

PEOPLE MATTER

*research
development
consulting*



LZ LASER ZENTRUM HANNOVER e.V.

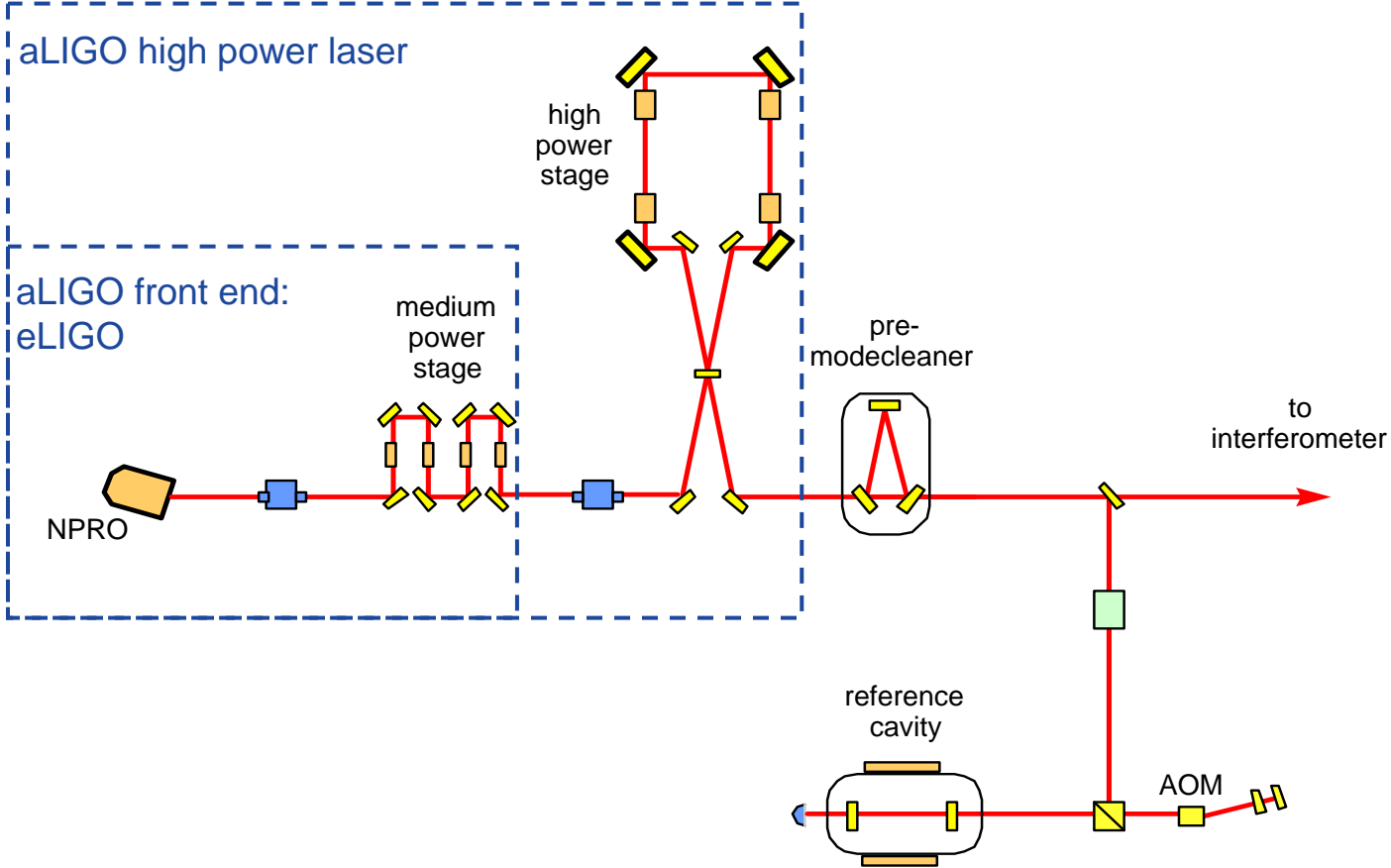
Enhanced LIGO Laser System

***S. Wagner, B. Schulz, R. Wachter, C. Veltkamp,
M. Janssen, P. Weißels, M. Frede, D. Kracht***

- Overview
- eLIGO Laser development
- eLIGO Laser System
 - Laser Head
 - Diode Box
 - Control Box
- Characterization
 - NPRO
 - Laser Head
- Summary and Outlook

