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Pump laser requirements for next generation lasers.

Outline

- Company introduction
- Product portfolio
- Pump lasers field of use
- Pump lasers for high power cw systems
- Pump lasers for ultrafast lasers
- Pump lasers in niche applications
- Pump lasers as ultrafast seed lasers
- Conclusions

Management & Company

Founders & owners

Gabriel Spühler, CTO (37)
- PhD at ETH Zürich in high-power ultrafast lasers, Prof. U. Keller
- GigaTera Inc.
- Posdoc at ETH

Lukas Krainer, CEO (35)
- PhD at ETH Zürich in high repetition rate ultrafast lasers, Prof. U. Keller
- GigaTera Inc.
- Postdoc at ETH
- European Commission Service since 2005 in Photonics

Company

- Registered: October 2005 in Zurich, Switzerland
- no VC, no business angels, profitable
- Operating class 10‘000 cleanroom with separated class 1‘000 areas
- Fully functional R&D and manufacturing facility
- Acquisition of Advanced Laser Diode Systems A.L.S. GmbH, Germany, Dec. 2008

Product Portfolio

Femtosecond platform ORIGAMI

780 nm, 1 μm, 1.5 μm
Pulse durations: 100 – 500 fs
Power levels up to 5 W, 5 μJ pulse energy
Pulse repetition rates: 100 kHz – 1300 MHz

Picosecond platform GENKI

1 μm, 1.5 μm
Pulse durations: 1 ps – 1 ns
Power levels: 5 W, 5 μJ pulse energy
Pulse repetition rates: 100 kHz – 1300 MHz

Picosecond laser diode platform PILAS

360 nm – 1800 nm
Pulse durations: < 30 ps – 1 ns
Power levels: 1 W peak power
Pulse repetition rates: Pulse on demand – 120 MHz

Tunable narrow linewidth cw laser SUMO

1 μm, 1.5 μm
Tuning range: 10 nm
Linewidth < 10 kHz
Power levels: 5 – 100 mW

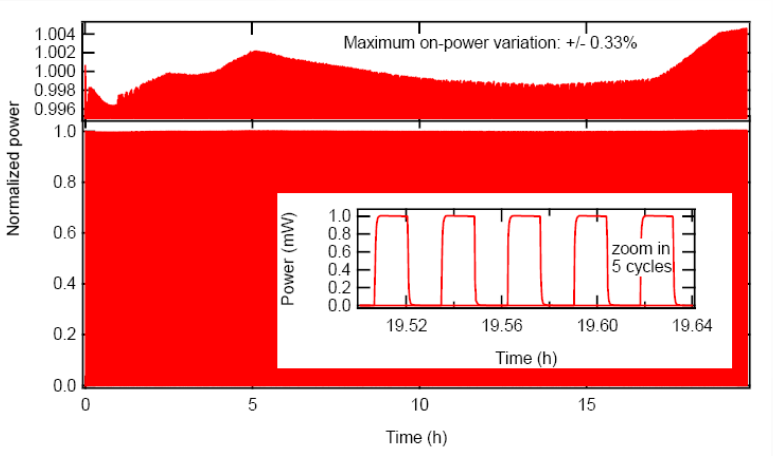
Performance

Sustained performance crucial for high-volume commercial applications.

