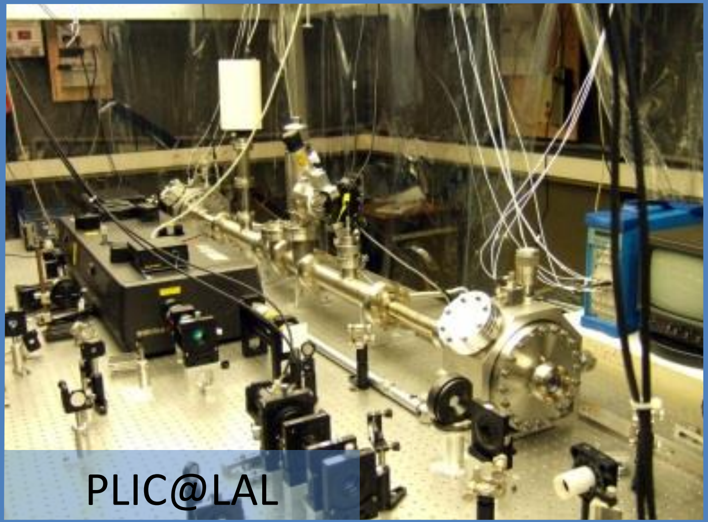
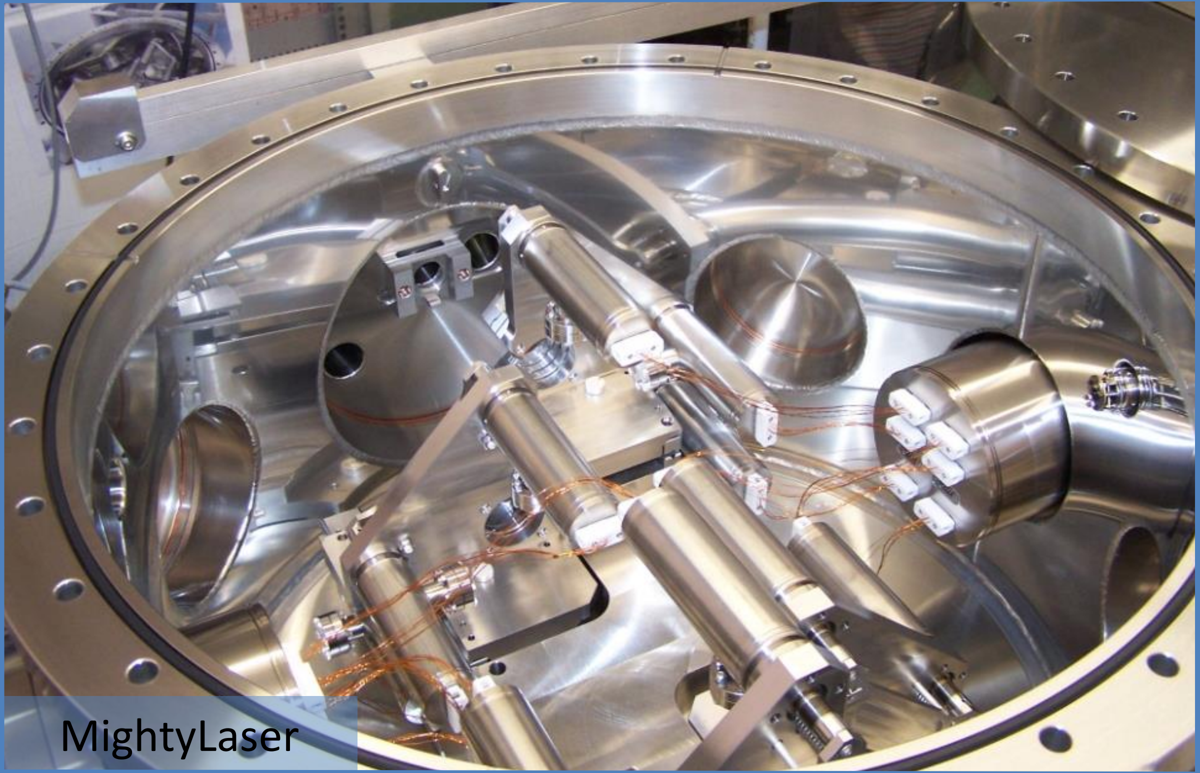
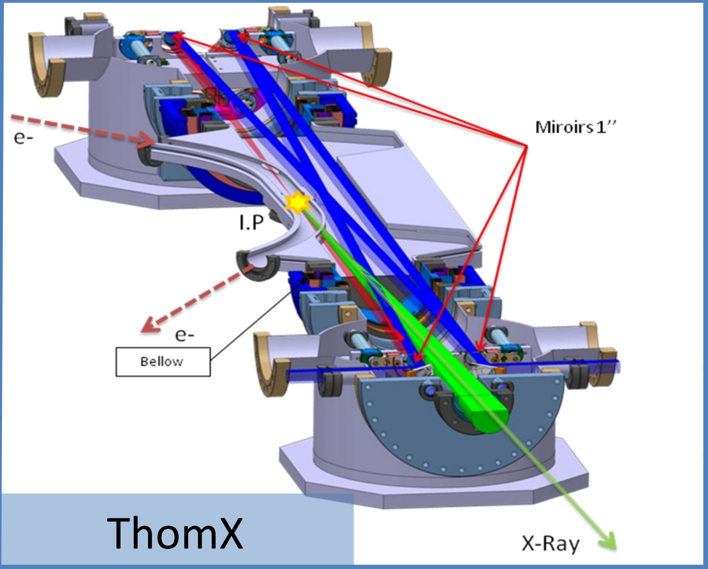
MightyLaser: setup, results & perspectives