Overview

- Power upgrade for observatories from 10 W to 35 W
- Front end for aLIGO



eLIGO Laser development

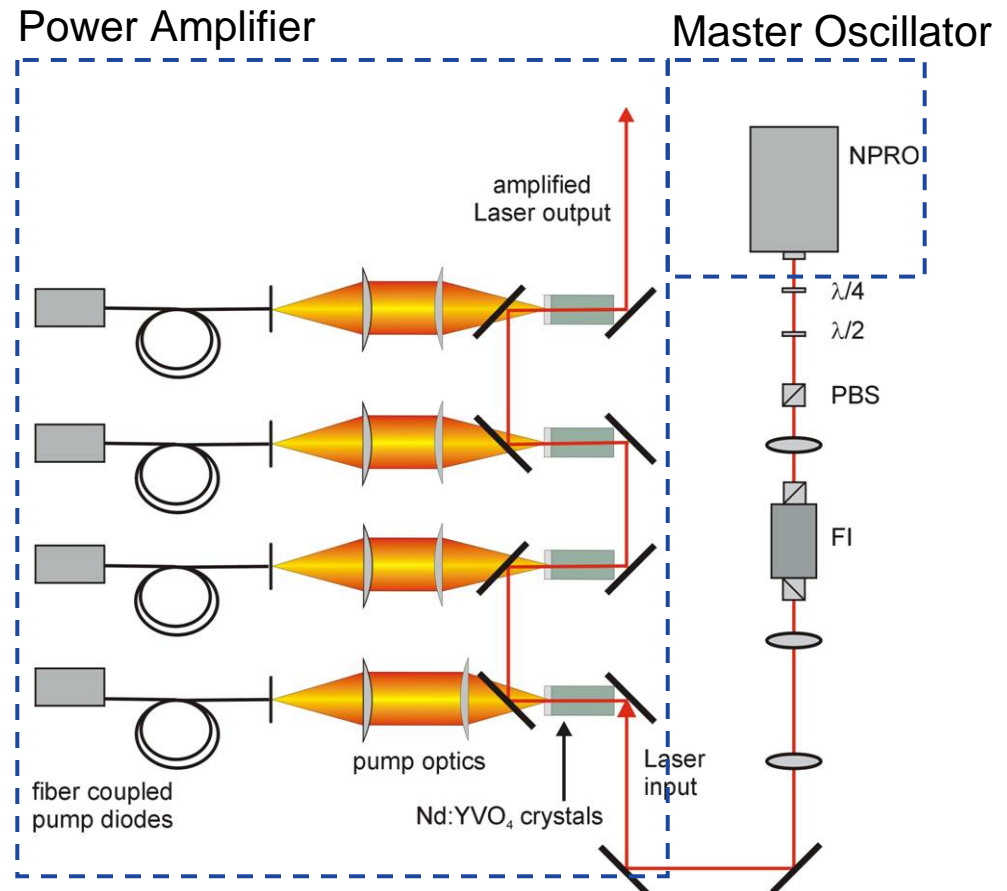
Goal:

Laser system with

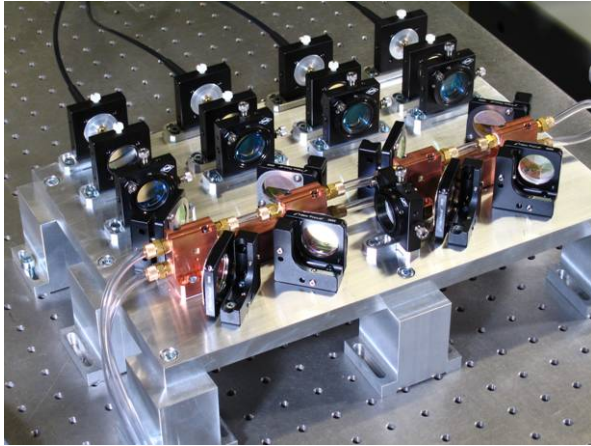
- output power 35 W
- good beam quality
- high long term stability

Realization:

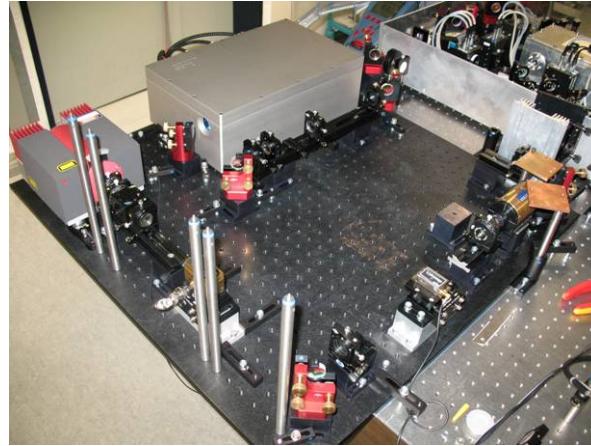
- Master Oscillator Power Amplifier (MOPA)



Development steps



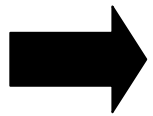
Lab.-prototype



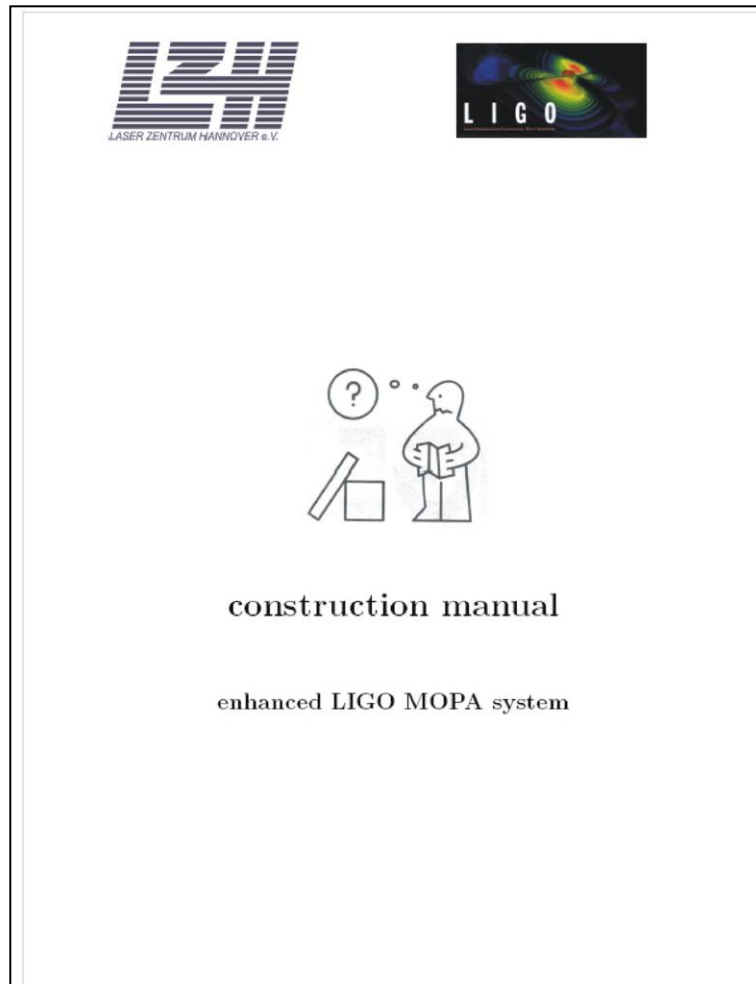
Func.-prototype



Eng.-prototype



Wrote construction manual to build following systems identically



- Built Reference System according to manual
- Rechecked construction manual
- Build Observatory and Spare Systems according to final construction manual



