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Eyewear for Short Pulses

Thomas Fröhlich

Product group manager
LASERVISION (Germany)

Peer pressure in the laser lab

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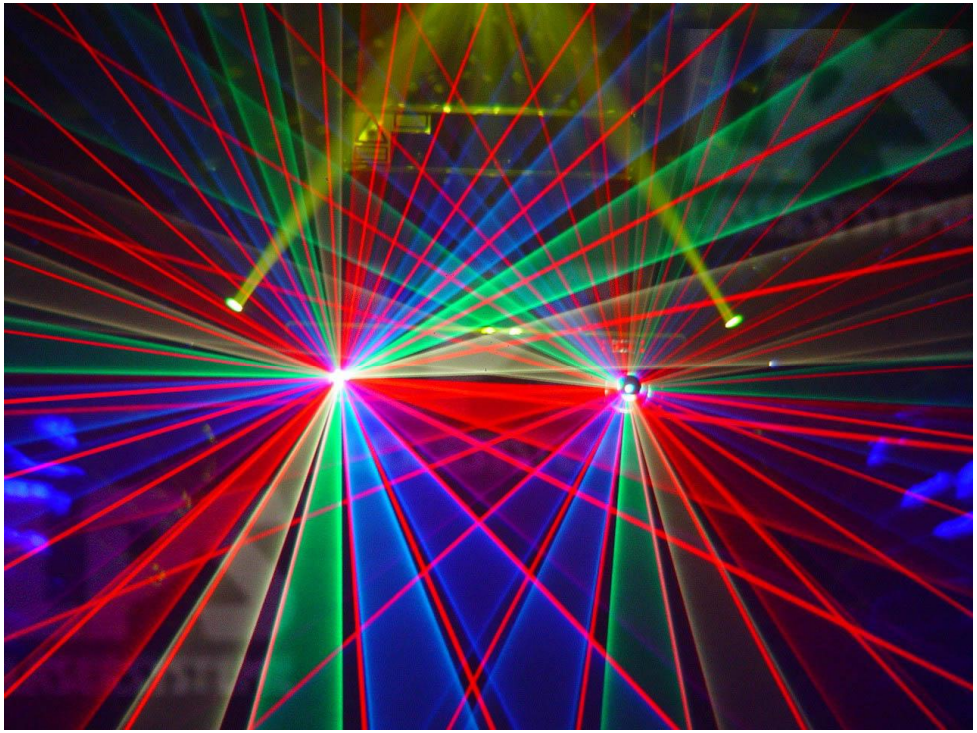
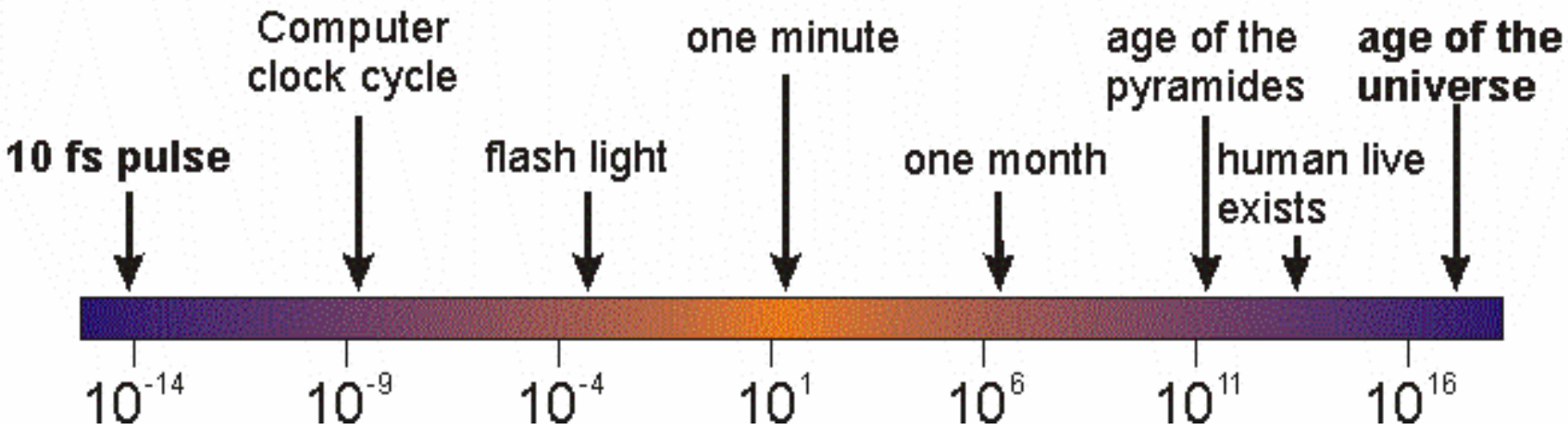
Introduction – Eyeweare for Ultrashort Pulses

- A little bit of physics
- Primary hazards
- Which type of laser filters are available?
  Testing of filters?
- Secondary hazards:
  - particle emission
- summary



time base



the ratio of

10 fs to one minute is the same as

one minute to the age of the universe

The ratio of

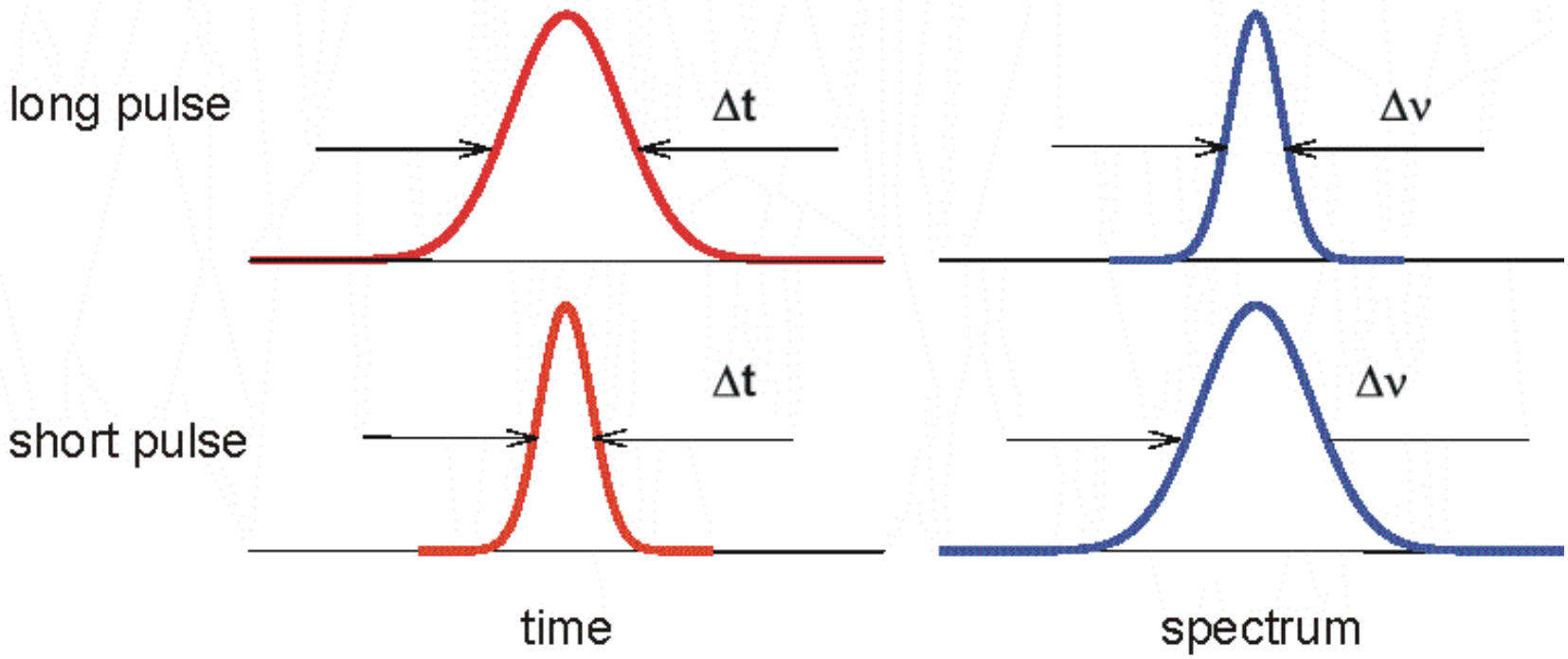
10 fs to one minute is the same as

1 dime to the national dept of the USA (~13 T$)

