Short-pulse, high-repetition rate, high-power Nd:YLF MOPA system

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Outline

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- Nd:YLF MOPA – Details
- Harmonic generation
- Conclusions

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Motivation

- Develop a 0.5-μ laser source per following specifications:
  - *> 30 W* — *average power*
  - 30-100 kHz — *high repetition rate*
  - <15 ns at 50 kHz — *short pulse*
  - TEM_{oo} — *high beam quality*
- Reliable, stable design

Q-Peak' MPS-523 QS20H Typical Laser Parameters

MPS-523 QS20H system (2 gain modules):

MPS-1047 QS10H oscillator (TEM_{00}) + 1 Amp

- Power:
  - ~ 45 W IR
  - ~ 25 W Green
  - > 55 % Conversion efficiency
- Repetition rate:
  - 10-30 kHz
- Pulsewidth:
  - 10 kHz ~ 30 ns
  - 20 kHz ~ 50 ns
  - 30 kHz ***~ 75 ns***

too long !!!

Osc multi-pass design and the need to establish a large cavity mode size lead to a relatively long cavity -> longer pulse

How to get there?

Power consideration:
> 30 W green
SHG
~50% eff.
~60 W at 1 μ

- Power oscillator: > 60 W ???
  - Short pulses ???
- MOPA ???
- Laser material ???

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Commercial TEM_{00} IR/Green systems – Some examples

		Max. Power, W	Pulsewidth, ns	Rep.rate, kHz
Coherent Vector 1064-3000-30	1064 nm	> 3 W at 30 kHz	***< 15 ns (30 kHz)***	***0-100***
Coherent Vector 1064-3000-150	1064 nm	> 3 W at 150 kHz	~ 100 ns (150 kHz)	0-200
Lightwave Electronics Q202-SM	532 nm	>18W at 80 kHz	280 at 80 kHz	40-210
SpectraPhysics HIPPO Series	1064 nm 532 nm	17 W 11 W	***< 13 ns at 50 kHz***	***15-100***

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Achieving High Power and Short Pulses at > 30 kHz

Nd:YVO_4 power oscillators? Nd:YVO_4 MOPA?

Higher gain than in Nd:YLF but:

- limited size of high-quality crystals
- strong, aberrated thermal lensing

$\Rightarrow$ *challenges in scaling up to high powers*

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Our Preferred approach

Develop a Nd:YLF MOPA system:

- Number of MPS gain modules as amplifiers
- Low-power, end-pumped, short-cavity Q-switched laser as a master oscillator:
  - Defines the repetition rate and required pulsewidth
  - Desired average power (>500mW)

Nd:YLF material for the amplifiers:

- Low dn/dT:
  - -> very low thermal lens
    - -> easier power scaling by adding amplifiers
- Natural birefringence
  - -> no depolarization in amplifiers

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Q-Peak' MPS Gain Module

Typical performance in CW, TEM_{00} mode either as:

- oscillator or
- amplifier (saturated)

	Early days	Nowadays (Standard)	Nowadays (advanced)
Diode pump power, W	40	65	80
1-μ output, W	~ 12	~ 25	32
Absolute efficiency, %	30	38	40

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Master Oscillator - Possible solutions

Short pulses can be generated in Nd:YLF !!!

- H. Plaesmann *et al.*, “Sub-ns pulse generation from diode-pumped AO Q-switched solid-state lasers”, App. Optics 32, 6616-6619 (1993).

❑ Buy a commercially available system

Commercial laser: Lightwave Electronics® Model 110

1047 nm, up to 400 mW, up to 100 kHz

	1 kHz	10 kHz	30 kHz	50 kHz	100 kHz
Pulsewidth, ns	<5	8	***26***	***39***	***>60***
Pulse energy, uJ	>100	40	11	6.3	3.4
Power, mW	>100	<400	<400	<400	<400

