Injection seeded ns-pulsed Nd:YAG laser at 1116 nm for Fe-Lidar

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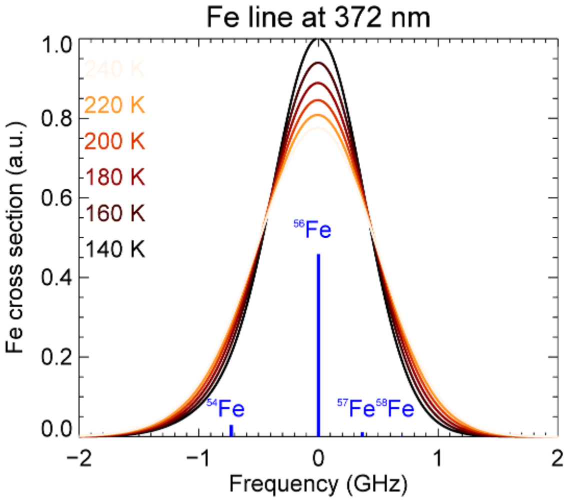
DLR

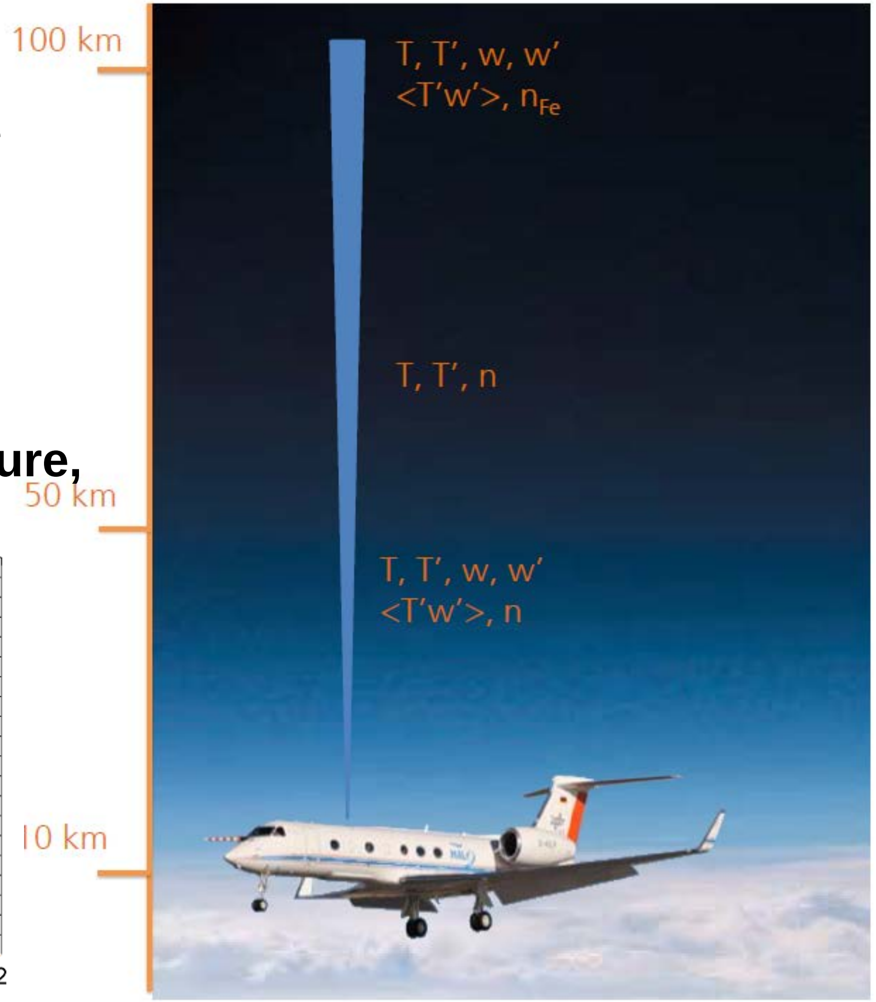
Motivation

- **Project Alima: Airborne Lidar for studying the middle atmosphere**
- **Cooperation with DLR Oberpfaffenhofen PA-LID**

- **Iron in the upper atmosphere (50-100 km)**
- **Fluorescence line of 372 nm suitable for resonance Lidar**
- **Analysis of the line gives information about air velocity, temperature, gravity waves**

