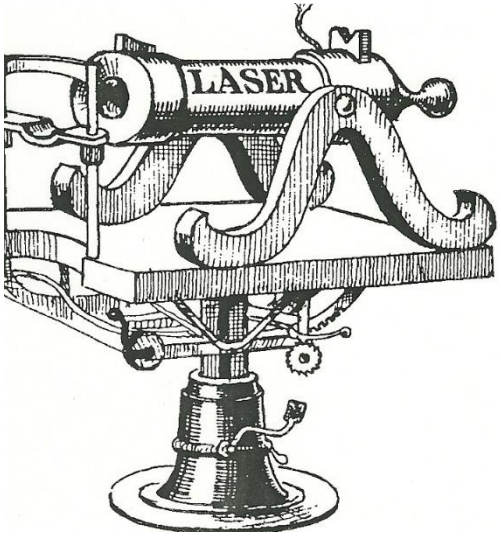
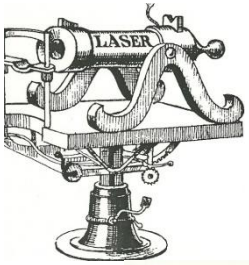
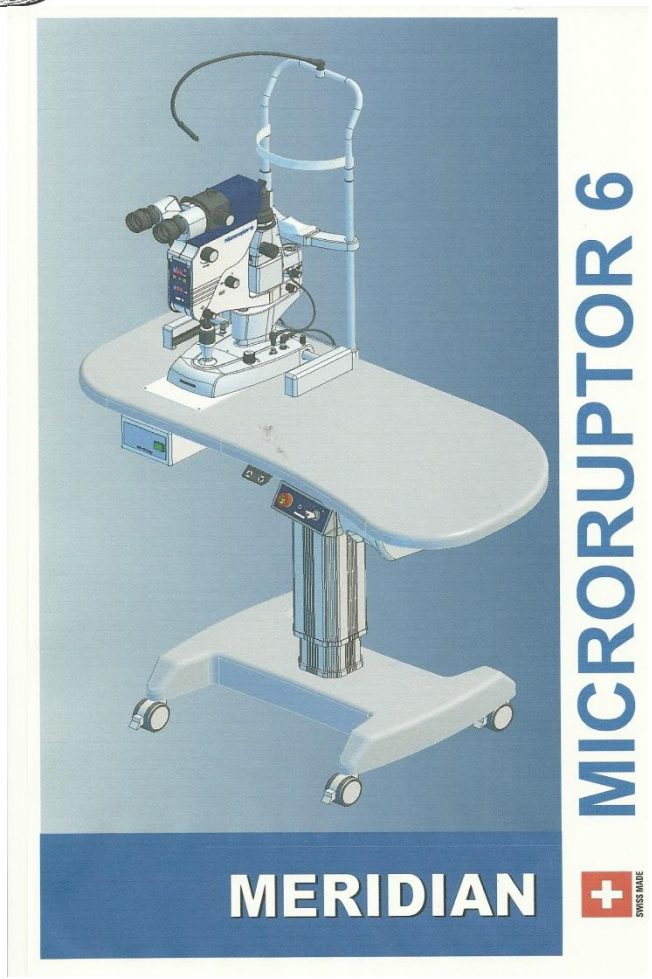
Market requirements for next generation fiber lasers for medical applications

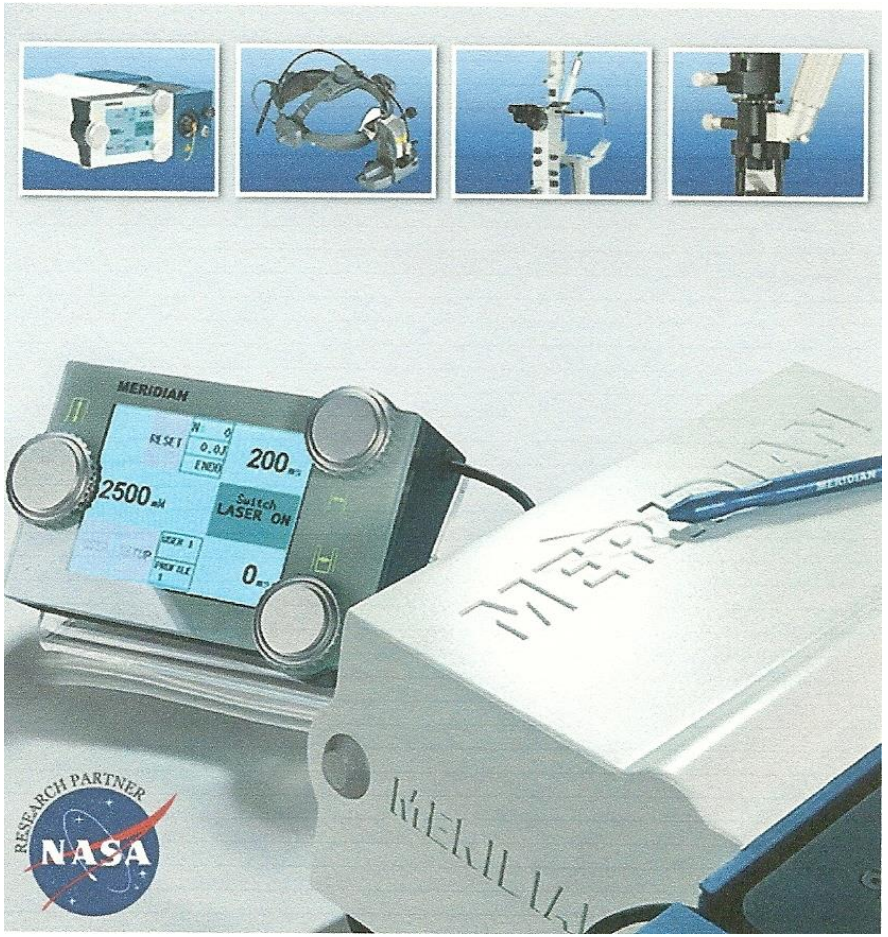


MERIDIAN

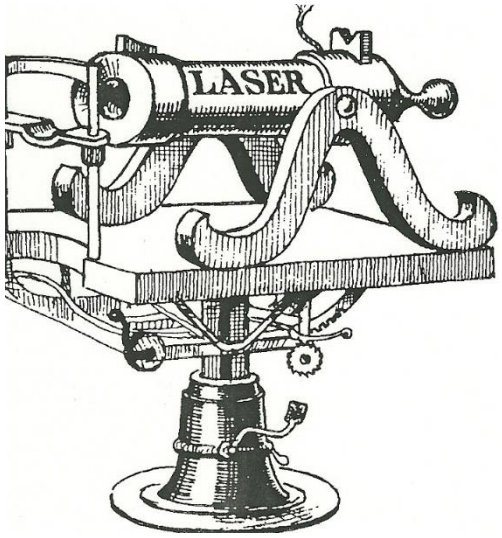
SWISS MADE


LASER


MICRORUPTOR 6
MERIDIAN
SWISS MADE

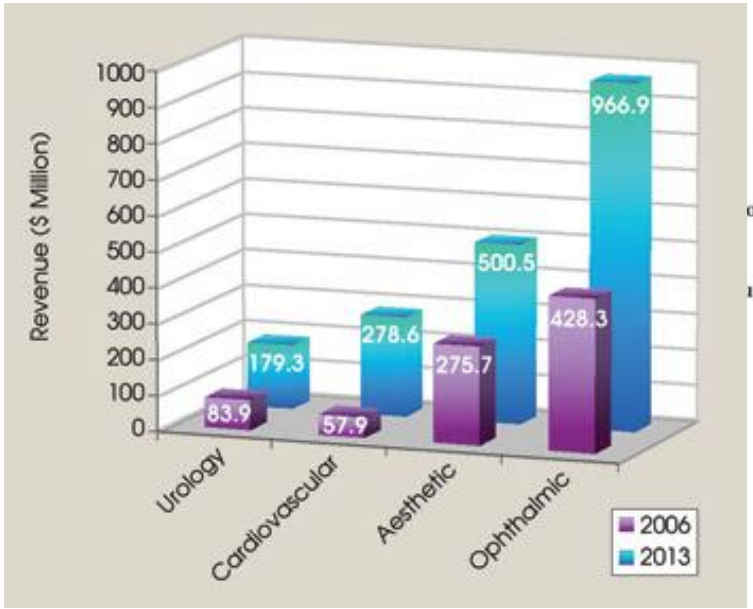

MERIDIAN
200
2500
Switch
LASER ON
0
RESEARCH PARTNER
NASA

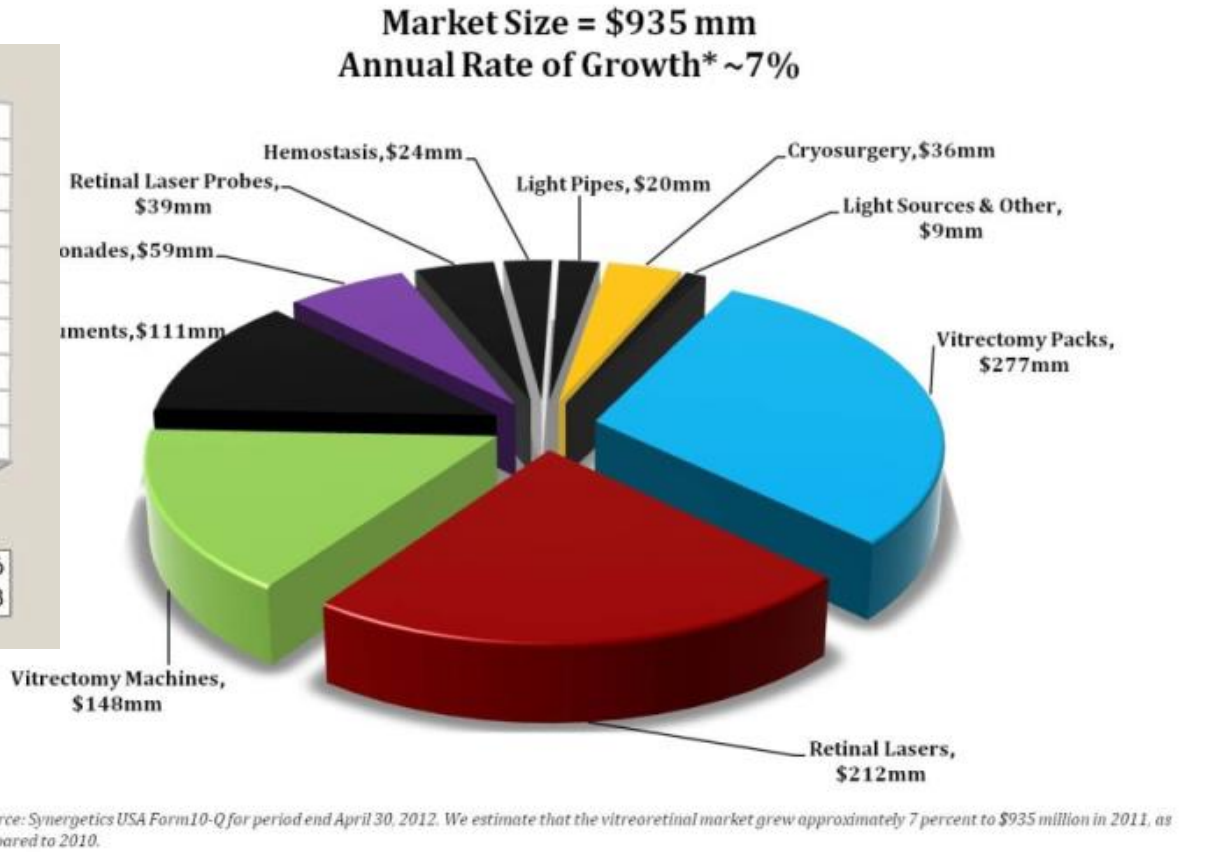
Market requirements for next generation fiber lasers for medical applications



