FIBER AMPLIFIERS FOR 3G DETECTORS

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GWADW

23.05.2018

LASER ZENTRUM HANNOVER e.V.

OVERVIEW

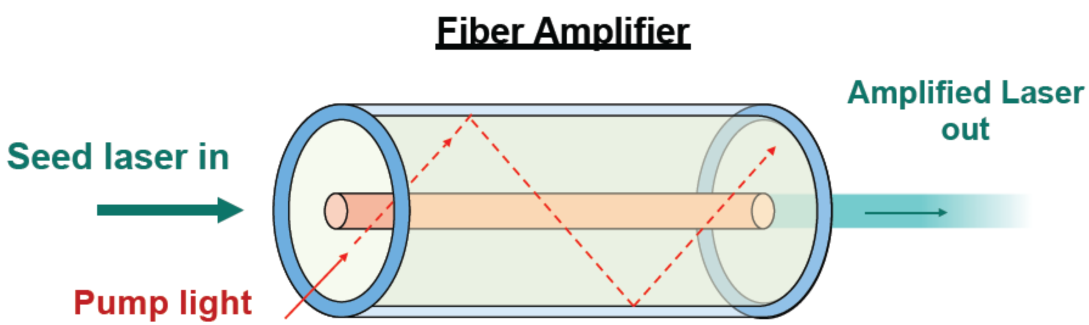
- Why fiber based lasers?
- LZH/AEI
  - 200W @ 1064nm
  - 100W @ 1550nm
- The future (in Hannover)
- VIRGO (Alphanov): 100W @ 1064nm
- MIT (Lincoln Labs): 180W @ 1064nm
- Conclusions

WHY FIBER BASED LASERS?

Fibers are waveguides

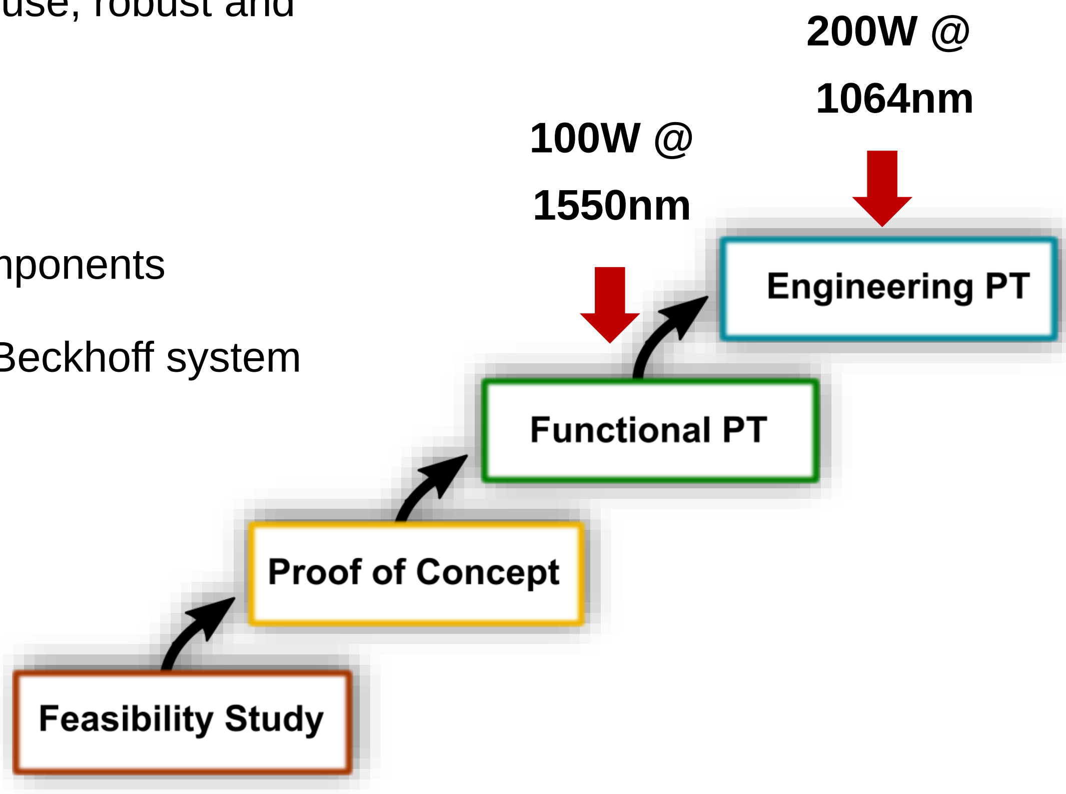
- High single pass gain
- Design determines many things

- Nonlinear effects
- Damage by seed drop-out



PROTOTYPE DEVELOPMENT IN HANNOVER

- Goal: Prototypes as turn-key, easy-to-use, robust and reliable as possible (reasonable)
- Commercially available fibers and components
- Controlled & monitored (interlock) by Beckhoff system
- Modular design
  - Simple interfaces
  - Simple replacement
  - Compatible to aLIGO 35W front-end