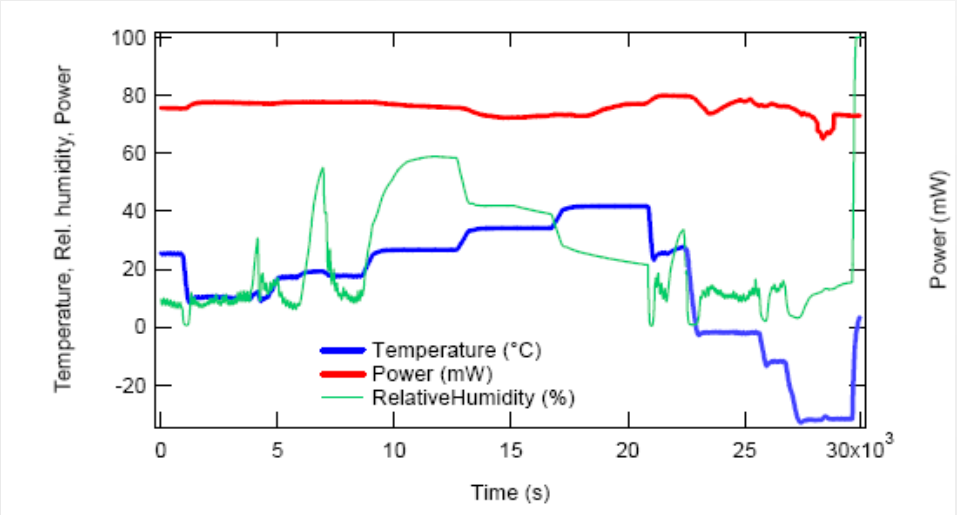
Required

- Operation temperature 10°C – 40°C
- Storage temperature - 20°C – 70°C
- On-off cycles > 10´000
- Lifetime > 100´000 h
- Shock & vibration proof (up to 40g)
- Maintenance free

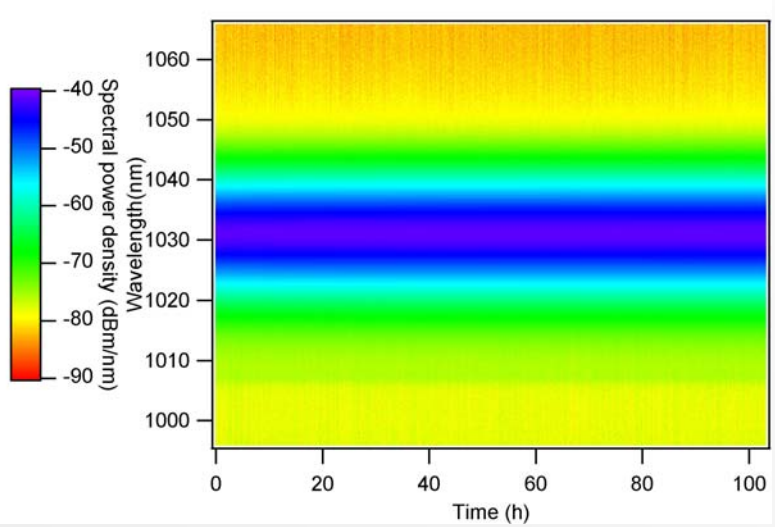
On/Off



Temperature & Humidity



Low-noise



Onefive Lasers

- as easy to use as a laser pointer
- compact, air cooled, light weight
- low power consumption < 10 W
- full remote control
- plug & play – life long
- shock & vibration tests up to 40 g
- Telcordia qualified pumps and components
- coatings in line with MIL-O-13830A spec

Pump lasers field of use

Direct diode systems

- Replacement for flash lamp pumped Nd:YAG (600M$)
- Computer-to-plate, Medical, ...

Diode pumped lasers and amplifiers

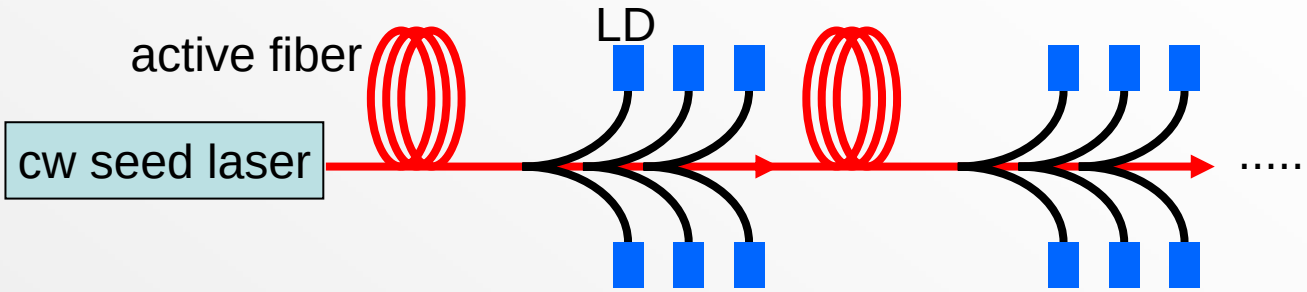
- High power cw DPSSL / fiber lasers (500M$)
- Telecom EDFAs (100M$)
- Ultrafast lasers (250M$)
- Low-noise fs laser, single frequency lasers, exotic wavelengths

