Universität Basel
Department of Biomedical Engineering

Project MIRACLE
Smart Laser Osteotome
BLOG

Measurements of coupling efficiency of high-power Er:YAG laser in different types of optical fibers

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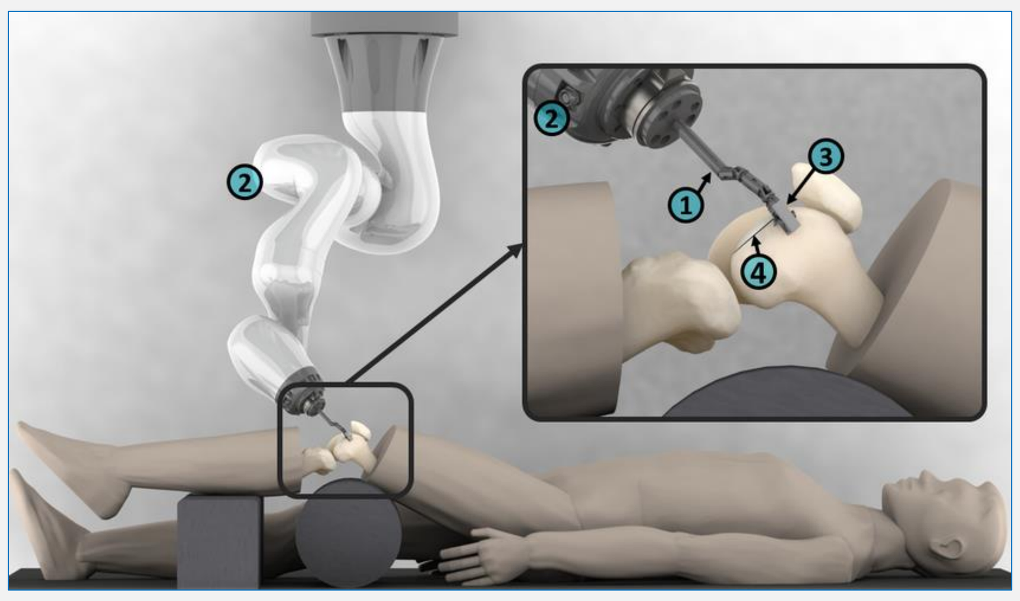
Motivation and background

Conventional bone surgery may lead to heat and vibrations of the surrounding tissues → Unwanted injuries and collateral damage

Laser ablation → Contact-free ablation

Laser ablation plus robotic guidance → Small cuts and flexible Shapes

Robotic system to ablate bone [1]

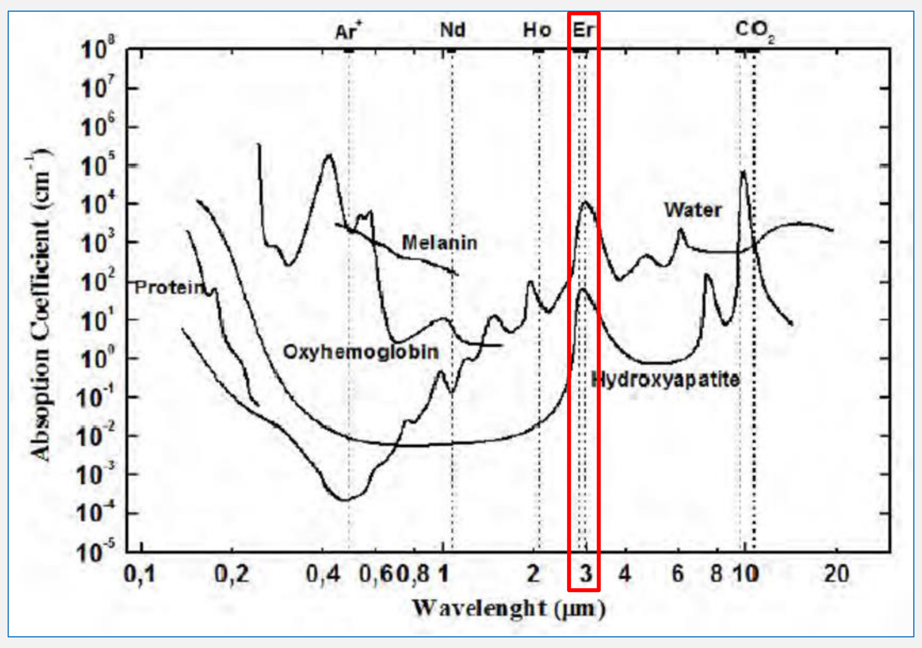


[1] Eugster, M., et al., "A parallel robotic mechanism for the stabilization and guidance of an endoscope tip in laser osteotomy" in *IEEE Conference on Intelligent Robots and Systems (IROS)*, pp.1306-1311, 2018.

