Ente Ecclesiastico

Ospedale Generale Regionale "F. Miulli"

Acquaviva delle Fonti

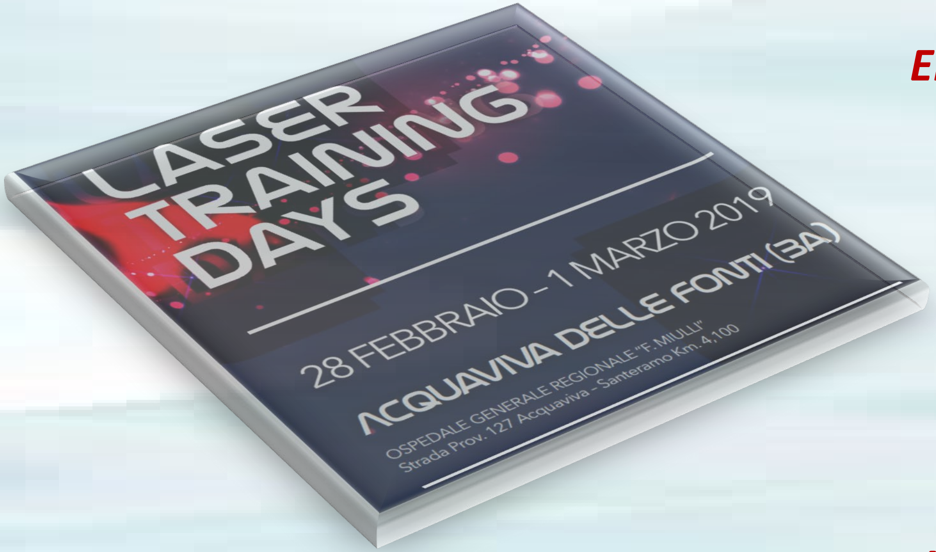
Struttura Complessa di Urologia

Centro di Chirurgia

Robotica - Laparoscopica – Mininvasiva

Direttore: Giuseppe Mario Ludovico

http://www.urologiamiulli.com



ENERGIA LASER IN UROLOGIA
APPLICAZIONI CLINICHE

G. Cardo

Acquaviva delle Fonti 28 febbraio 2019

Laser in urologia

Promesse

Aspettative

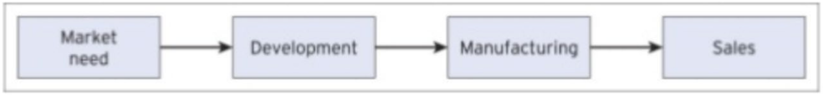
Risultati

Costi

Futuro

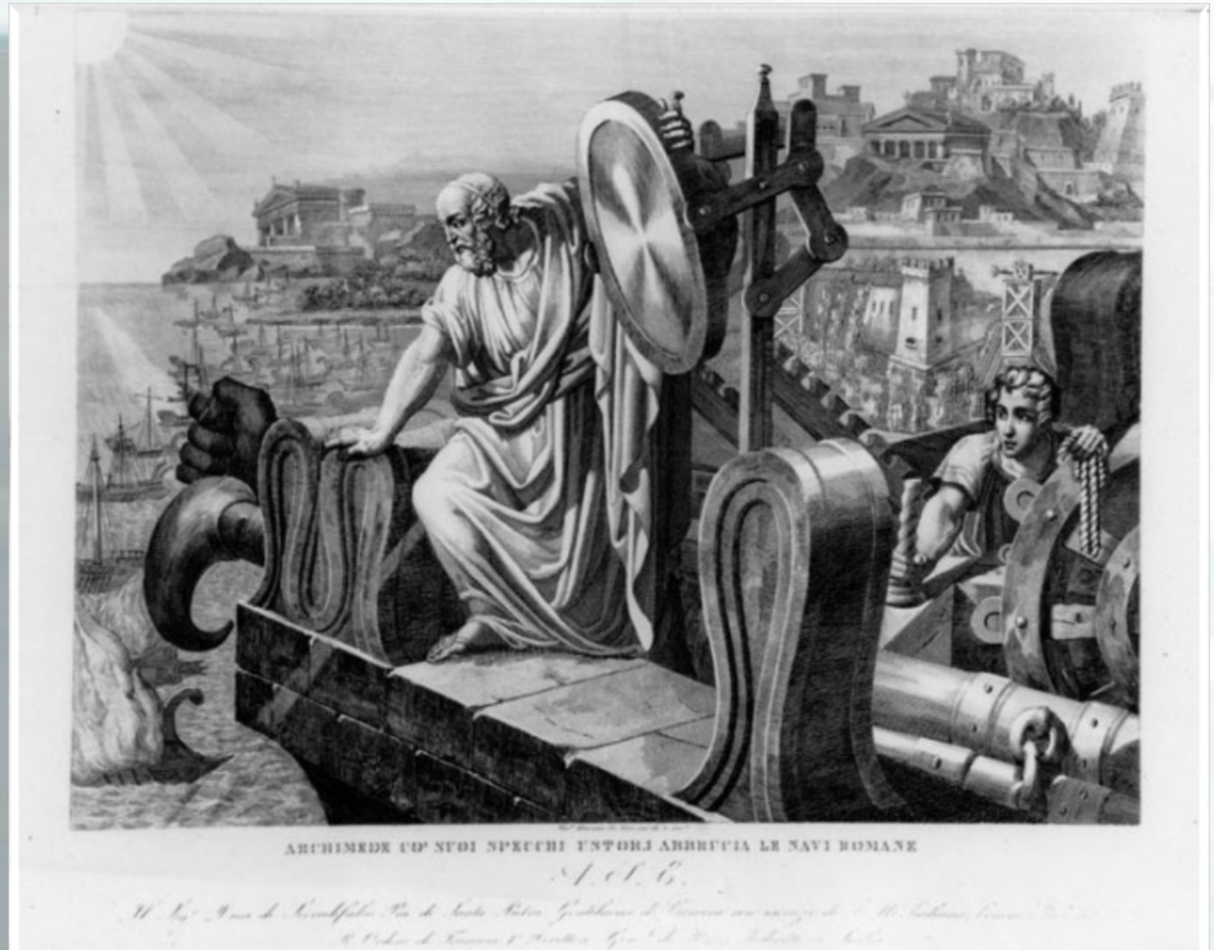
Tech-push innovation

Market-pull innovation



Trasmissione della luce

Archimede



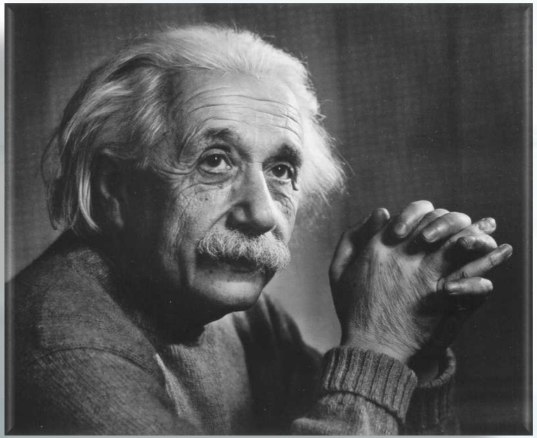
Console Marco Claudio Marcello
Assedio romano di Siracusa 212 a.c.

URΟLOGY DEPARTMENT

STORIA DEL LASER

Light Amplification by Stimulated Emission of Radiation

1917	Einstein propone il concetto di emissione stimolata di radiazione
1960	Maimen produce la prima emissione laser visibile (synthetic ruby cristal)
1966	Parson usa un laser ruby pulsato in una vescica di cane
1968	Mulvany esegue la frammentazione laser di calcoli urinari
1996	Gilling riporta la prima resezione laser di prostata



SITZUNGSBERICHTE

V.

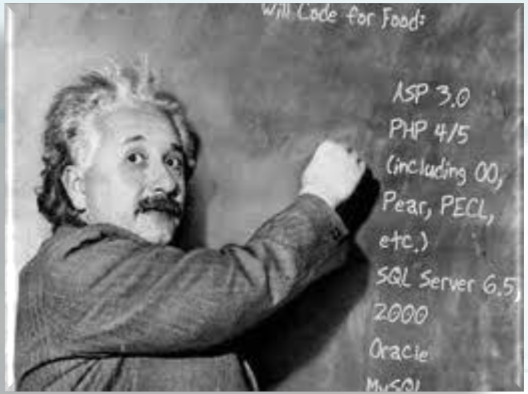
DER PREUSSISCHEN

AKADEMIE DER WISSENSCHAFTEN

Zur allgemeinen Relativitätstheorie.

Von A. Einstein.

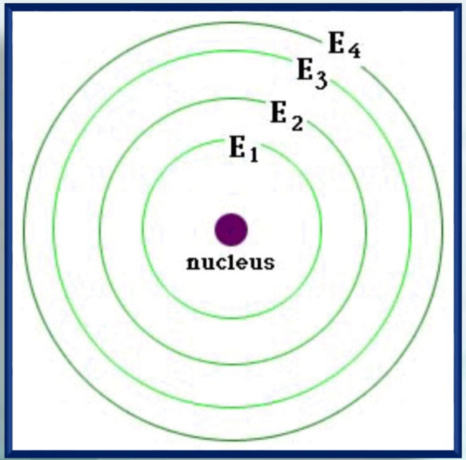
STORIA DEL LASER



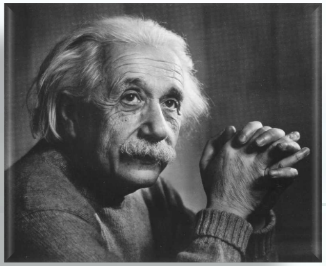
1 *La luce viaggia in quanti di energia definiti fotoni*

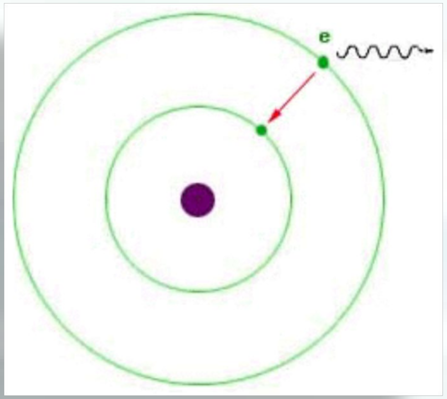
2 *La maggior parte degli atomi o molecole esiste naturalmente in uno stato basale di bassa energia (stato E^{0})*

