FIBER AMPLIFIERS FOR 3G DETECTORS

Michael Steinke on behalf of LZH/AEI team

Laser Zentrum Hannover, Germany
GWADW
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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

Fiber Amplifier

Seed laser in
Pump light
Amplified Laser 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

- 200W @ 1064nm
- 100W @ 1550nm

Diagram:
- Feasibility Study
- Functional PT
- Engineering PT
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Fiber amplifiers for 3G detectors
ISOLATION AND MONITORING STAGE

Fiber amplifiers for 3G detectors
SETUP

Fiber amplifiers for 3G detectors
Fiber amplifiers for 3G detectors

- 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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Measure MHz noise level: Most sensitive / relevant SBS detection method for GW application
See LIGO Document G1900507

- Measured asymmetric gain profile
- Assumed: 1/ν frequency noise of NPRO

- Intrinsic frequency noise of chosen seed laser technology matters
STIMULATED BRILLOUIN SCATTERING

Additional temperature gradient

No SBS
RELATIVE POINTING NOISE

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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200W @ 1064nm

100W @ 1550nm

Engineering PT

Functional PT

Proof of Concept

Feasibility Study
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)
We can now design, fabricate and draw fibers

Looking for collaborations (talk to me)
VIRGO (ALPHANOVO) 100 W AMPLIFIER

- 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
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)
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 dropout
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