Einstein Telescope : R&D Lasers

Margherita TURCONI & Walid CHAIBI, ARTEMIS, Observatoire de la Côte d'Azur

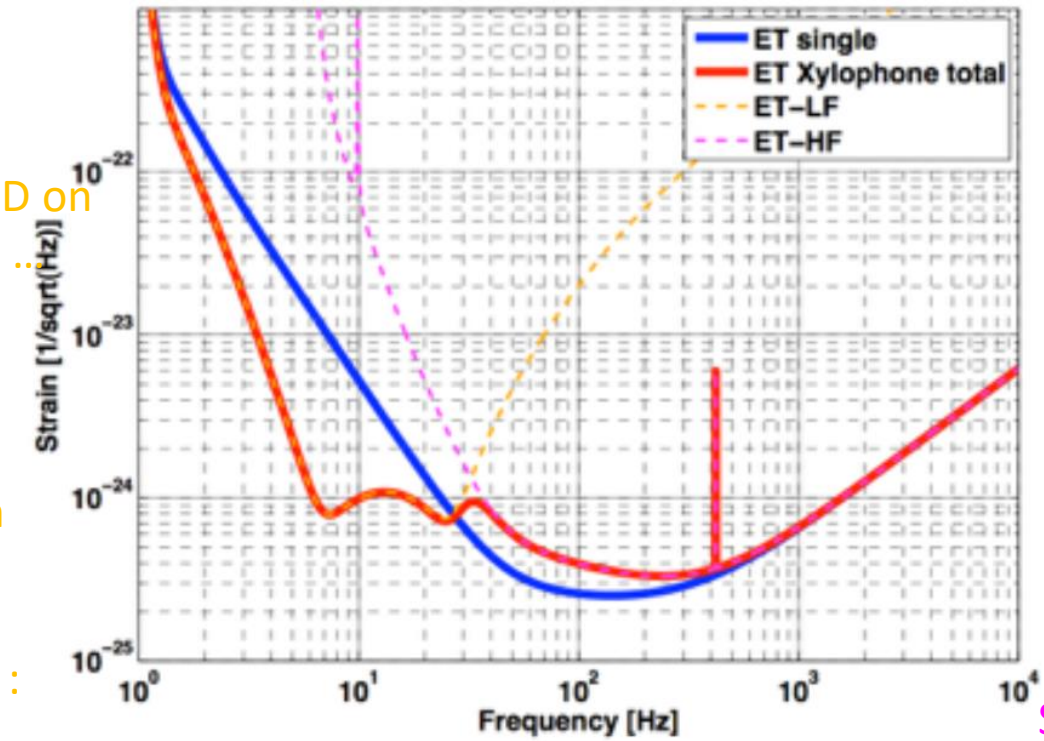
Workshop Workshop R&Ds - Développements Instrumentaux / Virgo-ET

ET laser requirements

Low frequency interferometer
- Design Wavelength : $\lambda = 1.5$ µm, R&D on longer wavelengths encouraged 2 µm, ..
- Laser Power: 5 W

Low frequency noise coupling through scattered light

- Exploring different technologies : Fiber laser, ECDL, NPRO
- Main constraint : Low noise



High frequency interferometer
- Wavelength : $\lambda = 1064$ nm
- Laser Power: 700W

