LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

Fabry-Perot cavity R&D at Orsay

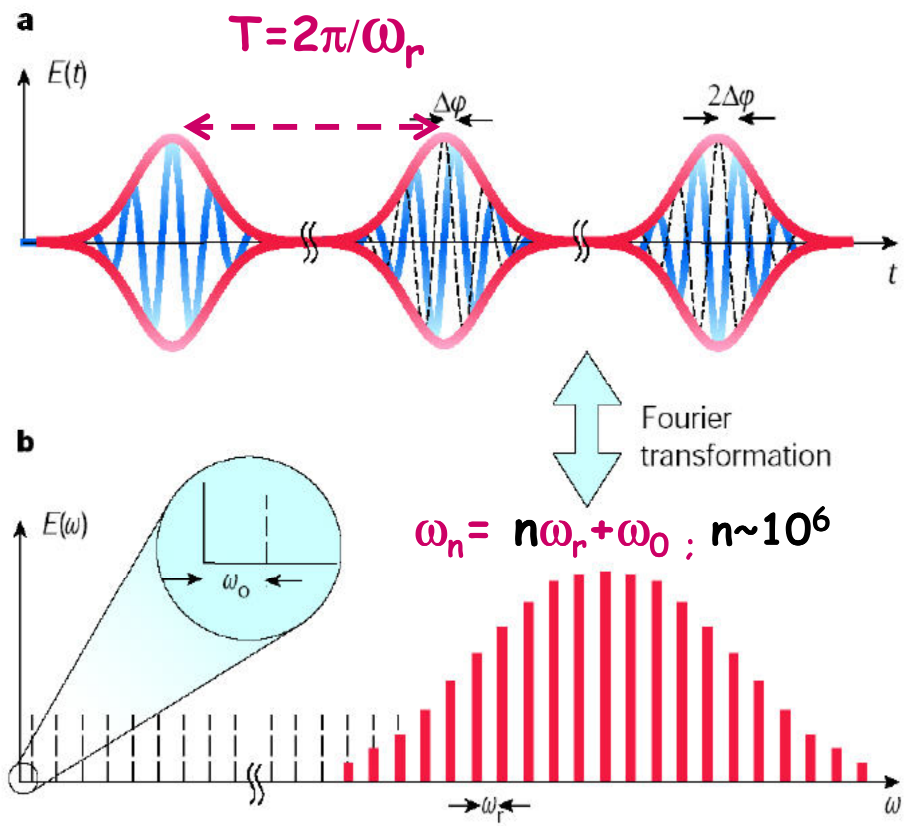
Alessandro Variola for the PLIC group LAL ORSAY

- -For polarised positron sources we need Comptn scattering between nC electron bunches and 0.x J photon pulses.
- -Frep very high (20-160 MHz)
- -Short pulses (high gamma flux cannot cross the high reflectivity mirrors coating. Need a crossing angle). To increase the luminosity the photon pulse must be longitudinally short (few ps) and transversally little (x 10 μm)
- -Need to develop locking system for very high finesse Fabry Perot cavity and stability for little waists
- -In LAL two directions : Locking on a 2 mirror confocal cavity, waist on different type of 4 mirrors cavity

Pulsed_laser/cavity feedback technique

Specificity ➔ properties of passive mode locked laser beams

Frequency comb ➔ all the comb must be locked to the cavity
➔ Feedback with
2 degrees of freedom :
control of the
Dilatation & translation



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

Technical constraints

•First technical constraint: laser phase noise

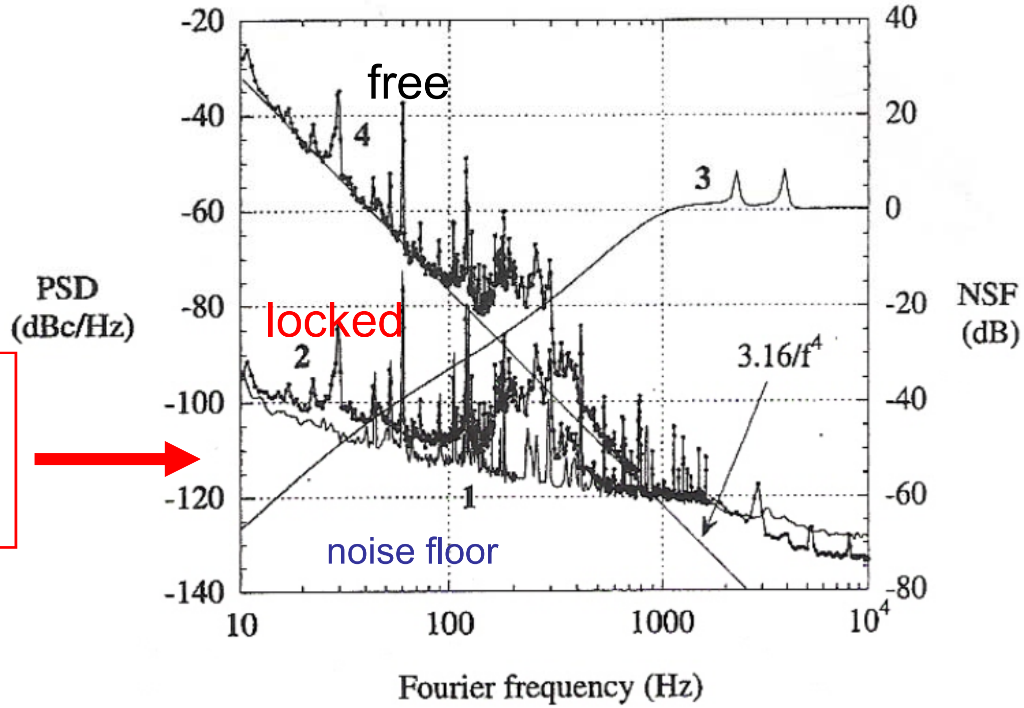
For all comb components $\omega_n = n\omega_r + \omega_0$ to be locked to a cavity of finesse F

$$\frac{\Delta\omega_r}{\omega_r} \approx \frac{1}{2n}\frac{1}{F} \quad \text{BUT: } n \approx 10^6 \text{ and } \omega_r \sim 2\pi \times 100MHz$$

$$\Rightarrow \frac{\Delta\omega_r}{\omega_r} \sim 10^{-10}\text{-}10^{-11} \quad \text{for F=10000}$$

Possible with mode locked lasers
Ex.: almost no phase noise above ~10kHz in Ti:sa oscillators