Seed lasers

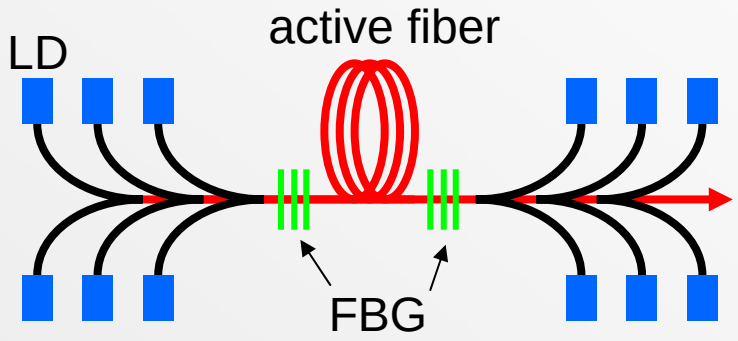
- CW
- Pulsed (ps, ns)

Pump lasers for cw DPSSL / fiber lasers

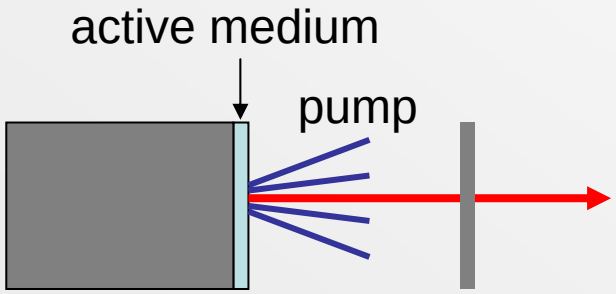
Master oscillator – power amplifier (MOPA)



Fiber laser



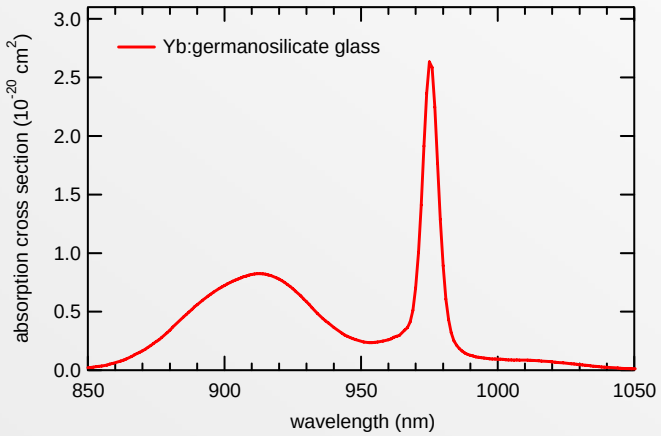
Thin disk laser

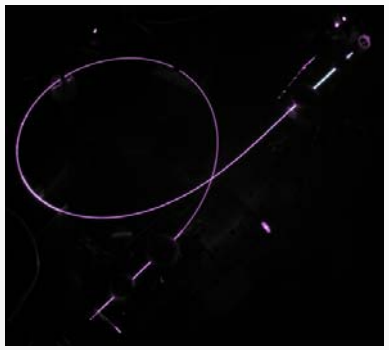


Pump lasers for cw DPSSL / fiber lasers

Fiber-based systems

- Active fiber length is not especially critical
- Tolerate longer pump absorption in the active fiber
- Pump must be fiber coupled