-Suitable for selective treatment of tissue with minimal side effects
-Reliable and stable laser beam
-low cost and compact
-High MTBF / easy plug and play (splice and play)
-Flexible in wavelength
-Scalable

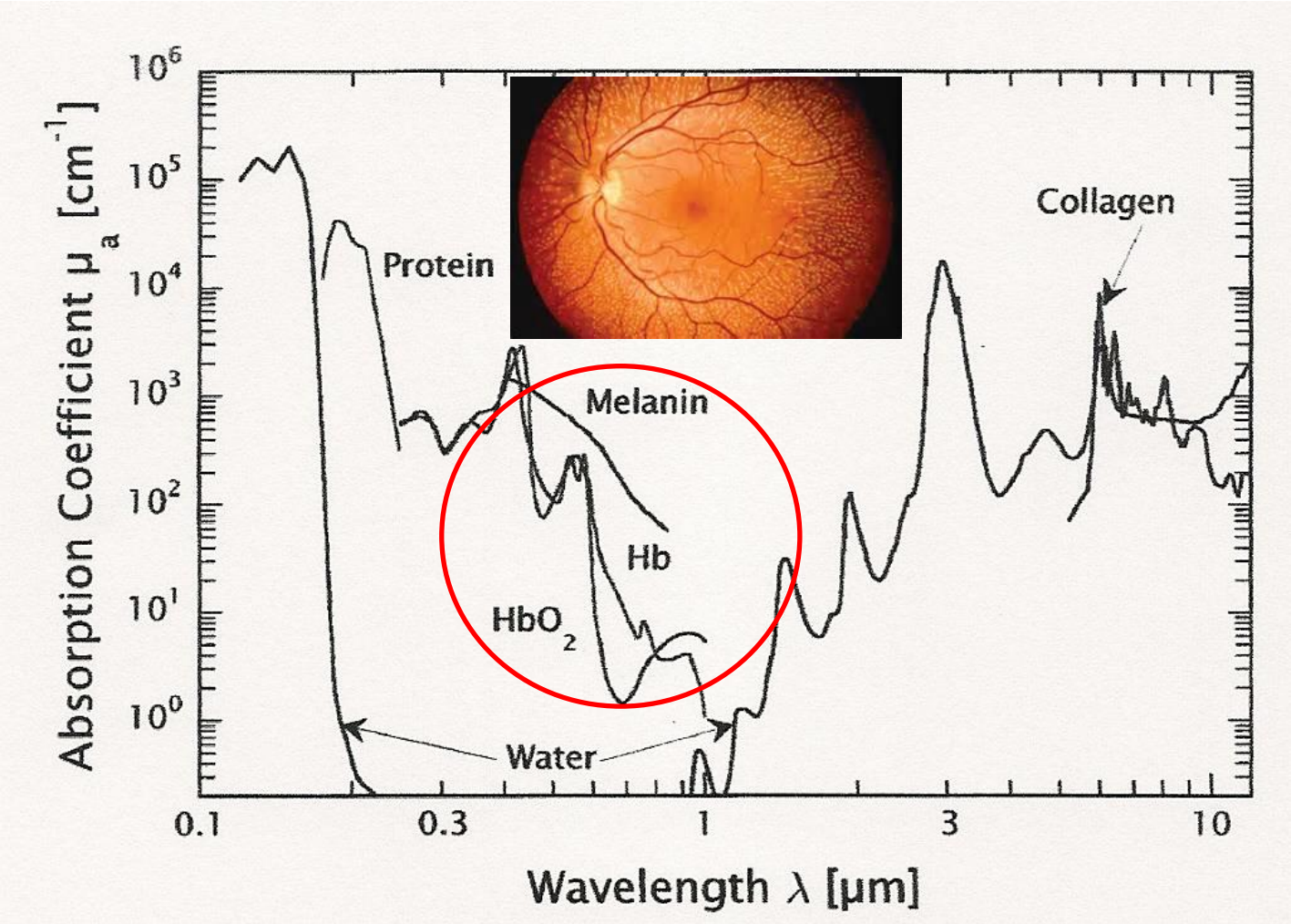
Medical Laser Market



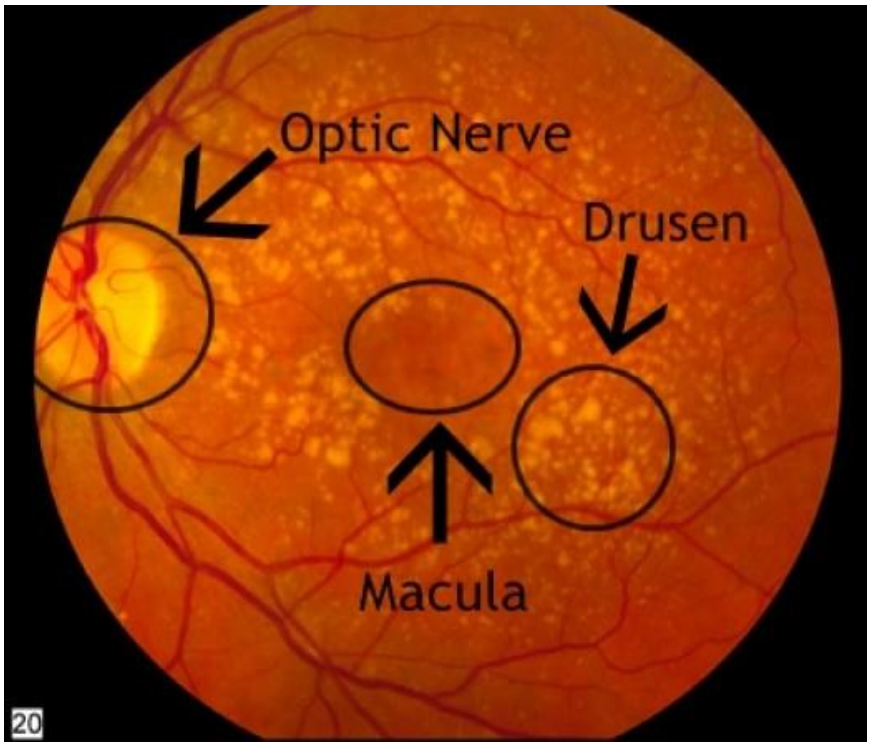


Medical Laser Market approx 15% of 9.4 B$ world Market (2014)

Low Power Optical properties of tissue



Standard treatment: Thermal coagulation of Retina



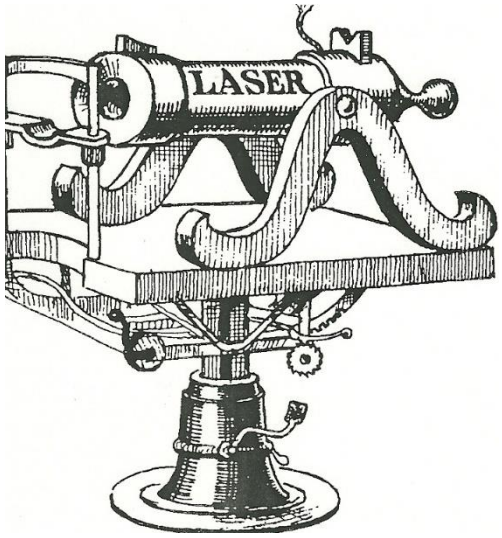
lÈsperance

In the laser spot a whitening of the Tissue is observed

Typical pulse duration: 0.5-1ms
Typical pulse power: 1-3W
Typical spot size 0.1-0.5mm

Standard laser: Nd:YAG 2f(532nm)
Argon (514nm)

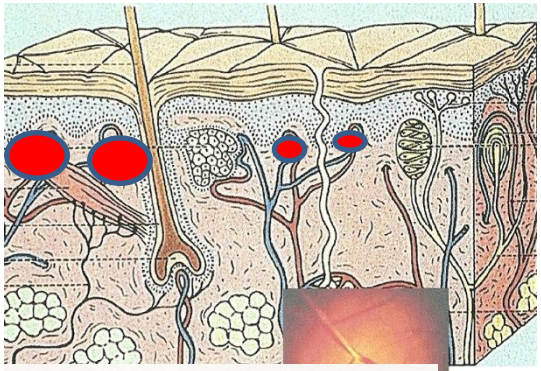
Market requirements for next generation fiber lasers for medical applications

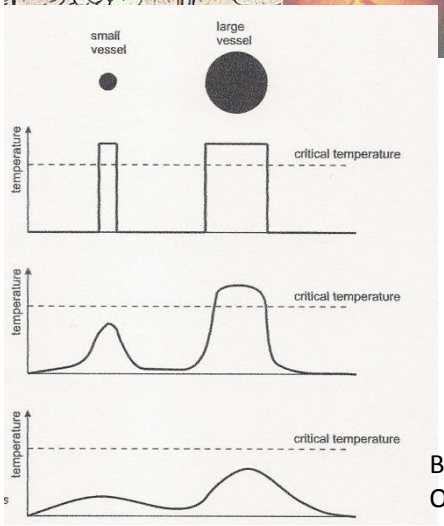


-**Suitable for selective treatment with minimal side effects**
-Reliable and stable
-low cost and compact
-High MTBF / easy plug and play (splice and play)
-Flexible in wavelength
-Scalable

