Lasers in Stone Surgery: Holmium and Thulium

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Disclosures

- Consultant
  - Ambu
  - Auris
  - Boston Scientific
  - BD
  - Calyxo
  - Dornier
  - Olympus
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  Mitchell Humphreys, MD (Mayo Clinic Scottsdale)

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Lasers in Endourology: Outline

- Overview of laser technology
  - Short vs long pulse
- Settings for lithotripsy
  - Dusting
  - Fragmenting
- Holmium laser options
- Thulium TFL options
- Thulium:YAG options
- How to think about treating a stone

http://waddahal-alem.com/

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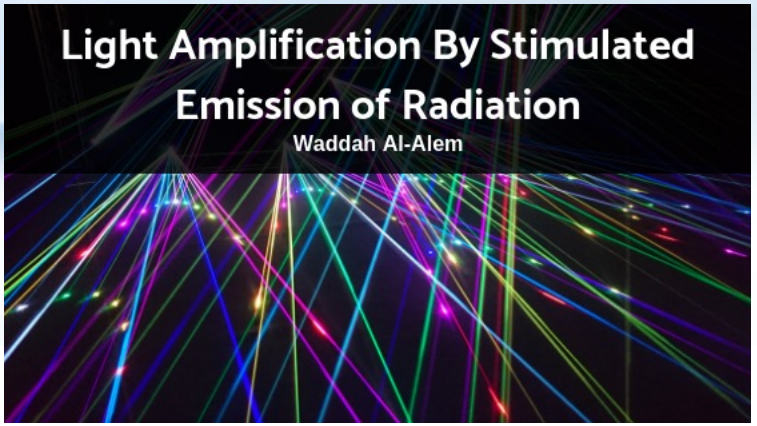
How Do Lasers Work?



- Photothermal
  - Photons absorbed by the stone → converted to heat
  - Water trapped in stone → vaporized → melting, cracking
  - Water adjacent to stone → vaporized → gas expansion fractures stone
  - Requires contact or near contact with stone

- Photomechanical
  - Photons absorbed by water → creates spherical bubble
  - Bubble collapse → cavitation jet and shockwave forces
  - No contact with stone

http://waddahal-alem.com/

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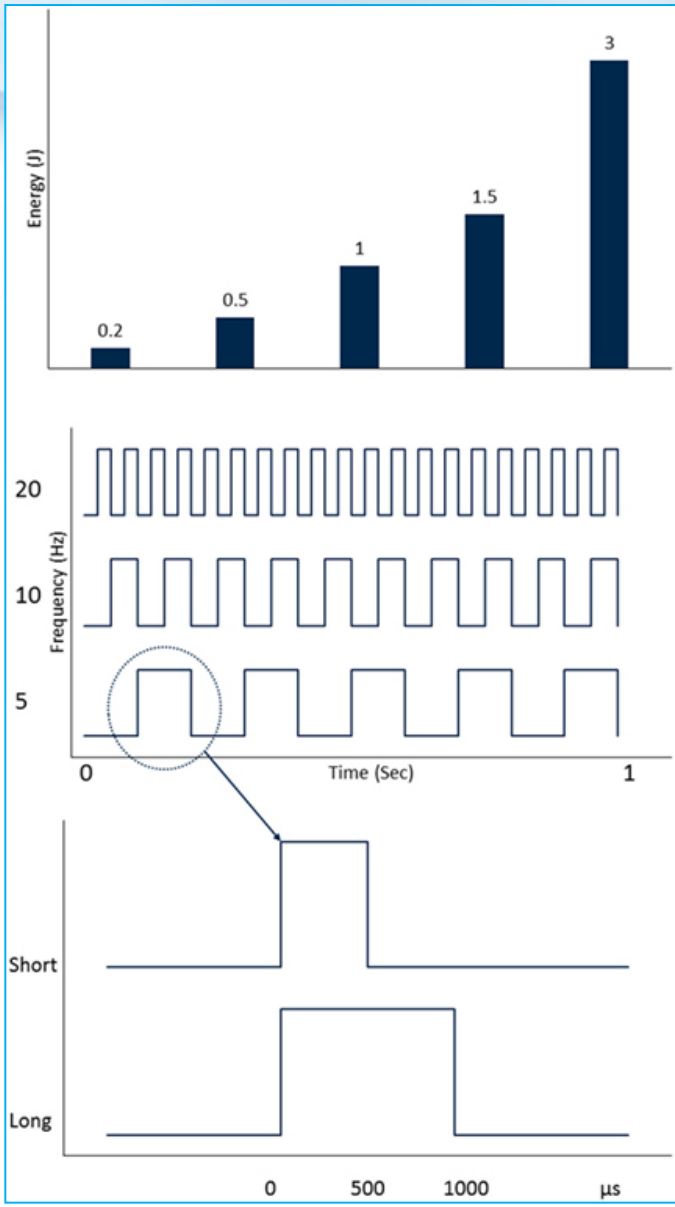
Laser Terminology

- Pulse Energy: emitted from laser fiber tip (J)
  - Retropulsion, fiber tip degradation
- Frequency: # of pulses per second (Hz)
- Pulse Width: duration of a single pulse (µs)
  - Short, medium and long 150-1200µs
  - Long: 50% less retropulsion, 60% more effective stone ablation
  - Solid state optical lasers w flashlamp can't produce low energy, long duration pulses
- Pulse Modulation
  - affects energy delivery, retropulsion



POWER (W) = Pulse Energy (J) x Frequency (Hz)

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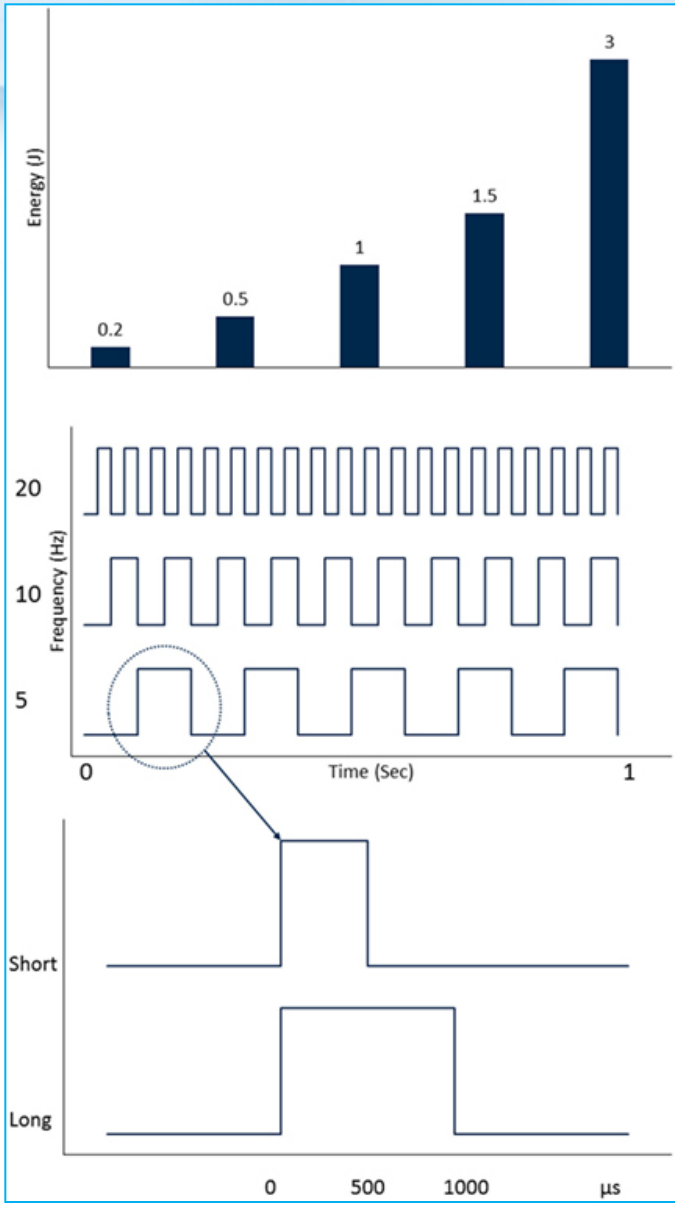
Laser Terminology