3 *Una piccola percentuale di atomi può naturalmente esistere per un dato tempo ad un definito livello di energia (E^{1} E^{2} E^{n})*



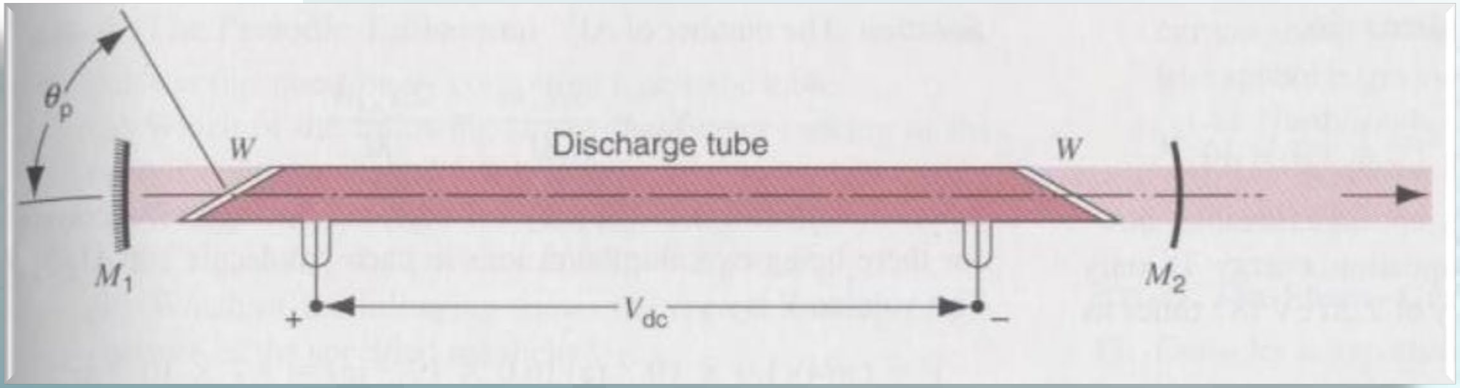
STORIA DEL LASER





Applicando elettricità, calore od energia luminosa agli atomi nel loro stato basale, il loro livello di energia raggiunge uno stato a maggiore energia.

L’energia viene in seguito rilasciata spontaneamente in forma di fotoni od onde elettromagnetiche (EM) ritornando al proprio stato basale.



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Per Teodor Cleve
1840- 1905

In 1879, the Swedish chemist Per Teodore Cleve separated from the rare earth oxide erbia another two previously unknown components, which he called holmia and thulia; these were the oxides of holmium and thulium, respectively.

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Holmium: Ho^{67}

Holmia
Latin name of Stockholm

Thulium: Tm^{69}

Thule (ultima Thule)
Greek name of Scandinavia

BIOFISICA DEL LASER

Interazione laser tessuto

Qualità del laser-interazione tissutale

Proprietà locali del tessuto

Lunghezza d’onda del laser

- Densità
- Grado di opacità (q.tà di pigmento)
- Contenuto d’acqua
- Vascolarizzazione

Maggiormente denso od opaco è il tessuto, maggiore è il grado di assorbimento dell’energia luminosa e quindi maggiore è il grado di trasformazione in calore

BIOFISICA DEL LASER

Interazione laser tessuto

Molecole
Proteine
Pigmenti
Acqua

→ Assorbono la luce ad una specifica lunghezza d'onda

Emoglobina assorbe energia luminosa ad una lunghezza d'onda di 600 nm

Argon laser produce energia a lunghezza d'onda di 458-515 nm altamente assorbita dall'emoglobina

Acqua assorbe energia luminosa iniziando in piccola quantità da 300-2000 nm a tale lunghezza d'onda il grado di assorbimento aumenta rapidamente e continua per parecchie migliaia di nanometri

CO_2 laser produce energia luminosa a 10600 nm – altamente assorbita dall'acqua contenuta nei tessuti ma con scarsa penetrazione

BIOFISICA DEL LASER

Interazione laser tessuto

La lunghezza d'onda del laser è proporzionale alla profondità della penetrazione nel tessuto specifico

Maggiore è la lunghezza d'onda maggiore dovrebbe essere la presunta penetrazione

La composizione tissutale e l'assorbimento molecolare rappresentano altri fattori cruciali nell'efficacia del laser