Selektive Laser Treatment

Example: Portwine stain





B.Cox 2013
Optics in Medicine

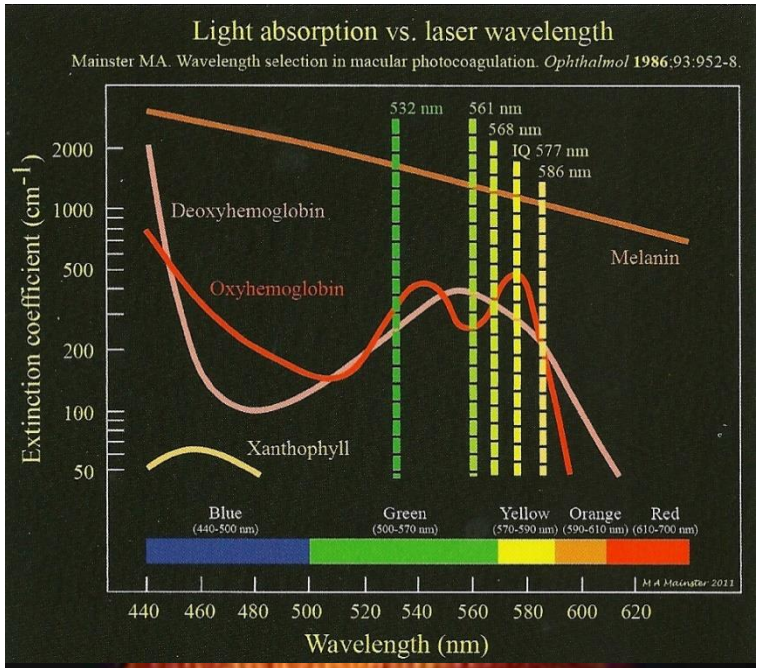
How to achieve selective irradiation:
-right wavelength
-right irradiation time
-right energy density

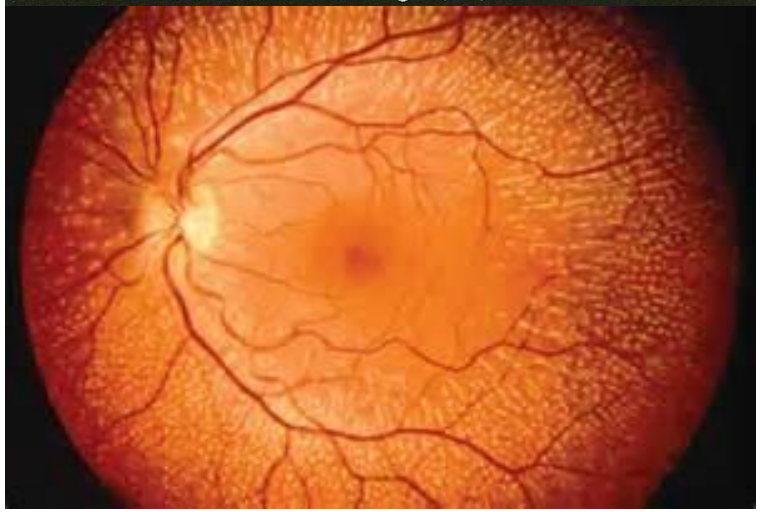
Heat relaxation time

$t = d^2/16D$ d= diameter of heated cylinder
D= diffusion constant tissue appr. $10^{-7} m^2/s$

Diffusion velocity in tissue: 0.7µm in 1µs

Medical Markets: advantage yellow radiation





Advantages yellow:

-less scattering in ocular media and aging lenses

-no absorption of Xantophyll and therefor treatment close to macula possible

-highest ratio HbO/Melanin optimal for vascular structures

-low scattering in retinal layers leads to smaller volumes, needs less power, and less side effects but requires shorter pulses

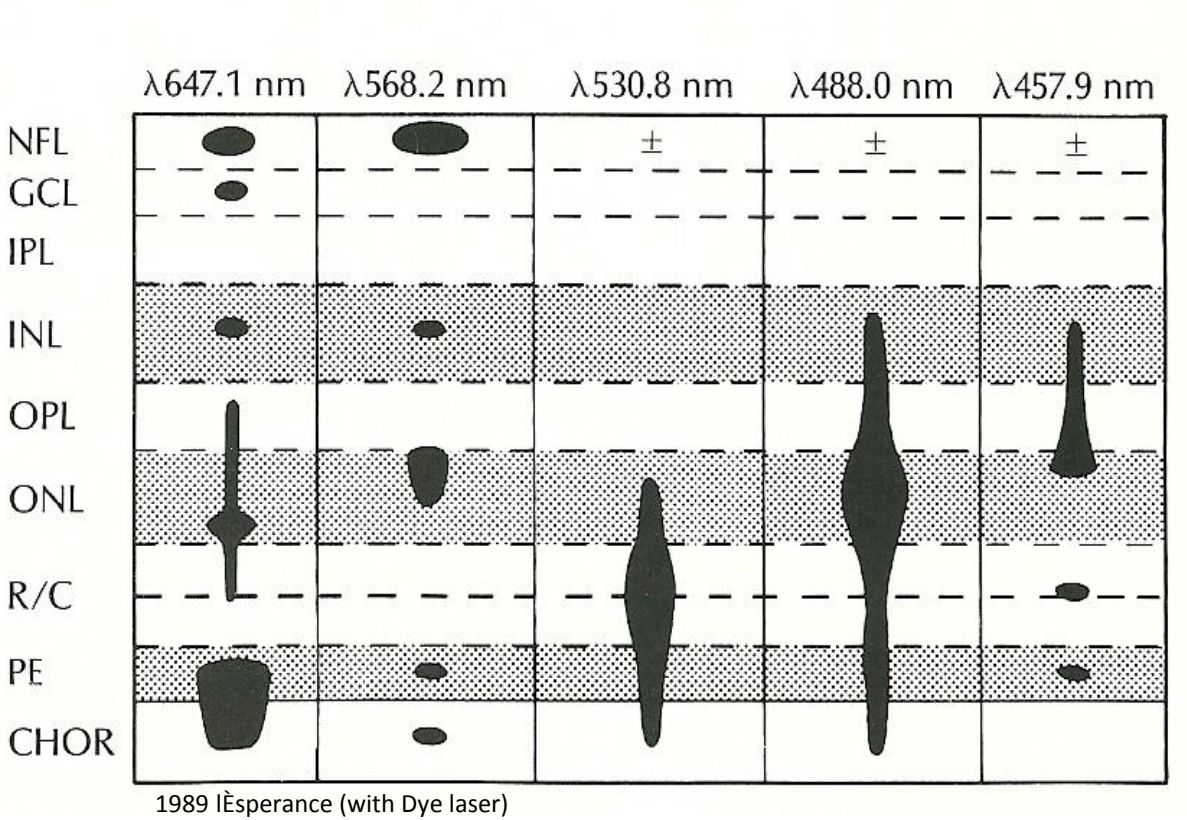
-high choriocapillaris absorption leads to more uniform effects in irregular fundus pigmentation

-less scarring

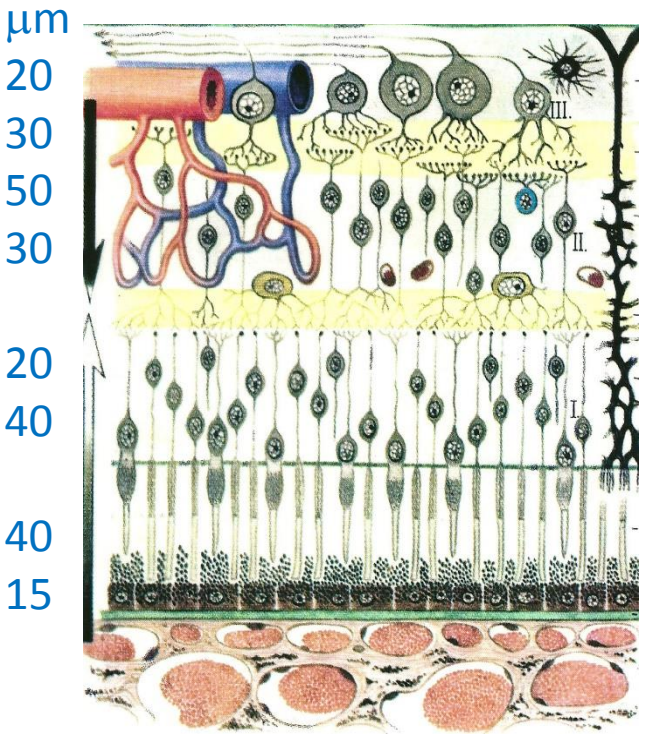
-less discomfort of patient

Yadav et al,Ind. J.Ophtalm.62(1), 2014

Optical properties of retina: Local Selective Absorption

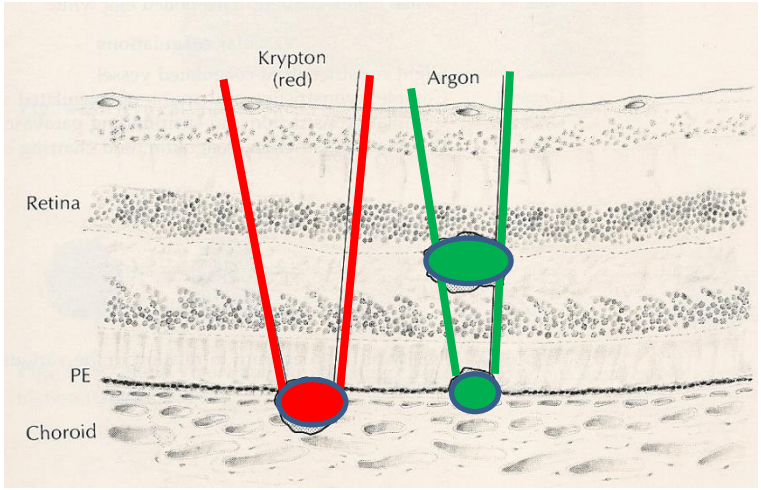


1989 lÈsperance (with Dye laser)