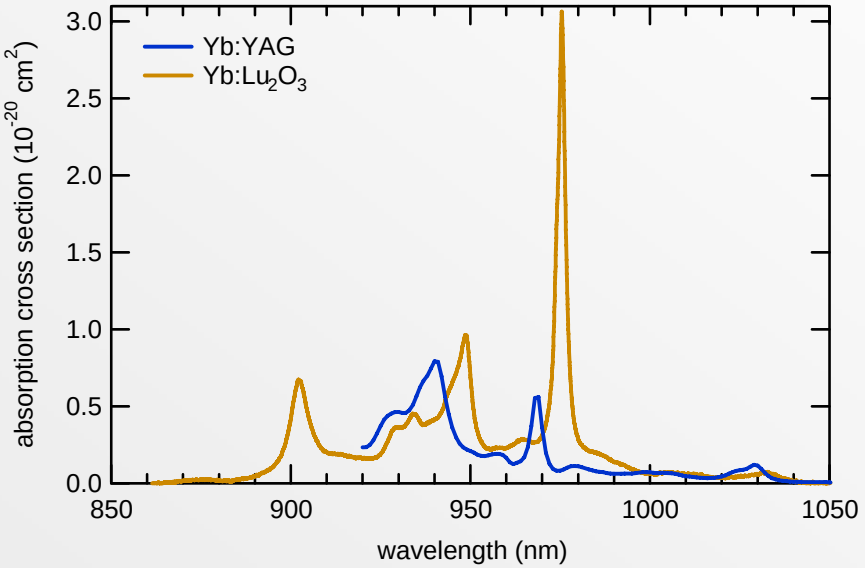
Pump into broad absorption band to be less sensitive on pump wavelength fluctuations, i.e. 915 nm instead of 976 nm.

Cost reduction: No active temperature stabilization needed for pump diode !

Pump lasers for cw DPSSL / fiber lasers

Thin disk laser

- Very thin gain medium requires multiple passes
- Pump wavelength bandwidth should match gain medium



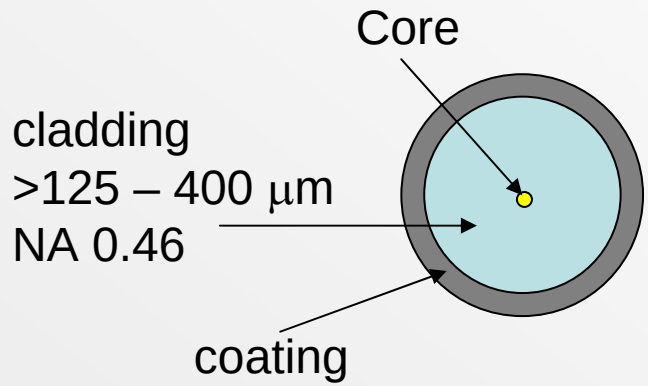
Pump into peak absorption band to reduce passes, 940 nm for Yb:YAG

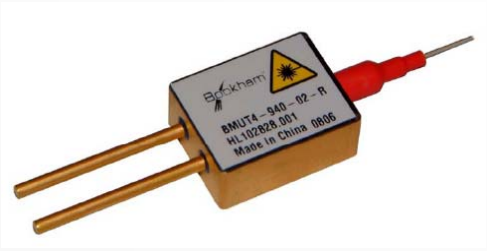
Cost reduction: Free space pump diode, low beam quality !