Changeable parameters						Parameter-dependable variables				
Defined by user					Defined by nature					
Lithotripter settings				Fiber diameter	Stone type	Effects on calculi		Effects on instruments		
Power (W)	Pulse energy (J)	Pulse frequency (Hz)	Pulse mode			Ablation volume	Retropulsion	Fiber tip degradation	Scope deflection	Irrigation
↑	↑	-	-	-	-	↑	↑	↑	n/a	n/a
↓	↓	-	-	-	-	↓	↓	↓	n/a	n/a
↑	-	↑	-	-	-	↑	=/↑	↑	n/a	n/a
↓	-	↓	-	-	-	↓	=/↑	↓	n/a	n/a
=†	↑	↓	-	-	-	↑	↑	↑	n/a	n/a
=†	↓	↑	-	-	-	↓	↓	↓	n/a	n/a
-	-	-	Short-pulse	-	-	↑	↑	↑	n/a	n/a
-	-	-	Long-pulse	-	-	↓	↓	↓	n/a	n/a
-	-	-	-	↑	-	=‡	↑	↓	↓	↓
-	-	-	-	↓	-	=	↓	↑	↑	↑
-	-	-	-	-	Hard stone	↓	N/K*	↑	n/a	n/a
-	-	-	-	-	Soft stone	↑	N/K*	↓	n/a	n/a



Kronenberg, WJU, 2014

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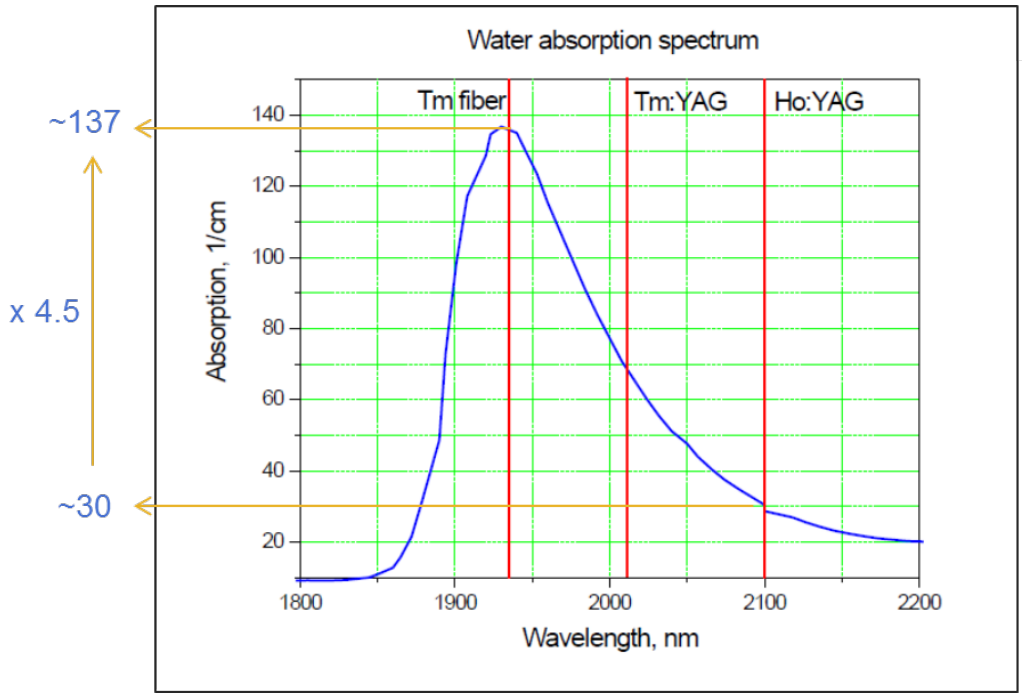
Laser Wavelengths and Water Absorption

- TFL >4x more absorbed in water
- Better absorption in H2O→ more conversion to steam → gas expansion fractures stone
- Improved bubble formation dynamics→less retropulsion
- BUT: greater increase in water temperature?



Wavelength absorption in water. Note the y-axis is a log scale.

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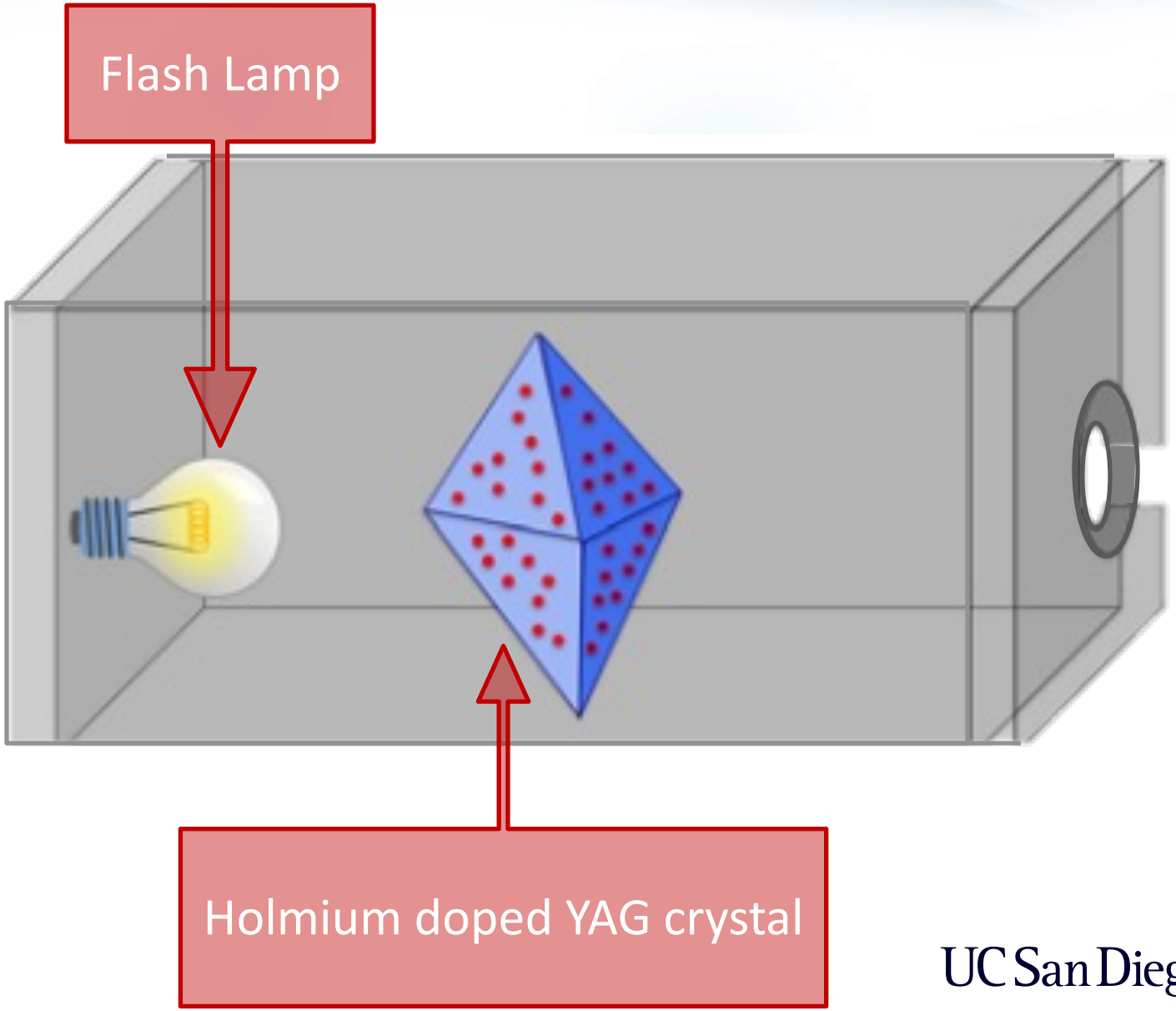
Laser Comparison