❑ Do it yourself

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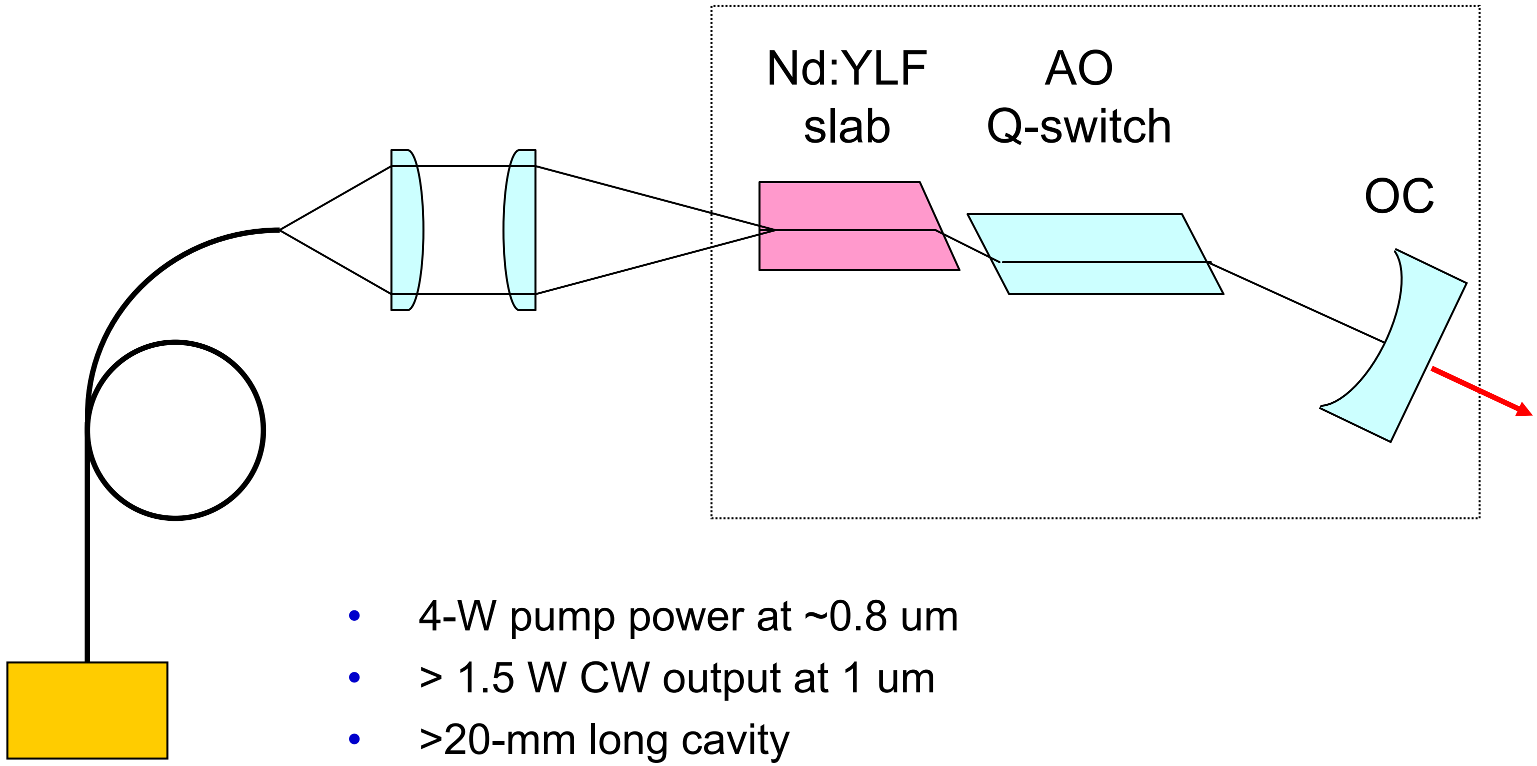
