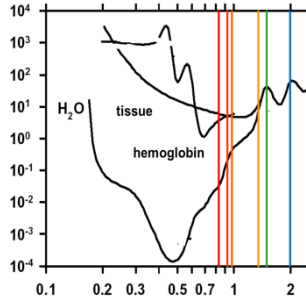
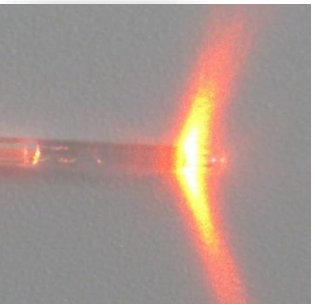
Medical Applications of 2µm Laser

Ronald Sroka

ESLA – Workshop 2015





Laser-Forschungslabor

Universities
Institutes
Laboratories

Companies for Medical-Technologies
Laser, Endoscopes, Pharmaceutics

Urology
Surgery
Gynecology
ENT
Radiology
Neurosurgery
...

Laser-Forschungslabor

Core Competence: Clinical Biophotonic
Minimally invasive and endoscopic approaches

Light Application Systems

Feedback & Sensors

Diagnostic

Photodynamic Therapy

Light-Tissue Interaction

Thermal Laser Application

from In-vitro to clinical	from prototypes to products

Support and consulting for clinical trials and research projects

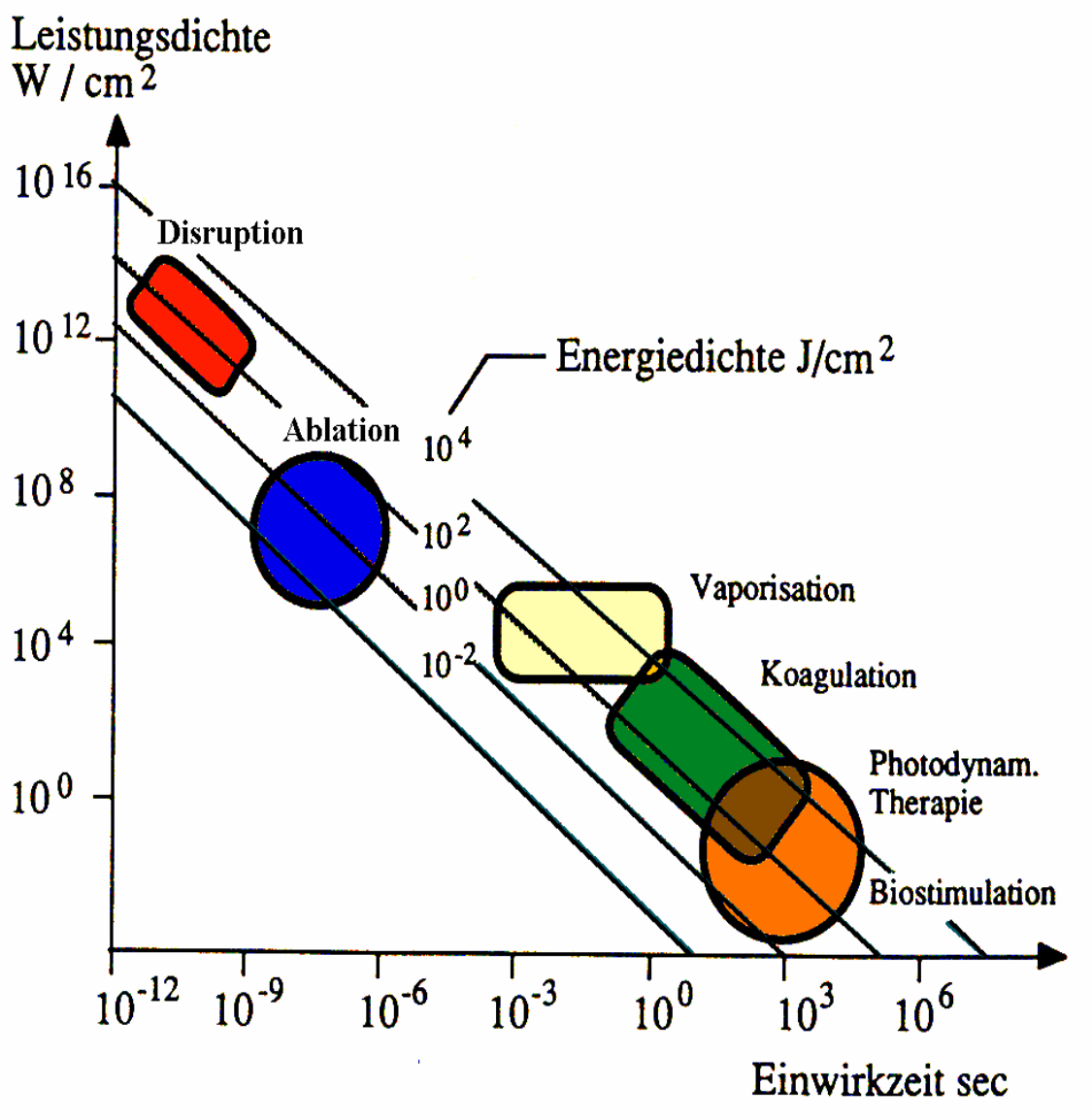
OUTLINE

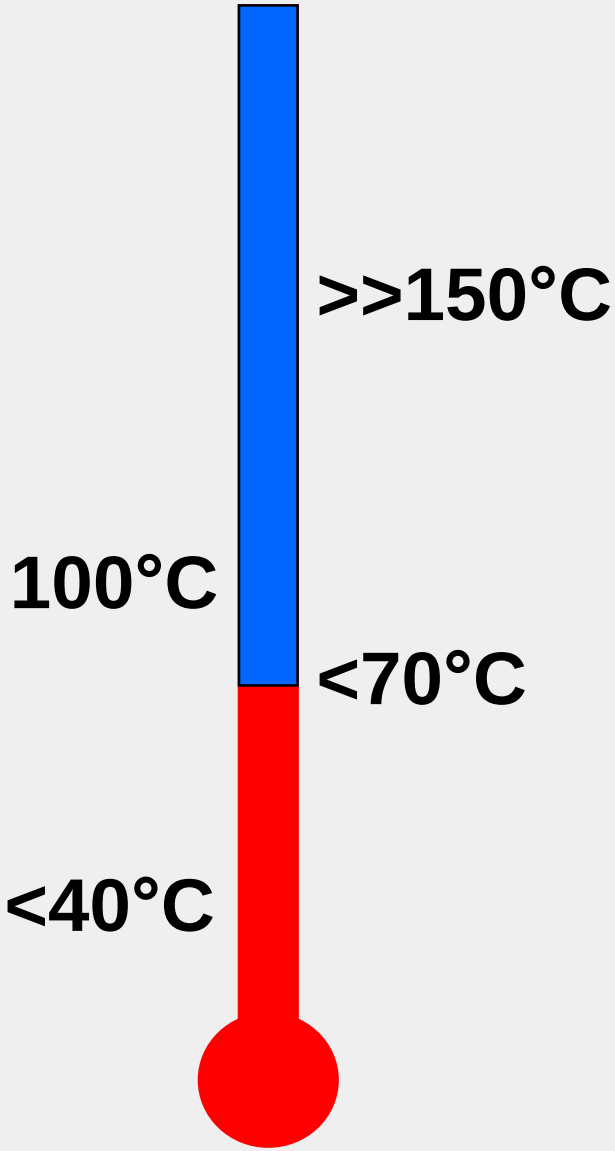
- Coagulation
  hyperplastic turbinates
  varicosis vein

- Vaporisation / Cutting
  prostate
  bronchi tumors
  kidney tumors

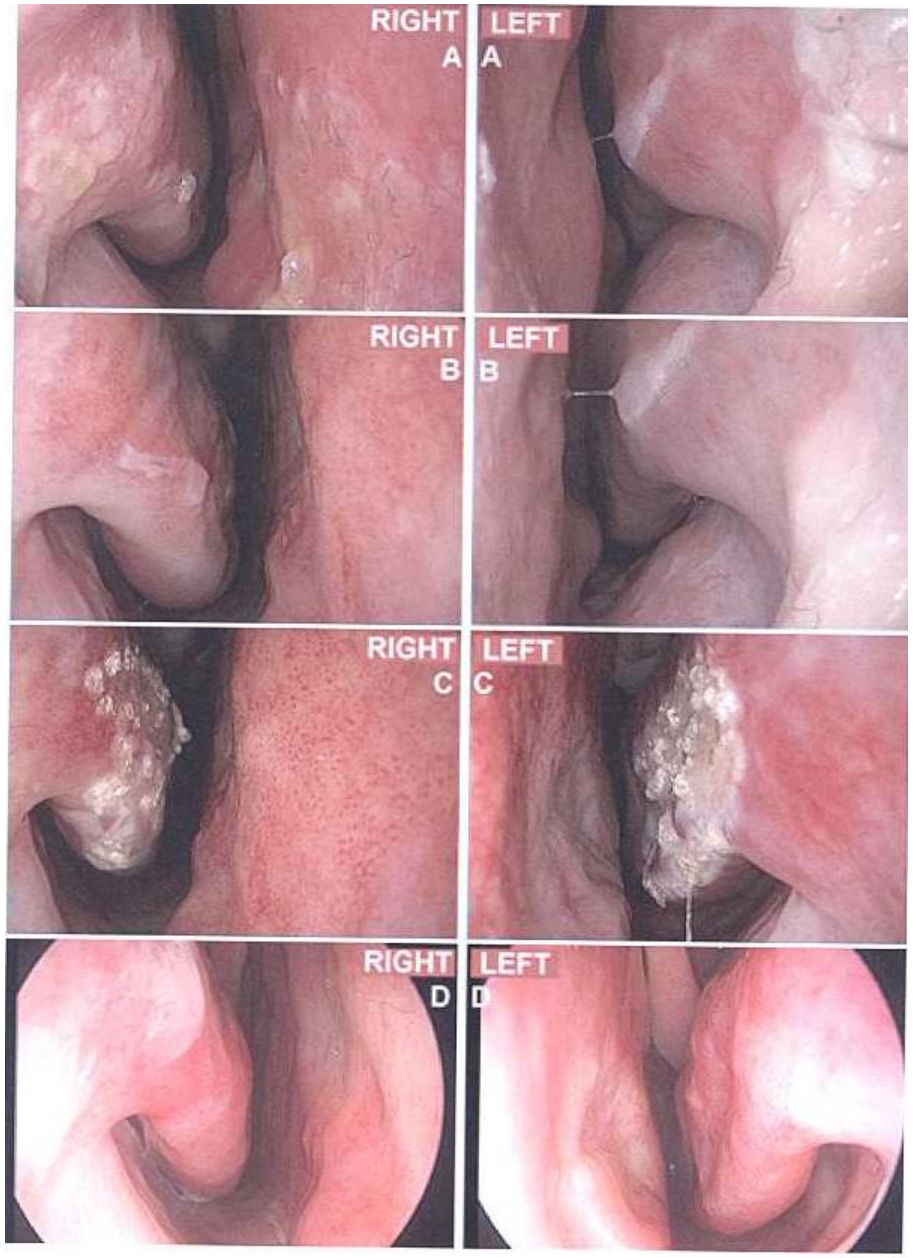
- Disruption / Fragmentation
  lithotripsy