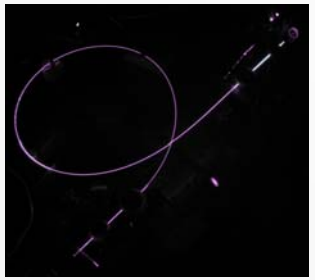
Pump lasers for cw DPSSL / fiber lasers

Fiber-based systems

- Active fibers: double clad designs





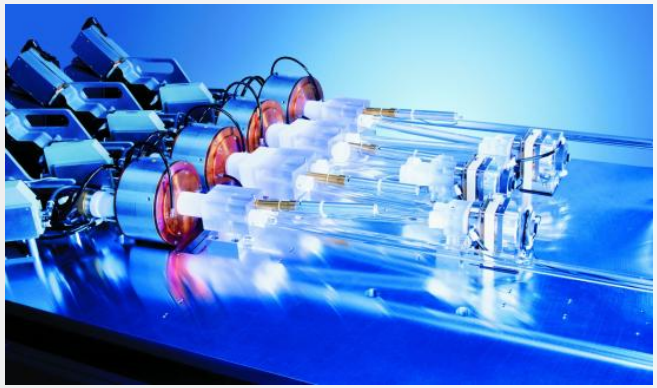


Pump fibers need to match size of cladding region of active fiber, i.e. 105 μm/125 μm

Pump lasers for cw DPSSL / fiber lasers

Thin disk laser

- Active gain medium: crystall (Yb:YAG)
- Pump laser can be free space, laser bar



Trump Thin disk 4kW

Oclaro 40 W high power bar

→ Free space pumps of „low“ beam quality acceptable, need homogizer optics for beam shaping

Pump lasers field of use

Direct diode systems

- Replacement for flash lamp pumped Nd:YAG (600M$)
- Computer-to-plate, Medical, ...

Diode pumped lasers and amplifiers

- High power cw DPSSL / fiber lasers (500M$)
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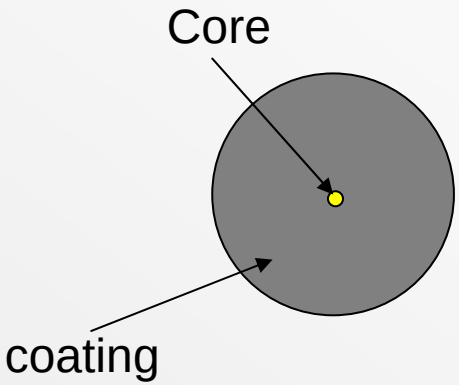
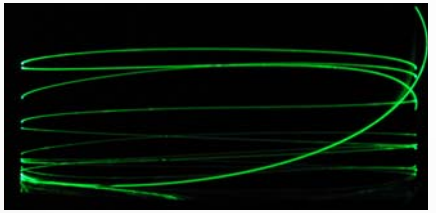
Seed lasers

- CW
- Pulsed (ps, ns)

Telecom EDFAs

- Core pumped ErYb-doped fiber amplifiers, W-level





- Compact, efficient, very reliable

  Reliability: In under sea transmission systems, pump cannot be replaced!

⇨ Very good qualification, lifetime > 250‘000 hours (30 years)
Single mode, 1 W pump @ 976 nm (Er-Yb)

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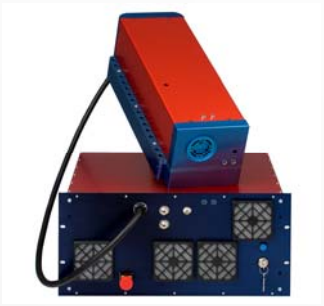
Ultrafast high energy lasers

Various types of laser designs

Ti:saphire

Spectra-Physics fs amplifier system

Picosecond 24 W, µJ fiber laser



Corelase X-Lase

Femtosecond 10 W, µJ fiber laser

IMRA FCAP

Femto / Picosecond µJ SSL laser

Time Bandwidth DUETTO

Ultrafast high energy lasers

Various types of laser designs

Ti:saphire

- Green pump 532 nm
  Frequency doubled 1064 nm

→ 808 nm pumps ($Nd:YVO_4$)