Source: Prof. Spielmann

Long and short pulses

correlation between pulse duration and spectral bandwidth for short light pulses



Source: Prof. Spielmann

Bandwidth of ultra short pulses

time bandwidth product $\Delta t \, \Delta \nu >= \text{const.}$

$\Delta \nu$ bandwidth of the spectrum

const. functionon of pulse shape

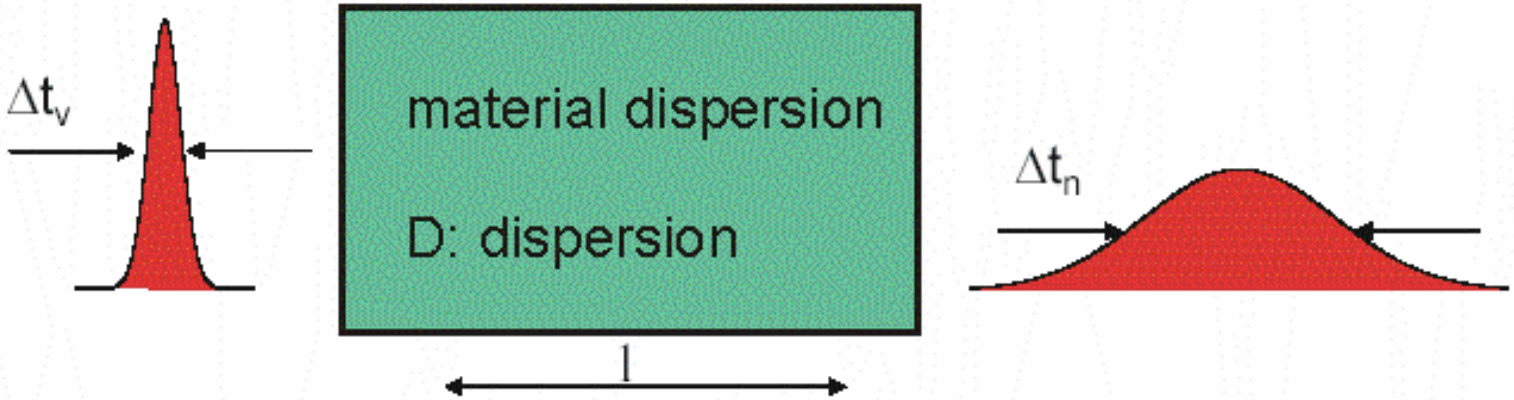
e.g. Gaussian shape: const. = 0.4

$\Delta \nu = 0.4/\Delta t$ resp. $\Delta \lambda = \lambda^2 \, 0.4/(\Delta t * c)$

Ti:Saphir λ ~ 800 nm	Telekom λ = 1500 nm	2ω Ti:Sa λ = 400 nm
1 ps ~ 1 nm	1 ps ~ 4 nm	1 ps ~ 0.2 nm
100 fs ~ 10 nm	100 fs ~ 40 nm	100 fs ~ 2 nm
10 fs ~ 100 nm	10 fs ~ 400 nm	10 fs ~ 20 nm

Source: Prof. Spielmann

color dispersion – enlarged pulses



$D = \beta * l$ β: material parameter (material dependent)

enlargement of pulse duration (e.g.: gausian Beam)

$$\Delta t_n = \Delta t_v \sqrt{1 + 7.7 * D^2 / \Delta t_v^2}$$

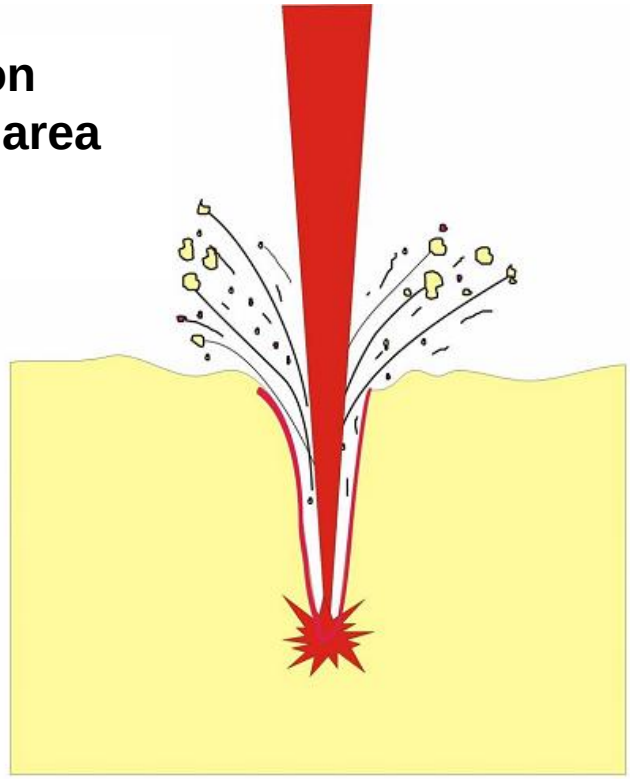
values for β @ 800 nm		1 cm glass		1 m air	
glass (BK 7)	500fs²/cm	Δt_v = 10fs	Δt_n = 140fs	Δt_v = 5fs	Δt_n = 12fs
glass (SF 57)	2000fs²/cm	100fs	101fs	10fs	11fs
air	0.2fs²/cm	1ps	1ps	100fs	100fs

Source: Prof. Spielmann

Interaction: Radiation - Skin

- **Laser induced, explosive ablation**
- **Ablation with a minimal heating area**
- **“cold ablation“**