Shot noise limited at high frequency

Baseline: Coherent Beam Combination of 2 or several

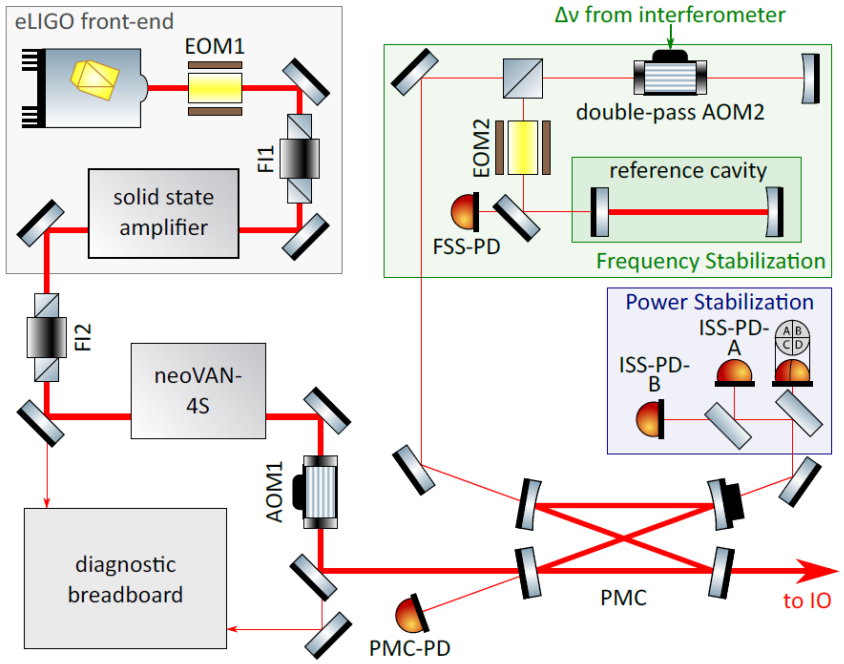
Content

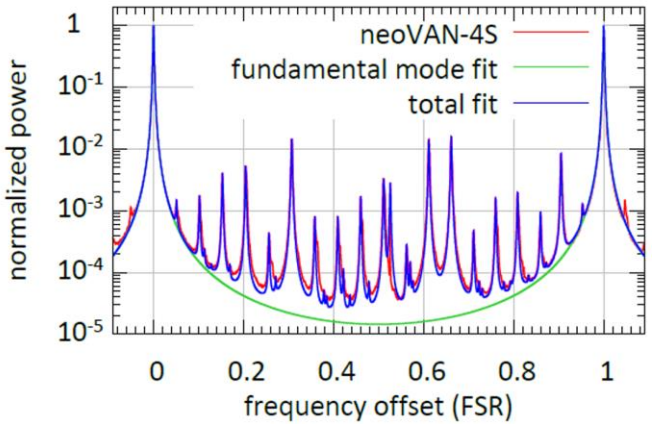
- Status of 1064 nm High power laser systems
  - Solid state lasers
  - Fiber lasers
- Status of 1500 nm lasers
- R&D plans in ARTEMIS

High power laser : The solid-state laser

MOPA (Master Oscillator Power Amplifier) configuration

LIGO O3 PSL (Pre-stabilized Laser) system



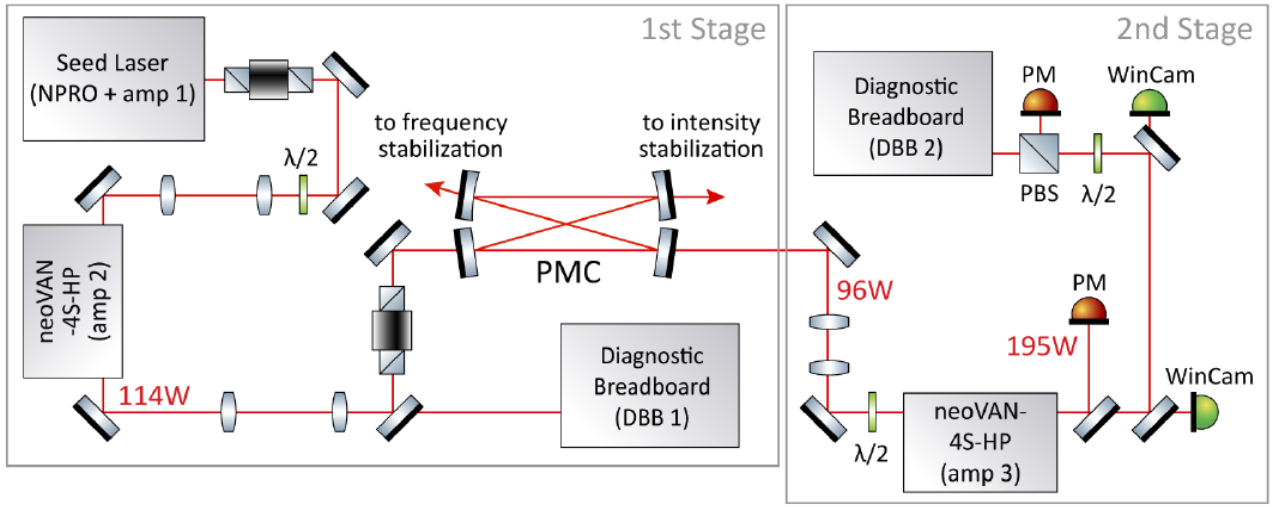


https://doi.org/10.3390/galaxies8040084 (2020)