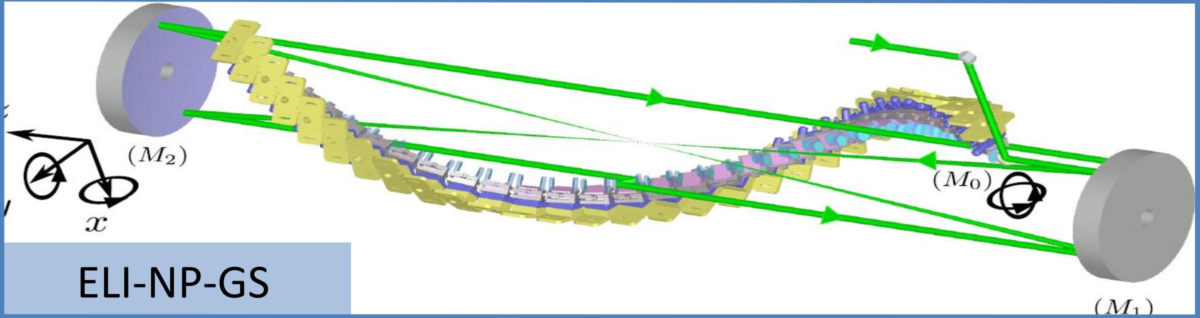
Aurélien MARTENS for MightyLaser

LAL, CELIA, KEK, LMA

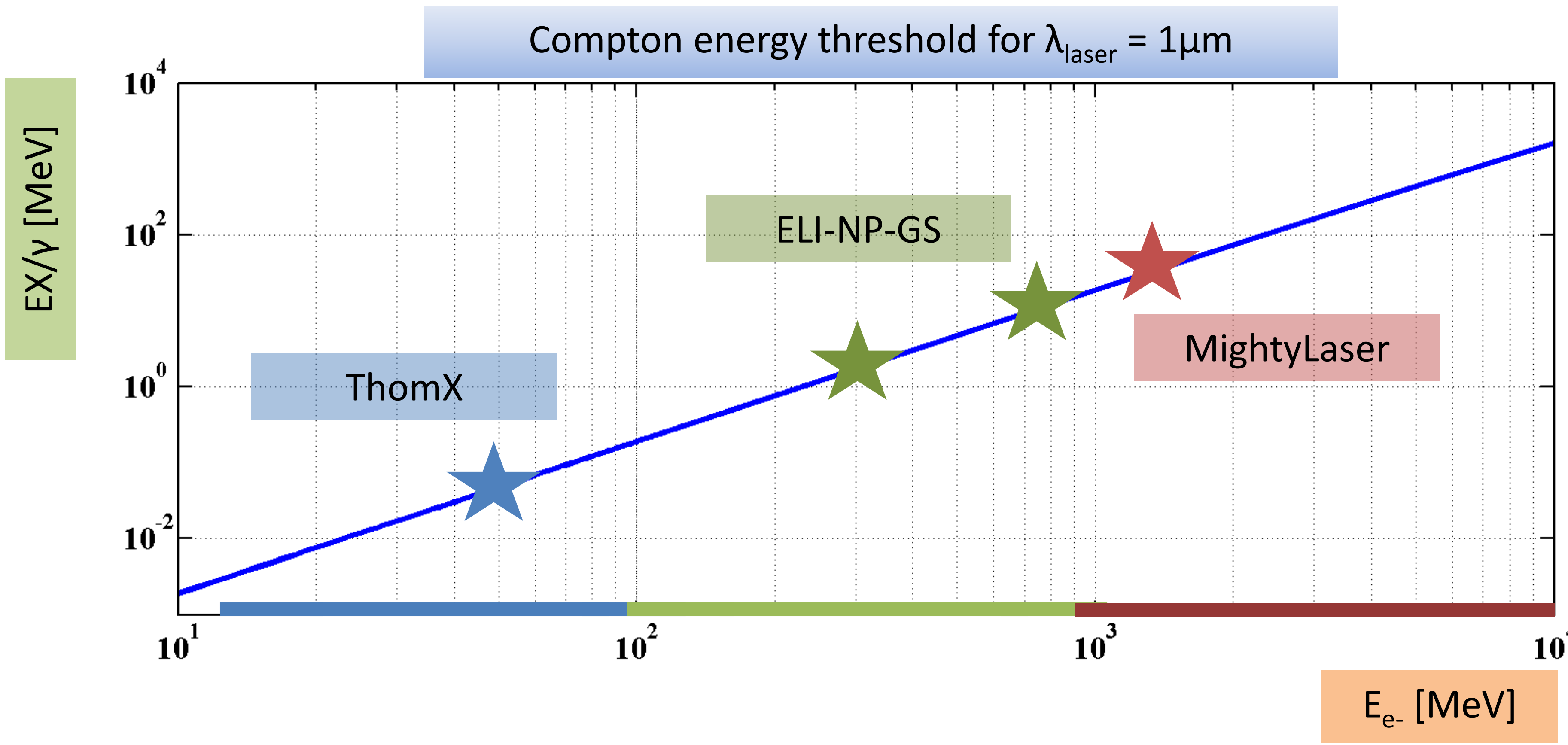








Applications of Compton scattering: $e^- + h\nu \rightarrow e^- + X/\gamma$



~10-1MeV
Low energy applications

Radiography & Radiotherapy
Museology
…

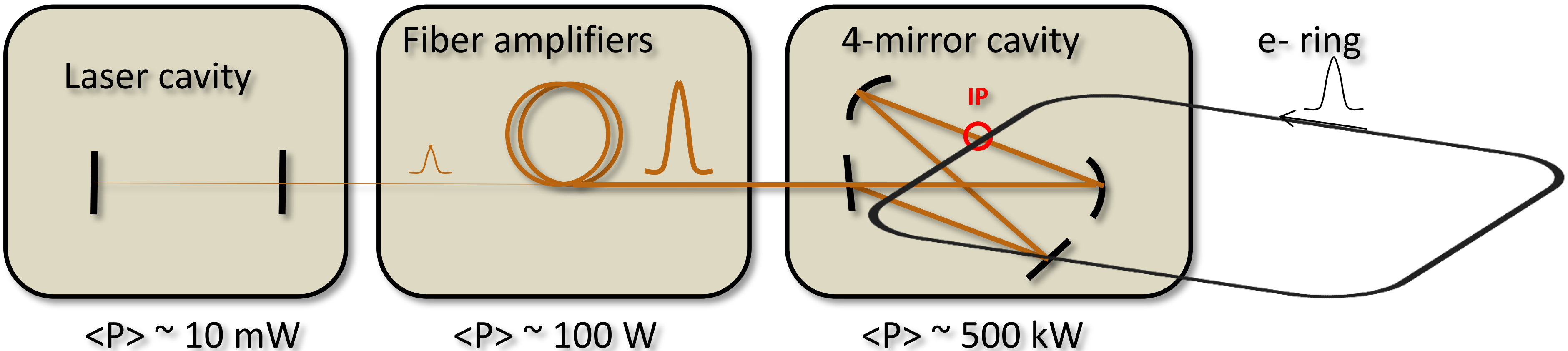
~1MeV-100MeV
Nuclear fluorescence

Nuclear physics
Nuclear survey
Nuclear waste management
…

>100MeV
High energy applications

Compton polarimeter
γγ collider
Polarised positron source
…

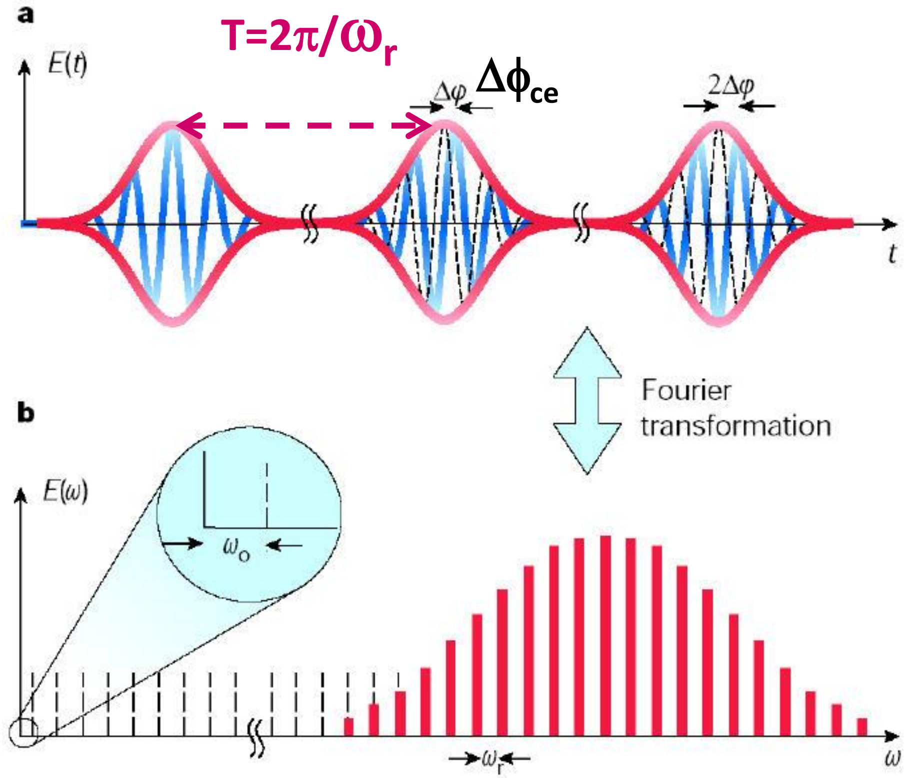
MightyLaser strategy and goal



Courtesy: E. Cormier, CELIA

Ultimately: reach MW stored power in cavity

Properties of passive mode locked lasers



The whole comb must be locked:
dilatation (f_{rep})
translation (f_{CEP})

T. Udem et al. Nature 416 (2002) 233

$$F = \frac{\nu}{\Delta\nu} = 30000$$

$$\nu = 178.5 MHz$$

$$\Delta\nu = 6kHz$$

Phase noise of the laser must be low to lock to a high finesse cavity

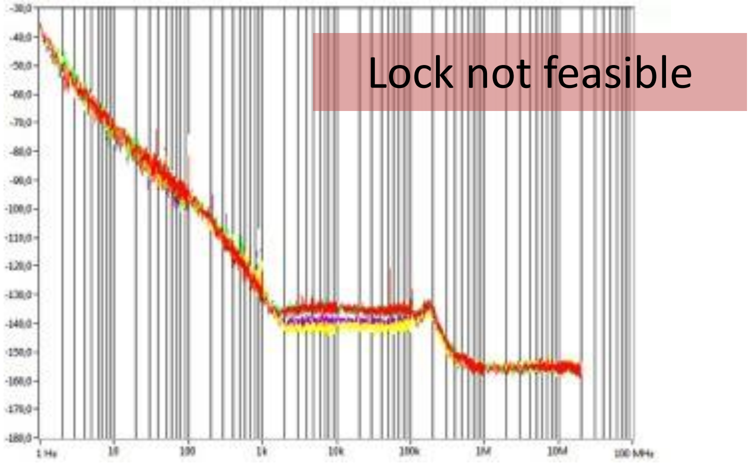
Noise limits coupling

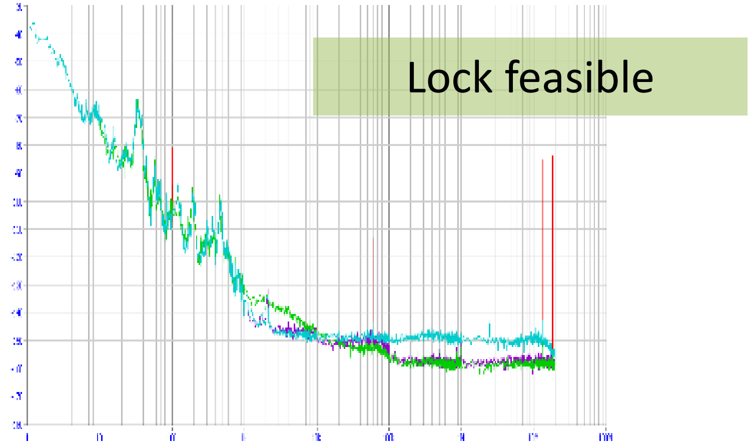
Laser choice

OneFive Genki
- ✓ P = 2 W

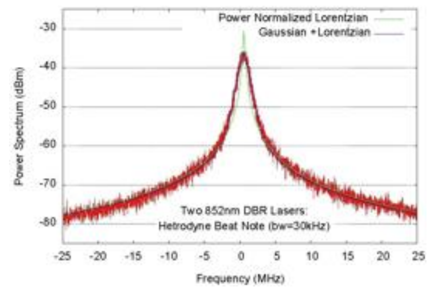
OneFive Origami
- ✓ P = 200 mW

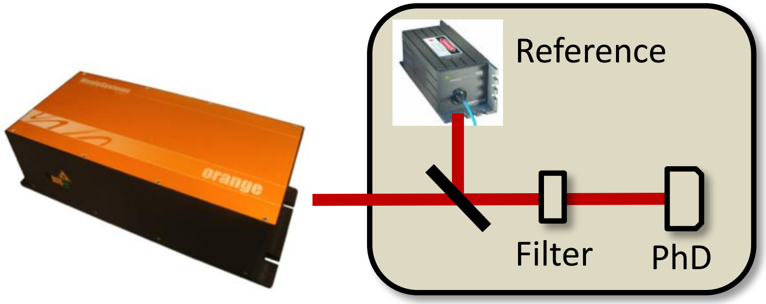
Memlo Orange
- ✓ P = 20 mW

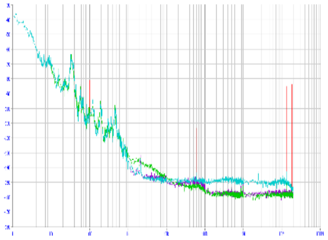




Phase noise measurement (ongoing)



