High power fiber laser research, with Advanced Virgo and ET applications

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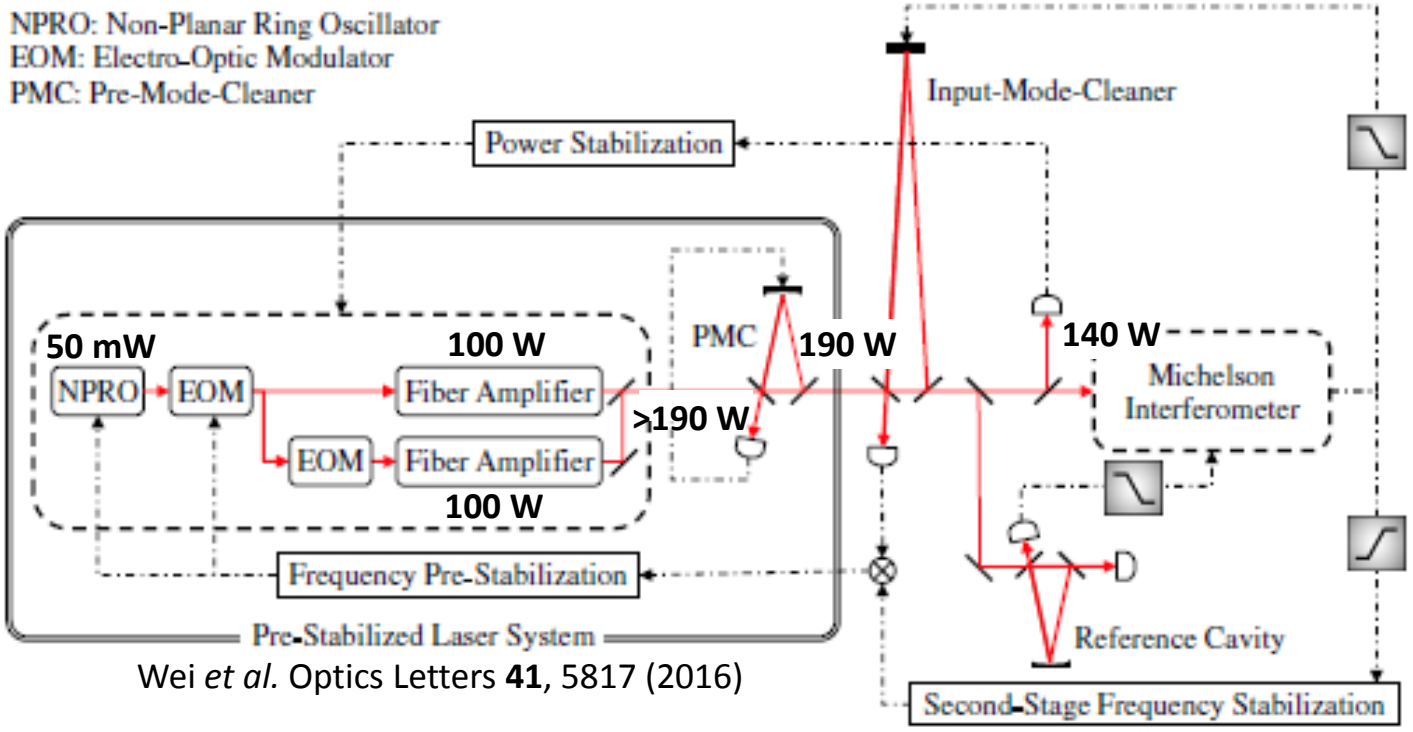
Advanced Virgo Pre-Stabilized Laser