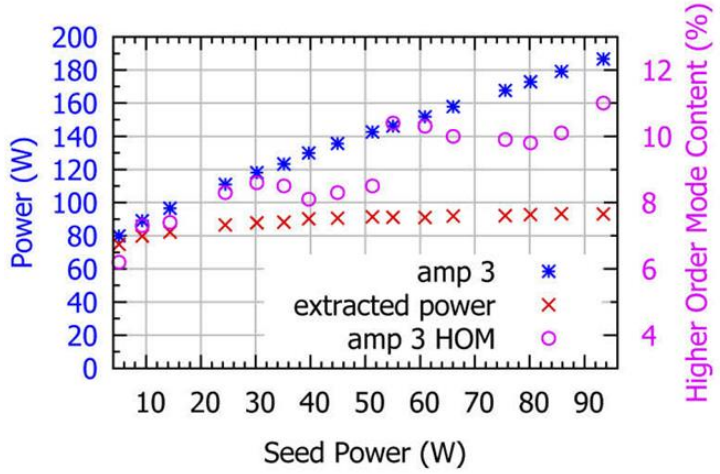
High power laser : The solid-state laser

LIGO O4 Laser MOPA laser system

2 sequential neoLASE amplifiers: neoVAN-4S-HP



https://doi.org/10.1364/OE.401826 (2020)



Lower beam quality at high power : limit of this technology

Another system at higher power:

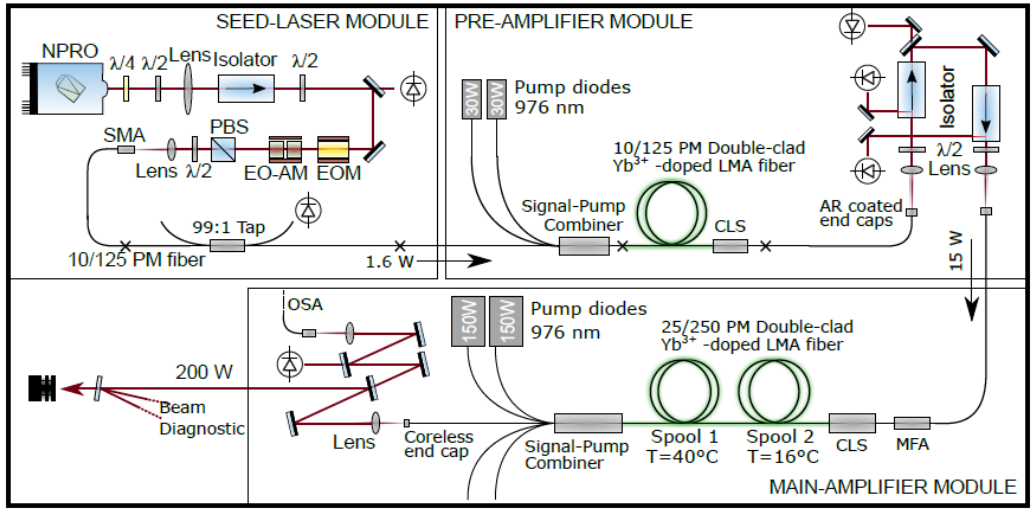
Fraunhofer-Institut für Lasertechnik ILT (https://doi.org/10.1117/12.2545934 (2020))

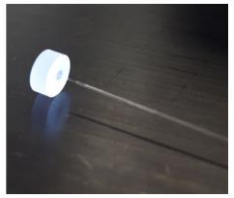
- Amplifier chain of a fiber amplifier (3W) and an innoslab solid state amplifier (Nd:YVO4) **437W**
- Poor beam quality $M^2 = 1.6$
- RIN Ok, no further characterization

Increasing the power : Fiber technology

Main issues :
- SBS (Stimulated Brillouin Scattering)
- Photodarkening : Colored centers absorption
- TMI (Transverse Mode Instabilities)