Laser Head



Diode Box



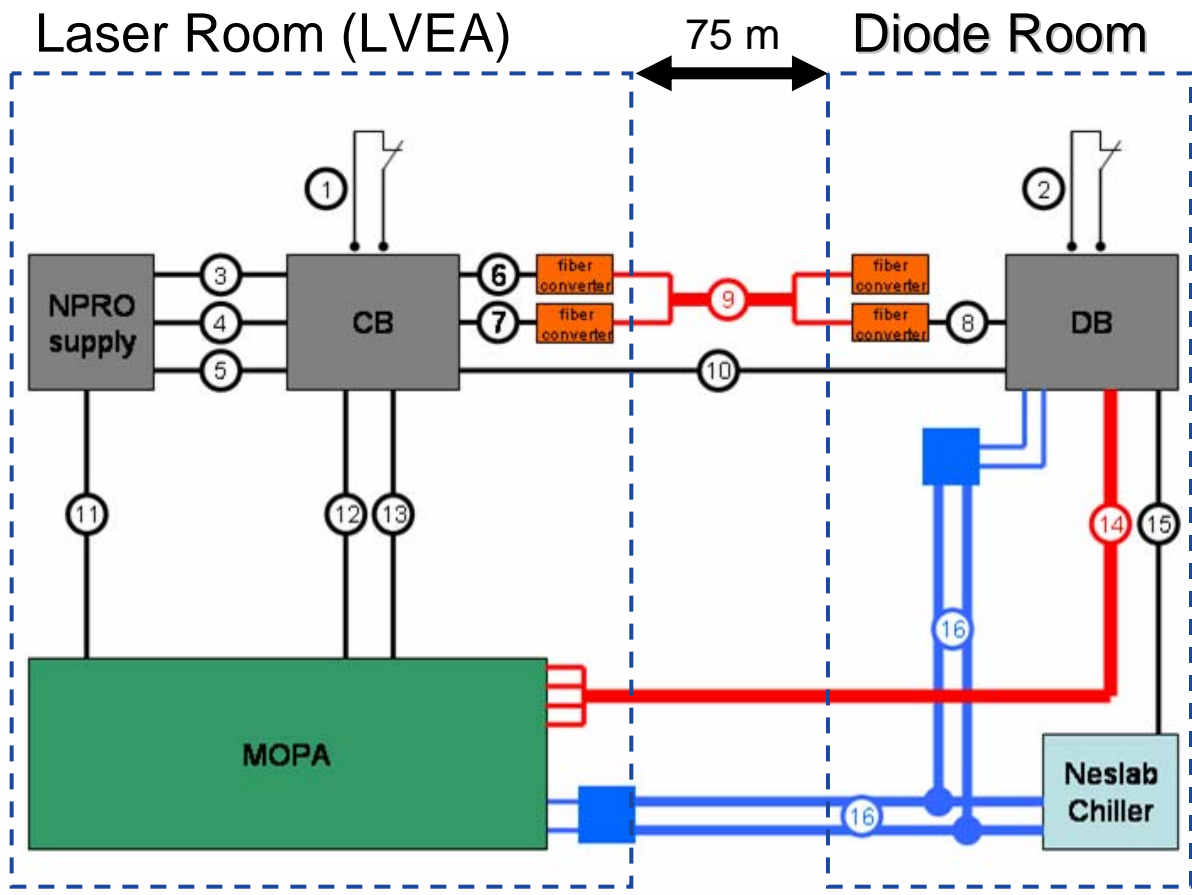
Control Box



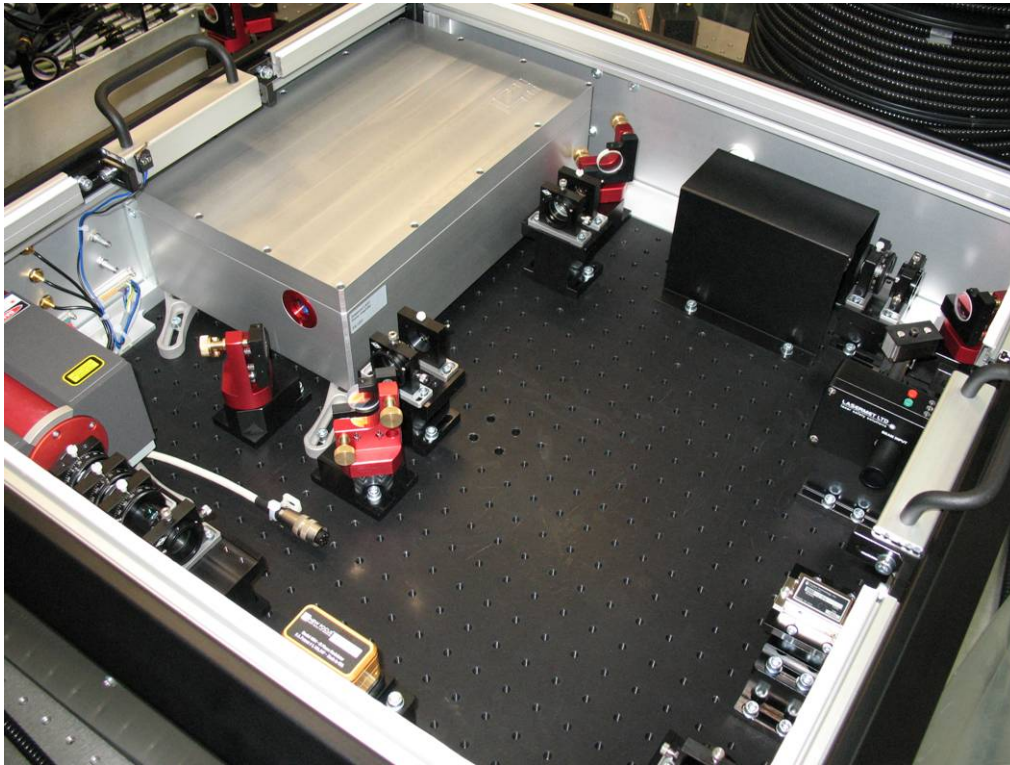
Chiller



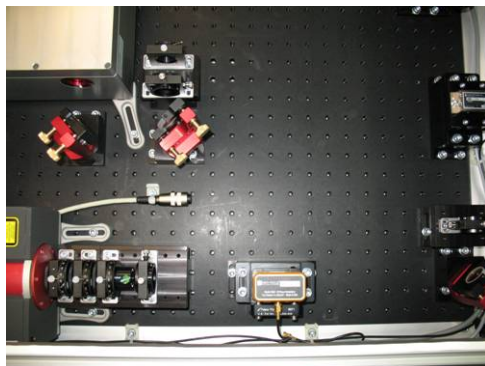
NPRO driver

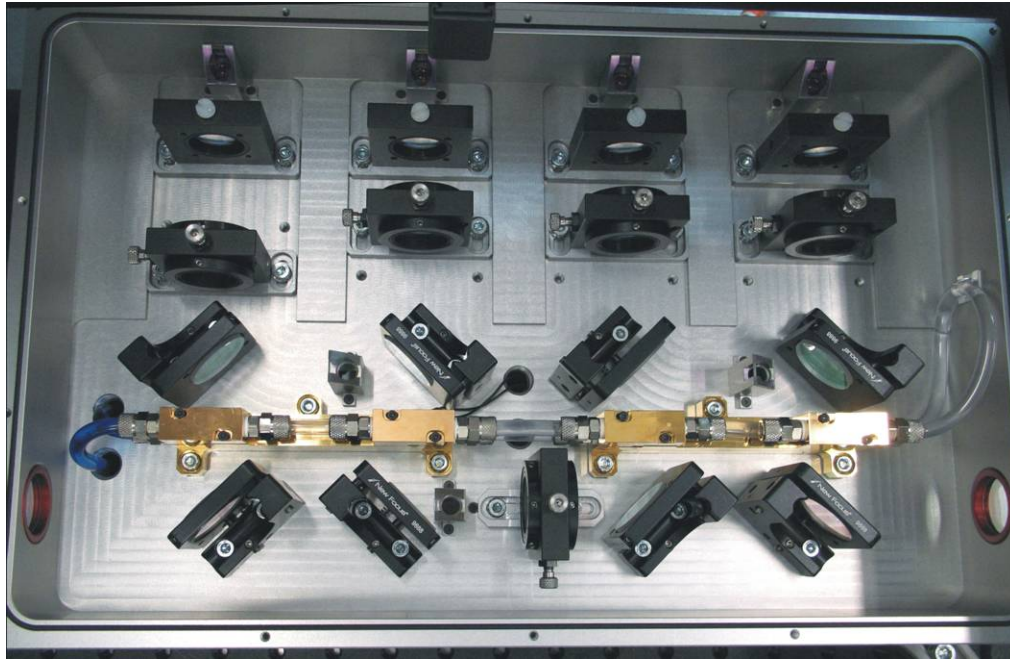


- 1) CB interlock
- 2) DB interlock
- 3) to NPRO interlock
- 4) NPRO Diag 1
