

Mode-locked lasers. Towards to technology

Dr. A.Michailovas

Special thanks for colleagues

Stasys Balickas

Mikhail Grishin

Saulius Jacinavičius

Jonas Kolenda

Overview



- Introduction
- Flash lamp pump systems (10-50Hz)
- Hybrid laser diode and flash lamp pumped systems (50-250Hz)
- LD pumped MO- Regenerative amplifier systems (pulsed RA pumping), (500-5000Hz)
- CW LD pumped MO- Regenerative amplifier systems (10-200kHz)
- Picosecond oscillator with cavity dumping (~1MHz)
- Conclusion

Typical features



Nanosecond lasers

- Simple design
- Narrow spectrum
- Medium peak power
- Very high pulse energy

Picosecond lasers

- Simple design
- Narrow spectrum
- High peak power
- Medium pulse energy

Femtosecond lasers

- Complex design
- Wide spectrum
- Very high peak power
- Weak pulses

Flash lamp pump systems (10-50Hz)



Conventional MO scheme:

Features

Pulsed operation

Passive mode-locking

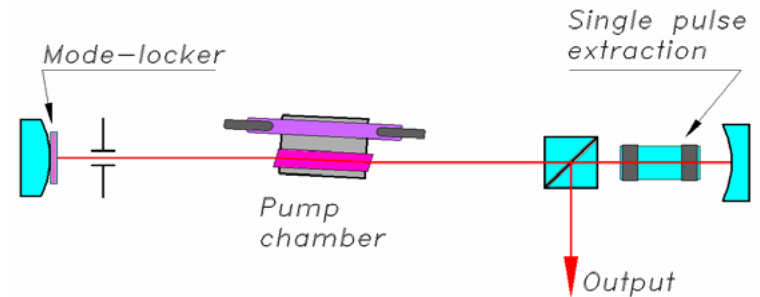
Saturable absorber is dye solution

Drawbacks

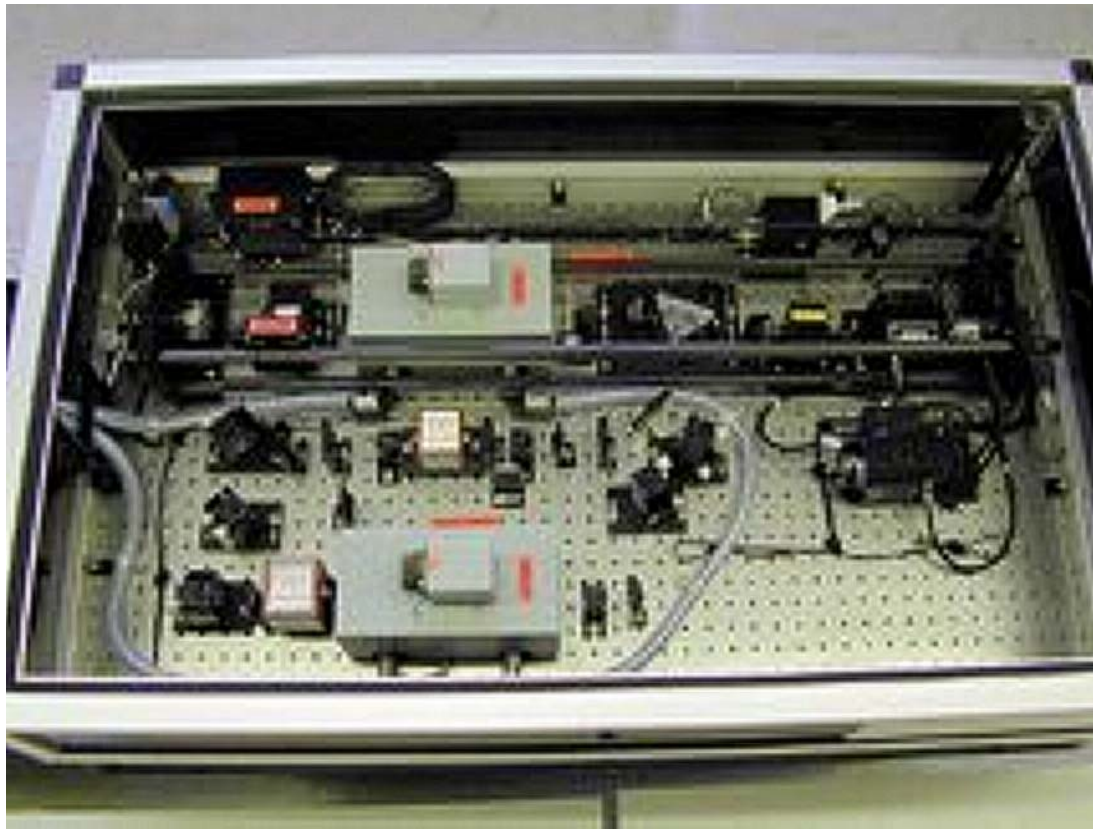
Poor energy and pulse duration stability

