Requirements for the laser pulses near 6.45 μm for minimally invasive surgery (MIS)

Pulse duration: not longer than few μs (e.g. <5 μs)

Pulse energy: sufficiently high to reach ablation threshold:
2 mJ (preferably 5 mJ)

Repetition rate: not too high say up to 100 Hz
(from considerations of thermal load and average power)

Repetition rate: sufficiently high for efficient ablation,
e.g. > 20 Hz

Too long (μs) pulses: Can not be frequency converted with sufficient efficiency because of their low peak intensity

Too short (fs-ps) pulses: Apart from difficulties in frequency conversion, would have too high intensity for mJ pulse energy @ 6.45 μm, which will lead to unwanted nonlinear effects in light-matter interactions

Possible time structure for efficient frequency conversion to 6.45 µm at 20-100 Hz

Single 10-150 ns pulses: available from 1 µm Nd-lasers or Tm-/Ho-lasers operating near 2 µm, i.e. closer to the target wavelength of 6.45 µm

Macropulses of µs duration: consisting of ps pulses at high (e.g. 0.1-1 GHz) repetition rate. Available only near 1 µm from Nd-laser based systems

Such time structure resembles FEL and can be advantageous for higher conversion efficiency (high intensity ps micropulses) and with respect to damage problems which are more pronounced for ns pulse durations

However: such laser systems are either flashlamp-pumped in the pulsed mode, or have to be developed on the basis of diode-pumping of continuous-wave mode-locked Nd-oscillators and acousto-optic pulse pickers for macropulse length and repetition rate control (demanding)

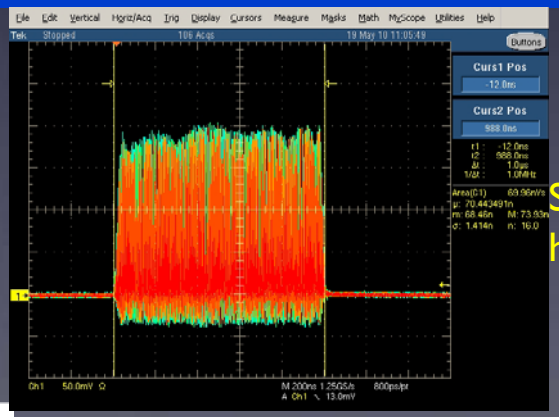
Frequency conversion based on macropulse time structure within MIRSURG

Upgrade of lamp-pumped pulsed Nd-laser ps system
2 μs long macropulses of 120 mJ, each consisting of 200 micropulses at 100 MHz

→ Single stage SPOPO based on wide band-gap mid-IR nonlinear crystals (exotic materials, damage issue)

Novel diode-pumped Nd-laser system with adjustable (μs) macropulse length: >100 mJ macropulse energy at 100 Hz, micropulses: follow at 500 MHz

→ First stage SPOPO based on thick periodically poled ferroelectric materials to convert to 2 or 3 μm wavelength



Smooth ps-pulse train at higher micropulse rate

→ Second stage SPOPO based on ZGP or OP-GaAs to convert to 6.45 μm

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Frequency conversion based on single nanosecond pulses within MIRSURG

Commercial Nd-laser with
100 mJ output at 100 Hz
(pulse duration: 14 ns)

Single stage OPO based
on wide band-gap mid-IR
nonlinear crystals (exotic
materials, damage issue)

Commercial Nd-amplifier with
200 mJ output at 100 Hz
(pulse duration: 14 ns)

First stage OPO based
on thick periodically poled
ferroelectric materials to
convert to 2 or 3 μm wavelength

Shorter nanosecond pulses facilitate the frequency conversion

Cascaded frequency conversion

or

Diode-pumped Tm-laser with
>50 mJ output at 100 Hz
(pulse duration: <150 ns)

Second stage OPO based
on ZGP or OP-GaAs to convert
to 6.45 μm

Single step frequency conversion

or

Diode-pumped Ho-laser with
>20 mJ output at 100 Hz
(pulse duration: <100 ns)

Ho-lasers are less advanced than diode-pumped Tm-lasers but potentially more powerful and better suited for the frequency conversion process to 6.45 μm

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