- **Goal: compact, airborne system**

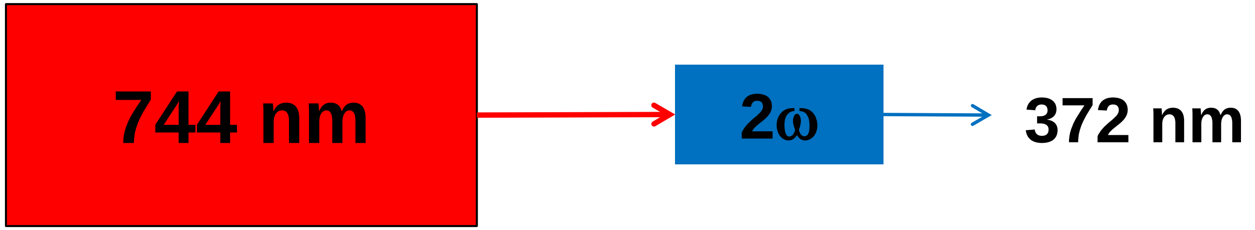




Gelbwachs J., Appl. Opt. 33, 7151 (1994)
Gardner et al, Geophys. Res. Lett. 27, 1199 (2001)
Chu et al, Appl. Opt. 41, 4400 (2002)

Kaifler et al. ;New Lidar Systems at the German Aerospace Center, LPMR 2015

Generation of 372 nm: existing systems



Alexandrite laser
single frequency

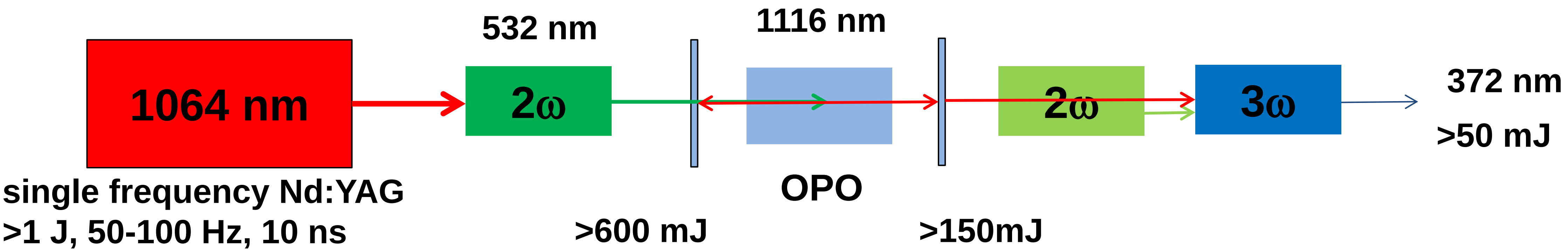
- 100 mJ
- ~60 ns
- 34 Hz
- 3 W

Chu et al., Appl. Opt. 21, 4400 (2002)
developed by the NCAR

cons:
- small emission cross section, heating required
- general challenges with Alexandrite lasers

pros:
- simple 2ω generation
- known and developed system

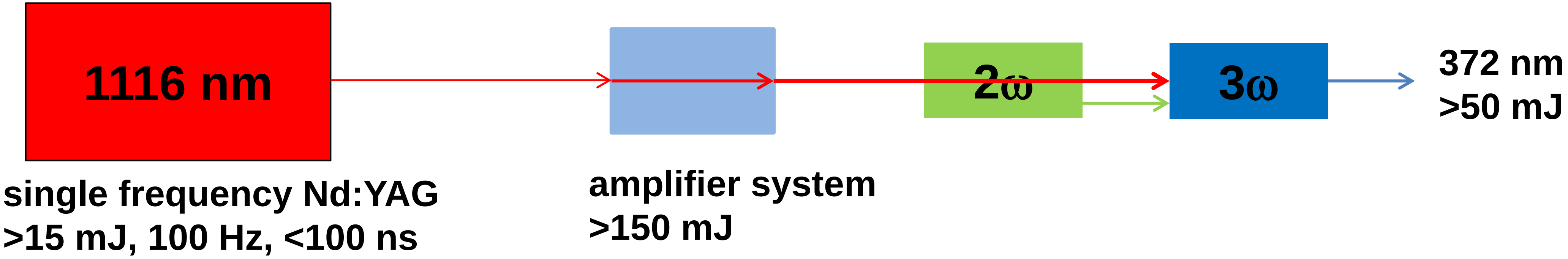
Generation of 372 nm: OPO



cons:
- 2 seed laser required (1064 and 1116 nm)
- (damage threshold)

pros:
- oscillator might be commercially available
- not dependent on specific transitions

