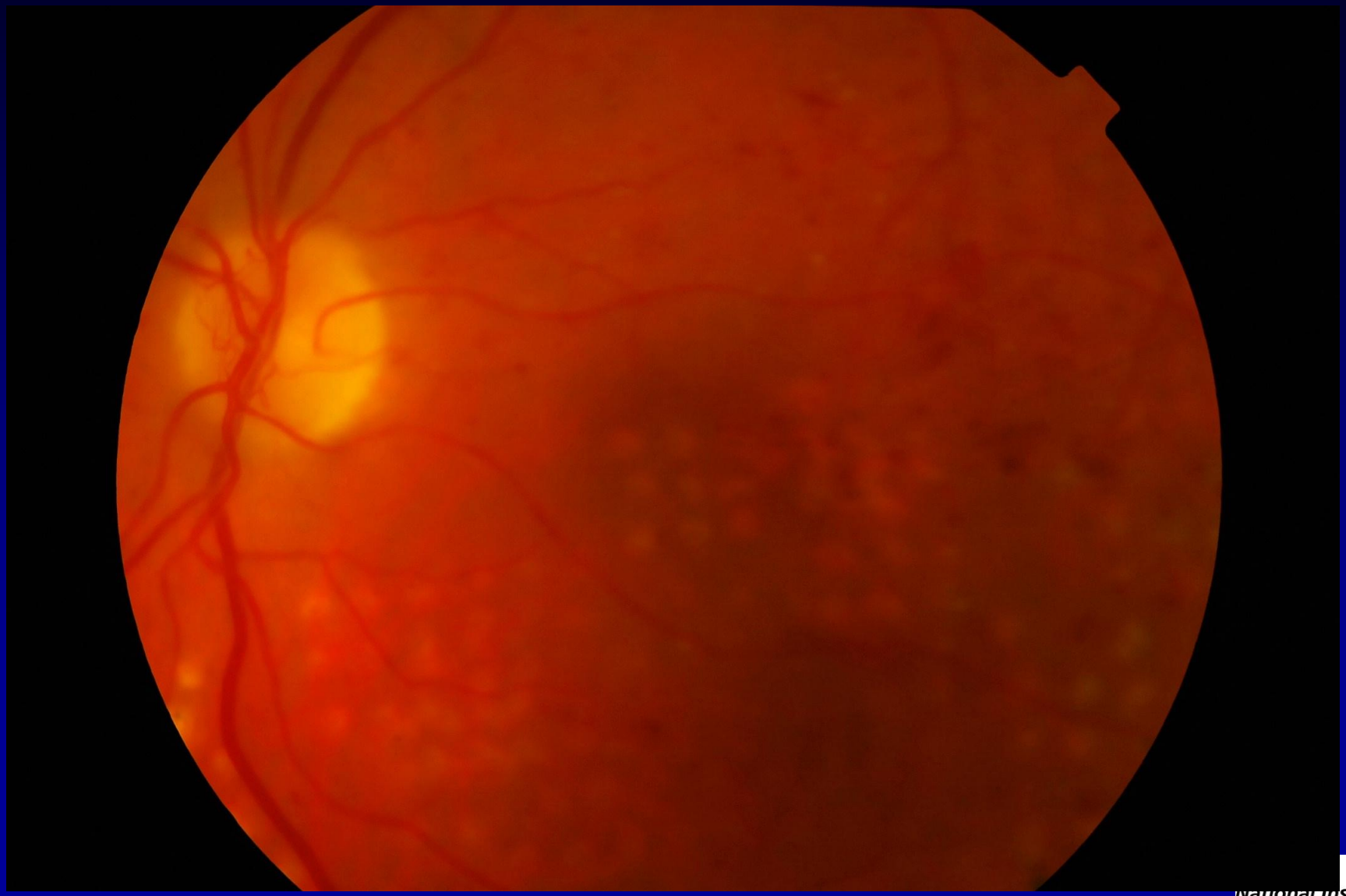
Pattern 3x3
and arc

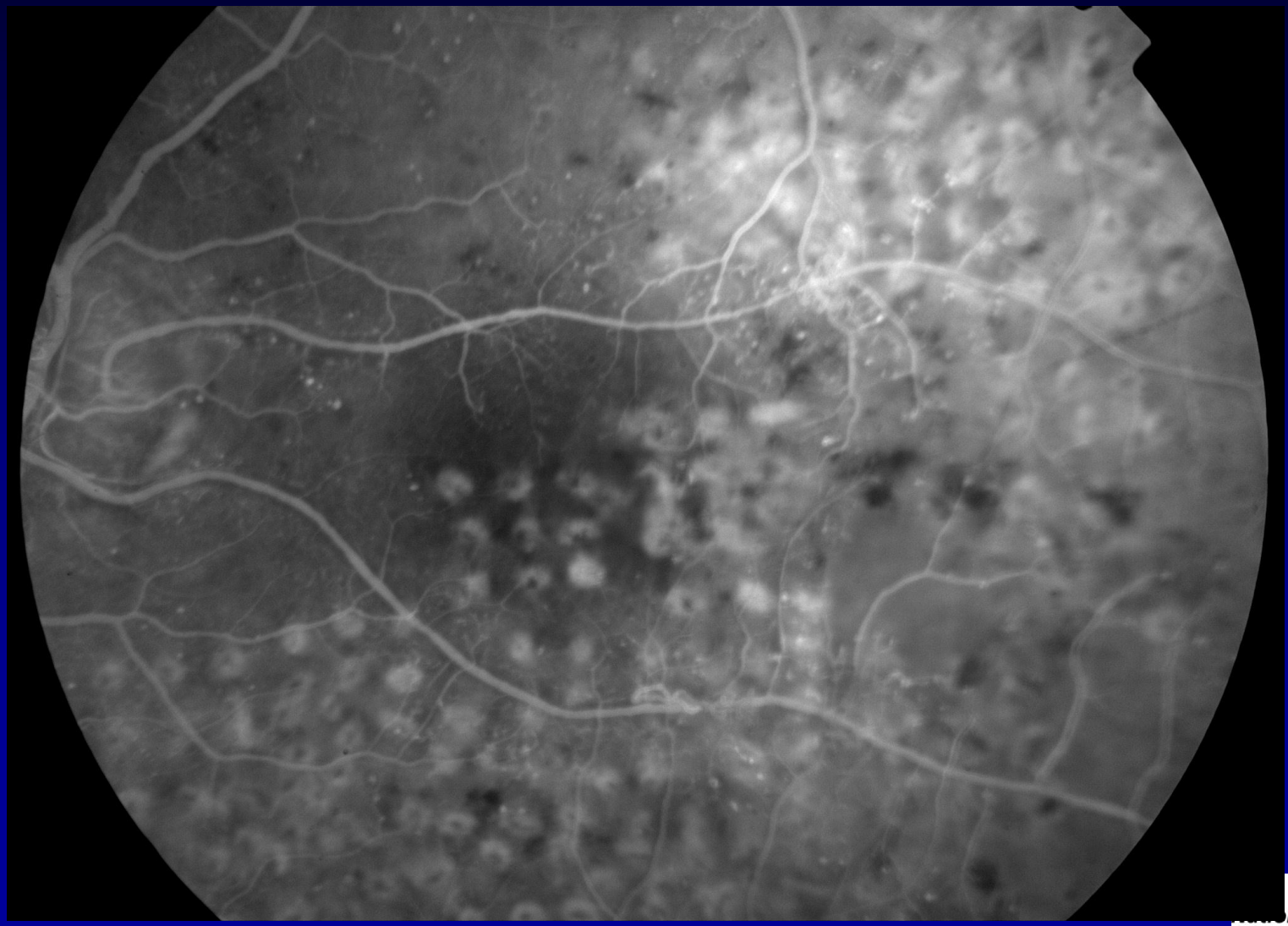
Settings:
20 msec,
450 mW,
400 microns

CAUTION

THIS MACHINE HAS NO BRAIN USE YOUR OWN







The newer lasers

- Navilas – Automated delivery
- Micropulse
- YLF/Selective Retinal Therapy
- 2RT

The Navigated Retina Laser

All-digital | More effective | More comfortable

Navilas® Laser System

All-digital retinal laser therapy