Nd:YAG	*1060nm*	*5-10mm*	*Hb ↓ H2O ↓*
CO2	*10600nm*	*0.1mm*	*H20 ↑↑*

BIOFISICA DEL LASER

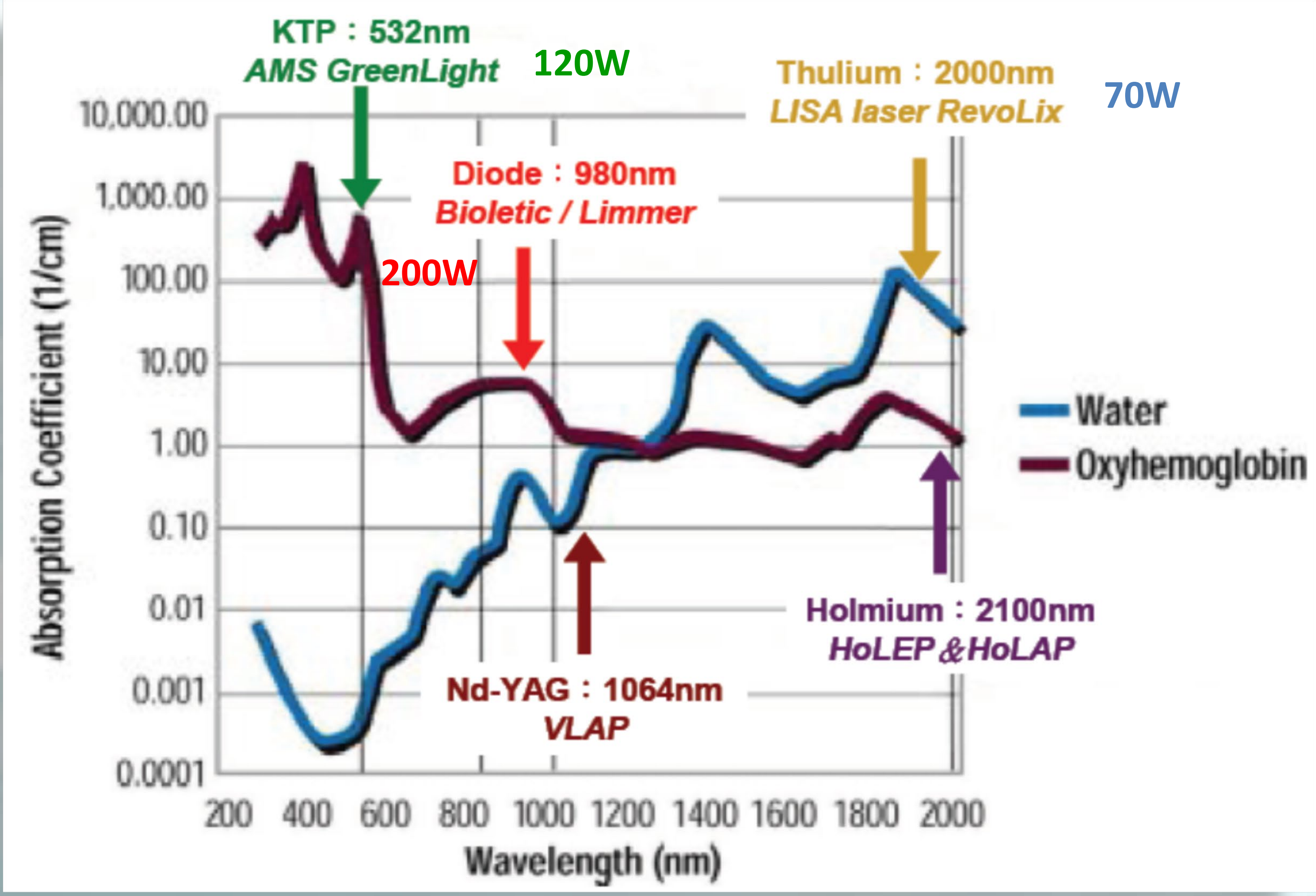
Interazione laser tessuto

Circolazione sanguigna locale modula il grado di assorbimento dell'energia laser

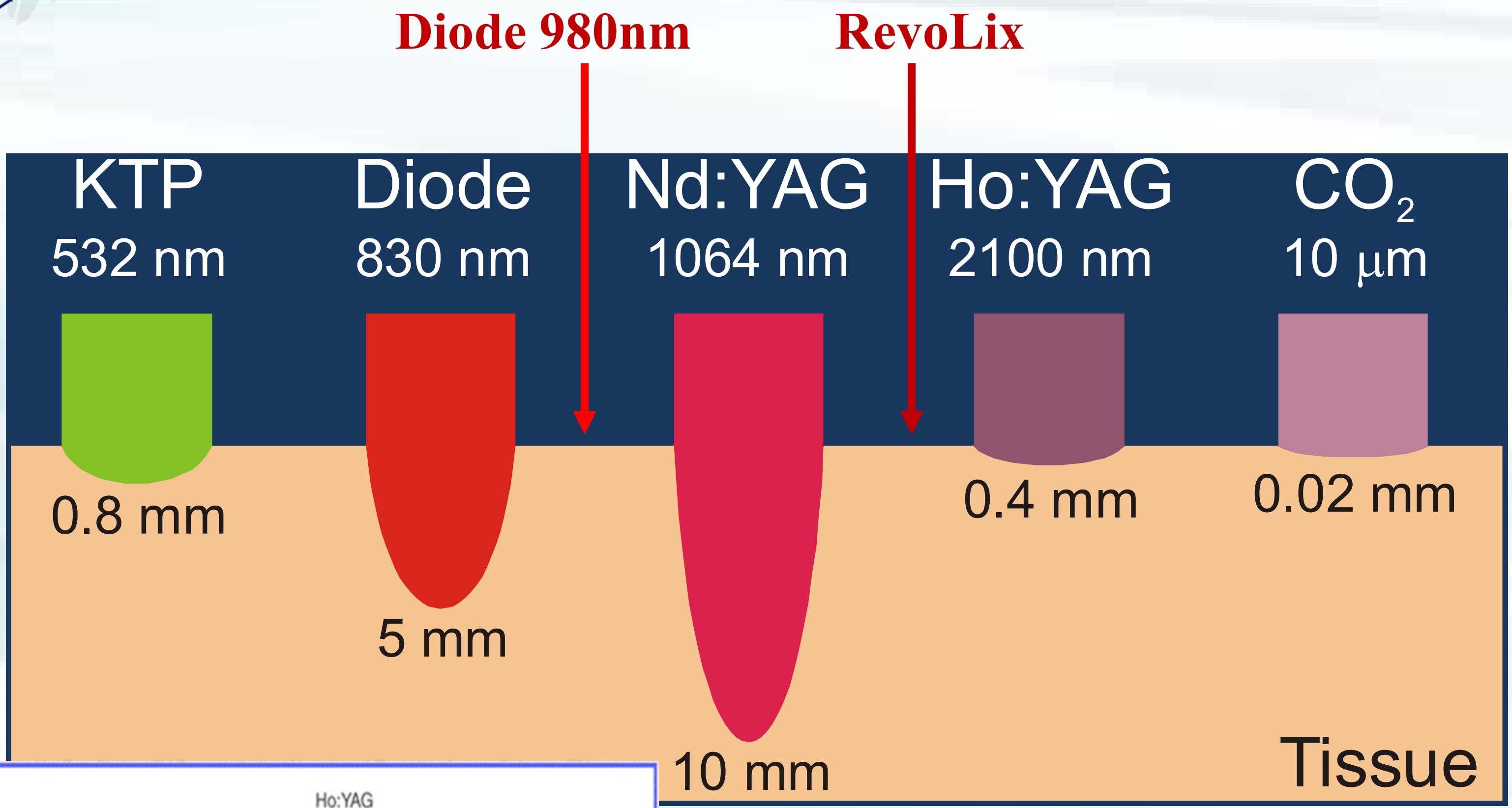
- proprietà assorbenti dei singoli componenti del sangue (emoglobina – acqua)

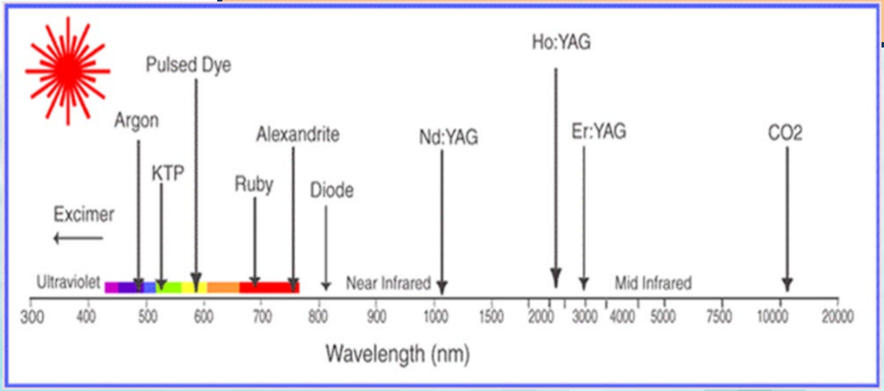
- circuito di raffreddamento che allontana l'energia termica prodotta dal luogo dell'applicazione

ABSORPTION vs WAVELENGTH



Optical Penetration Depth





BIOFISICA DEL LASER

Interazione laser tessuto

Operativamente si individuano 4 meccanismi efferenti:

Termico

Meccanico

Fotochimico

***Cicatrizzante** (energia termica mediato)*

Effetto termico

Prostata

Maggior utilizzo

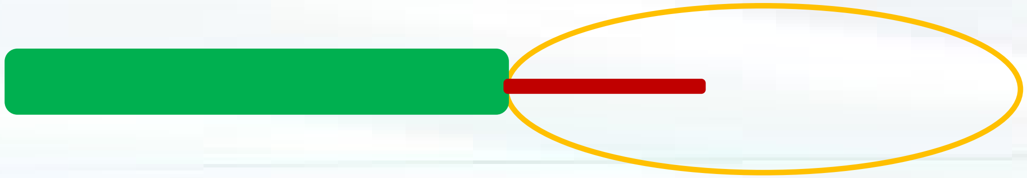
Energia luminosa assorbita e trasformata in calore

Denaturazione delle proteine	*42-65°C*
Coartazione venosa ed arteriosa	*70°C*
Disidratazione cellulare	*100°C*
Evaporazione dell'acqua	
Carbonizzazione	*250°C*
Vaporizzazione tissutale	*300°C*

BIOFISICA DEL LASER

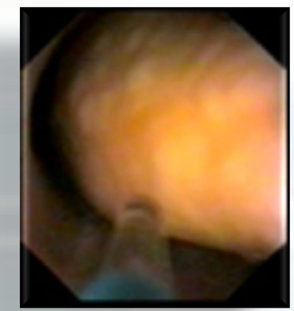
Interazione laser tessuto

Effetto meccanico



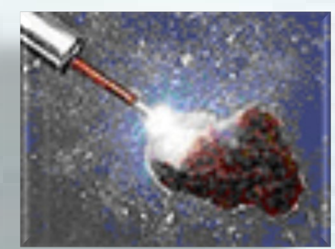
Litiasi

Energia ad alta densità applicata su superficie solida



Colonne di elettroni eccitati applicati ad alta frequenza

Creazione della bolla di plasma



Bolla di plasma agisce come un "espansore sonico"

Bolla di plasma agisce lungo una "stress line"

BIOFISICA DEL LASER

Interazione laser tessuto

Effetto fotochimico

Lesioni superficiali cutanee maligne e premaligne

Attivazione di molecole o farmaci ad una specifica lunghezza d'onda

Trasformazione delle molecole in componenti tossici

Creazione di radicali liberi che causano la morte cellulare attraverso la distruzione dei crosslinks del DNA

BIOFISICA DEL LASER
Interazione laser tessuto

Effetto cicatrizzante tissutale

Chirurgia plastica

Laser con particolare lunghezza d'onda che induce aggregazione del collagene

Aggiunta di materiale proteico come albumina umana al 50%

LASERS

FOUR TYPES OF LASERS ARE BEING USED IN UROLOGY

1. ND: YAG LASER
2. KTP (LBO) - GREEN LIGHT LASER
3. THULIUM LASERS (YAG & FIBER)
4. HOLMIUM: YAG LASER

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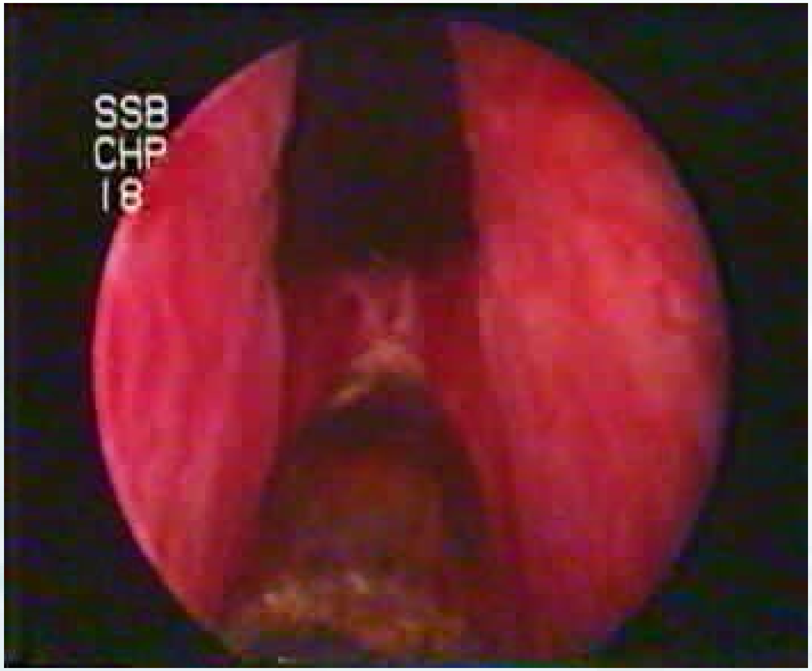
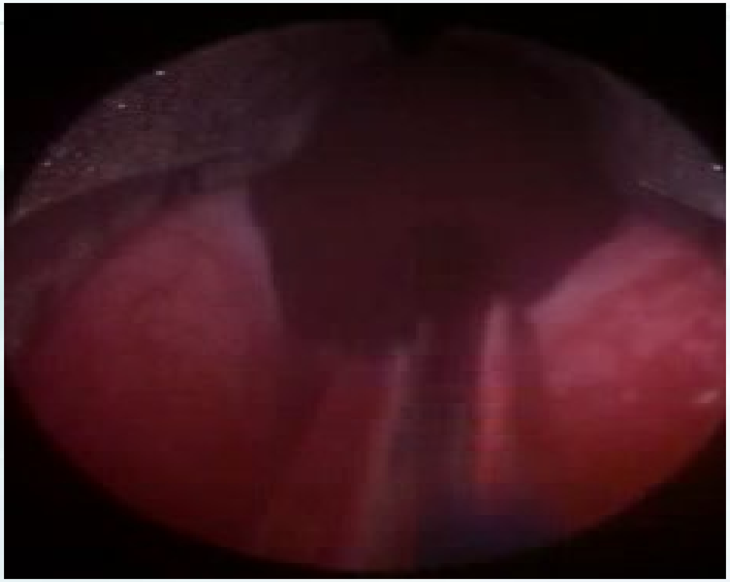
ND: YAG LASER

- ***NO IMMEDIATE SURGICAL EFFECT***
- ***DEPTH OF TISSUE DAMAGE UP TO 10 MM***
- ***EXCELLENT COAGULATION***
- ***NO CUTTING***
- ***NO EFFECT ON STONES***
- ***NOT POPULAR IN UROLOGY AT ALL***