- 5) NPRO Diag 2
- 6) Ethernet
- 7) EtherCAT
- 8) EtherCAT
- 9) Communication Fiberbundle
- 10) Interlock COM
- 11) NPRO laser cable
- 12) Amp Diag
- 13) MOPA Diag
- 14) Laser Diode fiber bundle
- 15) Chiller Diag
- 16) Cooling water hose

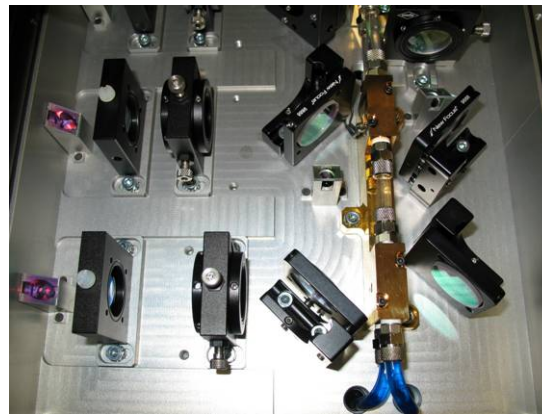
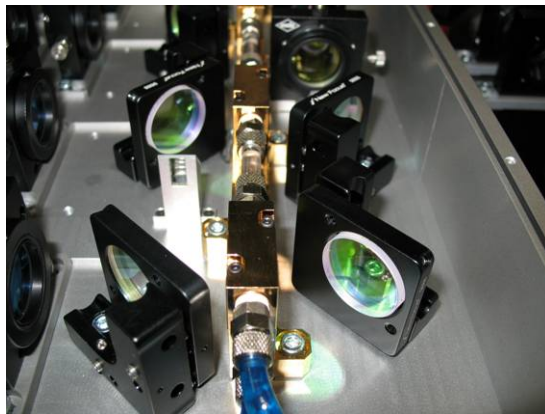