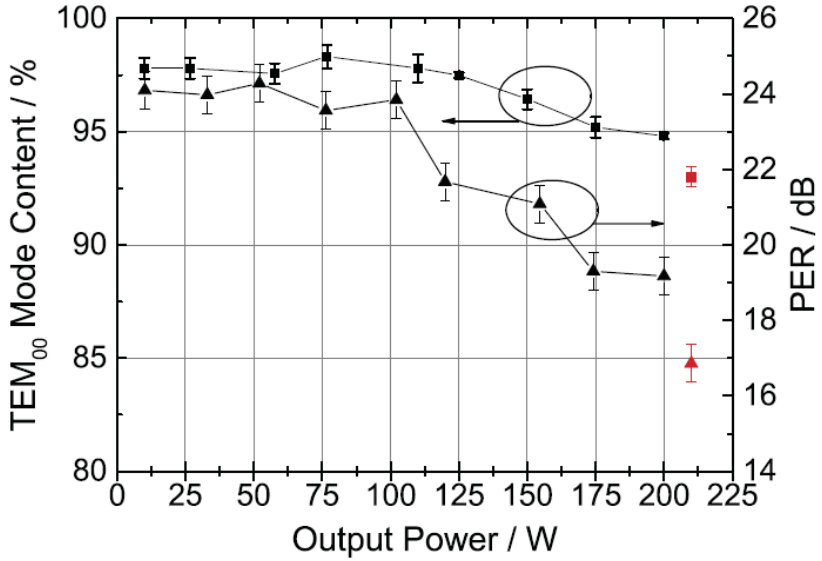
LZH : “standard” alumino-silicate fibers + end-cap free injection signal + counterpropagative pump





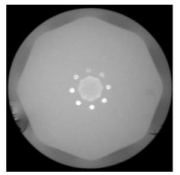
https://doi.org/10.1364/OE.27.028523 (2019)

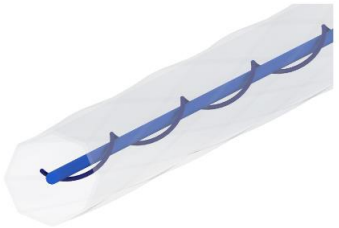
Mode content & PER

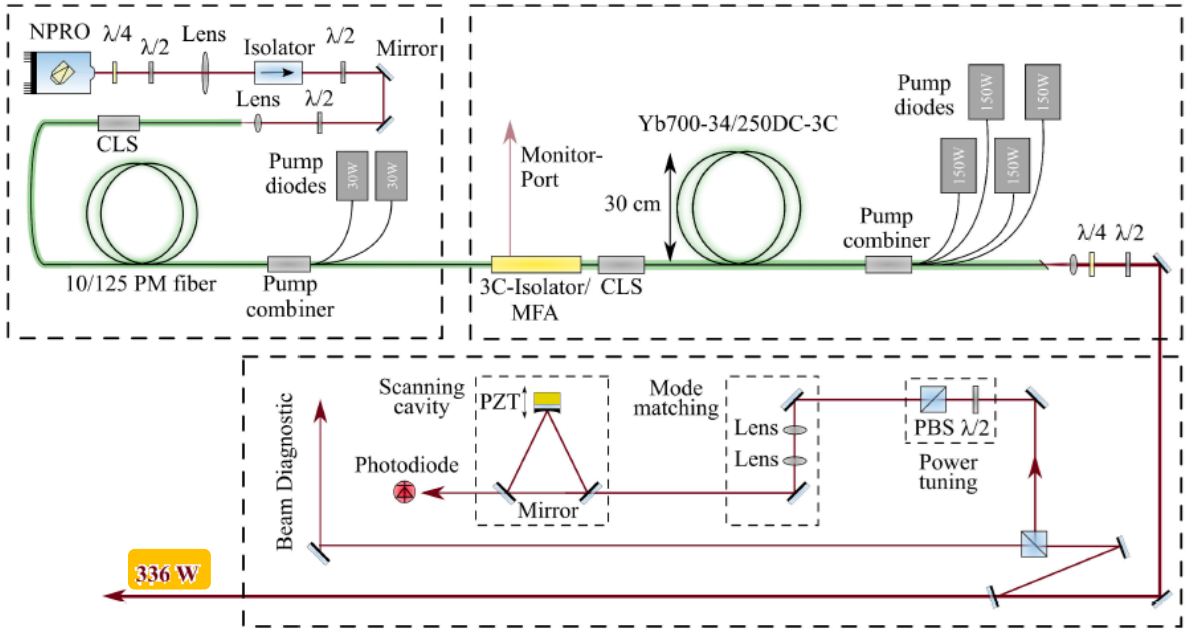


Increasing the power : Fiber technology

LZH : 3C fiber : Chirally-Coupled Core (SM)