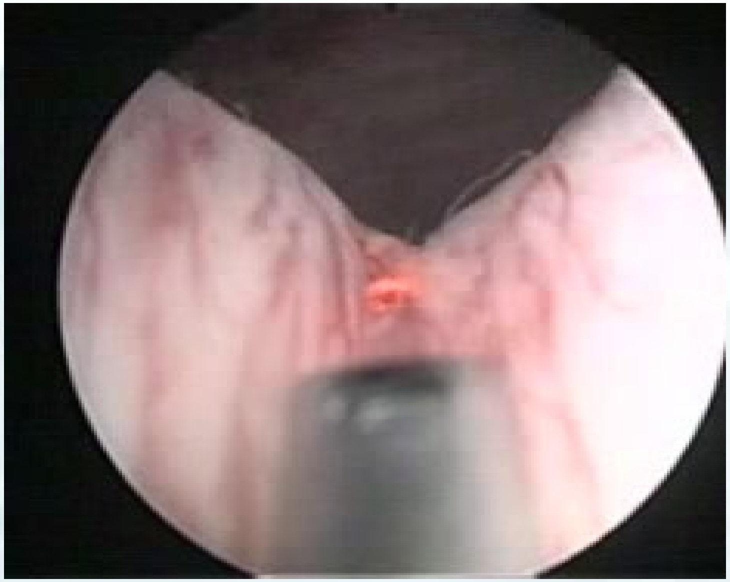
KTP (LBO) - GREEN LIGHT LASER

- ***VAPORIZATION OF RED TISSUE ONLY***
- ***ONLY APPLICATION IS FOR BPH***
- ***NO TISSUE FOR HISTOLOGICAL EXAMINATION***
- ***NO EFFECT ON STONE***
- ***SINGLE ORGAN CONFINED USAGE***
- ***HIGH RECURRENT EXPENSES FOR SINGLE USE SIDE FIRING FIBER***



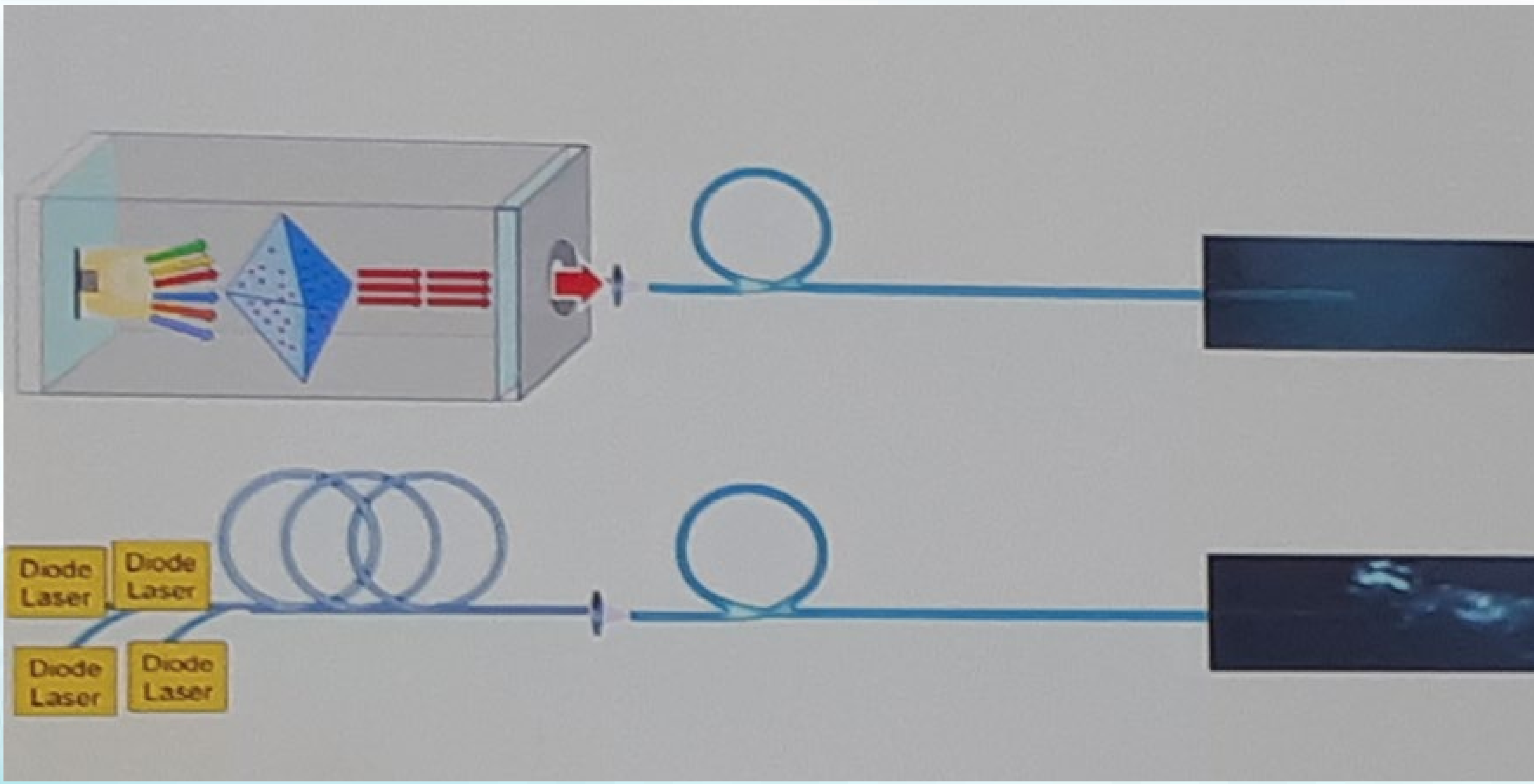
THULIUM YAG LASER

- *EXCELLENT CUTTING & COAGULATION*
- *NO VIBRATIONS TIP – BETTER CONTROL*
- *GOOD FOR ALL SOFT TISSUE CUTTING*
- *SOME DEGREE OF CHARRING OF THE TISSUE*
- *WIDELY USED IN UROLOGY*
- *LIMITED EFFECT ON SOFT STONES*



HOLMIUM LASER

- BEST FOR STONE FRAGMENTATION - OF ALL TYPES
- GOOD CUTTING & COAGULATION UNDER IRRIGATION
- PULSED LASER - VIBRATIONS TIP – NEEDS TIP STABILIZATION
- MULTI DISCIPLINARY USAGE
- AS OF TODAY – MOST POPULAR LASER IN UROLOGY


Diode Laser
Diode Laser
Diode Laser
Diode Laser

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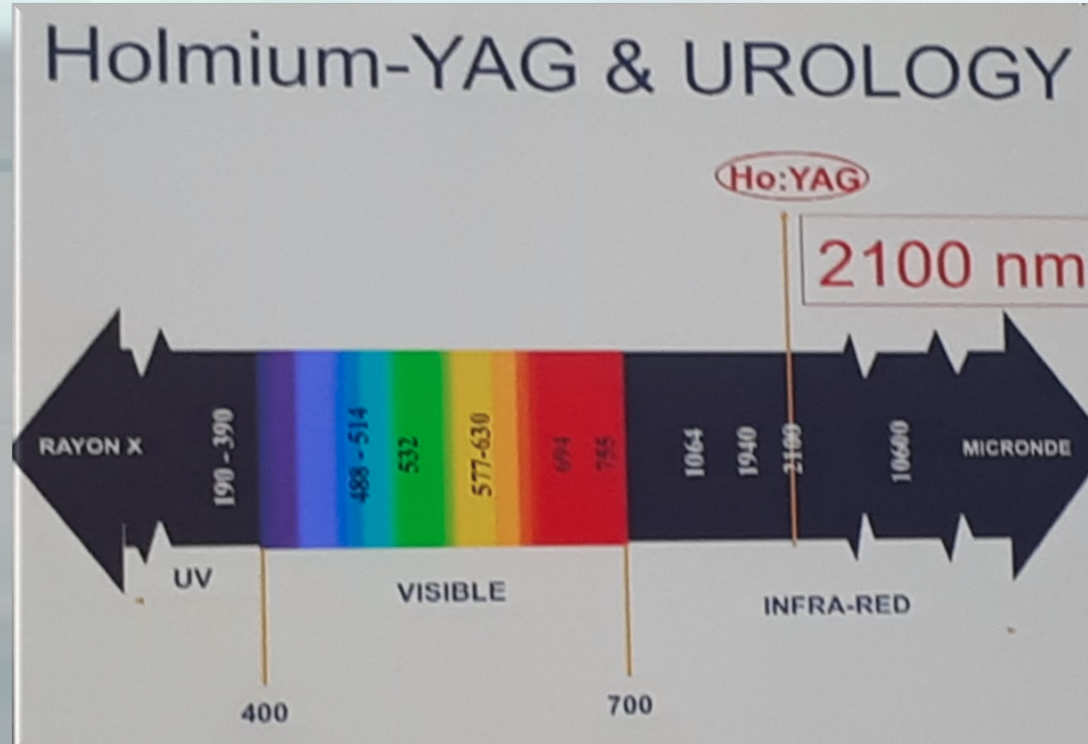