- NPRO
- EOM
 - sideband modulation
- AOM
 - amplitude stabilization
- Shutter
 - remote controlled
- Faraday Isolator
- 4-stage Nd:YVO₄ amplifier
- remote controllable





- 4 stage Nd:YVO₄
- water cooled
- fiber coupled pump diodes
- pump power 4 x 32 W
- seed power 1.7 W
- output power 35 W
- pump light pickups
- laser pickups
- temperature monitoring





- 4 pump diodes
- water cooled heat sink
- temperature interlocks
- diode power supplies
- peltier driver boards with power supply
- Beckhoff interface





Pickoff calibration	Diode Temps
Current mod	1: 25.0 °C
Power Watchdog	2: 25.0 °C
	3: 26.0 °C
	4: 28.5 °C
	Diode Current
	1/2: 46.0 A
	3/4: 46.0 A
	Mod. depth: 1.0 %
	System Status
Back	Shutter open - system running

Set	Diode Temps	Diode Power
Diag	1: 25.00 °C	1: 33.7 W
Manual mode	2: 25.00 °C	2: 32.4 W
Close shutter	3: 26.00 °C	3: 31.9 W
Reset	4: 28.52 °C	4: 30.9 W
System ON	Diode Current	Laser Power
System OFF	1/2: 46.0 A	1: 10.1 W
	3/4: 45.9 A	2: 13.2 W
		3: 23.6 W
	System Status	
	Shutter open - system running	

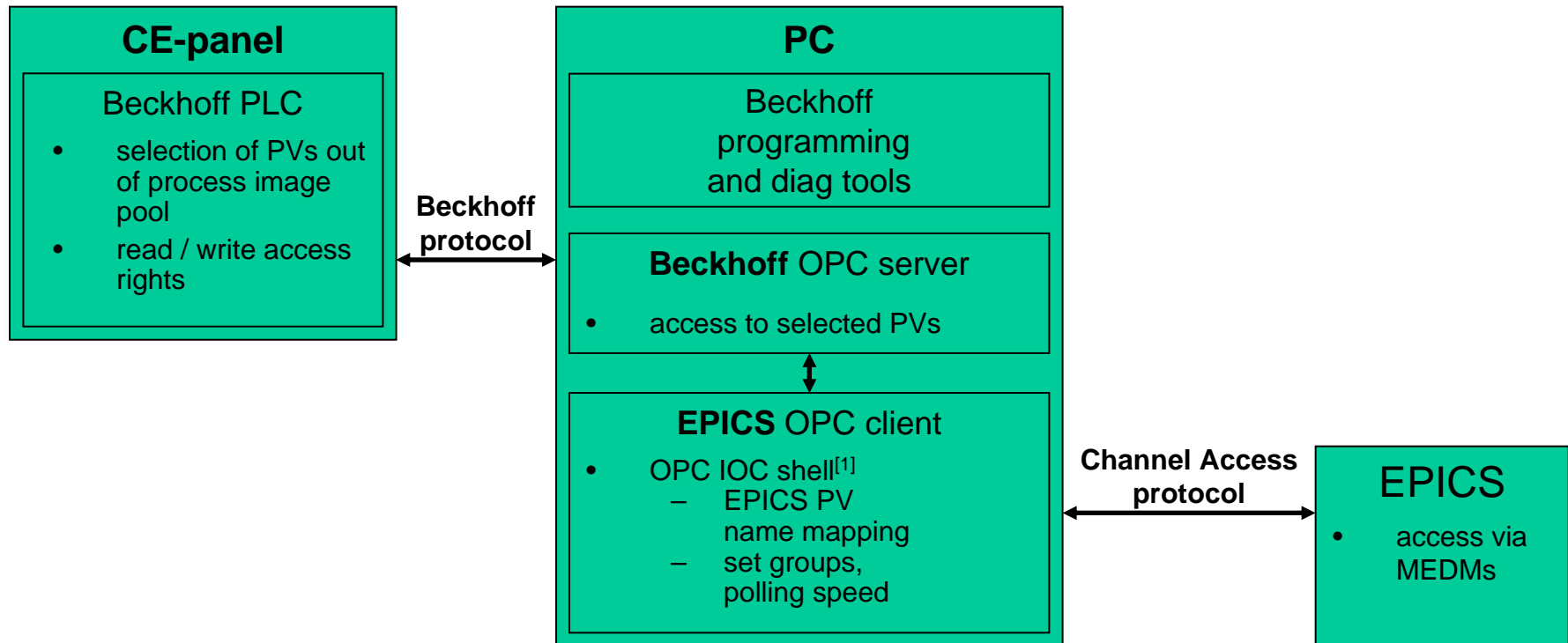
v5 build080219

System Operating Hours	NPRO Diag
0d 14h 12m 23s	D1 set temp: 22.0 °C
Misc Diag	D1 act temp: 22.0 °C
Xtal heatsink temp: 23.04 °C	D1 temp error: 0.00 K
DB heatsink temp: 22.60 °C	D1 act power: 2.74 W
	D2 set temp: 23.9 °C
	D2 act temp: 24.0 °C
	D2 temp error: -0.00 K
	D2 act power: 2.80 W
	Xtal set temp: 24.2 °C
	Xtal act temp: 24.2 °C
	Xtal temp error: 0.00 K
	NE monitor: 15.43 mA
	Diode set current: 1.99 A
	Diode act current: 2.00 A
	System Status
Back	Shutter open - system running