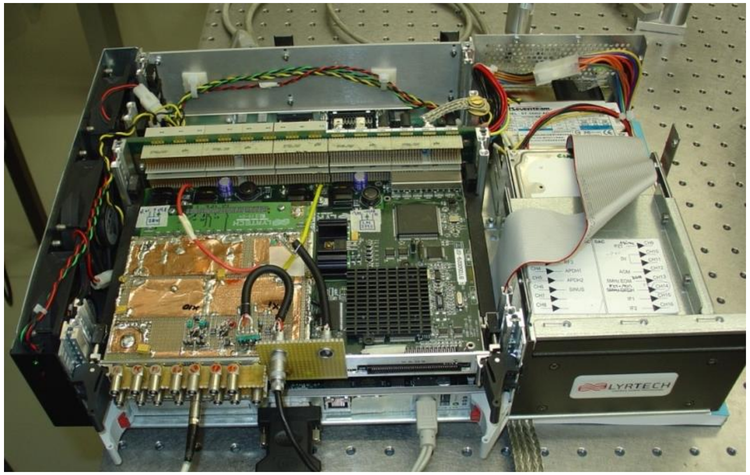




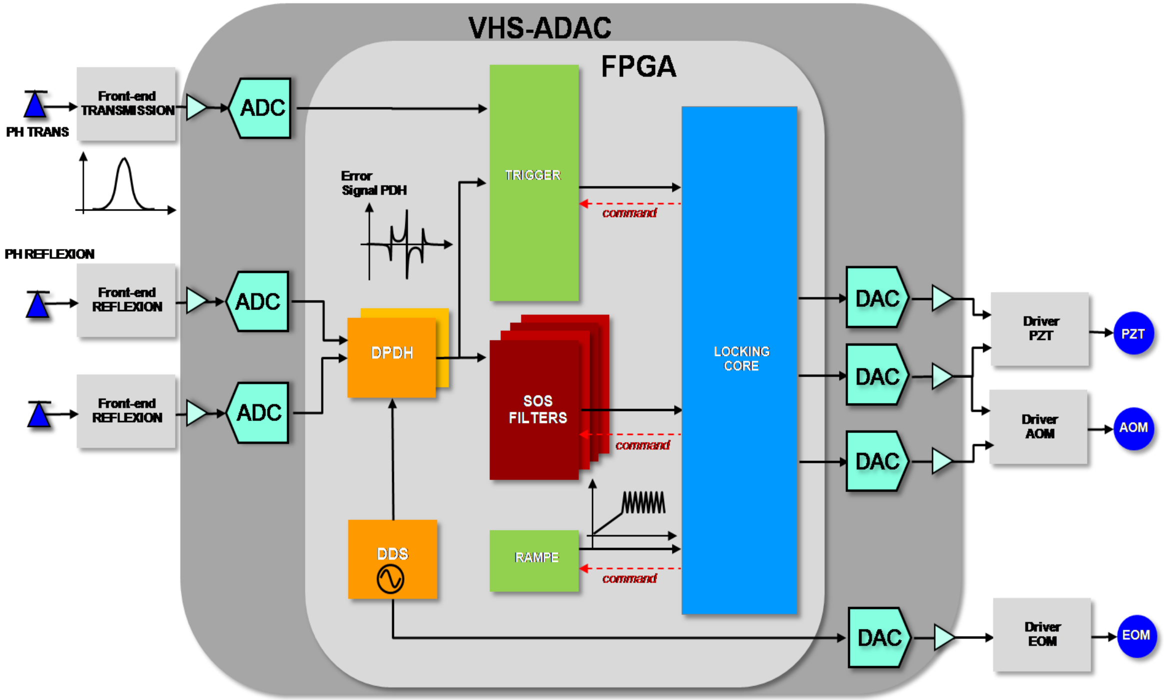
Benchmark noise level of various oscillators by beating with stable oscillator (metrology like experiment)

Also ongoing at CELIA:
design of a new home made laser → assert size of pump diode power noise

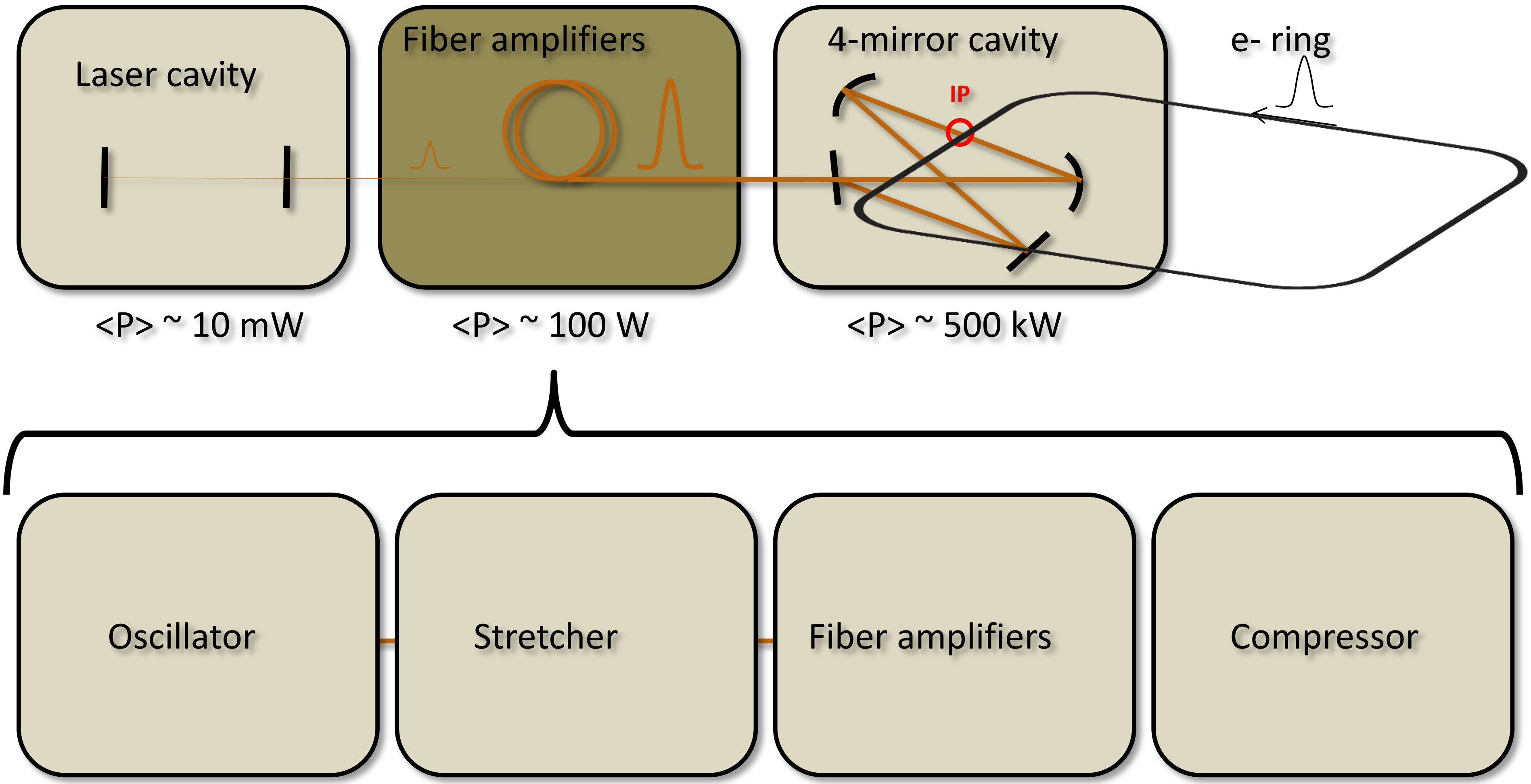
Numerical feedback



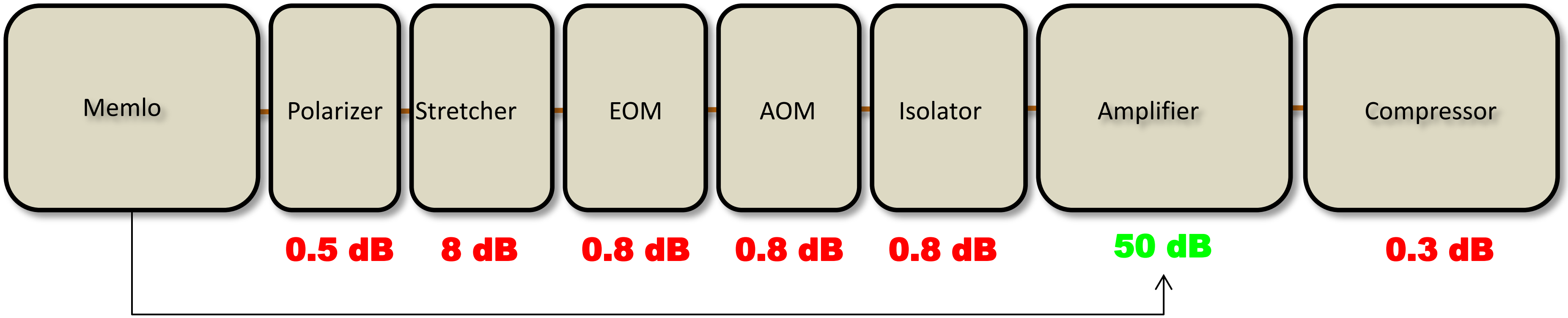
Feedback bandwith ~10MHz



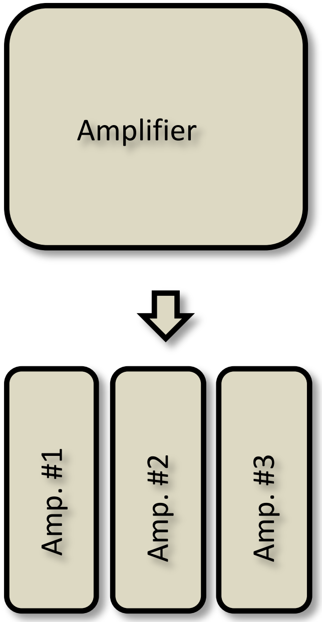
Amplification



Challenge of amplification chain



Total loses before amp 11.4 dB ➜ 92.7 %



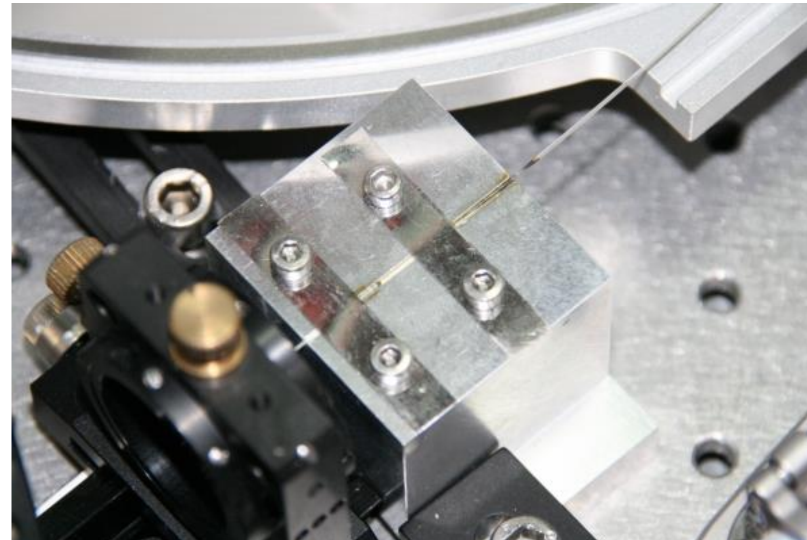
Available input power :1 mW
Output power : 100 W
Net gain : 10^5
Requires adapted amplifier sectioning