Ti:sa oscillator phase noise measurement

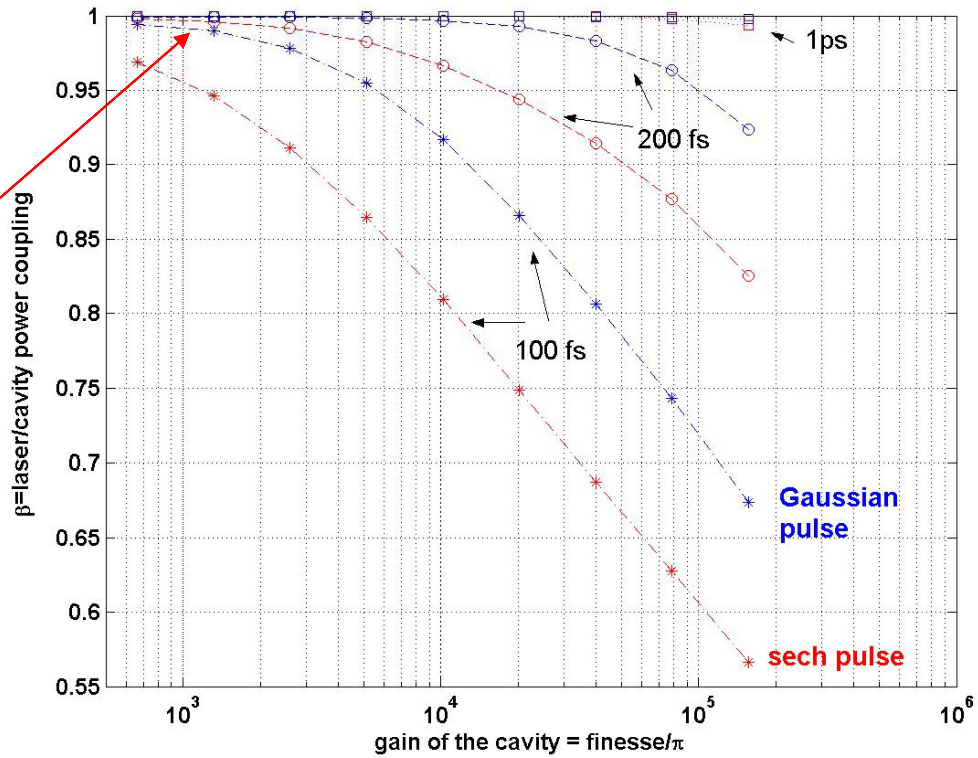


Ivanov et al. IEEE Trans Ultr, 50(2003)355

•Second technical constraint:

➔Chromatic dispersion of the cavity mirror coating gives a limit on laser pulse width

➔ No effect for ~1ps pulses



•Third technical constraint:

➔coating damage

➔ ~10MW average power for ps Pulses

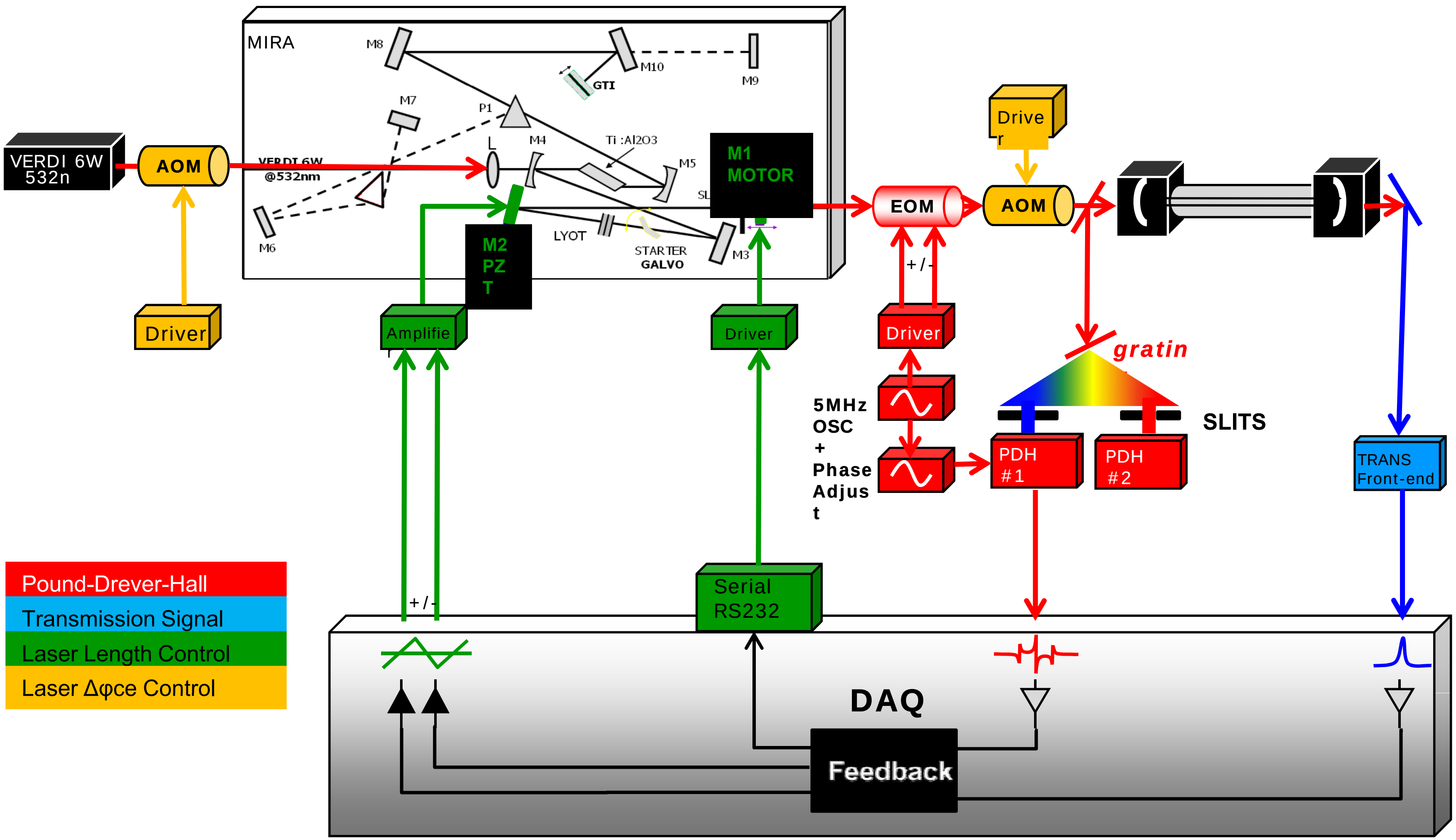
➔High finesse cavity could be operated in ps regime as in cw regime up to the MW average power regime

- State of the art:
- Loewen (PhD), gain 6000 for ~30ps pulse width (but this needs only 1 degree of freedom)
- KEK/ATF cavities, gains ~1000 for ps lasers
- Femto comb stabilisation, low finesse ~200 (Jones et al., PRL**86**(2001) 3288)

- Need to increase the gain and to reduce the pulse length
- 1st target => 1000 gain @ 1 ps
- 2nd target => 10000 gain @ 1 ps

Flexibility of the Feedback strategy needed to reach highest cavity finesses
➔ Pound Drever Hall locking + digital feedback system was chosen

Experimental setup
Pound-Drever-Hall locking technique



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Digital Feedback System

LYRTECH DFS :