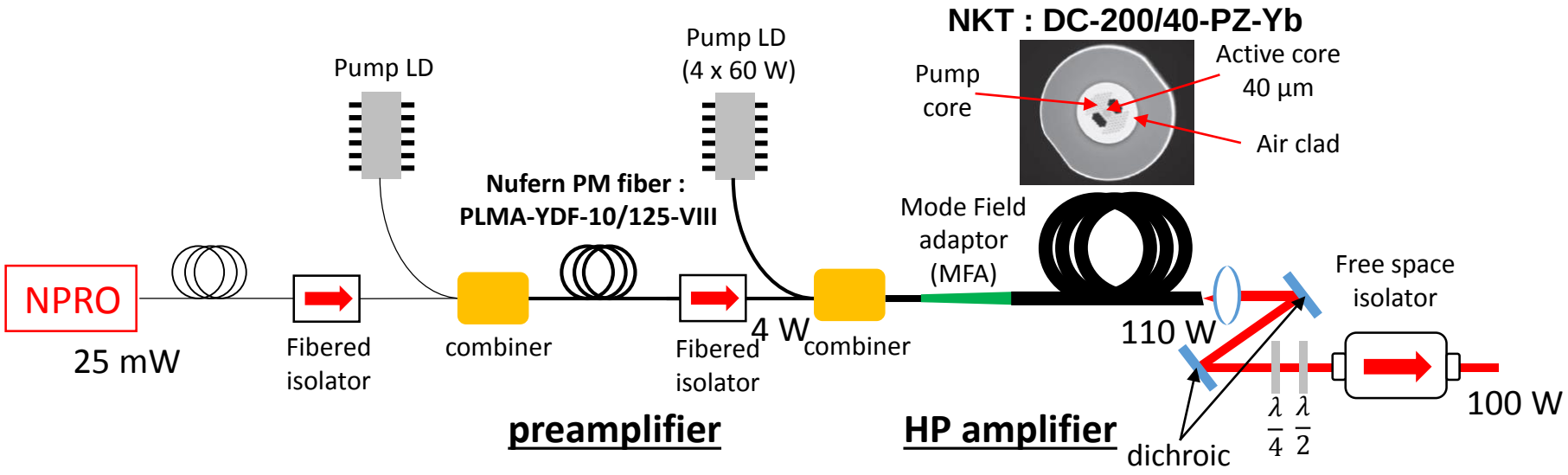


Wei *et al.* Optics Letters **41**, 5817 (2016)

Advanced Virgo requirements :

- Input power : 125W ➡ with parametric instabilities : < 50W
- Gaussian mode content : >90%
- RIN : Relative intensity noise
- Phase noise added by the amplification process : 7 orders of magnitude with respect to NPRO (G. Santarelli LP2N)
- Beam pointing noise : into intensity noise by the PMC
- Long term operation : peak to peak fluctuations +/- 2% for months

100W single unit : All fibered design (ALS + Alphanov)



- Custom design MFA (Alphanov)

- NKT High power polarizing fiber

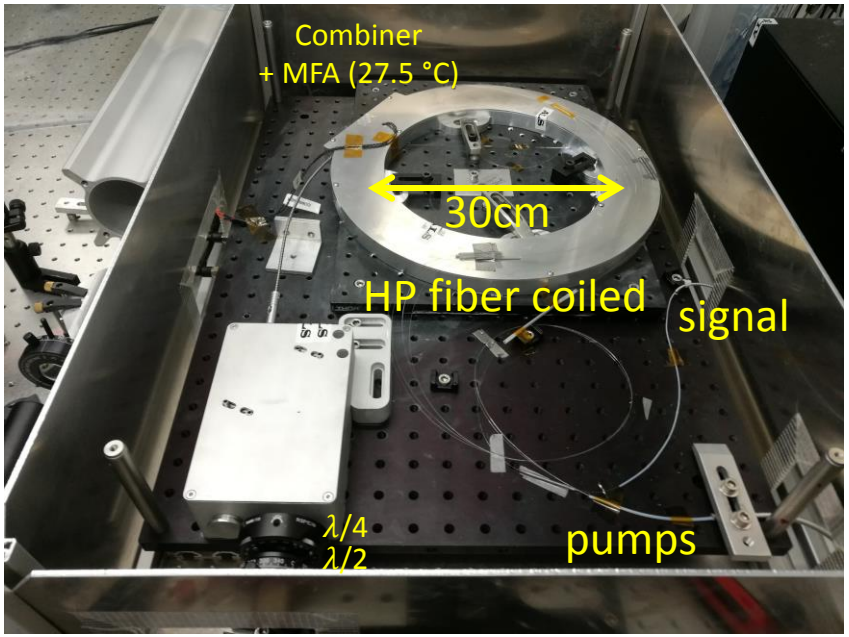
- Large mode area 760 µm² : Stimulated Brillouin Scattering (SBS) limits the power >300 W.