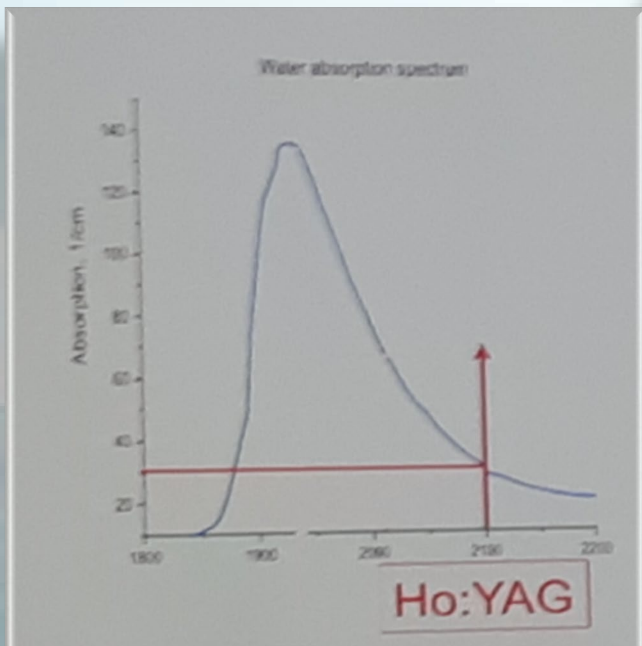

HOLMIUM LASER

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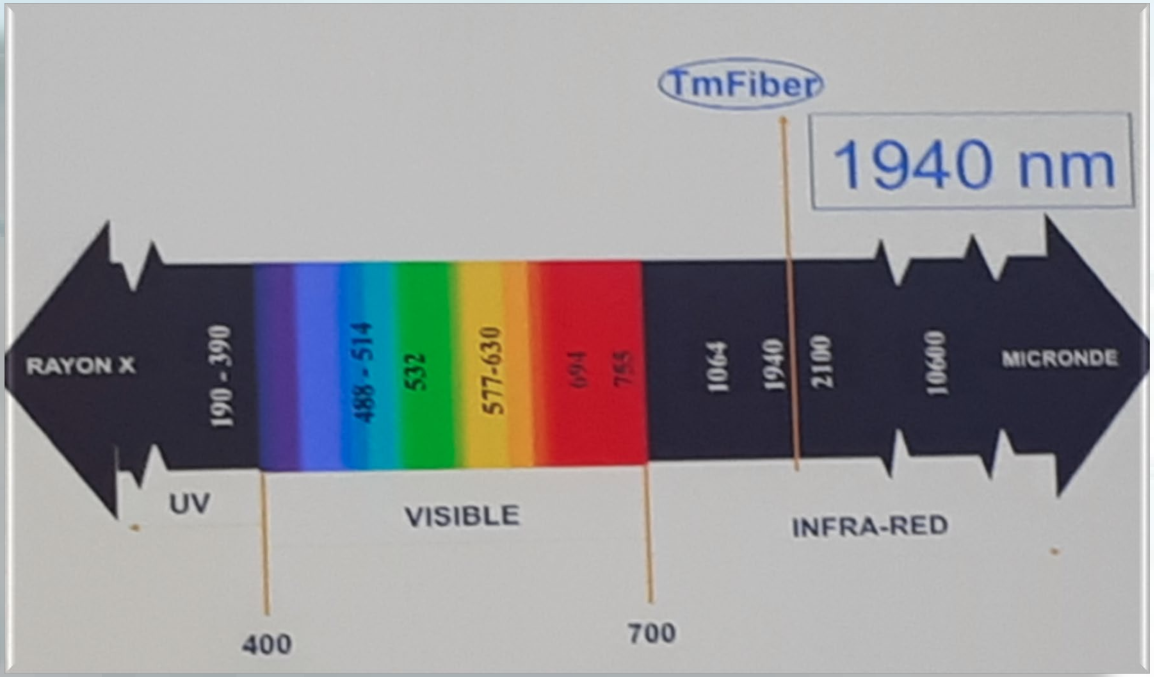
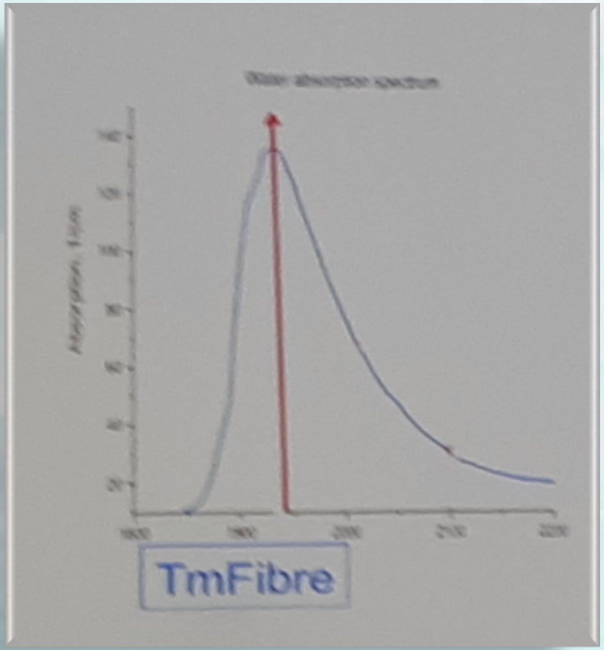
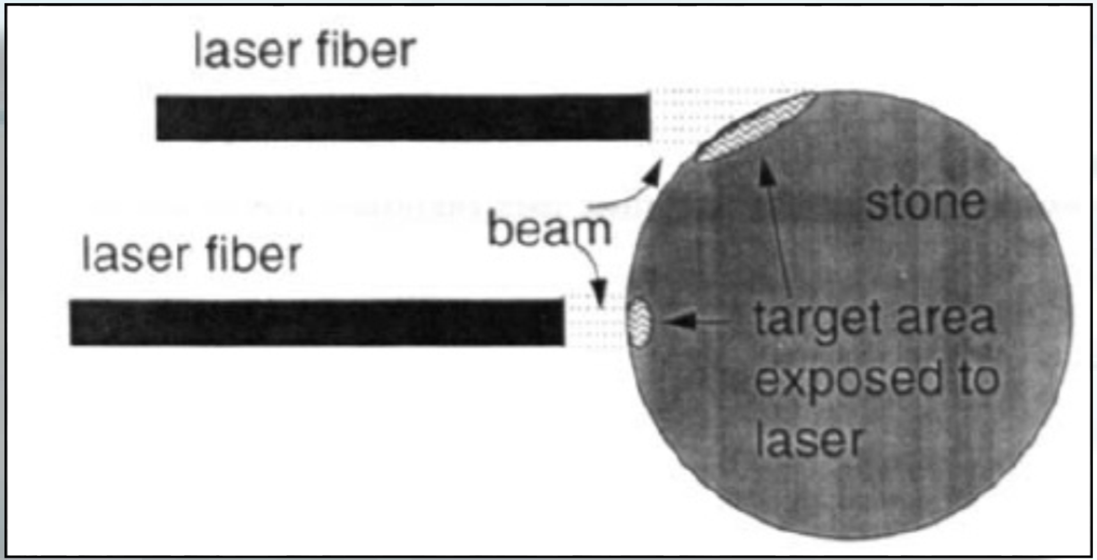




THULIUM YAG LASER



Long-pulsed lasers generally fragment a calculus component within the volume of light absorption, producing well-demarcated craters with minimal collateral thermal damage.

Short-pulsed lasers fragment a calculus by a shockwave generated at cavitation collapse, while nanosecond lasers pulverize a calculus with an initial shockwave during plasma expansion and a shockwave at cavitation collapse.

Long-pulsed lasers generate a plume during laser lithotripsy, whereas short-pulsed and nanosecond lasers result in large fragment dissociation of the calculus

CLINICAL APPLICATION

Urolithiasis

Benign prostatic hyperplasia

Bladder tumours

UTUC Laser ablation

Urinary tract strictures

Laser assisted robotic procedures

kidney tumour Laser enucleation

Robotic pyelolithotomy Laser lithotripsy

Lesions of the external genitalia

……………………………………………..

Benign prostatic hyperplasia

There are a lot of advantages of laser procedures over traditional surgeries

First, there is a greater precision and accuracy

Secondly lasers procedures are less invasive, lasers energy heat-seals blood vessels and in result there is less bleeding, swelling, pain, or scarring

Third, laser procedures are good alternative for patients with high comorbidity who are not suitable for open operations

Furthermore laser operating and hospitalization time may be shorter, more procedures may be done in outpatients settings

Benign prostatic hyperplasia

On the other hand some disadvantages of laser operations should be also taken into account.

First of all not many doctors are trained to use lasers.

Additionally laser equipment is expensive and unwieldy and it should also be remembered that strict safety precautions must be followed in the operating room when lasers are used.

Benign prostatic hyperplasia

SUMMARY OF ENUCLEATION ADVANTAGES

Complete tumorectomy makes sense for BPH

Better relief of BOO than resection & vaporisation

Outcomes indipendent of prostate volume

More effective for treating retention than resection & vaporisation

Most durable endoscopic BPH technique

Tissue for histology

Benign prostatic hyperplasia

PROSTATE VOLUME REDUCTION USING PSA AS A SURROGATE MARKER

- *HoLEP - ThuLEP*	*82-91%*
- *M – B TURP*	*45-65%*
- *PVP*	*32-52%*
- *TUNA – TUMT*	*no change in PSA*

Surgical techniques for BOO			
	Vaporisation	Resection	Enucleation
Monopolar	M-TUVP	M-TURP	M-enucleation
Bipolar	B-TUVP	B-TURP	B-enucleation
Holmium	HoLAP	HoLRP	HoLEP
Greenlight	PVP	PVP	GreenLEP GreenLEV
Thulium	ThuVaP	ThuVaRP	ThuLEP ThuVEP
Diode	DiLAP	DiLRP	DiLEP

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BPH SURGERY COMPLICATIONS			
Complication	B-TURP	HoLEP – ThuLEP	PVP
Capsular perforation	0.1	0.2	0
Transfusion	2.0	0	0
TUR-syndrome	0.8	0	0
Bladder mucosal injury	0	3.3	0
Clots retention	4.9	0	0
Dysuria	0.8	1.2	8.5
Stress urinery incontinence	0.6	1.2	0
Bladder neck contracture	2.6	1.2	5.0
Urethral stricture	4.1	4.4	6.3
Reop for BPH	0.5	0	5.6

Urolithiasis

CRUCIAL STEPS

- *Should I perform a retrograde pyelography?*
- *Should I place a safety guidewire?*
- *Should I dilatate the ureteral orifice?*
- *Should I use a ureteral access sheath?*
- *How would I irrigate?*
- *Which laser settings?*
- *What about stone retrieval?*
- *Should I place a ureteral stent?*

PREVENTION OF SEPSIS: GOLDEN RULES

- *Operate only if urine culture is negative*
- *To evaluate the possibility of second look*
- *Whenever possible place a UAS*
- *Active irrigation should always be performed gently while checking the continuous outflow from the UAS*
- *Avoid prolonged surgery*
- *Carefully observe patients after surgery (90% of these rare but potential lethal complications occur within 6 hours)*
- *Procalcitonin is very reliable in early recognition of an ongoing septic status and in follow up*

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HOLMIUM – YAG LASER
The Mose's effect