Coagulation





Laser- Coagulation
nasal turbinate hyperplasia



Laser- Coagulation nasal turbinate hyperplasia

Tm:fiber laser

2-4W

365µm-fiber

2-4mm/s

Sroka R et al., Photon Lasers Med 2012: 2015-222

Otorhinolaryngology - Synechia

Precise cutting without any bleeding and small coagulation

Tm:fiber laser, 2-4W, 365µm-fiber

Sroka R et al., Photon Lasers Med 2012: 2015-222

VARICOSIS

- **Varicosis**

  Longterm widened vessels
  Irregular bending
  Lower extremeties

- **Orign**

  Insufficiency of vein valve
  Reflux problems
  Ineffective connective tissue
  Sometimes genetic preconditions

- **Clinical symptoms**

  Tension
  Edema
  Pain while sitting and standing
  Pigmentation, skin irritation
  Phlebitis
  Ulceration

VARICOSIS

- **Incidence**

  50% population in med-Europe aged 20 -75

  women / men 4 / 2

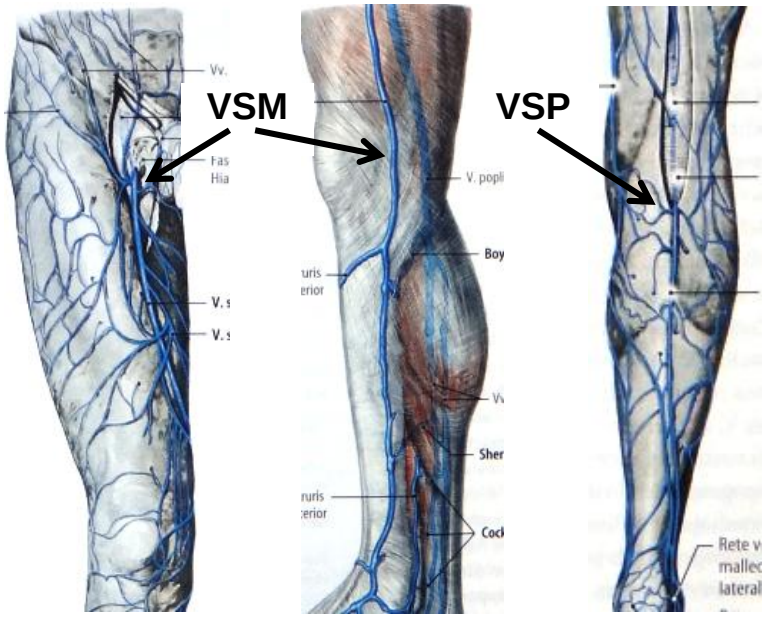
  50% needs therapeutic intervention

  2010: n>350.000 treatments in Germany

- **Target vessel**

  Vena saphena magna (VSM)

  Vena saphena parva (VSP)



Thiery L et al. Insightful Phlebology 2009
Leitlinie DGP und DGG 2009

VARICOSIS Therapy-Options

- **Primary aim of treatment**

  Reduction of reflux in superficial vein system
  Destruction / ablation of vessel

- **Therapy**

  conservativ

  surgery (CHIVA, EVP,…)

  stripping (Cryo-Stripping, Partial-Stripping)

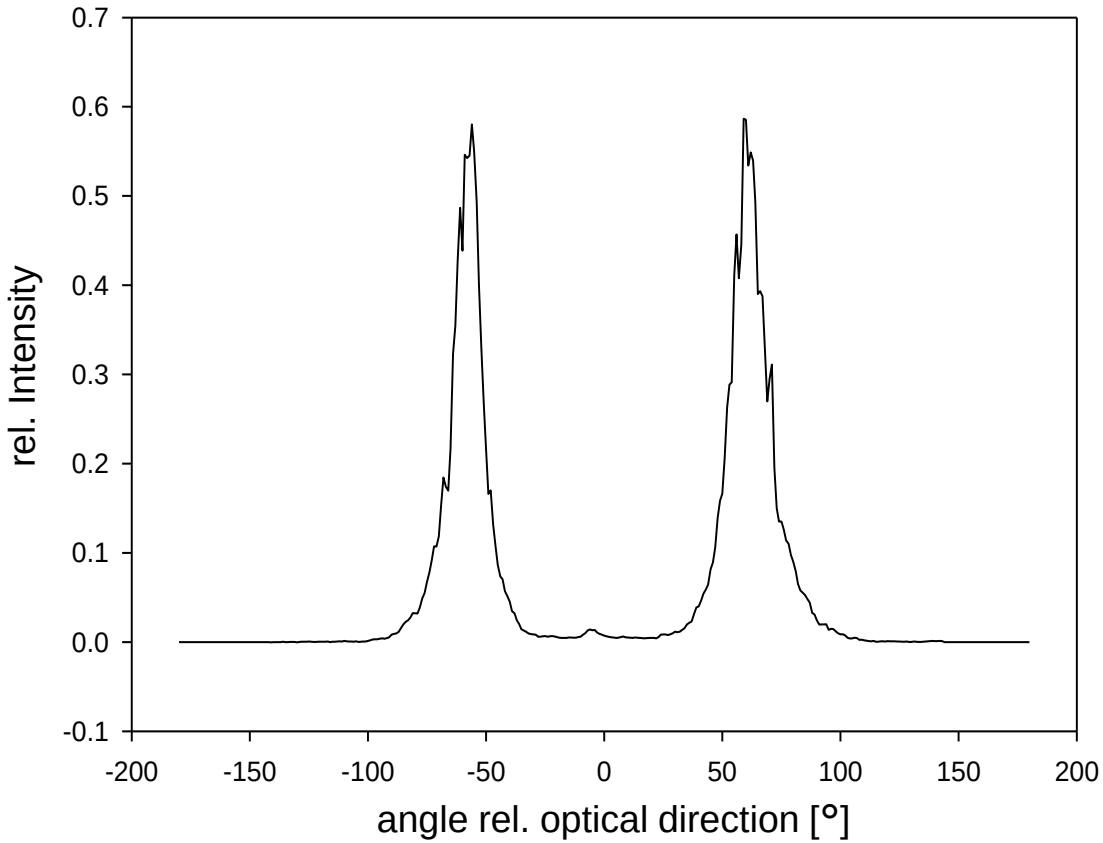
  minimally invasive procedures:

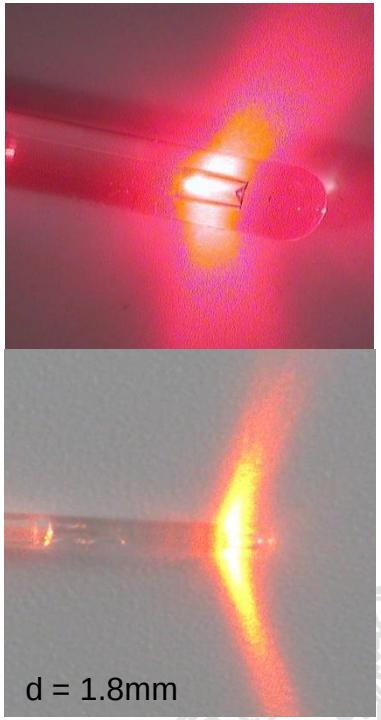
  Sclerosis (medication, foam, …)

  Radiofrequency

  Endovenous Lasertherapy / Laserablation (ELA)

RADIAL LIGHT APPLICATION



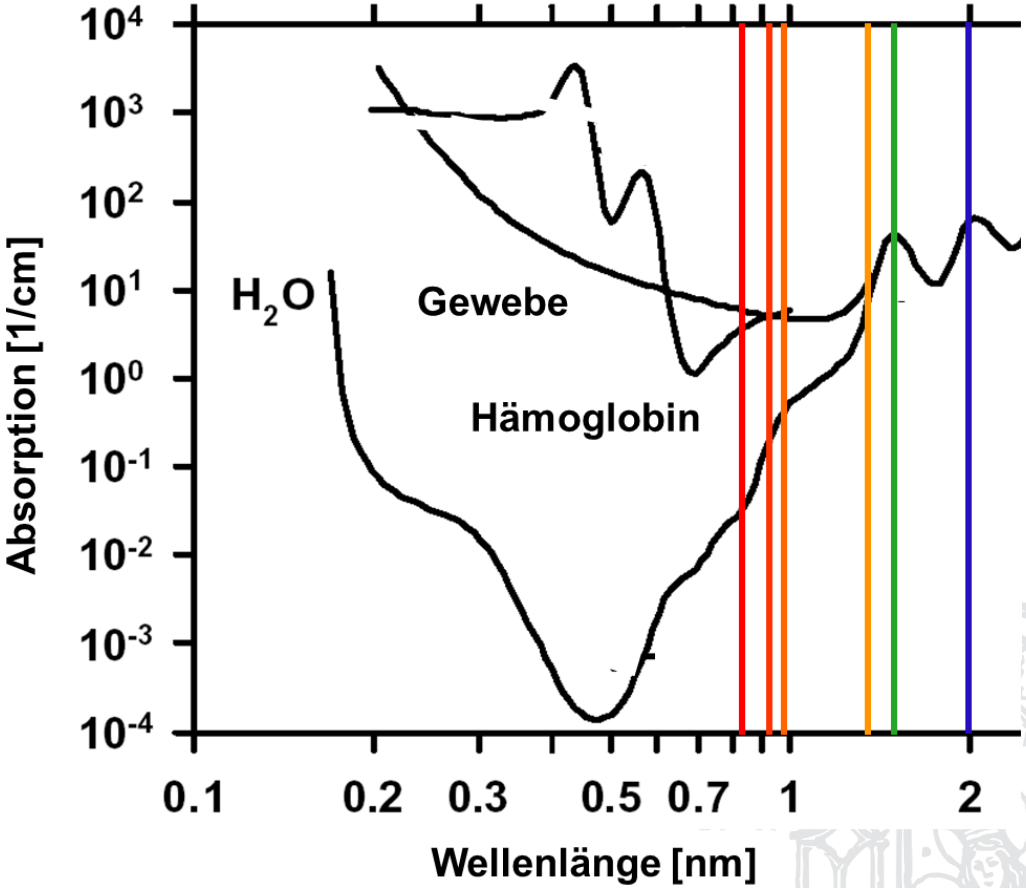


radial direction: 65°
divergency angle (FWHM): 25-30°

Sroka R et al. J Biophotonics 2010; 3:269
Sroka R et al. Phlebologie 2013;42:121

TISSUE OPTICS

[nm]	µa H_2O [1/cm]	µa Hb [1/cm]
830	0.03	4.15
940	0.27	5.41
980	0.43	6.95
1320	1.38	n.m.
1460	28.4	n.m.
1940	70-80	n.m.