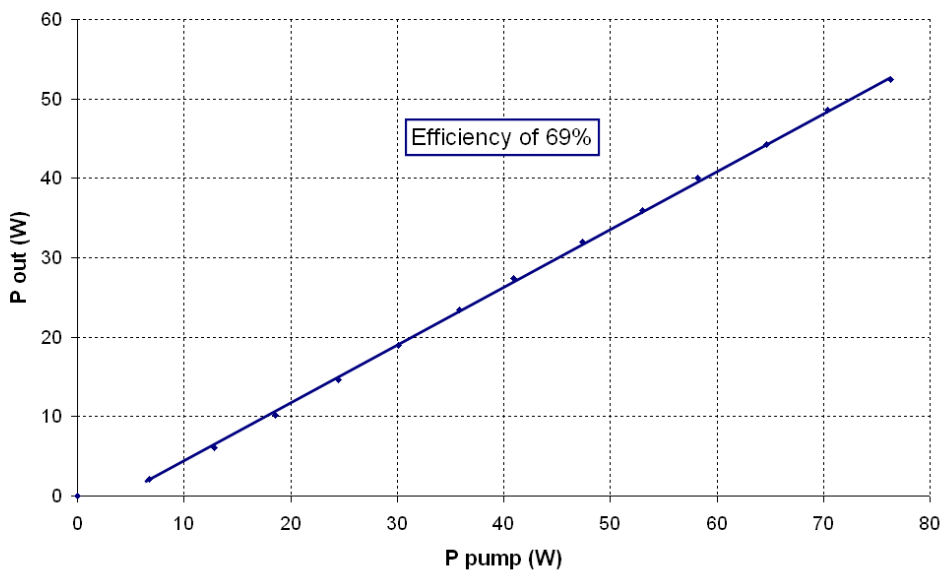
Amplification issue

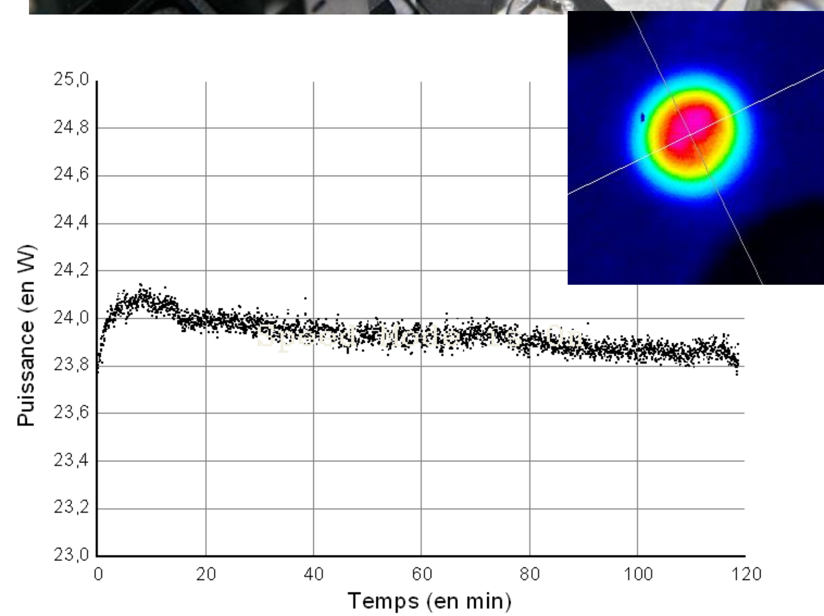
Technological R&D to have
stability and realiability

60W average power roughly stable
800W (11µJ/pulse) demonstrated in litterature

Limpert OL35 (2010) 94



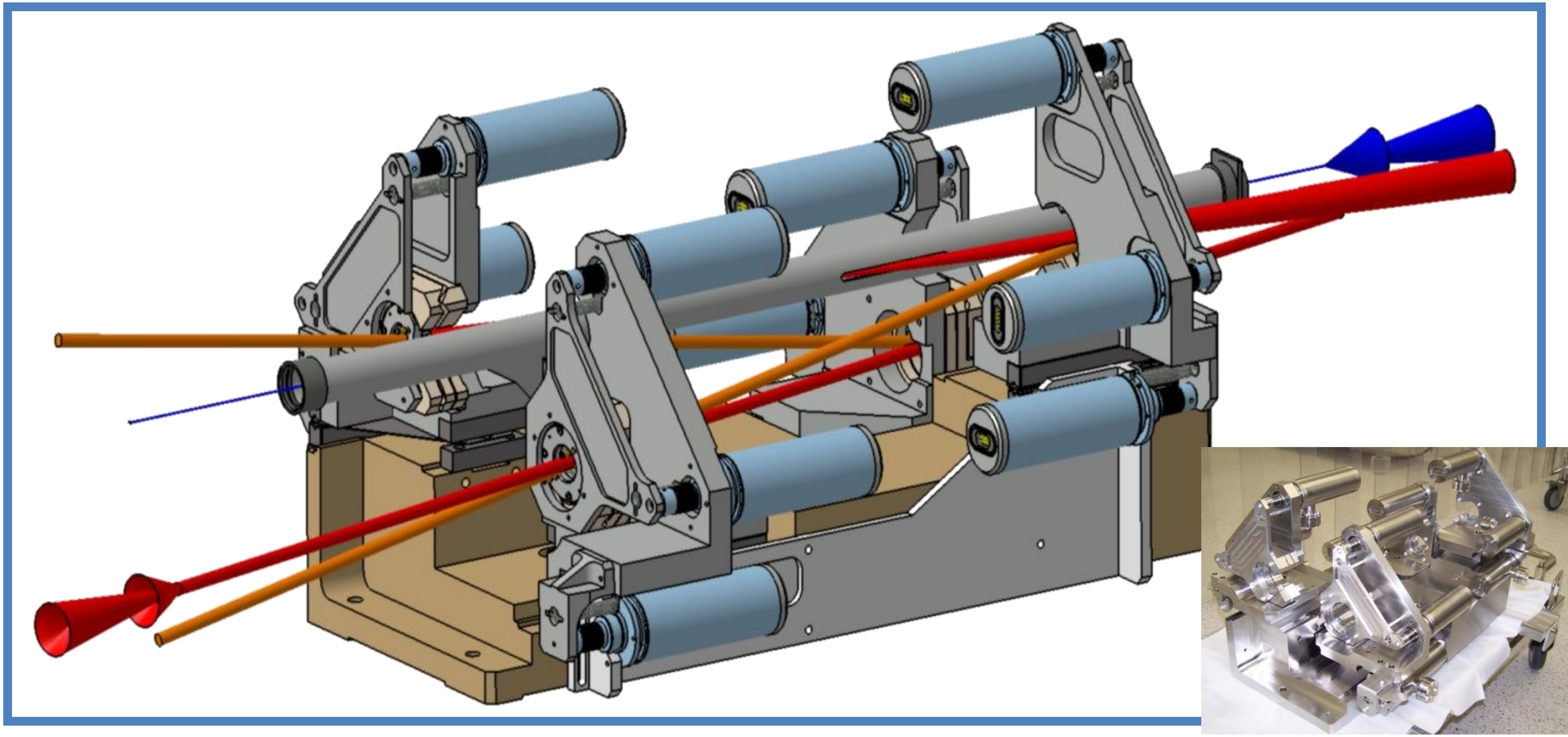




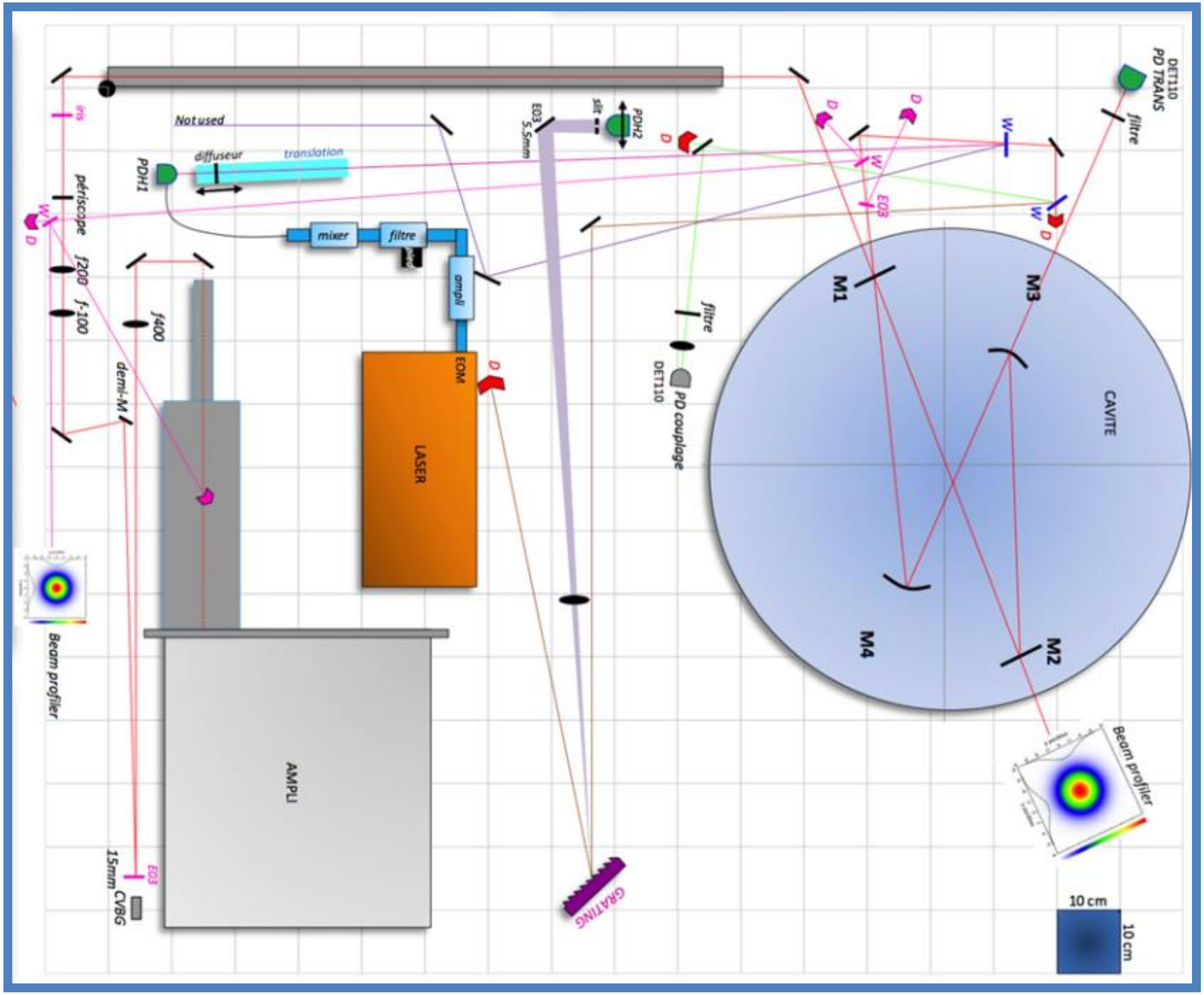
cavity

R&D for polarized positron source for LC
→ circularly polarized laser
→ non planar geometry