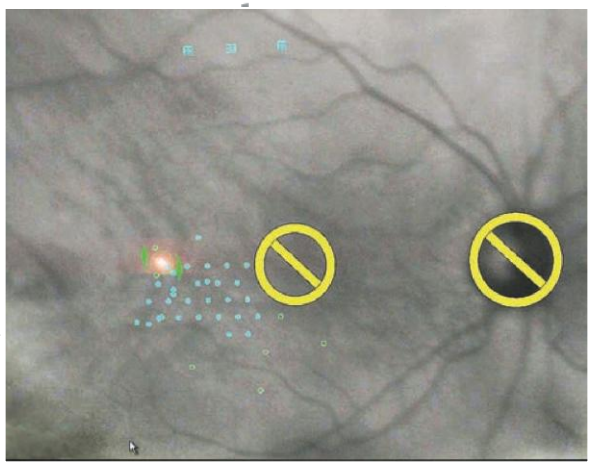
Navilas® is the first all-digital system for navigated focal and peripheral laser treatments.

The key elements of laser therapy are effectively integrated into one smart solution.

Structured treatment workflow

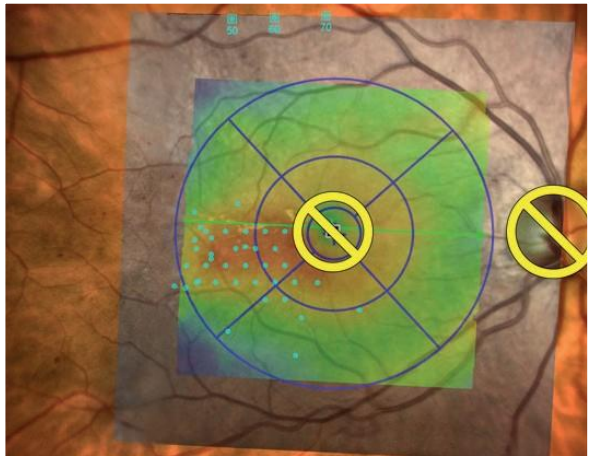
Navilas® uniquely provides retinal specialists with an all-digital treatment workflow, enabling precise, comprehensive care and bringing back confidence in laser therapy.