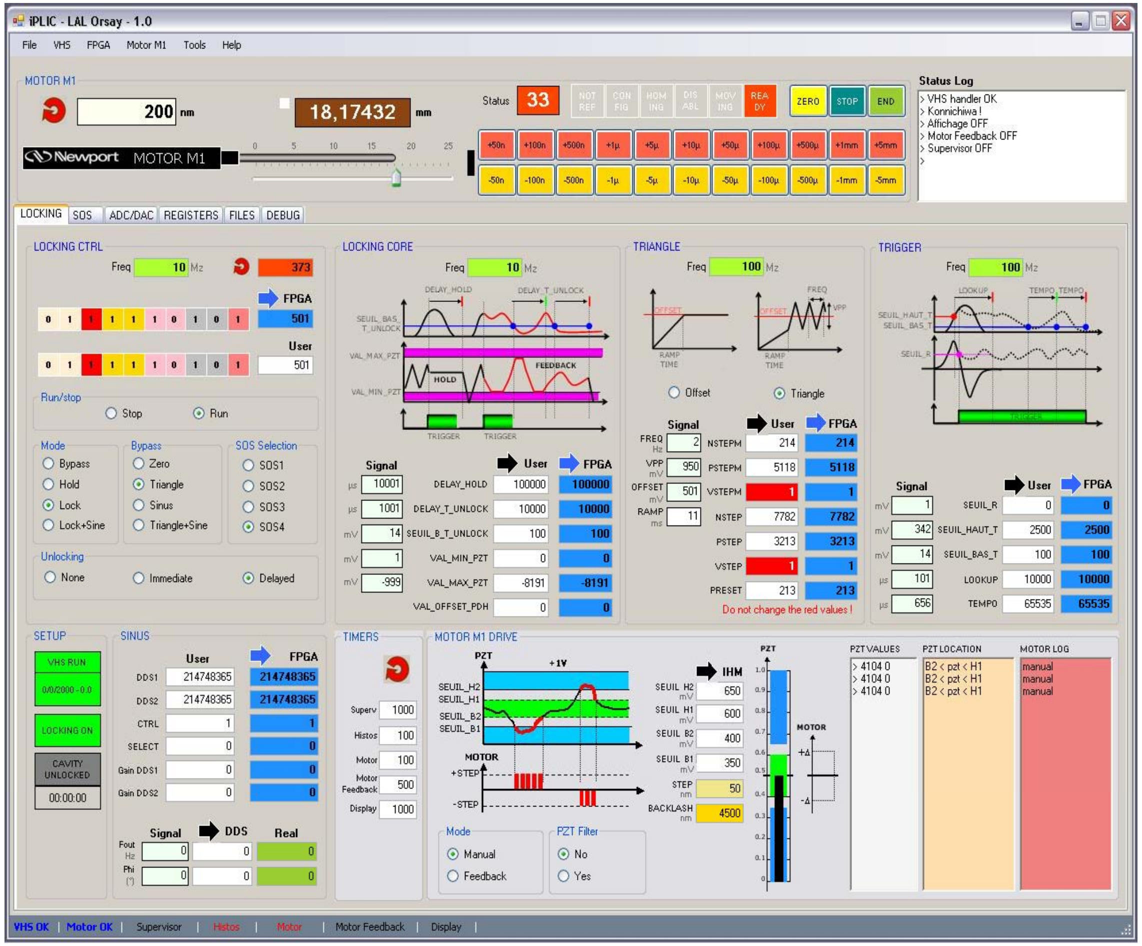
- 8 ADC channels
- Sampling @ 105 MS/s
- 14 bits resolution

- Virtex-II FPGA : XC2V8000
- 60ns latency

- 8 DAC channels
- Conversion rate @ 125 MS/s
- 14 bits resolution

LYRTECH DAQ

C++ GUI



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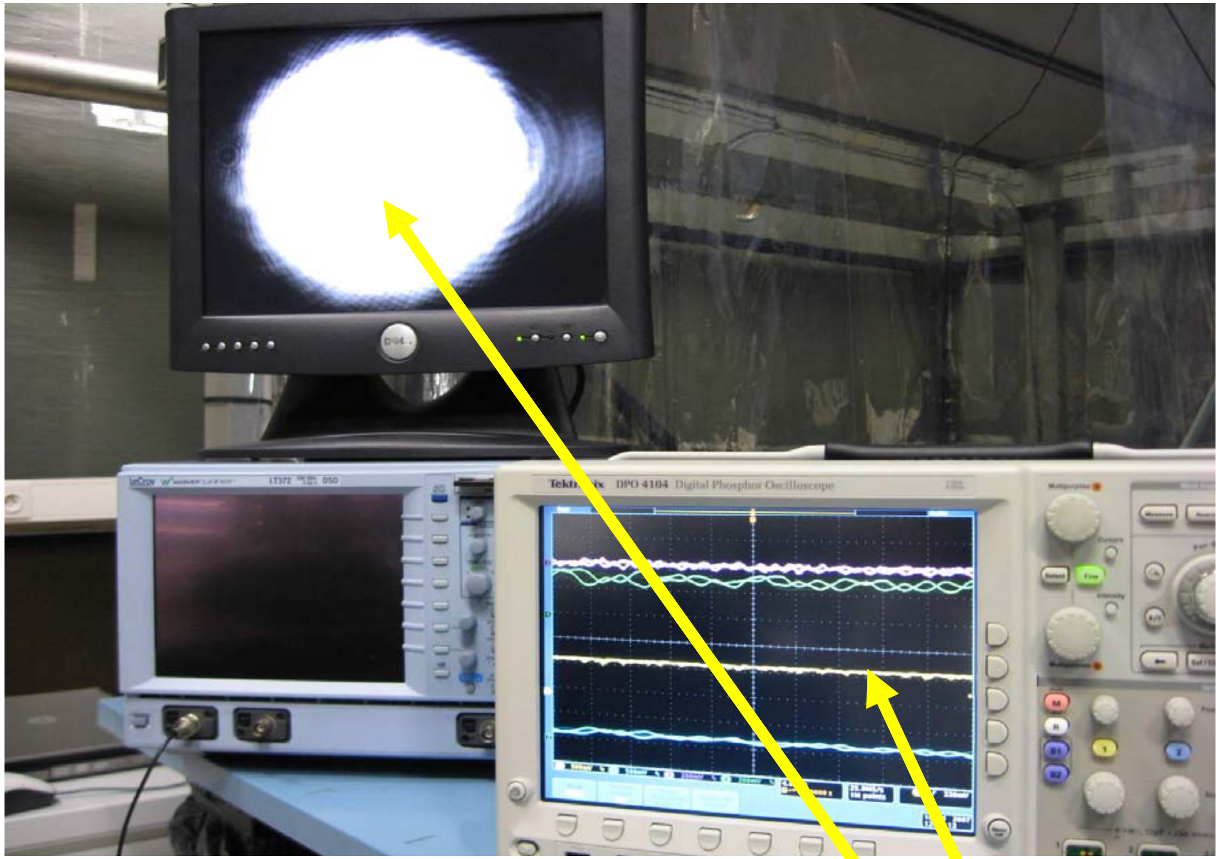
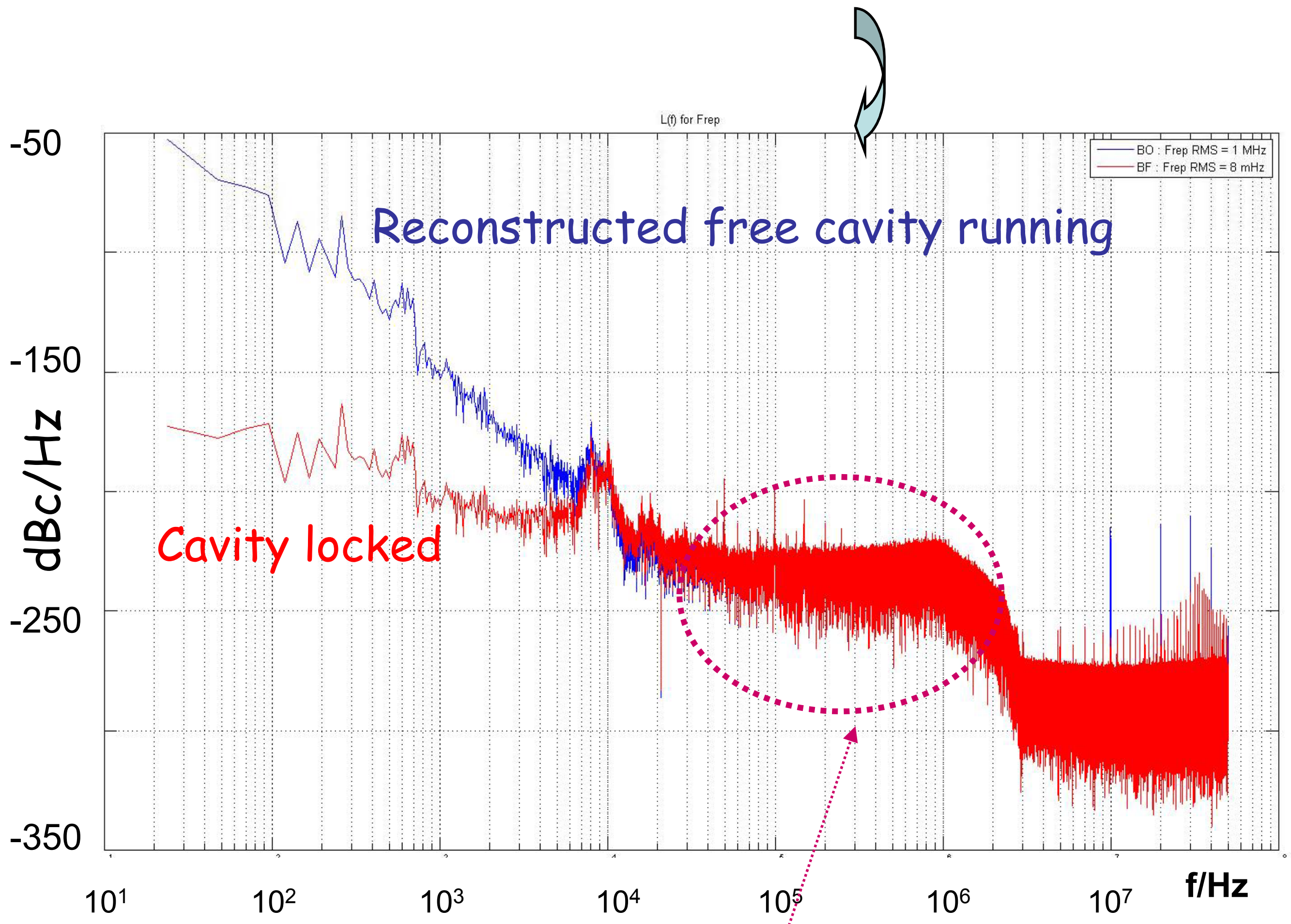
1st STEP:
Cavity locked (*low gain* ~1200)
·Digital feedback (5k VHDL lines of code)
·Already $\Delta f_{rep}/f_{rep}$~10^{-10} ➔ Δf_{rep}~76mHz for f_{rep}~76MHz