Sroka R et al. J Biophotonics 2010; 3:269

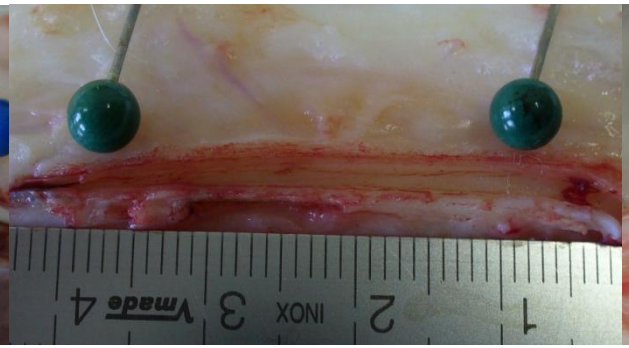
WAVELENGTH comparison

Experiment:	oxen-foot-model
Parameter:	Fibre radial, v=1mm/s, P_{start}=2W increments 1-2W
Aim:	same outer macroscopic sensation
	shrinkage, rigidity – palpable „macaroni al dente“

λ = 980nm

P=20W
LEED=200J/cm
carbonized blood

λ = 1470nm



P=6W
LEED=60J/cm
coagulated tissue

λ = 1940nm

P=3W
LEED=30J/cm
coagulated tissue

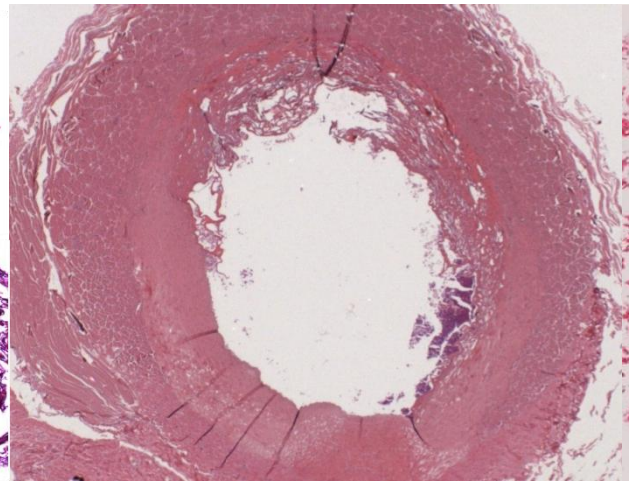
Sroka R et al. Phlebologie 2013; 42:121

WAVELENGTH Histology

λ = 980nm / bare fibre

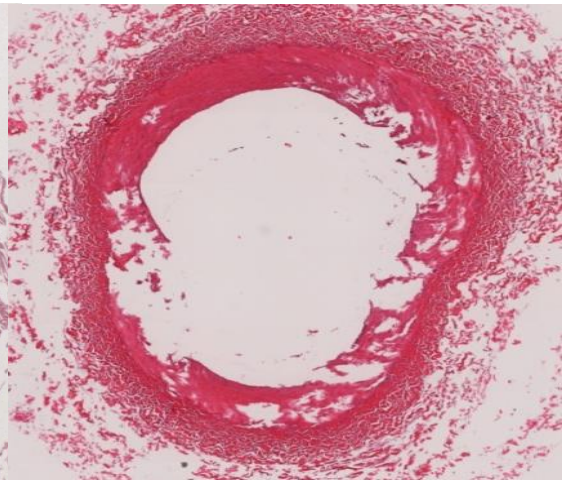
P=15W
LEED=150J/cm
carbonization
perforation

λ = 1470nm



P=6W
LEED=60J/cm
intima / media / adventitia

λ = 1940nm



P=3W
LEED=30J/cm
intima / media

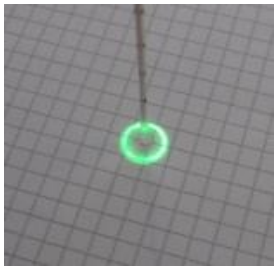
circular thermal destruction
vacuolization / delamination

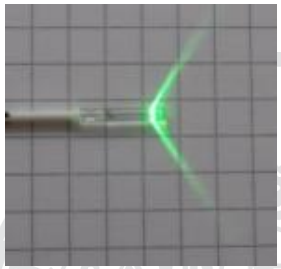
SINGLE CENTER PROSPECTIVE CLINICAL STUDY

Das Diak: Klinikum

LFL

Study	1940nm – fibre Laser (Vela XL, StarMedTec, Percha, Germany)
Start	Juli 2013
Patients	176
Protocol	1940nm, 3-9W, 1mm/s
Intra-OP	LEED 35-90J/cm no complication radial fibre faultless after OP
Follow-Up	3d, 4m, 6m DUS & Questionnaire





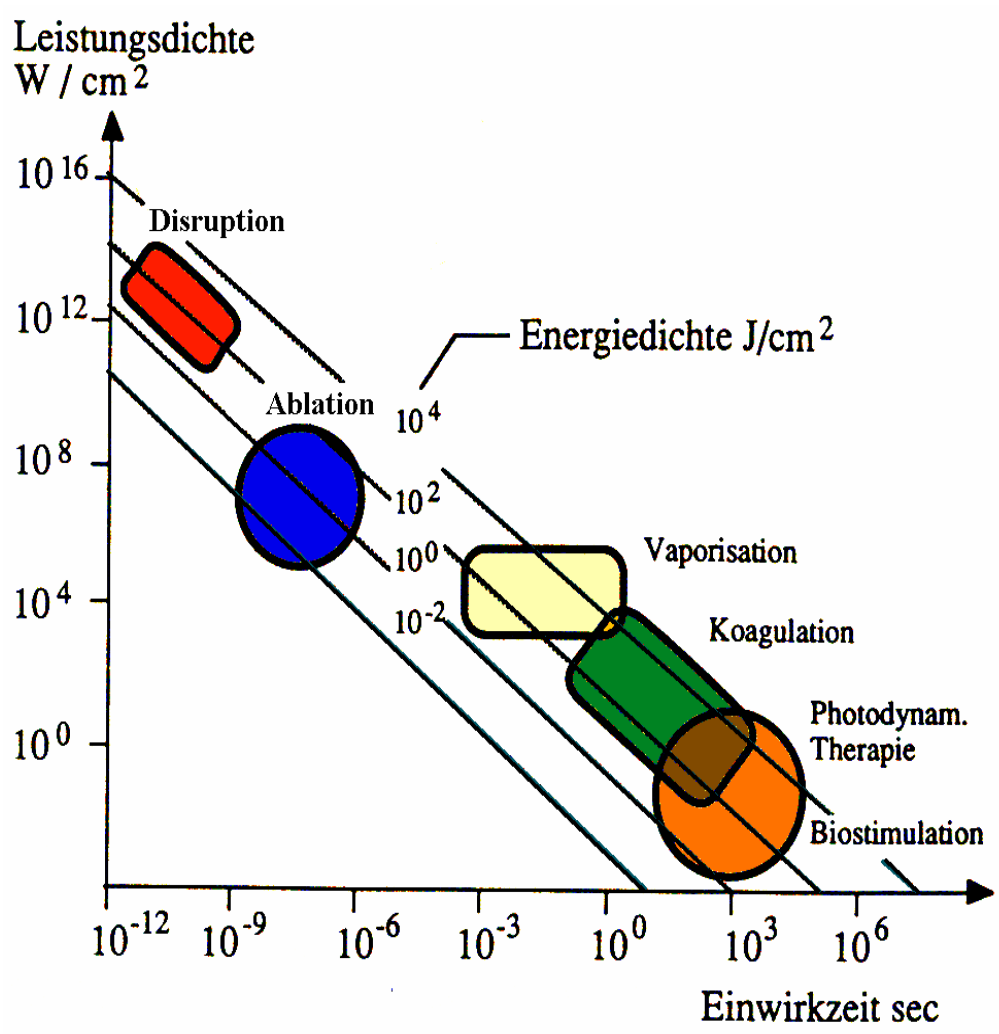
CLINIC

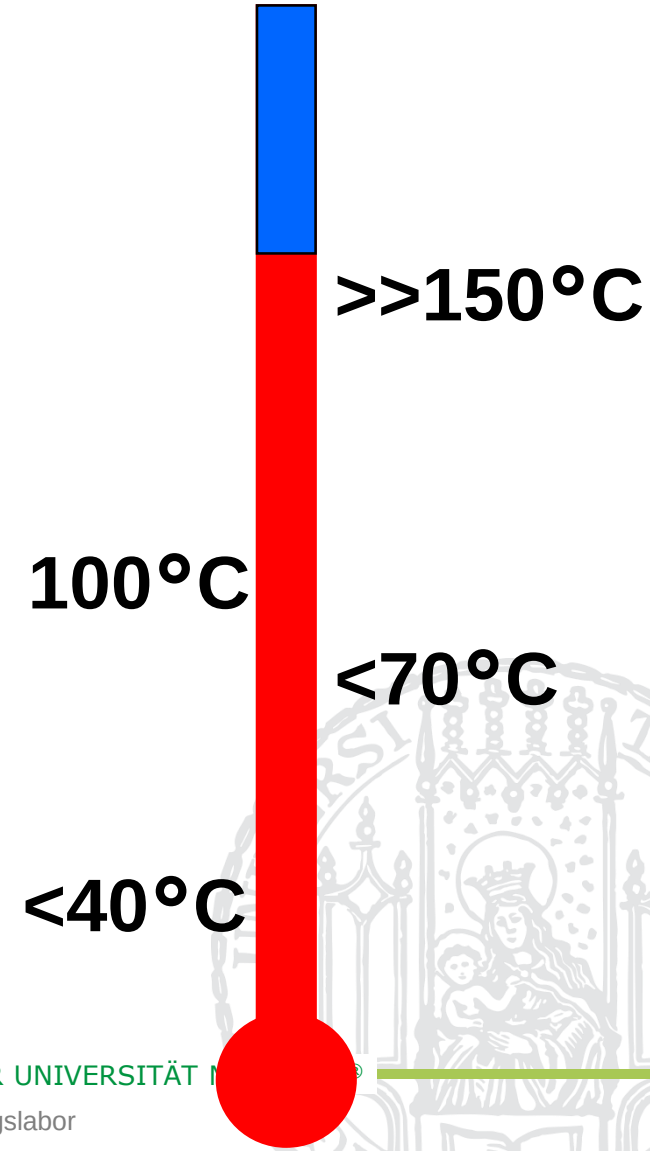
ELT-Protocol

Protocol		prior 2006	2009	2013
wavelength	[nm]	800-1320	1470	1940
pull-velocity	[mm/s]	div.	1	1
fibre		bare fiber	radial	radial
carbonisation energy	[J]	50	600	1000
power	[W]	15-30	8-12	3-9
irradiance	[W/cm²]	<10000	<400	<150
EFE	[J/cm²]	40-100	25-50	<15
LEED	[J/cm]	40-80	60-100	40-80
tissue effect		carbonized	cylindrical homo. coag.	
occlusion rate	[%]	>90	>95	-100%
side effects		diverse	pain	minor