Probabilistic way of building-up of the picosecond pulse

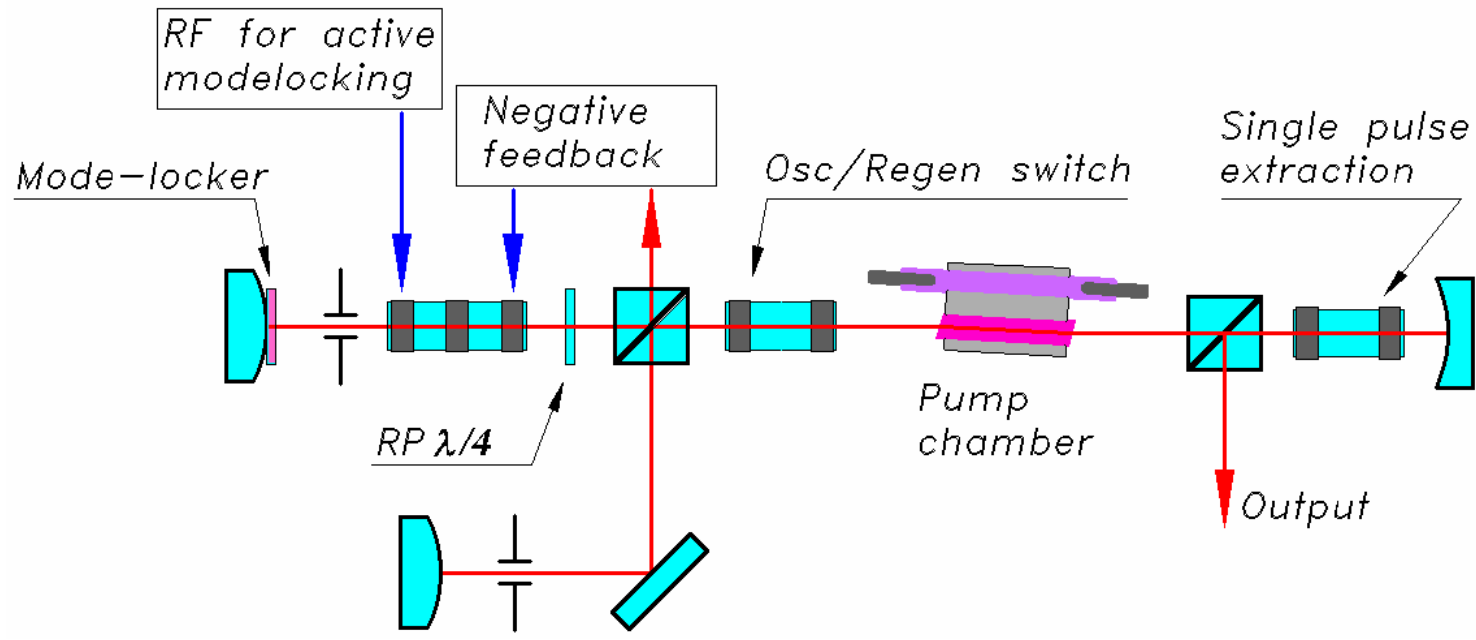
Dye solution degradation



Typical lay-out



Flash lamp pump systems enhanced (10-50Hz)