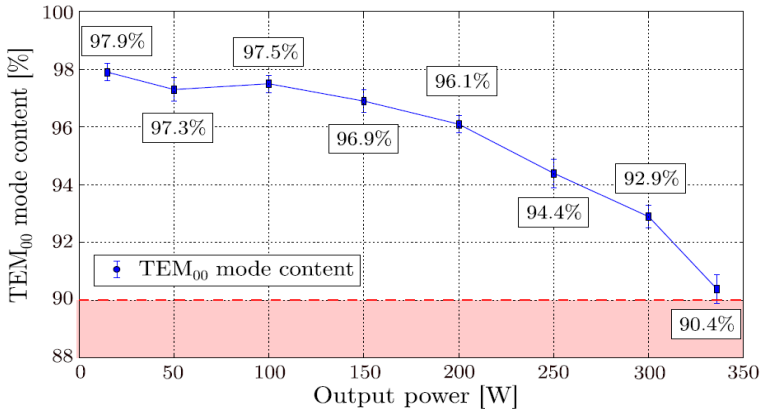


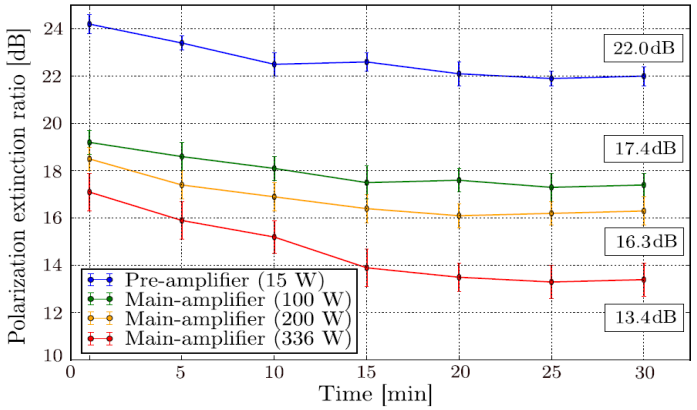




DOI:10.1109/JLT.2021.3133814 (2022)