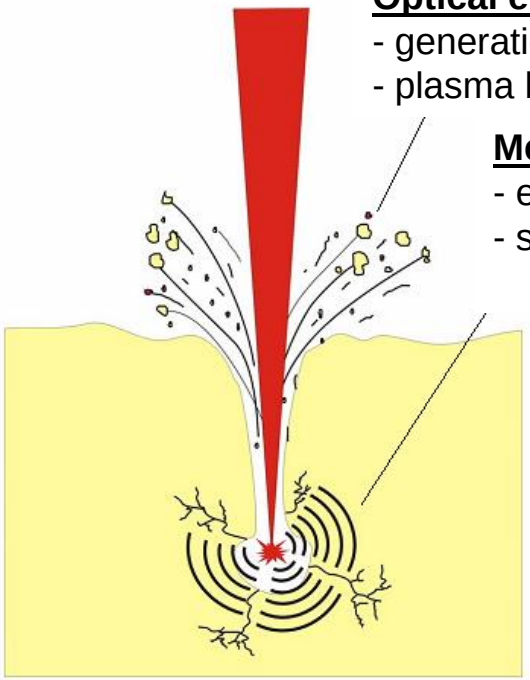
Laserzentrum Lübeck
Courtesy: Technolas



Typical energy densities and exposure times

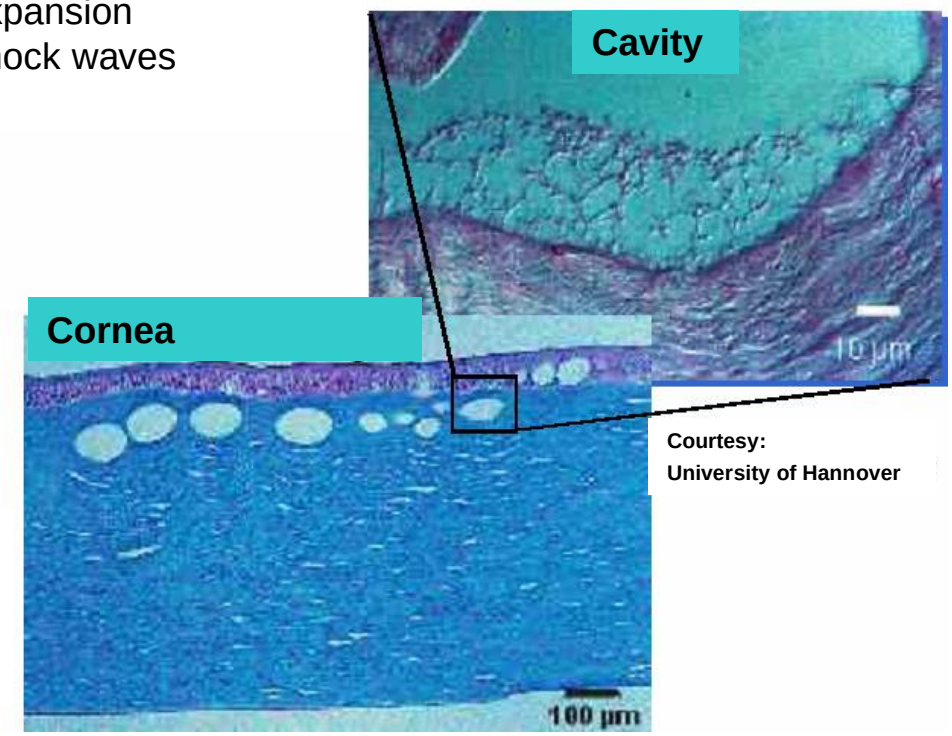
$1*10^3$ … $5*10^3$ J/m² - fs - µs

Interaction: Radiation - Skin



Optical effects:
- generation of plasma
- plasma heating

Mechanical effects:
- expansion
- shock waves



Courtesy:
University of Hannover

Energy density: 10^7 J/m^2
Pulse duration: 10^{-15}s – 10^{-9}s

Characteristics of Laserlight

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Working Mode		Typical pulse length
Continuous wave D (cw)*	...is the continuous emission of laser radiation.	> 0.25 s
Pulsed mode I	...is the short-term single or periodically repeated emission of the laser radiation.	> 1 µs to 0.25 s
Giant pulsed mode R	... is like pulsed mode, but the pulse length is very short.	1 µs to 1 ns
Modelocked M	... is the emission of laser radiation with all the energy stored in the laser medium released within the shortest possible time.	< 1ns

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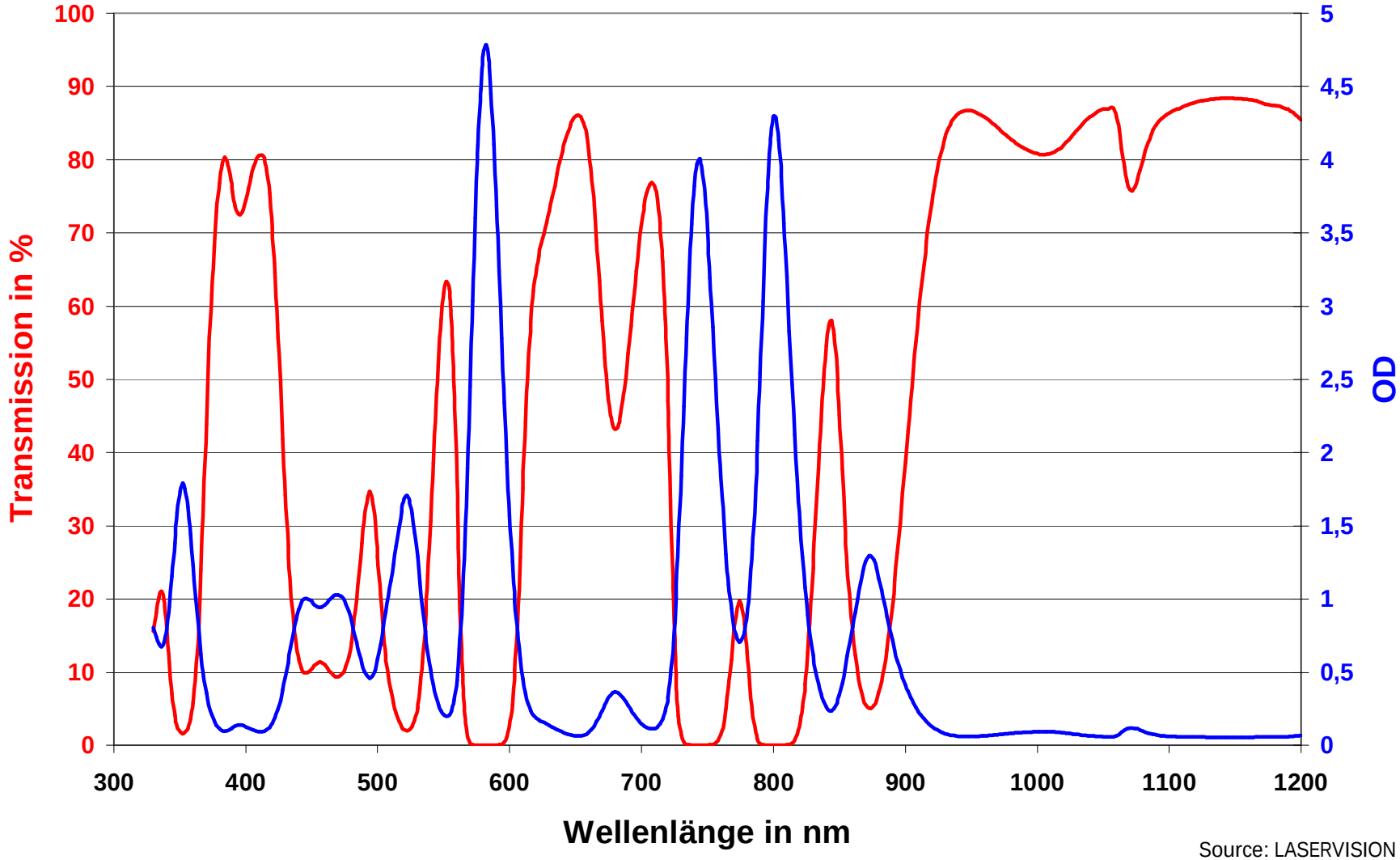
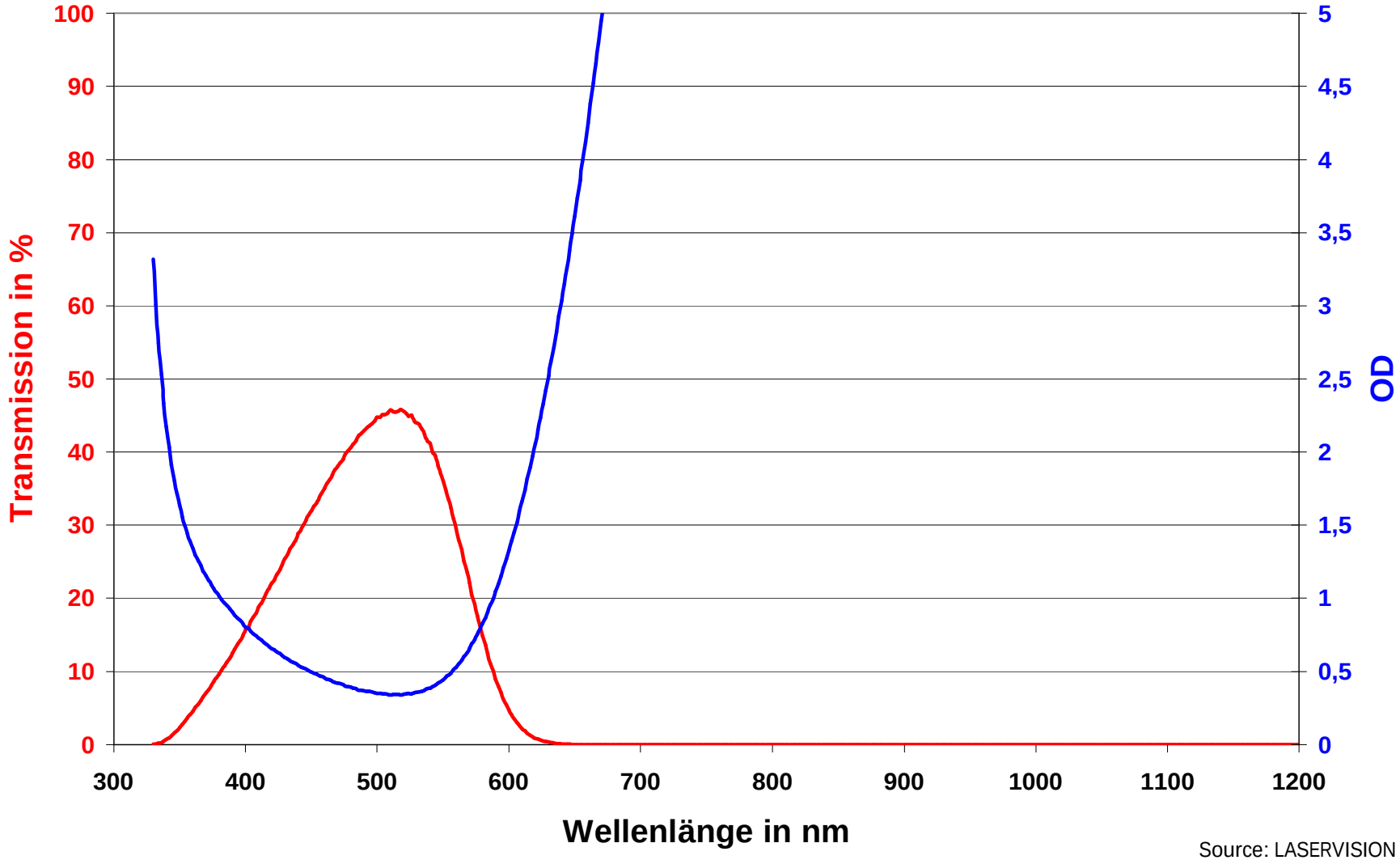
Transmission and OD curve T16 (multi – notch – filter)