Generation of 372 nm: oscillator at 1116 nm



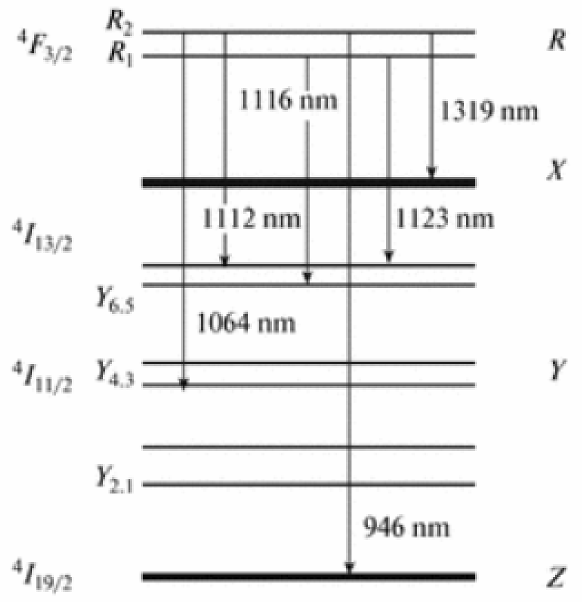
pros:
- can be realized very compact
- avoids very high pulse energies
- just a small cooling system required

cons:
- oscillator and amplifier has to be developed

Nd:YAG laser line at 1116 nm

Table 1. Spectral parameters of representative transitions in Nd:YAG

Emitting level	Terminating level	λ@20°C (nm)	$\nu_{if}(0)$ (cm^{-1})	$\Delta\nu_{if}(0)$ (cm^{-1})	a_i	b_{if}	c_{if} (cm^{-1})	d_{if} (cm^{-1})
R_1	Y_1	1061.46	9425.22	1.771	0.9199	0.2363	105.7	127.6
	Y_2	1064.44	9398.01	3.001		0.1472	86.29	113.3
	Y_3	1073.73	9318.31	2.124		0.1914	123.6	128.9
	Y_4	1077.89	9282.03	5.448		0.1551	117.3	208.5
	Y_5	1115.99	8960.44	11.49		0.1553	–5.212	162.3
	Y_6	1122.60	8908.01	9.334		0.1147	3.319	77.11
R_2	Y_1	1052.03	9509.67	2.383	1.119	0.1668	105.9	143.6
	Y_2	1054.94	9482.37	3.267		0.009102	78.02	92.72
	Y_3	1064.06	9403.15	2.387		0.4455	130.6	134.2
	Y_4	1068.11	9366.97	5.666		0.1335	119.0	186.8
	Y_5	1105.45	9046.02	12.93		0.09041	–3.508	232.4
	Y_6	1112.07	8992.69	9.236		0.154672	9.951	108.7



emission cross sections:

$$\sigma_{1064} = 2{,}80 \cdot 10^{-19}\ \text{cm}^2$$

$$\sigma_{1116} = 0{,}42 \cdot 10^{-19}\ \text{cm}^2$$

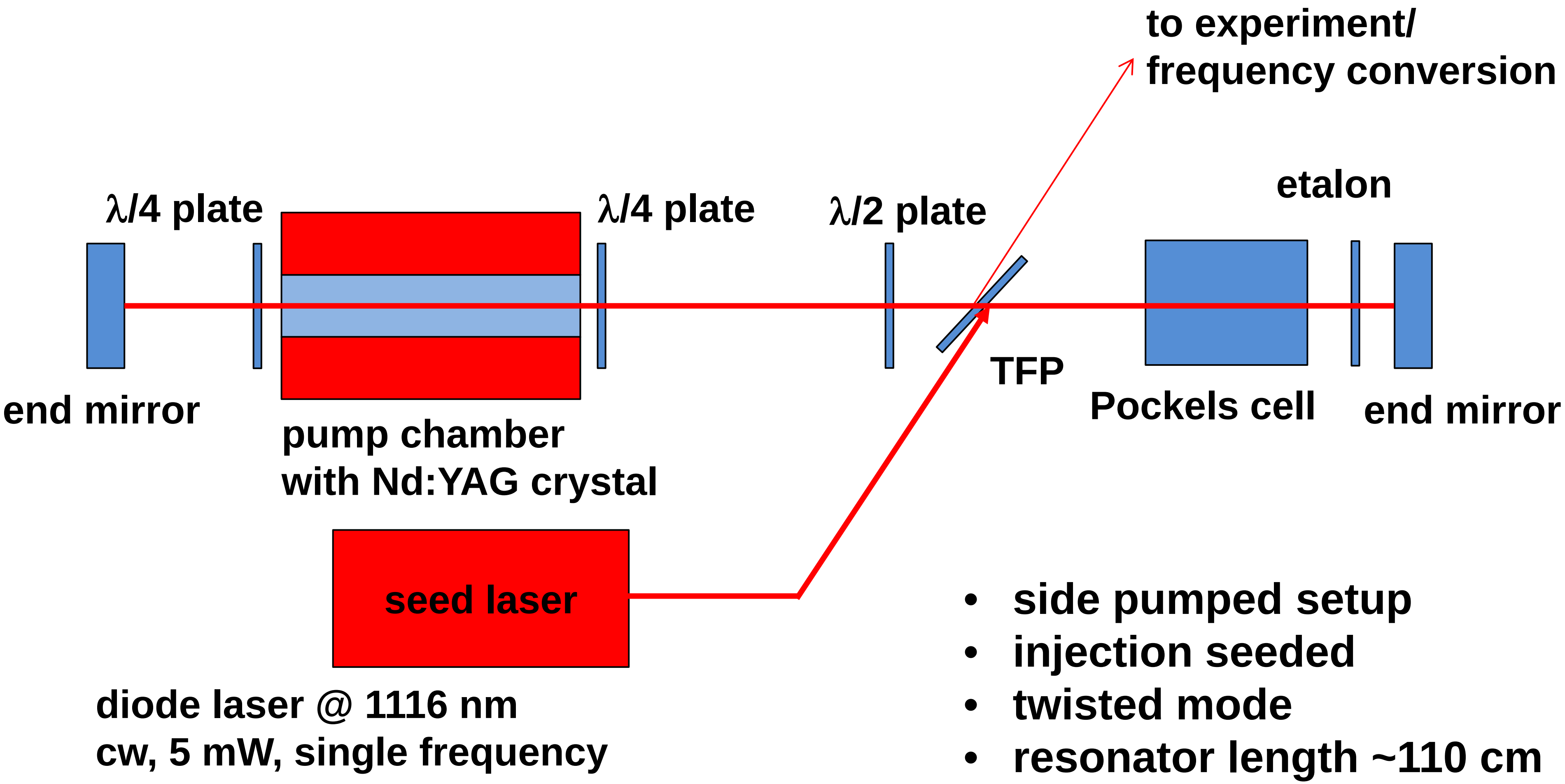
Alexandrite σ_{744} = 0,07*10^{-19} cm² (295 K)
and 0,30*10^{-19} cm² (463 K)

challenges with 1116 nm:

- **~7 times lower amplification than with 1064 nm**
- **supression of 1064 nm**

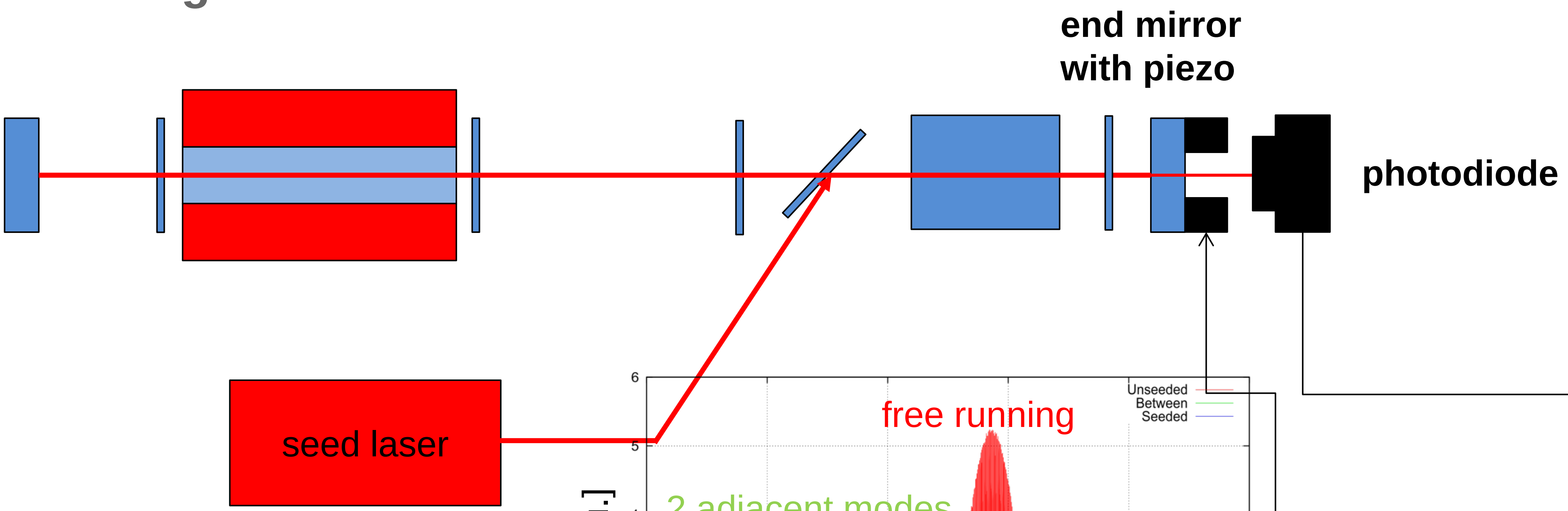
Marling, IEEE J. Quant. Electron, 14, 56 (1978)
Wang et al.; Appl. Phys B (2011) 104:45–52
Huan et al.; Chin. Phys. B Vol. 21, No. 10 (2012) 104208
Zhang et al.; CHIN. PHYS. LETT. Vol. 30, No. 10 (2013) 104202