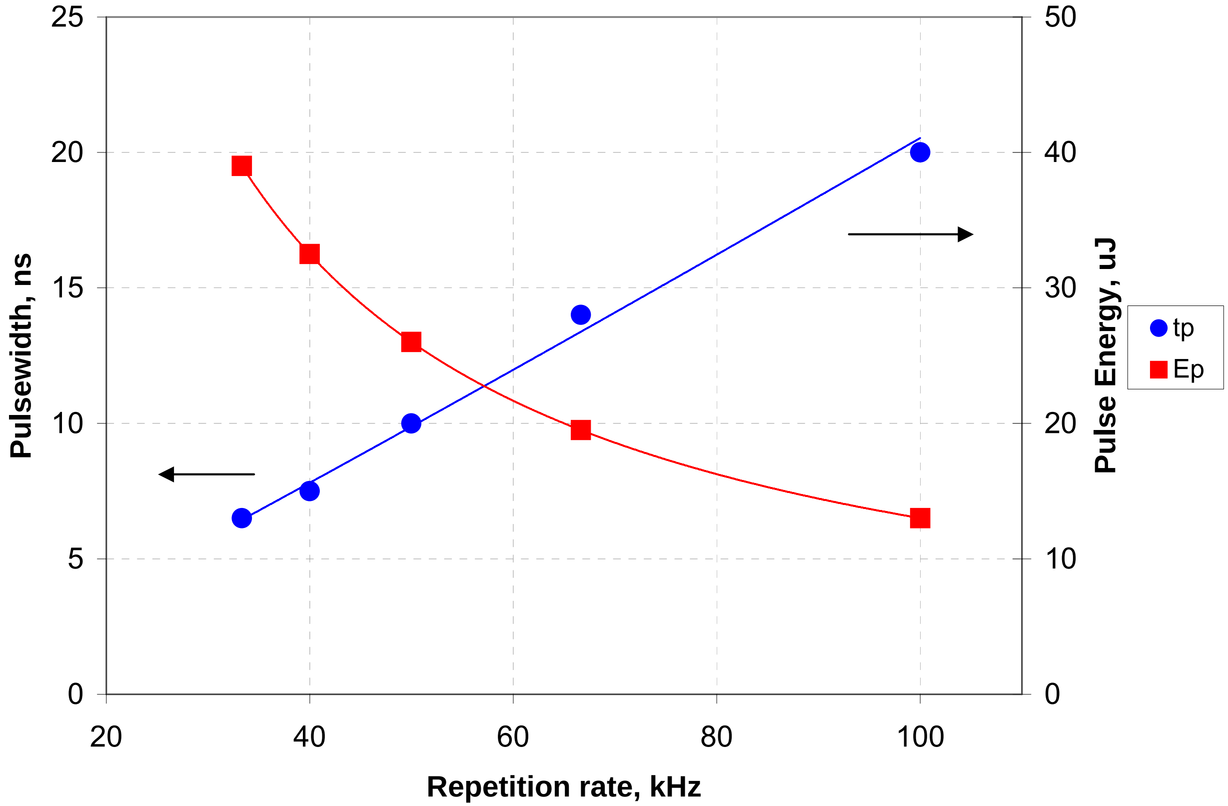
Short-Pulse Oscillator - Layout