Negative feedback
Solid-state absorber

Active mode-locking

Two in one system: MO-RA



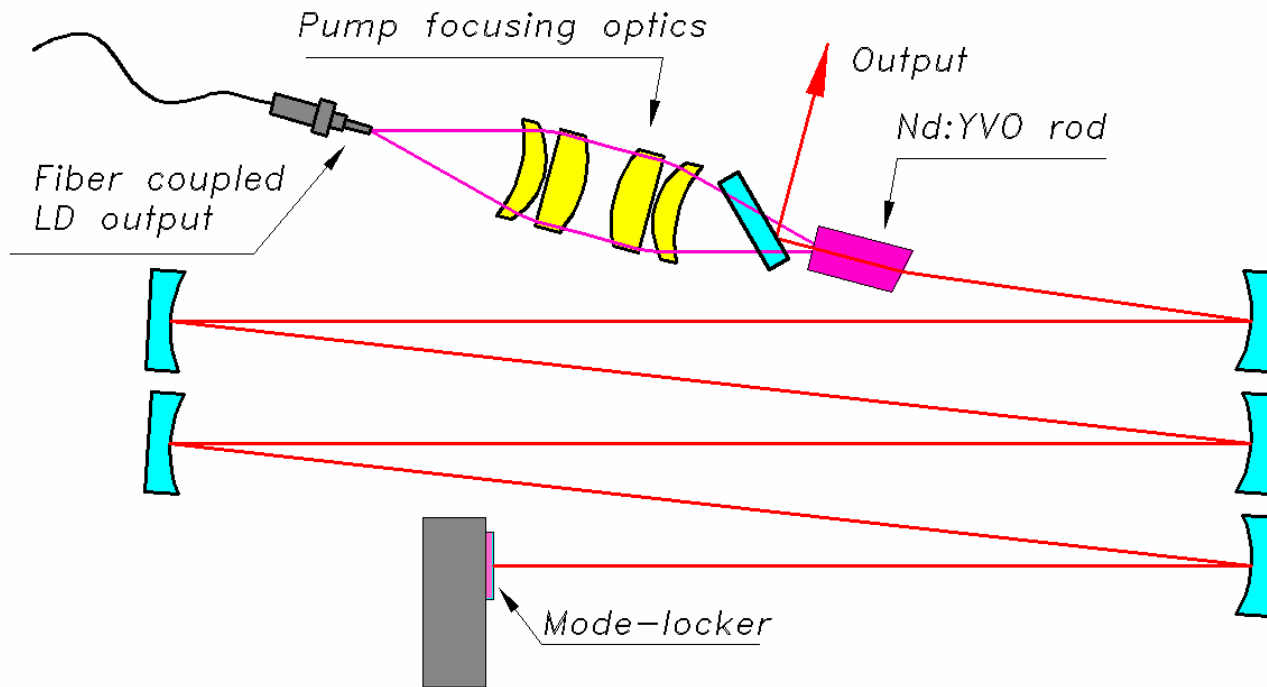
Typical parameters:

Laser crystal	Nd:YAG
Wavelength	1064nm
Repetition rate	10-50Hz
Pulse-width	20ps
MO output	3-4uJ
Regen output	0.5mJ
Energy stability	1%

Drawback – short flash-lamp lifetime.
 What to do? Use LD pump.

Output after one double pass and one single pass power amplifier is 110mJ

CW LD pumped ML master oscillator

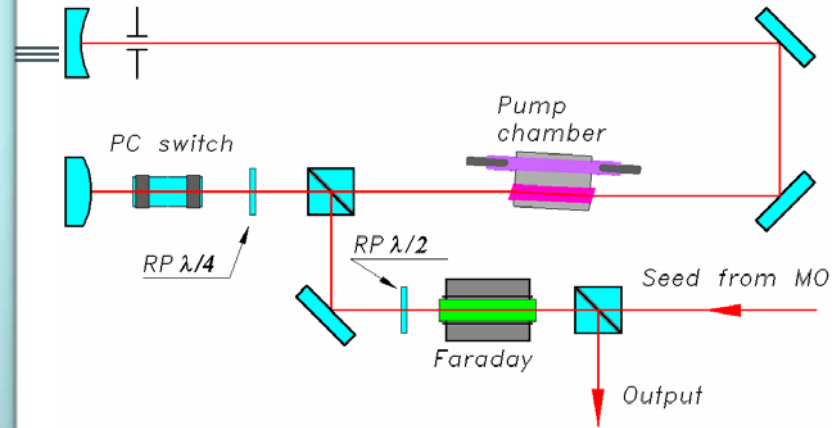


Hybrid pump systems (50-250Hz)