Source: LASERVISION

transmission and OD curve T58 (short pass filter)



Source: LASERVISION

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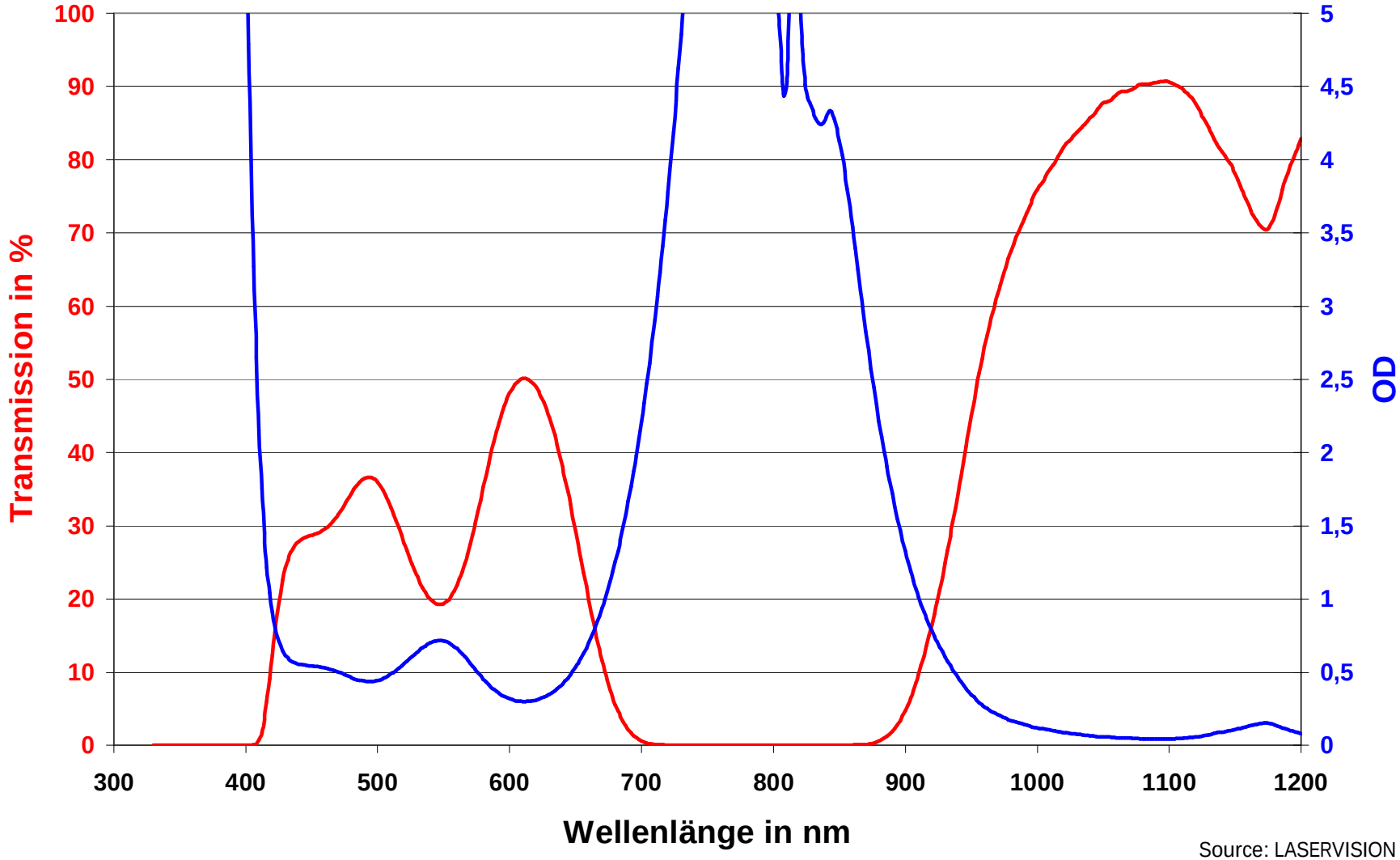
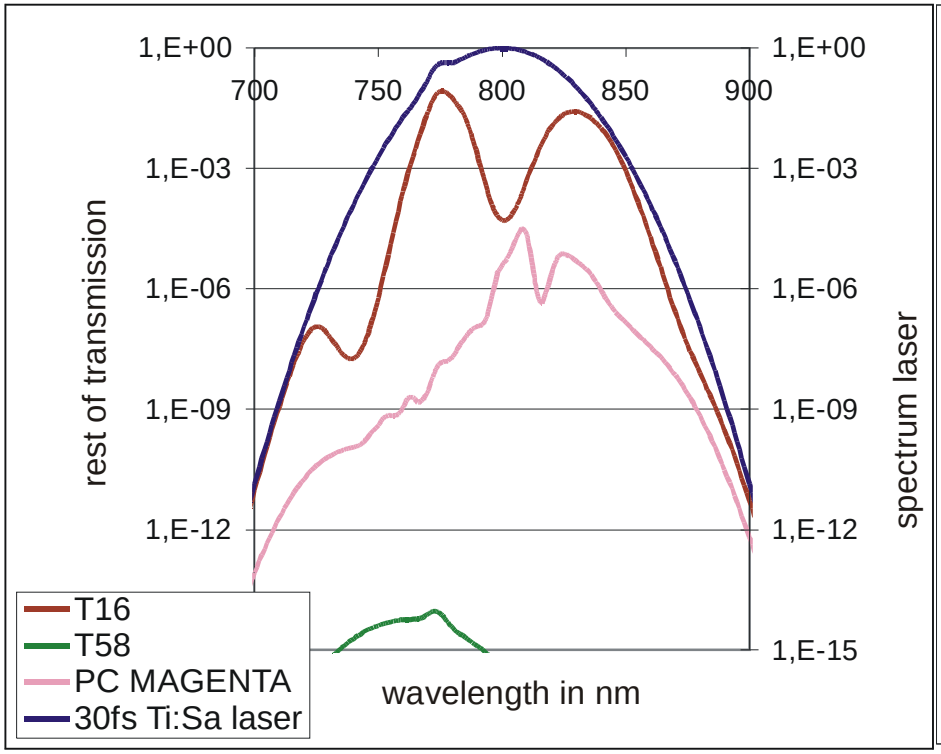
transmission and OD curve polycarbonat MAGENTA (single notch)