1064NM PT

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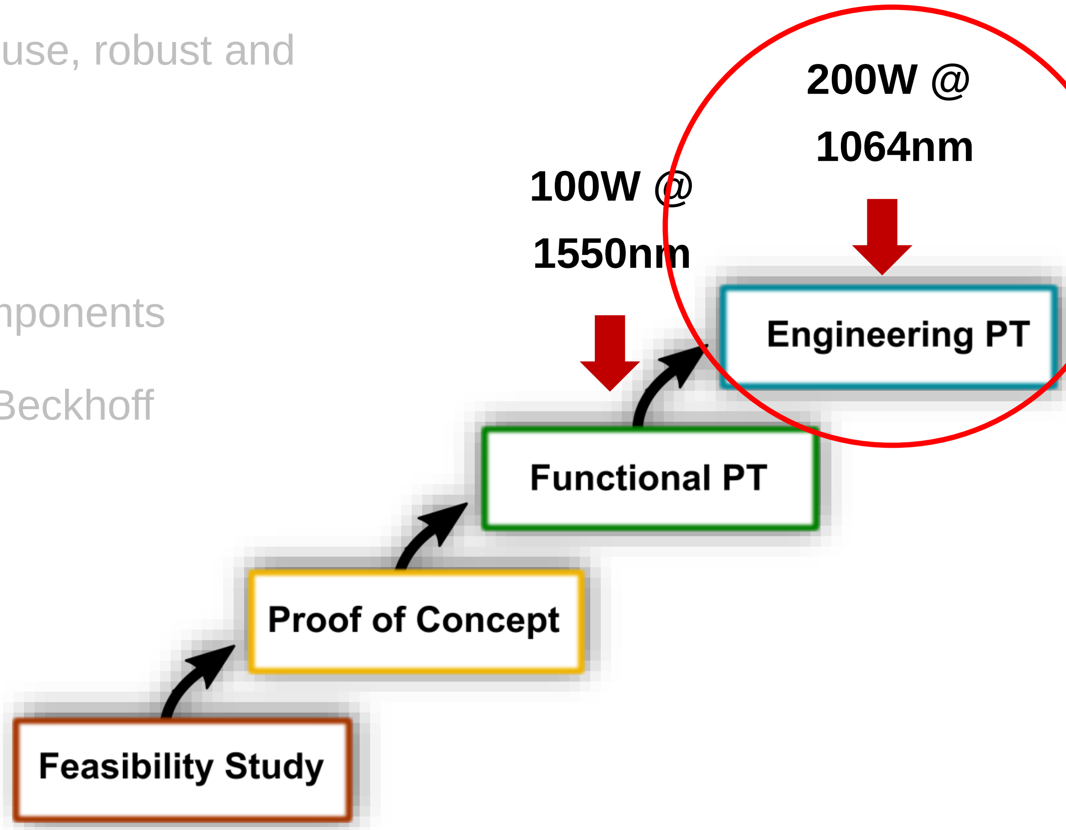
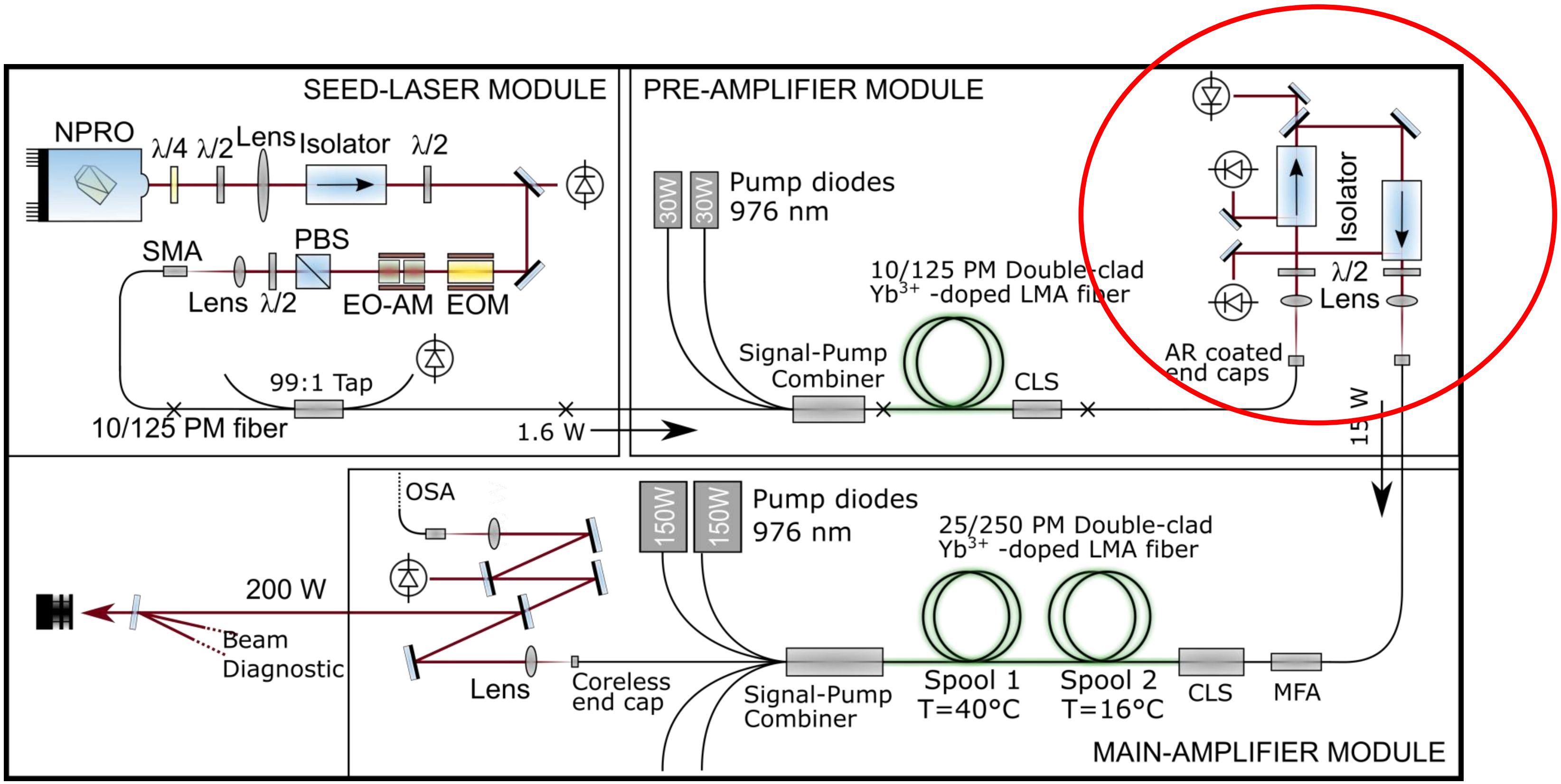


SETUP



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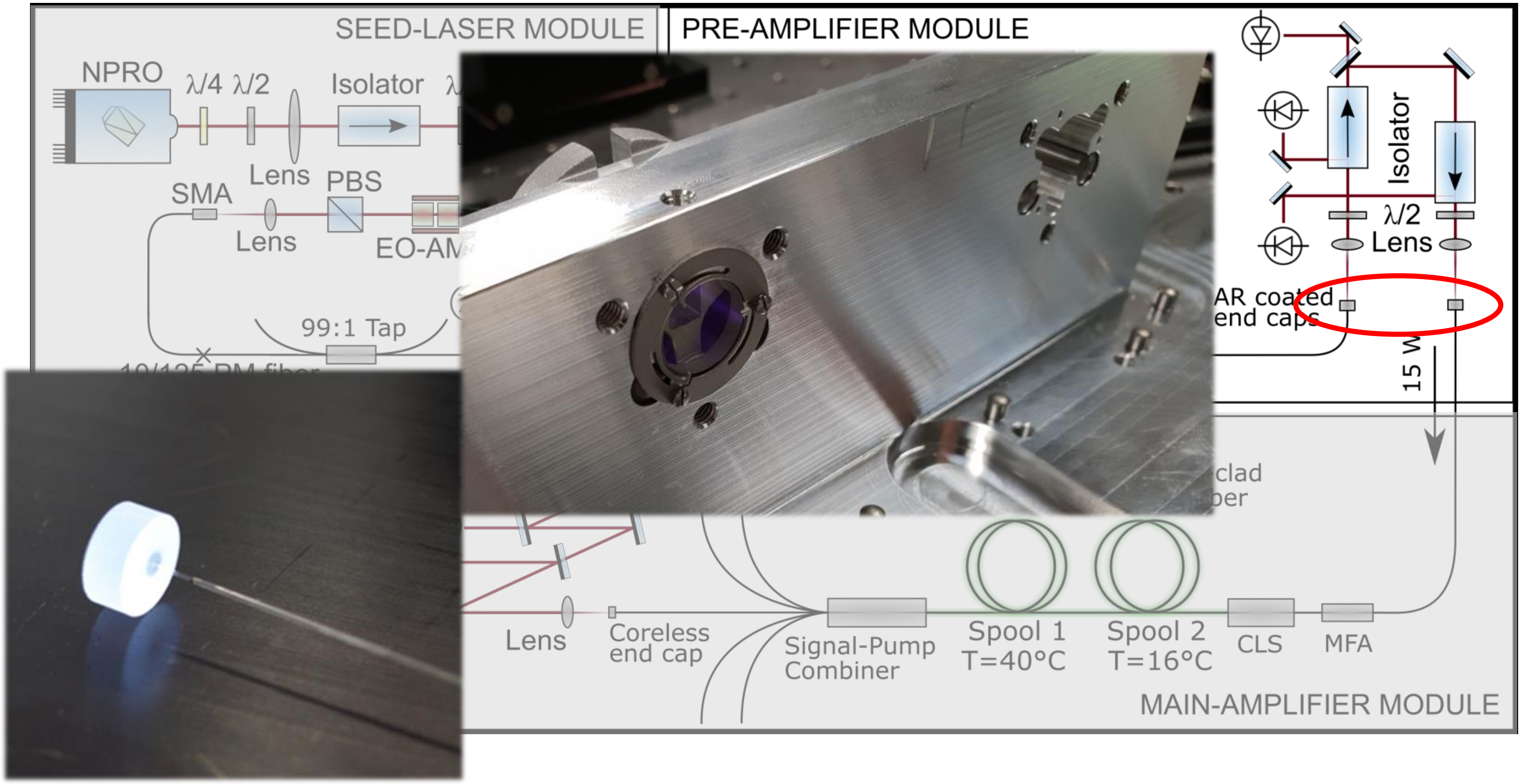
ISOLATION AND MONITORING STAGE