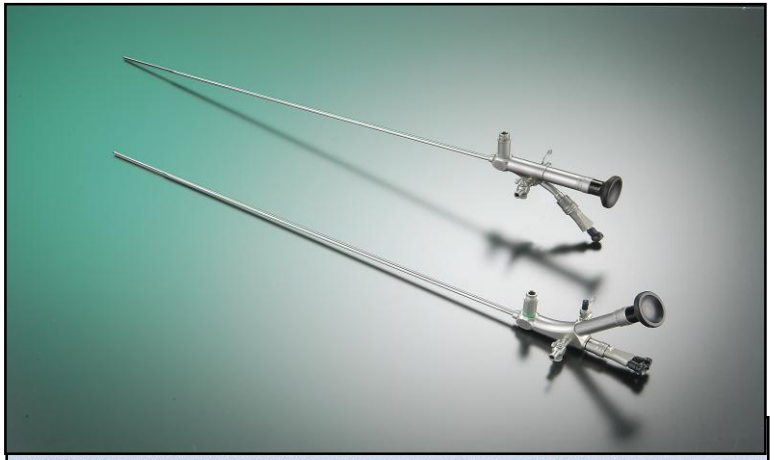
Pannier F et al. Phlebology 2009; 24: 26
Pannier F et al. Vasa 2010;39:249
Pannier F et al. Phlebology 2011: 26: 35
Maurins U et al. Int Angiol 2009; 29: 32

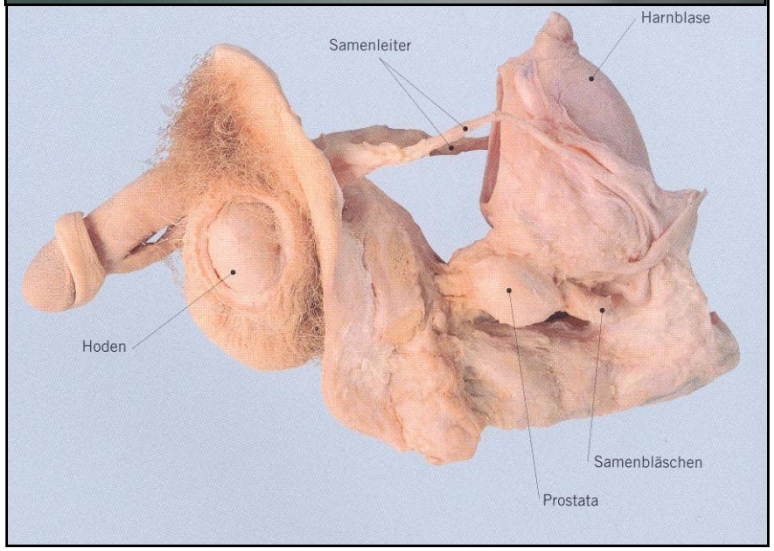
Vaporisation - Ablation





Trans-Urethral Urological Inspection

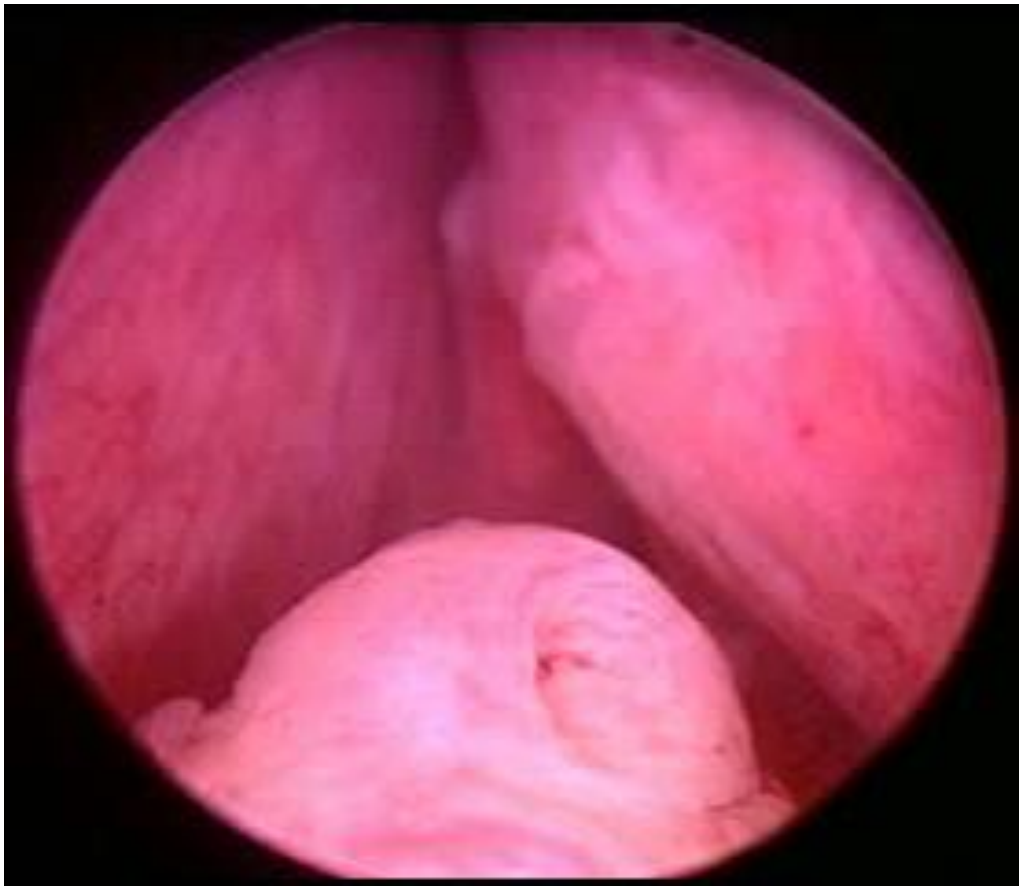




aus: Körperwelten (v. Hagen)

Prostate Enucleation

HoLEP: the gold standard for the surgical management of BPH in the 21st Century



For many years TURP gold standard to surgically alleviate obstructive voiding dysfunction (BPH).

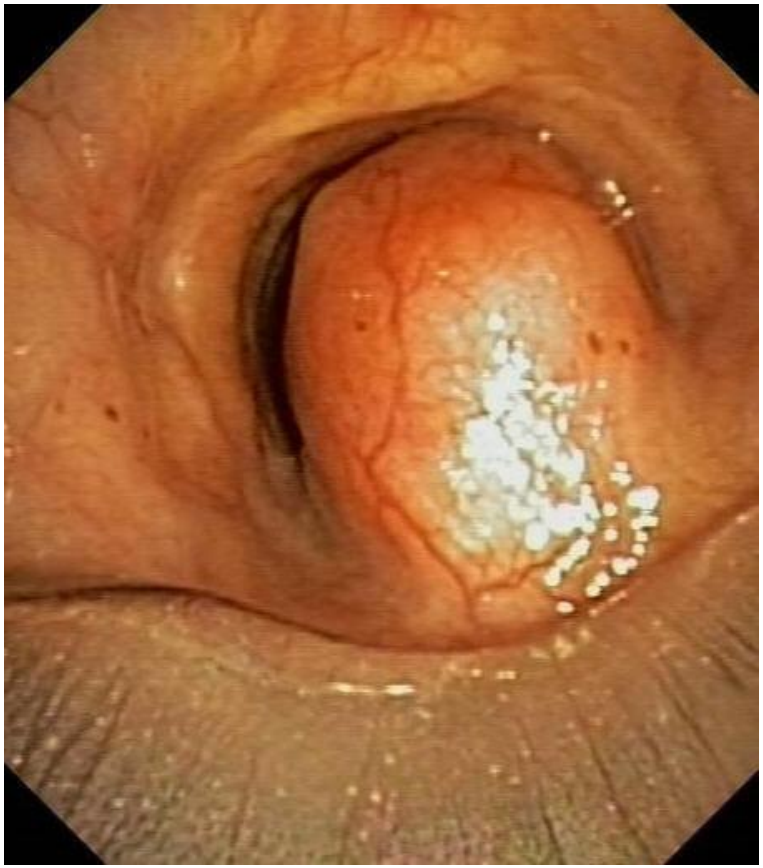
TURP has been challenged repeatedly over the last decade by consistent data demonstrating the superiority of Holmium enucleation of the prostate (HoLEP).

Review summarizes and compares HoLEP vs traditional therapies

Michalak J et al., Am J Clin Exp Urol. 2015; 3(1): 36–42.

ENDOBRONCHIAL THERAPY WITH 1940 NM

stent removal, no fire, no popcorn, no perforation, more precise



Gesierich W et al., J Thorac Cardiovasc Surg. 2014;147(6):1827-32.

LAPARASCOPIC PARTIAL TUMOR RESECTION

Clinical problem

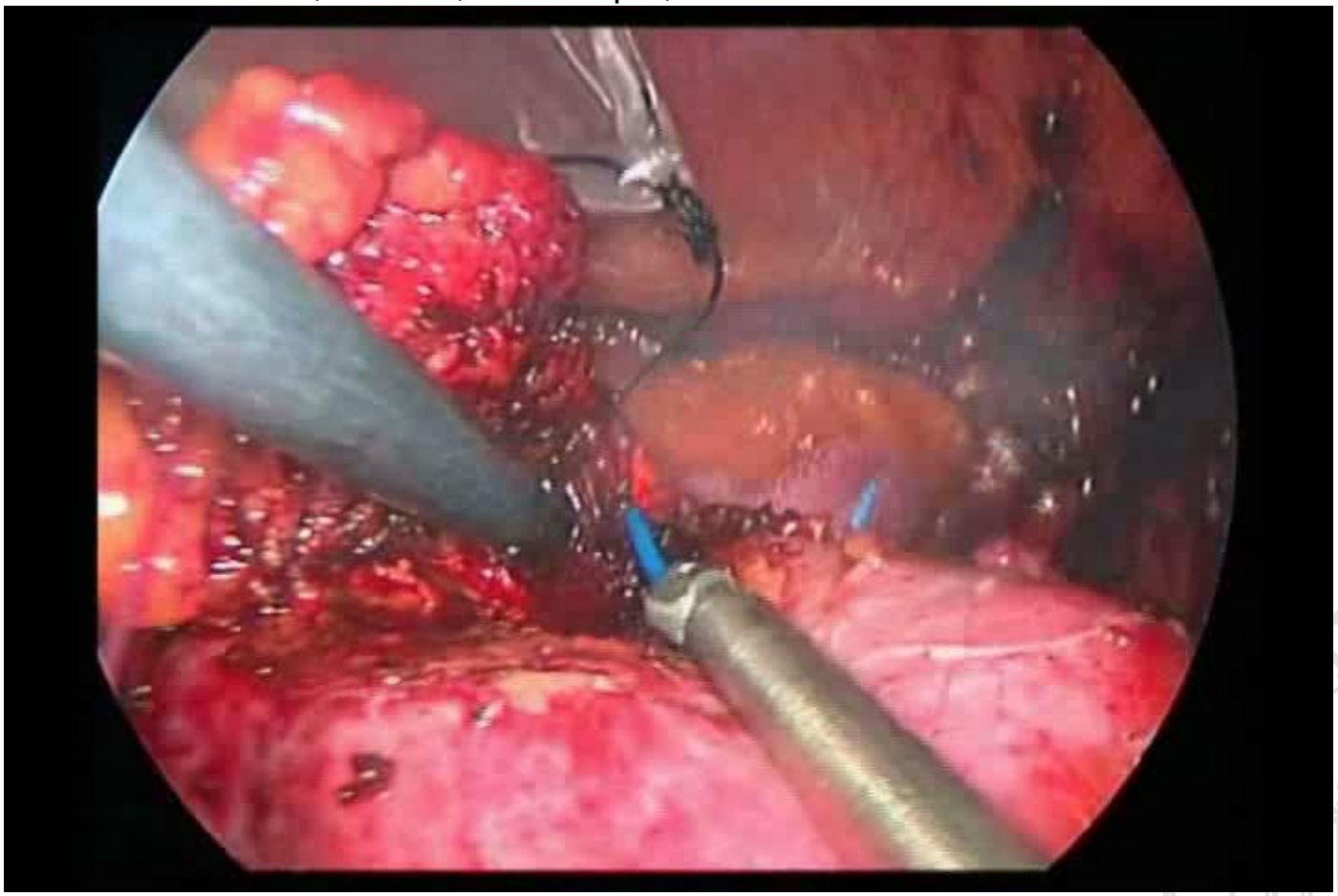
surgical removal of tumors and malformations