- 4-W pump power at ~0.8 um
- > 1.5 W CW output at 1 um
- >20-mm long cavity
- Slab design -> good thermal management
- All elements are conductively cooled

1047-nm Short-Pulse Oscillator - Performance

- 1047 nm
- 1.3 W QS output
- 30-100 kHz
- TEM_{00} ($M^2 < 1.1$)



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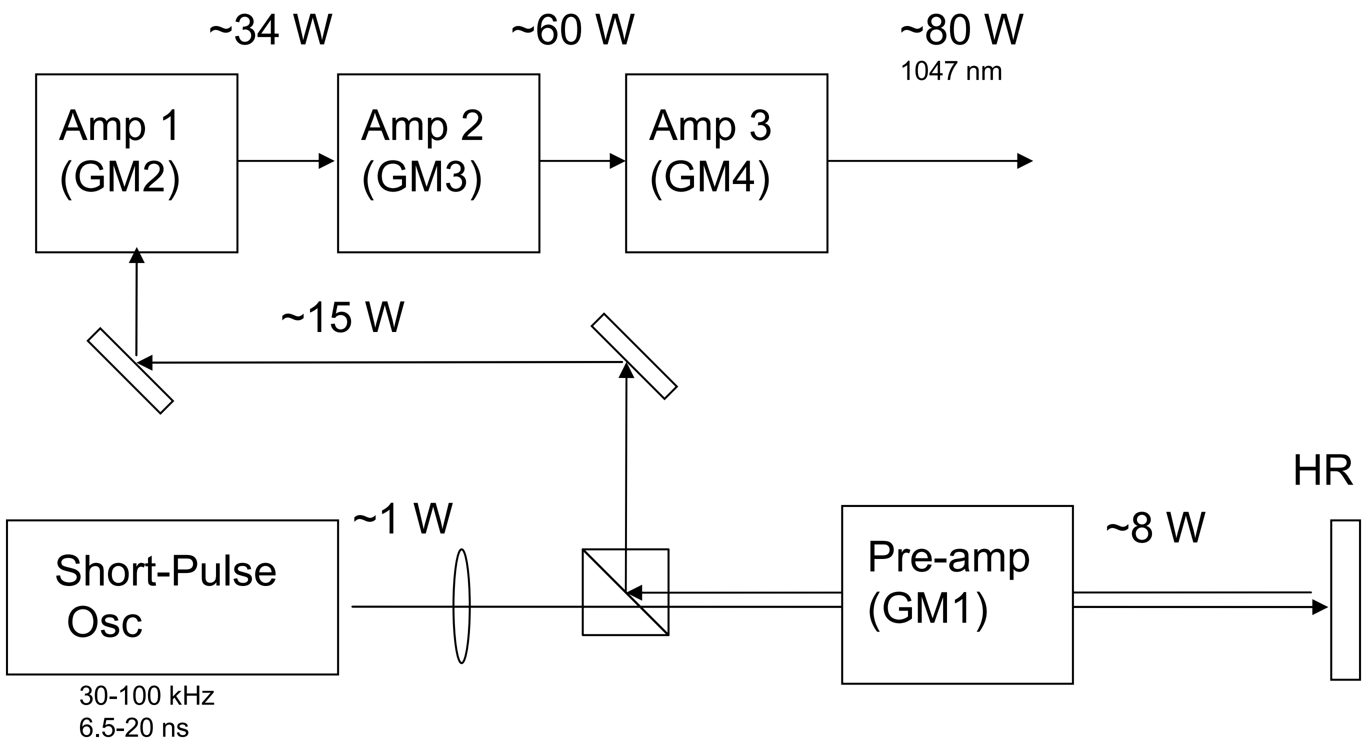
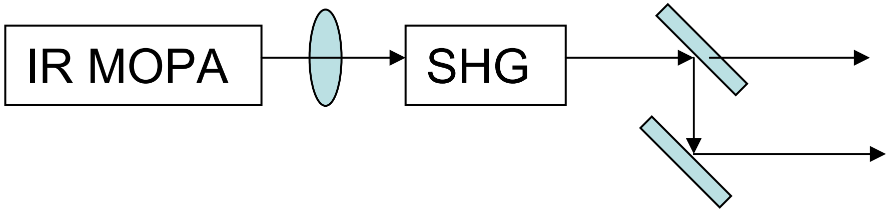
Short-Pulse Nd:YLF MOPA