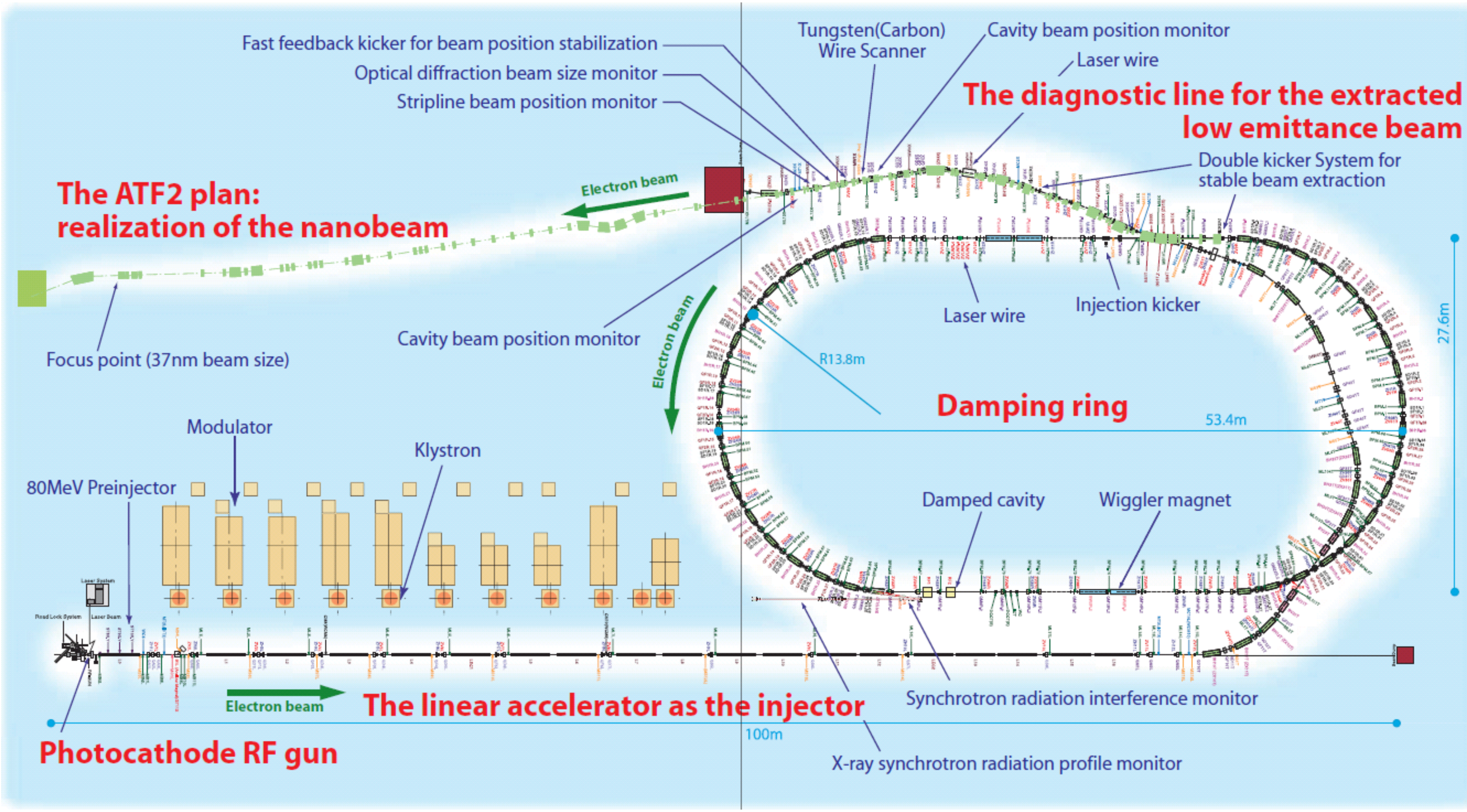
Optical round-trip vs waist size
→ 4-mirror cavity
2 plane + 2 spherical mirrors
→ ellipticity



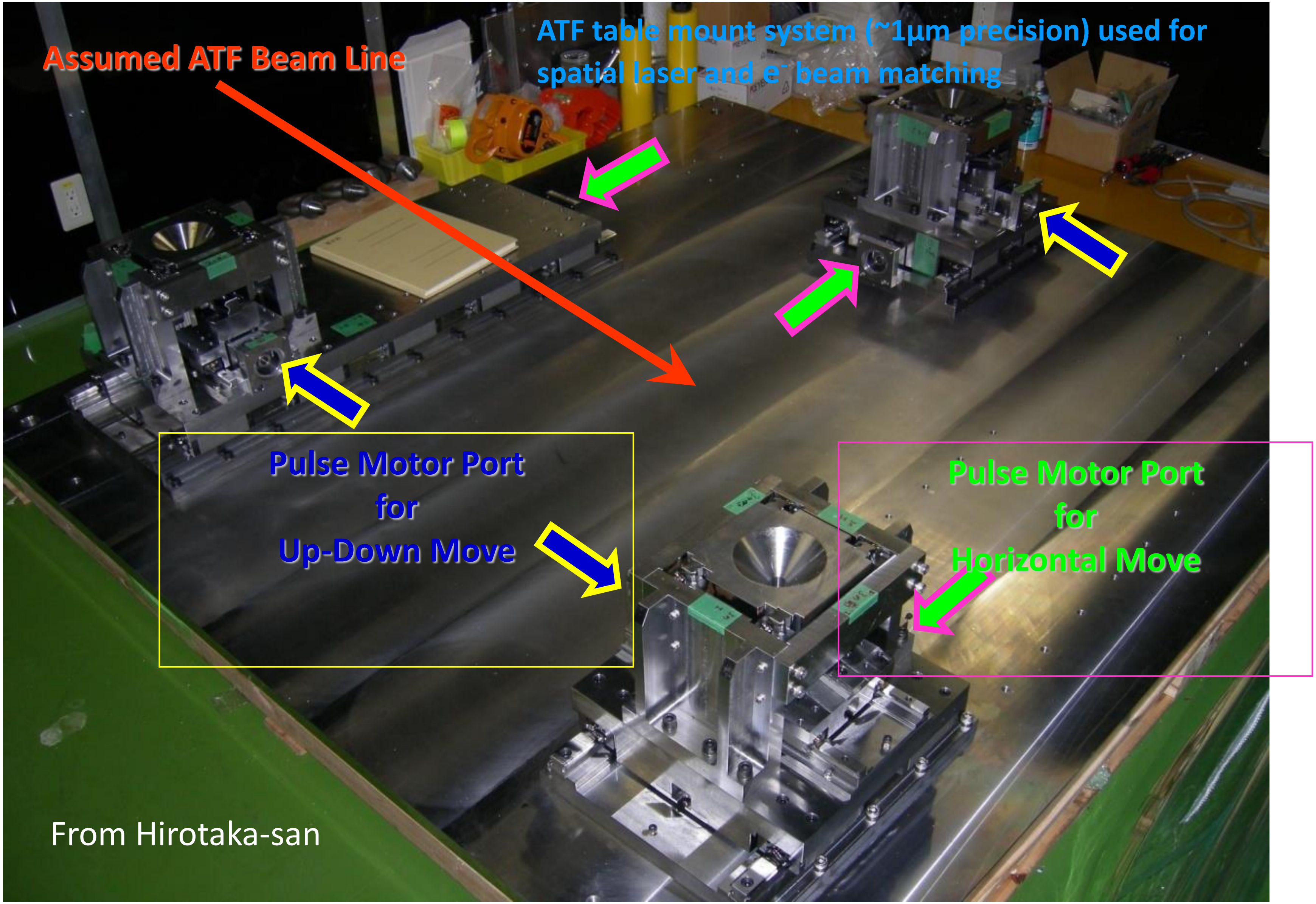
setup: summary



MightyLaser at KEK



MightyLaser movers



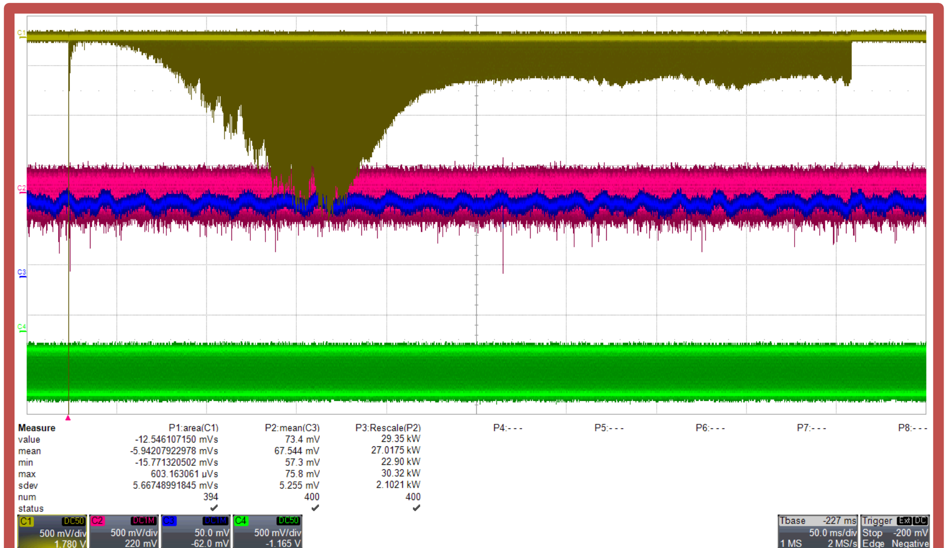
Installation of the cavity

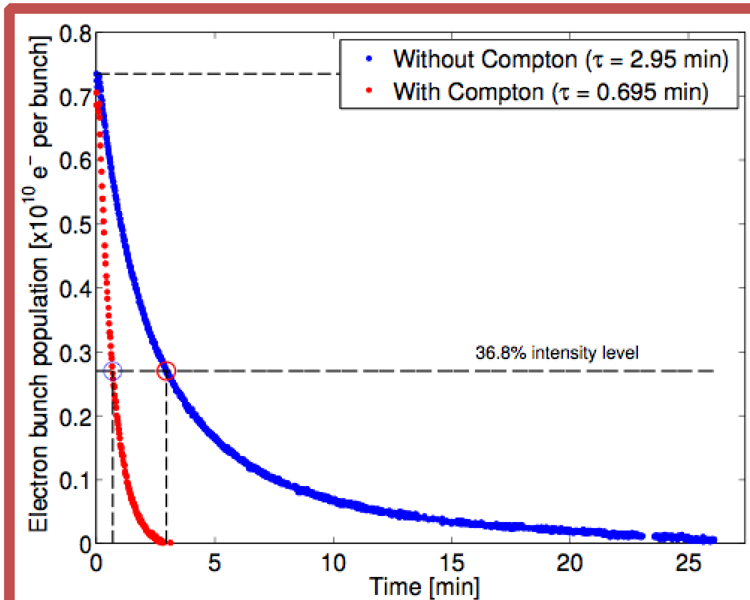
MightyLaser preliminary results

Results obtained at the KEK ATF: collaboration with KEK colleagues
1.08MHz collision rate, ~1nC beam charge, 1.3GeV damping ring