Idea of building an endoscopic device (1) controlled by a robot (2). The end-effector tip (3) of the endoscope contains the laser system to be able to perform the bone cut (4).

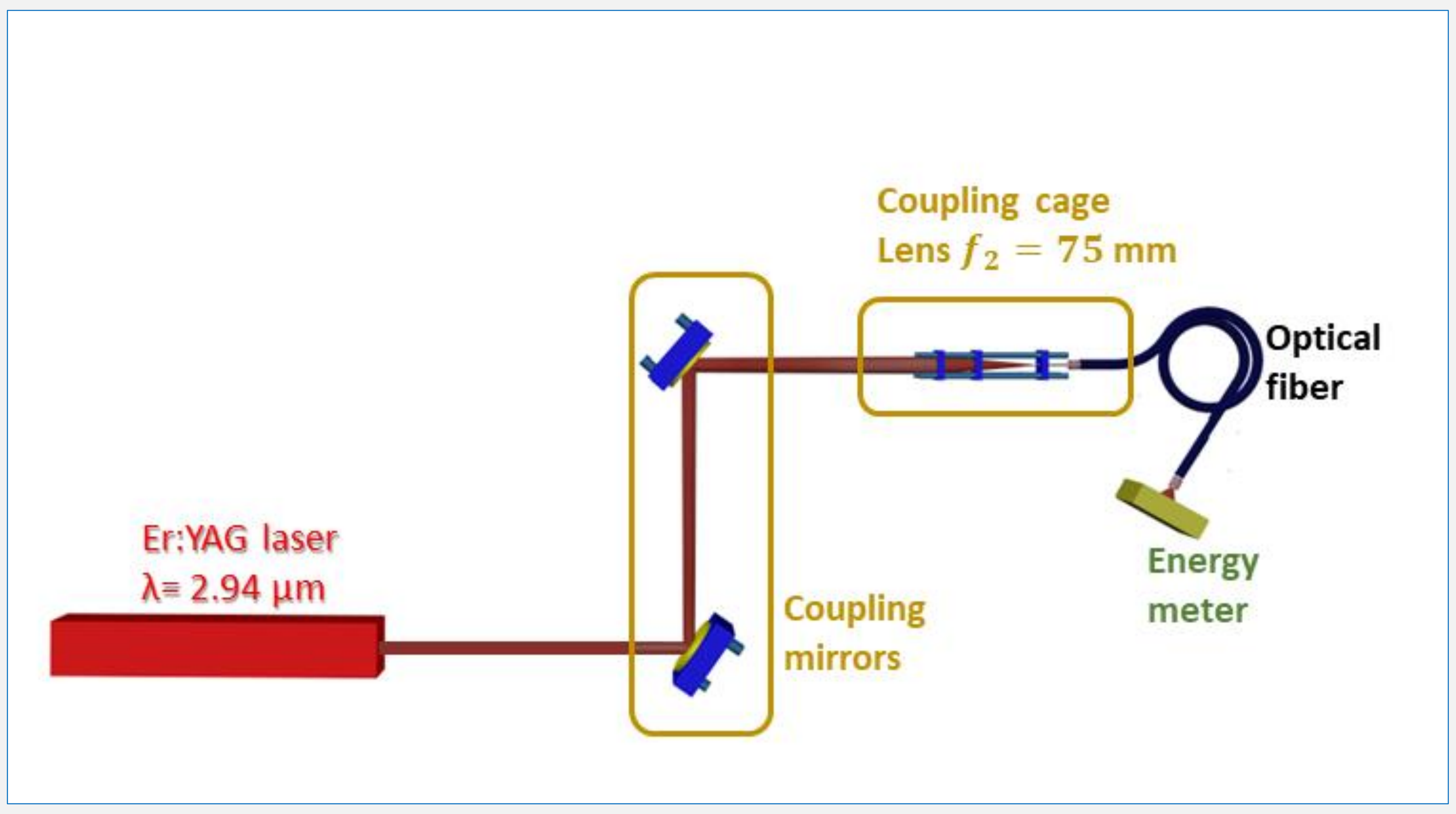
Materials and methods

Phototermal ablation principle [2]



[2] Bona, A., et al., "Laser technology for caries removal" in *Contemporary approach to dental caries*, Intech, 2012, Ch. 15, sec.2, pp.294.