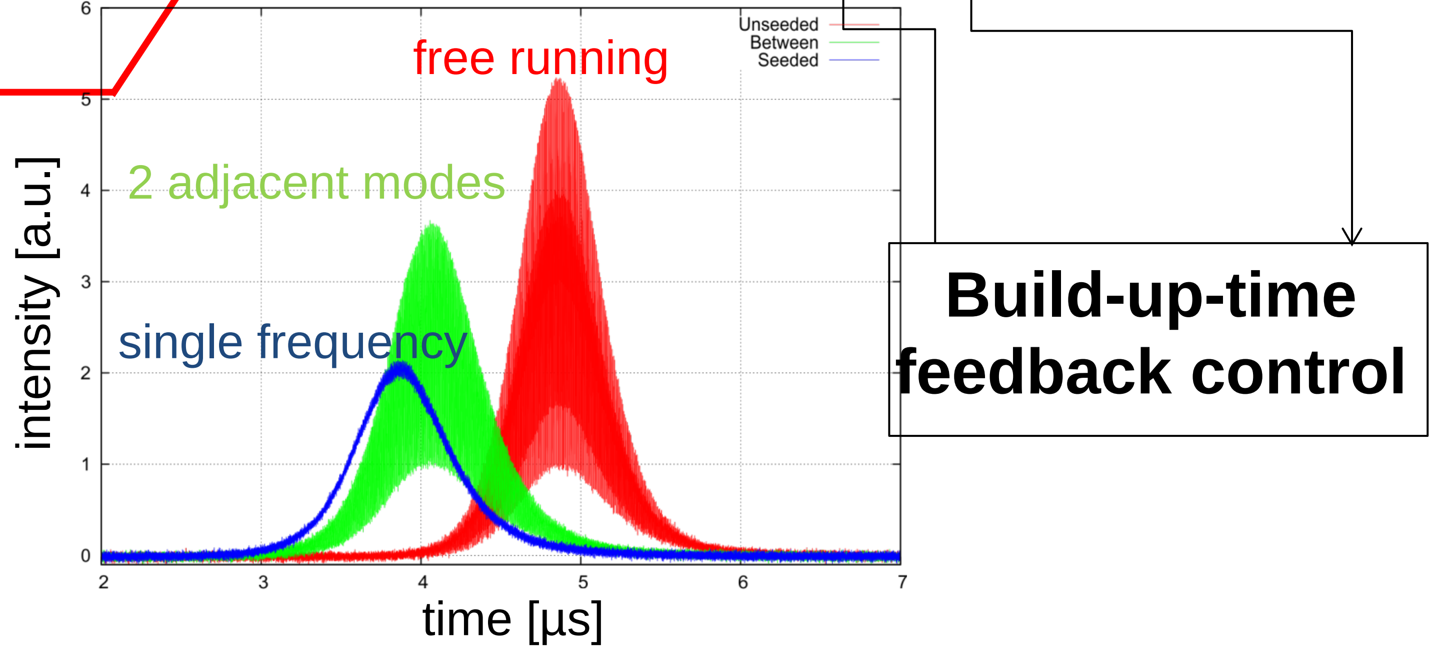
Realisation of the oscillator



- side pumped setup
- injection seeded
- twisted mode
- resonator length ~110 cm
- pump duration 300 µs @ 100 Hz
- output coupling ~10%