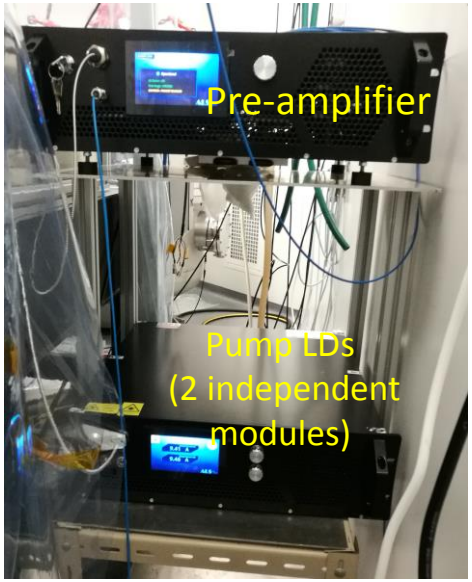
All fibered design (ALS + Alphanov)

MFA T°

Combiner T°

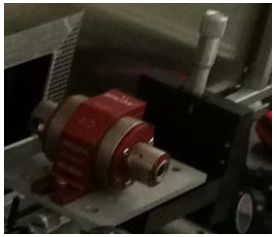
Datas : pumps current, seeder power, pre-amplifier power





Chiller 2

18°C : stabilizing the fiber T° + controlling the combiner + MFA T°



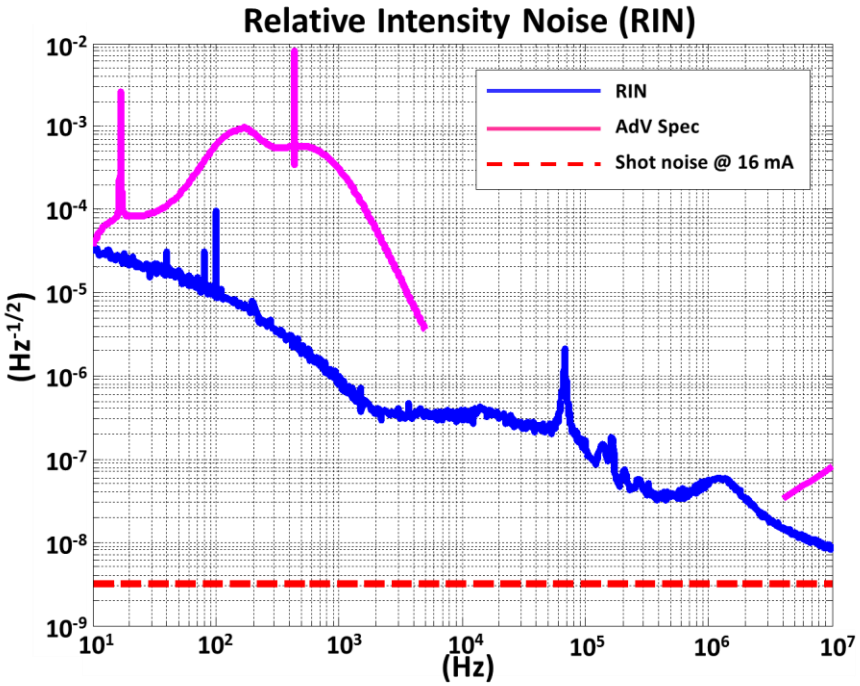
isolator

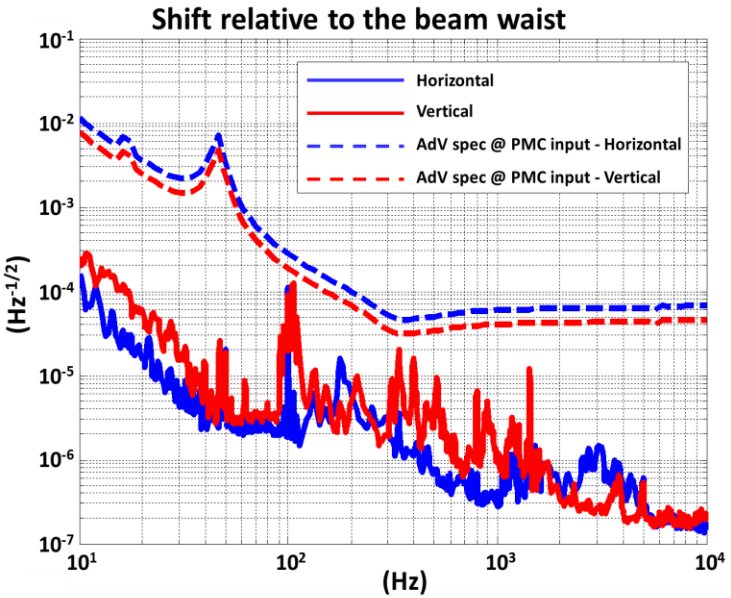
Slow (50%) and fast (few %) control of the power