Picosecond 24 W, µJ fiber laser

- Yb-doped fiber MOPA systems

→ 915 / 935 / 976 nm pumps
Fiber out, var. power levels

Femtosecond 10 W, µJ fiber laser

- Yb-doped fiber MOPA systems
  Dispersion management important

→ ~~915 / 935 /~~ 976 nm pumps
Fiber out, var. power levels

Femto / Picosecond µJ SSL laser

- Nd/Yb Oscillator/MOPA/Regen

→ 795 / 808 / 9xx nm pumps
Fiber/free space, var. power levels

Ultrafast high energy laser

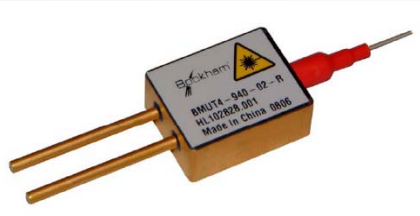
Femtosecond Master Oscillator – Power Amplifier (MOPA)

Seed Laser
fs, 40 MHz

Pulse Picker
&/or Stretcher
100 kHz

Bulk/ Fiber
Pre/Booster
Amplifiers

Compressor



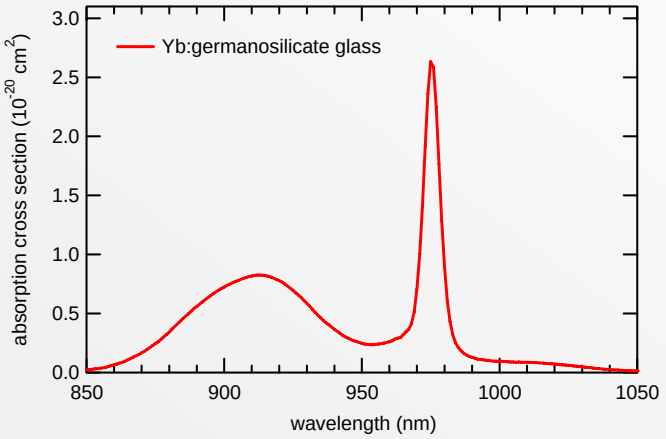
Ultrafast high energy laser

Dispersion Management

- Nonlinear effects & dispersion in fiber degrade pulse and optical quality
- Reduce pulse peak power in fiber
- Reduce interaction length in fiber

- Fiber MOPA systems
  Dispersion management important

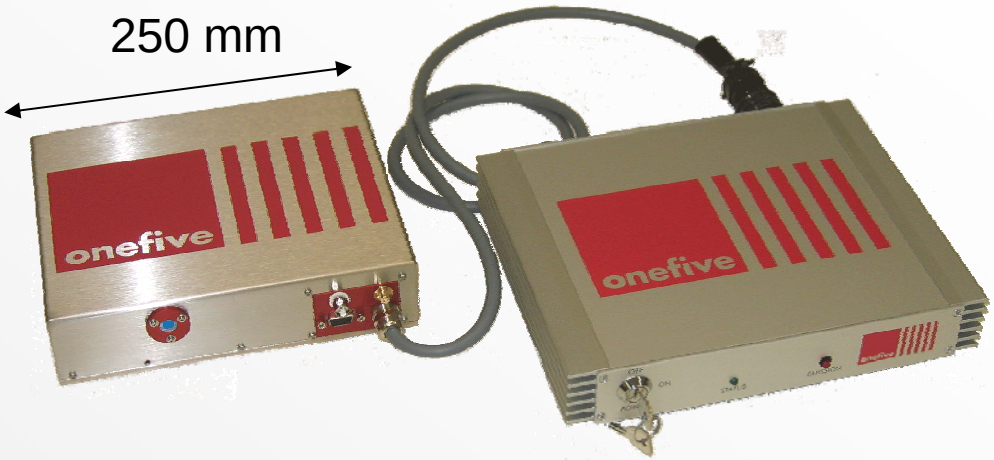
→ ~~915 / 935 /~~ 976 nm pumps
Fiber output, var. power levels