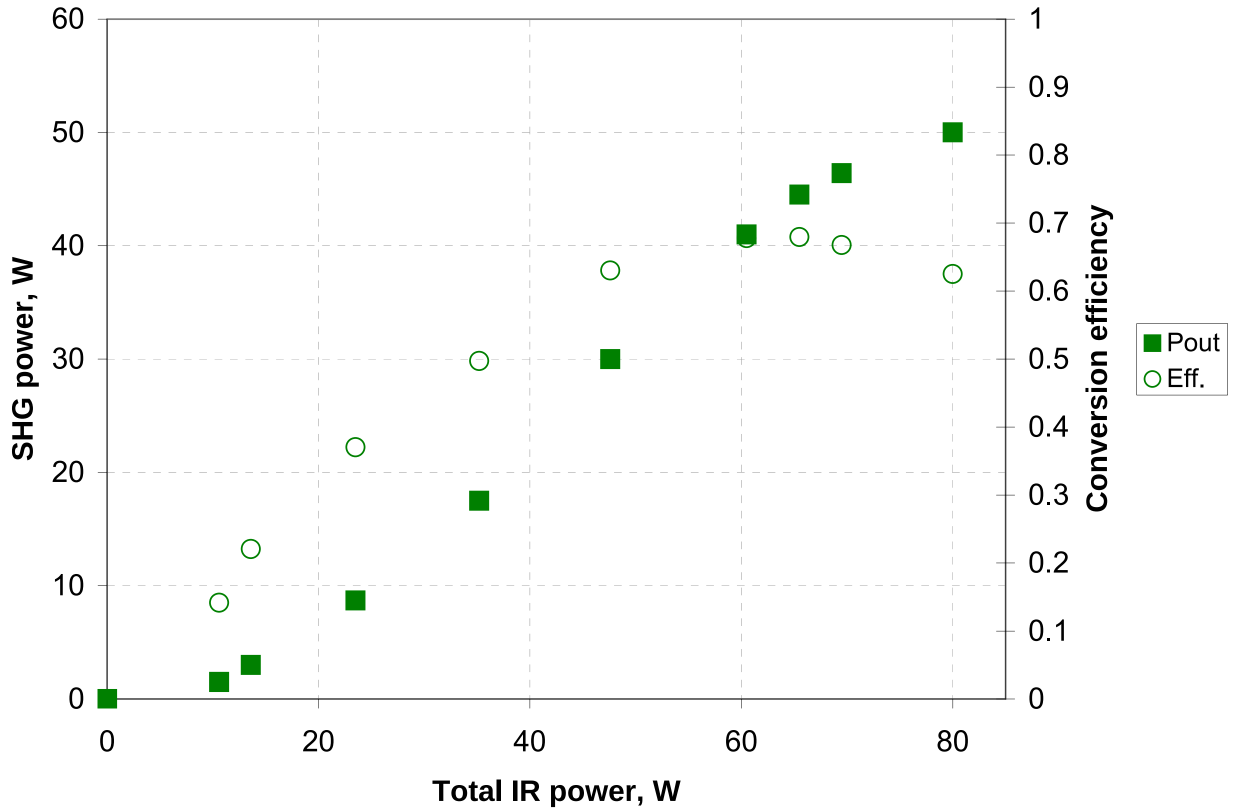
SHG IN LBO



- IR Power
  - Up to 80 W
- LBO
  - 20-mm long
  - NCPM
  - 170 C

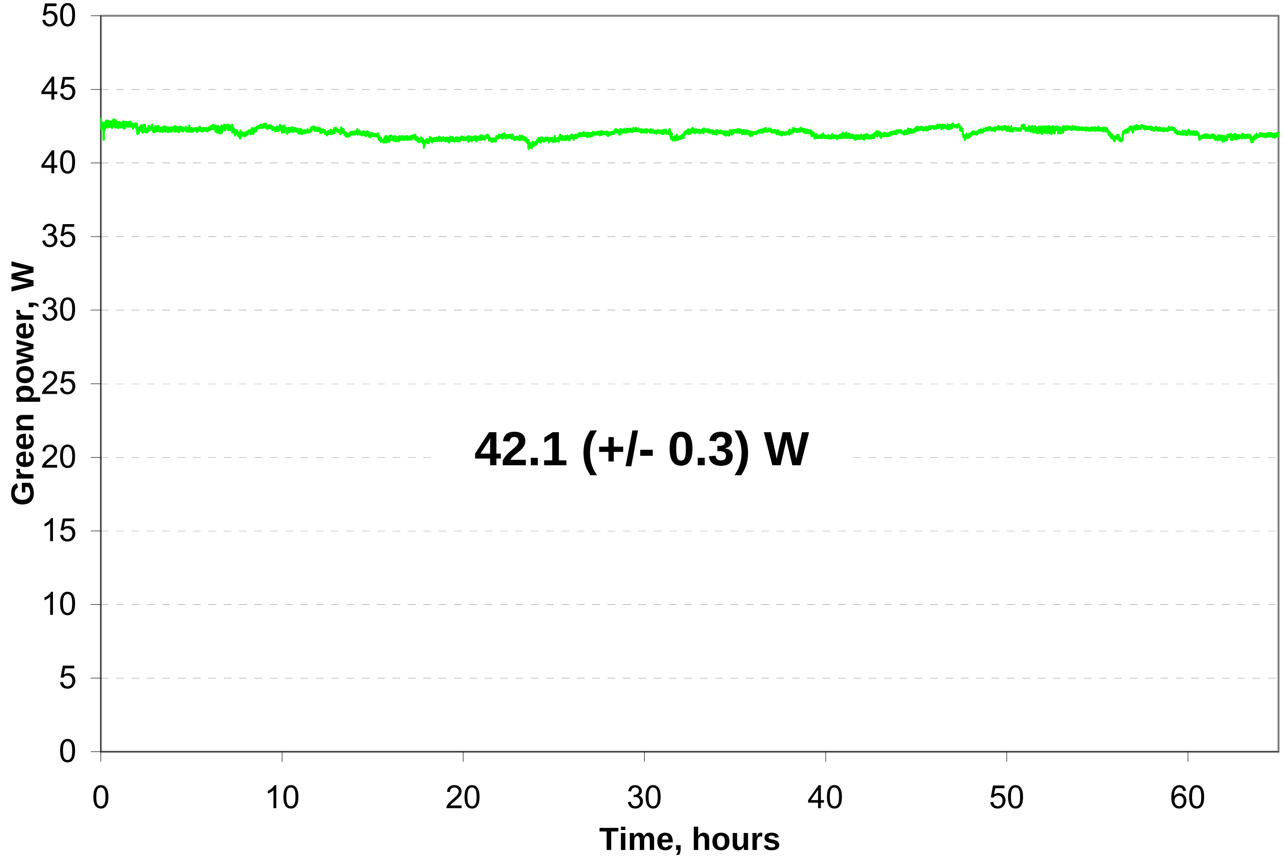
SHG in LBO

- ≤50 W at 523 nm
- ≤ 68% eff.
- 30-100 kHz
- TEM_{00}



Typical performance at 30 kHz

SHG Stability Measurement