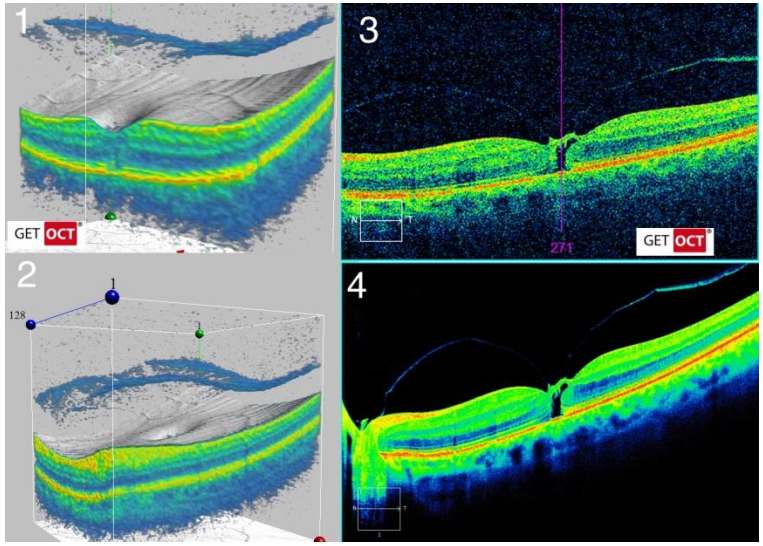


(Thiel)

Selektive «Subthreshold» Laser Treatment



lÈsperance(1989)

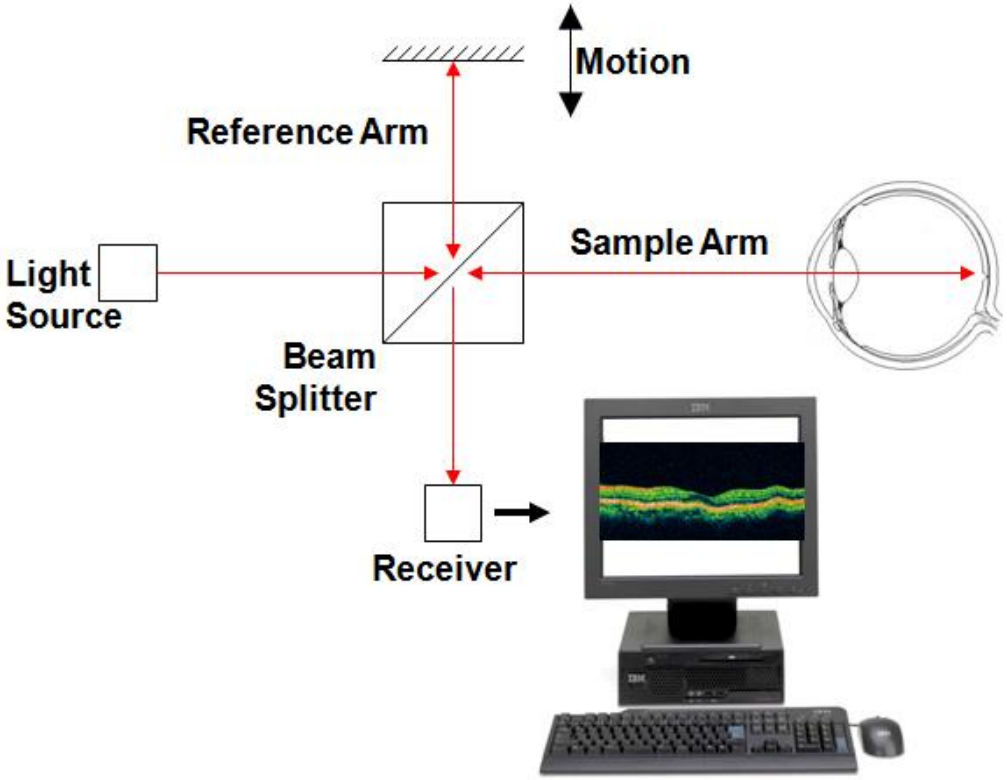


(Google Pictures)

Effect not visible with microscope

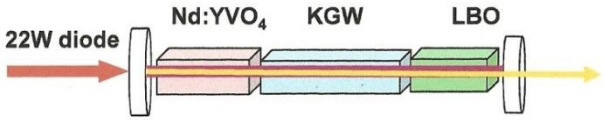
Solution:

OCT (Optical Coherence Tomography)



Medical lasers for the yellow-orange spectral region

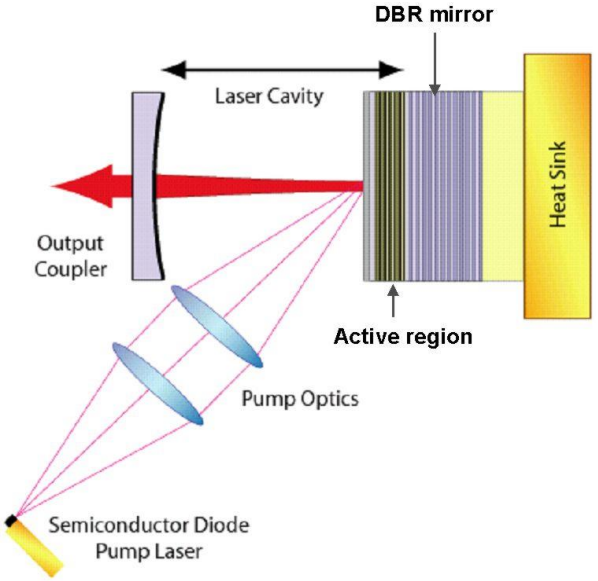
Raman-DPSSL



Dekker, Pask and Piper (submitted to *Optics Letters*) report 700mW CW output at 588nm by intracavity SHG of 1196nm 1st -Stokes of KGW pumped intracavity by 1064nm from diode-pumped Nd:YAG, at diode-yellow efficiency ~5%.

KGW: KGd(WO4)2

OPDL



e.g. Coherent/Philips

FL/Raman-FL

«old» lasers: Ar, Kr, Dye Lasers ; lasers to come: Diode lasers

Fiberlaser for the yellow-orange spectral region

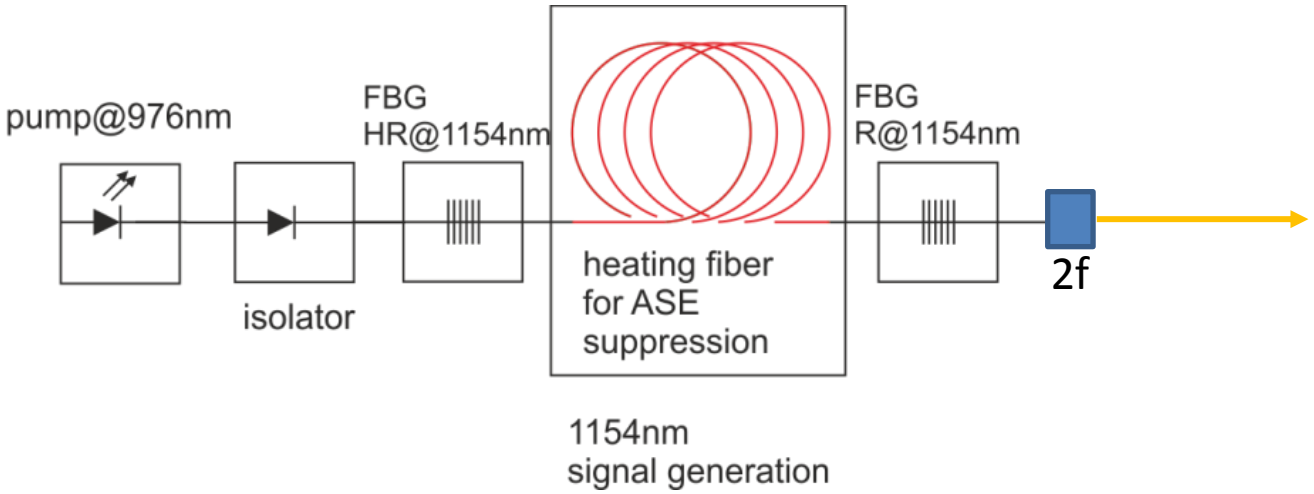
Raman-DPSSL
Diode Pumped Solid State

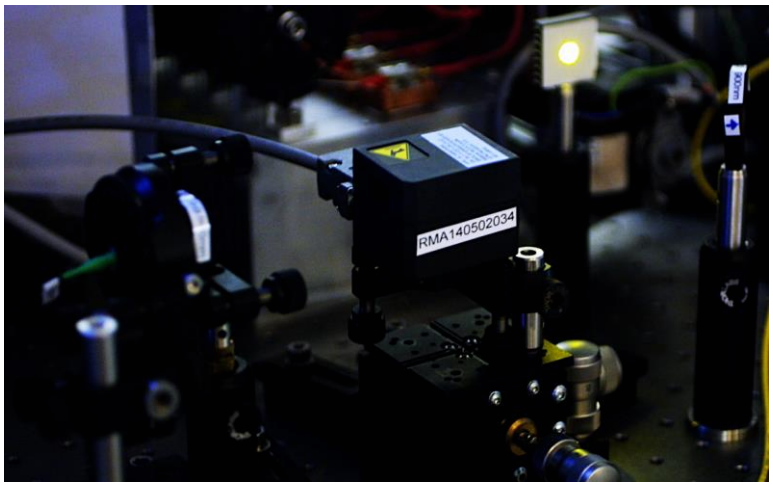
OPDL
Optically Pumped Diode/VECSEL

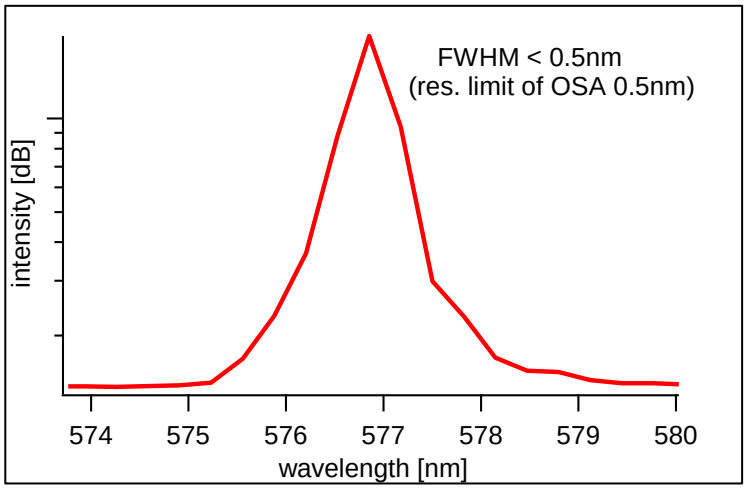
FL/Raman-FL
Fiberlaser

- What is the problem?
  - 1154 nm light required to frequency double it to 577 nm
  - Lasing of ytterbium doped fibers occur preferentially at 1030 nm (2f = 515nm)
- Possible solutions:
  - Yb fiber laser at 1100 nm and subsequent Raman shift to 1154 nm
  - Yb fiber laser at 1100 nm with Raman fiber cavity at 1154 nm
  - Yb fiber laser at 1154 nm with heated fiber