Up to now

surgery	open or laparascopic
warm ischemia	vessel-clamping OP-duration max 20min
cold ischemia	takes about 15min to T<20°C OP-duration complete 45min
bloodloss	ca. 500ml

LAPARASCOPIC PARTIAL TUMOR RESECTION

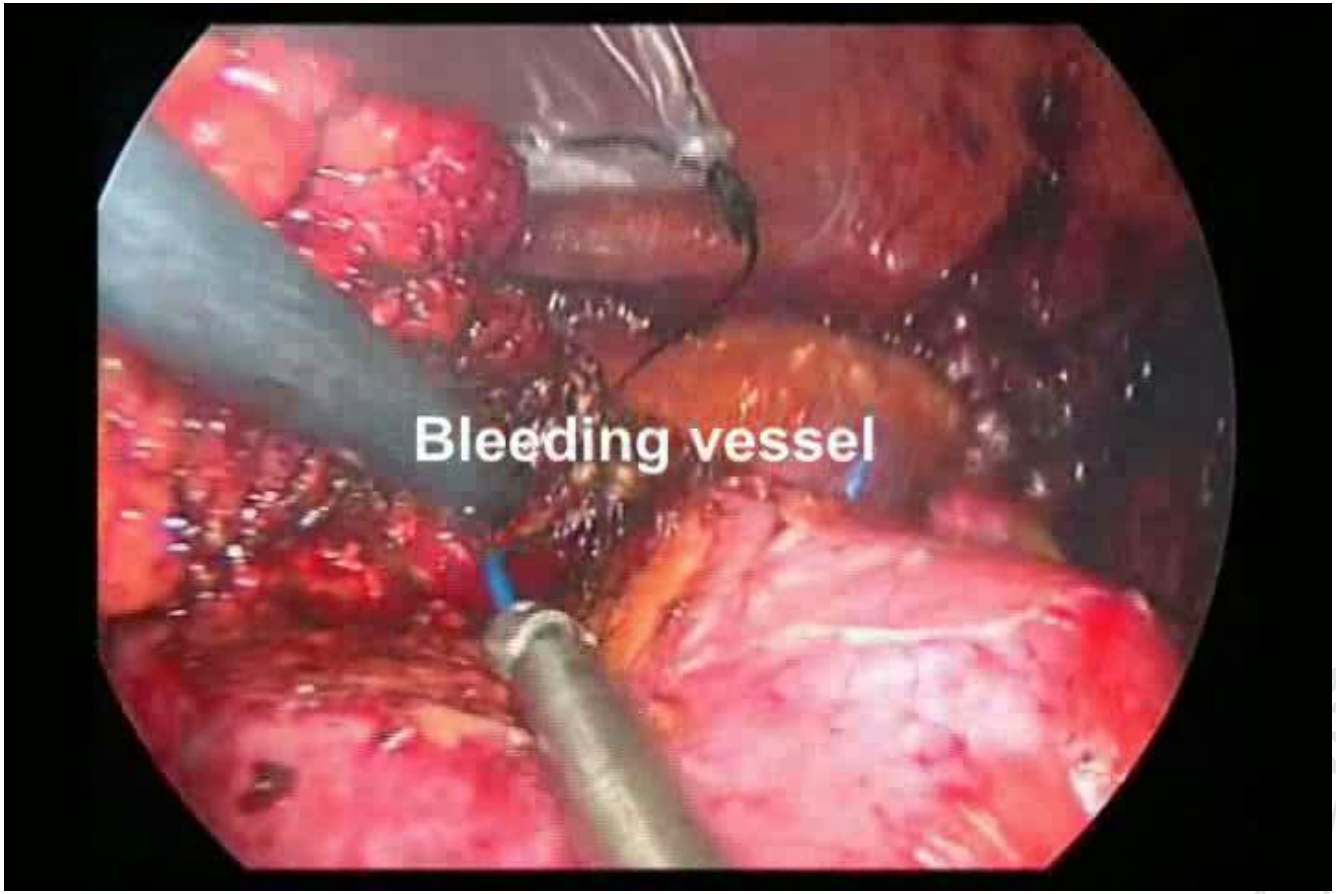
diode laser 1320nm, 55-70W, fibre 600µm, 1-3mm/s



Khoder WY, Sroka R et al Journal of Endourology Part B, Videourology. 2011

LAPARASCOPIC PARTIAL TUMOR RESECTION

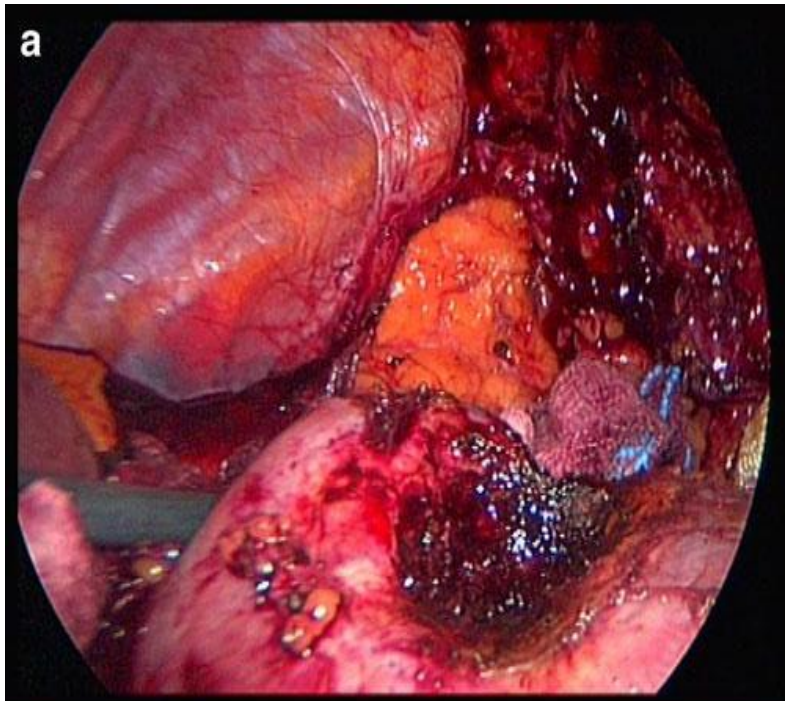
Cave: large vessel destruction

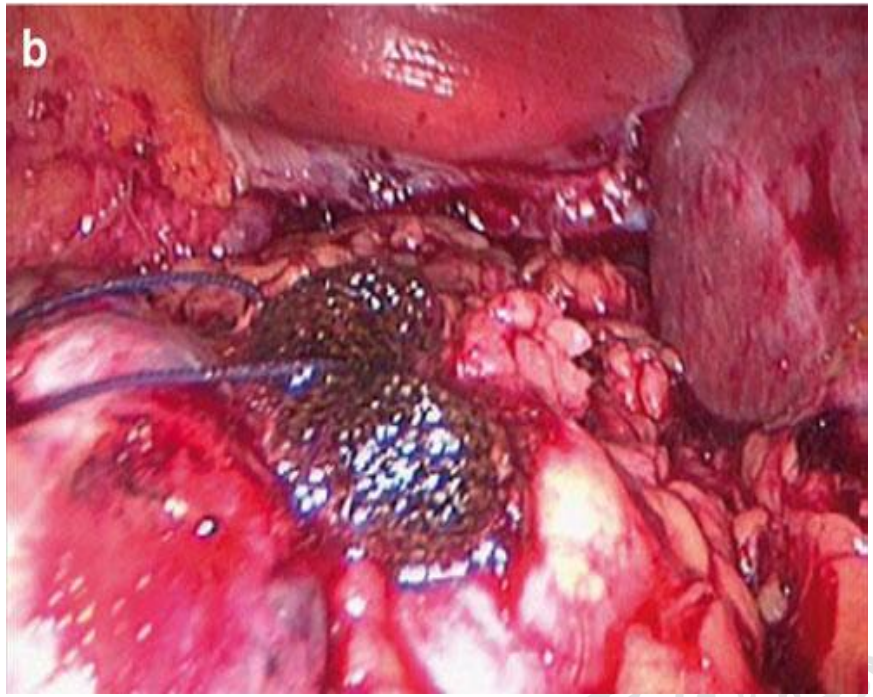


Khoder WY, Sroka R et al Journal of Endourology Part B, Videourology. 2011

LAPARASCOPIC PARTIAL TUMOR RESECTION

AFTER LASER APPLICATION





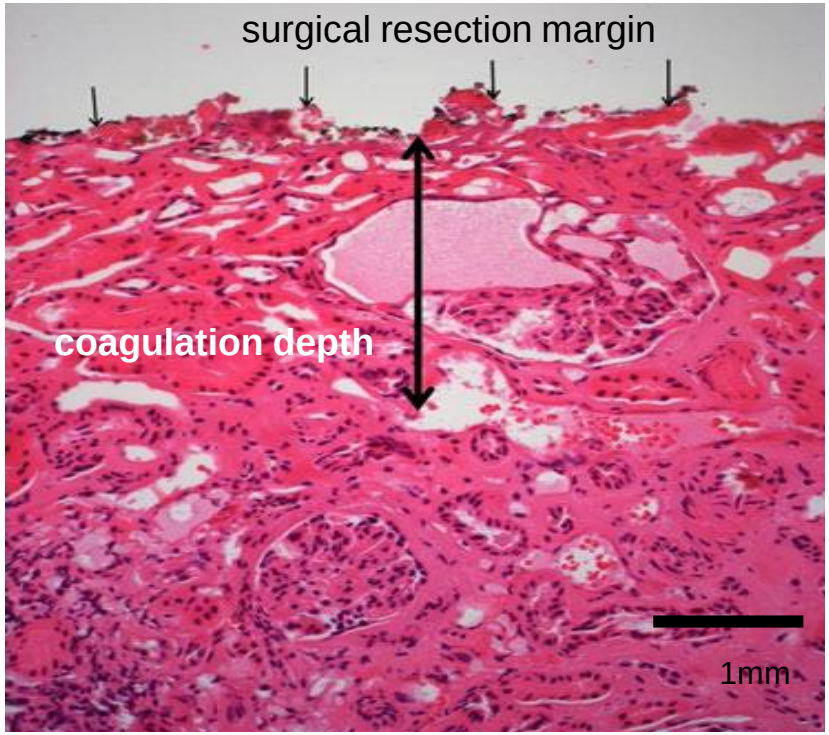
tumor bed after tumor excision and coagulation