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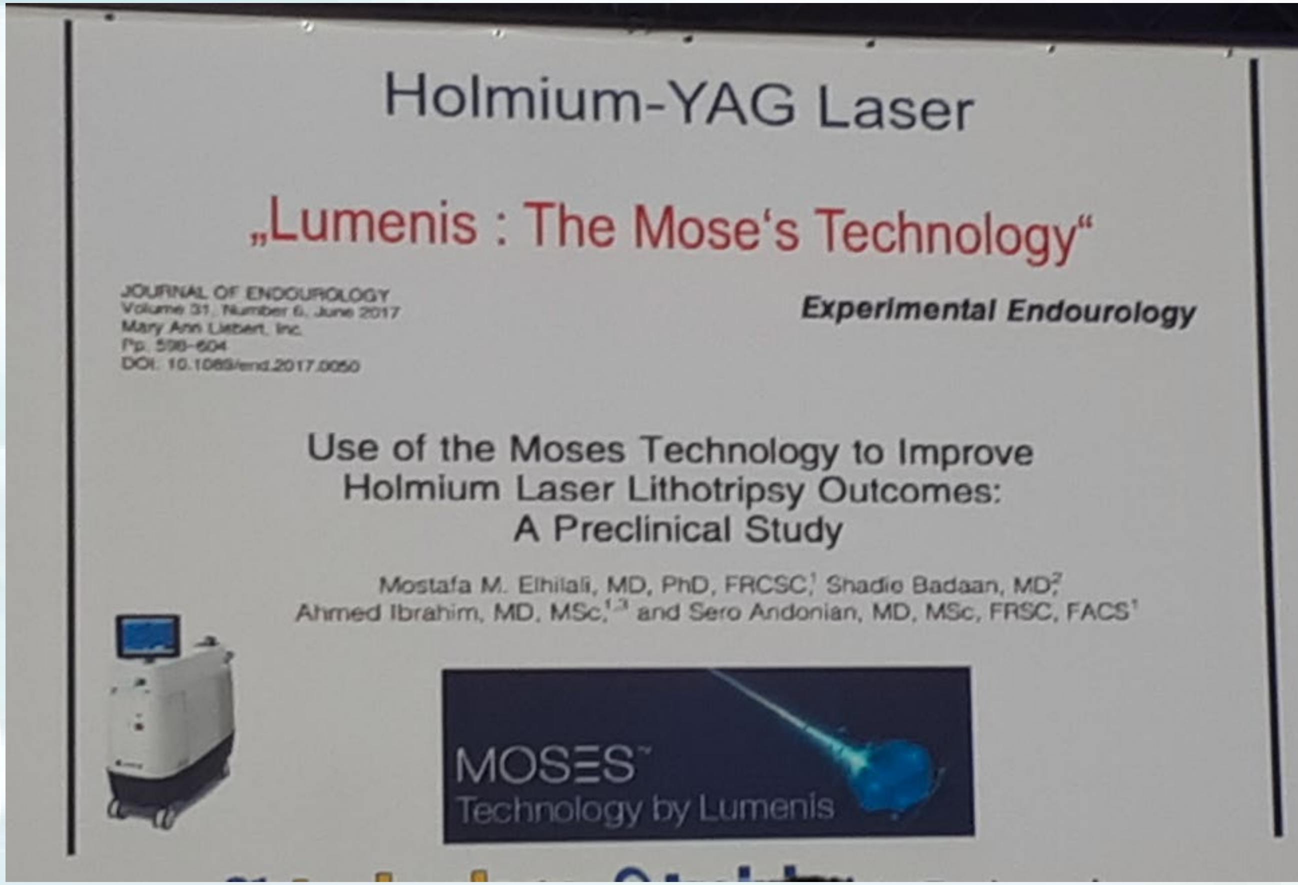
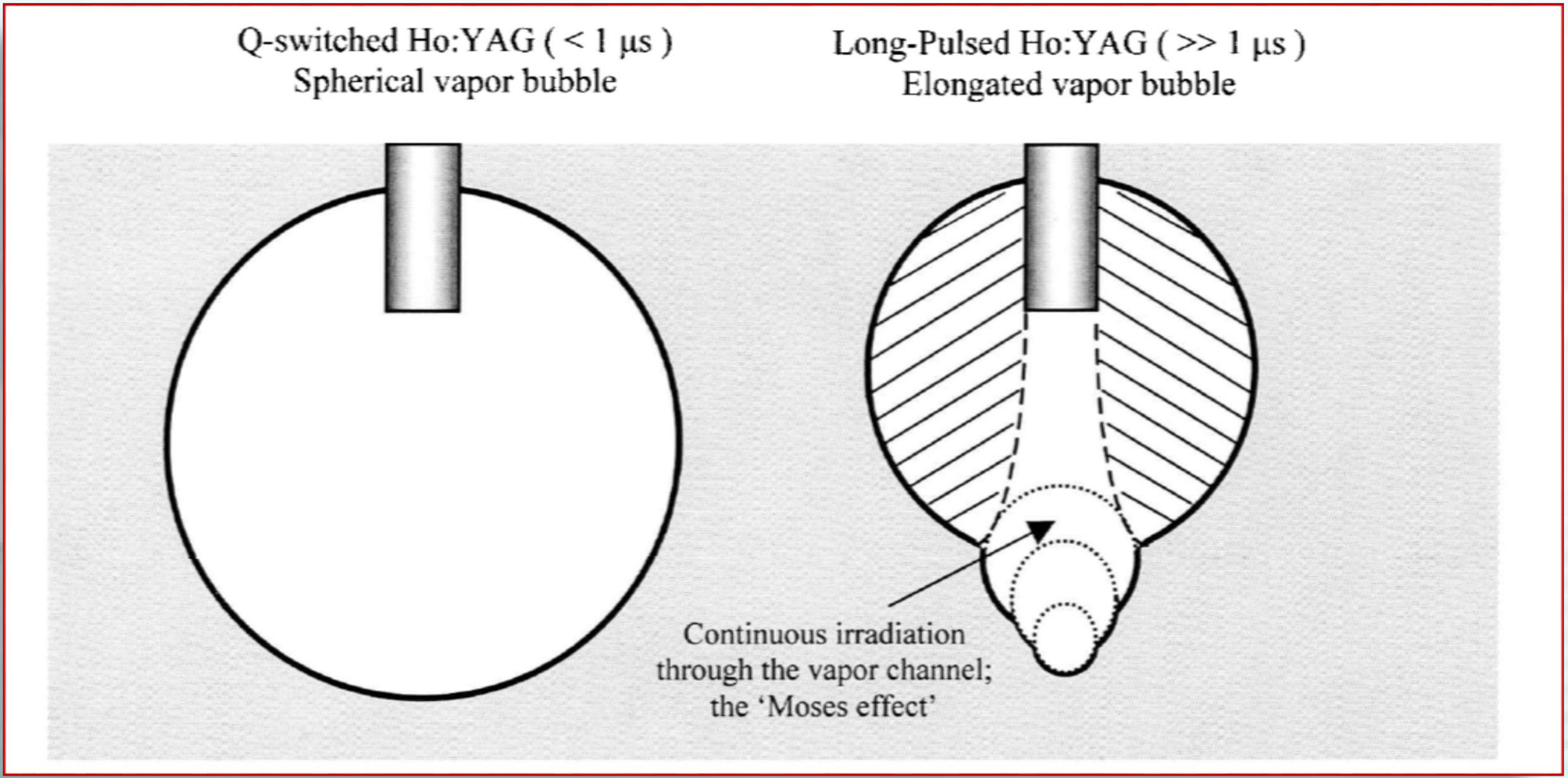


1989 Isner JM report Mose's Effect

1992 Johnson DE first report in urology



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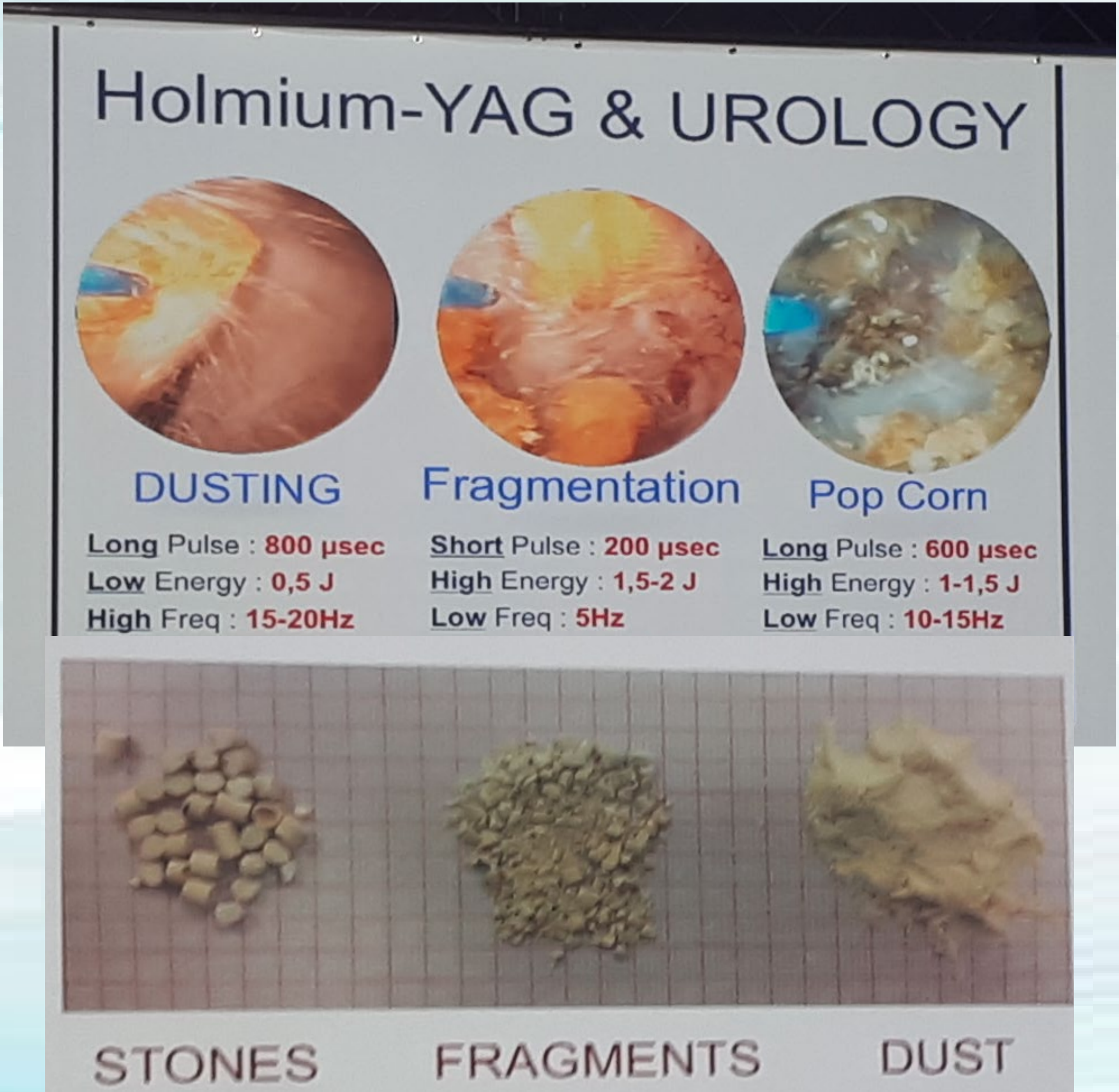
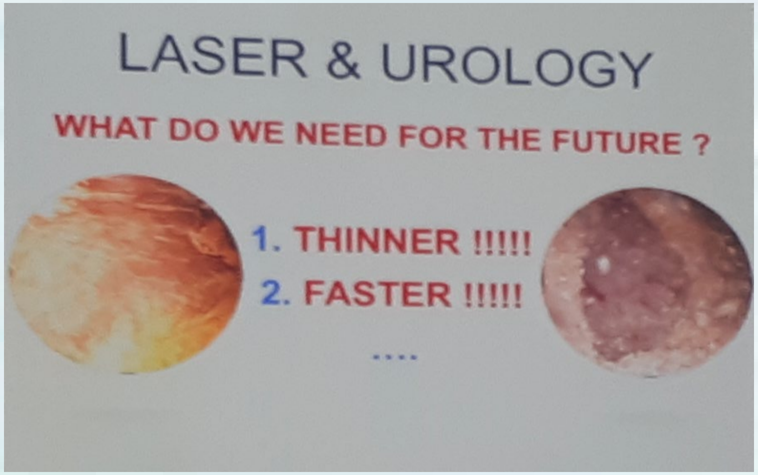