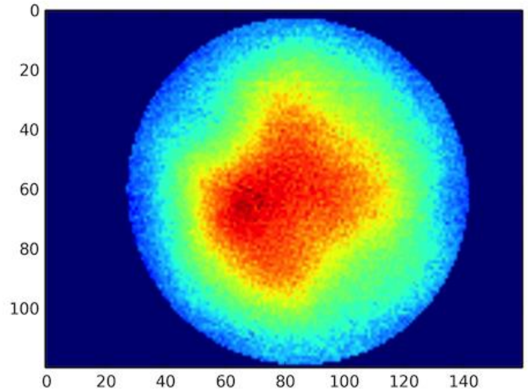
march'11 results
→ finesse 1000π
→ ~50W incident laser power
→ 10^6 γ/s @ ~25MeV
→ 0.2 kW (continuous regime)
→ T. Akagi *et al* 2012 *JINST* **7** P01021
→ J. Bonis *et al* 2012 *JINST* **7** P01017

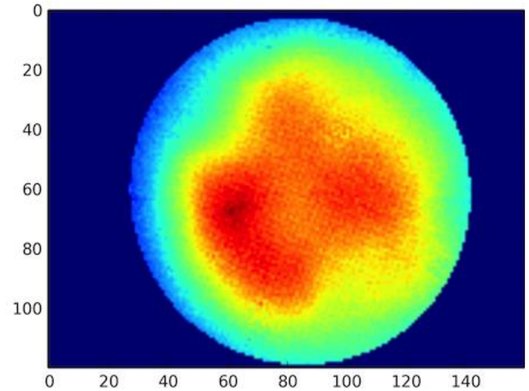
December '13 results:
→ finesse ~10000π
→ ~50W incident laser power
→ ~100 γ/crossing @ ~25MeV
→ >100kW (transient regime)
→ 40kW (continuous regime)
→ Publication in preparation

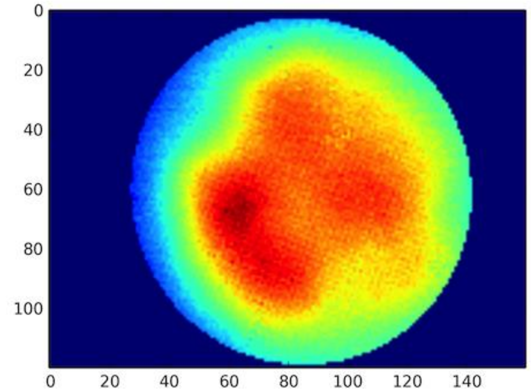




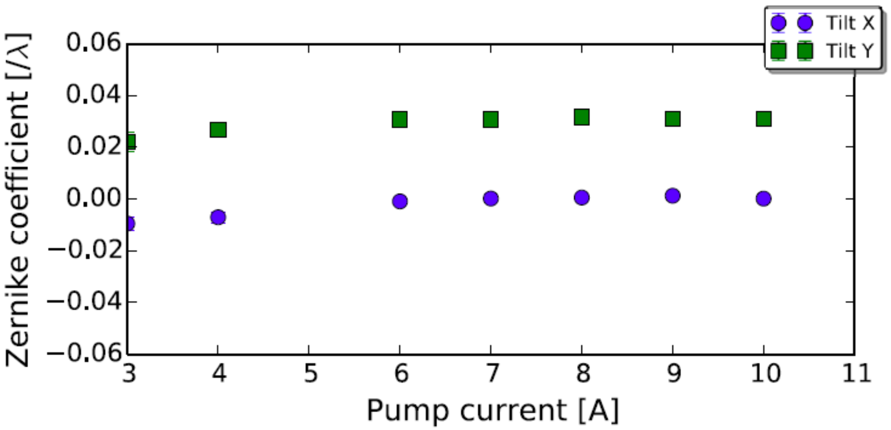
After amplification

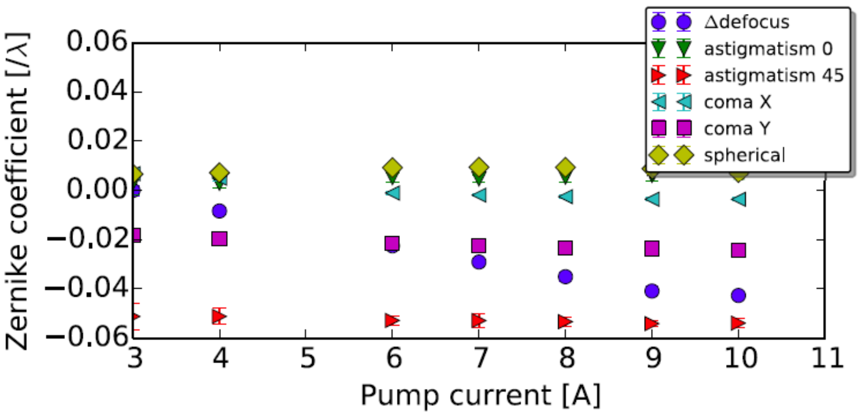




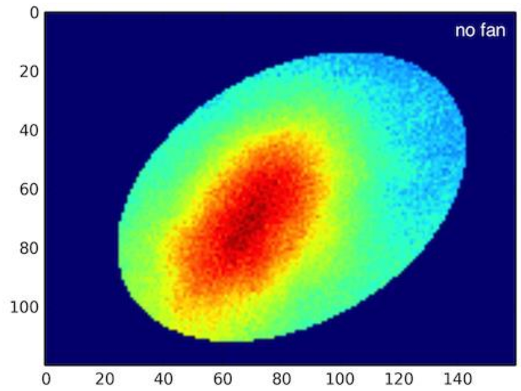


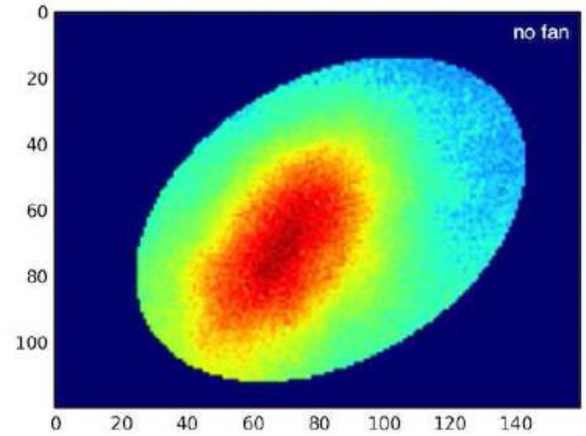
R&D on amplification still interesting: quality of the laser beam