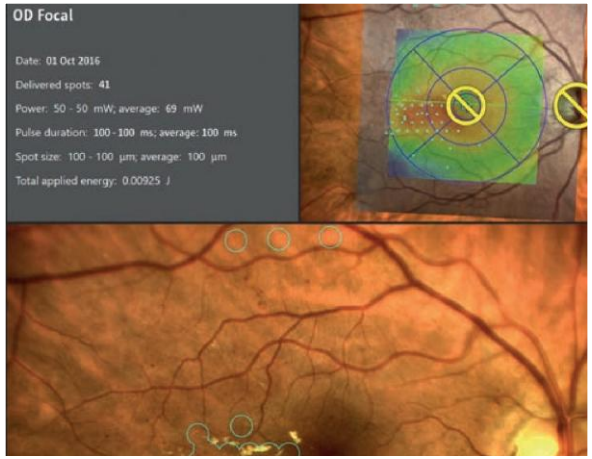
Digital Fundus imaging



Target-assisted Laser Treatment

Digital Treatment Planning



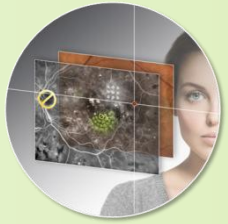


Digital Treatment Report

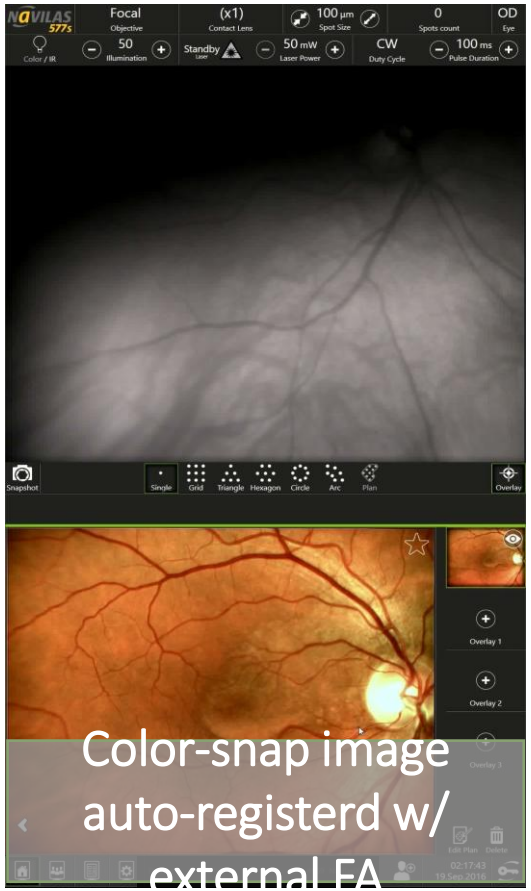
Navigated Macular Laser Treatment

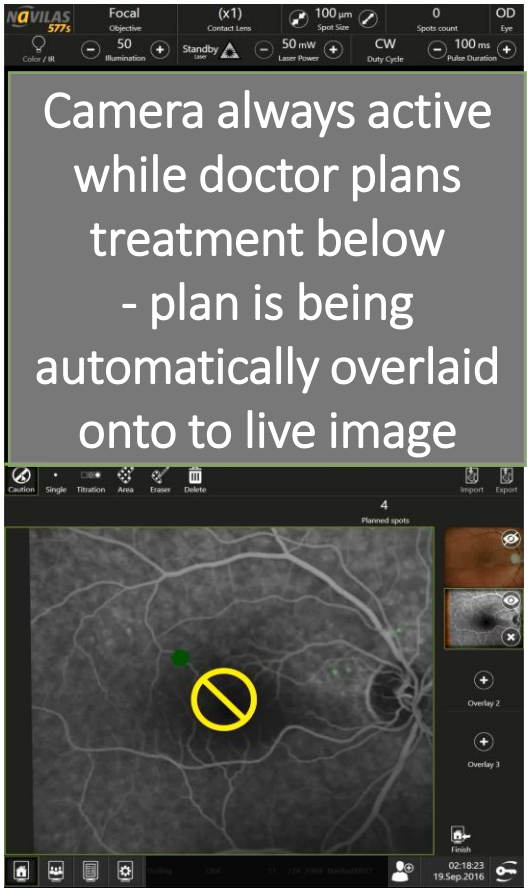
Image

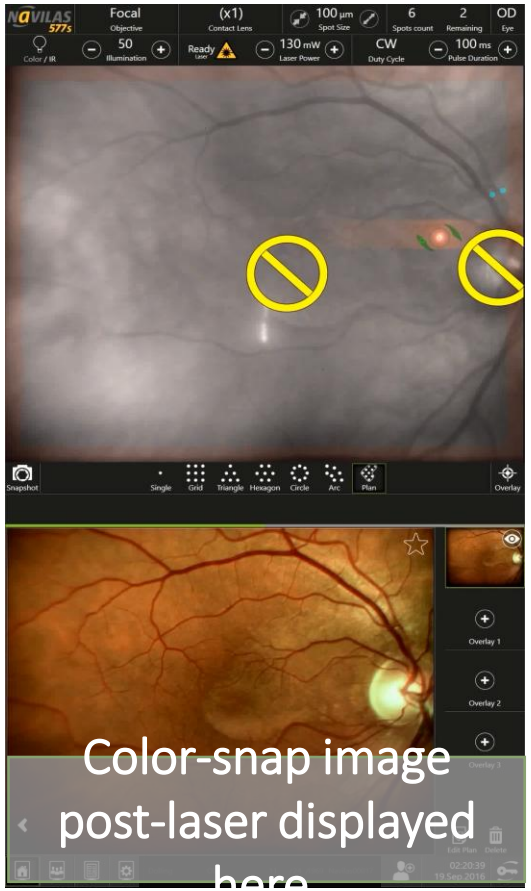
Plan



Treat





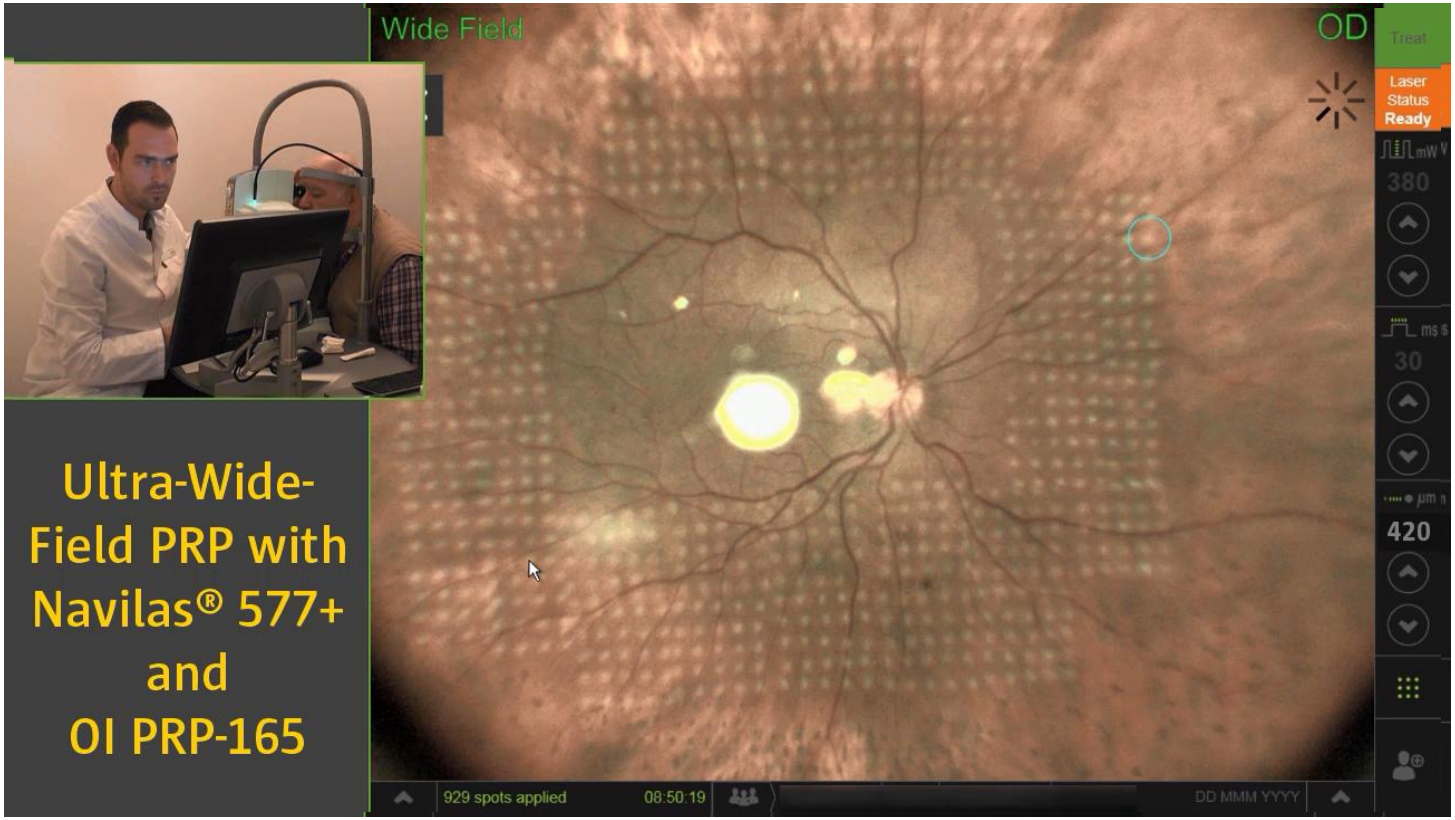


Leaking MA in Macular Edema