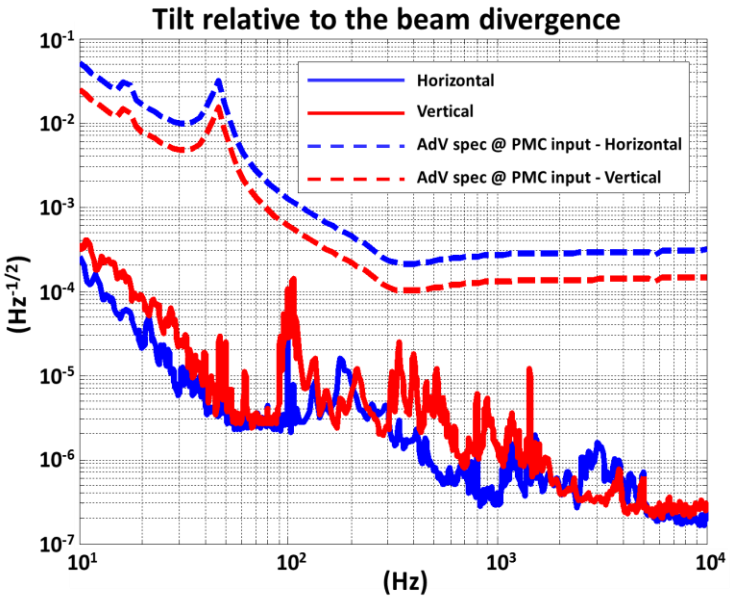
Chiller 1

Heat extraction

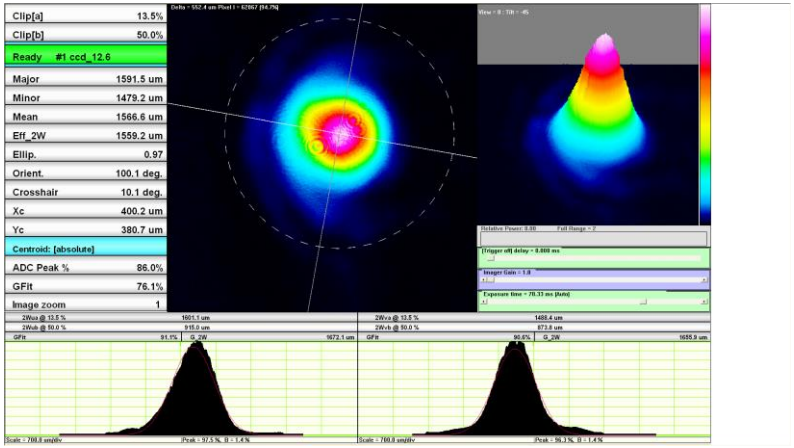
System characterization : RIN and Beam Pointing Noise