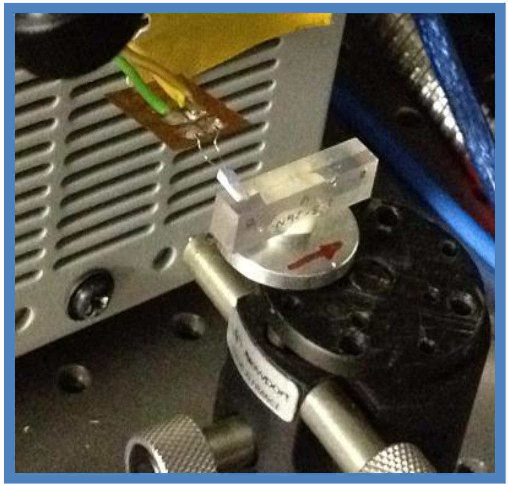


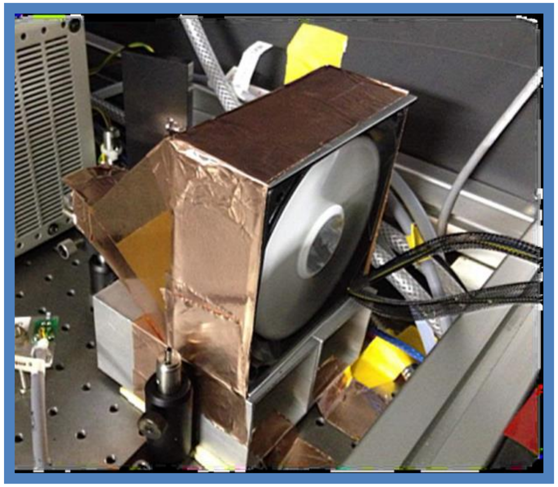
After compressor

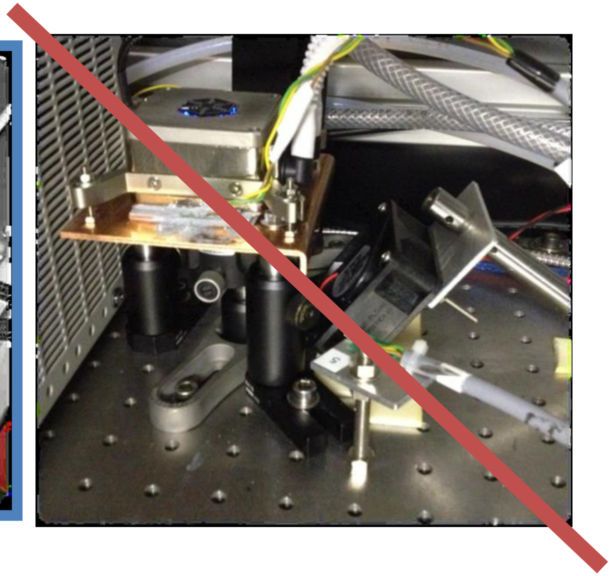




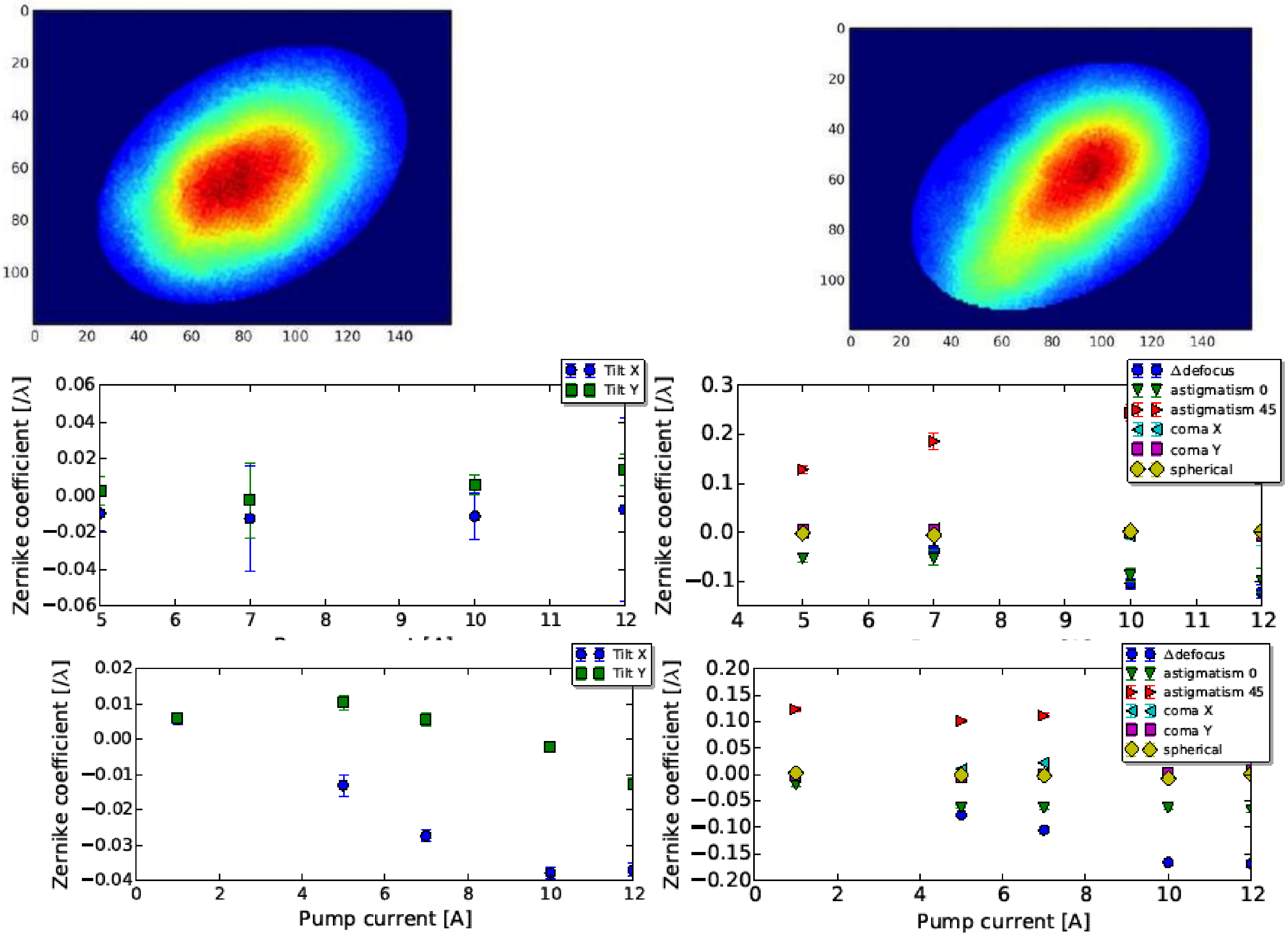
R&D/benchmarking of commercial products required to prevent this effect





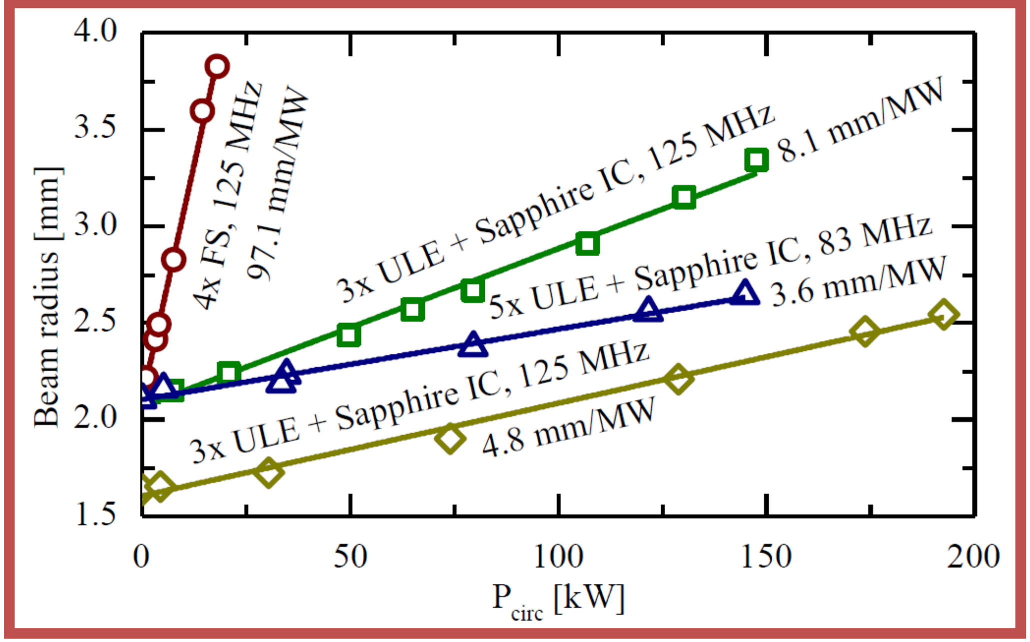


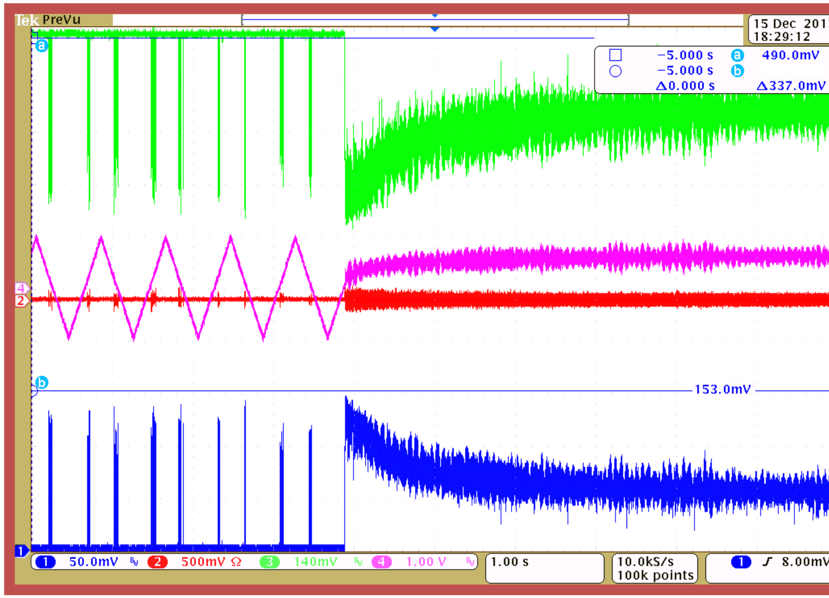
Impact of mitigation



Thermal effects in cavity

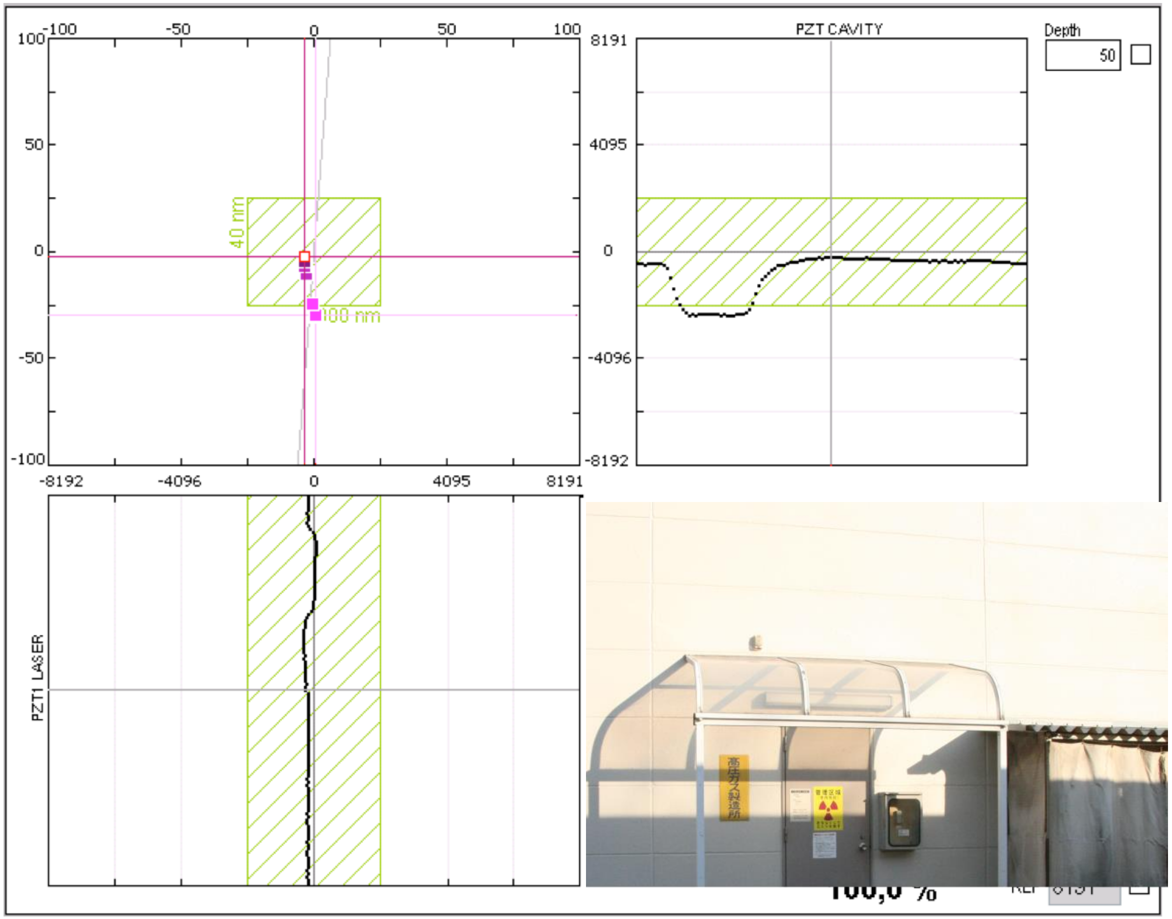
From H. Carstens et al., ASSL JTh5A (2013) 3





ULE mirrors expected to solve most of the problems observed with MightyLaser

Cavity mechanical design



Quantitavive understanding of the origin of the effect ongoing

Summary: towards a MW

Improve understanding of oscillator phase noise
→ Beating with stable reference

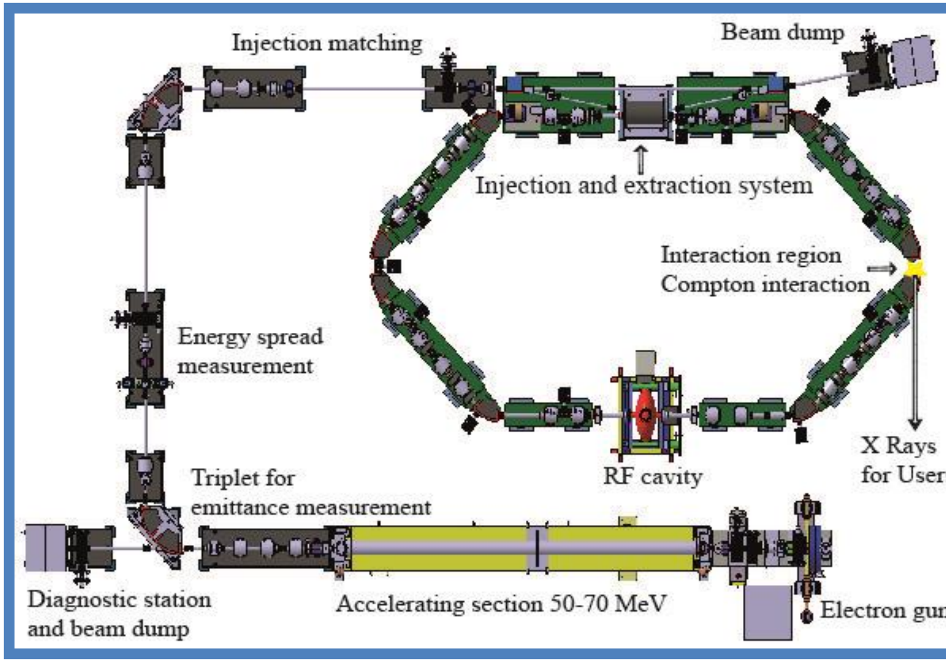
Solve compressor heating issue
→ R&D
→ benchmarking of commercial compressors ?
→ Use grating instead of CVBG's ?