Laser Type	Holmium:YAG	TFL: Soltive	TFL: FiberDust	Thulium:YAG
Wavelength (nm)	2120	1920-1960	1900	2013
Absorption coefficient (1/cm)	31.98	123.92		58.88
Maximum power	120W	60W	60W	100W
Pulse energy (J)	0.2 – 6.0	0.025 – 6.0	0.02 – 6.0	0.1 – 2.5
Operating mode	Pulsed or continuous	Pulsed	Pulsed	Pulsed or continuous
Pulse duration (ms)	0.05-1	0.2 – 50	0.05 – 15	0.15 – 1
Frequency (Hz)	5-120	1 – 2400	1 – 2500	5-300
Electrical	120-240V	120	120	120-240V

Holmium Laser Mechanics



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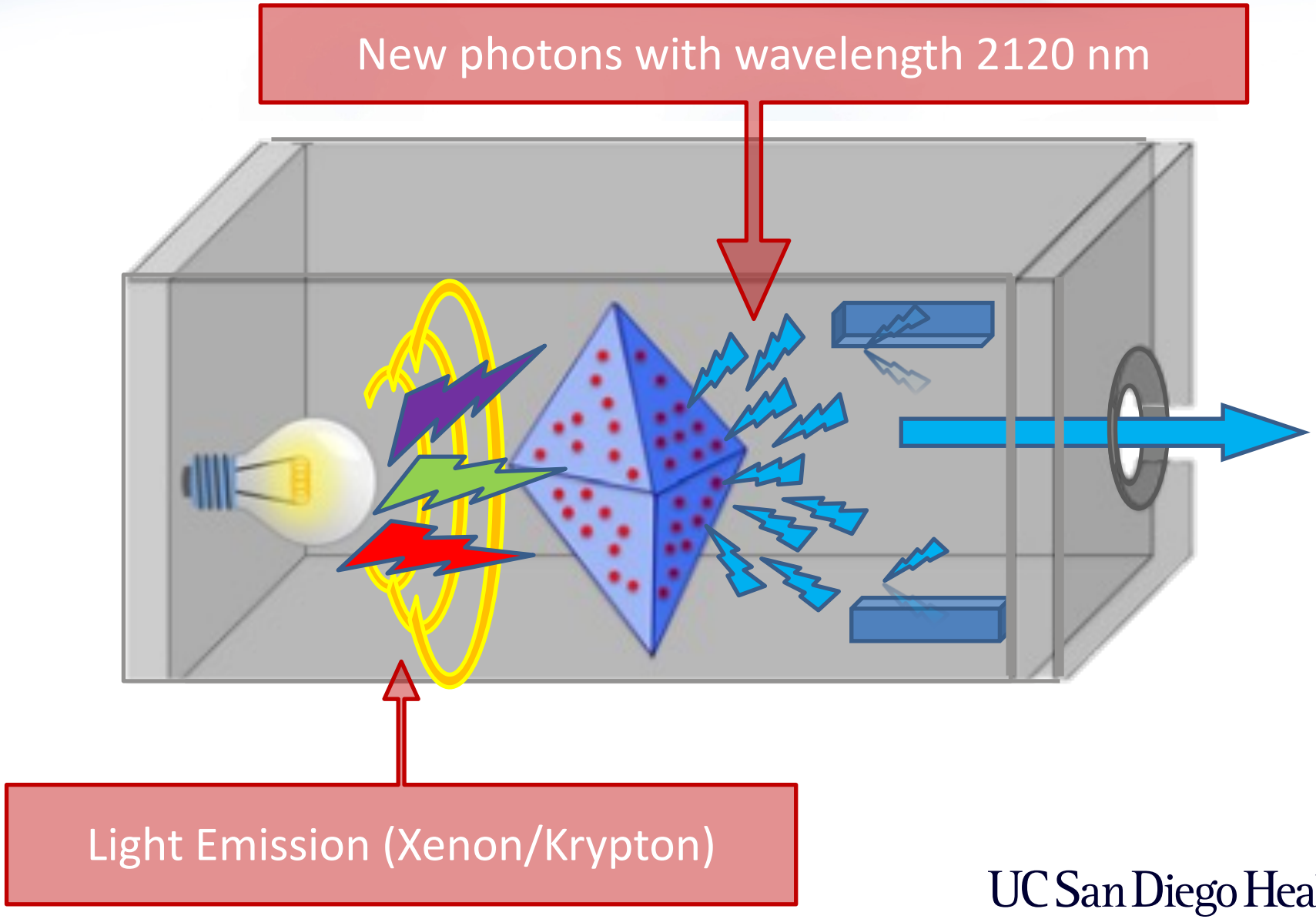
Holmium Laser Mechanics



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Options for Holmium Lasers: Low & High Power

- Low Power
  - 35, 65 W with dusting mode
  - Less expensive
- High Power
  - 100-150 W
  - Pulse modulation
  - Use for BPH (HoLEP)
  - Loud, heavy, need 30-50A

Short versus Long Pulse

- Short Pulse
  - Fragmenting
  - 0.6 J, 6 Hz
  - 1.0 J, 10 Hz

	Short Pulse	Long Pulse
Retropulsion	↑	↓
Fiber Degradation	↑	↓
Ablation/Fragmentation	—	—

- Long Pulse
  - Dusting
  - 0.4 J, 20 Hz
  - 0.2 J, 80 Hz

Aldoukhi AH, Roberts WW , Hall TL, Ghani KR. J Endourol. 2019 Feb;33(2):120-126
Winship B et al J of Endourology. Dec 2018.1131-1135.