Remark on pump laser efficiency

Requirements

- Air cooled
- Low power consumption
- Compact
- Light weight



Issues in Powerscaling

- Driver electronics
- Efficiency

2 W, 1060 nm, 10 ps
40 MHz, 50 nJ
250 x 250 x 54 mm^3
4 kg
50 W electrical power consumption

Remark on pump laser efficiency

Pump laser efficiency increase

Multimode Pump
10 W output power (1.7 V, 12 A)
50 % e-o efficiency
10 W heat power
20 W electrical power consumption

TEC controller
10 W heat „cold side“
50 % efficiency
30 W heat „hot side“
20 W electrical power consumption

40 W electrical power consumption
30 W heat

+ 16.6 %

Multimode Pump
10 W output power
66.6% e-o efficiency
5 W heat
15 W electrical power consumption

TEC controller
5 W heat „cold side“
50 % efficiency
15 W heat „hot side“
10 W electrical power consumption

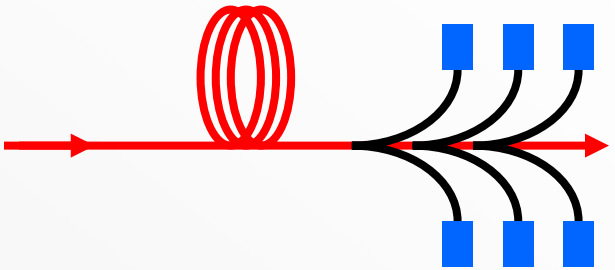
25 W electrical power consumption
15 W heat

- 37 % less electrical power
- 50 % reduction in generated heat

Remarks on lifetime & quality

Fiber amplifiers require multiple pumps

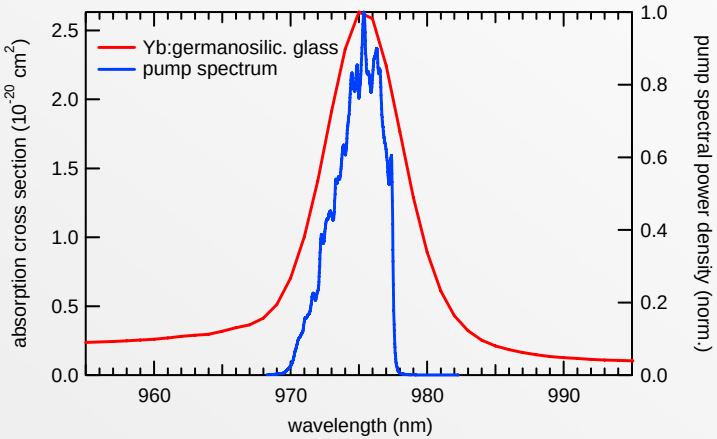
- Overall MTTF needs to be re-evaluated
- Backreflections



⇒
- Protective coating on pump facet
- Redundancy important for industrial applications

Pump emission & fiber absorption

⇒
- Narrow pump bandwidth
- Good wavelength stability



Pump lasers field of use

Direct diode systems

- Replacement for flash lamp pumped Nd:YAG (600M$)
- Computer-to-plate, Medical, ...

Diode pumped lasers and amplifiers

- High power cw DPSSL / fiber lasers (500M$)
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Seed lasers

- CW
- Pulsed (ps, ns)