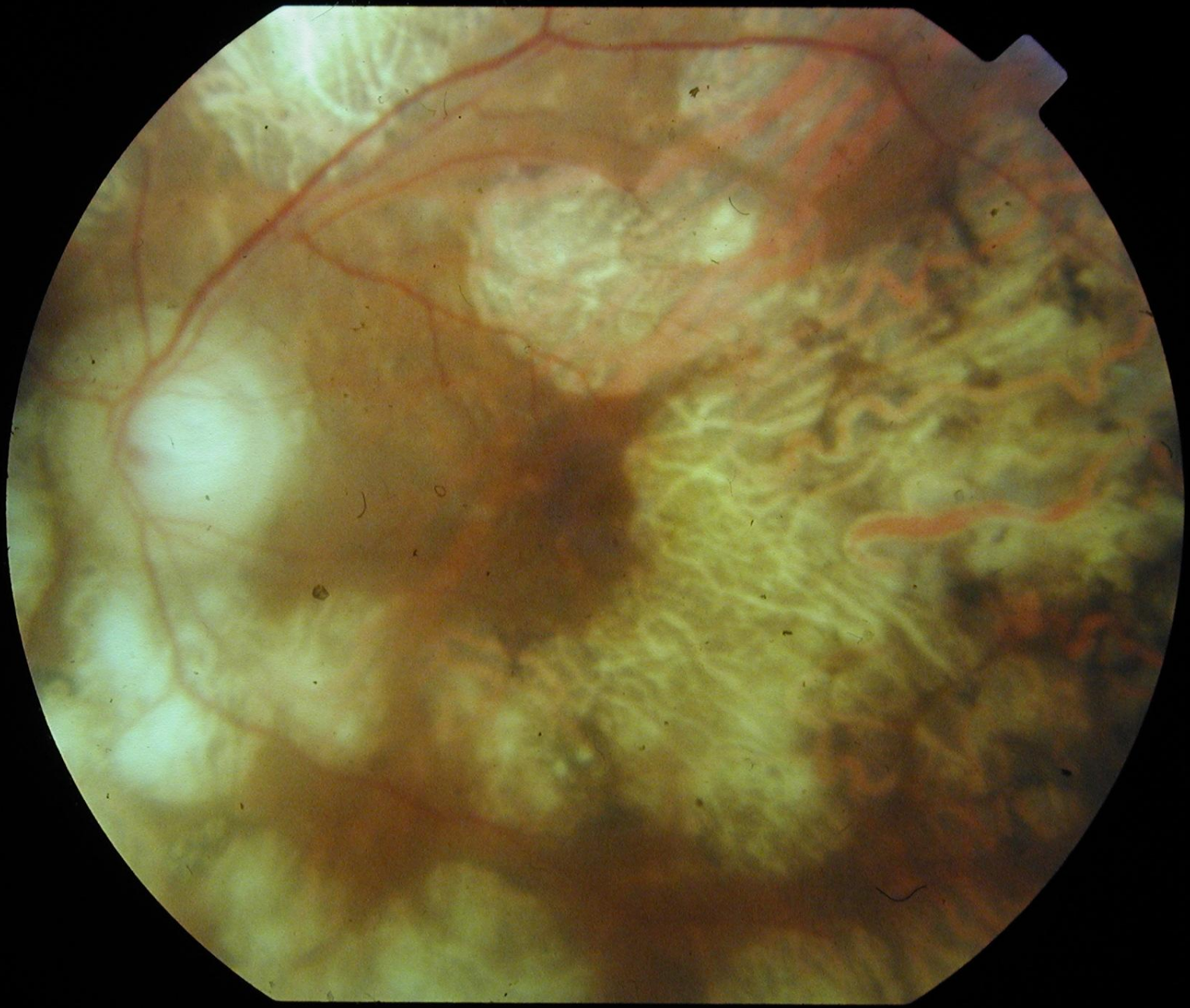
(W. Lloyd Clark MD, Columbia SC)

Faster treatment with better patient comfort

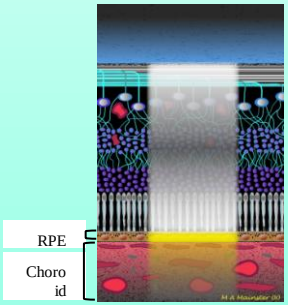
- Fast patterns with 10-30 ms pulses
- Navigated patterns
- Wide static field-of-view



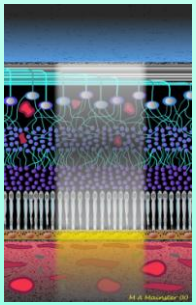
Micropulse Diode Laser



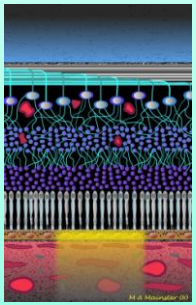
Subthreshold Photocoagulation - Micropulse



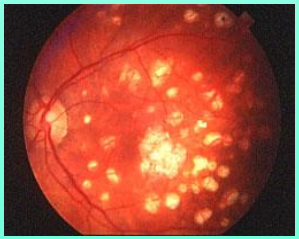
Continuous-Wave,
Conventional – DRS / ETDRS