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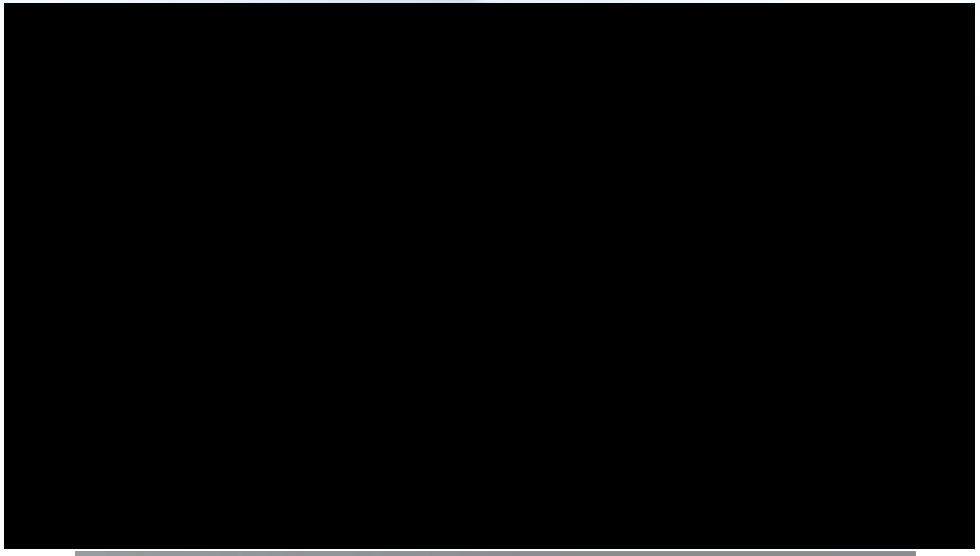
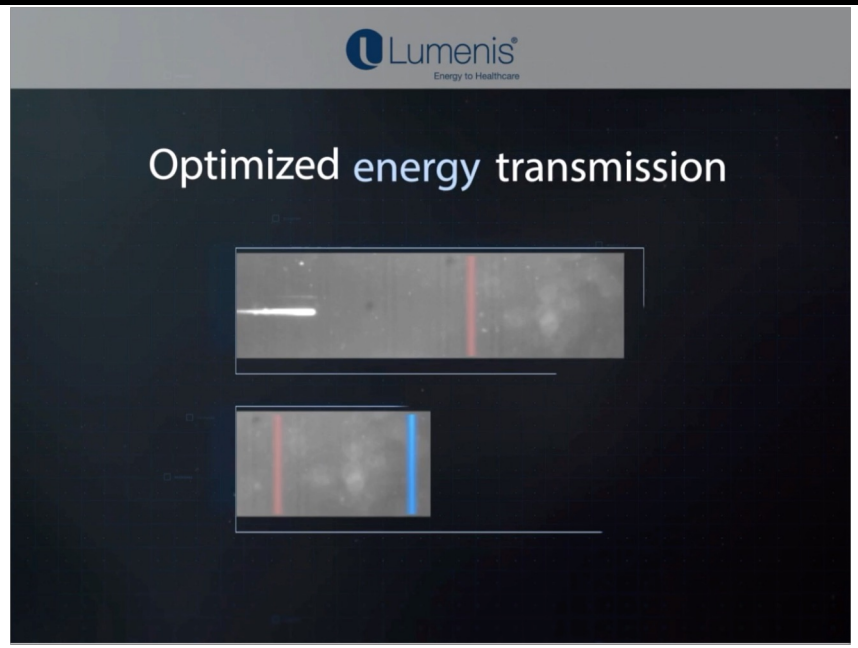
MOSES™ Pulsed Laser Modulation

- Introduced in 2017
- Changes “bubble” configuration
- More efficient energy targeting
  - Water displacement and vapor tunnel
  - Less energy displacement into surrounding water
  - Less stone retropulsion
- Contact and Distance modes

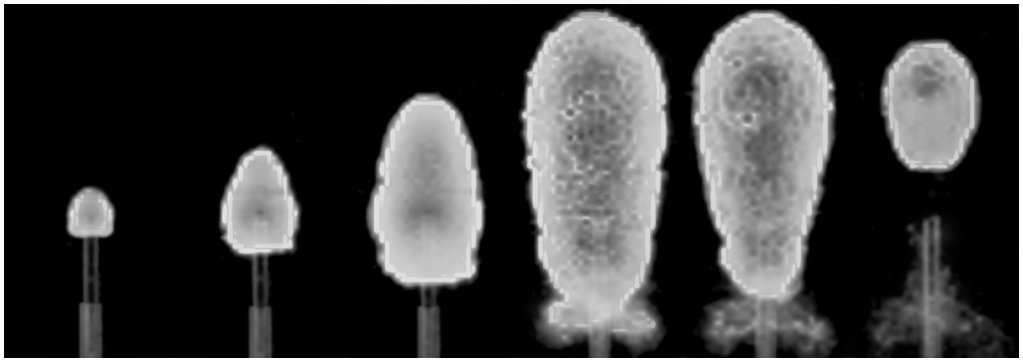




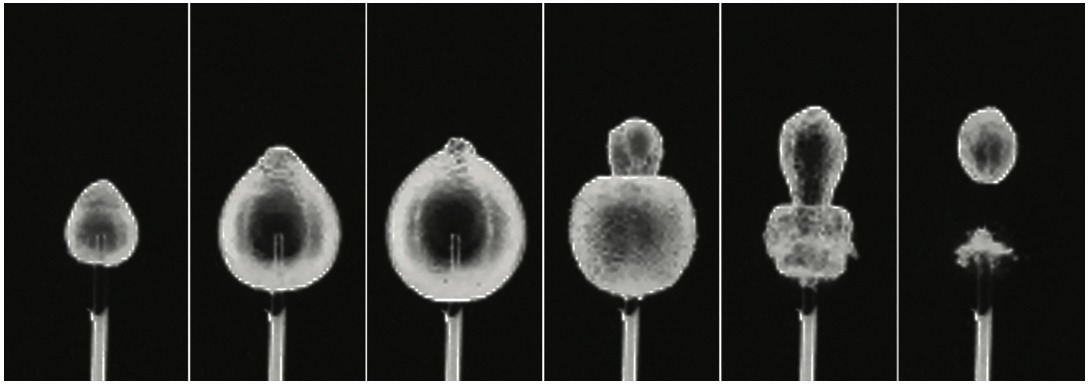
Lumenis.com

Vapor Tunnel™ and Virtual Basket™

- Single specific long pulse
- Uses minimum peak power
- Direct connection between fiber tip and stone



- Changes “bubble” configuration
- More efficient energy targeting
  - Double pulse modulation
  - 1st pulse: vapor bubble
  - 2nd pulse: moves through the bubble to hit target