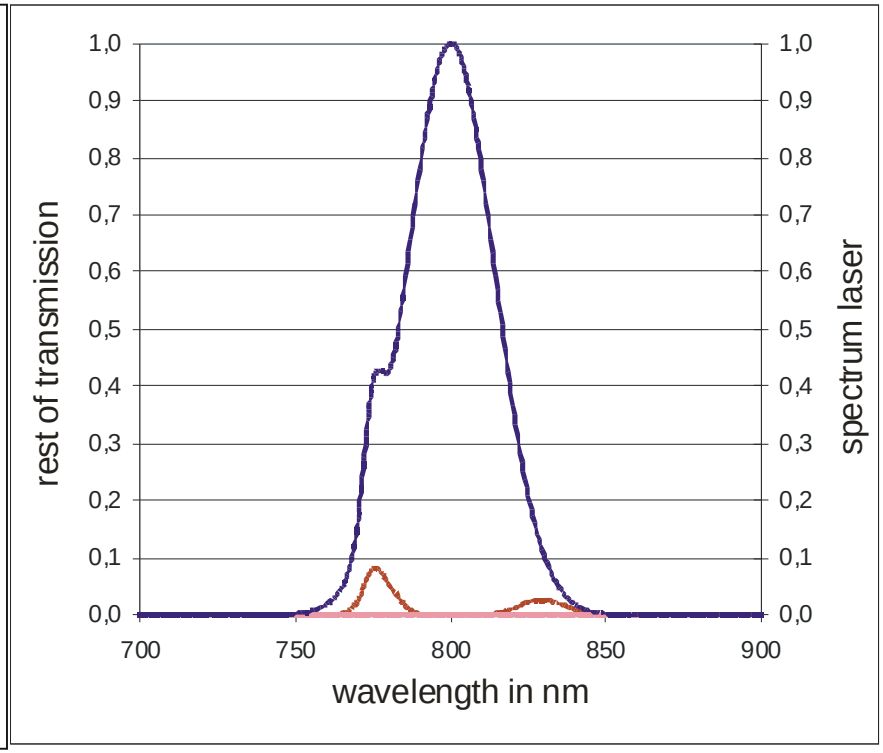


Source: LASERVISION

Ti:Sa 30 fs – transmission at the edges

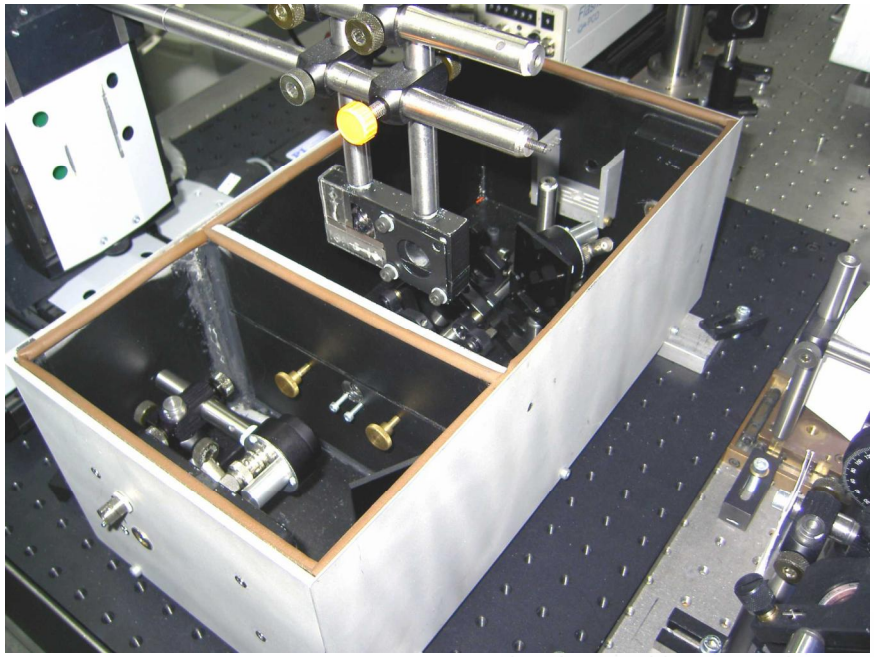
Source: BAM





Source: BAM

Laser impact test on the filters

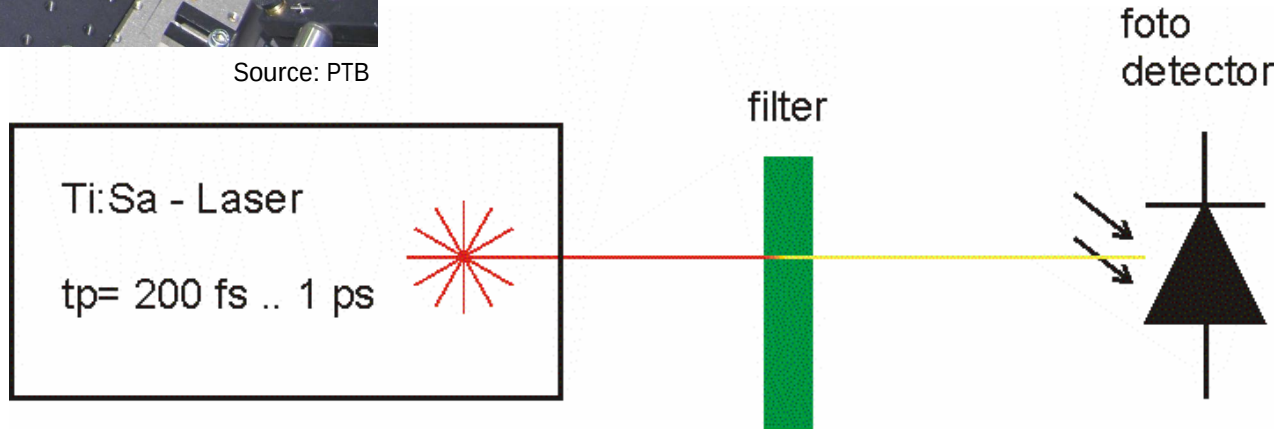


Source: PTB

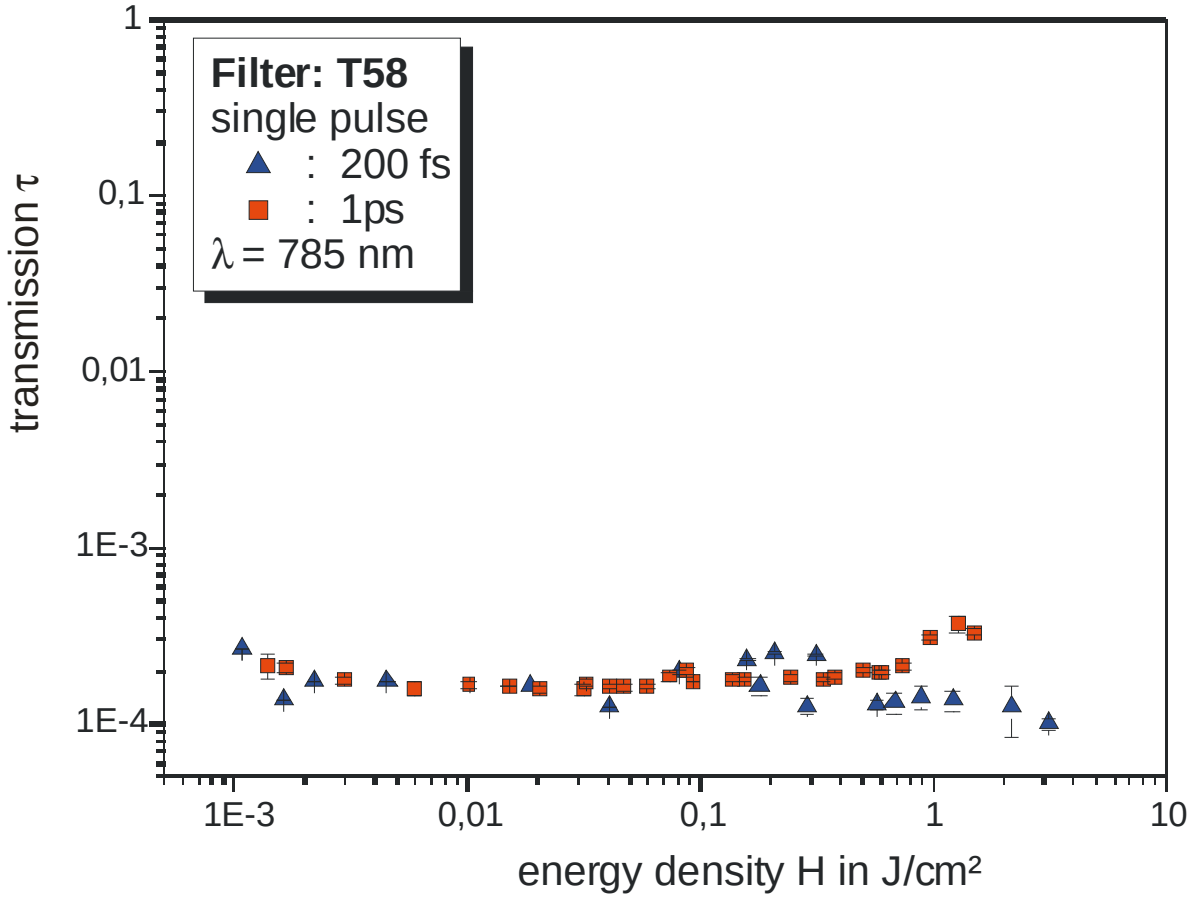
Tests with different filter materials:

T58

PC (Magenta)



Single pulse testing – glass filter T58



filter T58 (short pass filter)

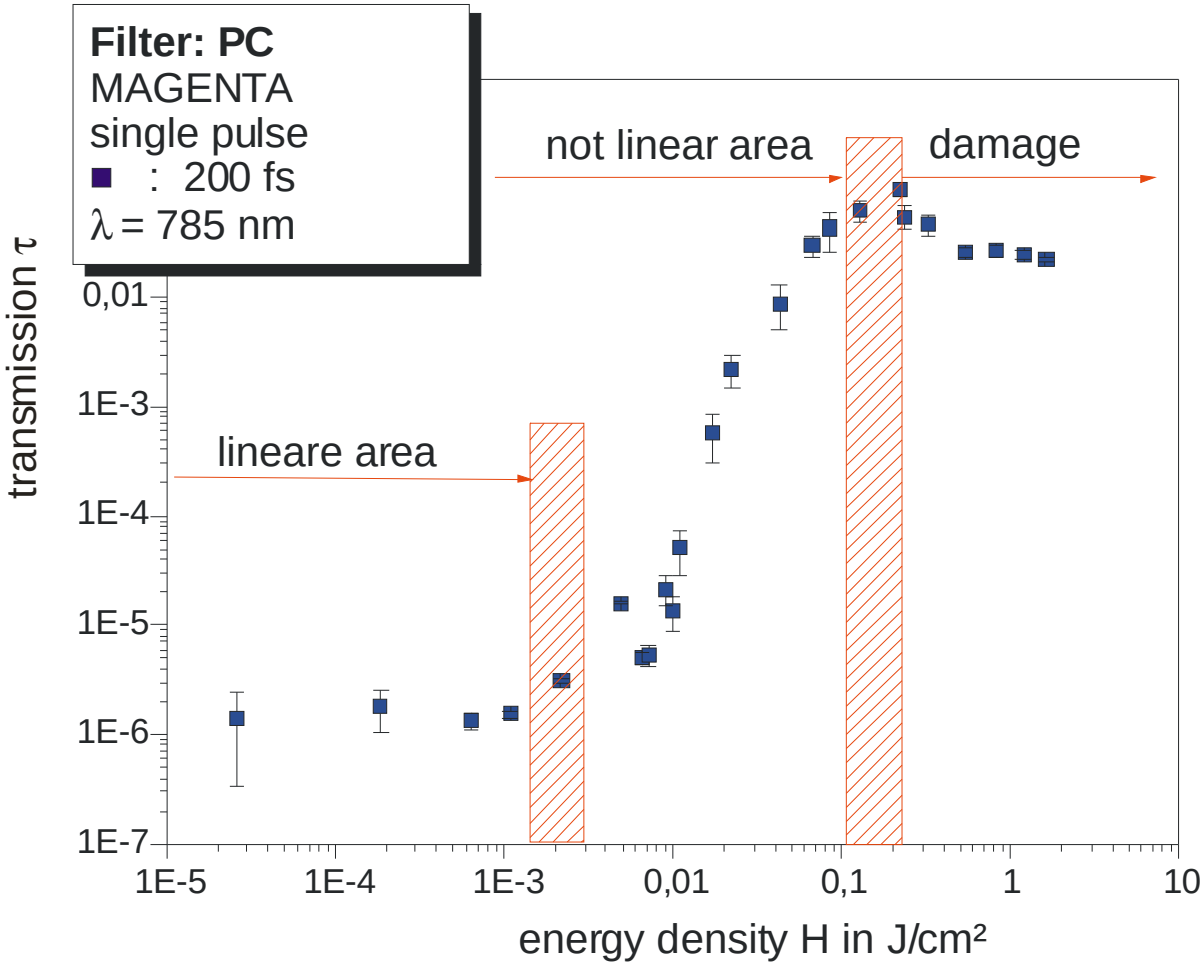
probe thickness: 1 mm

measured transmission:
$\tau = 2x10^{-4}$
maximum at 200 fs:
$\tau = 2x10^{-4}$
maximum at 1 ps:
$\tau = 3x10^{-4}$

related diameter: $d_{86,5}$

Source: PTB

Single pulse testing – PC filter MAGENTA



Filter type: MAGENTA (notch filter)

probe thickness: 1.7 mm

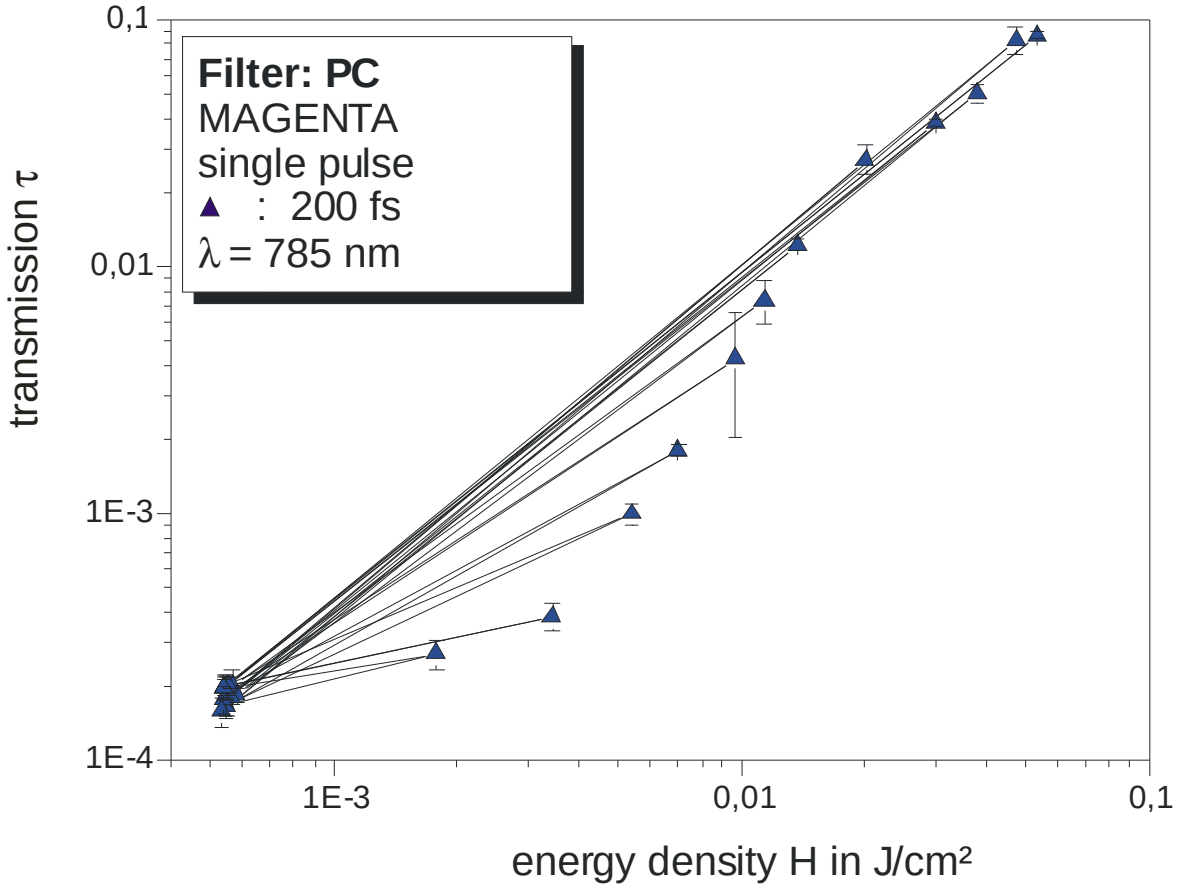
measured transmission: $\tau = 1{,}5 \times 10^{-6}$