Typical parameters:

MO Laser crystal	Nd:YVO
RA Laser crystal	Nd:YAG
Wavelength	1064nm
Repetition rate typical	50Hz
Pulse-width	20ps
Seed energy	~1nJ
Regen output	0.5mJ
Energy stability	1%

Output after one double pass and one single pass power amplifier is 110mJ



Precision synchronization is possible

Special design systems produce

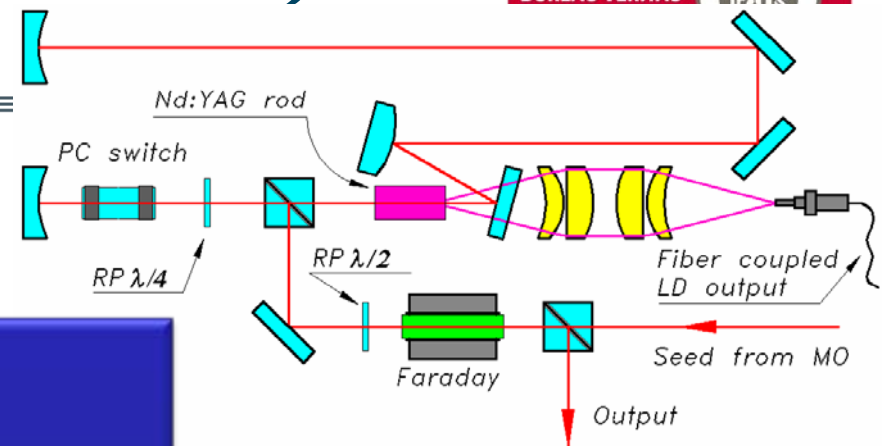
1,6J output

For OPCPA

Next step? LD pumping!!!



Regen pumped with QCW LD (500-5000Hz)

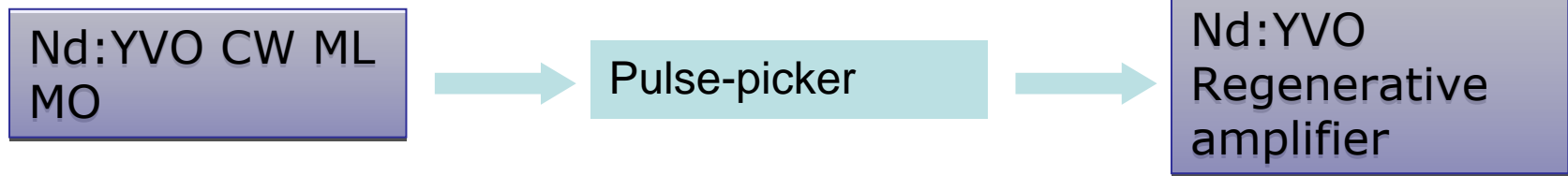


Typical parameters:

MO Laser crystal	Nd:YVO	
RA Laser crystal	Nd:YAG (Nd:YVO)	
Wavelength	1064nm	
Repetition rate	1kHz (1-5 kHz)	
Pulse-width	20ps	70ps
RA output	1mJ	3mJ
Energy stability	0.2%	

Industrial applications:
 Rep Rate > 1kHz → micromachining
 Is it enough ??? No!!!

CW LD pumped MO - Regenerative amplifier (10-200kHz)