Yellow Fiberlaser (Romano, Ryser et al SNFL)

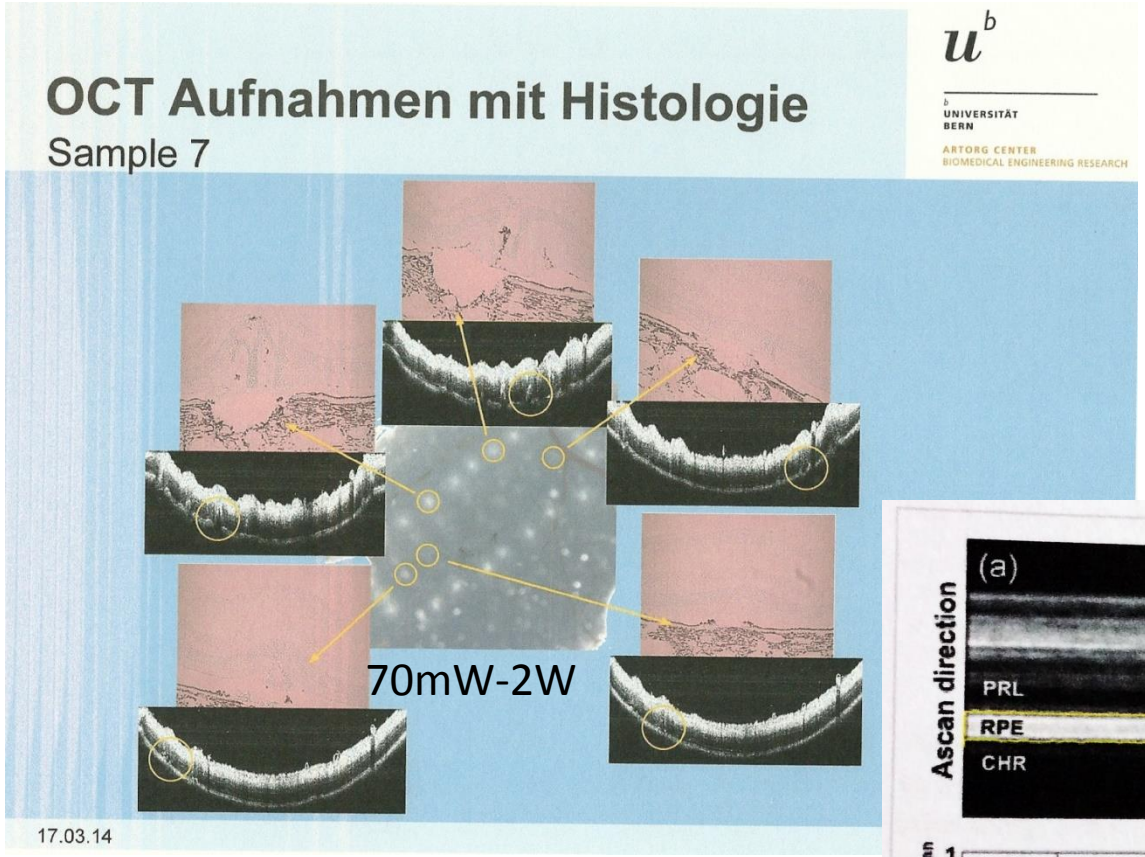






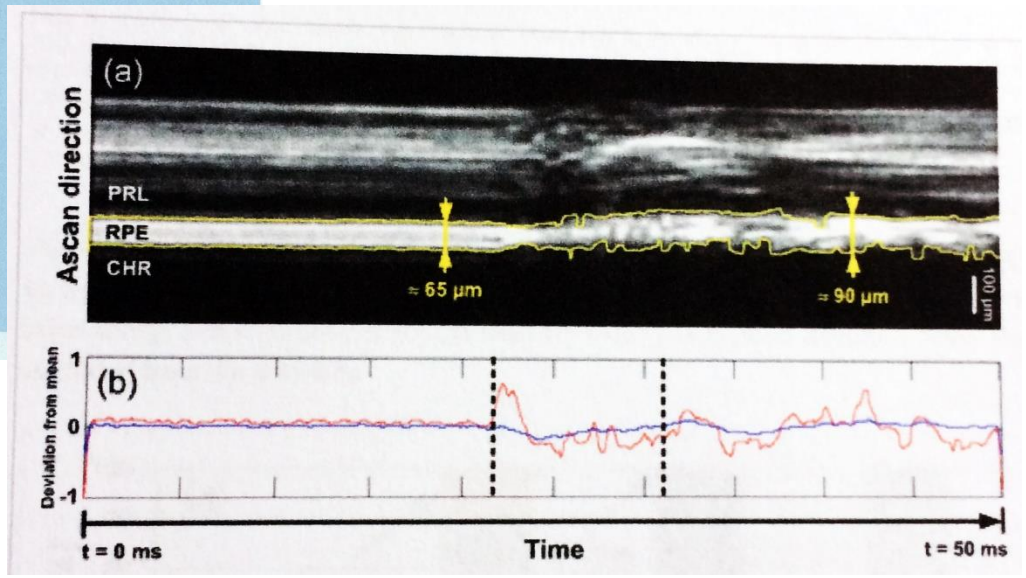
First Results: Combination of A-Scan OCT with 577nm Laser Beam

Steiner, Kowal et al



M scan
A scan 60kHz
Resol. approx 2µm
Integ.time 14µs

Steiner et al,Phot. Journ. IEEE Dec 2014



Advantages of FL

Performance

Stable SM laser

Efficient Frequency Doubling

Flexibility

Power scalable (limits are ASE and nl-effects in SM Fiber-improvement: large core fibers)

Simple change of wavelength

Combiner and other fiber modules available on market (increasing component market)

(e.g. integration of fiber sensors)

Repair by Splicing

Investment Costs/Cost of ownership

Low costs of fibers (Bragg grating mask)

Compact, modular assembly

Lifetime, MTBF

Vision: «All in Fiber» Ophthalmic Treatment system

(12) **Patent Application Publication** (10) **Pub. No.: US 2008/0058780 A1**
Vogler (43) **Pub. Date: Mar. 6, 2008**

(54) **LASER SYSTEM FOR REFRACTIVE SURGERY**

(75) Inventor: **Klaus Vogler**, Eckental (DE)

Correspondence Address:
J. Andrew Lowes
Attorney for Applicants
Haynes and Boone, LLP
901 Main Street, Suite 3100
Dallas, TX 75202-3789 (US)

(73) Assignee: **WaveLight AG**, Erlangen (DE)

(21) Appl. No.: **11/835,283**

(22) Filed: **Aug. 7, 2007**

(30) **Foreign Application Priority Data**

Aug. 7, 2006 (EP) 06 016 465.4

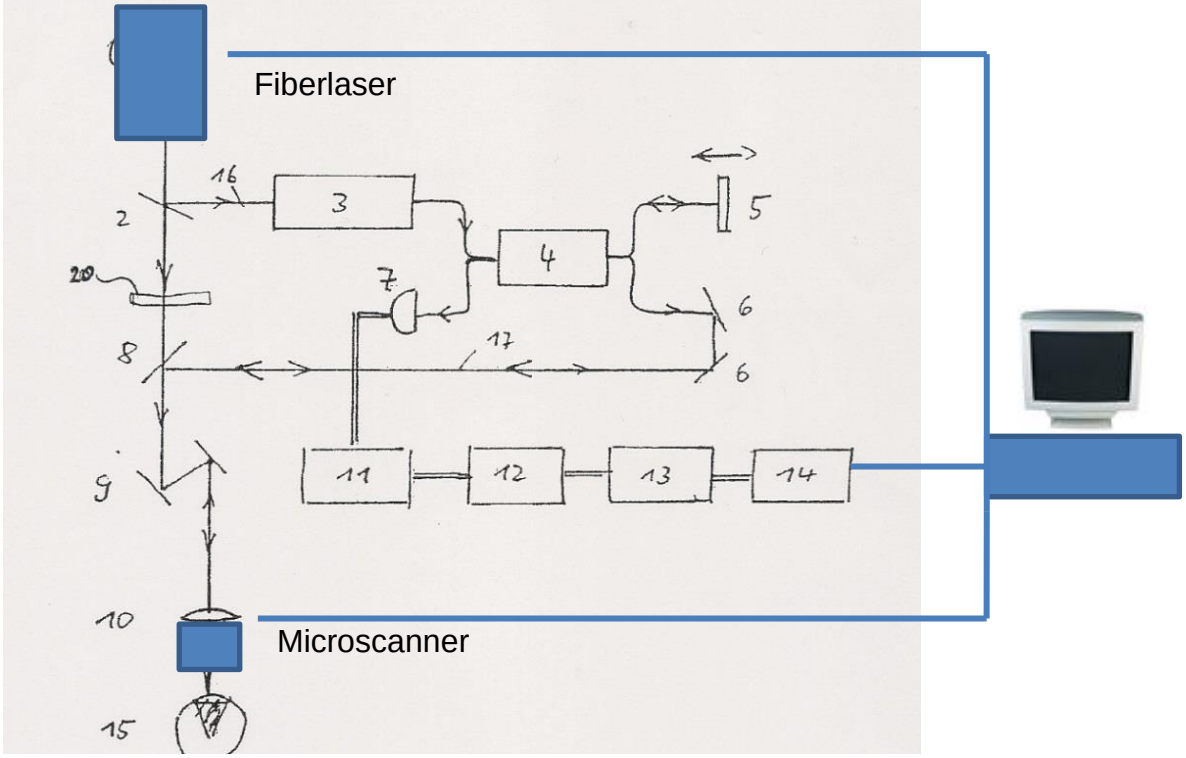
Publication Classification

(51) **Int. Cl.**
A61F 9/008 (2006.01)

(52) **U.S. Cl.** **606/5**

(57) **ABSTRACT**

A laser system for refractive surgery comprises a laser beam for generating laser beam pulses and optical means for directing these laser beam pulses as a working beam onto an eye. Some of the working radiation is extracted for optical coherence tomography, in order to measure geometrical structures in the cornea.