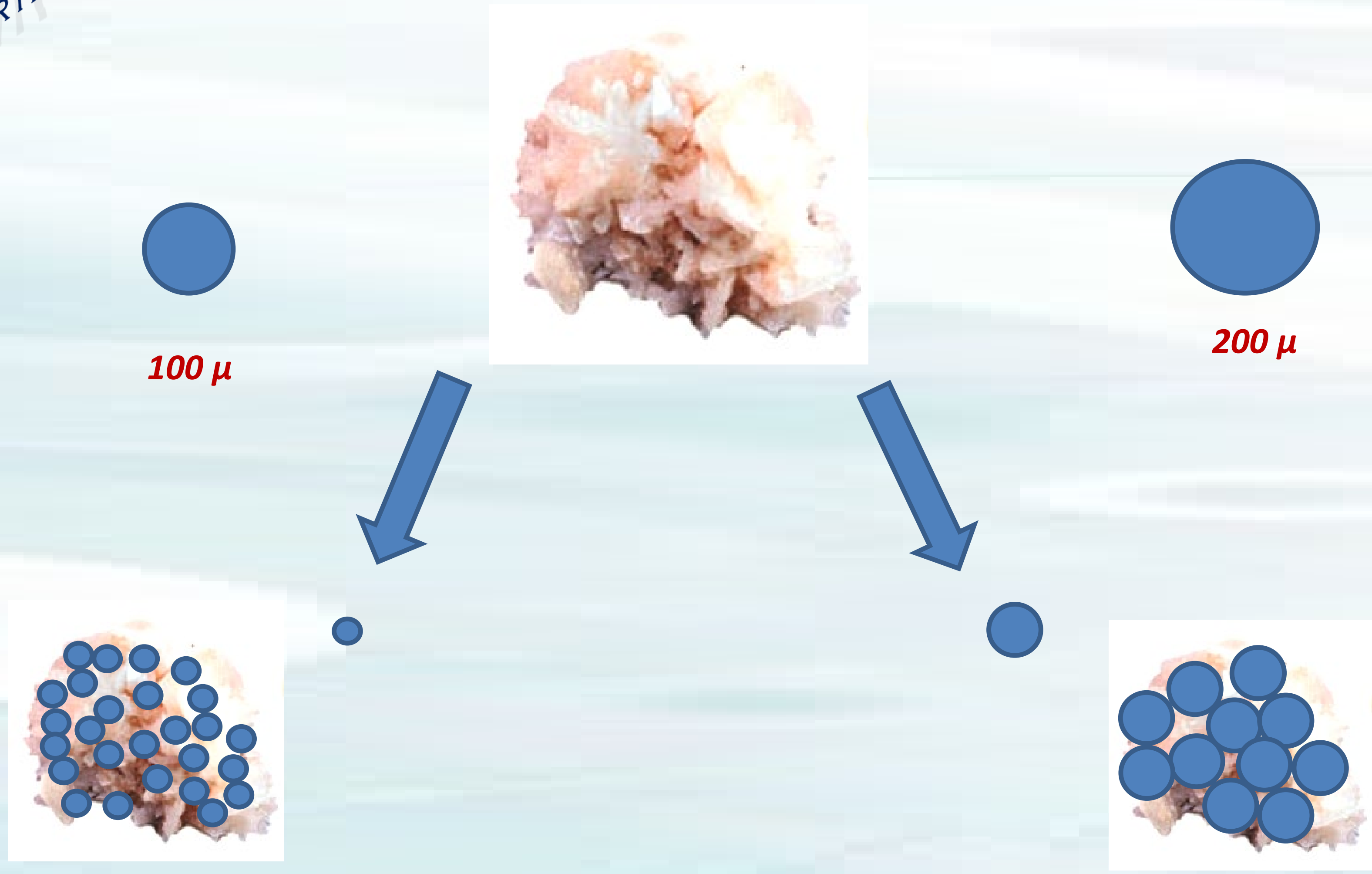
WHAT DO WE NEED FOR THE FUTURE

1. THINNER

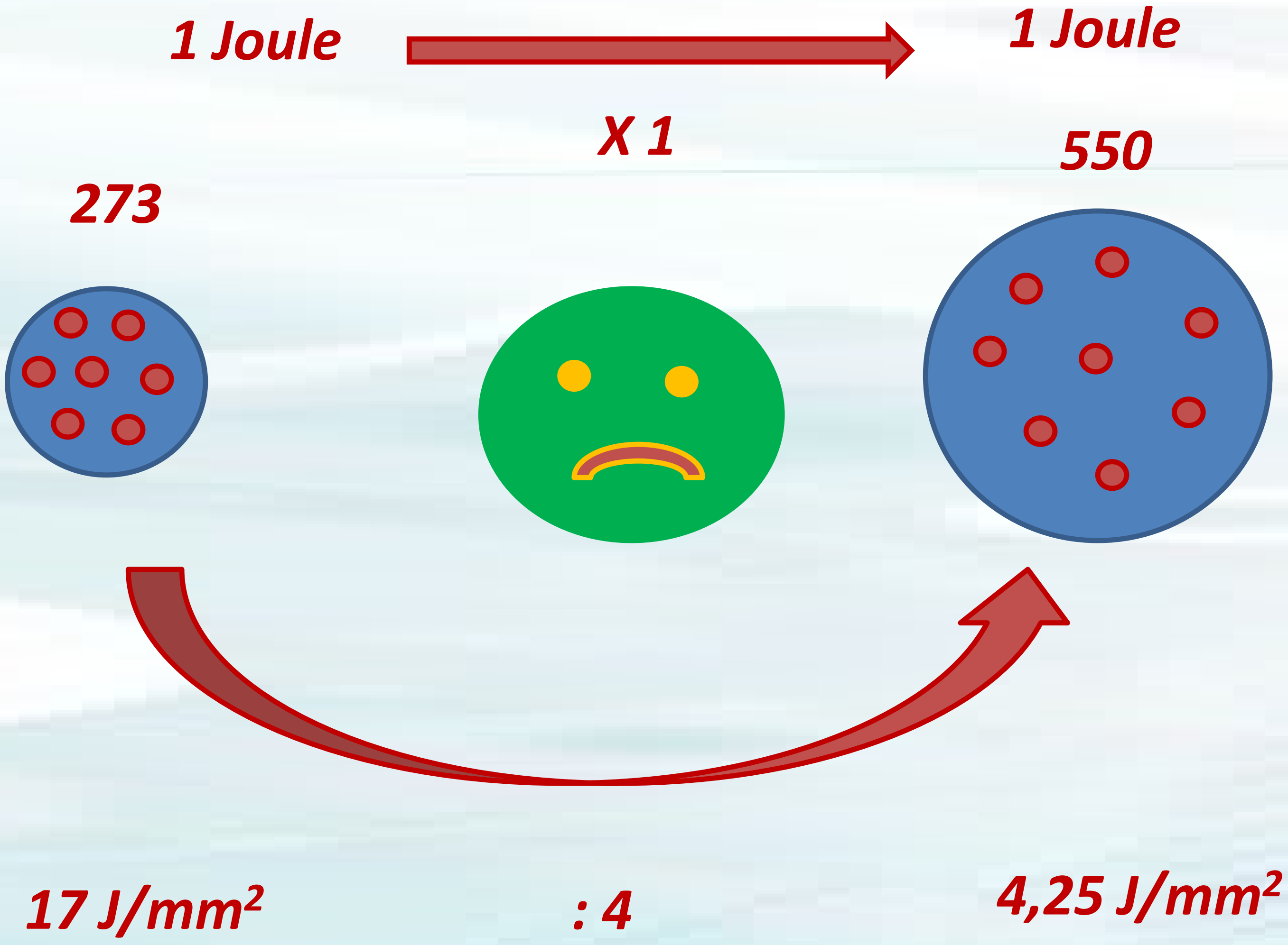
2. FASTER



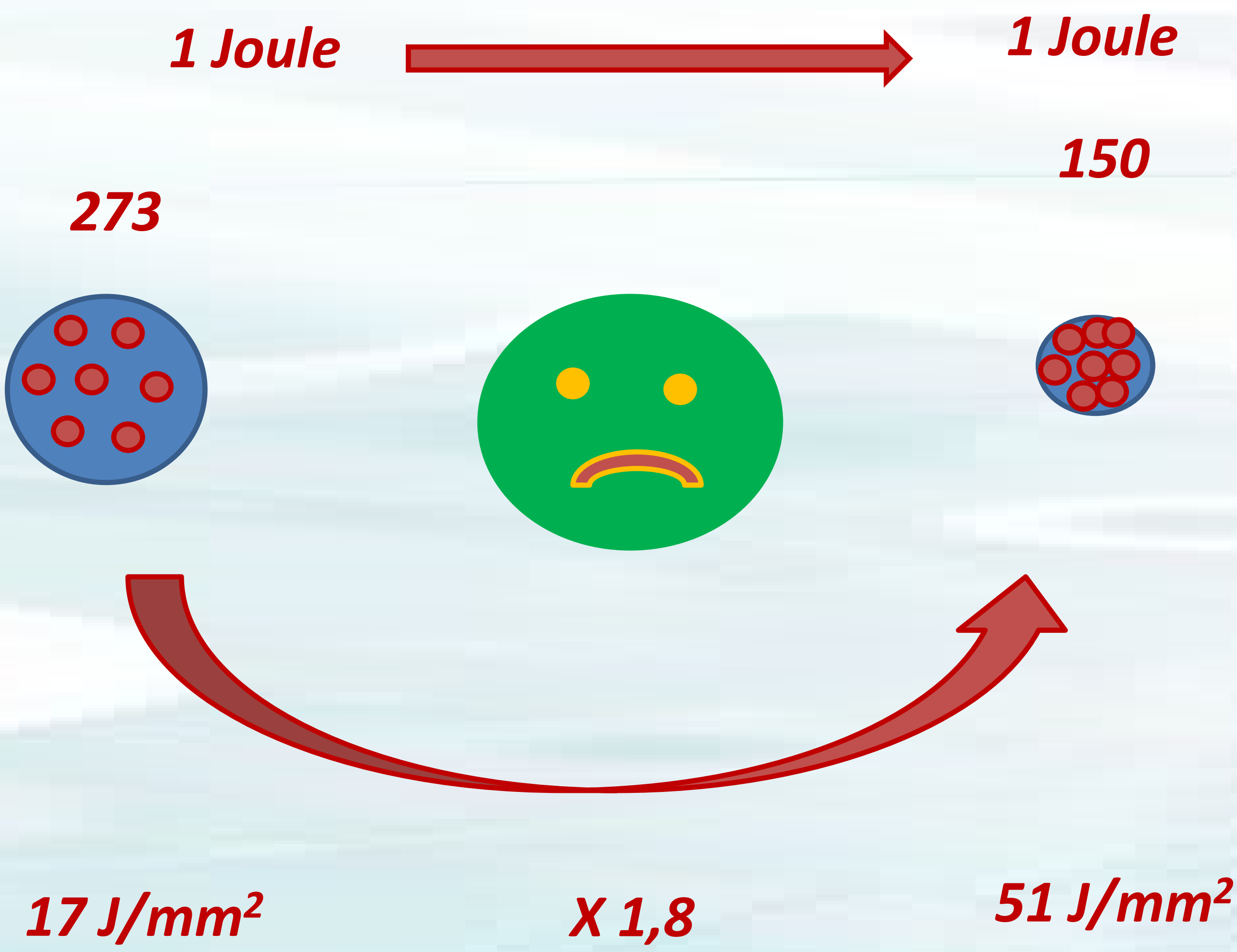
WE NEED SMALLER FIBERS



LASER FIBER: Energy Density



LASER FIBER: Energy Density



LASER FIBER: Energy Density

1 Joule → ***330 mJoule***

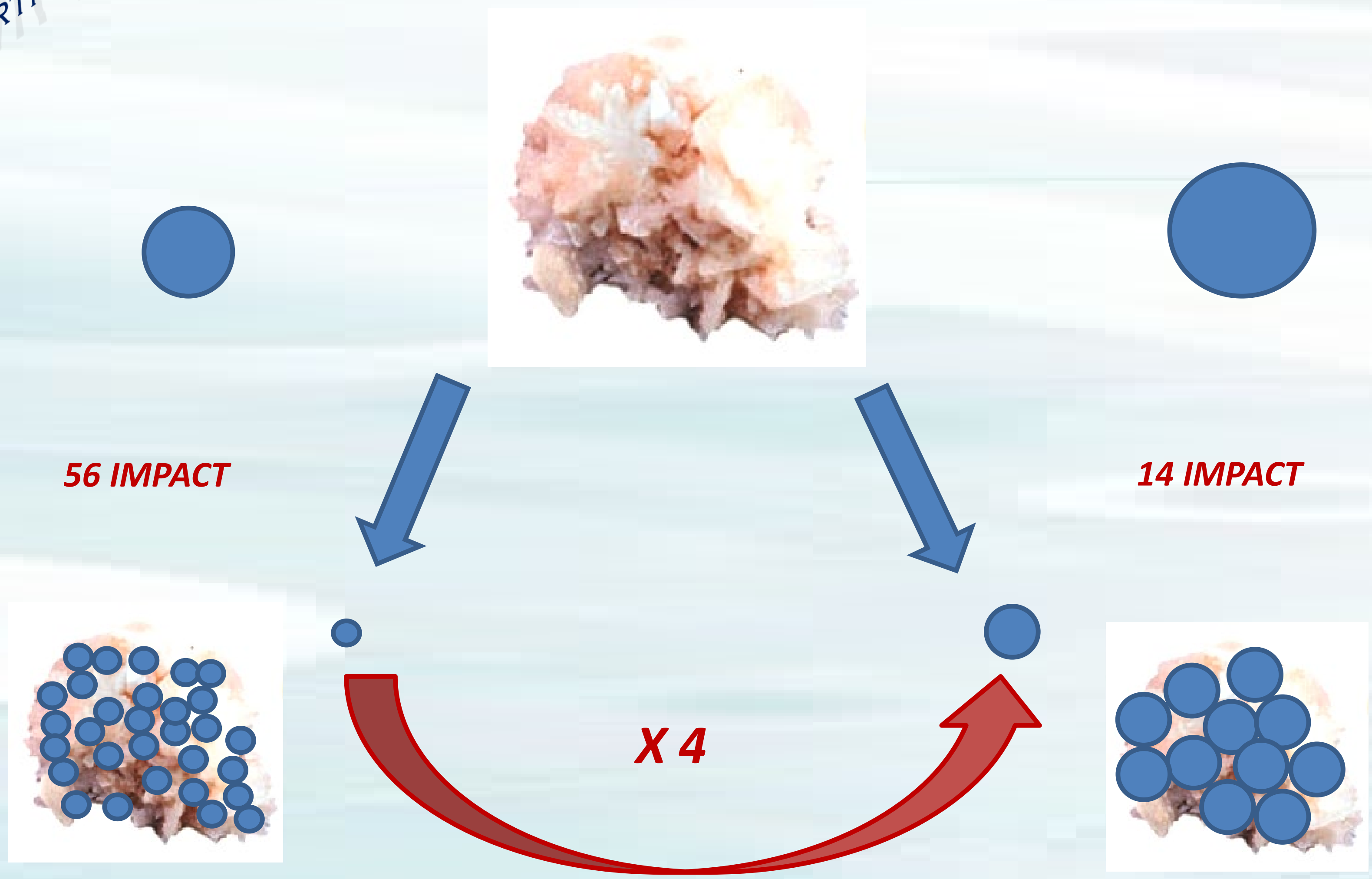
: 3

150

273

17 J/mm² ***X 1*** ***17 J/mm²***

WE NEED MUCH HIGHER FREQUENCY



WHAT DO WE NEED FOR THE FUTURE HOLMIUM

THINNER **FASTER**

1. **Smaller Fiber:** **100 microns**
2. **Low energy:** **50 TO 100 mJ**
3. **Super high frequency:** **300 – 1000 Hz**

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WHAT DO WE NEED FOR THE FUTURE THULIUM

THINNER **FASTER**

1. **Smaller Fiber:** **starting 50 microns**
2. **Low energy:** **25 - 50 mJ**
3. **Super high frequency:** **up to 2000 Hz**

CRUCIAL STEPS

TEMPERATURE

1 Calorie = 4.18 J

Rises the temperture of 1 ml of water by 1 °C

In 1 minute (2 ml calyx)

0.5 J / 15 Hz	*7.5 ws*	*450J*	*50°C*
1.0 J / 10 Hz	*10 ws*	*600J*	*70°C*
0.2 J / 80 Hz	*16 ws*	*960J*	*110°C*

+ body and saline temperature

CRUCIAL STEPS

Temperature threshold of 54-55 °C has been used as the critical temperature for complete tissue necrosis