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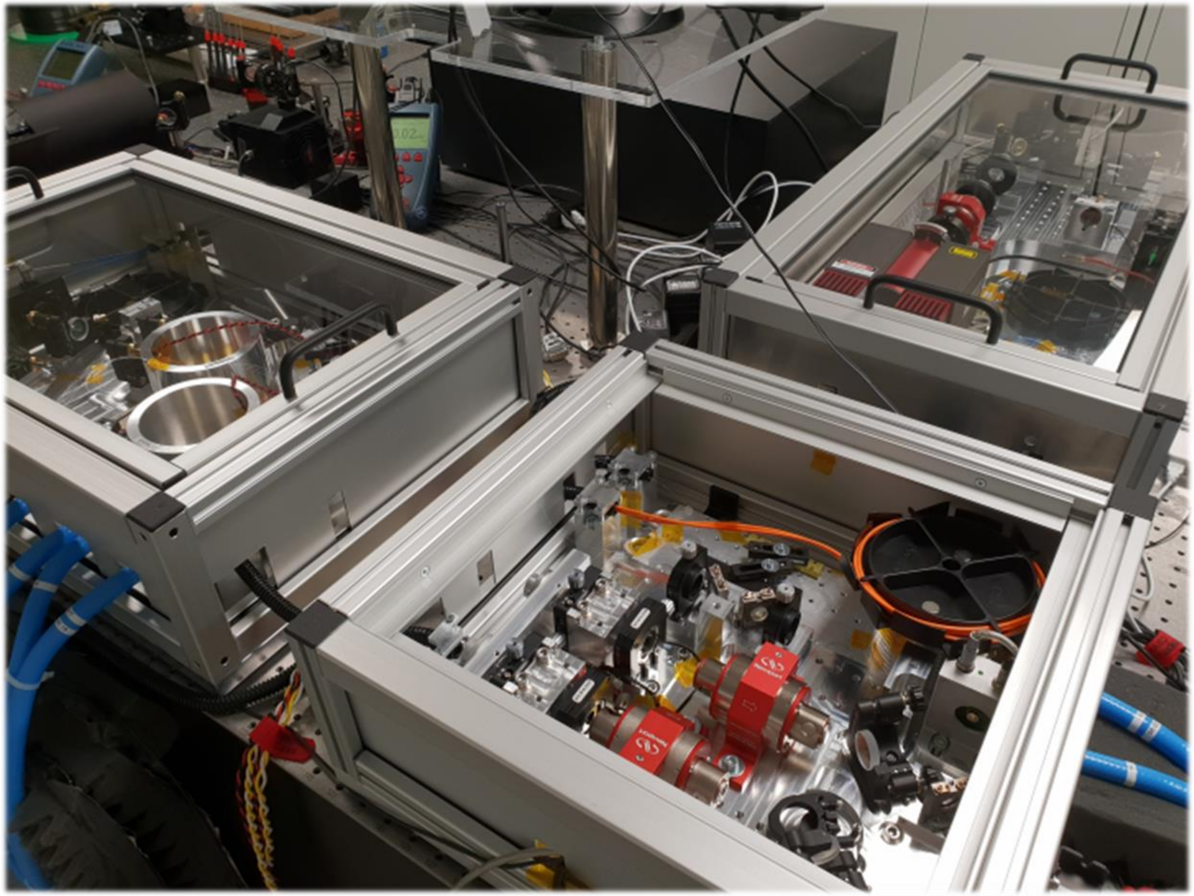
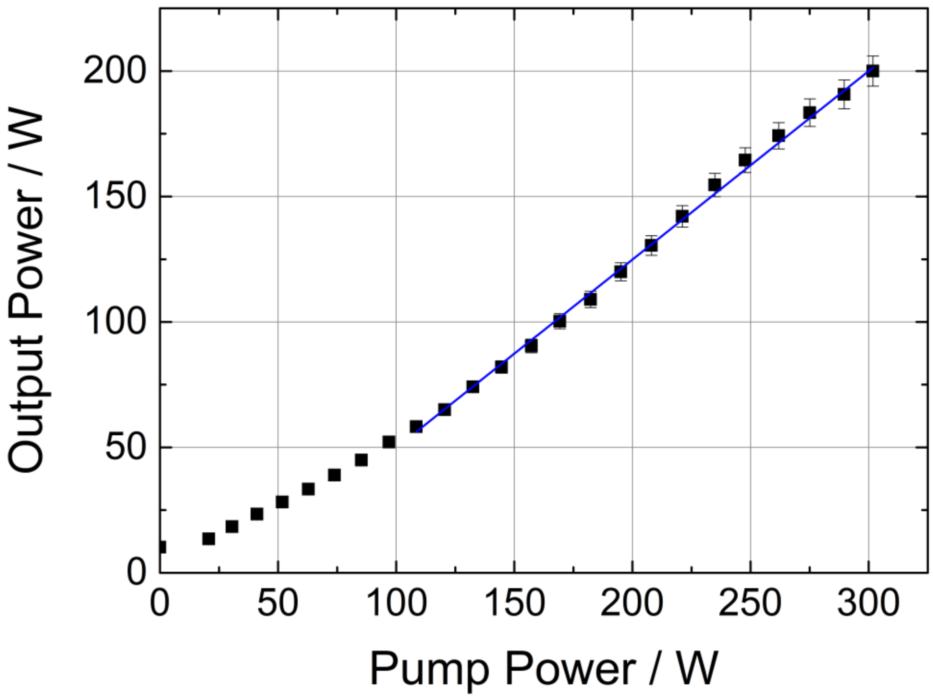
SETUP



LZH LASER ZENTRUM HANNOVER e.V.