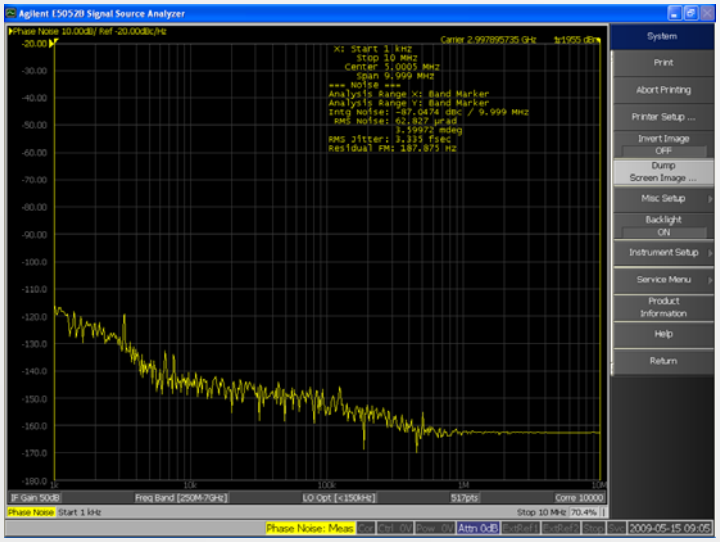
Pump lasers for niche applications

Myriads of different gain crystals, fibers, applications.

- Handpick individual pump lasers
- Non standard, „out of spec“ lasers

Example: Ultra low timing jitter fs laser

- Pump noise very important
- Low RIN, narrow linewidth pump



In collaboration with PSI

- Timing jitter 3.3 fs

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- Computer-to-plate, Medical, ...

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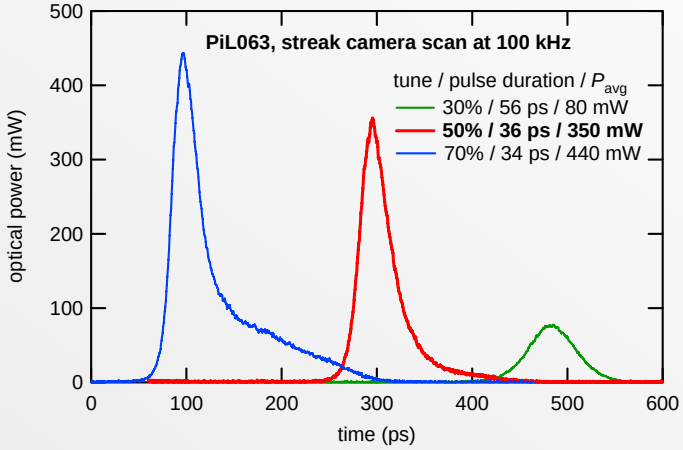
Seed lasers

- CW
- Pulsed (ps, ns)

Pump lasers as ultrafast seed lasers

Short (ns,ps) pulses directly from the diode

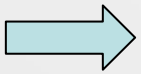
- ✓ Ultimate low cost ultrafast solution
- ✓ Robust, compact
- ✓ Long lifetime
- ✓ Pulse on demand (electrically triggered)
- ✓ „Any“ wavelength



Pump lasers as ultrafast seed lasers

Drawbacks

- Low pulse energy (few pJ)
- Long pulses (few tens of ps to ns)
- Pulse shape
- RIN (a few %)
- Timing jitter



- Higher power chips
- Low threshold current, efficient (low nominal current)
- Shorter gain sections
- Different structures (including saturable absorber sections)
- DFB/DBR type chips at 1030 / 1064 nm

Conclusions

- Pump lasers are the key element in the laser industry
- More power, pay less
- Higher electric to optical efficiency
- MTTF important
- Wavelength stability
- ✓ Beam quality is ok for high power pumps
- ✓ Size is ok

Conclusion

Exact specifications very fragmented

CW fiber lasers	▪ 915 nm, multi mode, maximum power ▪ Fiber output
Thin disk laser	▪ 940nm, laser bar, maximum power ▪ Free space
Telecom EDFA	▪ 976 nm, single mode, 1 W ▪ Fiber output ▪ Telcordia specifications
Ultrafast lasers	▪ 808 - 976 nm, single & multi mode 1 W – maximum power ▪ Fiber output, free space ▪ Narrow pump spectrum
Niche applications	▪ 981 nm, single mode, maximum power ▪ Low RIN, narrow pump spectrum
Ultrafast seeders	▪ 1030 / 1064 nm, single mode, DFB / DBR ▪ Low threshold current, different chip design, ...