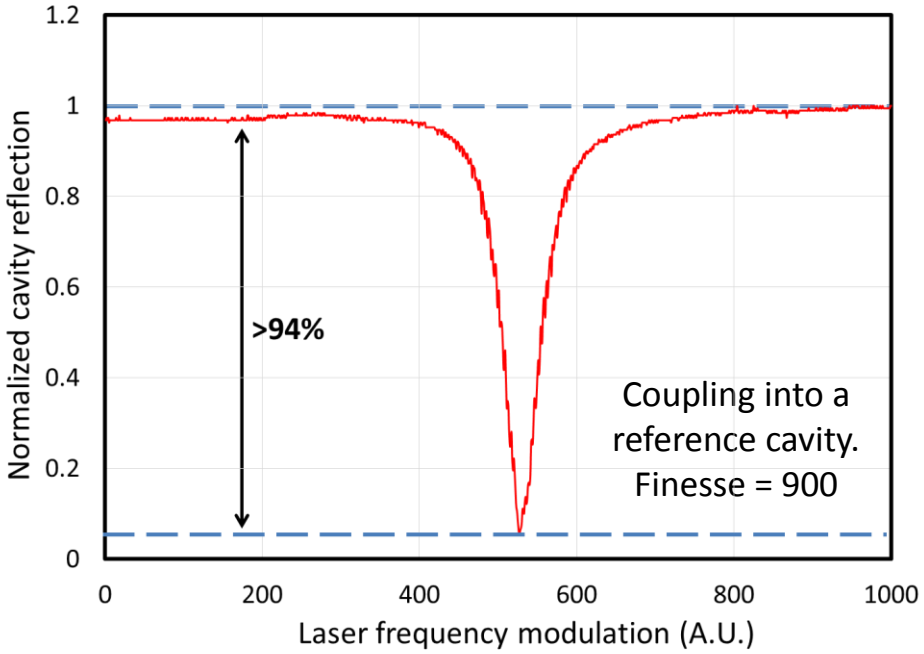


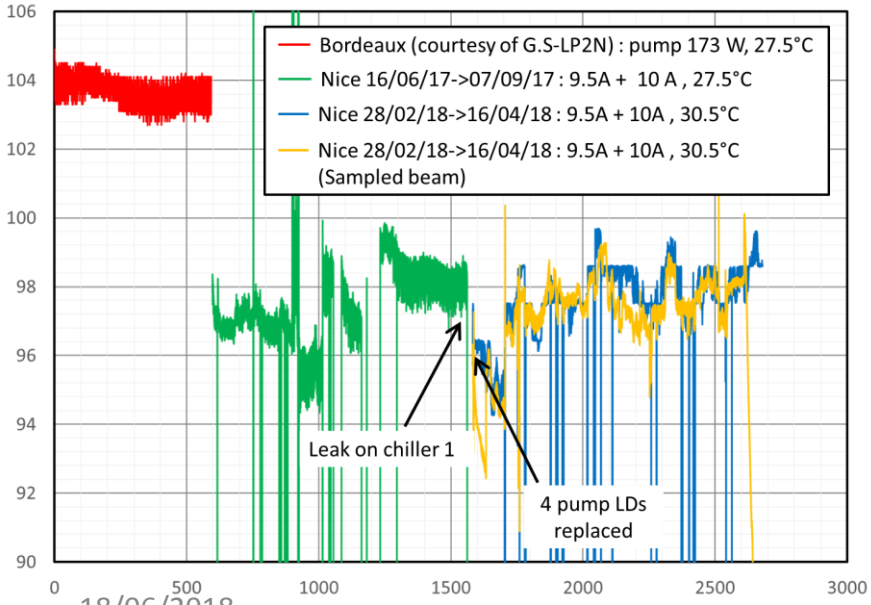


System characterization : Beam quality and long term operation



Beam shape, radius @ waist ~ 600 µm

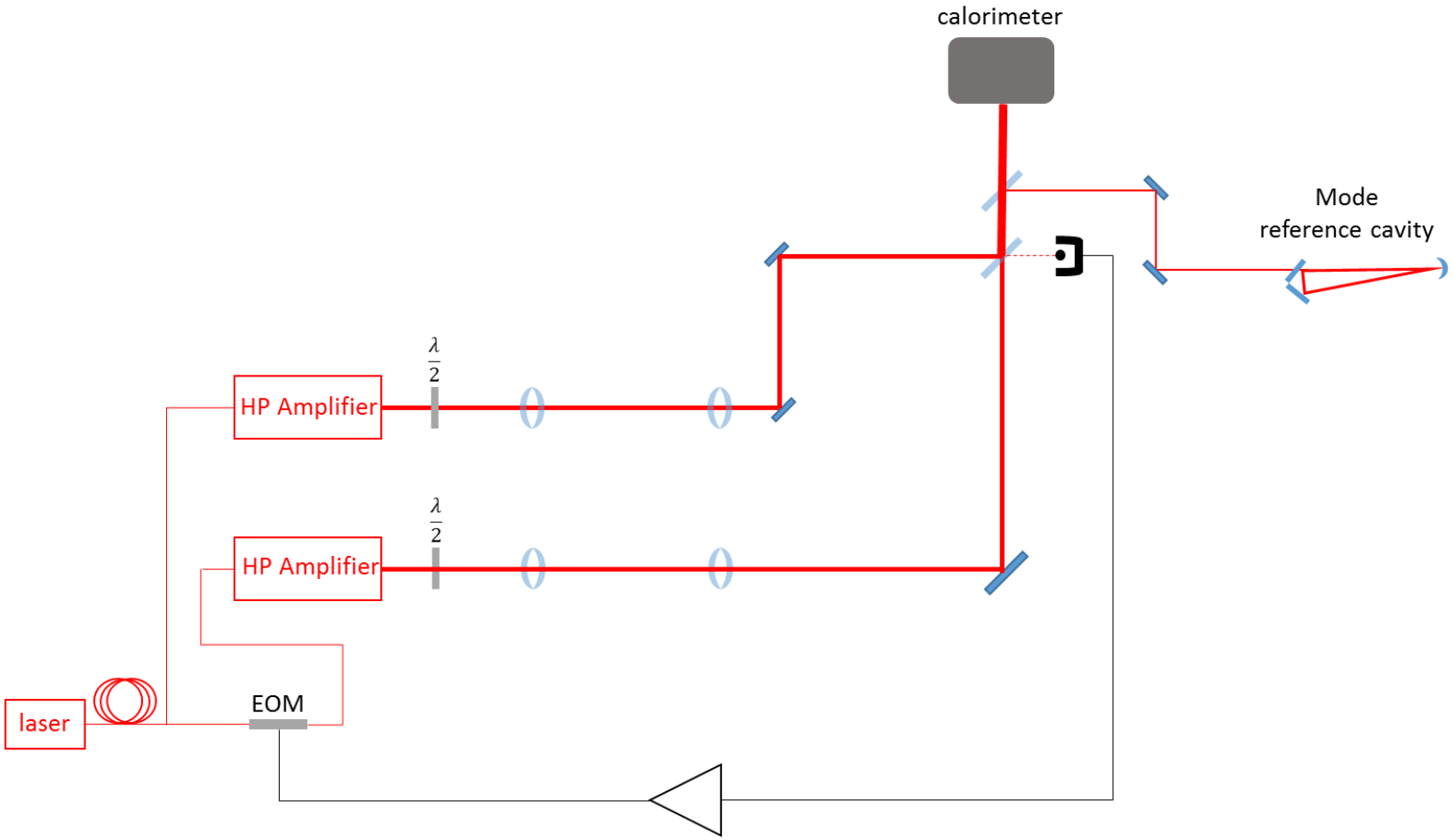




Overall functioning time > 2500 h, 3W peak to peak

Zhao *et al.*, App.Phys. B **124**, 114 (2018)

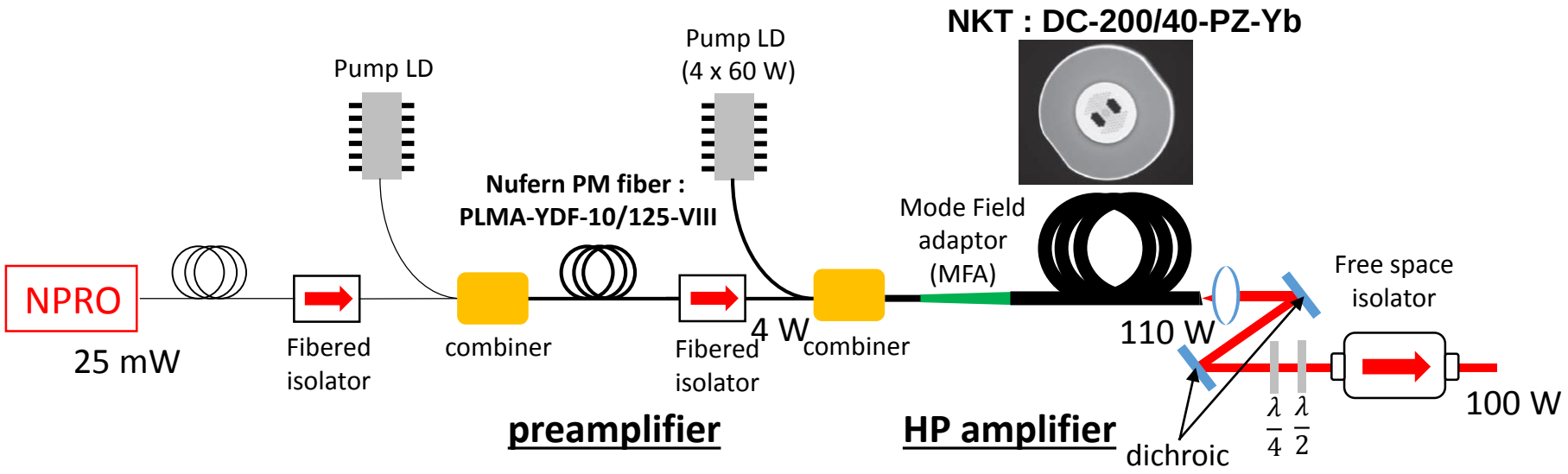
Coherent beam combination CBC



Triangular cavity as a mode reference cavity on which the two beams are adapted

Towards ET…

Einstein Telescope high power interferometer → ~ 1kW input, 3MW intracavity



Critical points :

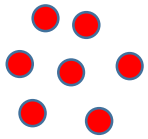
- Signal and pumps combination and coupling into the High power fiber

- Photodarkening

- Transverse mode instability (TMI)