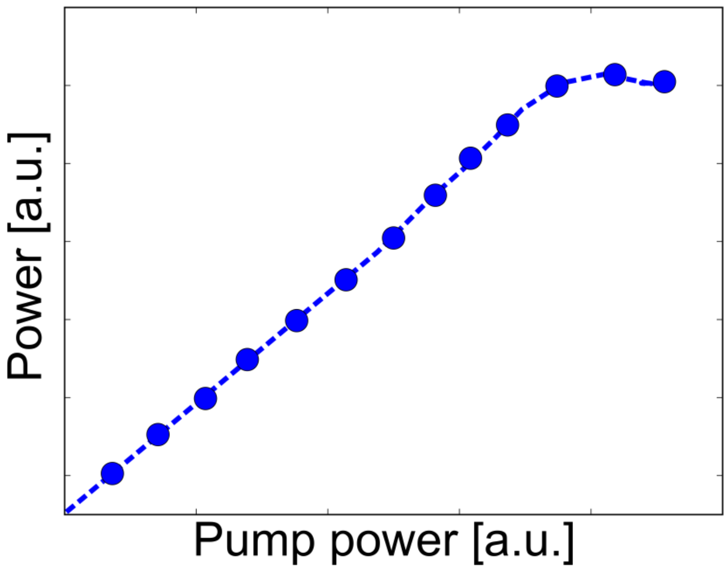
RESULTS



- Max. output power: 200 W
- PER: 19 dB
- > 94 % TEM_{00}
- No excess frequency noise
- Intensity noise spectrum ok

STIMULATED BRILLOUIN SCATTERING

Show-stopper for most applications



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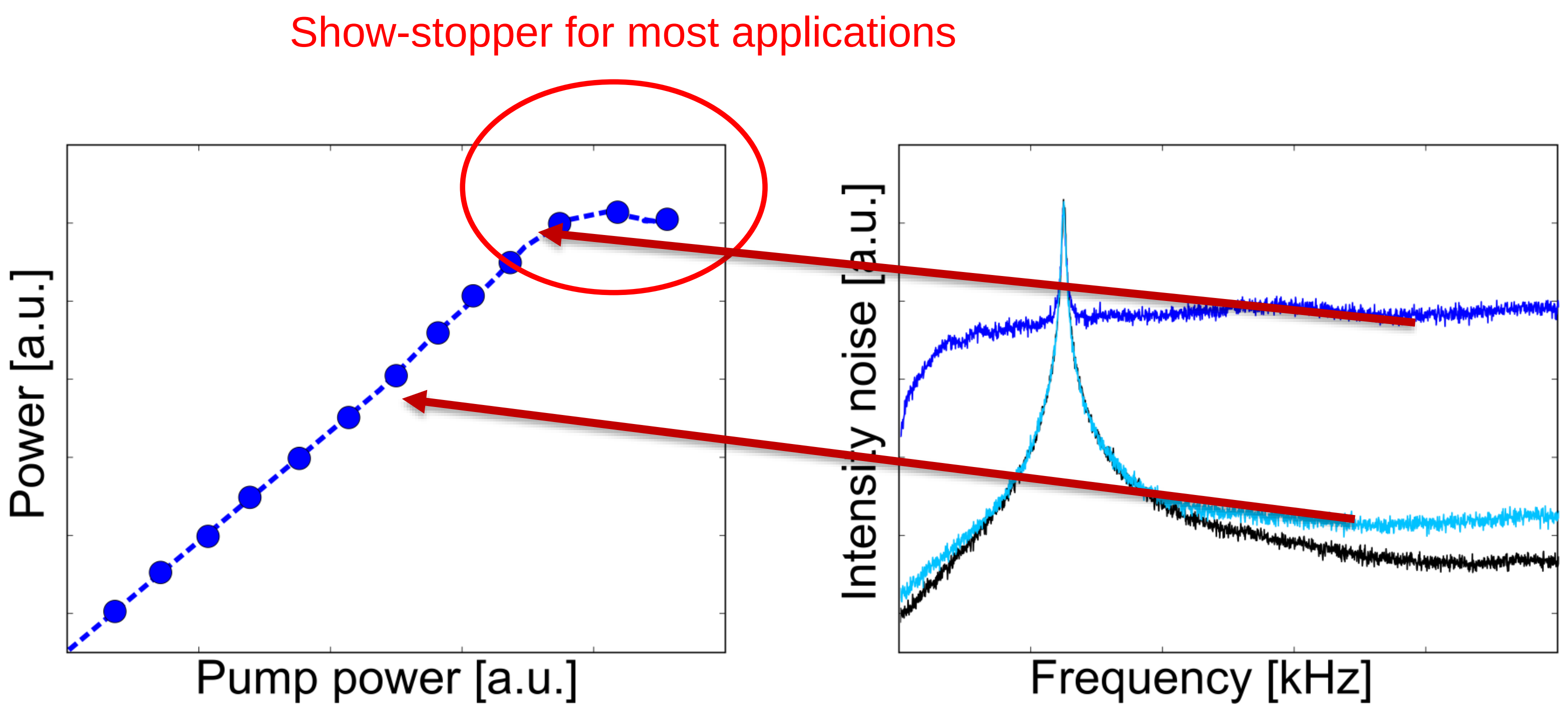
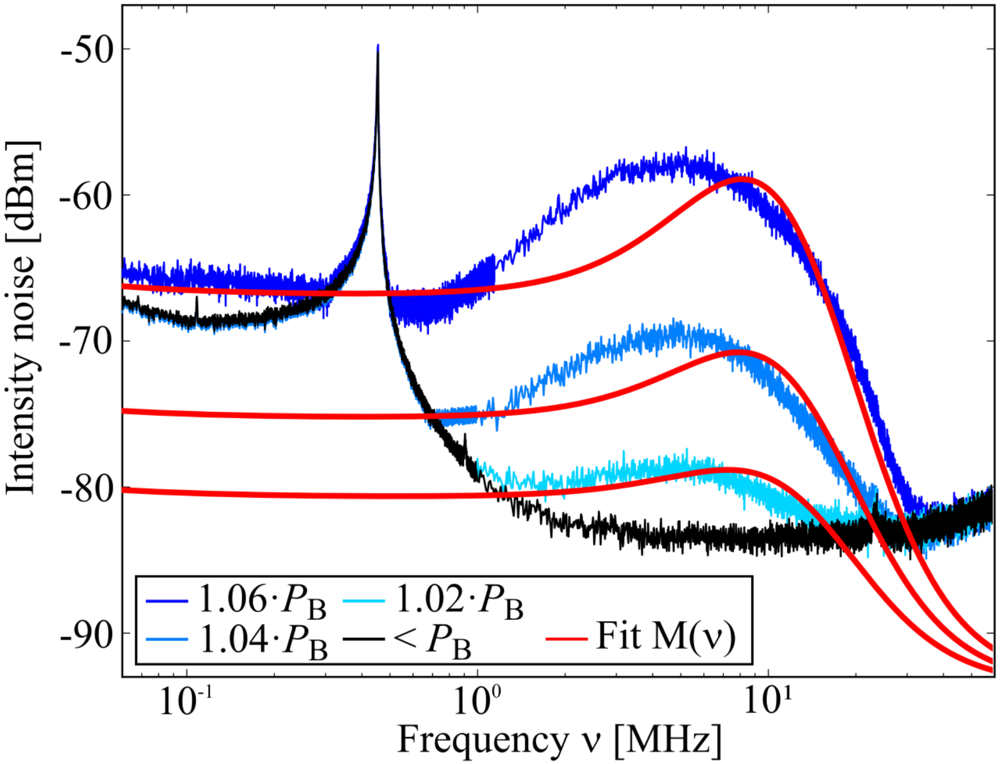
STIMULATED BRILLOUIN SCATTERING