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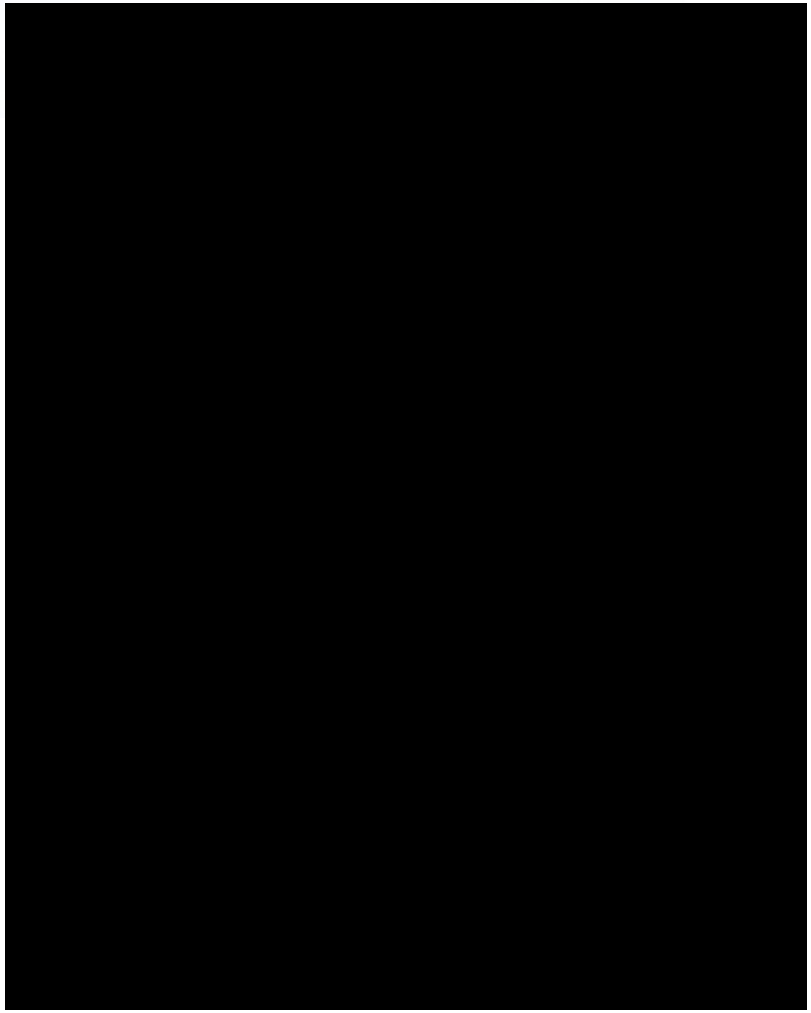
Treating Stones: Fragmenting



- Any stone location or type
- Any traditional laser
- 0.6-1.0 J, 6-10 Hz
  - 3.6-10 Watts
- HOWEVER
  - Retropulsion
  - Need to basket
  - ?more disposables
  - ? Longer case

Matlaga BR et al. J Endourol. 2018 Jan;32(1):1-6.

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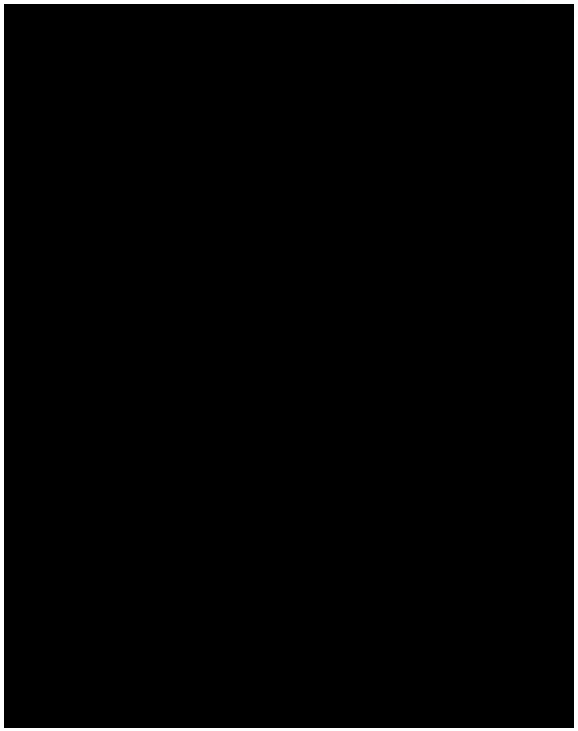
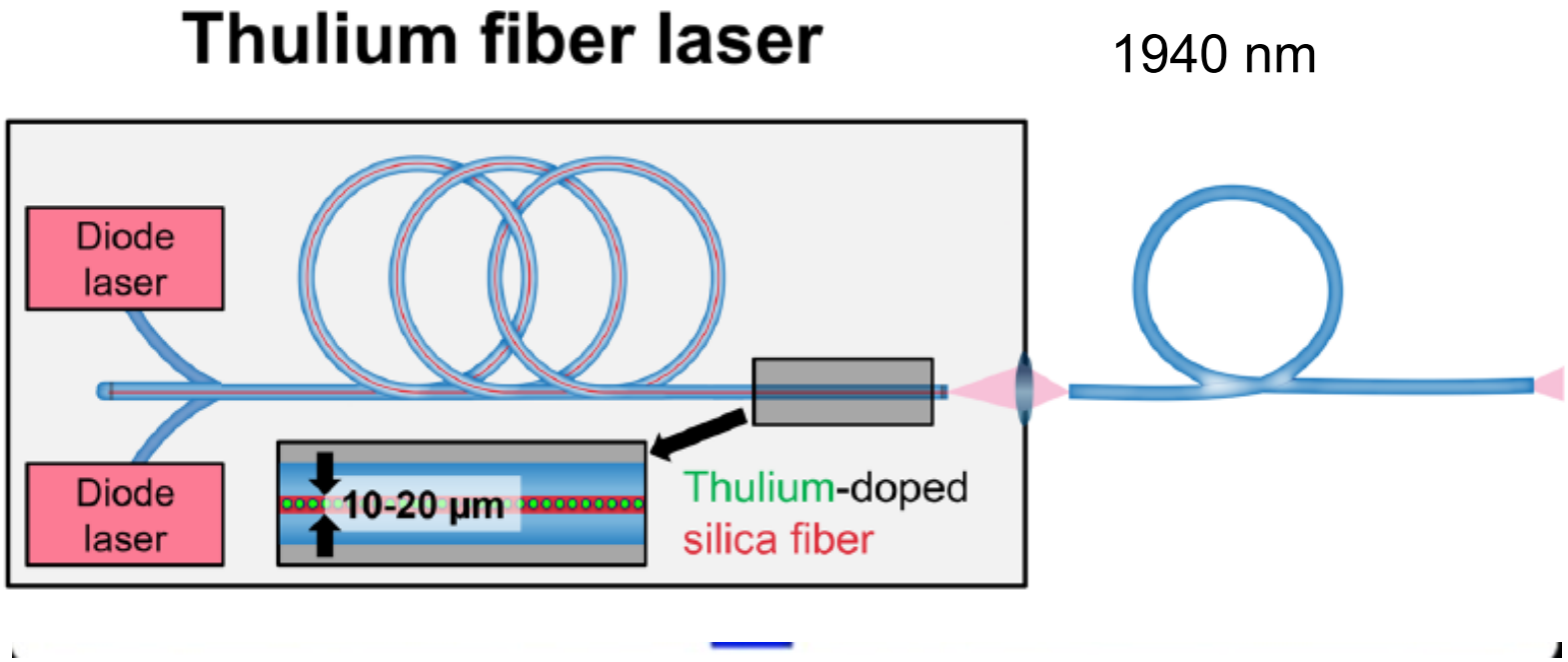
Treating Stones: Dusting



- Better for upper pole
  - Consider translocating stone
- Painting Technique
- 0.2-0.4 J
  - >50 Hz (100-120W laser)
  - 12-15 Hz (<30W laser)
- HOWEVER
  - Less effective for harder stones