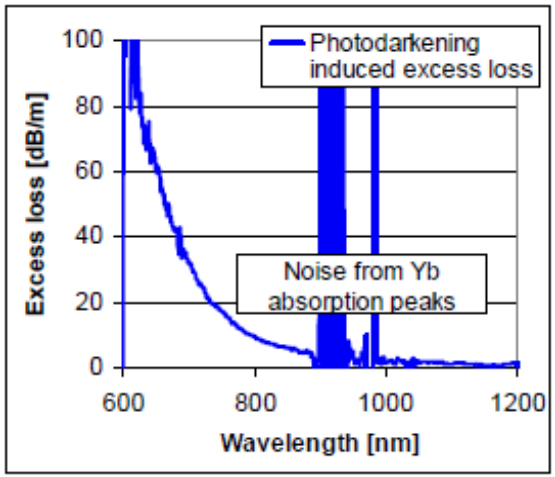
All fibered design (ALS + Alphanov)

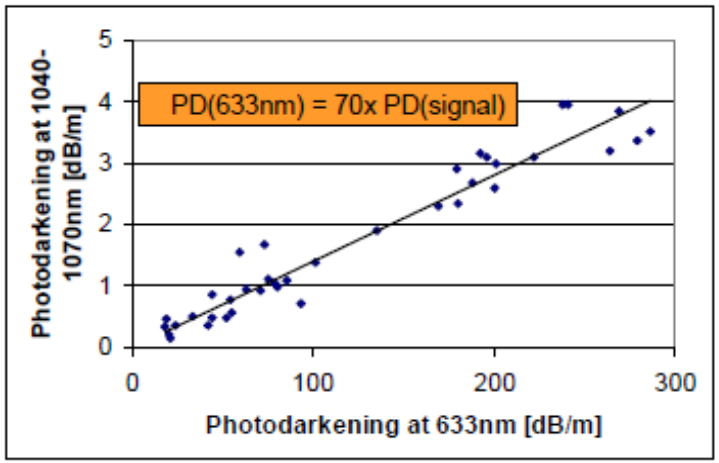
Photodarkening : generation of color centers



6 to 7 Yb^{3+} in excited level

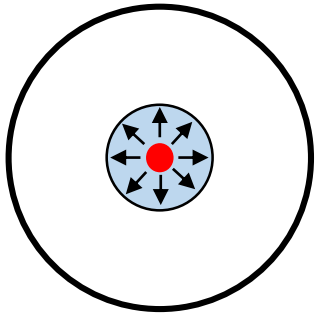
- Highly non linear
- Depends on the pump & signal spatial distribution





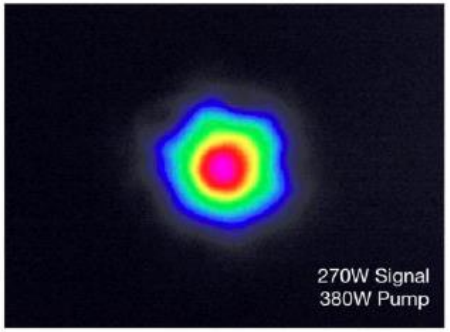
Koponen *et al.*, Proc of SPIE **5990**, 599008 (2005)

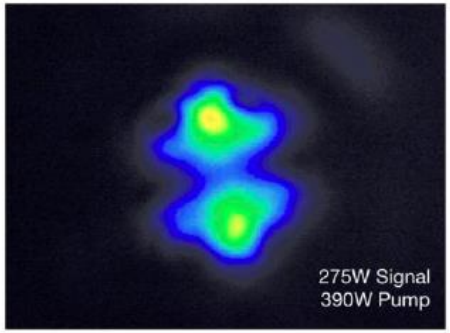
Transverse Mode Instability (TMI)



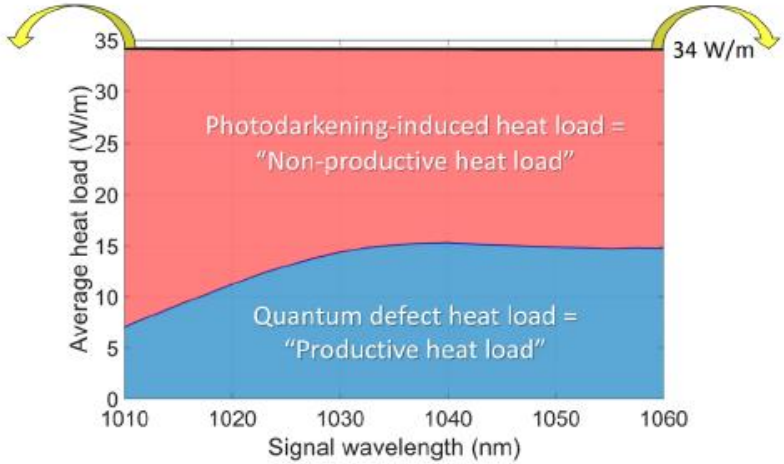
High power transverse mode → Temperature gradient = index gradient