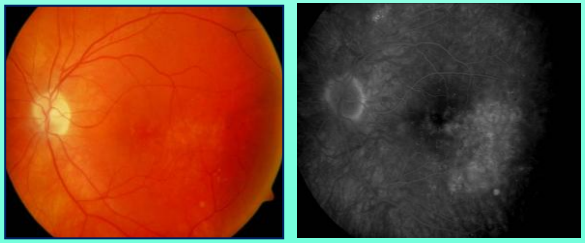


Modified
ETDRS

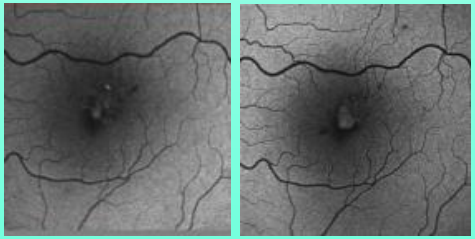


MicroPulse
Invisible by Biomicroscopy





Subthreshold CW Laser[1]
532 nm; 200 µm spot; 50 mW; 30 ms

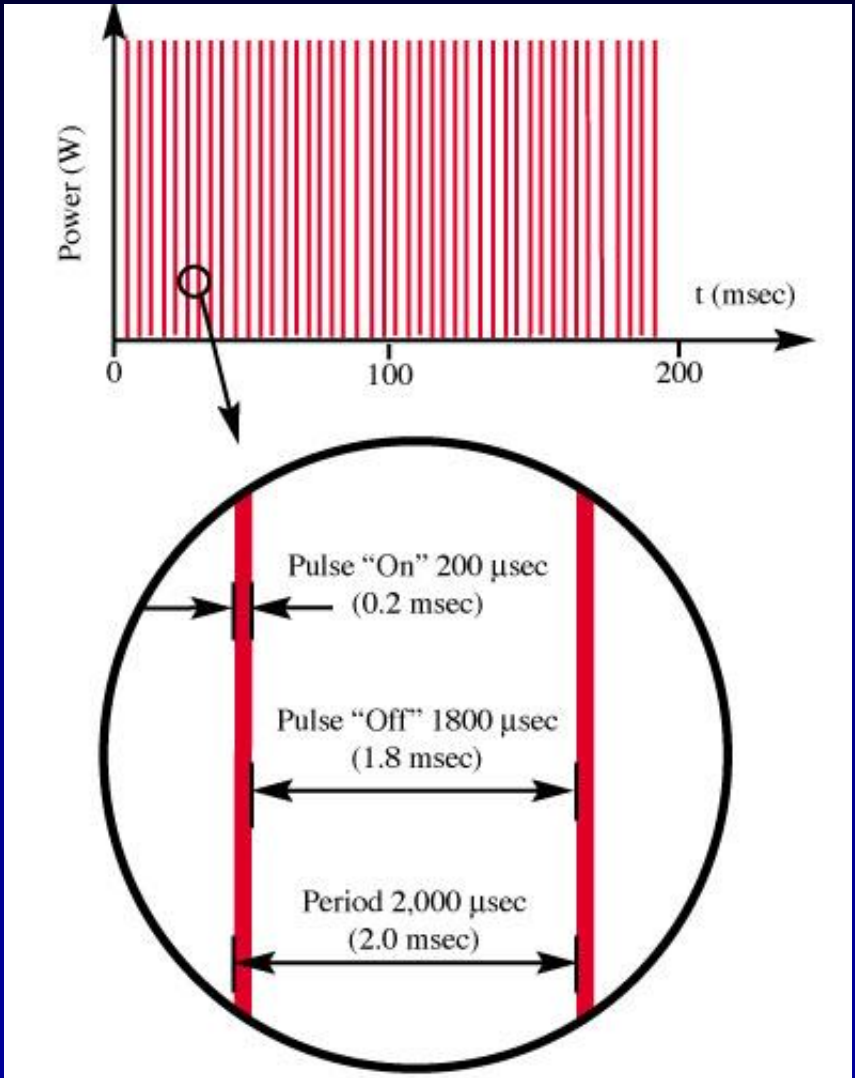


FAF Pre and 6 months post two IRIDEX MicroPulse[2]
577 nm, 100 µm spot, 250 mW, 200 ms

1. Compliments of Sam Mansour, MD, Warrington, VA
2. Vujosevic, et al Retina 2015

Illustrations compliments of Martin A. Mainster, PhD., MD, FRCOphth

Micropulse laser



Duty Cycle

Pulse width = 100 microseconds

Interval width = 1,900 microseconds

Total time = 2,000 microseconds

Duty cycle is : 100

------- x 100 = 5%

2,000

Selective Retinal Therapy

- 30 laser pulses
- Nd:YLF-Laser
  - 527 nm
  - **1.7 microsec**
  - 100 Hz
- 450-800 mJ/cm(2) per pulse


Neodynium Yttrium Lithium Fluoride (Nd:Y
Laser
Stop
(527nm)
2µs
100Hz
200µm
30 pulses
MEDIZINISCHES LASERZENTRUM LÜBECK
Selective RPE Treatment