maximum transmission: $\tau = 0{,}1$

related diameter: $d_{86,5}$

Source: PTB

Reversibility of the bleaching effect



Filter type: MAGENTA (notch filter)

probe thickness: 1 mm

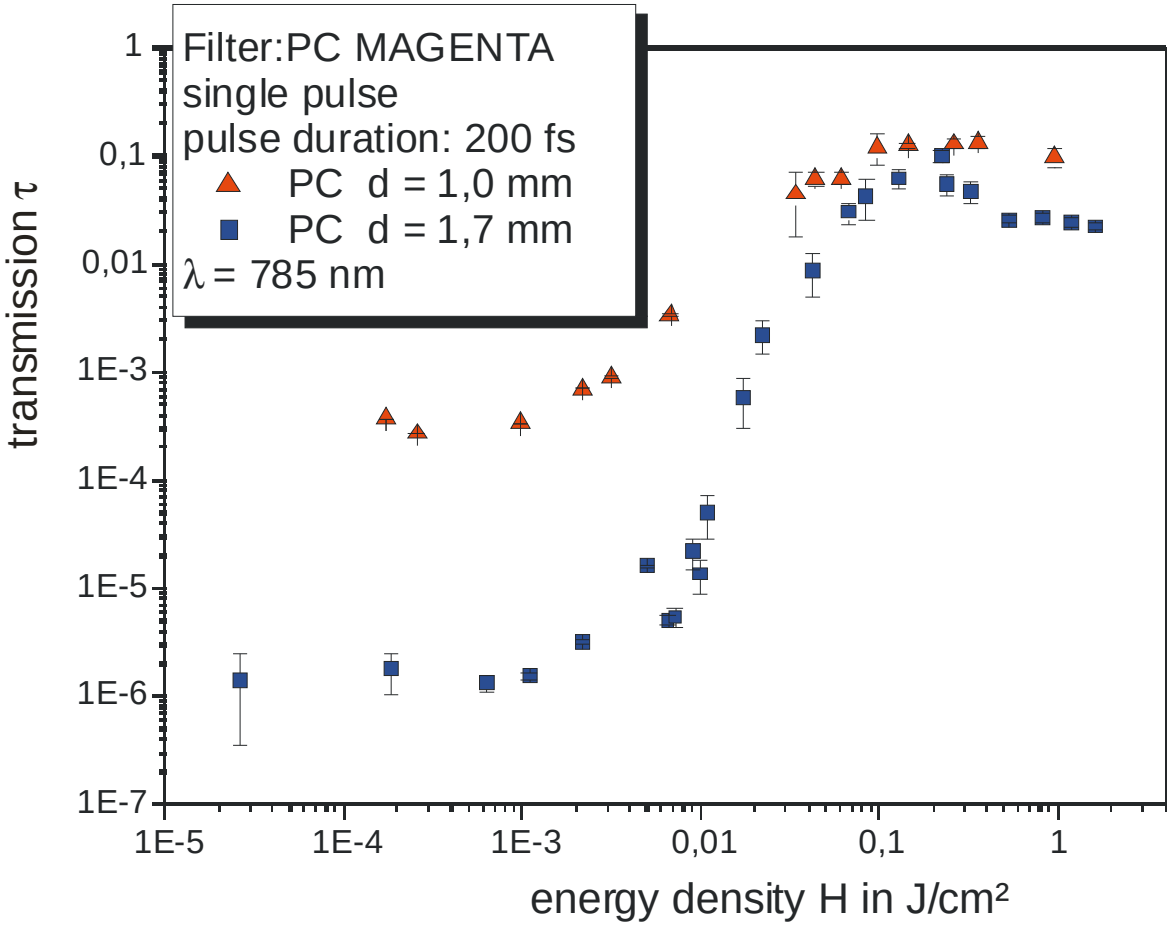
measured transmission: $\tau = 2x10^{-4}$

maximum transmission: $\tau = 0,09$

related diameter: $d_{86,5}$

source: PTB

Influence of the probe thickness



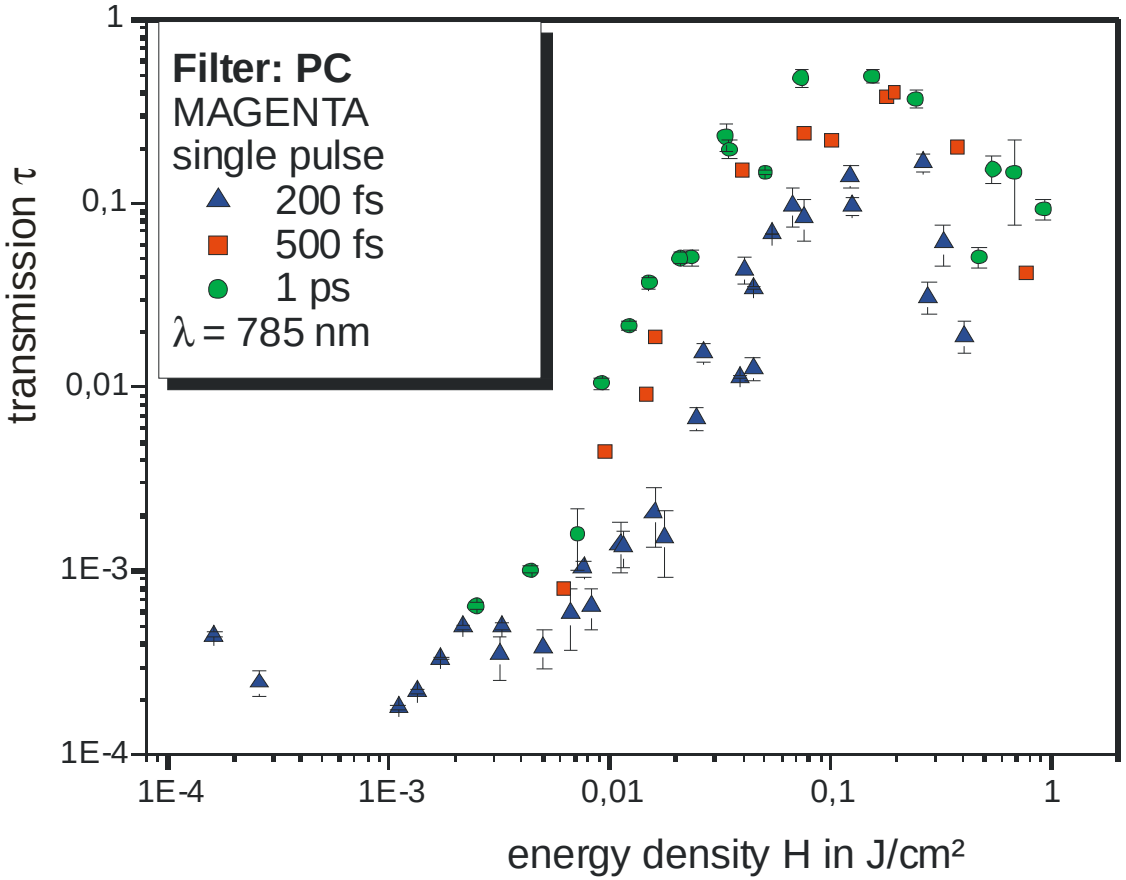
Filter type: MAGENTA (notch filter)