Cavity locked
With gain 1200

Phase noise of the Ti:sa locked to the 1200 gain cavity



Integrated residual noise rms ~ 8mHz on frep

We are presently working on the locking of a 30000 cavity finesse

- Ex. of improvement: the photodiode readout noise is a little bit too high…

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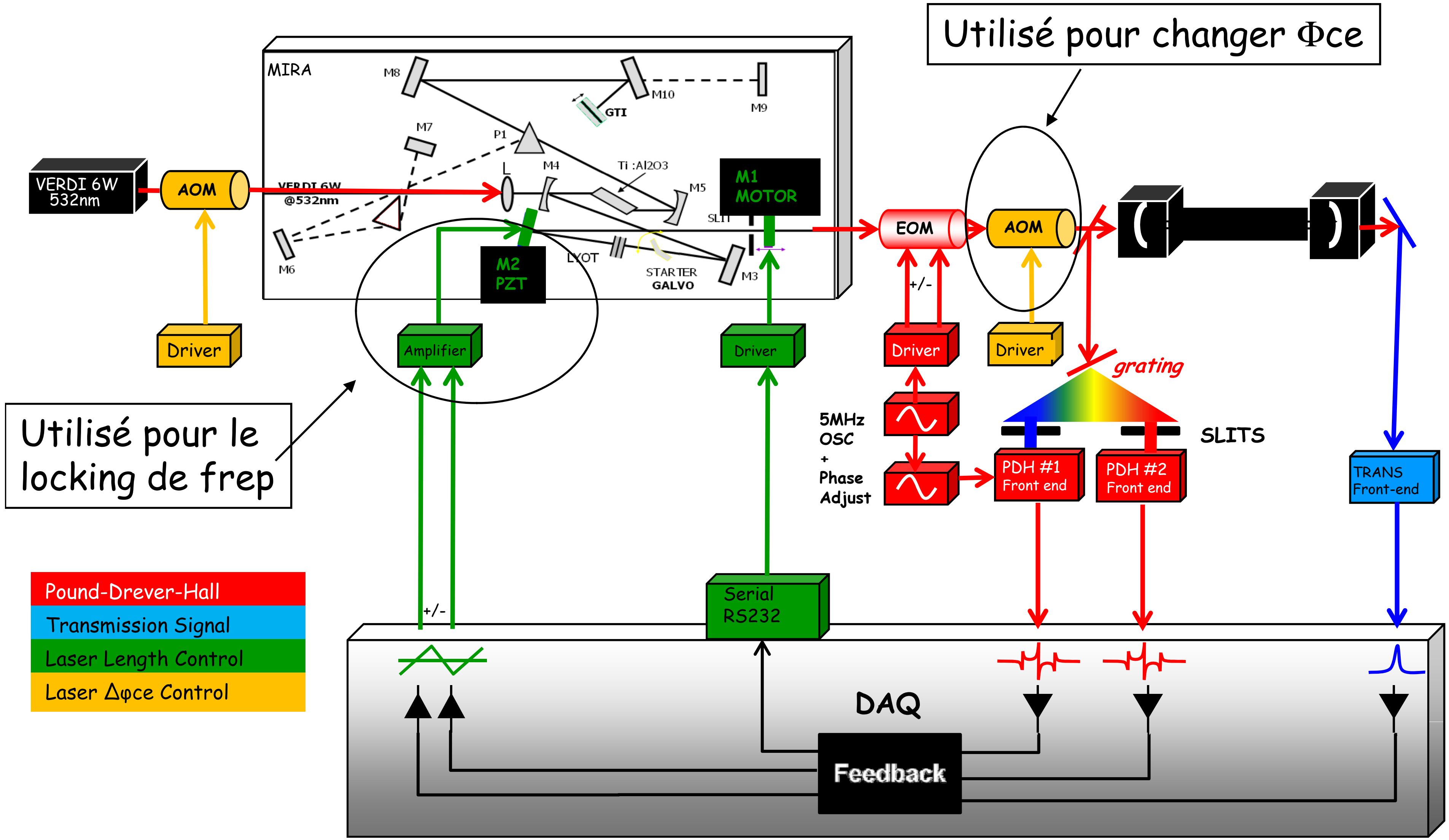
2nd STEP => GAIN ~ 10000
Locking only on one degree of freedom