EPICS interface via OPC-server

(O)peness (P)roductivity (C)ollaboration

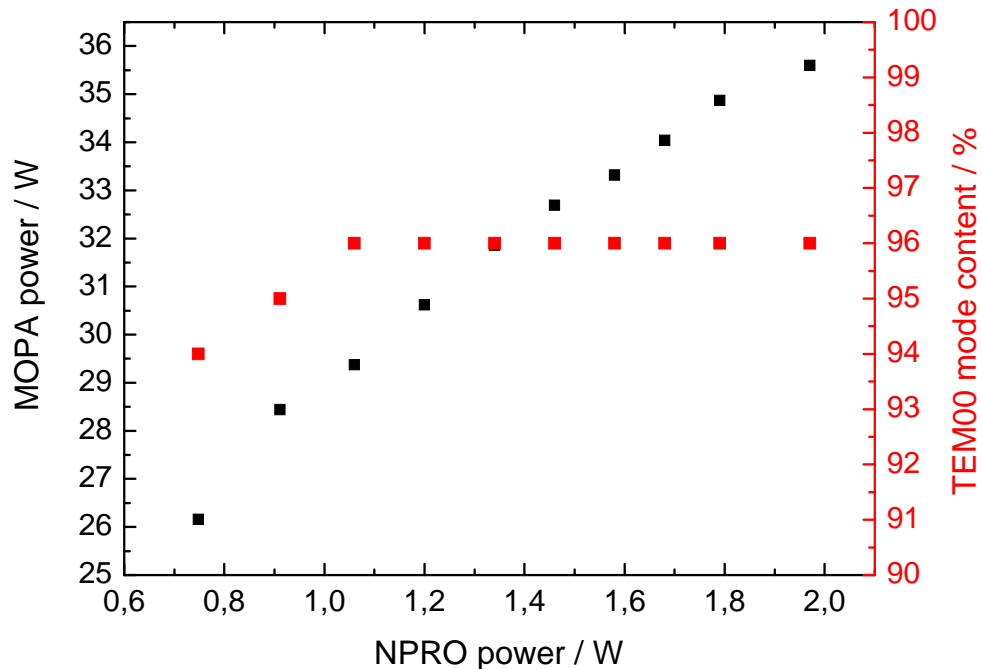
(platform-independent software interface for industrial automation)



NPRO characterization at AEI

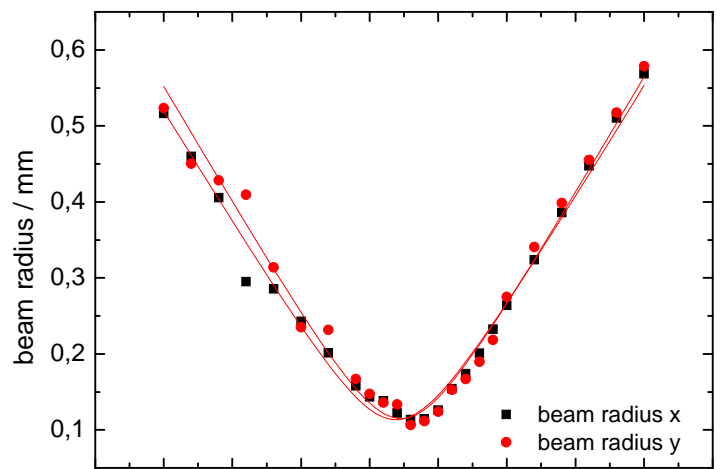
Laser	func	eng	ref	obs1	obs2	obs3	spare1	spare2	average
Total output power / mW	2250	2010	2230	2160	2210	2200	2270	2230	2195±76
Output power after FI / mW	1940	1560	1860	1870	1900	1940	1920	1930	1865±119
Output power fluctuations, relative rms / 10 ⁻⁶	±857	±186	±777	±252	±394	±154	±428	±460	441±247
Relaxation oscillation frequency / kHz	1230	1210	1210	900	1160	975	1230	1200	1139±120
PZT frequency actuator calibration / (MHz / V)	1.60	1.26	1.33	1.33	1.26	1.45	1.26	2.00	1.48±0.25
Temperature frequency actuator calibration / (GHz / V)	3.4	2.8	2.7	2.7	2.8	3.0	2.5	2.5	2.8±0.3
Temperature frequency actuator bandwidth / mHz	90	200	220	220	130	150	200	175	163±41
Pointing fluctuations 1X, relative rms / 10 ⁻³	±6.6	±6.6	±4.0	±8.1	±4.6	±3.6	±3.6	±6.9	5.5±1.6
Pointing fluctuations 1Y, relative rms / 10 ⁻³	±8.7	±9.8	±2.8	±11.5	±2.5	±2.8	±2.1	±9.0	6.1±3.7
Pointing fluctuations 2X, relative rms / 10 ⁻³	±4.1	±5.4	±1.8	±5.4	±1.8	±1.4	±1.9	±4.5	3.3±1.6
Pointing fluctuations 2Y, relative rms / 10 ⁻³	±6.2	±7.4	±1.6	±7.9	±1.8	±1.3	±1.8	±6.6	4.2±2.8
Beam quality (higher order mode content) / %	2.43	2.37	1.39	4.37	1.37	3.39	2.23	2.28	2.49±1.00
Relative ellipticity / astigmatism	0.065	0.073	0.059	0.151	0.013	0.148	0.072	0.089	0.084±0.043