- Measure MHz noise level: Most sensitive / relevant SBS detection method for GW application

STIMULATED BRILLOUIN SCATTERING



- See LIGO Document G1900507
- Measured asymmetric gain profile
- Assumed: 1/v frequency noise of NPRO
- Intrinsic frequency noise of chosen seed laser technology matters

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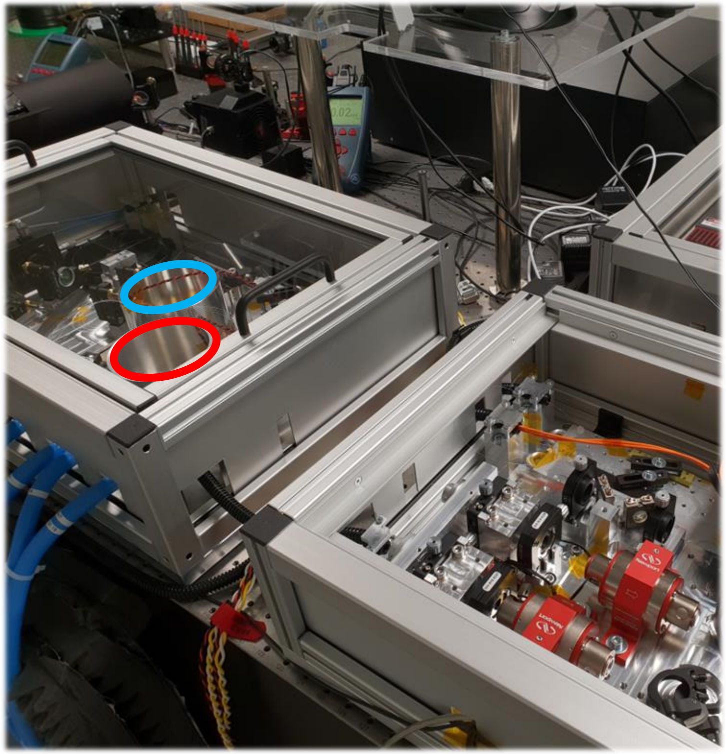
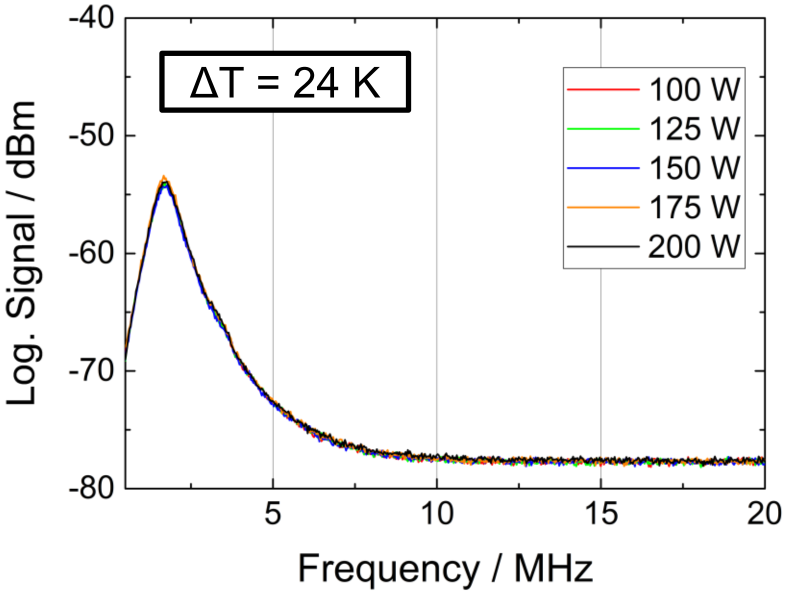
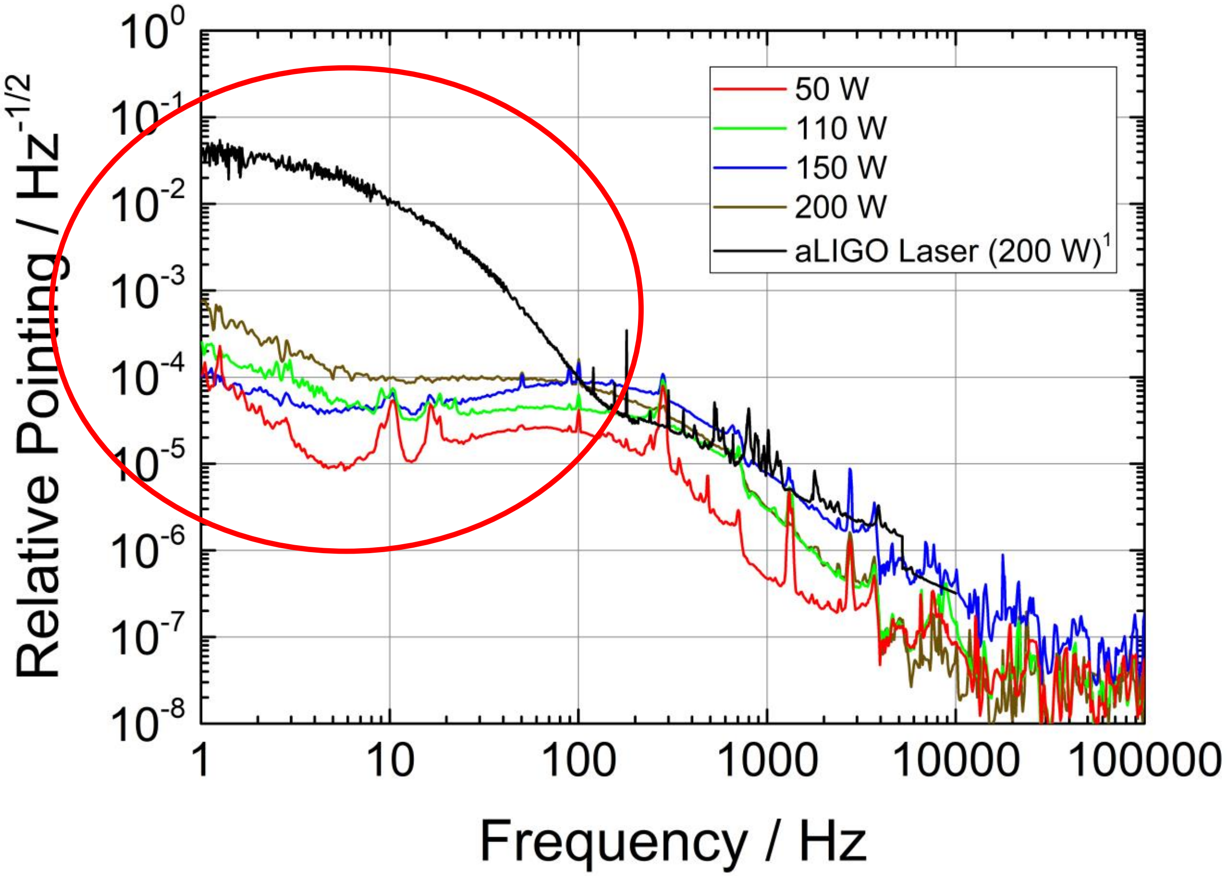
STIMULATED BRILLOUIN SCATTERING