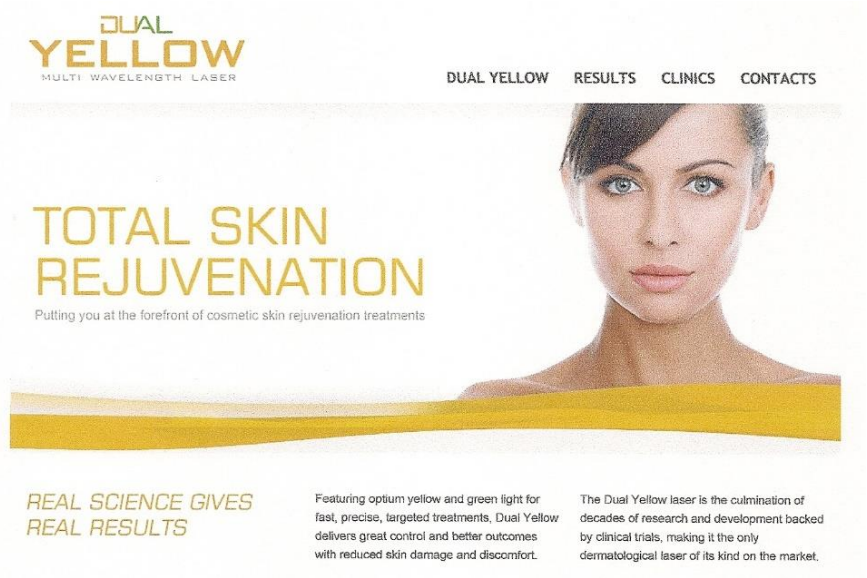


Offline workstation for identifying and Marking of laser treatment Sites in OCT-Tomogram
Transfer of position to scanner and release of laser pulse and online control

MERIDIAN

Future: Combination of FL and F-Sensors(OCT) in Dermatology for selective Treatments

DermaLumics(2015)



Dual FL
1550nm(Er-FL)/
1972nm(Th-FL)

At the moment DPSSL
611nm(DPSSL)
578nm(DPSSL)

But potential for FL

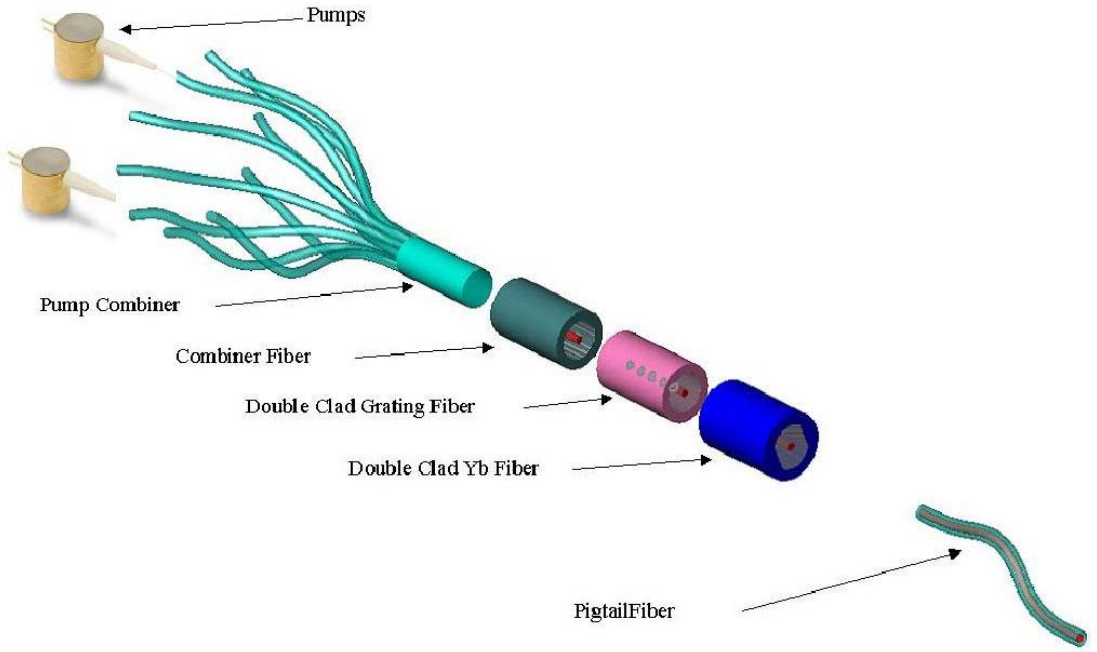
Possible Support of a small company by SNFL

Is a small Swiss company able to develop FL for medical niche applications and to produce sustainable without larger investments costs?

Possible support by SNFL

A) <u>Research and pre-development</u>:

-Identification of solutions with low costcomponents and modules on the market
- consideration of MP requirements,
-ability to finish/optimise fibers



B) <u>Product development</u>

Technical support for trans

C) <u>Production of small number of units</u>

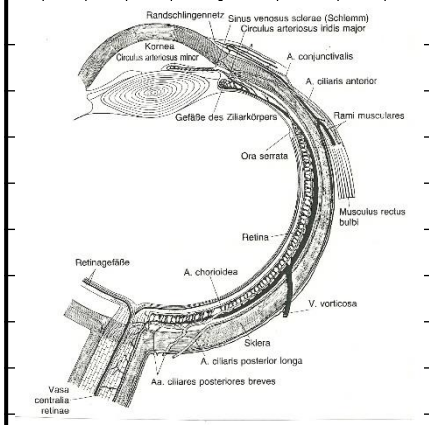
Possibility to share expensive tools (e.g.Splicing)

Laser in Ophthalmology

Laser in Ophthalmic Market

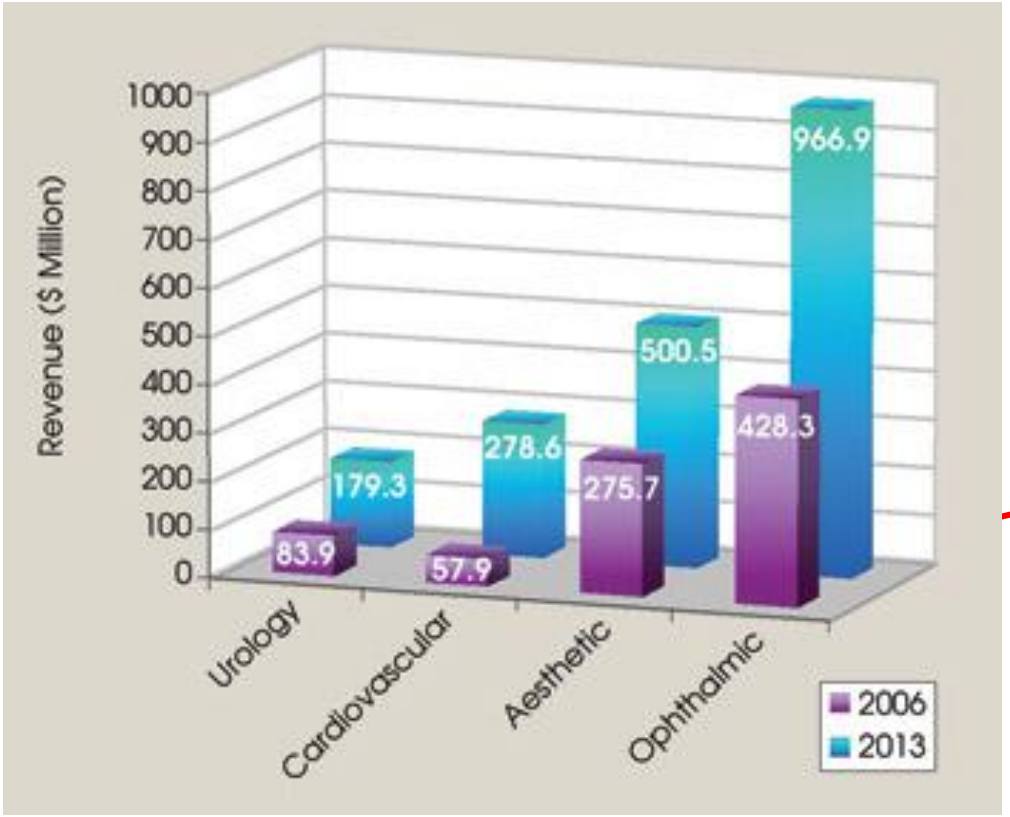
Products of LASAG/MERIDIAN

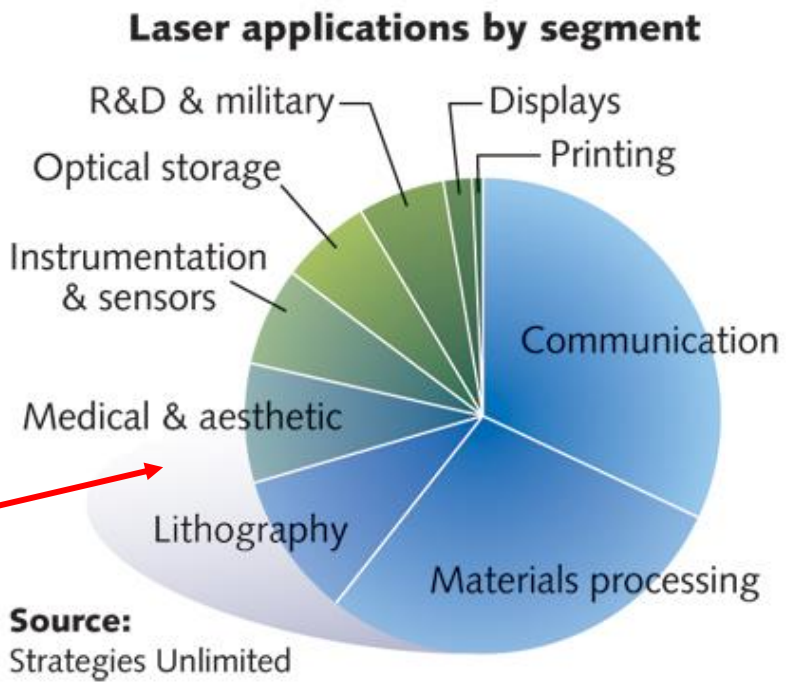
Rubin
Argon
QS-Nd:YAG
Krypton
CO2
cw-YAG
P-YAG
p-Dye
Excimer
Diode
ps-Laser
2f-YAG
Er:YAG
2f-OPDL
2f-DPSSL
2f-FL
fs-Laser