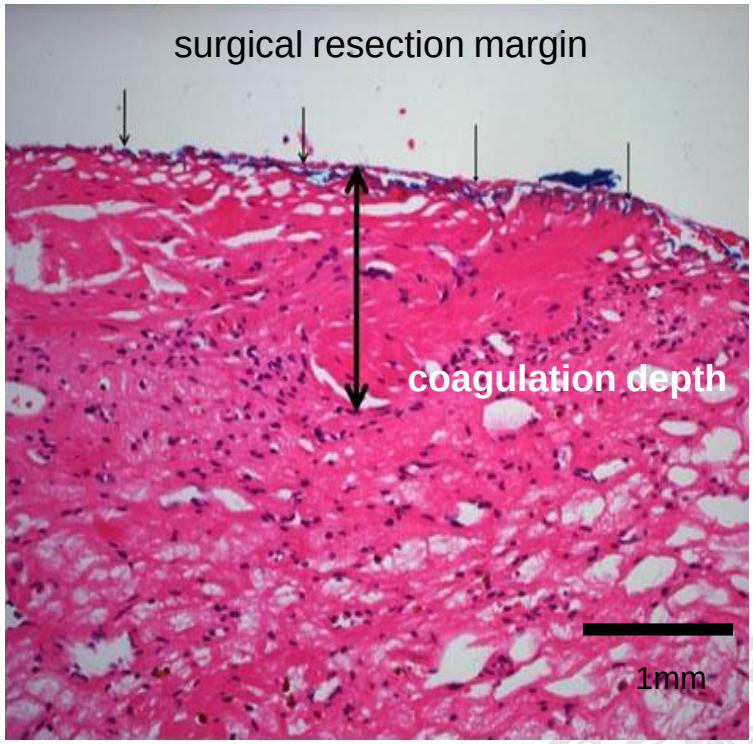
reconstruction of the parenchymal surface covered with cellulose mesh using 0–0 Vicryl sutures

Khoder WY, Sroka R et al. Lasers Med Sci. 2011 (Epub)

LAPARASCOPIC PARTIAL TUMOR RESECTION

HISTOLOGY





Specimen of two patients (HE mag. 200)

tubular structures and stroma are partially destroyed
tubular epithelium shows marked hypereosinophilia

Khoder WY, Sroka R et al. Lasers Med Sci. 2011 (Epub)

LAPARASCOPIC PARTIAL TUMOR RESECTION

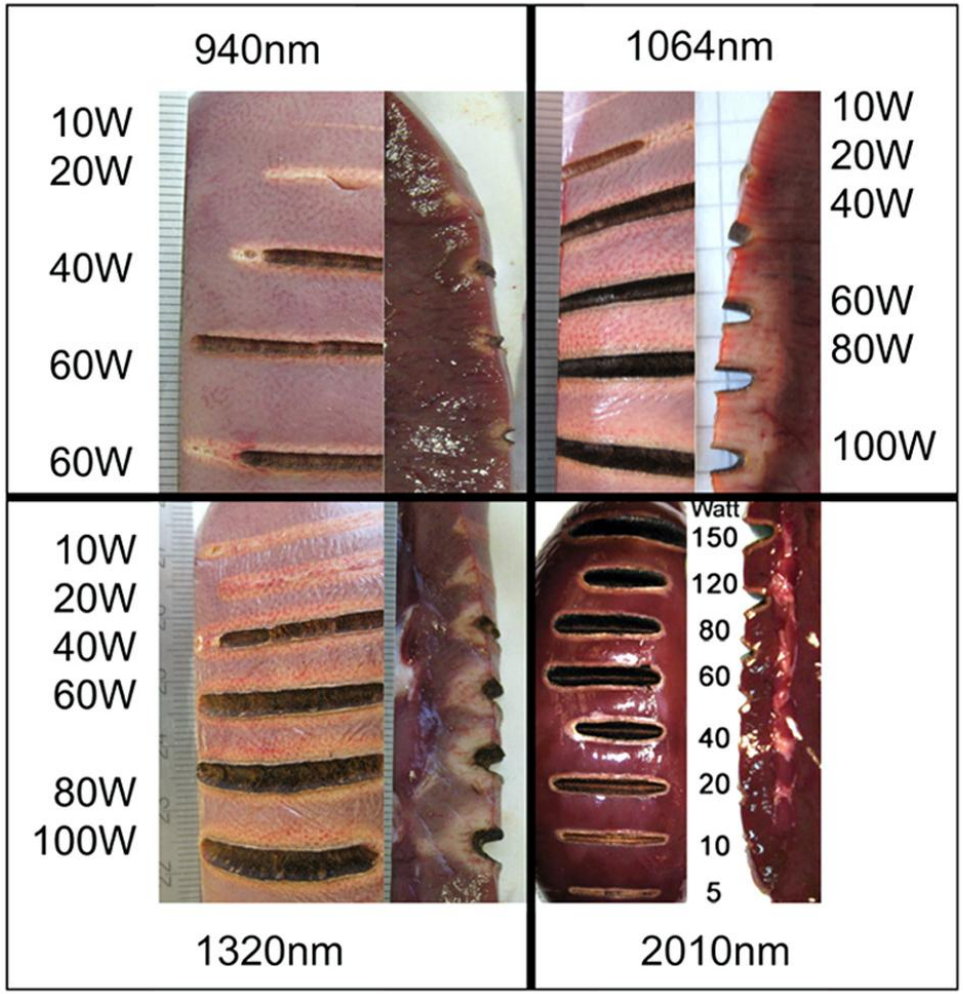
Clinical Results

	open surgery n=5	**laparascopic n=8**	**conv.**
OP-time	60-90min	110-175	equal
Laser time	ca.10min	ca.15min	equal
Blood loss	20-400ml	50-600ml	equal
Coag rim	1-2mm	1-2mm	equal
Ischemia	1/5 partial	2/8 (19, 24min)	better
Complication	none	none	equal

Khoder WY, Sroka R et al. Lasers Med Sci. 2011 (Epub)

LAPARASCOPIC PARTIAL TUMOR RESECTION

Challenge



Tissue samples macroscopy:

(superficial view and saggital cuts)

Note the color changes, the carbonized surface with underlying whitish coagulation

Parameter:

fiber 600µm
1mm/s
contact mode

Khoder WY et al Journal of Biomedical Optics 17(6), 068005 (2012)

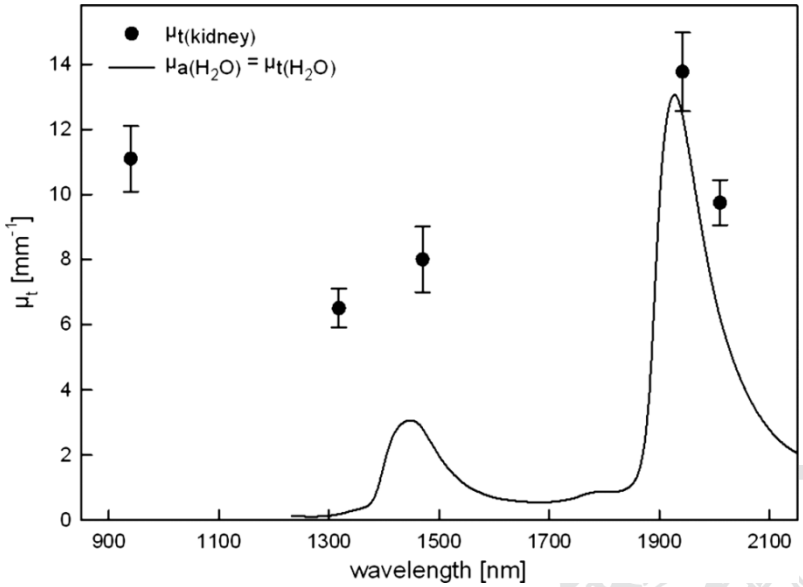
LAPARASCOPIC PARTIAL TUMOR RESECTION

Challenge

Table 3 Subjective correlation of the appearance of tissue surface colors to laser output and different wavelengths used for laser-induced cutting experiments by means of continuous wave, fiber velocity of 1 mm/s and contact mode.

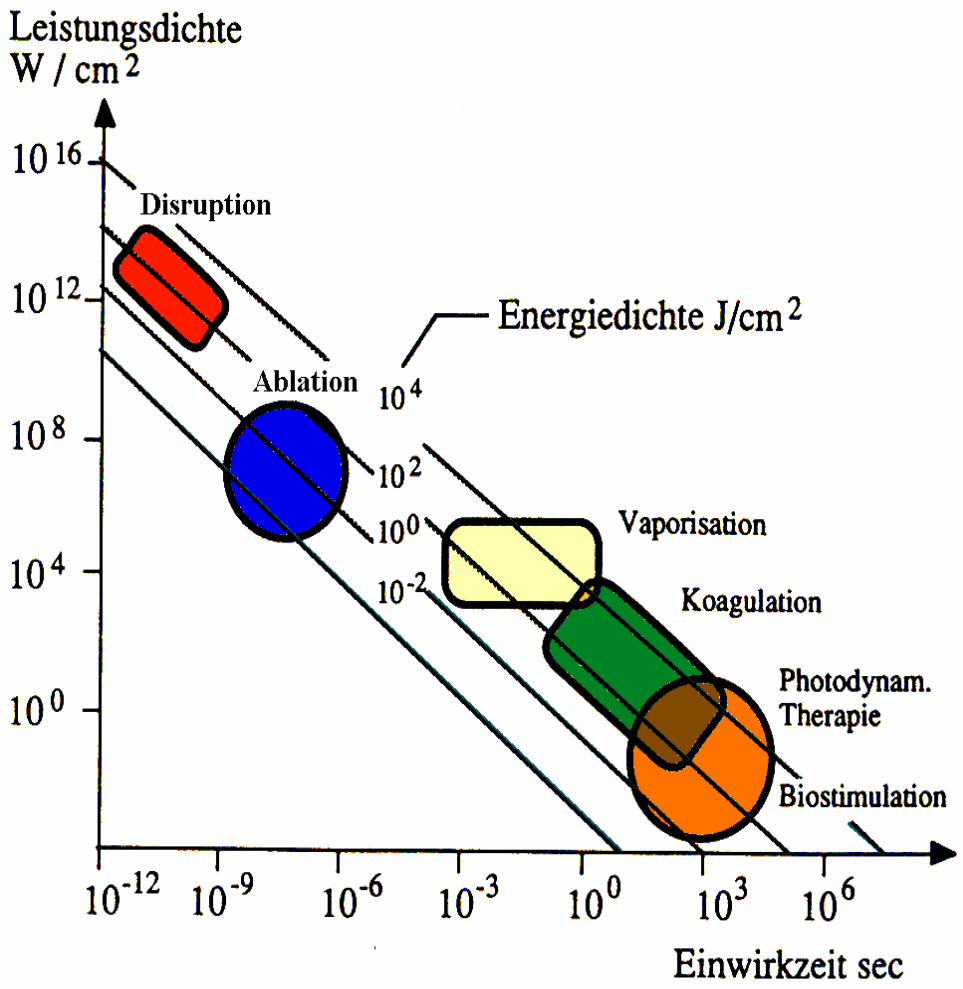
Contact-mode v=1 mm/s	Correlation of appeared tissue surface color to laser power		
Wavelength (mm)	Whitish-coagulation	Brown	Black-carbonization
940	10 to 20 W		≥40 W
1064	10 W	20 W	≥40 W
1318	10 to 20 W	40 W	≥60 W
1470	10 to 20 W	30 W	40 W
1940	5 W	10 to 20 W	≥40 W
2010	5 W	10 to 20 W	≥40 W