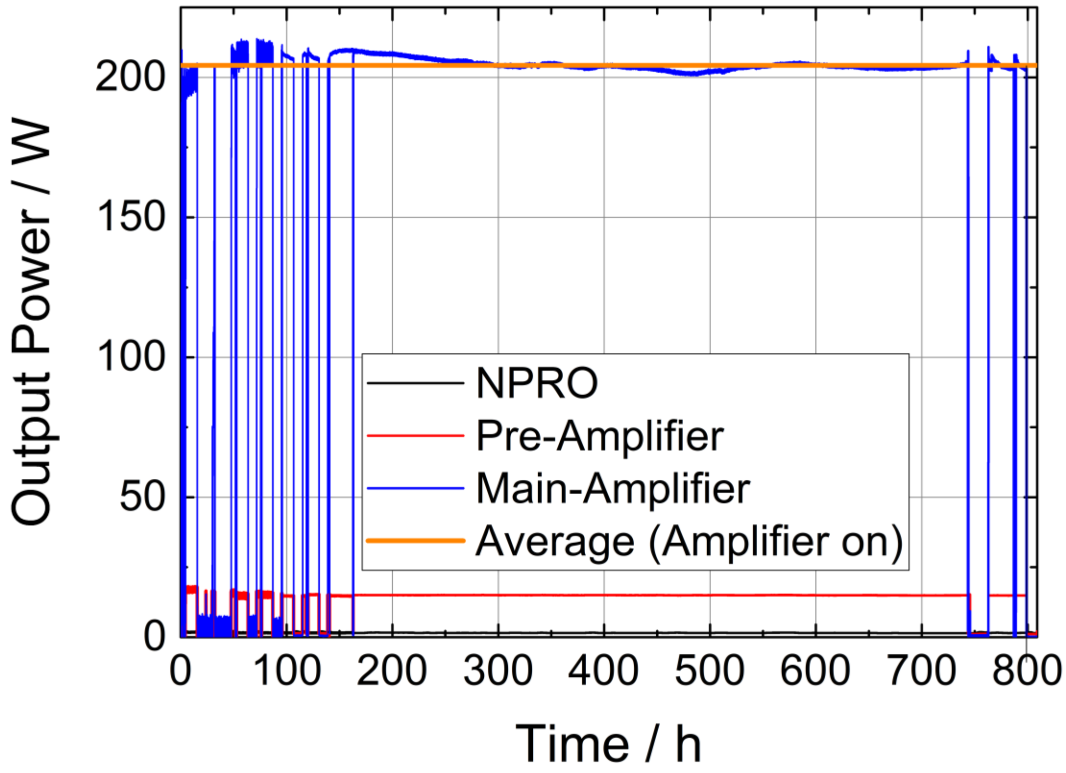
- Additional temperature gradient
- No SBS

RELATIVE POINTING NOISE



[1] Data from: LIGO Scientific Collaboration, Technical Report No. LIGO-E1100716-v6, 24-30 (2012).

LONG TERM OPERATION



- >600 h continuous operation
- Average: 204.17 W ± 1.76 W (less than 2 %)
- <1°C temperature increase at components
- After 800 h: Fatal failure of pump combiner

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HIGH LEVEL DESIGN DRIVERS AND DECISIONS