Mode content & PER

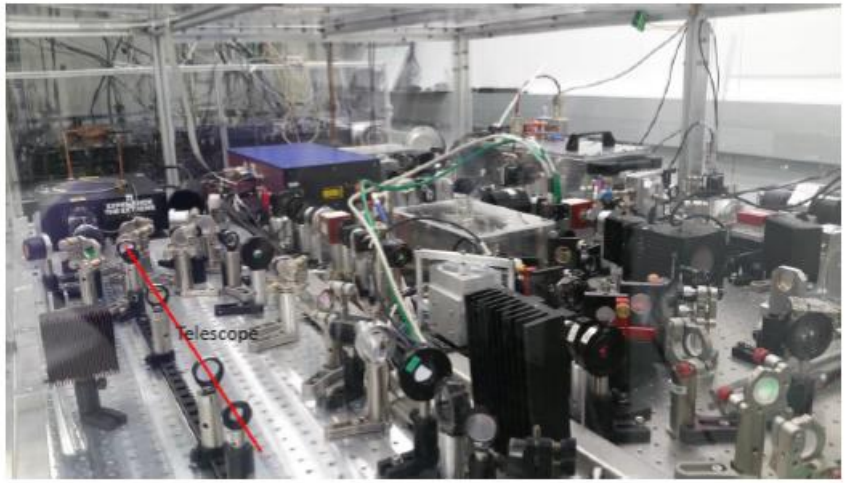


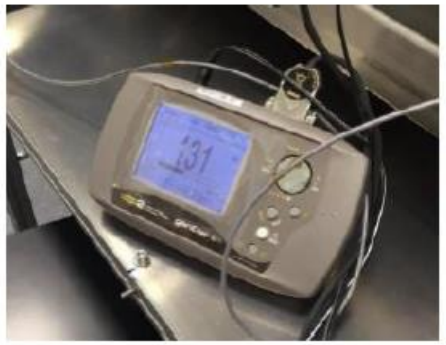


Increasing the power : Fiber technology

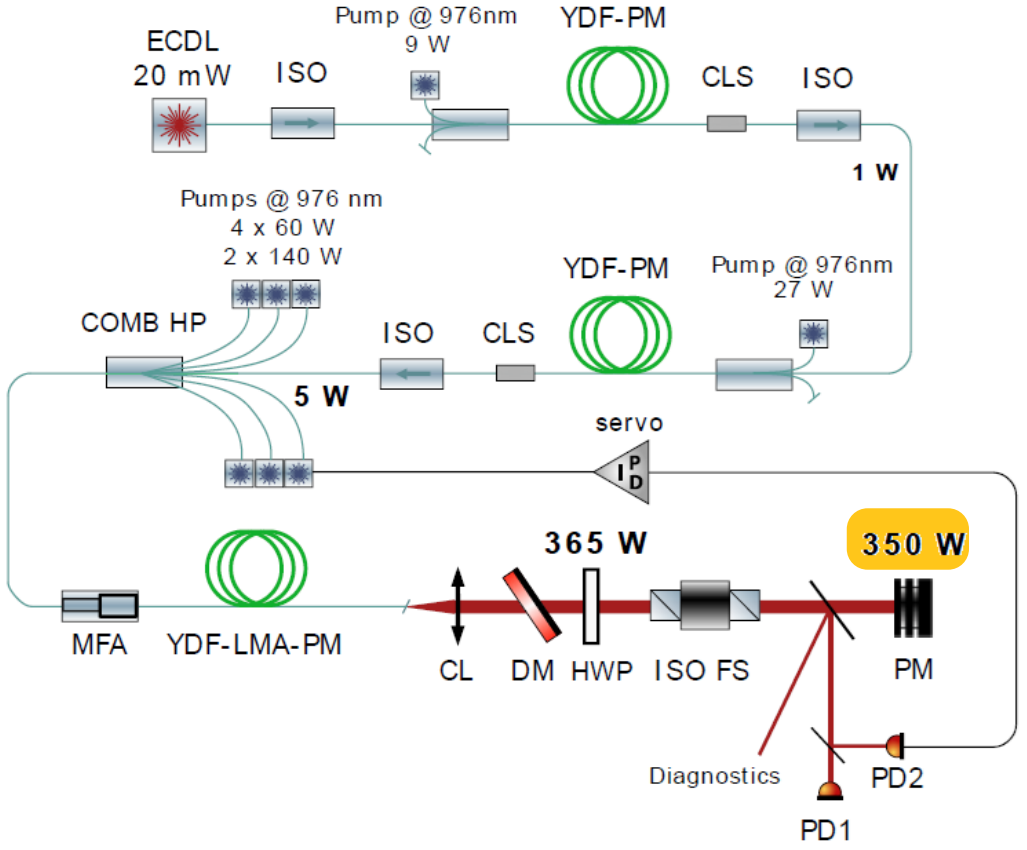
ARTEMIS - ALS(Toptica) - ALPHANOV
- All fibered system : Mode Field adapter (MFA)
- Phosphosilicate fiber : photodarkening free

https://doi.org/10.1364/OE.385095 (2020)





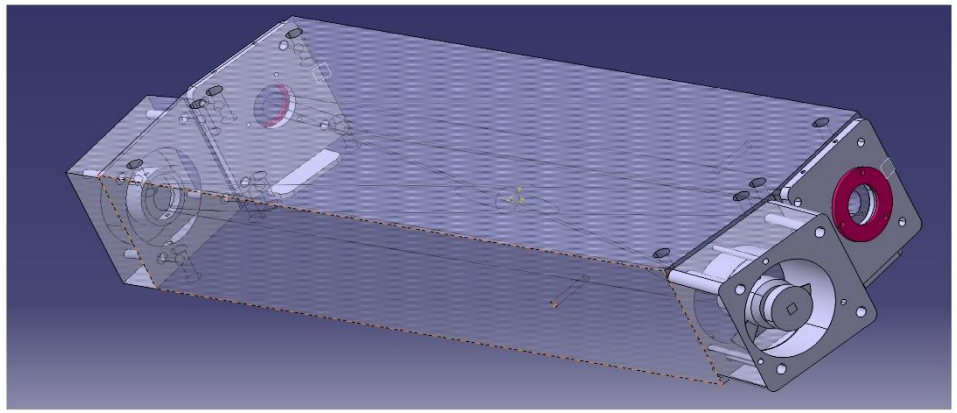
Installed and tested on Virgo



- Robustness issue
- High frequency phase noise ; common to fiber technology : to be solved…