Courtesy Marcelino Rivera

Thulium Fiber Laser Mechanics



- Long silica fiber (30 meters) doped with thulium ions
- Allow higher frequency up to 2000 Hz
- Deliver same energy with smaller diameter laser fibers
- Operates at high power ranges >50 W

Thulium Fiber Laser - Console

- Small console, easy to maneuver in OR
  - More versatile to use in variety of settings/room types
- Uses standard 110 volt electric outlet
  - Normal current
- Quiet
  - small fans similar to a home computer

Soltive™ Premium Laser Soltive™ Pro Laser

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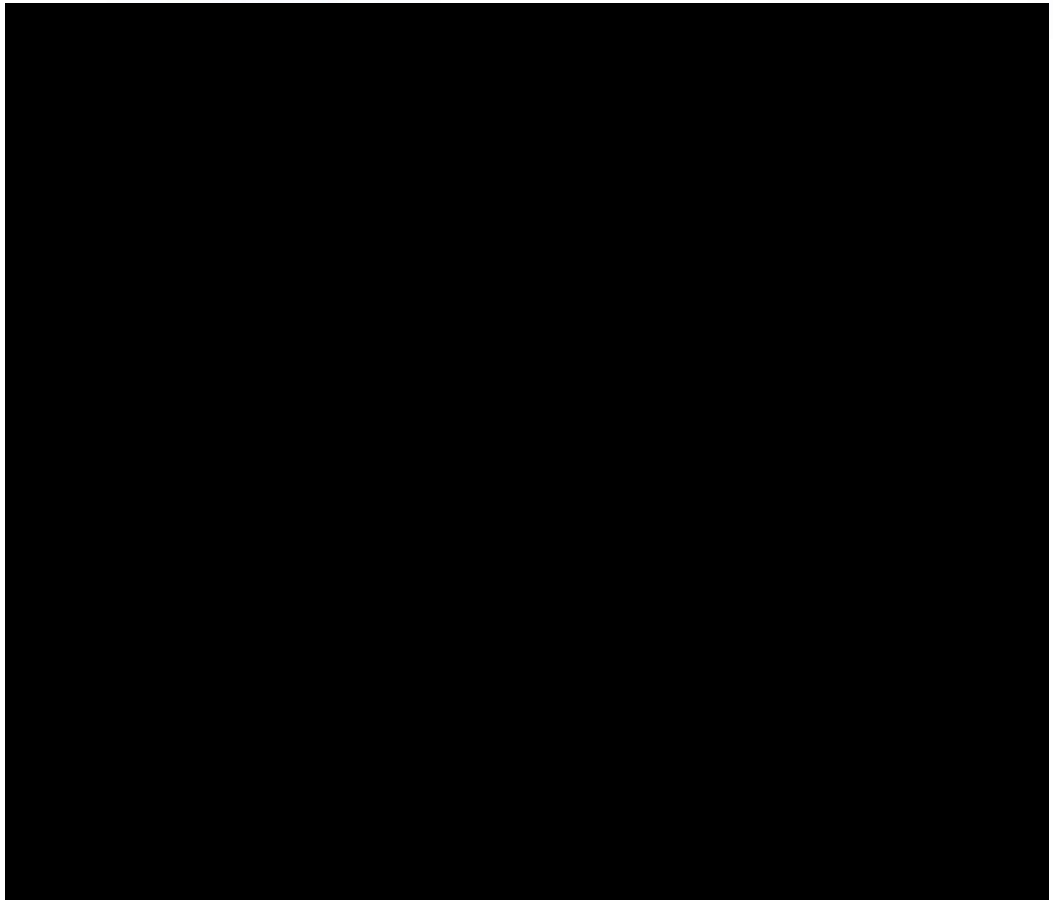
Thulium Fiber Laser - Console



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Thulium Fiber Laser Performance Data

- Compared to Ho:YAG (non Moses):
- Faster, finer dusting
  - 1.5-4x faster (49 vs 57 mins per OR Case)
  - Smaller fiber (150µm TFL) → finer dust (vs 272µm)
- Shorter case time→decreased cost
- Higher stone free rate
  - 49% vs 86% at 3 mo CT for renal stones
- Comparable safety profile
  - Temperature rise is a function of energy level
    - Irrigant reached 40-41º for 0.1 J, 200 Hz (TFL) or 0.3 J, 70 Hz (Ho:YAG)
  - No injury or necrosis on histological analysis of ureter

1 Panthier F, Traxer O et. Al. W J Urol 2020.
2 Glybochko P, Vinnichenko V et al. J Urol 2017:197(4)
3 Chew B, Molina W et al. Investig Clin Urol 2023:64(3)
4 Blackmon RL, Irby PB, Fried NM.. J Biomed Opt 2011:16(7).
5 Dymov A, Proskura A et al. J Urol 2017:197(4).
6 Ulvik et al. Erur Urol 2022:82(1).

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Thulium Fiber Laser Performance Data

Review > Eur Urol. 2024 Jan 29:S0302-2838(24)00012-5. doi: 10.1016/j.eururo.2024.01.0
Online ahead of print.

Thulium Fiber Laser Versus Holmium:Yttrium Aluminum Garnet for Lithotripsy: A Systematic Review and Meta-analysis

Alessandro Uleri [1], Alba Farré [2], Paula Izquierdo [2], Oriol Angerri [2], Andrés Kanashiro [2], Josep Balaña [2], Vineet Gauhar [3], Daniele Castellani [4], Francisco Sanchez-Martin [2], Manoj Monga [5], Adolfo Serrano [6], Mantu Gupta [7], Michael Baboudjian [8], Andrea Gallioli [2], Alberto Breda [2], Esteban Emiliani [2]

- 11 studies, 1286 Ho:YAG, 880 TFL patients
- TFL had higher SFR (OR 1.84) when no residual frags
- BUT no difference when compared to MOSES Ho:YAG only
- No difference in operative time or overall complication rate