MIRA 1ps@frep=76MHz => finesse F=30000

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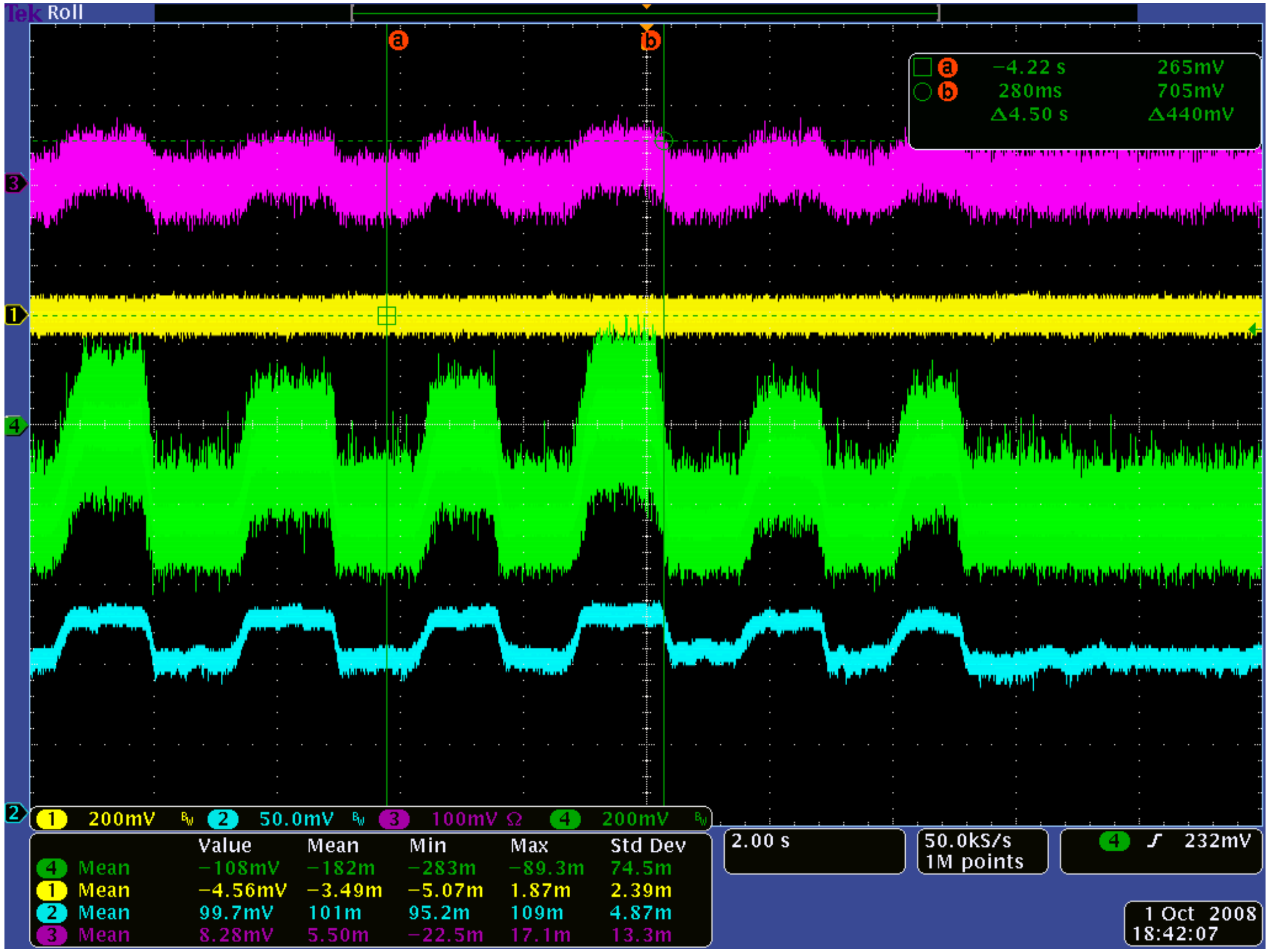
- Laser locked with PDH1 (acting on the piezo ➔ f_{rep})
- After this we saw the reactionon PDH2 (➔Φce) varying the frequency shifter



Signal commande piezo

Signal PDH1 (lock)

Signal PDH2

Signal transmis par la cavité

Régime pico haute finesse ⇔ régime femto basse finesse

Status with our Ti:sa oscilllator@frep=76MHz

- 1rst demonstration of the cavity / comb coupling at very high finesse in ps regime (previous publications were in fs regime)
- We are implementing a 2nd feedback loop to stabilised actively Φce in addition to frep (short time scale ~ 1 month)
- Finesse 30000 !!!!!!!!!!!! (world record@1ps)

Next step (in ~ one month)

- Try higher finesse (300000 ?) with the Ti:sa oscillator
- Repeat the experiment with an Yb doped oscillator

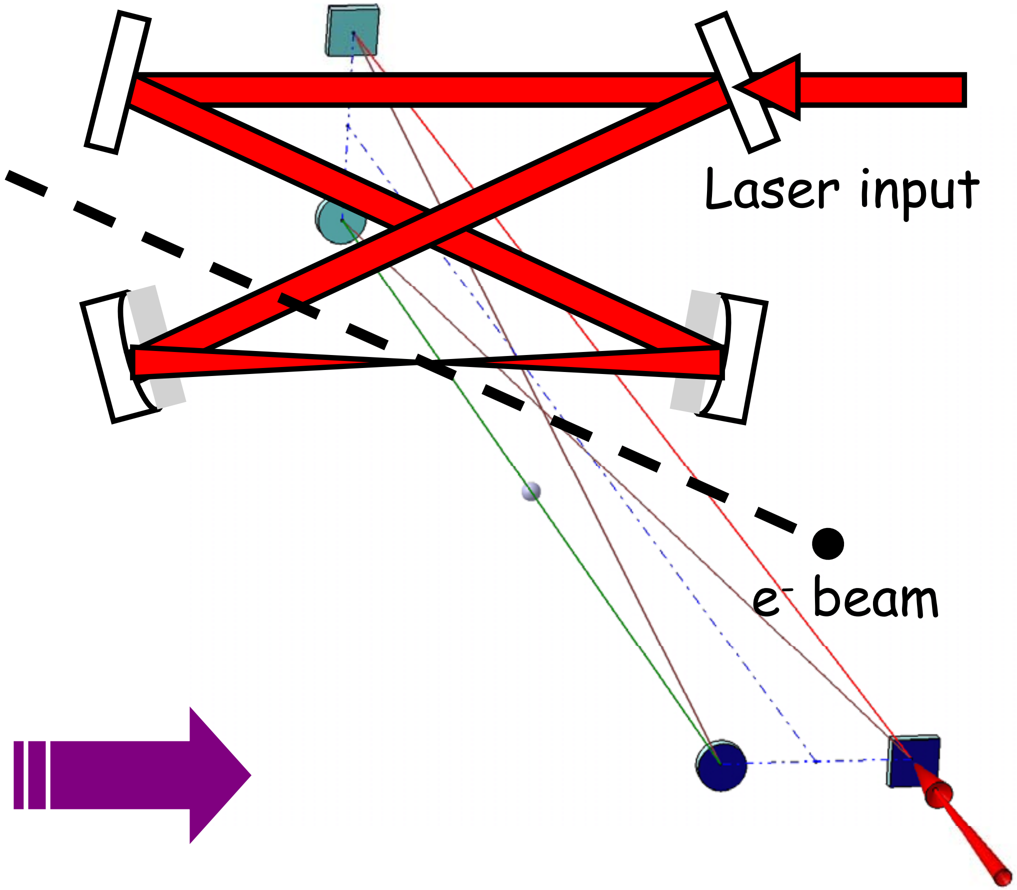
Small laser spot size

Small laser spot size &2 mirrors cavity ➔ unstable resonator (concentric resonator)