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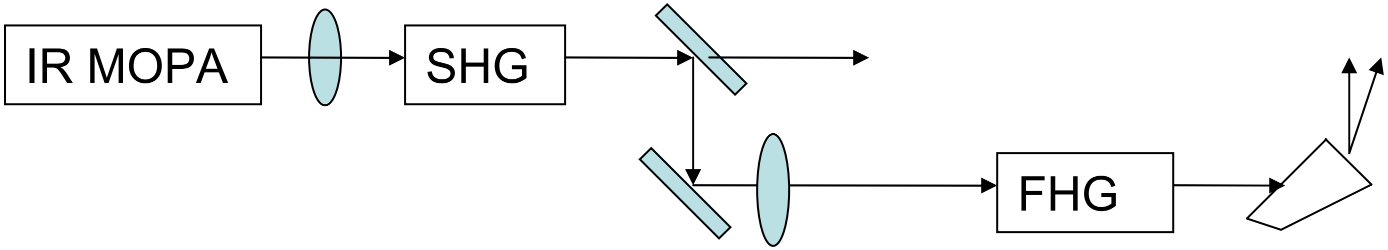
FHG IN CLBO - LAYOUT



- CLBO
  - 15-mm long
  - unmounted
  - 160 C
  - 2.5 years old
- Focusing:
  - Collimated beam - 18 MW/cm^2 max
  - Focused beam - 100 MW/cm^2 max