2RT

Wavelength
532nm

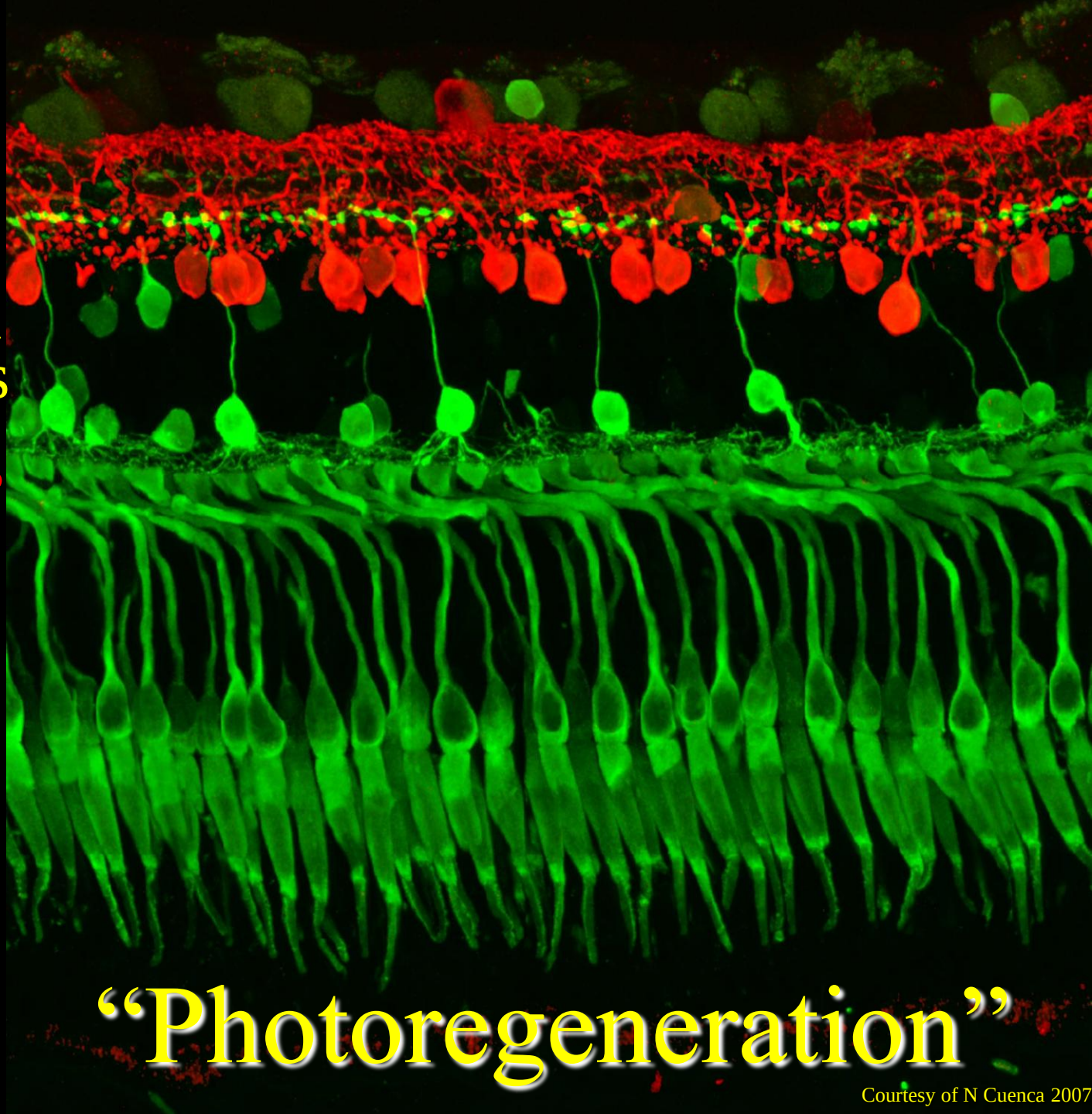
Pulse duration
3 nanoseconds

Discontinuous
Beam
Distribution

Max energy
1mJ/pulse

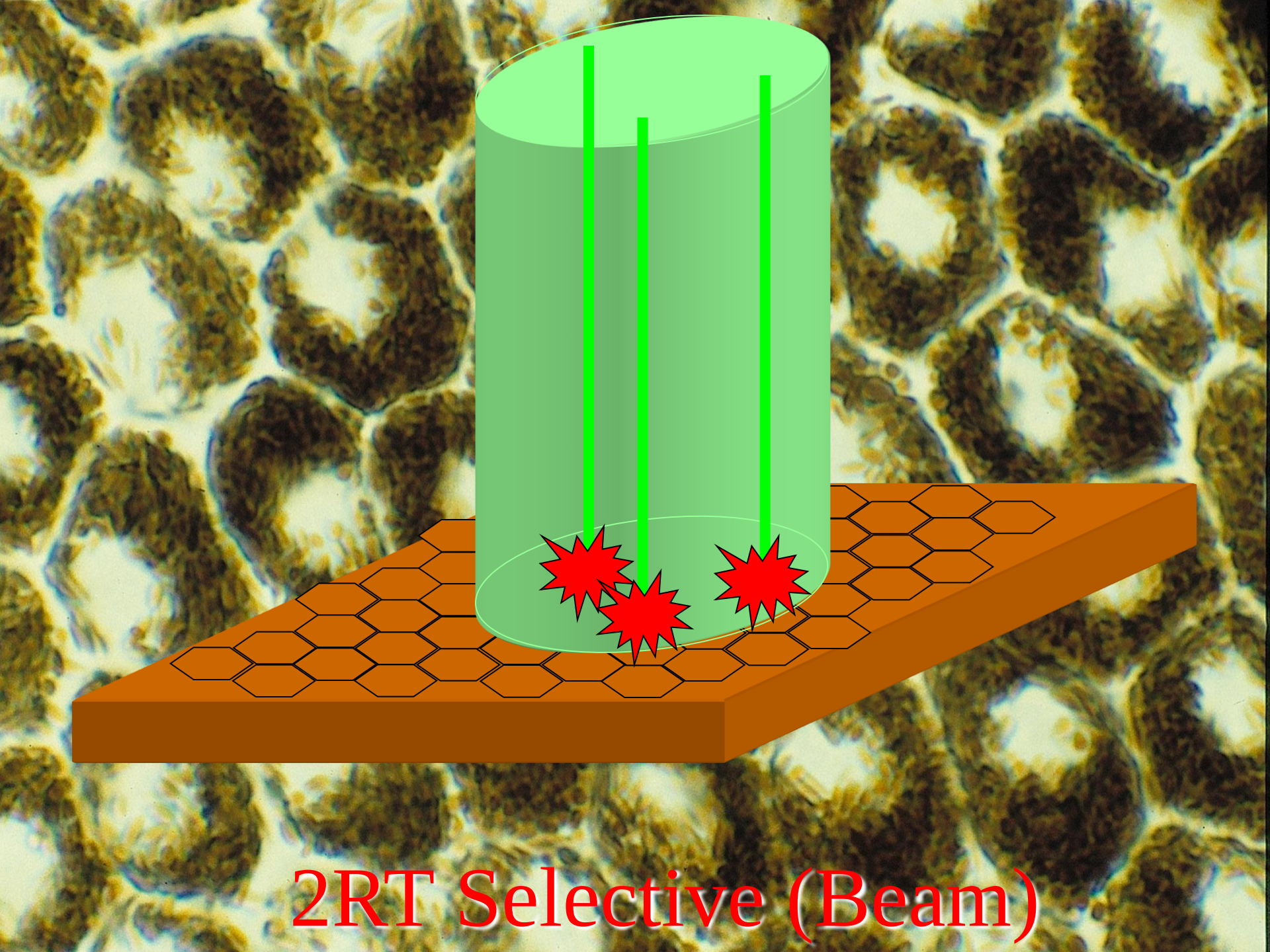
Spot size
400 microns

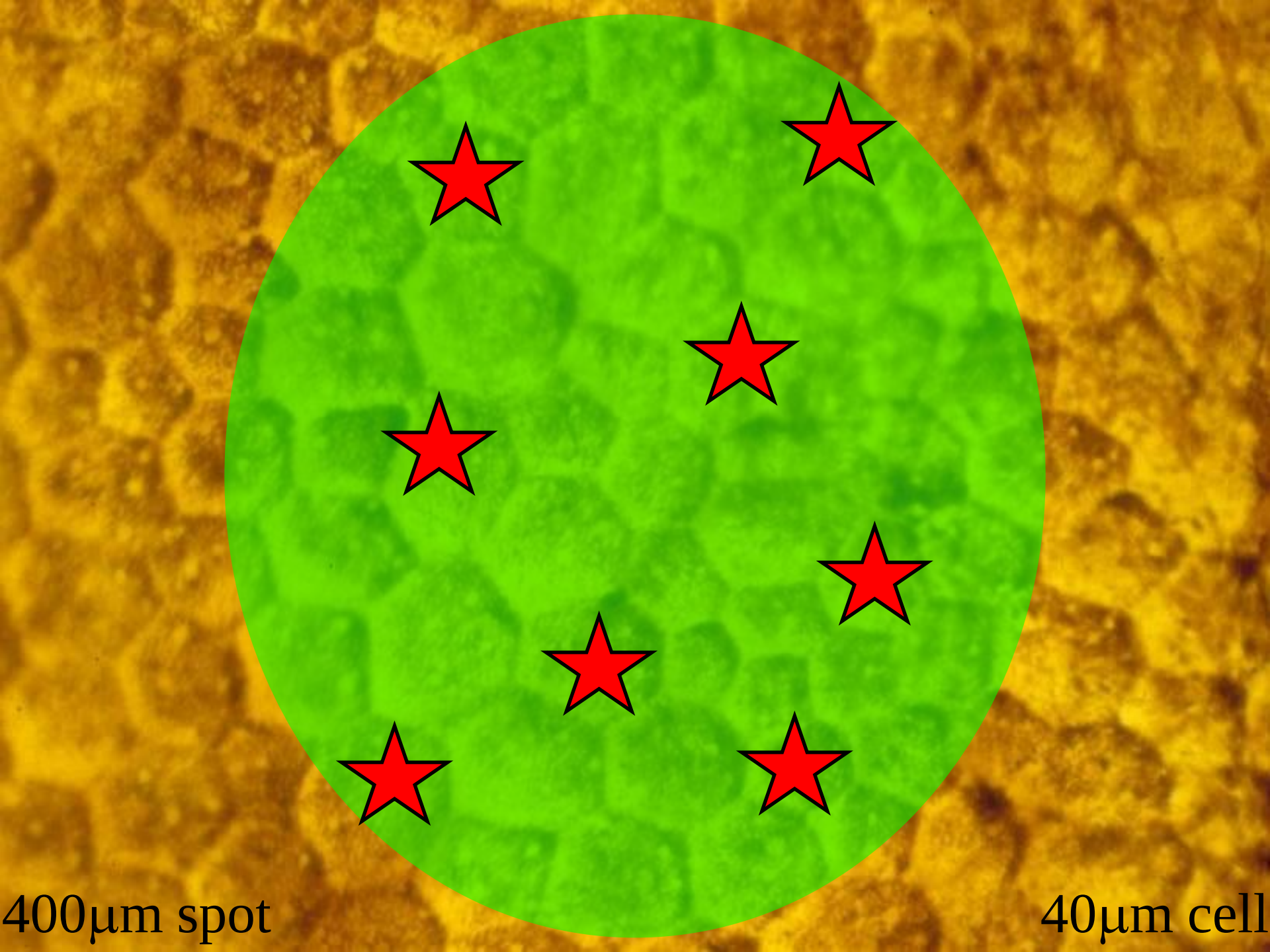
Not
SLT Laser

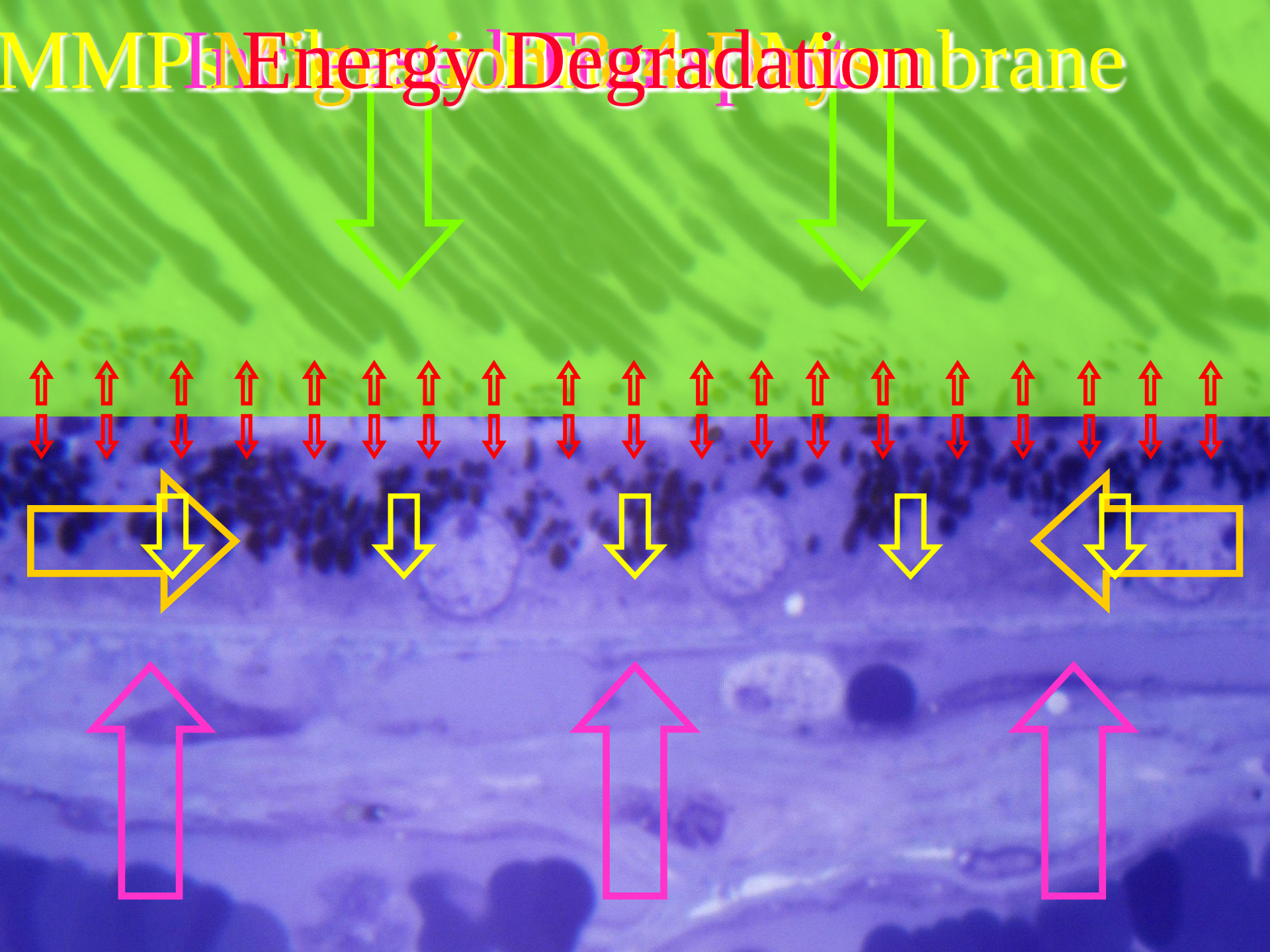


Ellex 2RT treatment parameters compared to standard macular photocoagulation.

	Ellex 2RT	Photocoagulation
Pulse Duration	3 nanoseconds	0.1 seconds