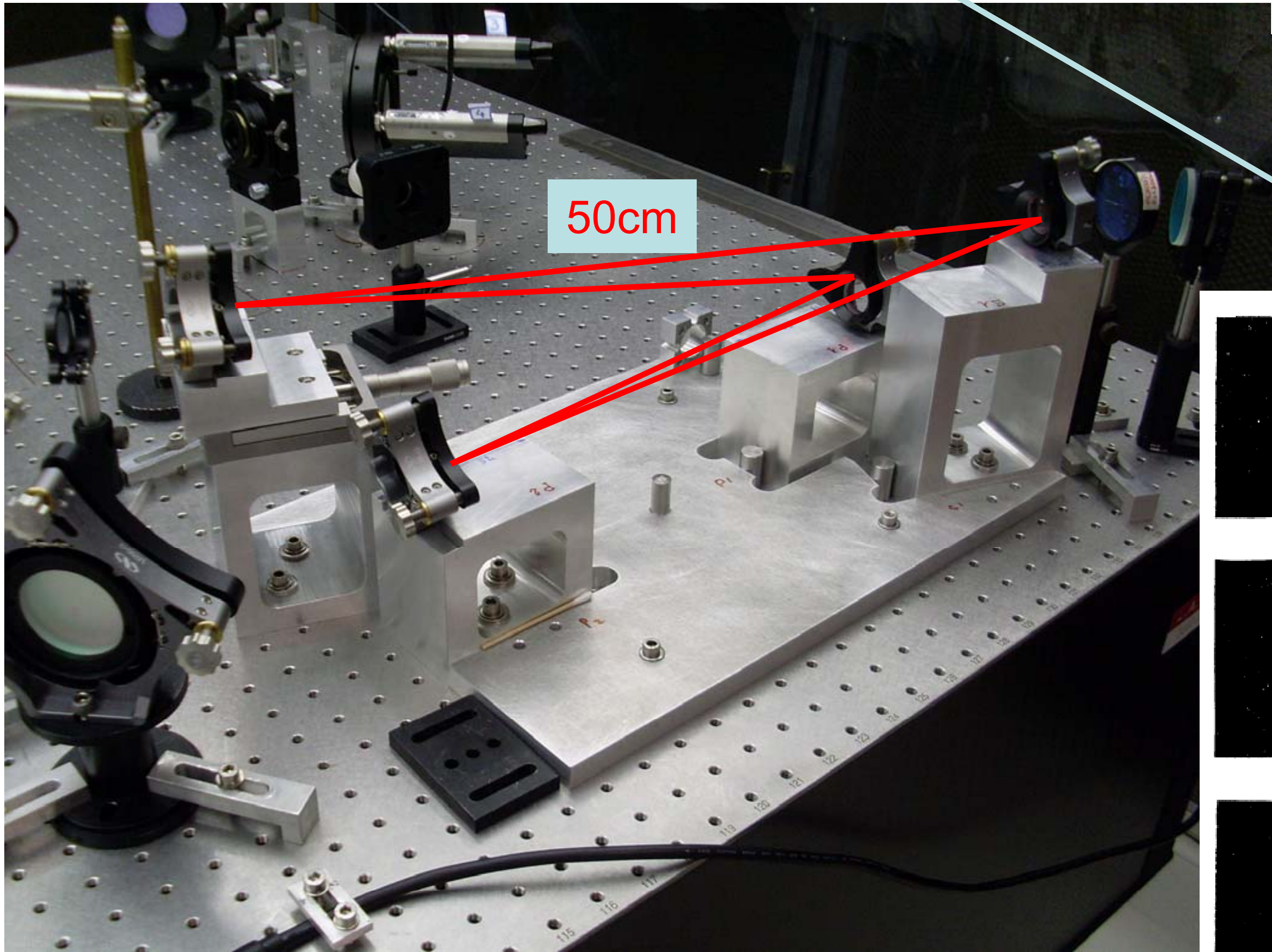
Stable solution: 4 mirror cavity as in Femto lasers

BUT➔ astigmatic & linearly polarised eigen-modes

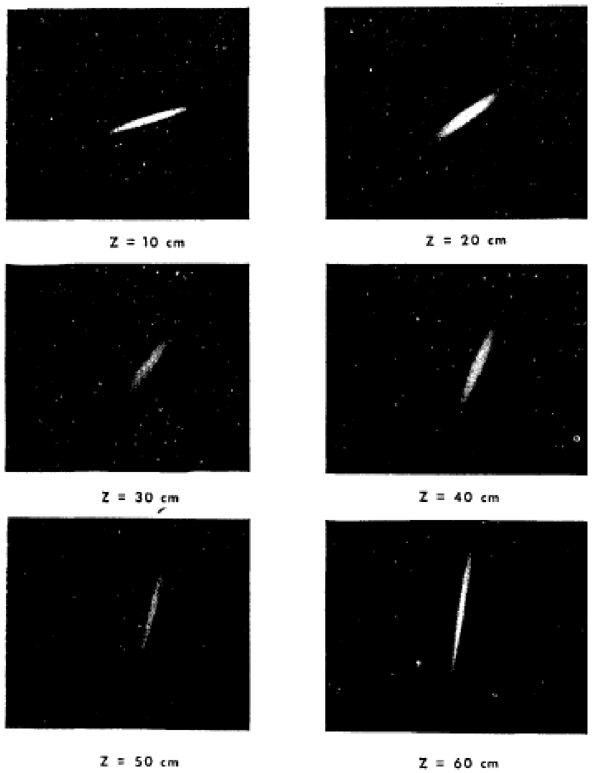
Non-planar 4 mirrors cavity
➔Astigmatism reduced &
➔Stable circularly polarised eigenmodes



Prototype of nonlanar 4 mirrors resonator (low finesse)
•Check the general astigmatism mode shape/propagation
(*Arnaud, Bell Syst. Tech. (1970)2311*)
➔ ok



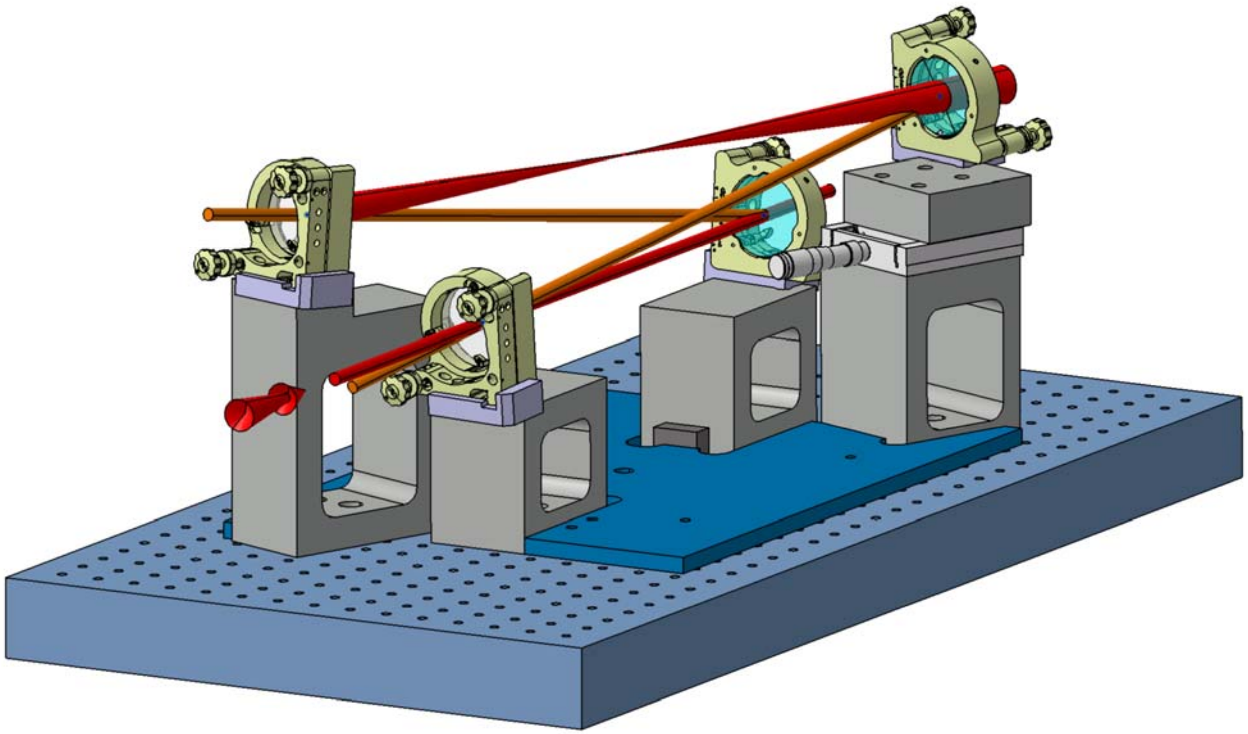
Ellipse intensity
profile 'turning'
Kogelnik, Apl. Opt. 8(1969)1687