Currently, we use an Er:YAG laser for coupling into fibers. λ=2.94 µm. Max. energy 900 mJ.



The fibers we used are GeO2, Sapphire, ZBLAN fluoride, and hollow core silica waveguide (HSW).

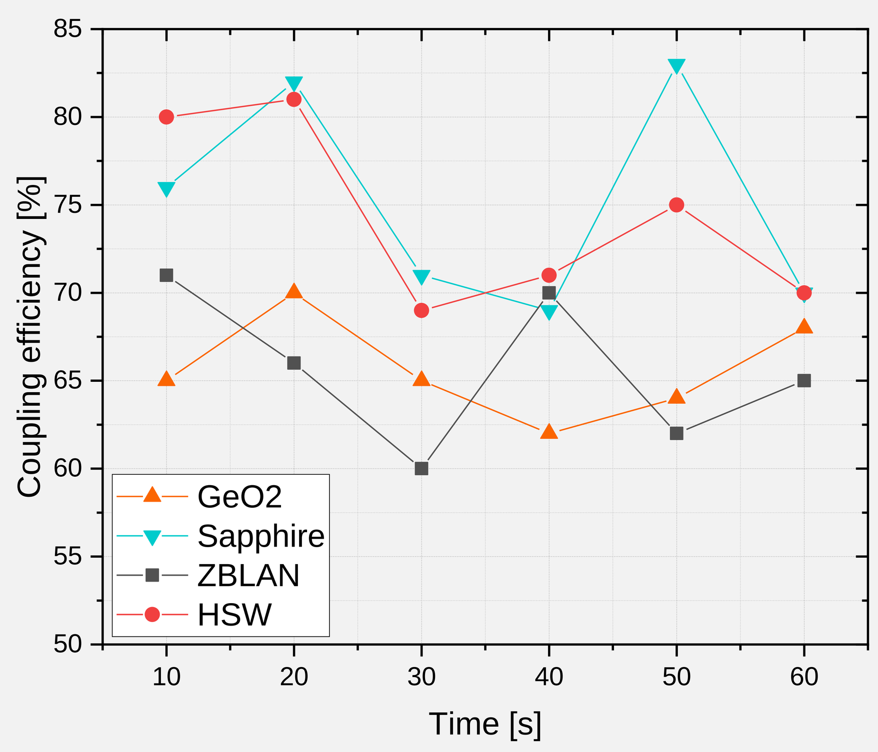
Results

Main properties of the optical fibers:

	GeO2	Sapphire	ZBLAN	HSW
Core size [µm]	450	425	450	500
Transmission per meter [%]	70	80	95	71
Provider	Infrared Fiber Systems (USA)	Photran (USA)	Thorlabs (GER)	Laser Components (GER)

Beam size at tip of the fiber is ca. 330 µm, which is approximately 70% of fiber's core.

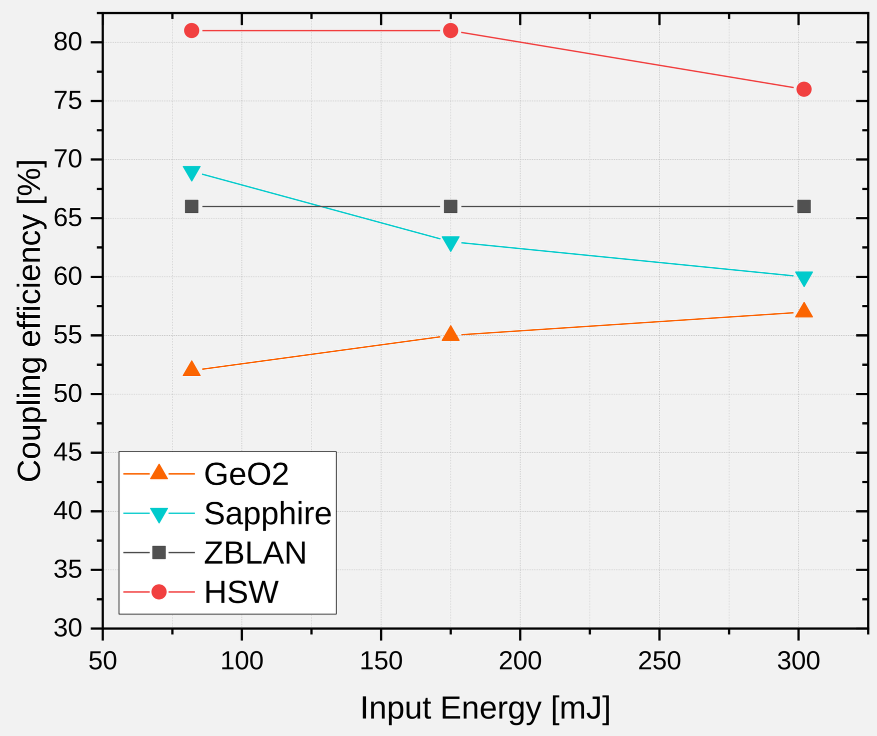
Coupling optimization process:



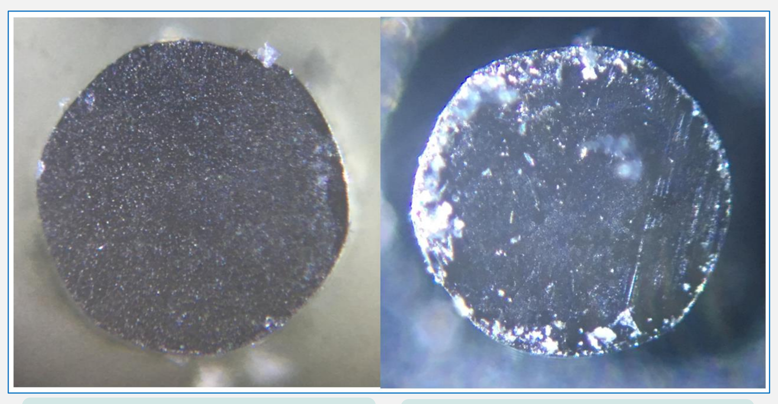
Fiber coupling optimization at low energies (10-50 mJ). Stabilization evaluated at different times (10-60 s).

Results

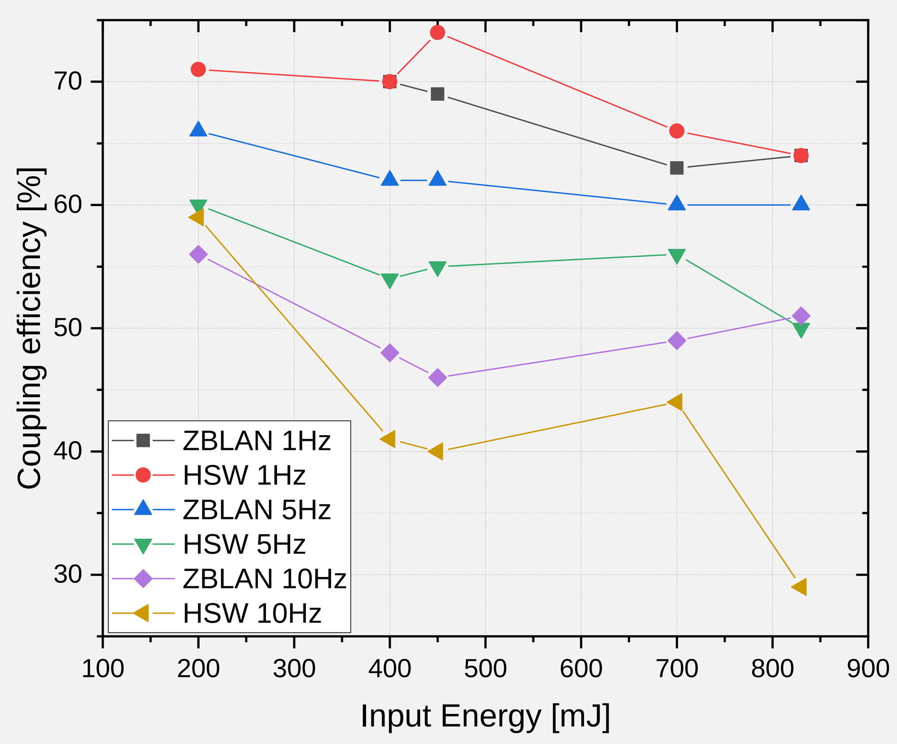
Resistance of the fibers to the input energy:



All fibers were tested at 1 Hz and different input energies. ZBLAN and HSW survived up to 300 mJ.



Sapphire before Sapphire after



ZBLAN and HSW were tesed at higher energies and higher repetition rates. The two fibers were burned with just few pulses at 5 and 10 Hz, respectively.

Side lobes of the poor quality laser ($M^2 \approx 20$) might be coupled in the cladding!

Outlook

- Continue research on the fibers to couple Er:YAG laser (use better connectors for coupling, isolate the fiber better)
- Choose the best fibers and test them inside the endoscopic robot built by our colleagues
- Test ablation of bone through the fibers and evaluate ablation efficiency as well

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