probe thickness:
1,0 mm
measured transmission
$\tau = 2x10^{-3}$
maximum transmission:
$\tau = 0,1$
probe thickness:
1,7 mm
measured transmission:
$\tau = 1,5x10^{-6}$
maximum transmission :
$\tau = 0,1$

related diameter: $d_{86,5}$

Source: PTB

Influence of the pulse duration



Filter type: MAGENTA
(notch filter)

probe thickness: 1 mm

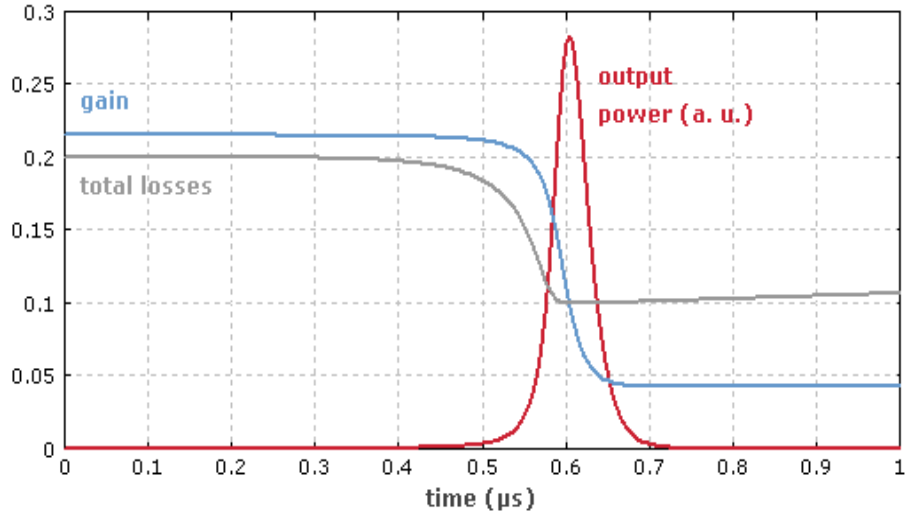
measured transmission:
$\tau = 2x10^{-4}$

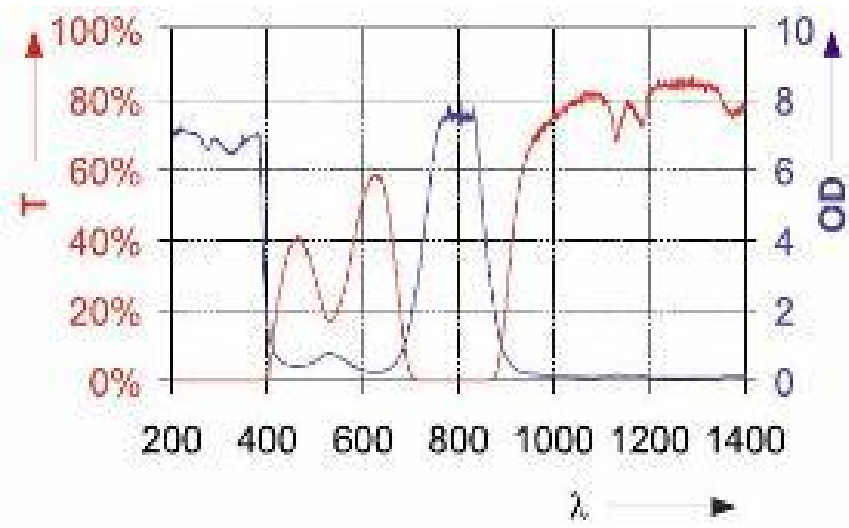
maximum transmission (200fs):
$\tau = 0,16$
maximum transmission (500 fs):
$\tau = 0,40$
maximum transmission (1 ps):
$\tau = 0,48$

related diameter: $d_{86,5}$

Source: PTB

Q – Switch Effects





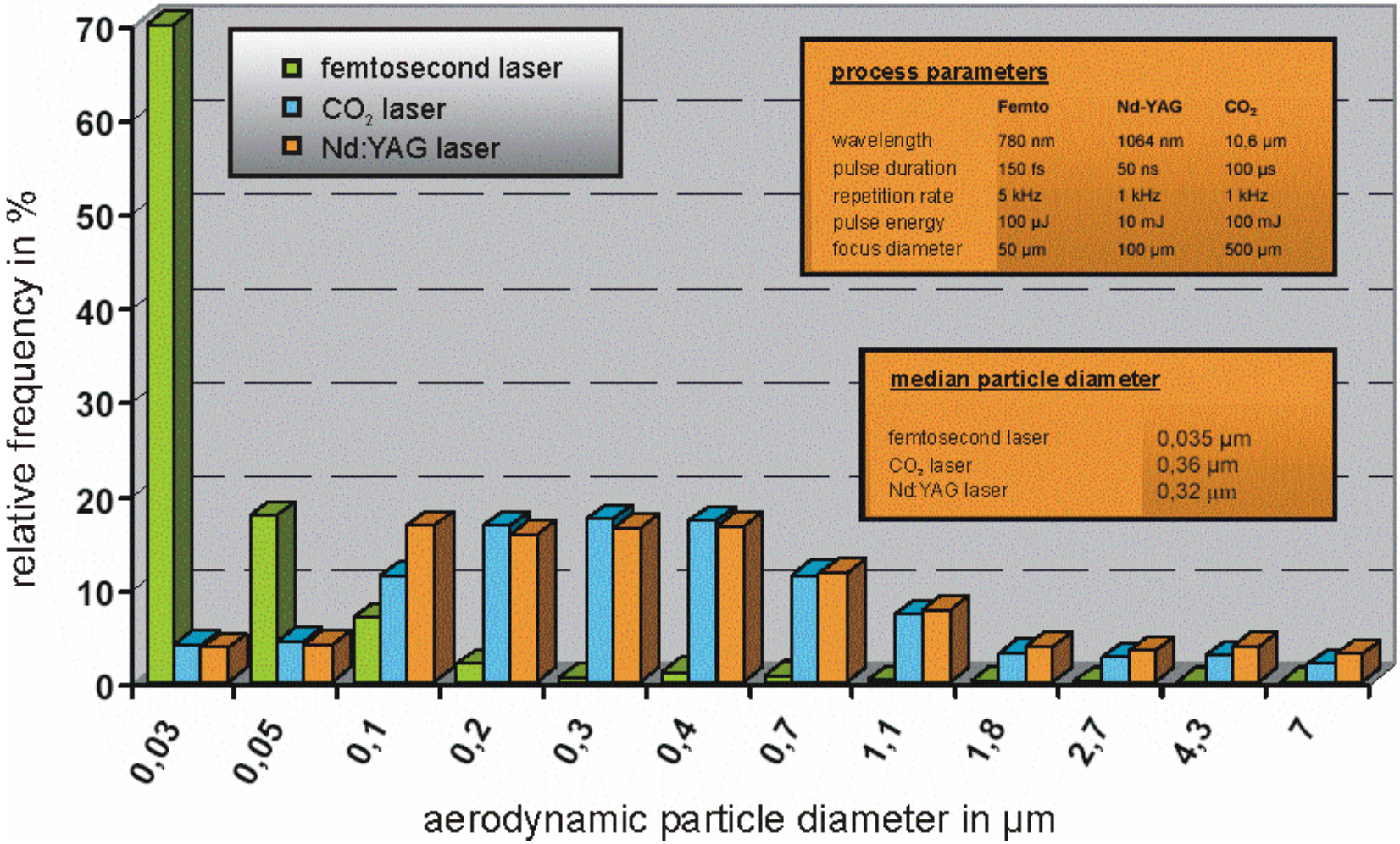
Critical factors for Q – switch effects

Possible Scale Number:

755-840 D L5 + I L7 + R L5 + M L5

- pulse duration in the order of fs up to µs

laser ablation - relative frequency of emitted particle sizes



Source: LZH

summary

Primary hazards:
Be aware about the spectral bandwidth!

Saturable absorbers - reversible bleaching effect
→ use tested filters: M-ratings are helpful
→ in case of M-ratings: use the correct one

Secondary hazards:
reduced size of the emitted particles in material processing
→100% respirable particles