We observed funny aberrations of the cavity mode for cavity waists ~40μm (➔20μm spot size) in our geometrical configuration

➔Calculation quite challenging

➔We have ordered 2 inches mirrors to study higher divergent configuration



IN2P3

INSTITUT NATIONAL DE PHYSIQUE NUCLÉAIRE
ET DE PHYSIQUE DES PARTICULES

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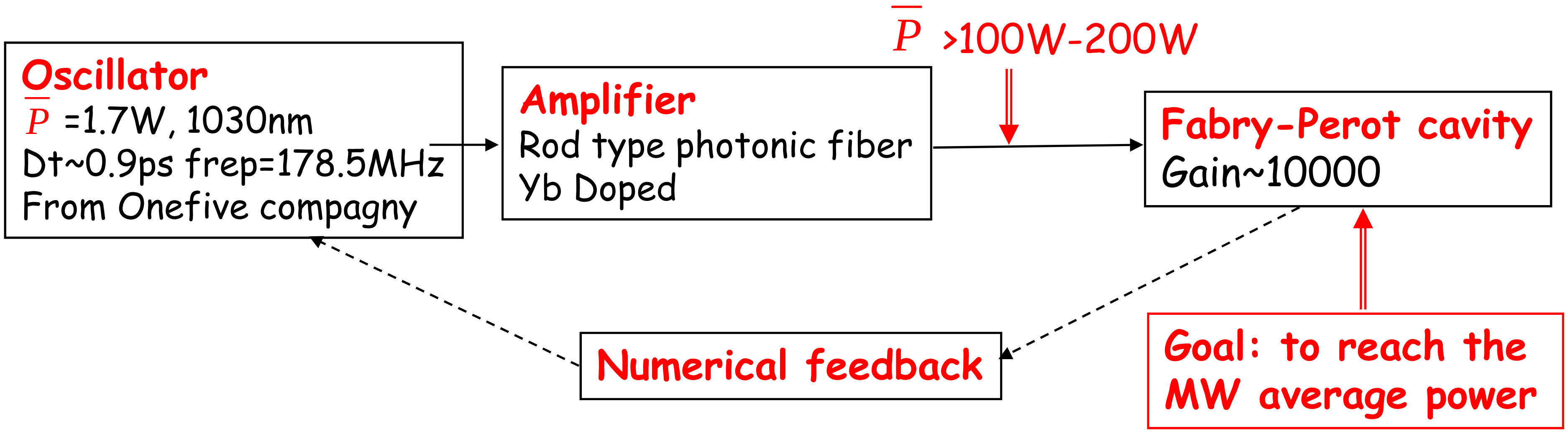
ANR

Continuation of the R&D will start 2009 → 2011

- CELIA / Bordeaux (Laser Lab.)
- KEK/ATF
- LAL/Orsay
- LMA/Lyon (Mirror coating Lab.)

- LAL & CERN are collaborating on the positron source design. The results of these activity will be rescaled for the CLIC parameters.

1. Setup the following system at Bordeaux/Orsay



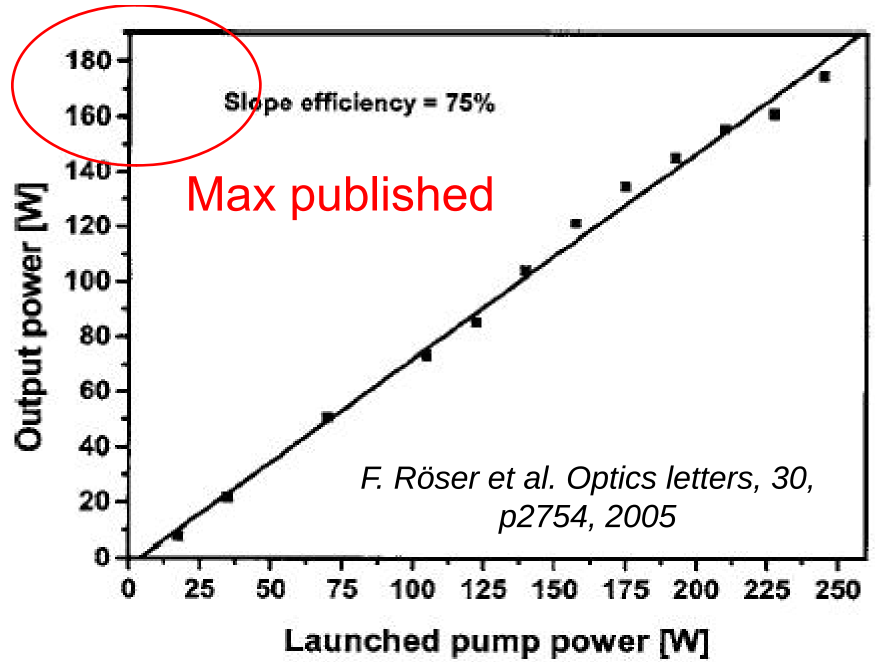
2. Study thermal effects Lyon/Bordeaux (a priori dominated by thermal length in the mirror substrat)

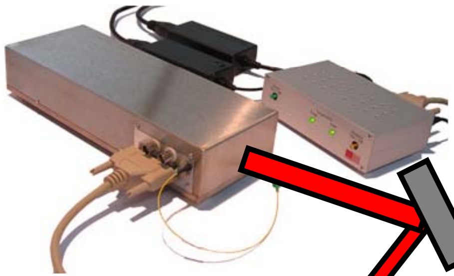
3. Installation of the system at ATF/KEK, in collaboration with ATF group