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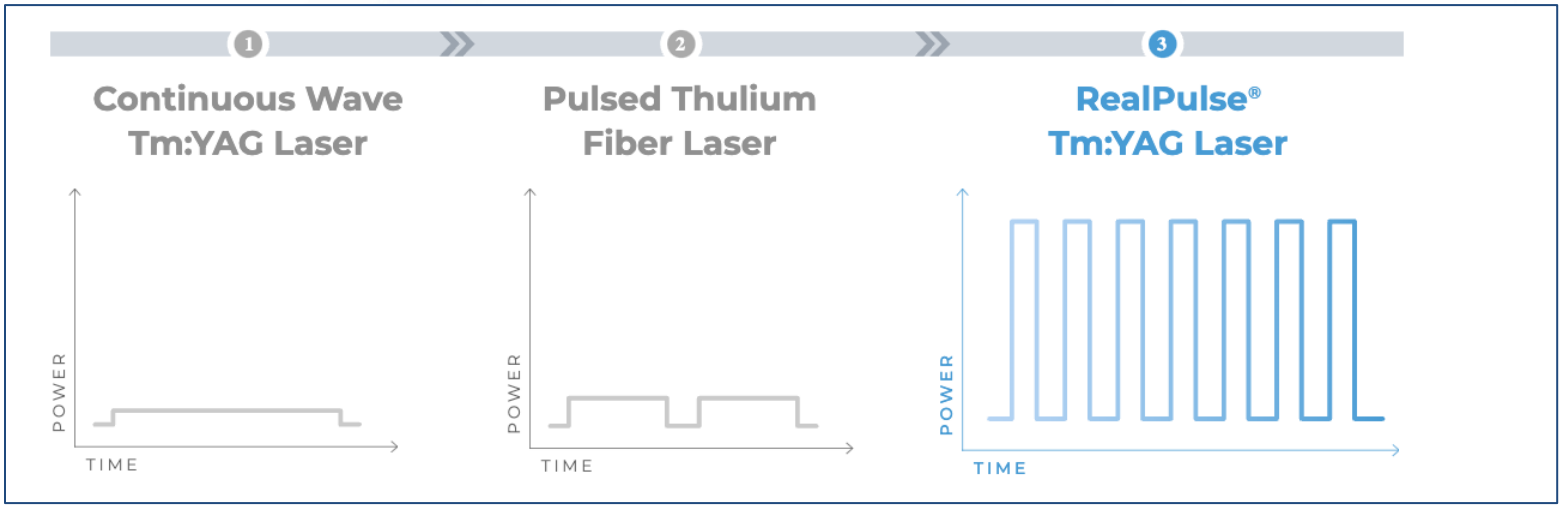
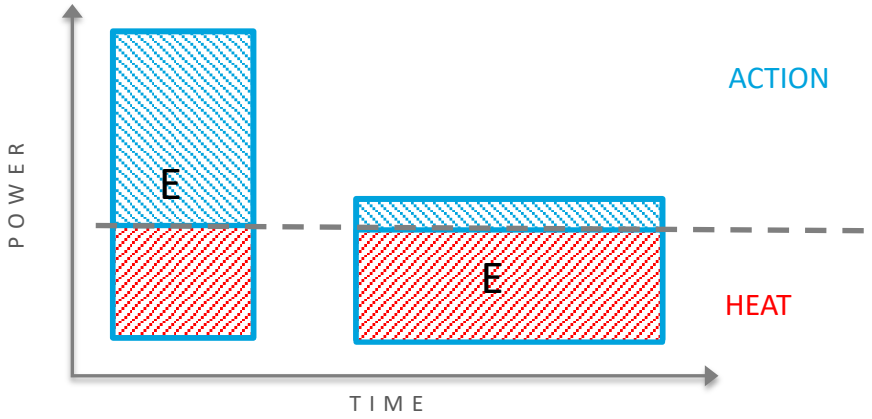
Thulium Laser Evolution





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Thulium:YAG Laser

- Tm:YAG crystal with pulsed diode
- Compared to Ho:YAG:
  - 10% more efficient fragmentation
  - 55% less fragmentation
  - Finer dust <125µm
  - Better coagulation (enucleation)
- Compared to TFL:
  - Higher peak powers→better fragmenting
  - Less total energy needed to fragment
  - Equivalent fine dusting
  - Coagulation equal or better
- Able to ablate all stone types into fine dust[3]

1 Petzold, R. et al. *World J Urol* , 2021
2 Petzold, R. et al, *J Endourol.*, 2020
3 Kwok J et al. World J Urol, 2023

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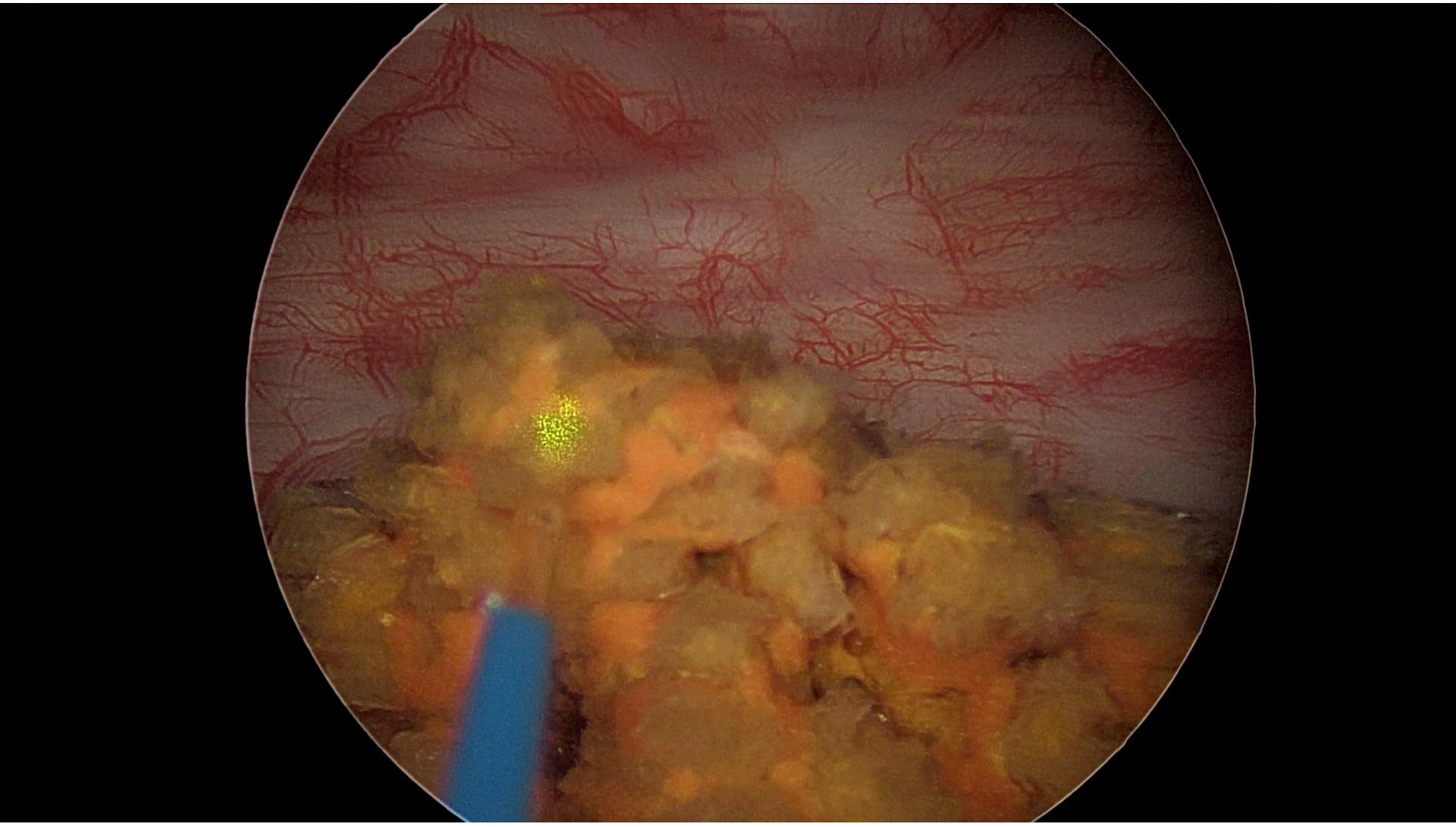
Thulium:YAG Lithotripsy Options

- Dusting
  - Fine clay powder
- Captive Fragmenting
  - Minimal retropulsion, fragments while still forming dust
- Fragmenting / Short Pulse
  - Retropulsion, good for popdusting