CW pump

Both crystals are Nd:YVO

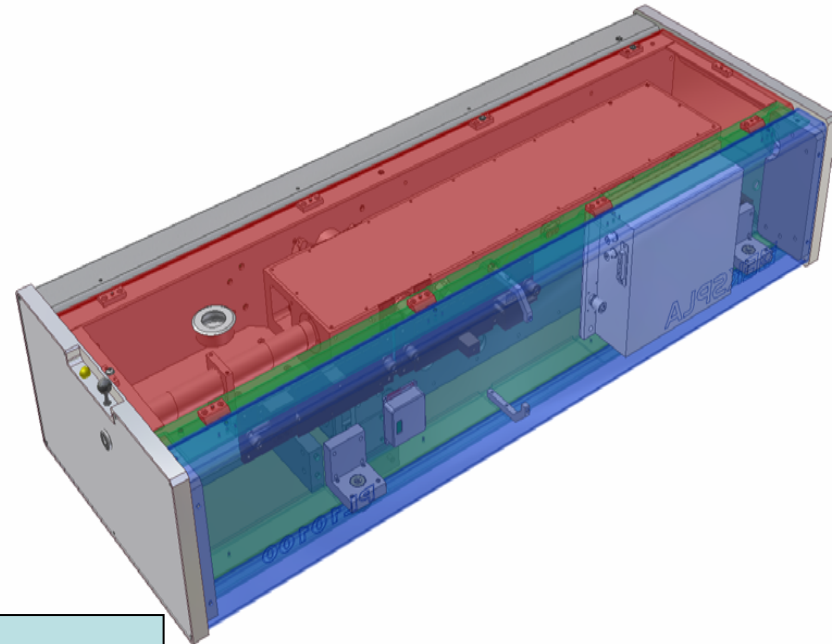
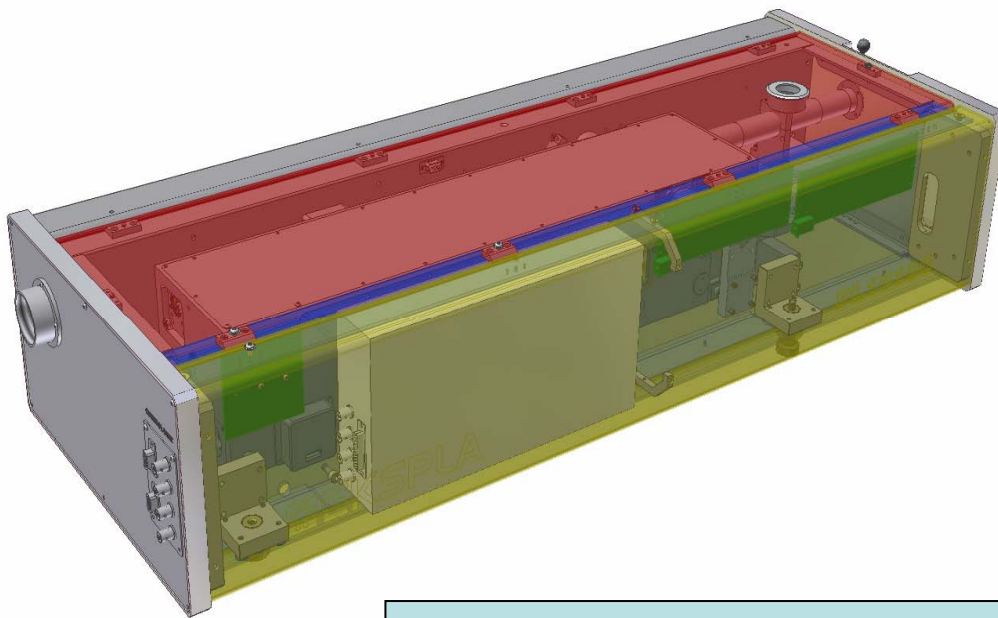
Pulse-picker improves contrast

PC drivers up to 1MHz are available

Typical parameters:

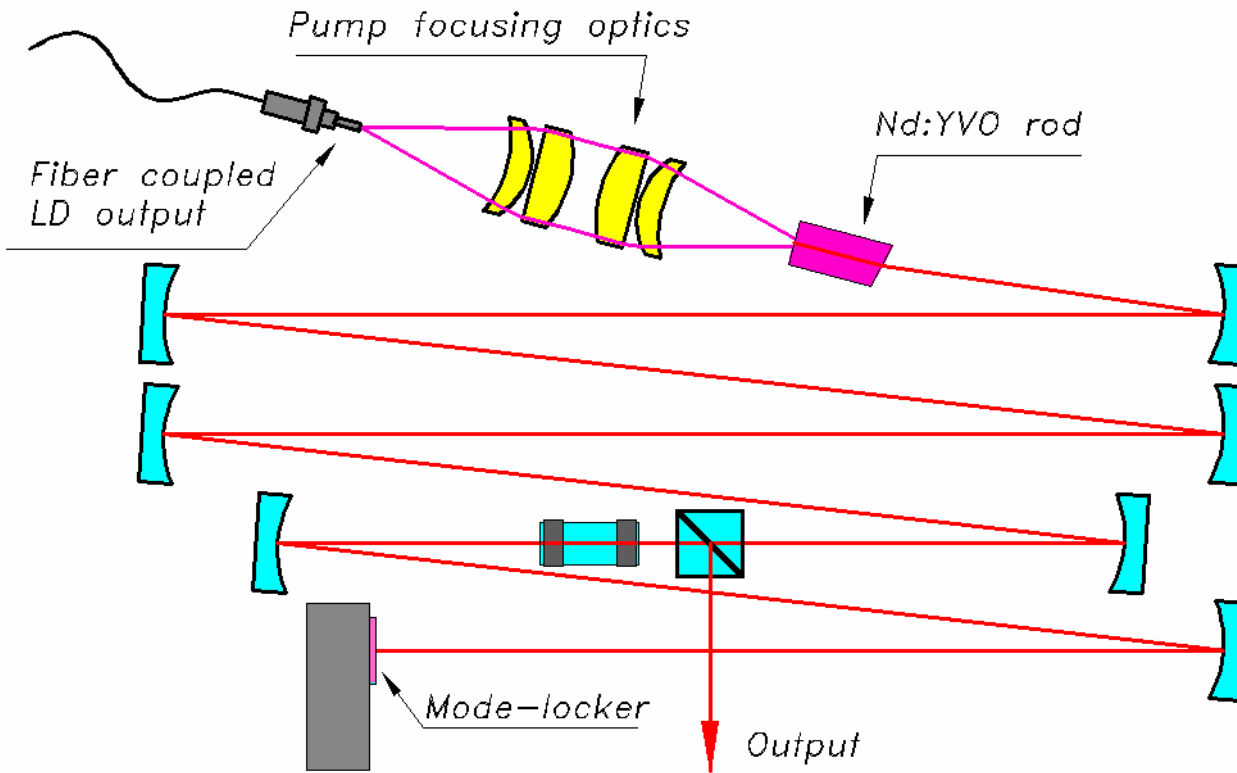
Repetition rate	50-100 kHz
Pulse-width	8.5 ps
Output power	10 W
Energy stability	0.7%
MO pumping	1.5 W
PA pumping	2.0 W
RA pump power	40 W

Mechanical Design



Industrial-grade design .
200kHz- limit? No !

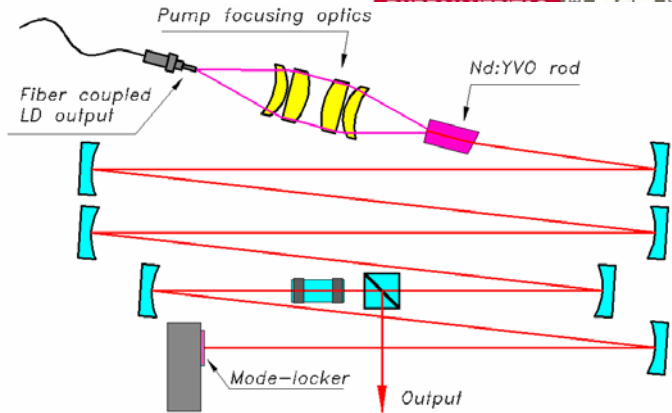
Picosecond oscillator with cavity dumping (~1MHz)



Picosecond oscillator with cavity dumping (~1MHz)

Typical parameters:

Laser crystal	Nd:YVO
Cavity length	~4 m
Repetition rate	1 MHz
Pulse-width	7 ps
Output power	1 W
Output energy	1 μ J
Pump power	~3.2 W



ISO 9001



Industrial applications:

Either Low power CDO + power amplifier

Or High power CDO

Conclusion



- Started from traditional flash-lamp pumped mode-locked lasers for scientific applications
- Introduced mixed FL & LD pumping technology for scientific applications
- LD pumping paved way to industry
- Application laboratory in FI