1960 **70** **80** **90** **00** **10** **20**

Medical Laser Market





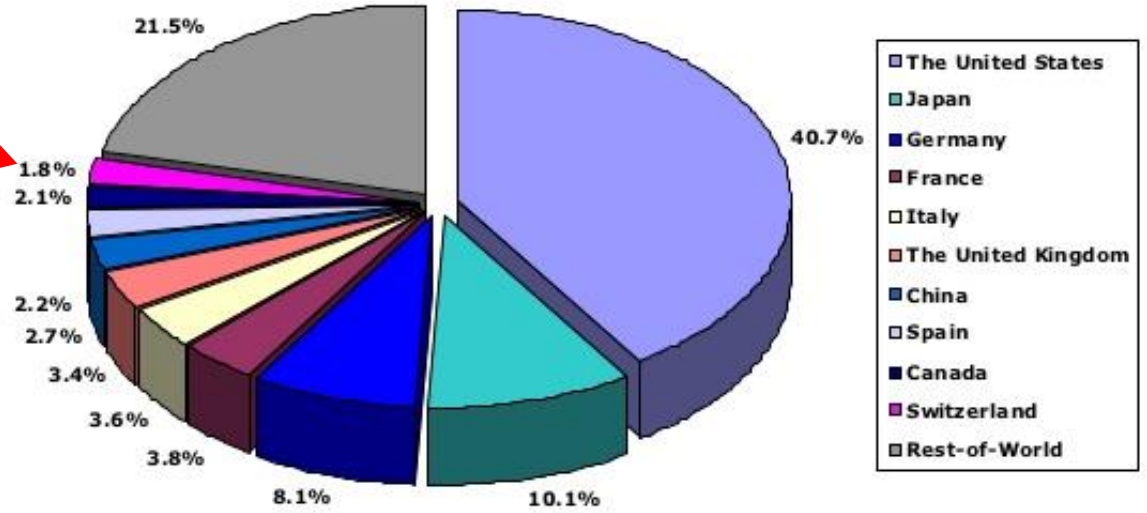
2014 approx 9.4 B $

Source: Laser Market Place 2014

2010 Medical Device Market Regional Analysis

Medical Device Market: Percent Split of Revenues by Geographical Region (World), 2010

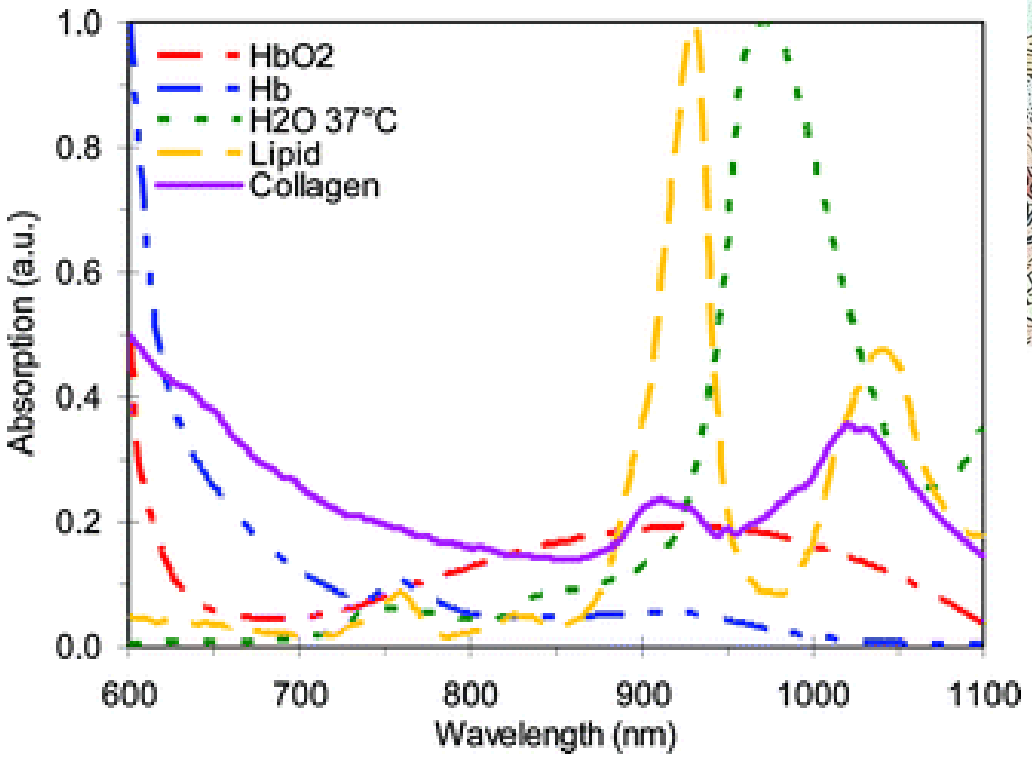
CH

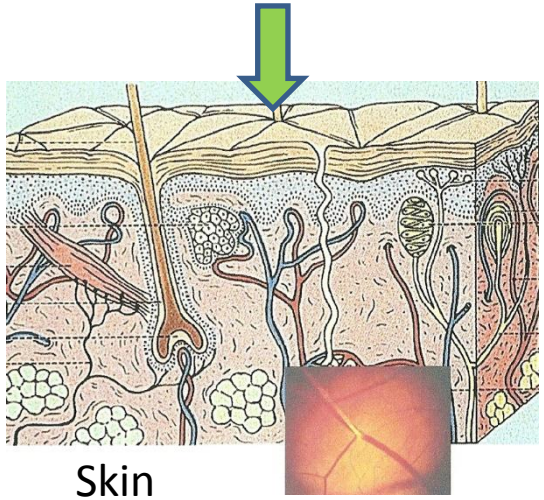


Source: Frost & Sullivan

The majority of medical device manufacturers' markets are set on a global basis and manufacturers are seeking expansion into new regions, such as Asia, Eastern Europe and Latin America, in order to achieve greater profits. In Europe, local companies usually have subsidiaries, direct sales offices or distributors in several European countries. Non-European companies tend to establish a head office in Europe and direct sales offices in major markets. The intensive coverage of the European sales territory has resulted in strong competition in all regional markets. Accordingly, local manufacturers do not have monopolies in their own countries, and smaller companies are forced to market their products on an international level.

Medical Markets: example skin





Skin

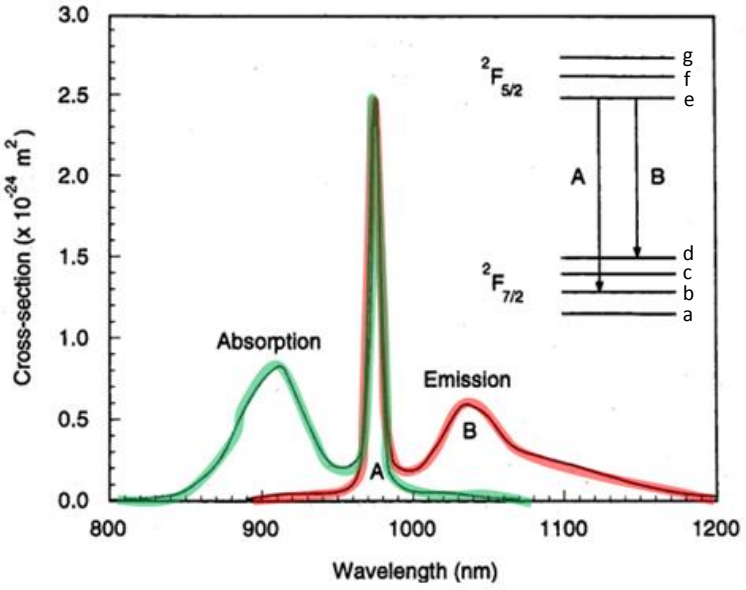
Biological results of (Laser) Irradiation

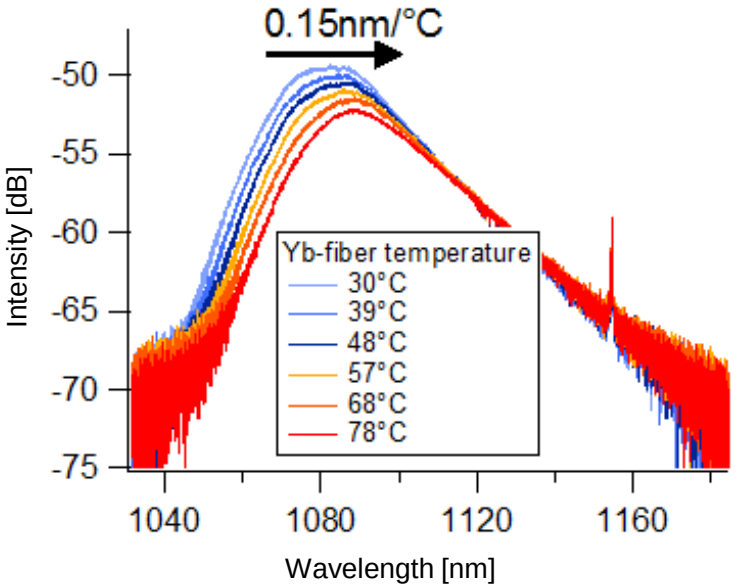
Temperature	**37-60 ^{0}C**	**60-65 ^{0}C**	**90-100 ^{0}C**		**some 100 ^{0}C**		**some 1000 ^{0}C**
Effect	**Heat / inceased diffusion**	**Denaturisation Coagulation**	**Phase Change**	carbonisation		vaporisation Verbrennung	Shockwave plasma
Optical change	**Scattering refraction reversible**	**whitening Scattering Destruction of structures**	**shrinking Scattering**	Darkening Increased Absorption.		Gases Vapor	Vapor debrises
Biological result	**Stimulation**	**Damage**	**Shrinking**		heavy Damage		mechanical Damage

How to operate a cavity at 1154 nm

Romano, Ryser et al(SNFL)