Investigations on derated NPRO

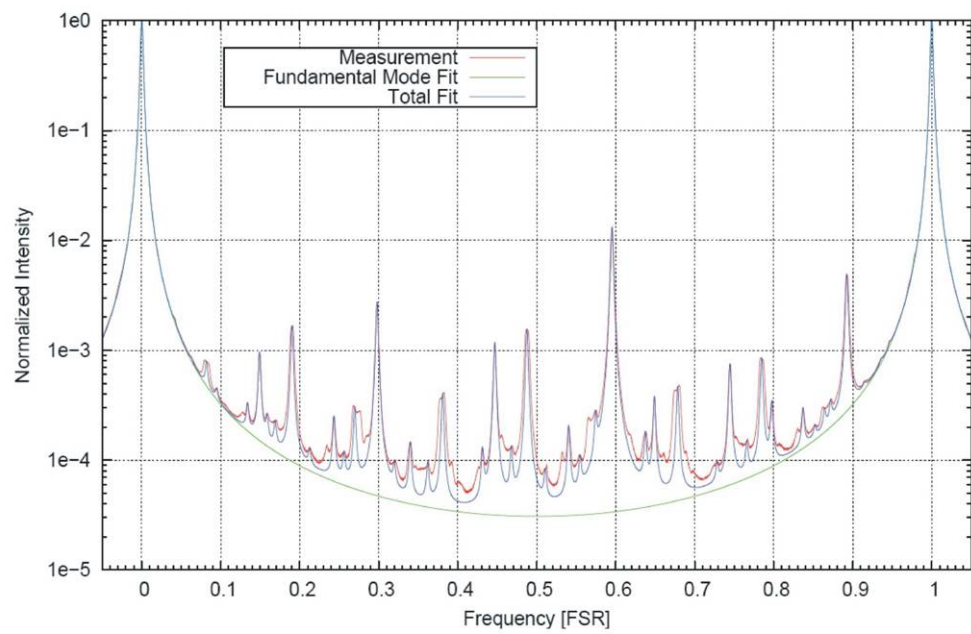
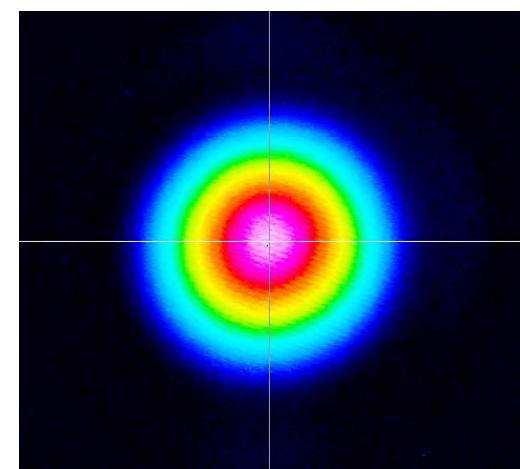


Actual System settings for output power ≥ 35 W :

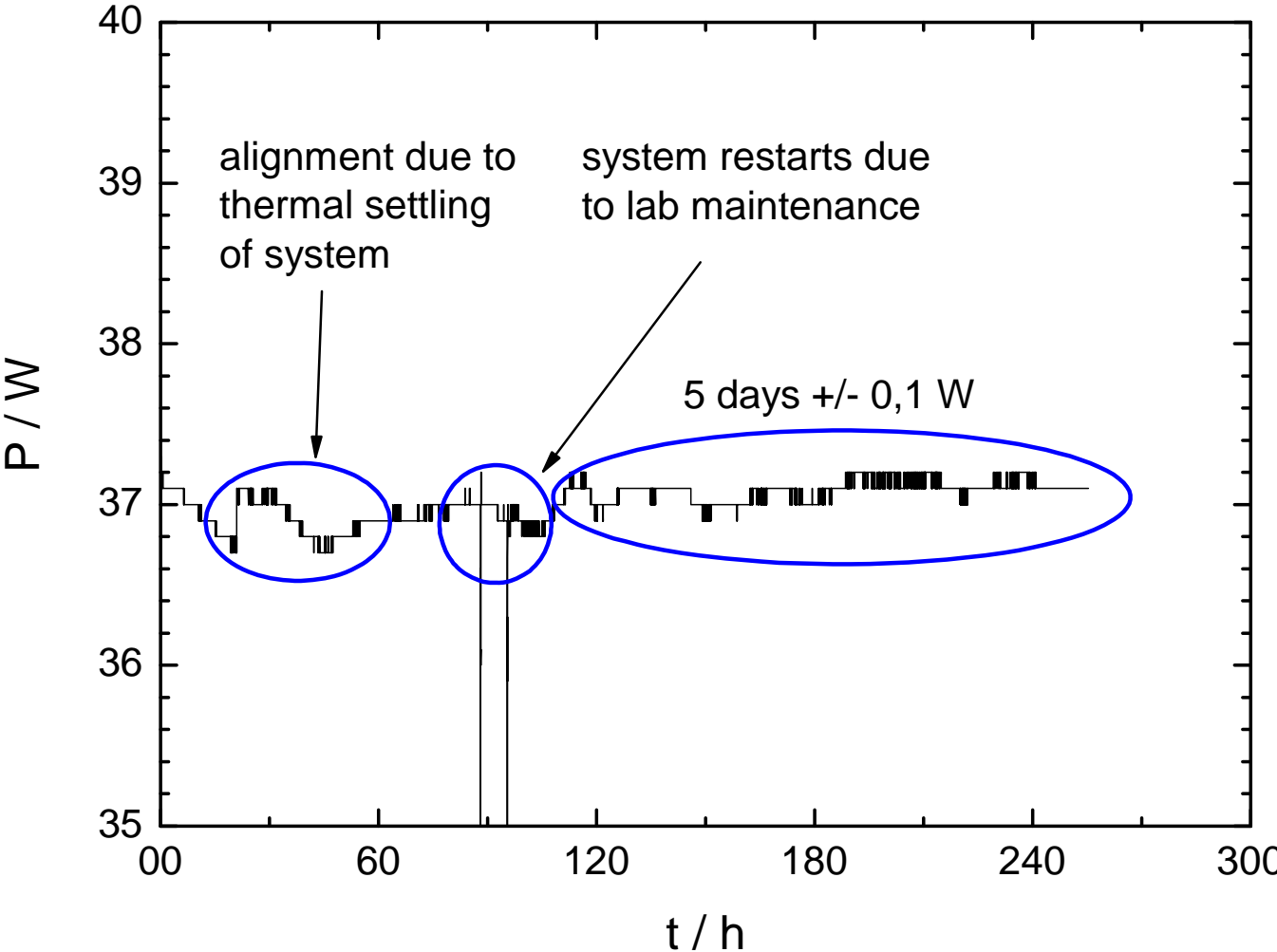
- NPRO power 1.8 W
20 % derated (nominal 2.2 W)
- Amplifier pump power 32 W
per stage
30 % derated (nominal 45 W)