Eidam *et al.*, OPTICS EXPRESS **19**, 13218 (2011)





Modification of the guiding structure → Transverse mode instability



Jauregui *et al.*, OPTICS EXPRESS 23, 20204(2015)

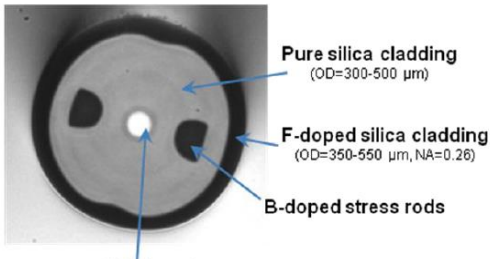
→ Irreversible grating inscription

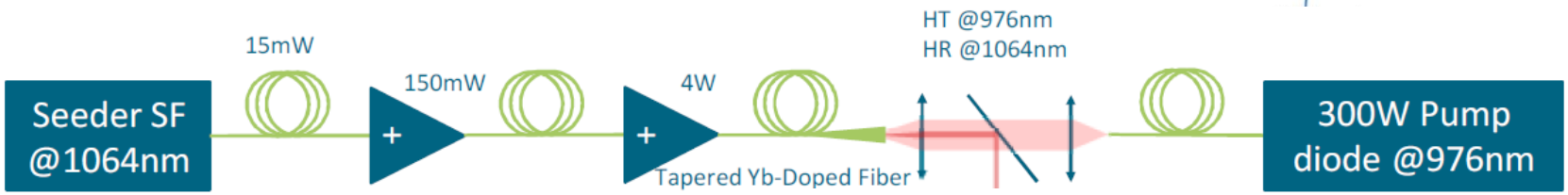
→ @1.5 µm, less phtodarkening, but higher quantum defect…

200W amplifier based tapered fiber (Alphanov)

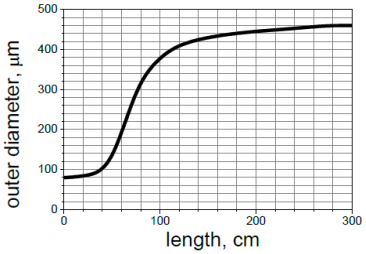
Alumino-silicate ⇒ Phospho-silicate, a better dilution of Yb : less photodarkening

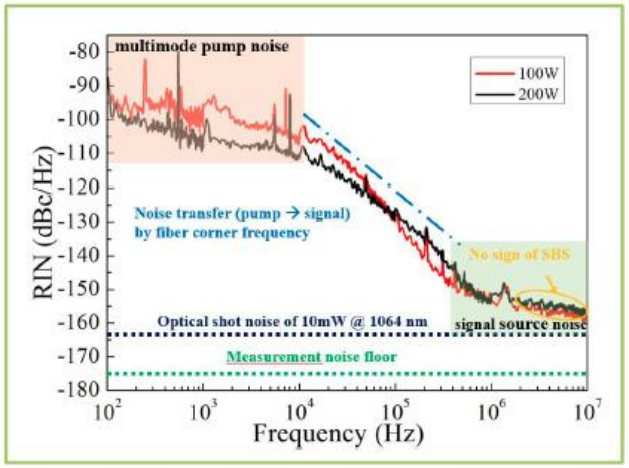
Innovation company «FORC — Photonics» Institution of the Russian Academy of Sciences Fiber Optics Research Center RAS FORC RAS

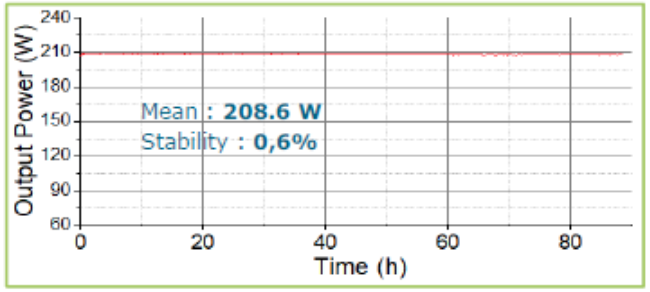




Free space counter-propagating pumping







Pierre *et al.*, Proc of SPIE **10512**, 105122A-1 (2018)

Conclusion

- 100 W fiber laser fulfills the Advanced Virgo specifications as a single unit for coherent summation.

- Fiber technology is evolving fast enough. CBC as a back up