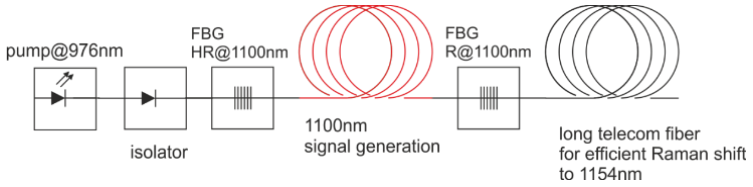
- If an Yb-doped fiber is heated, the lowest energy levels «a» and «e» are less populated
- This causes a shift in the emission spectrum towards higher wavelengths
- This allows to run a cavity directly at 1154 nm



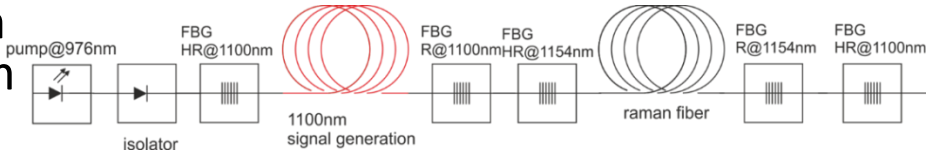


Yellow laser

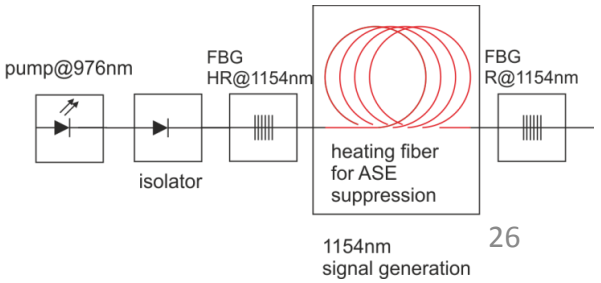
- Yellow laser at a wavelength of 577 nm hardly exist
- What is the problem?
  - 1154 nm light required to frequency double it to 577 nm
  - Lasing of ytterbium doped fibers occur preferentially at 1030 nm
- Possible solutions:
  - Yb fiber laser at 1100 nm and subsequent Raman shift to 1154 nm



  - Yb fiber laser at 1100 nm with Raman fiber cavity at 1154 nm



  - Yb fiber laser at 1154 nm with heated fiber

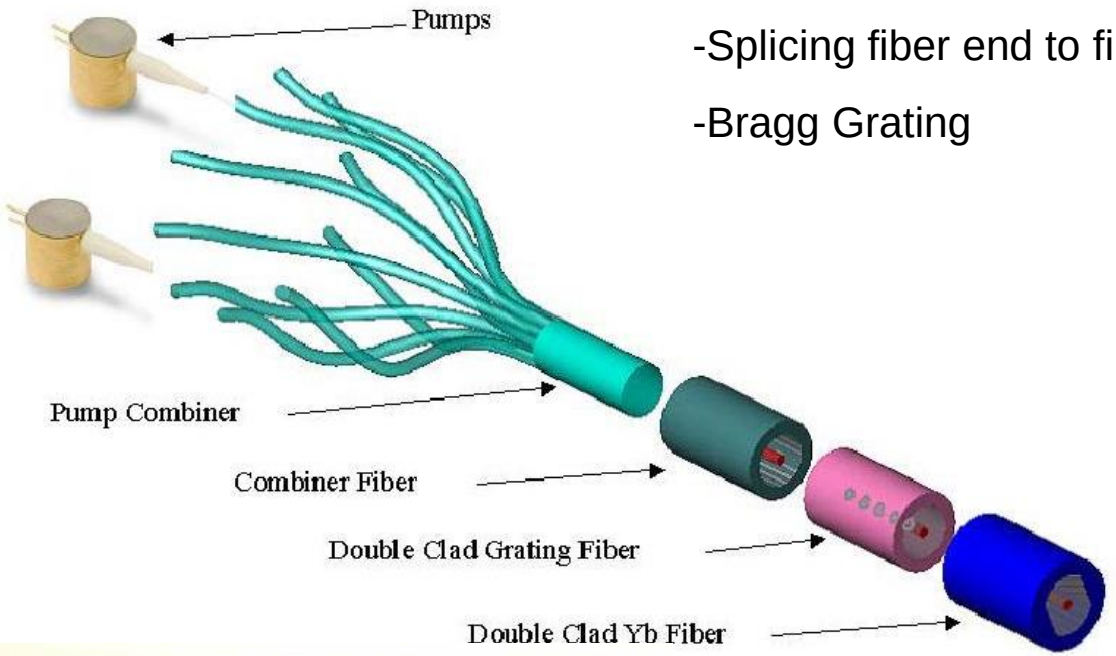


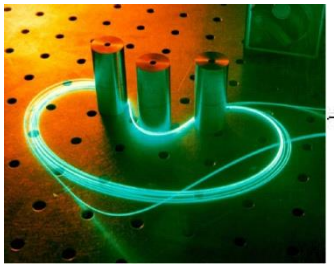
Fiber Laser: Principle

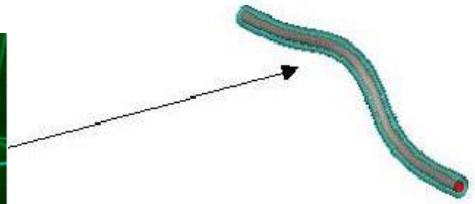
Key Technology:

-Splicing fiber end to fiber end

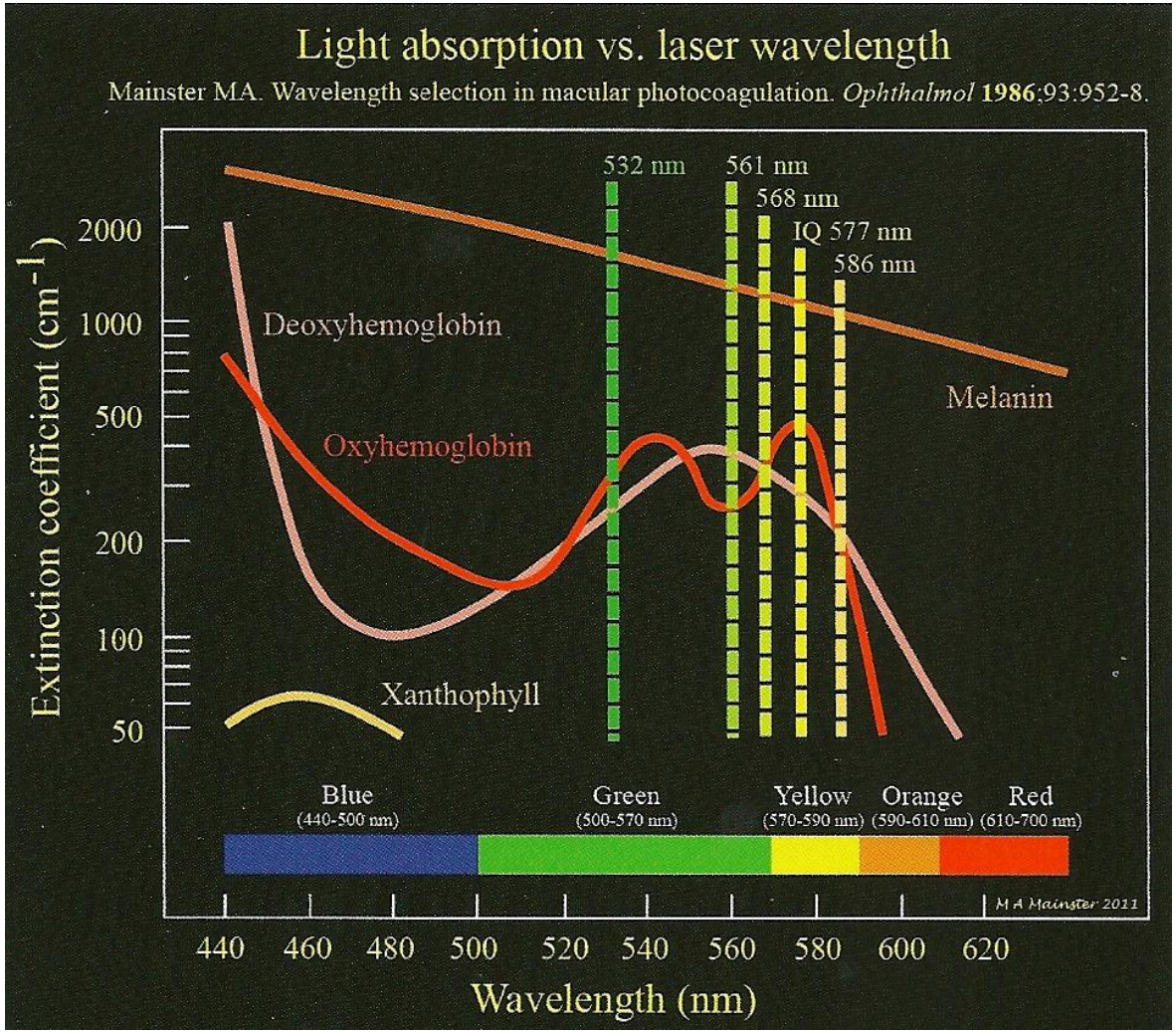
-Bragg Grating

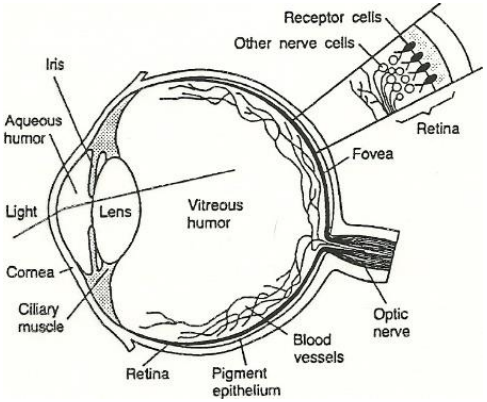


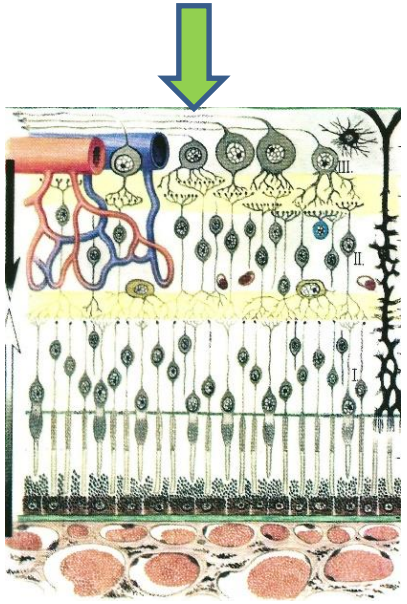




Absorption properties of Retina







(Thiel)