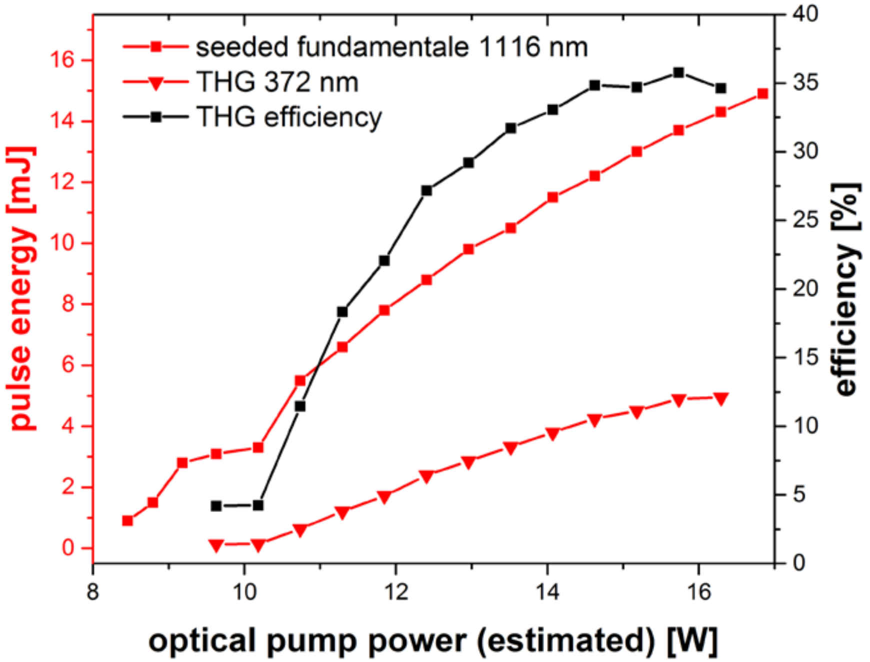
Injection Seeding

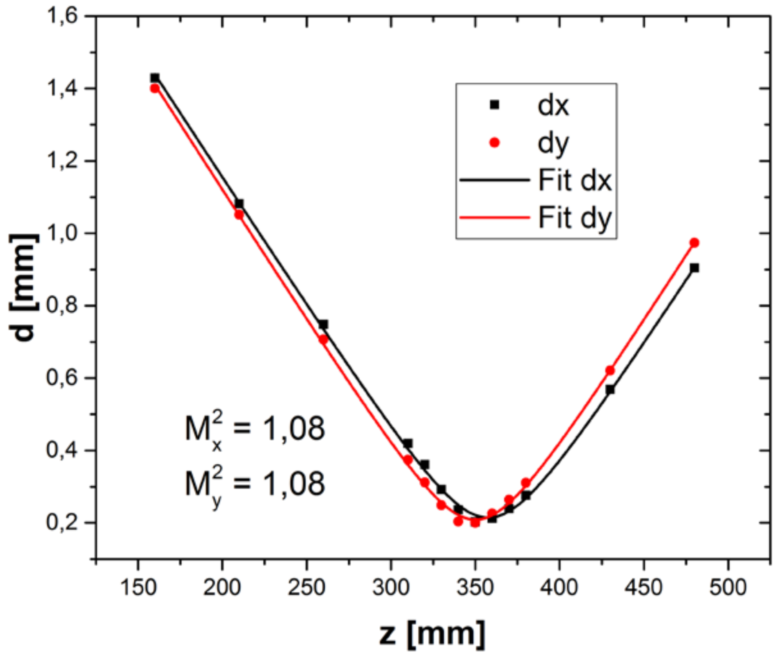




Need for stabilization of the resonator length to get proper seeding

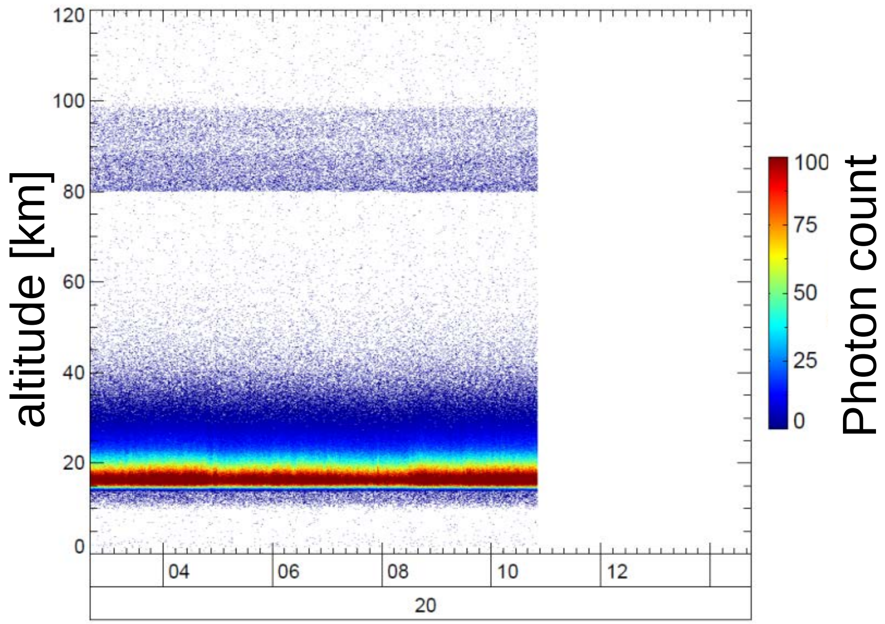
Output power and beam quality





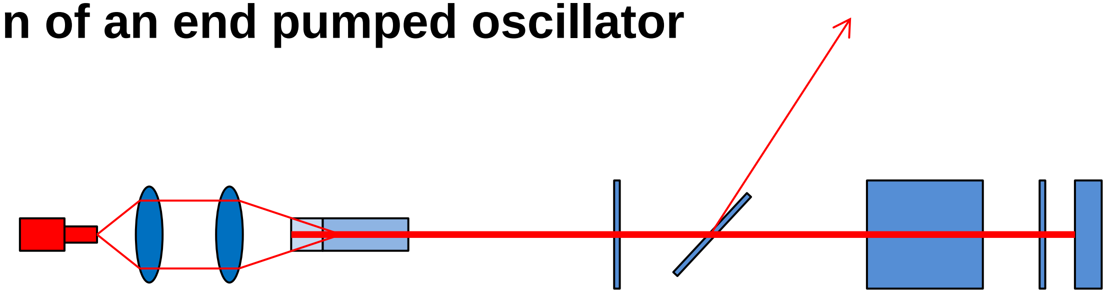
- M^2 ~ 1.1
- maximum pulse energy ~14.3 mJ @ 1116 nm
- 4.9 mJ @ 372 nm (max. efficiency 35%)
- pulse length 80 ns

Further Work



- **First Lidar test measurements in Oberpfaffenhofen successful**

- **implementation of an end pumped oscillator**



- **amplification tests of the laser output with newly developed amplifiers from Montfort GmbH**
- **max. amplification ~3.3 in a double pass setup**

Conclusion

- successful implementation of a q switched, injection seeded Nd:YAG laser at 1116 nm
- first Lidar measurements in Oberpfaffenhofen promising
- test of an end pumped laser system at 1116 nm, improvement in progress
- amplification of laser output possible
- amplifier system needs improvement