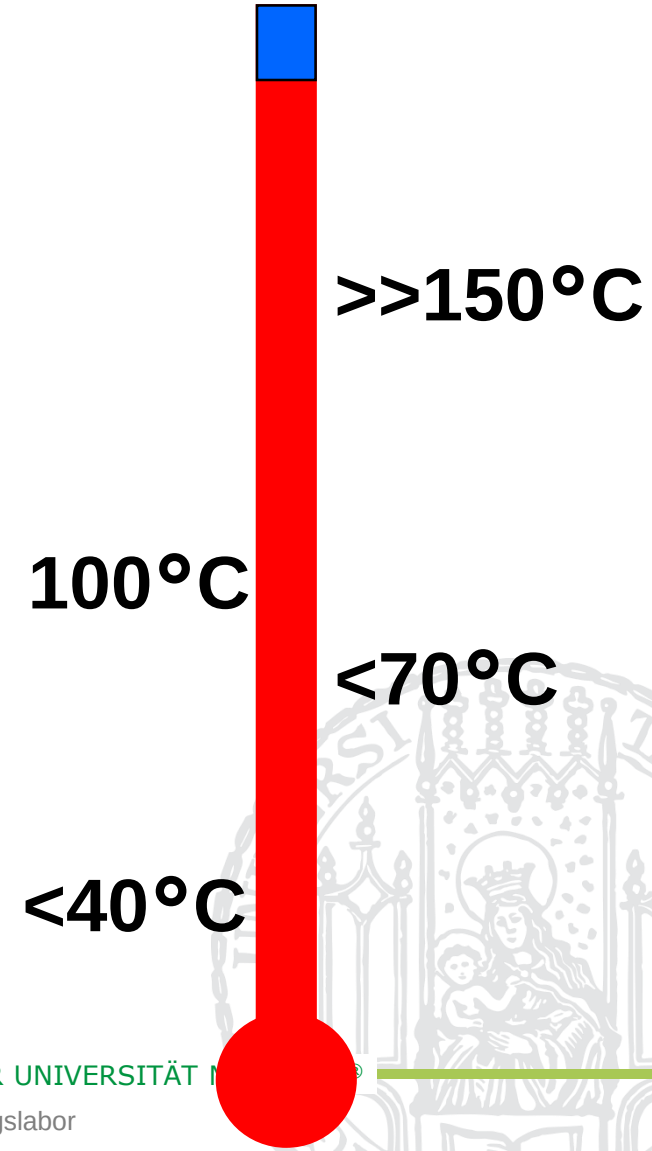
Kidney optical attenuation coefficient in comparison to water absorption coefficient in the spectral region of 900 to 2150 nm.



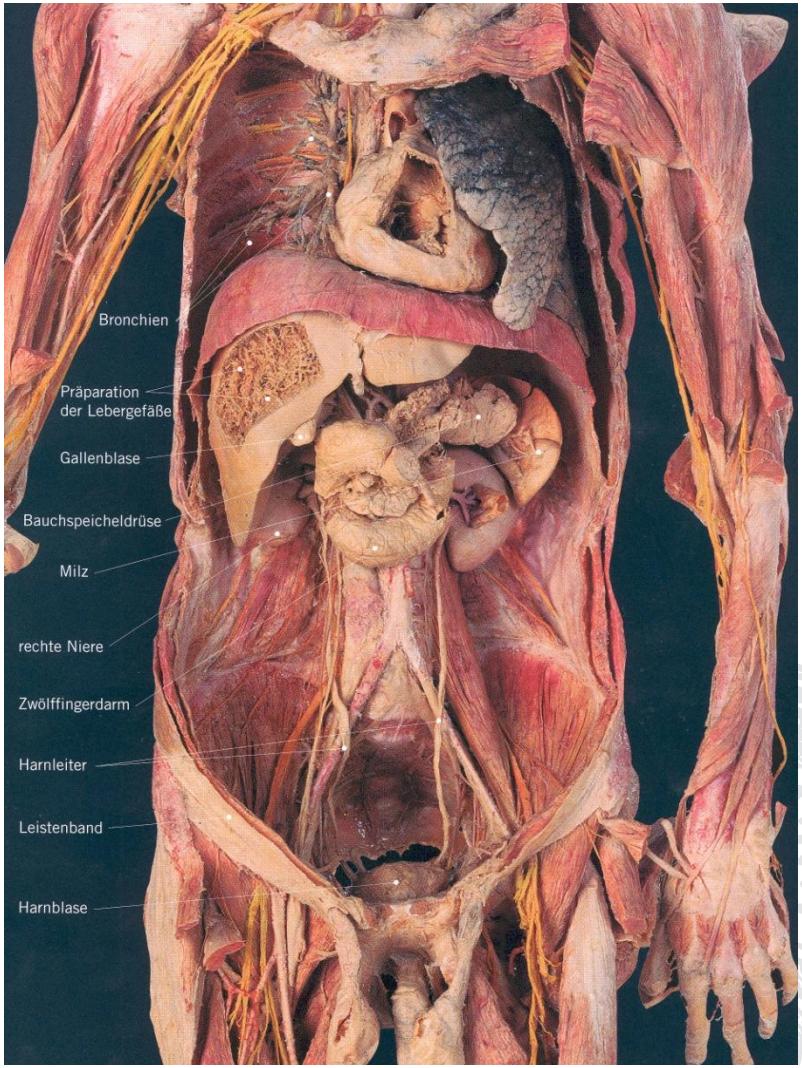
Khoder WY et al Journal of Biomedical Optics 17(6), 068005 (2012)

Disruption - Fragmentation





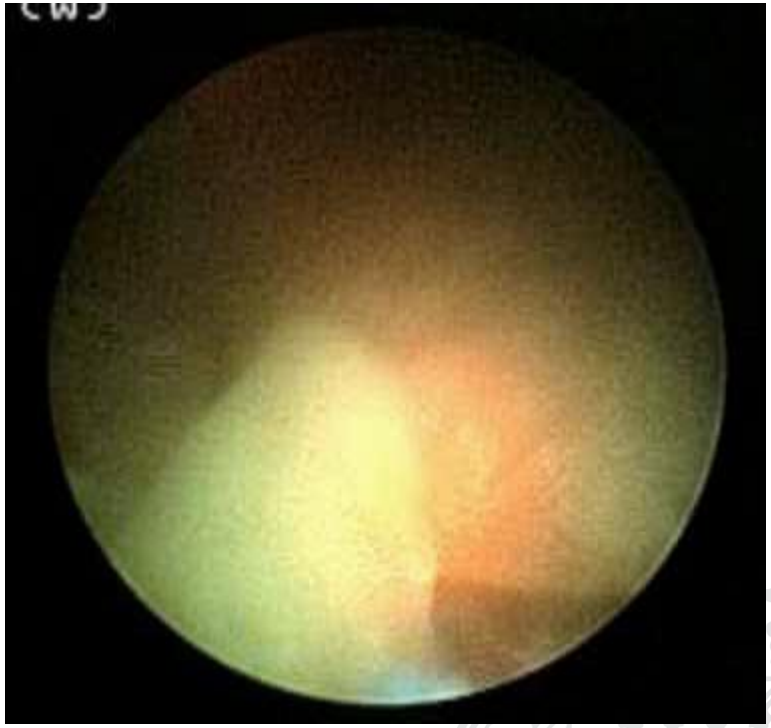
Lithotripsy Clinically



aus: Körperwelten (v. Hagen)

Lithotripsy

2-10µs-laser pulse



250-1000µs-laser pulse

Scope

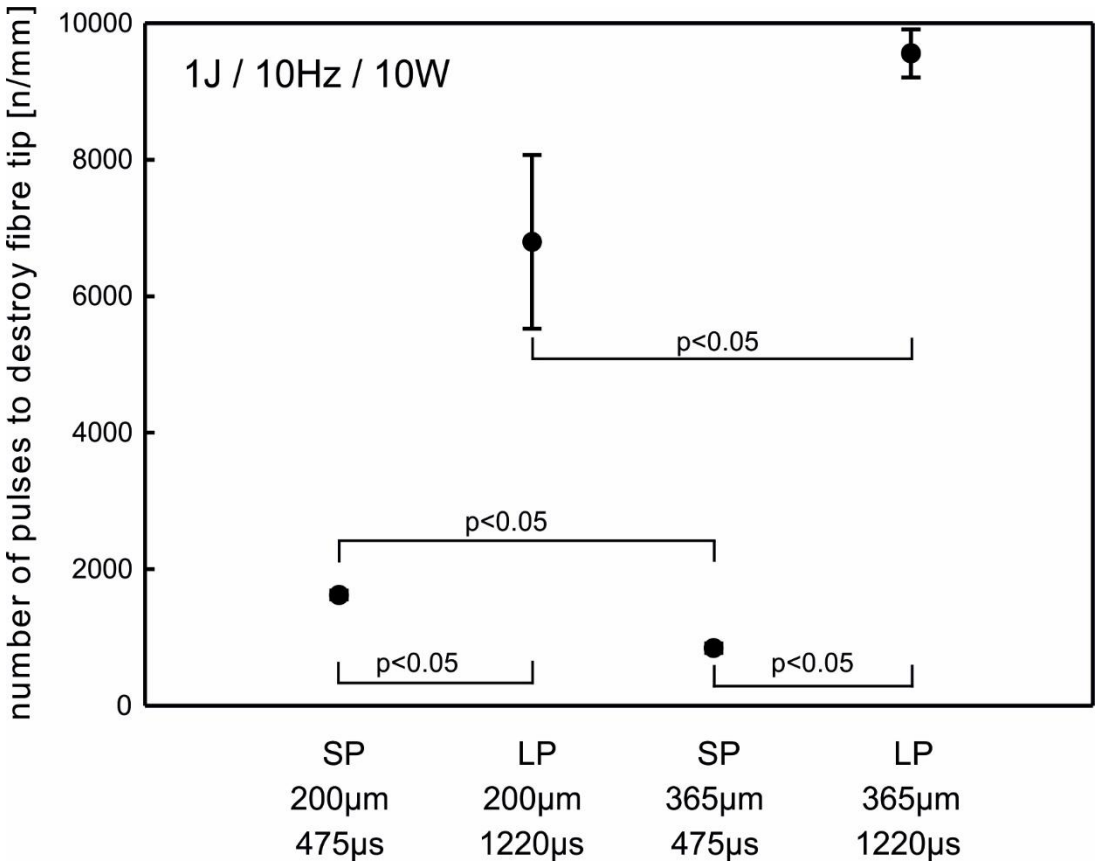
MD subjective statement

LongPulse show better effects than ShortPulse

Aim Objective experiments to show differences in effects related to the pulse duration