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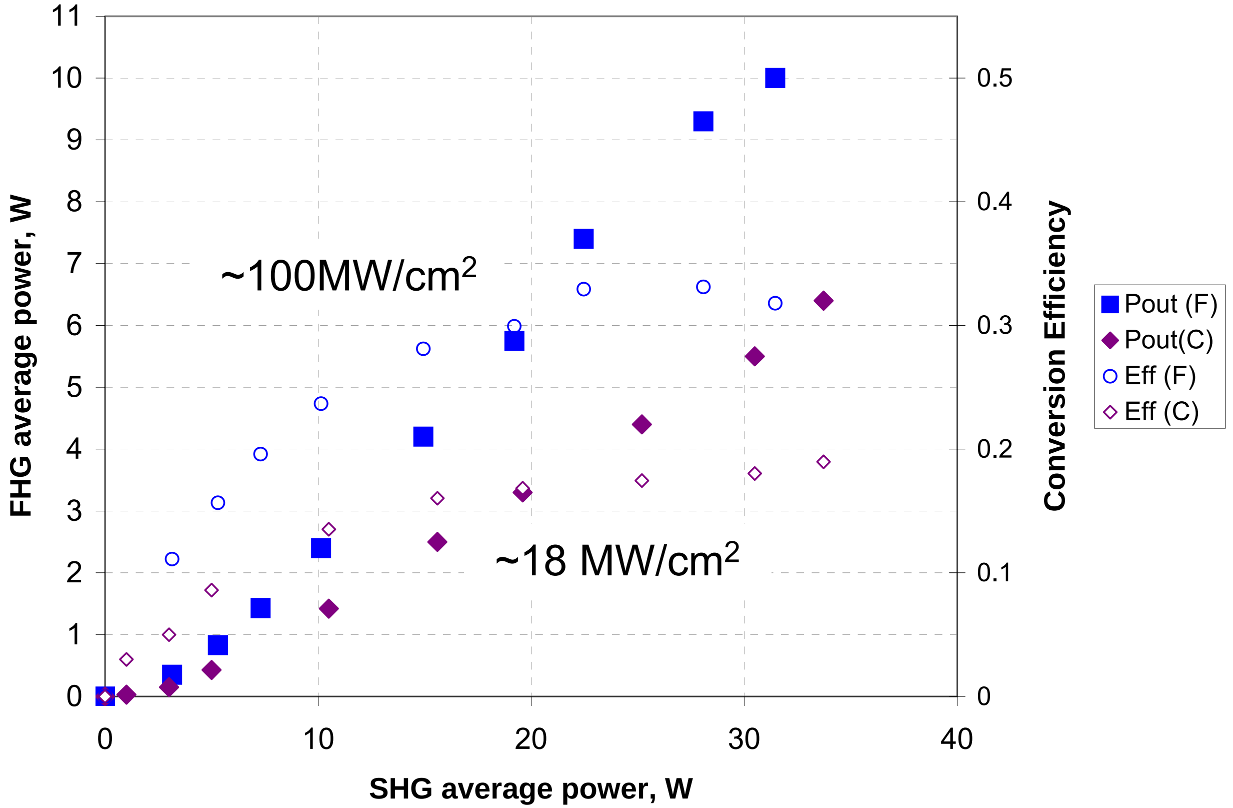
FHG in CLBO