$M^2 < 1.05$



97 % TEM_{0,0}



Laser	func	eng	ref	obs1	obs2	obs3	spare1	spare2
NPRO power / W	2.25	2.1	2.23	1.84	1.79	~ 1.8	~ 1.8	~ 1.8
NPRO diode 1 temperature / °C	24.98	31.98	23.76	21.90	23.18	-	-	-
NPRO diode 2 temperature / °C	23.80	20.65	20.75	23.83	20.55	-	-	-
average pump power per stage / W	32.5	32.0	32.0	33.0	33.0	-	-	-
MOPA power / W	35.4	36.5	37.1	37.0	37.2	-	-	-
M ² <	1.1	1.1	1.1	1.1	1.1	-	-	-
TEM _{0,0} mode content / %	93	92	94	97	95	-	-	-
installation / location	LZH	CALTECH	AEI	May 2008 / LLO	next week / LHO	- / LHO 2	-	-

Summary and Outlook

- Output power of about 37 W
- $M^2 < 1.1$
- $> 95\%$ in $TEM_{0,0}$
- Enhanced LIGO systems ready for installation at Hanford and Livingston
- Laser installation at Hanford next week
- Laser installation at Livingston May '08

PEOPLE MATTER

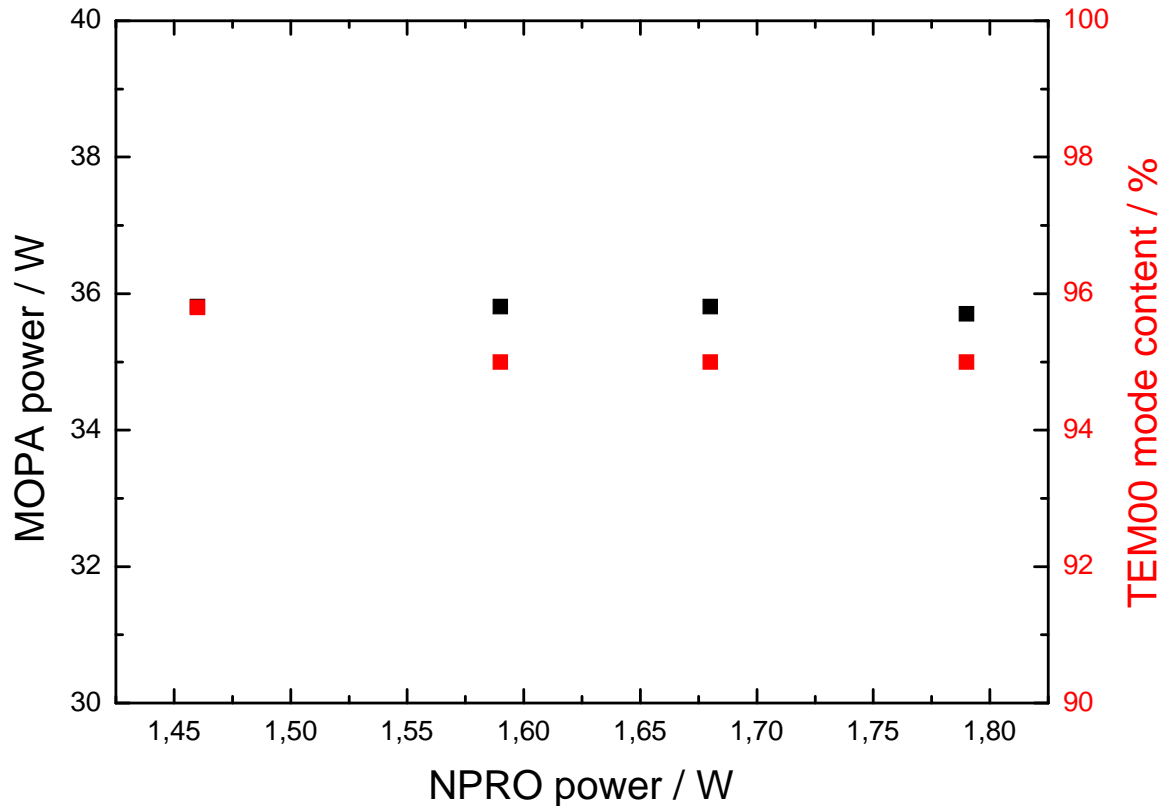
*research
development
consulting*



LZ LASER ZENTRUM HANNOVER e.V.

Thank you for your attention!

Investigations on derated NPRO



- increased amplifier pump current to maintain output power of ≥ 35 W
- no significant decrease of beam quality measurable