Cellular and tissue thermal injury behaviours are cell/tissue type dependent

Hyperthermic cell death has been shown to be markedly enhanced at temperature above 43 °C (thermal dose determination in cancer therapy)

Heat increases the permeabillity of the cellular membrane (higher penetration of MMC into the urothelium)

- ***During perforation of the ureter, thermal values were higher than during laser lithotripsy***

- ***Irrigation non only improved endoscopic visualization during lithotripsy but also minimized tissue heating***

- ***Interruption of the saline flow could pose a risk for urothelial thermal injury***

- ***Without irrigation there is a relevant bubble formation which should be an indicator for physician to stop lithotripsy***

- ***TEMPERATURE > 43 °C*** ***danger zone***
- ***LONGER LASER TIME*** ***higher thermal dose***
- ***TEMPERATURE > 50 °C*** ***irreversible damage***
- ***LOWER CAVITY VOLUME*** ***higher temperature***

Good irrigation is essential but think about pressure

HIGH POWER

HIGH TEMPERATURE

BETTER OUTCOMES

?

LASER: OUR WISH LIST

- ***ADJUSTABLE WAVELENGTH***
- ***PULSE***
- ***APPLICATION SPECIFIC SETTINGS***
- ***LASER WAVELENGTH CAN BE DECIDED BY THE SURGEON***
- ***THINNER***
- ***FASTER***

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