Fluence	0.2J/cm^2	160J/cm^2
Spot Size	400 microns	100 microns
Wavelength	532nm (green)	532nm (green)
Tissue Interaction	Intra-cellular Micro-bubble Formation	Thermal Coagulation


2RT Selective (Beam)

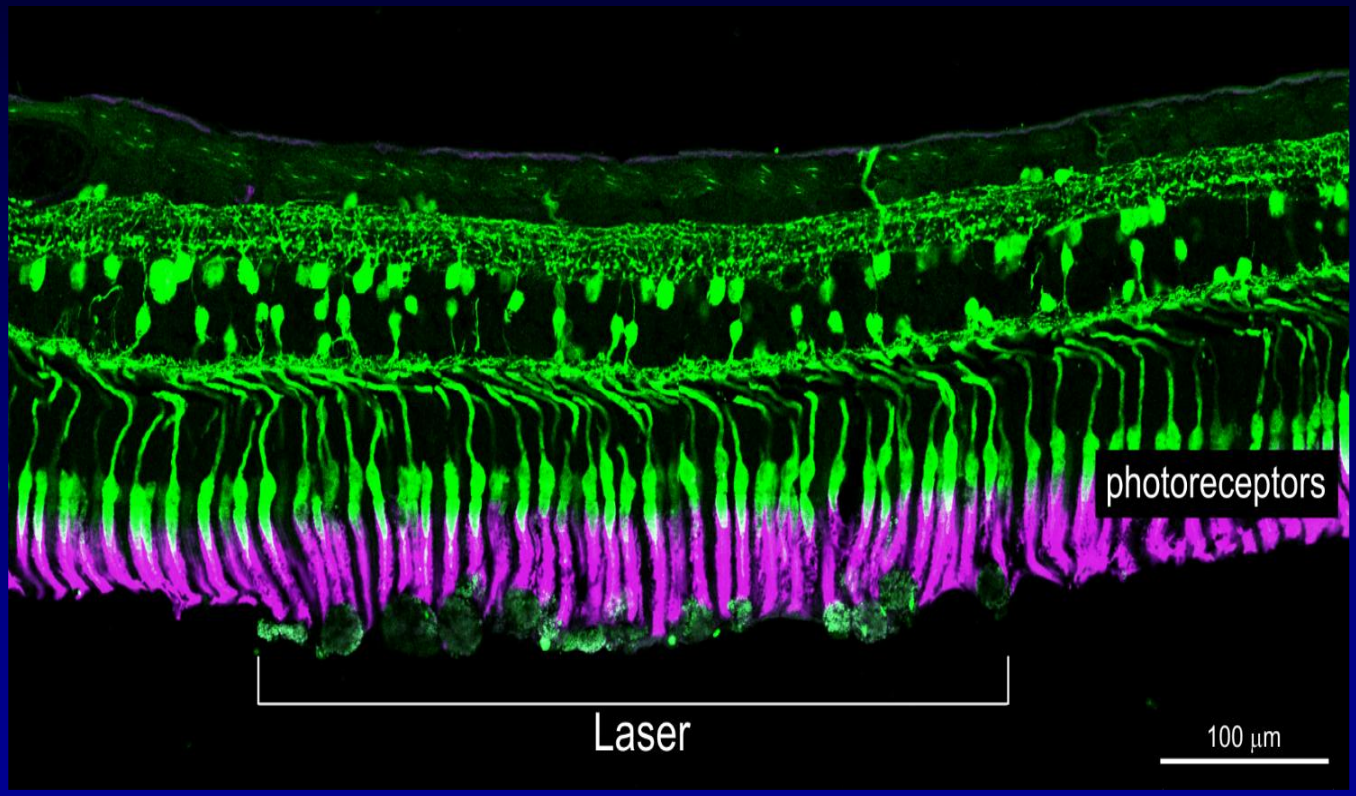

400μm spot
40μm cell


MMPIN
Energy Degradation
Energy Degradation
Membrane

Clinical: 1/52 Post 2RT live human Histology

- 2RT Applied at 0.3 mJ
- Photoreceptor layer preserved

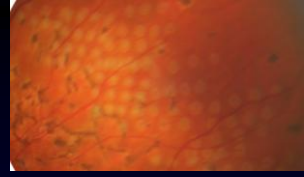
- Evidence of mononuclear cells at distal regions of the outer segments of the photoreceptors



RPE Removed

(1)Jobling et al. FASEB J. 29(2), 696-710 (2015)

Source: Prof Erica Fletcher (University of Melbourne)



Summary

- New treatment technologies
- Treat without causing harm
- Maintain macular and retinal anatomy
- Alter physiology only
- Nanosecond lasers …….
- Automated delivery of lasers
- Future…..

Thank You


MOORFIELDS
EYE HOSPITAL
ROYAL LONDON OPHTHALMIC HOSPITAL