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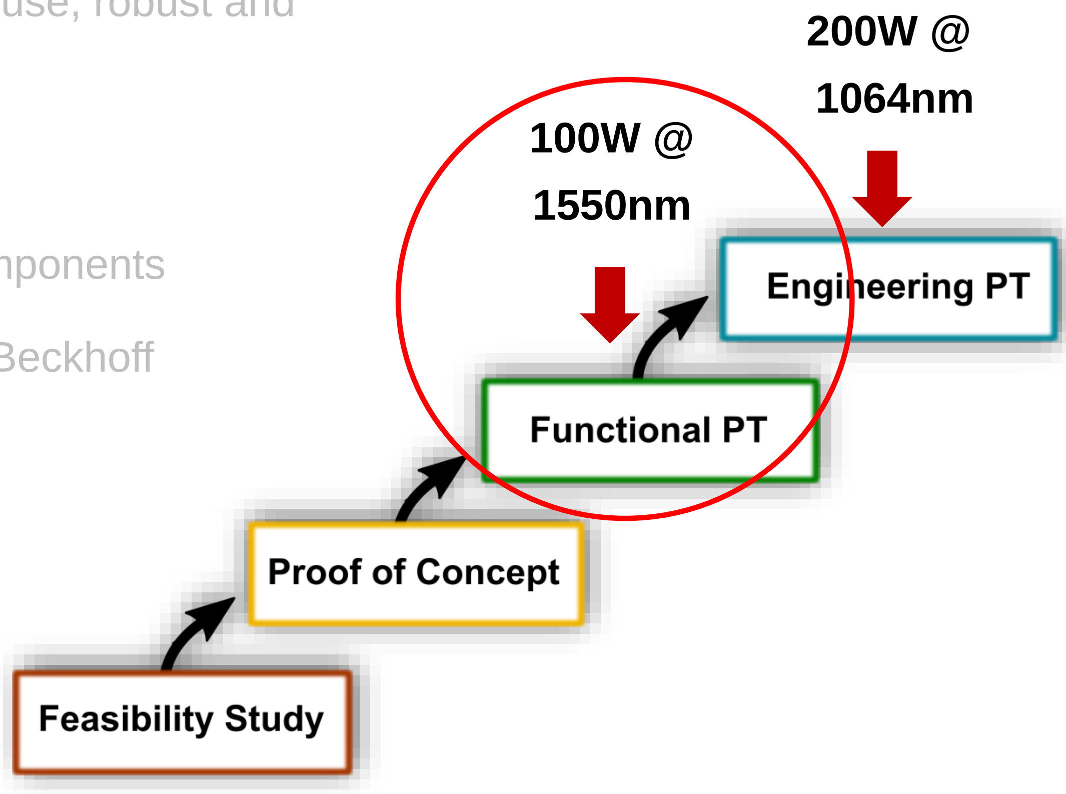
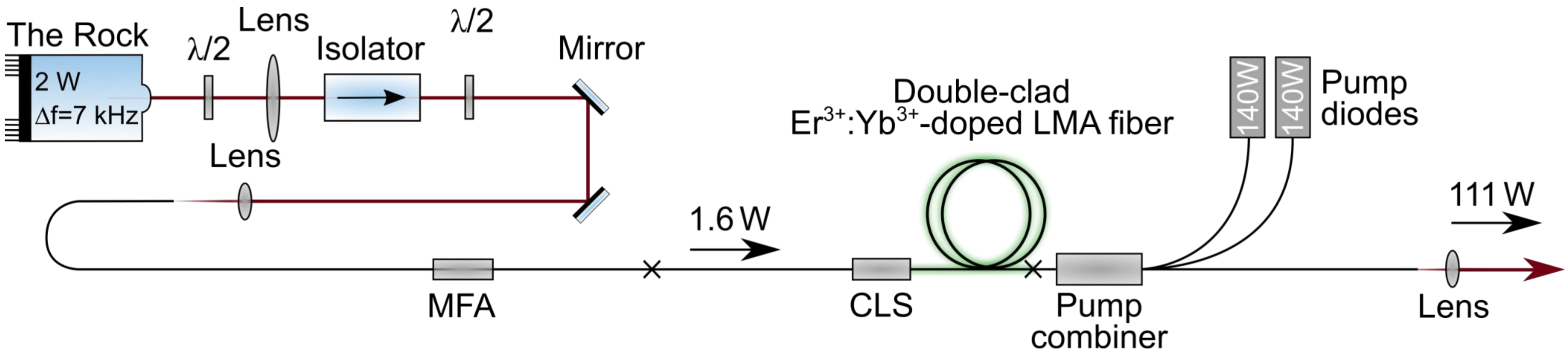
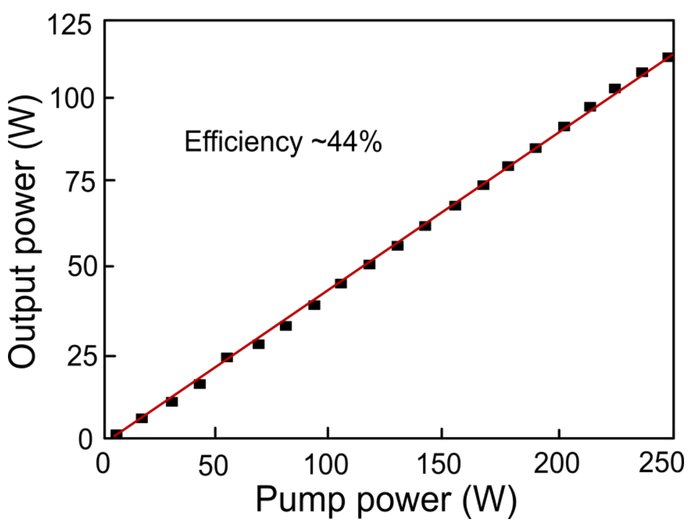


SETUP AND RESULTS





- Maximum output power 111 W
- Limited by available pump power
- PER: 13 dB
- >94% TEM_{00}
- No excess frequency noise
- Intensity noise spectrum ok
- No SBS
- Seed laser technology screening @ AEI

THE FUTURE (IN HANNOVER)

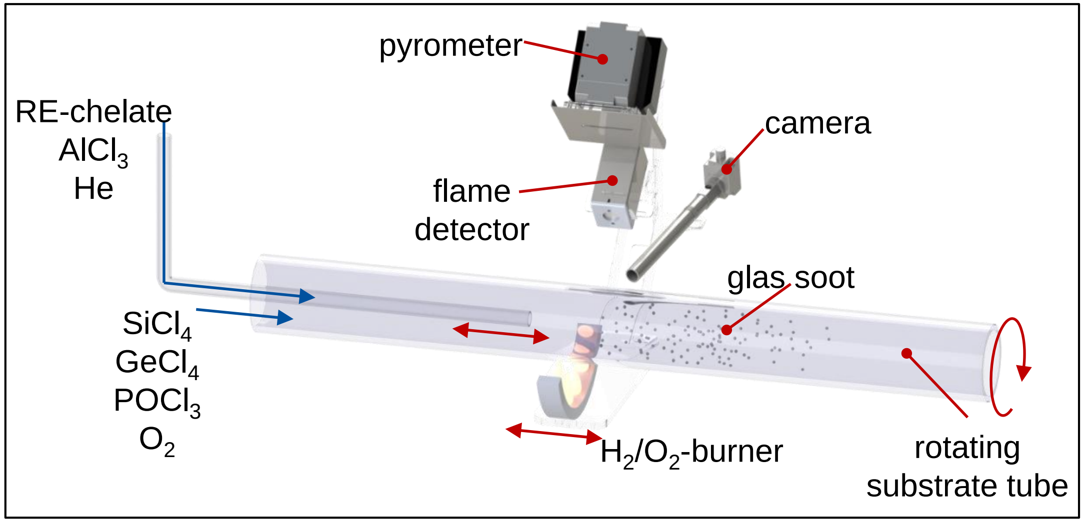
- 1064 nm 200 W prototype
  - Repair system & second end-cap: Emergency shut-down tests
  - Two new systems (1x at LZH, 1x at AEI): Statistics & long-term tests
  - Coherent beam combination
  - Power scaling with all-solid specialty fibers
- 1550 nm 100 W prototype
  - Upgrade to pump power for 200 W (will there be photodarkening?)
  - Upgrade to PM system (not that easy……)
  - Long-term tests
- Start with 2000 nm (depends on funding)

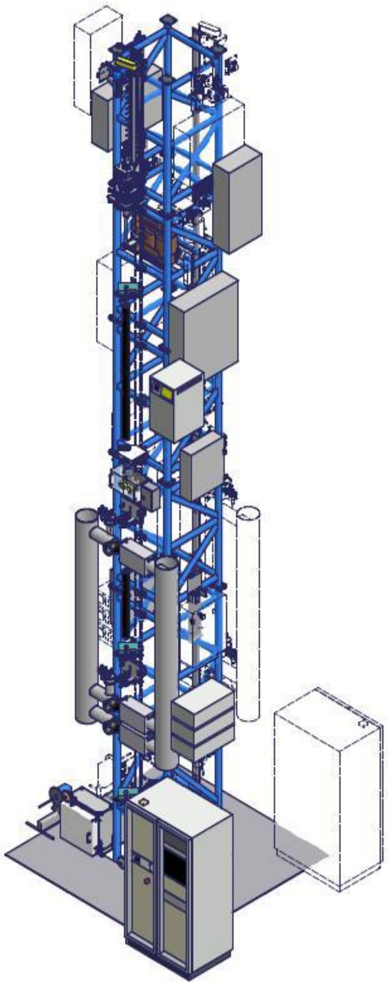
MY THE FUTURE

HITec

Hannover Institut
für Technologie

- We can now design, fabricate and draw fibers
- Looking for collaborations (talk to me)