- ≤10 W at 262 nm
- ≤ 33% eff.
- 30 kHz
- TEM_{00}



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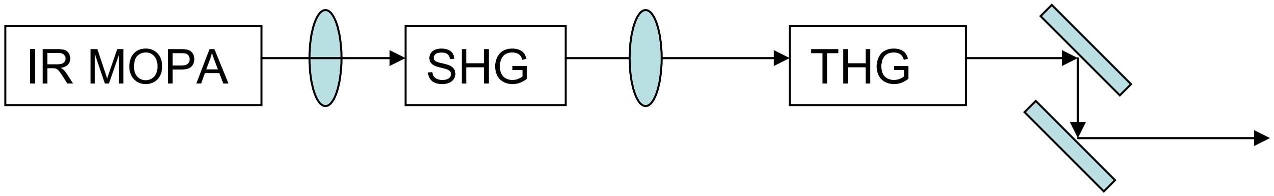
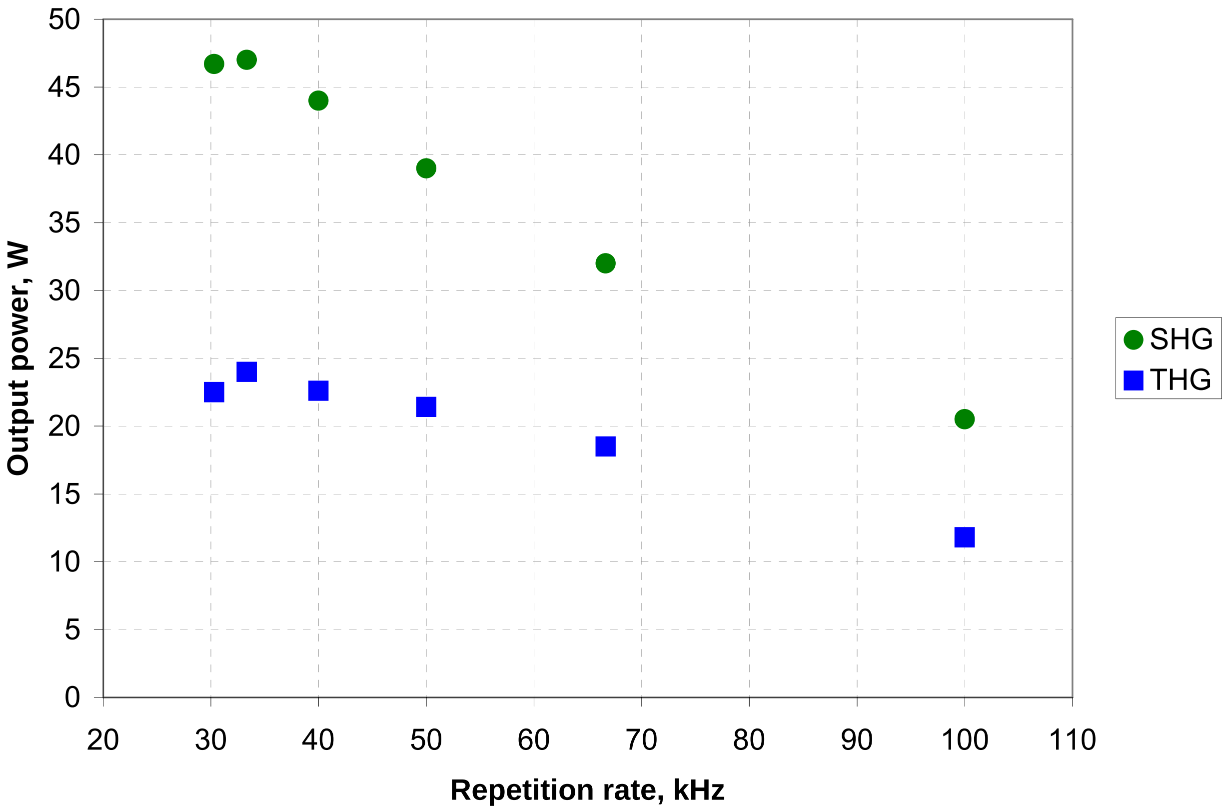
THG IN LBO



- LBO
  - 20-mm long
  - Type II (θ=46^o, φ=90^o)
  - RT

Second and Third Harmonics Generation

Focusing in SHG and THG crystals optimized at 33 kHz



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TEM$_{00}$ UV systems

3ω

355 nm

	Max. Power	Pulsewidth	Rep.rate, kHz
Coherent Avia-X	> 10 W (50 kHz)	< 30 ns (60 kHz)	0-100
Coherent Avia Ultra 355-500	> 0.5 W at 30 kHz	< 10 ns (40 kHz)	0-100
Lightwave Electronics Q30_-SM Series	>10 at 10 kHz >8 at 30 kHz >6.5 at 70 kHz	34 at 10 kHz 80 at 30 kHz 135 at 70 kHz	10-30 30-70 70-130
SpectraPhysics HIPPO Series	6 W	< 13 ns at 50 kHz	15-100 kHz

4ω

266 nm

Coherent Avia 266-3000	> 3 W (30 kHz)	< 25 ns (30 kHz)	0-100
SpectraPhysics HIPPO Series	2.5 W	< 13 ns at 50 kHz	15-100 kHz

MOPA Parameters

	IR (1047 nm)	SHG (523 nm)	THG (355 nm)	FHG (262 nm)
Max average power, W	80	50	25	10
Rep.rate, kHz	30-100	30-100	30-100	30-100
Pulsewidth, ns	8-20	< 8-20	< 8-20	<8-20

Conclusions

High power short-pulse Nd:YLF MOPA system:

- Diffraction limited beam
- Pulsewidth:
  - < 10 ns below 50 kHz
  - 10-20 ns at 50-100 kHz
- Up to 50 W of green power
- Up to 25 W of UV power at 349 nm
- Up to 10 W of UV power at 262 nm

Possible applications:

- High average/peak power green driver for nonlinear frequency conversion:
  - Harmonics, OPOs, Raman etc.
  - Pump for RGB systems
- High gain, modular, scalable 1047-nm (1053-nm) amplifier system:
  - CW or Q-switched
  - Single frequency

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