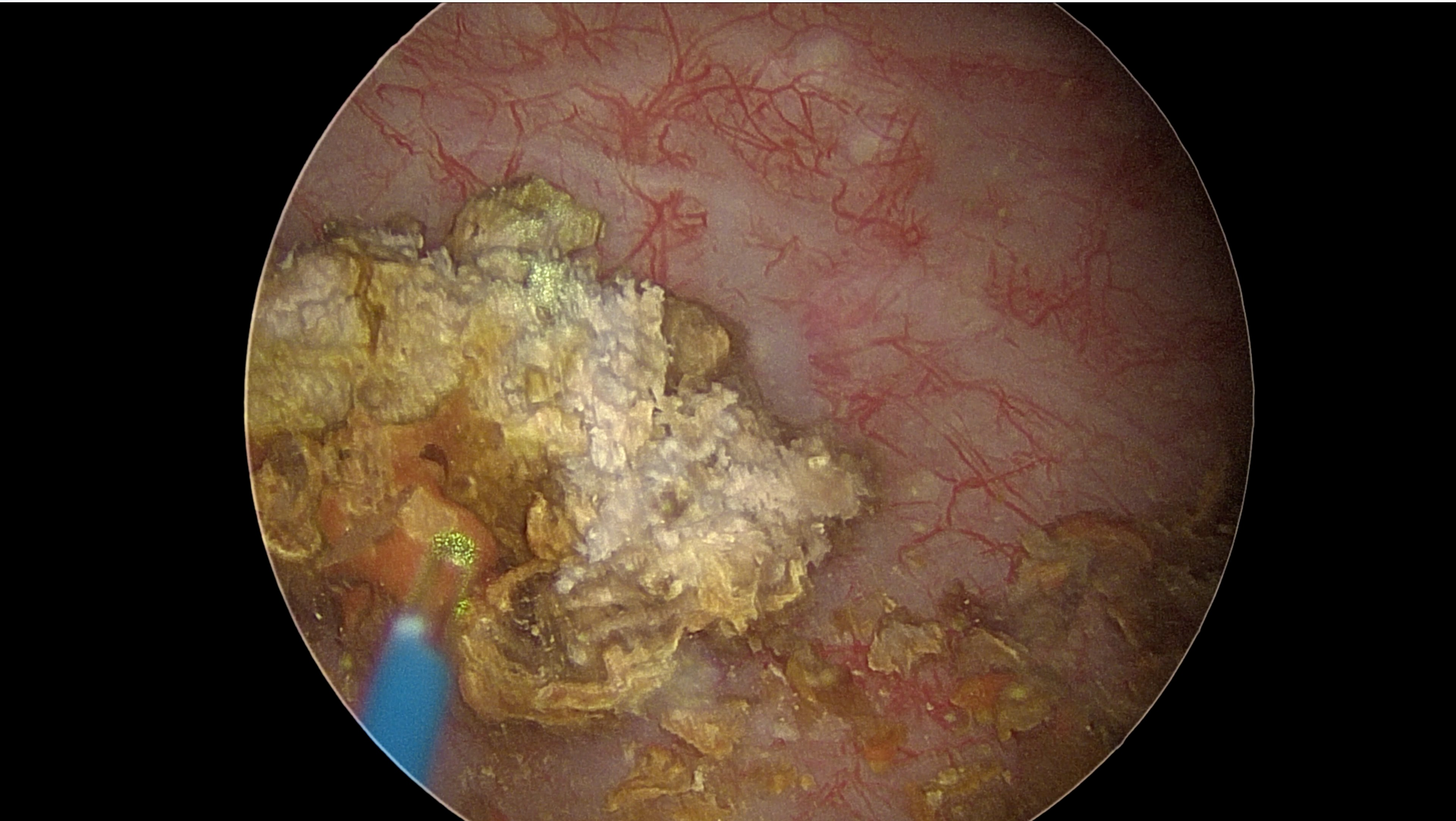
Dusting – Bladder Stone

- 200mJ, 50Hz (10 W)



Fragmenting – Bladder Stone

- 2000mJ, 10Hz (20 W)

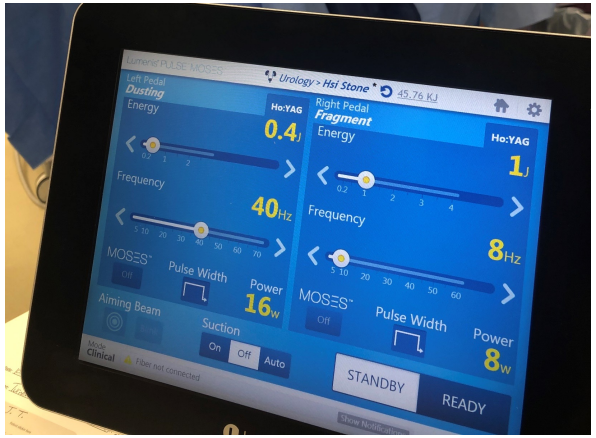


HOW TO THINK ABOUT TREATING A STONE

Pulse energy

Frequency

Pulse width/ modulation



Your laser setting

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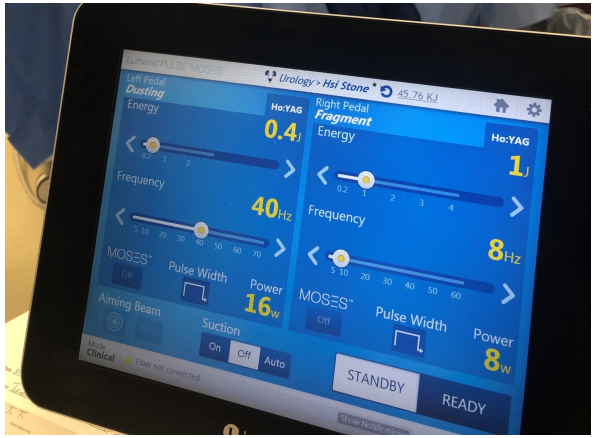
HOW TO THINK ABOUT TREATING A STONE

Pulse energy

Frequency

Pulse width/ modulation



Your laser setting

Dusting
Fragmenting
Popdusting
Retropulsion
Total energy

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Patient Case -- REALITY

Multiple factors are involved

- STONE
  - Stone burden, density
  - Sheath / no sheath
  - Stent / no stent
  - Stent duration
  - Collect stone sample
- INTRAOP
  - Anatomy
  - Equipment
  - Time
  - Visualization
  - Irrigation system
  - Ergonomics / Assistant
- PATIENT
  - UTI history
  - Comorbidities
  - Staged procedure
  - Patient expectations

Patient Case -- GOALS

What is your goal for treatment?

- 41 year old male with
  - Flank pain, 6mm stone behind a narrowed mid calyceal infundibulum (HU 700)
  - Symptomatic 10mm renal pelvis stone (HU 400)
  - 7mm distal ureteral stone (HU 1100)
  - Recurrent UTI and 9mm lower pole stone (HU 400)

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— *Fragment/basket, popdust*

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  - 7mm distal ureteral stone (HU 1100) — *Fragment/basket, low energy*
  - Recurrent UTI and 9mm lower pole stone (HU 400) — *Fragment/basket, relocate to upper pole*

Conclusion

- Many great systems are available
  - Variety in laser modality/wavelength, settings, energy optimization, fiber sizes, machine dimensions
- Regardless of system, need to optimize technique
  - Understand and take advantage of the settings available
- Try to set specific treatment goals for each patient
  - Use these to guide your choice of laser and settings

Thank you!

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