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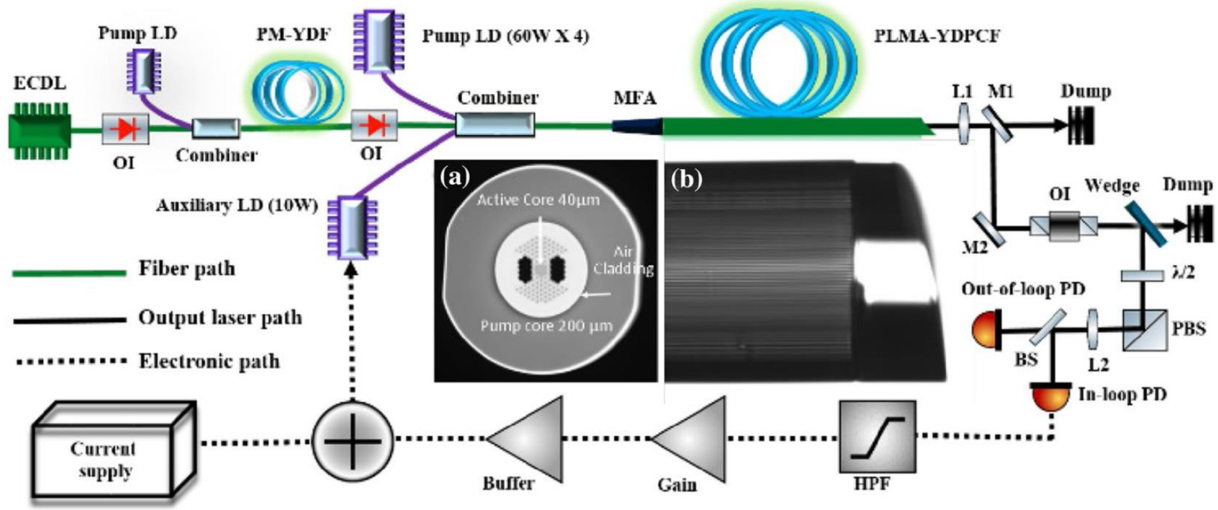
VIRGO (ALPHANOV) 100 W AMPLIFIER

- See Applied Physics B (2018) 124:114



- 2 stage design
- Commercial 40 µm PCF
- Max. 120 W (limited by modal instabilities); >94 % TEM_{00}
- 600 h (2500 h) long-term tested at 100 W
- No SBS (confirmed by noise measurements)
- To be installed after O3

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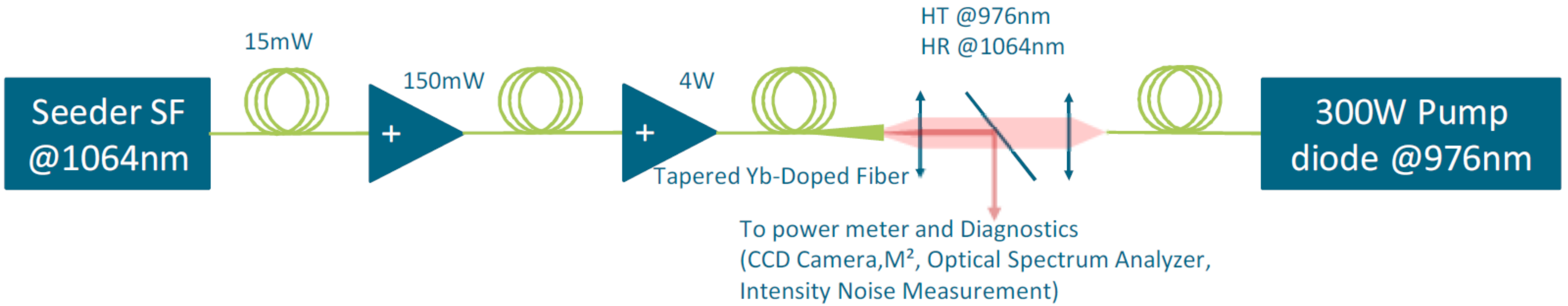
ALPHANOV 200 W AMPLIFIER

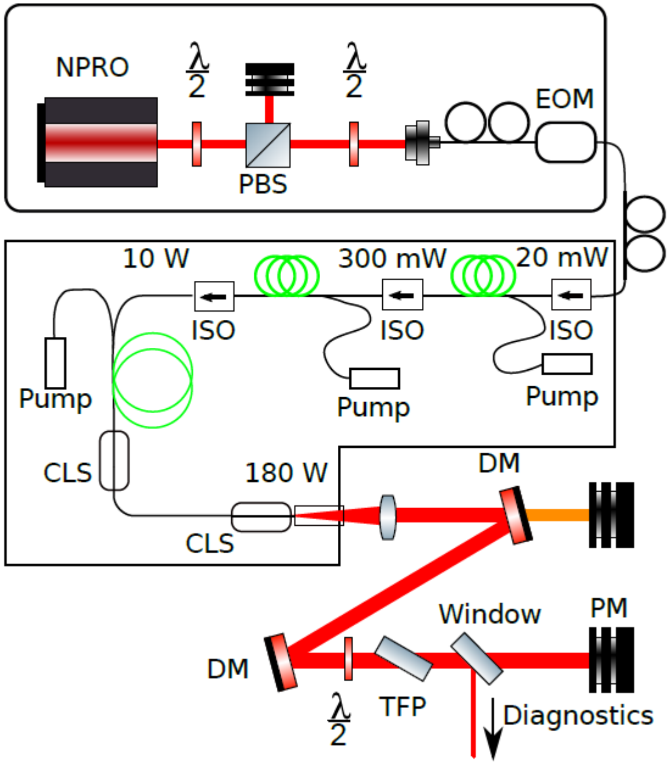
- See doi: 10.1117/12.2290424



- 3 stage design
- Custom fiber with long taper (free-space pumped)
- 200 W, no TEM_{00} measurement ($M^2 < 1.2$), operated for ca. 100 h
- No SBS (confirmed by noise measurements)

MIT 180 W AMPLIFIER

- See LIGO Document P1800387
- 3 stage design
- Specialty 35 µm step-index fiber (with 20 µm commercial passive fiber)
- 180 W with >90 % TEM_{00}
- 10 % output power variations (time varying beam quality in active fiber)
- Operated for 6 days, damaged due to seed drop-out



CONCLUSION

- Several groups demonstrated / working on fiber amplifiers at 1064 nm
  - LZH/AEI: 200 W (600 h)
  - VIRGO: 100 W (2500 h)
  - MIT: 180 W (6 days)
- Slightly more power than solid-state lasers, reliability is still an issue

- 100 W at 1550 nm
- Only technology (?) at 1550nm or 2000 nm