Fiber burn back

result

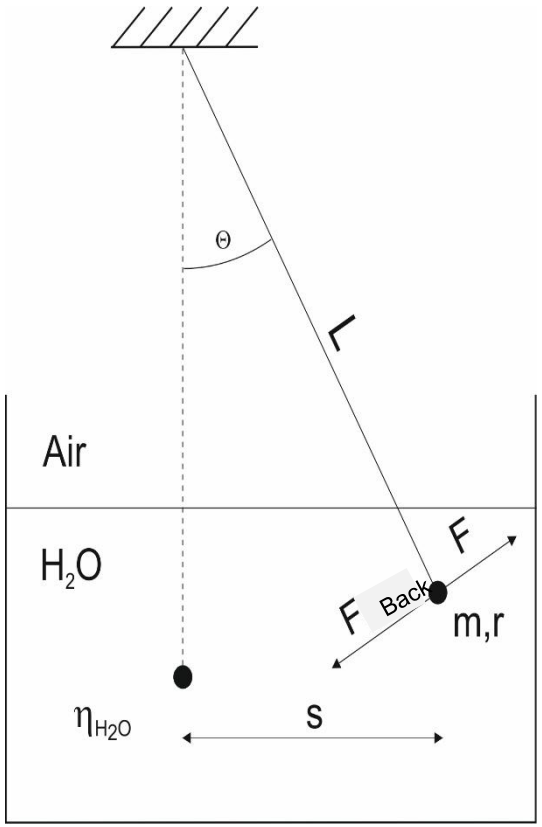


Fibre burn back is a stochastic process
n(LP) >> n(SP) to destroy fibre

Sroka R et al., World J Urol. 2015 Apr;33(4):479-85.

Repulsion

set-up



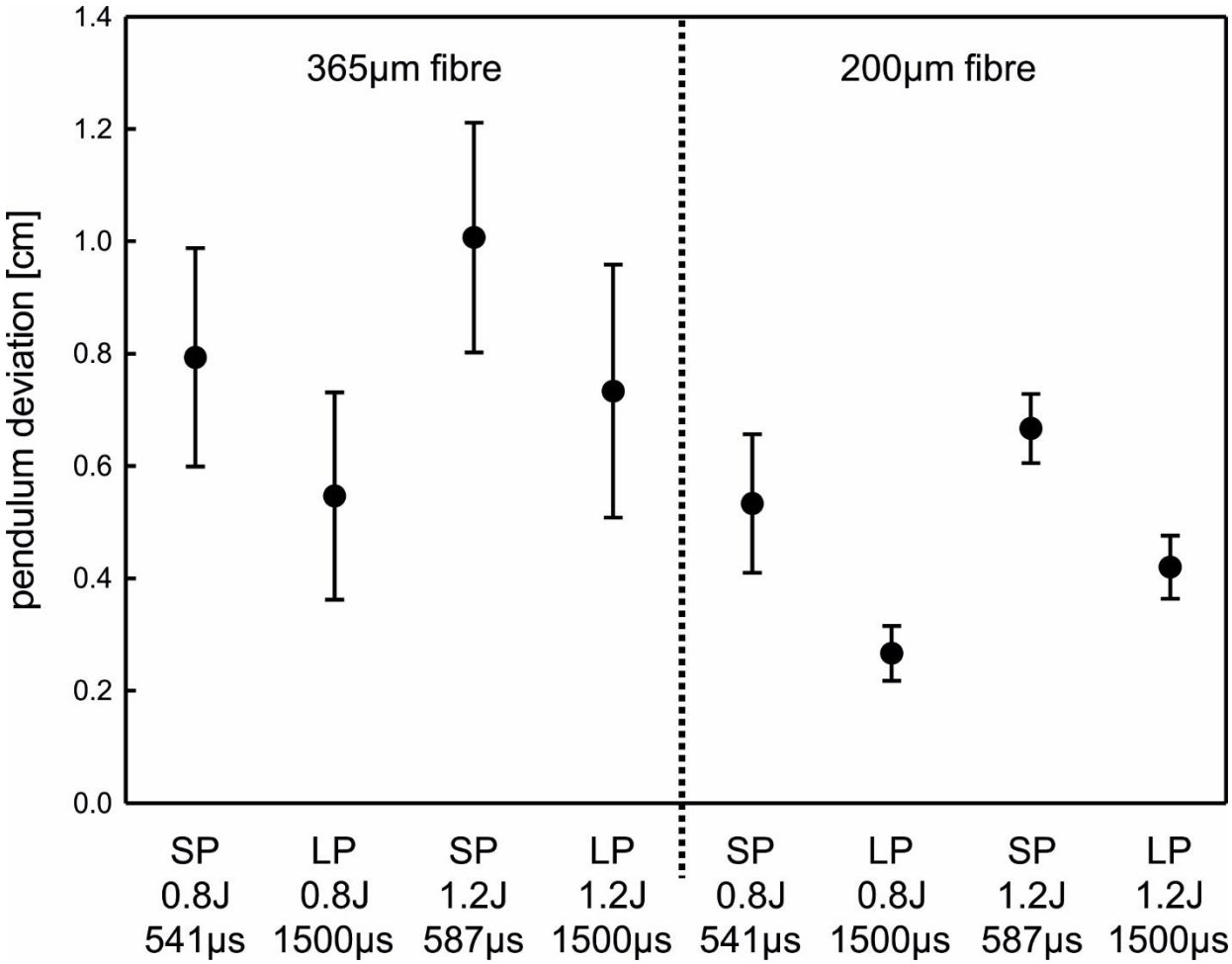
Schematic diagram of the forces involved in the equation of motion of the pendulum experiment:

F	Stokes friction
F_{back}	restore force
m	mass of the pendulum
r	radius of the lead ball
s	deflection
L	length of pendulum
Θ	deflection angle
η_{H2O}	viscosity of water

Experimental set-up, measurements and evaluation were previously described

Sroka R et al. Lasers Med Sci. 2012 May;27(3):637-43

Repulsion result



max. pendulum deviation

high energy per pulse
short pulse duration
large fibre core diameter

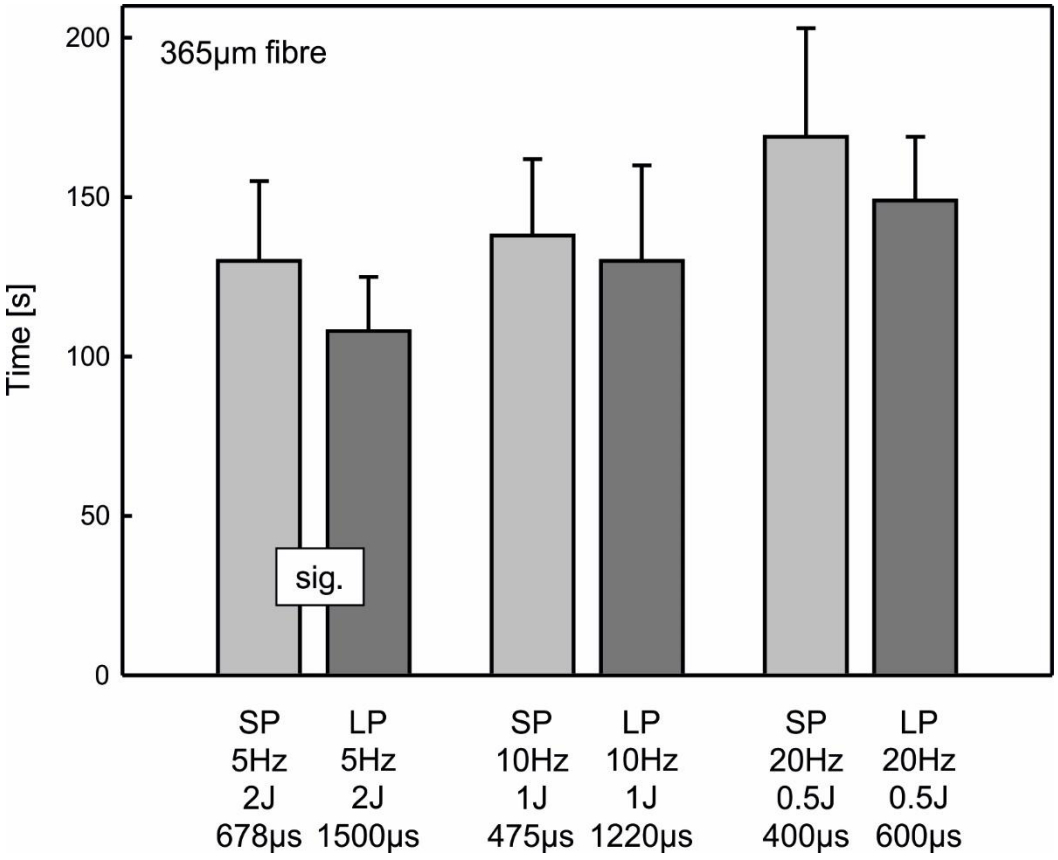
repulsion decreases

reduced energy per pulse
smaller fibre core diameter
longer pulse duration

Sroka R et al., World J Urol. 2015 Apr;33(4):479-85.

Fragmentation

hand-held



Hand-held and motivated fragmentation showed no sign. differences LP vs SP but for 2J-5Hz

Bader MJ et al., World J Urol. 2015 Apr;33(4):471-7.

Conclusion

Fragmentation	experiments showed no sign. difference
Single Pulse	trends may reflect clinical observation

Recommendation

LongPulse	reduced side effects additional maneuvres could be reduced effect on soft tissue may be reduced smaller fragments could be beneficial
ShortPulse	fixed urolith repulsion effects are minimized fast fragmentation looks promising

Summary

- variety of medical application
  - coagulation – sealing
  - vaporisation – cutting
  - disruption – fragmentation

- Challenge
  - optimization of treatment parameter
  - wavelength
  - pulse duration
  - fiber

- Acceptance in Medical Community

THANK YOU FOR ATTENTION

Special Thanks

LFL-Team:

H Stepp

A Rühm

W Beyer

G Hennig

C Homann

N Markwardt

R Baumgartner

T Pongratz

Clinical Partners:

Otorhinolaryngology

Phlebology

Urology

Pulmology

Financial & Equipment:

National Grants

International Grants

Companies

Students:

Internship

Bachelor

Master

PhD & MD