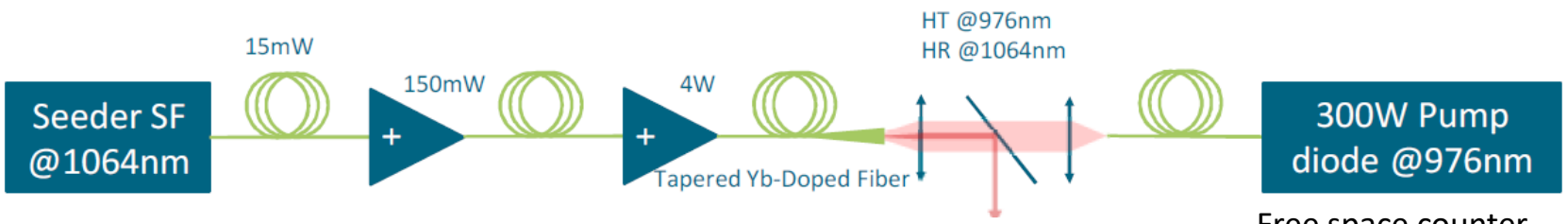
ARTEMIS – Exploratory program

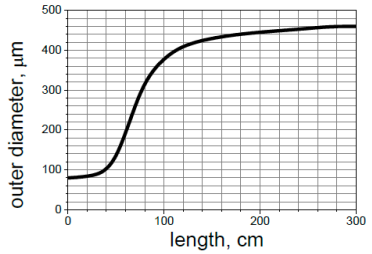
Higher finesse PMC



Long term coatings' behavior

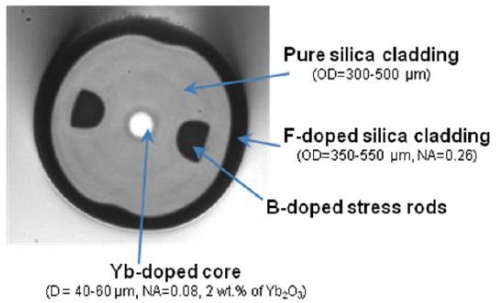
Tapered fibers + pump free injection





Free space counter-propagating pumping

Innovation company «FORC — Photonics» | Institution of the Russian Academy of Sciences Fiber Optics Research Center RAS | FORC RAS

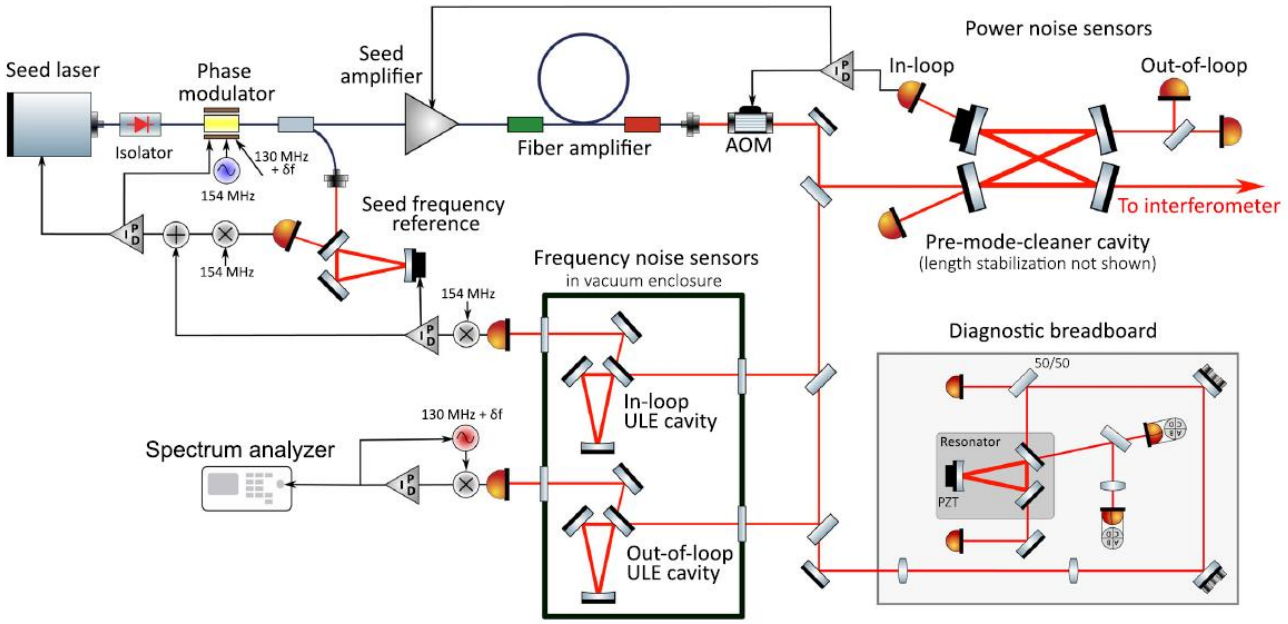


https://doi.org/10.1117/12.2290424 (2018)