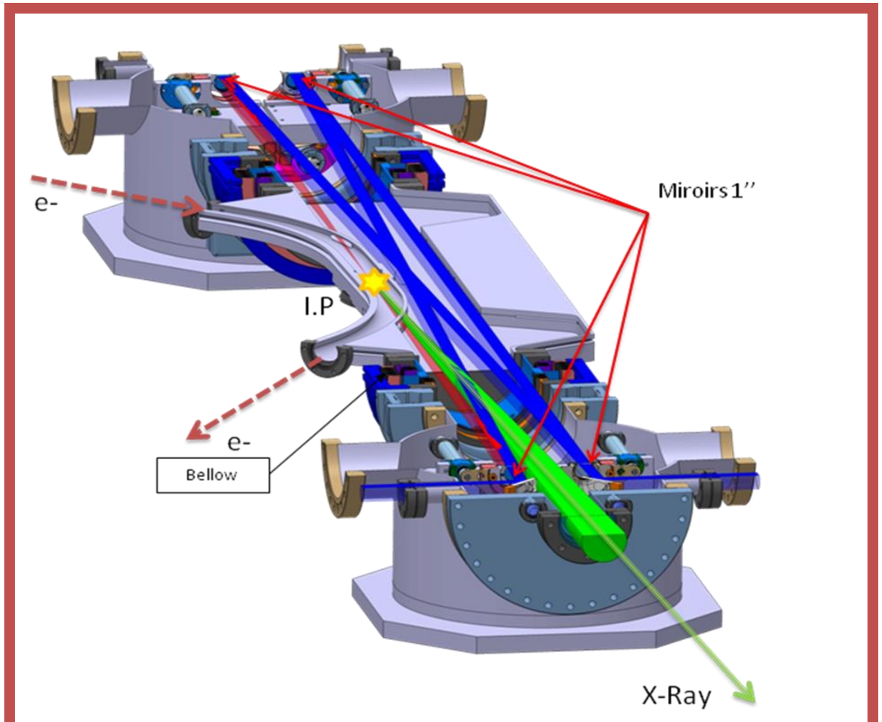
Mitigate thermal effects in cavity
→ ULE + saphirre mirrors expected to strongly mitigate thermal effects in cavity
→ 400kW reached by colleagues at Garshing
→ Can we do better by being cleaner with the optics ?

Increase incident power on the cavity and improve wavefront
→ parallelisation of several amplification fibers: feedback
→ High average power amplifier (Garshing): cost

ThomX

~50 MeV ring, 1nC
17.8MHz repetition rate
300kW expected in cavity
commissioning in 2016
Applications: medical and cultural heritage





Design: 10^{11} - 10^{13} γ/s
1%-10% spectral bandwidth (w/ diaphragm)
10 mrad divergence w/o diaphragm

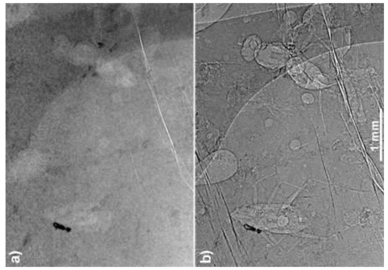
ThomX: a machine turned toward societal applications

- **Transfer of the SR techniques to these new machines. Many fields can be interested…**
- **At present two contributors: *Medical field (ESRF, INSERM Grenoble)**
  ***Cultural Heritage (C2RMF CNRS – Louvre Museum)→**
  LAMS(Archeology Labs.)

K-edge imaging

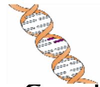
Phase contrast imaging

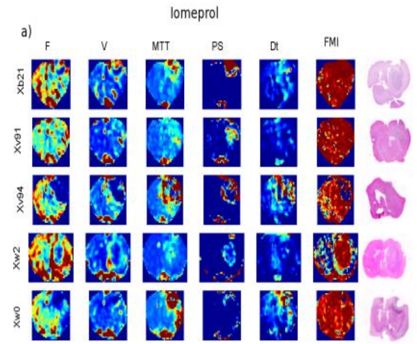
Paleontology
Non-destructive analysis

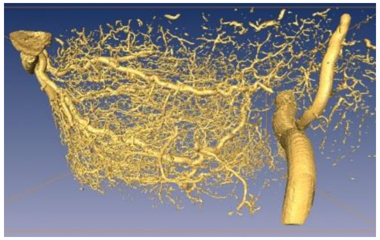


K-edge imaging (Pb→white, Hg→ vermilion…) of a Van-Gogh's painting
J. Dik et al., *Analytical Chemistry*, **2008**, *80*, 6436

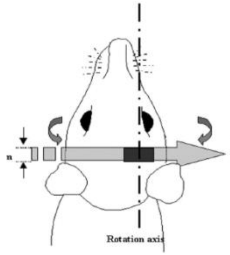
Physiopathology and Contrast agents,
Dynamic Contrast Enhancement SRCT
Convection Enhanced Delivery =>Stereotactic Synchrotron RT

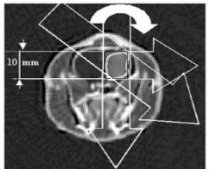






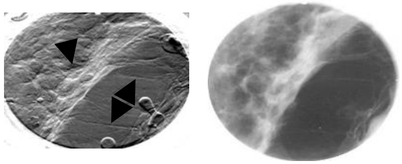
J Cereb Blood Flow and Metab, 2007. 27 (2):292-303.





Imaging,
Mammography
Microtomography

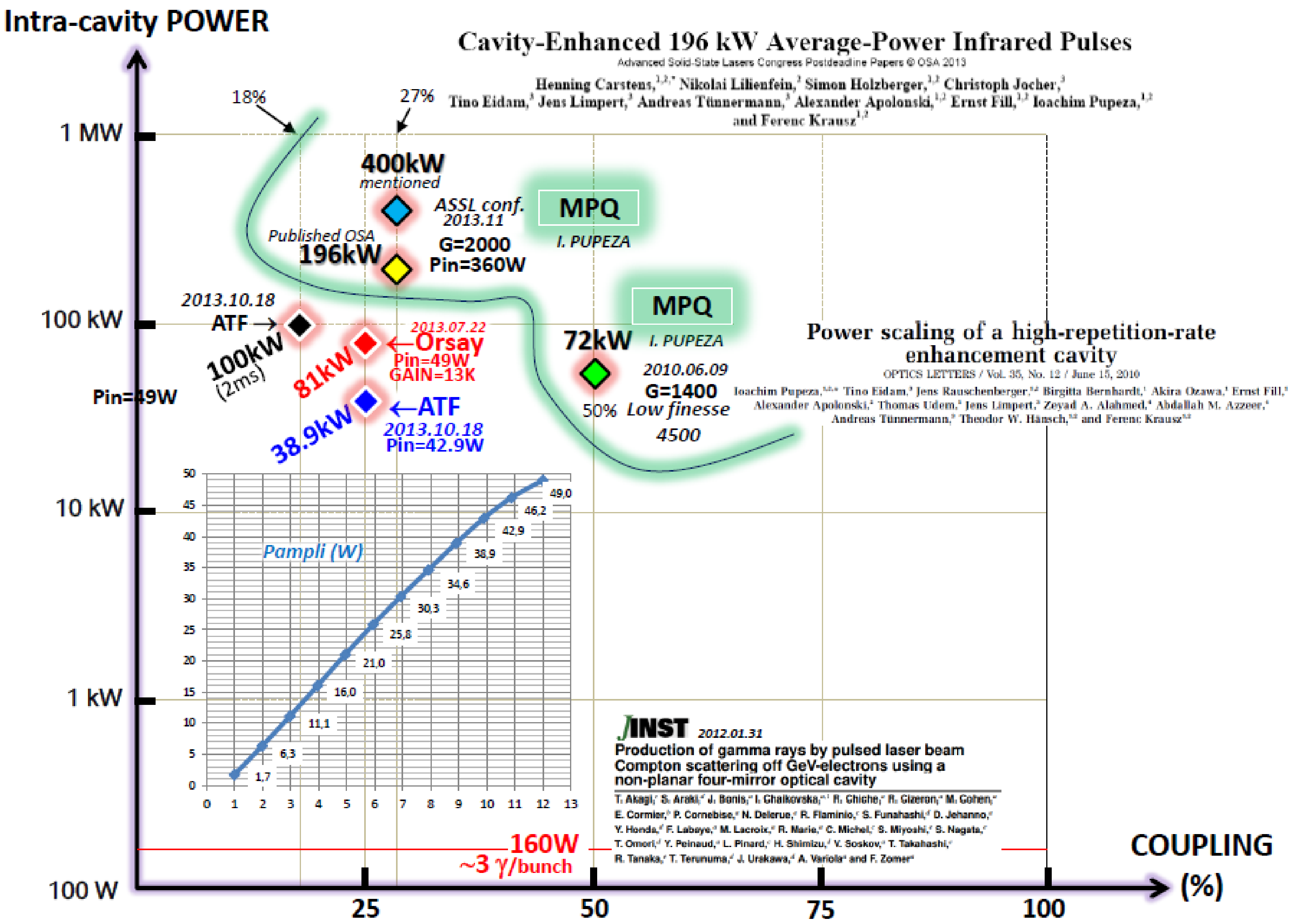
Biston et al, Cancer Res 2004, 64, 2317-23



Journal of Radiology 53, 226-237 (2005)

Acknowledgments to G.Le Duc, P.Walter

What we know is reachable



Increasing incident power on the cavity