Low frequency interferometer

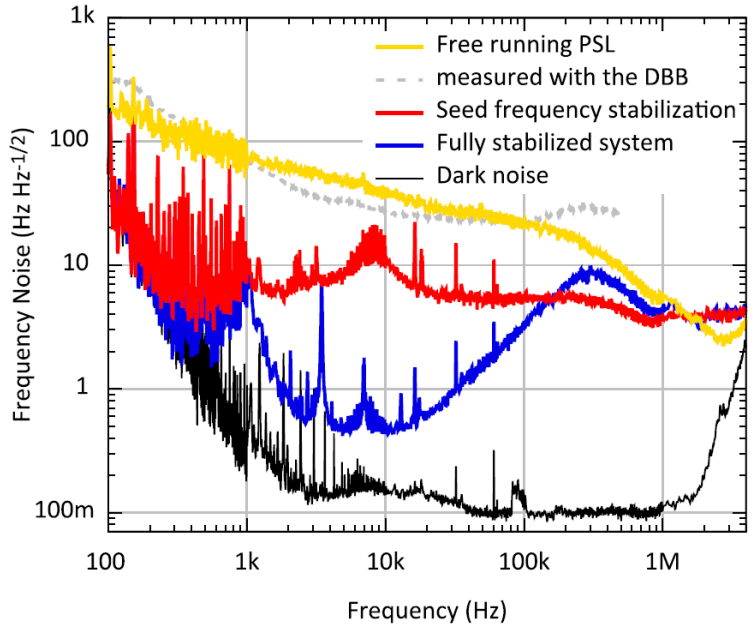
Several technologies for higher wavelengths

AEI Hannover : RIO ECDL +fiber amplifiers



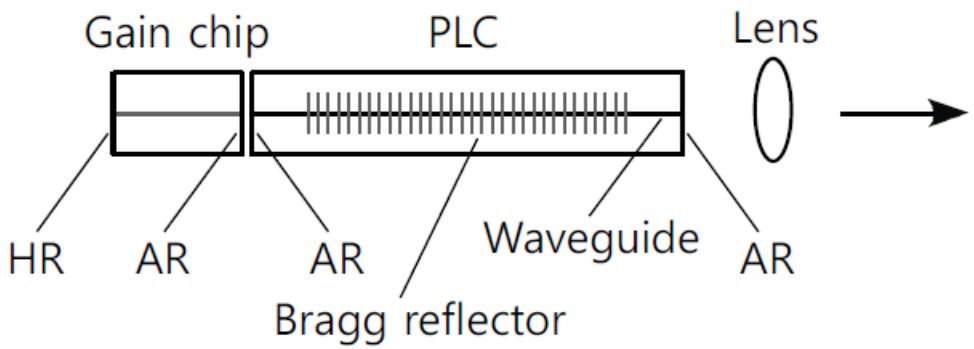
DOI: 10.1103/PhysRevD.105.122004 (2022)

Frequency noise



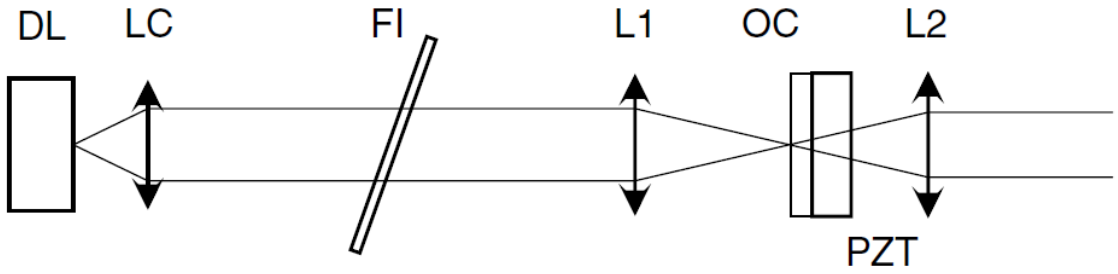
Extended Cavity Diode Laser (ECDL)

RIO system



https://doi.org/10.1364/OE.18.022781

SYRTE



https://doi.org/10.1016/j.optcom.2006.05.011

➡ ARTEMIS - Exploratory program on selective optics

THANK YOU FOR YOUR ATTENTION!