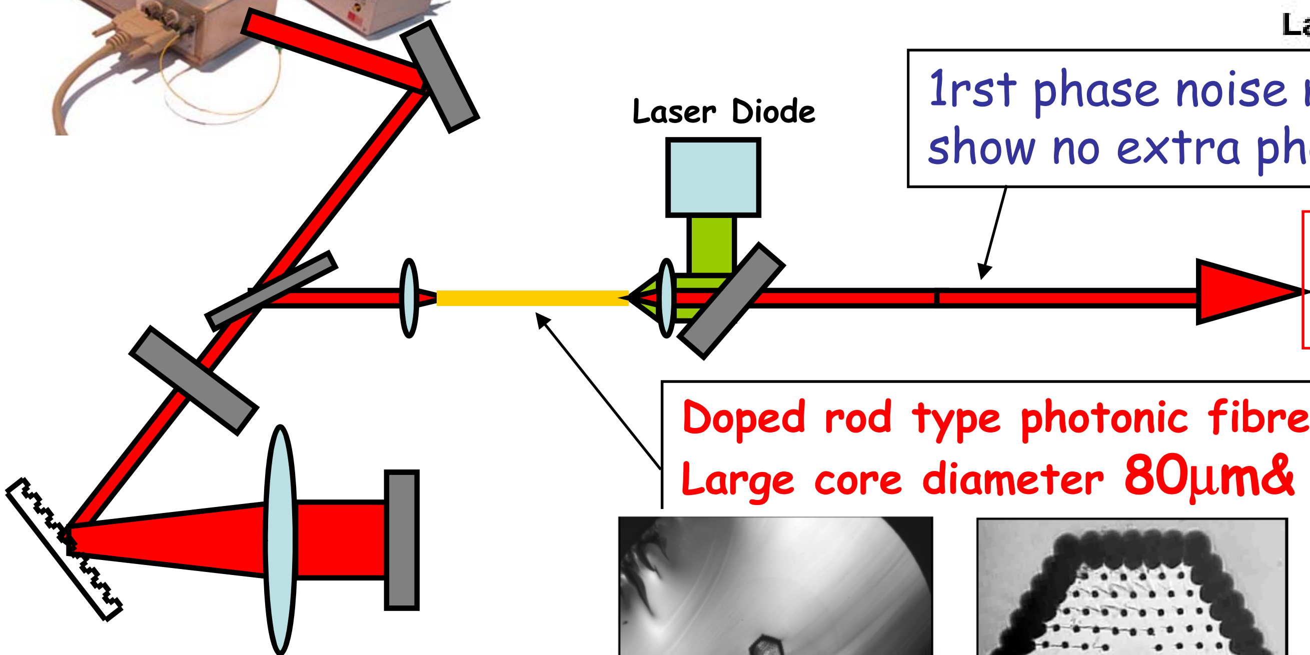
The laser amplification R&D
E. Cormier (CELIA)

OneFive laser, 1030 nm

Dt=0.9ps, 178.5 MHz, 1.7W





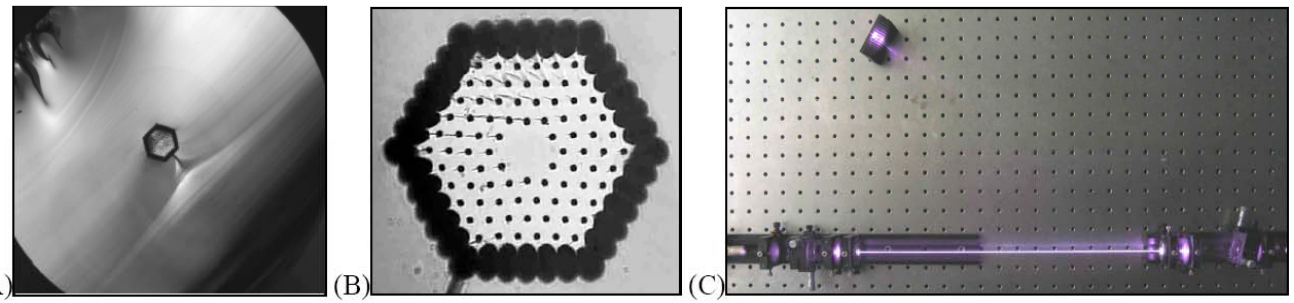


1rst phase noise measurements up to 80W show no extra phase noise

Possible average power 100W-300W (simulation)

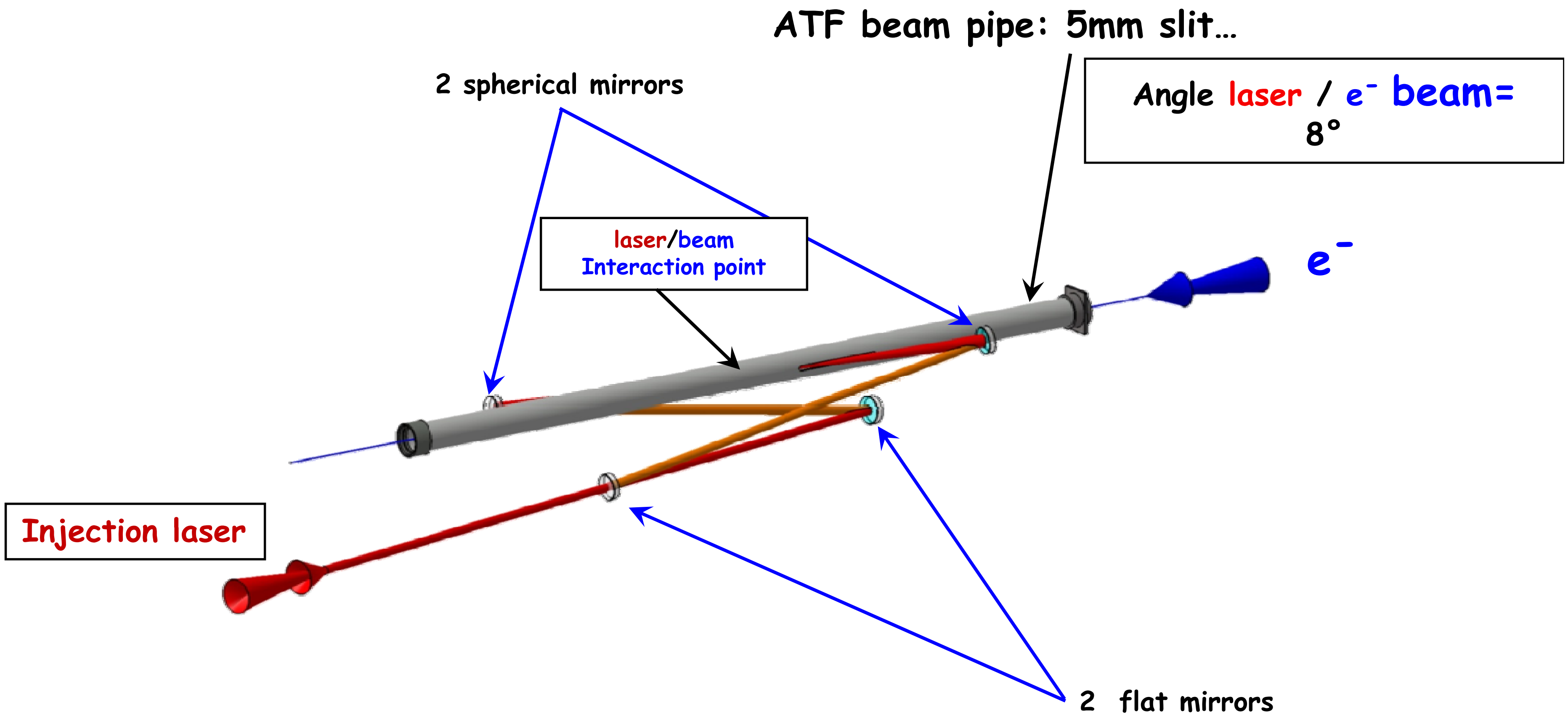
Doped rod type photonic fibre:
Large core diameter 80μm& monomode

Gold grating-based strectcher gives negative chirp for spectral compression



(A) (B) (C)

4 mirror cavity for KEK



4 mirror cavity for KEK

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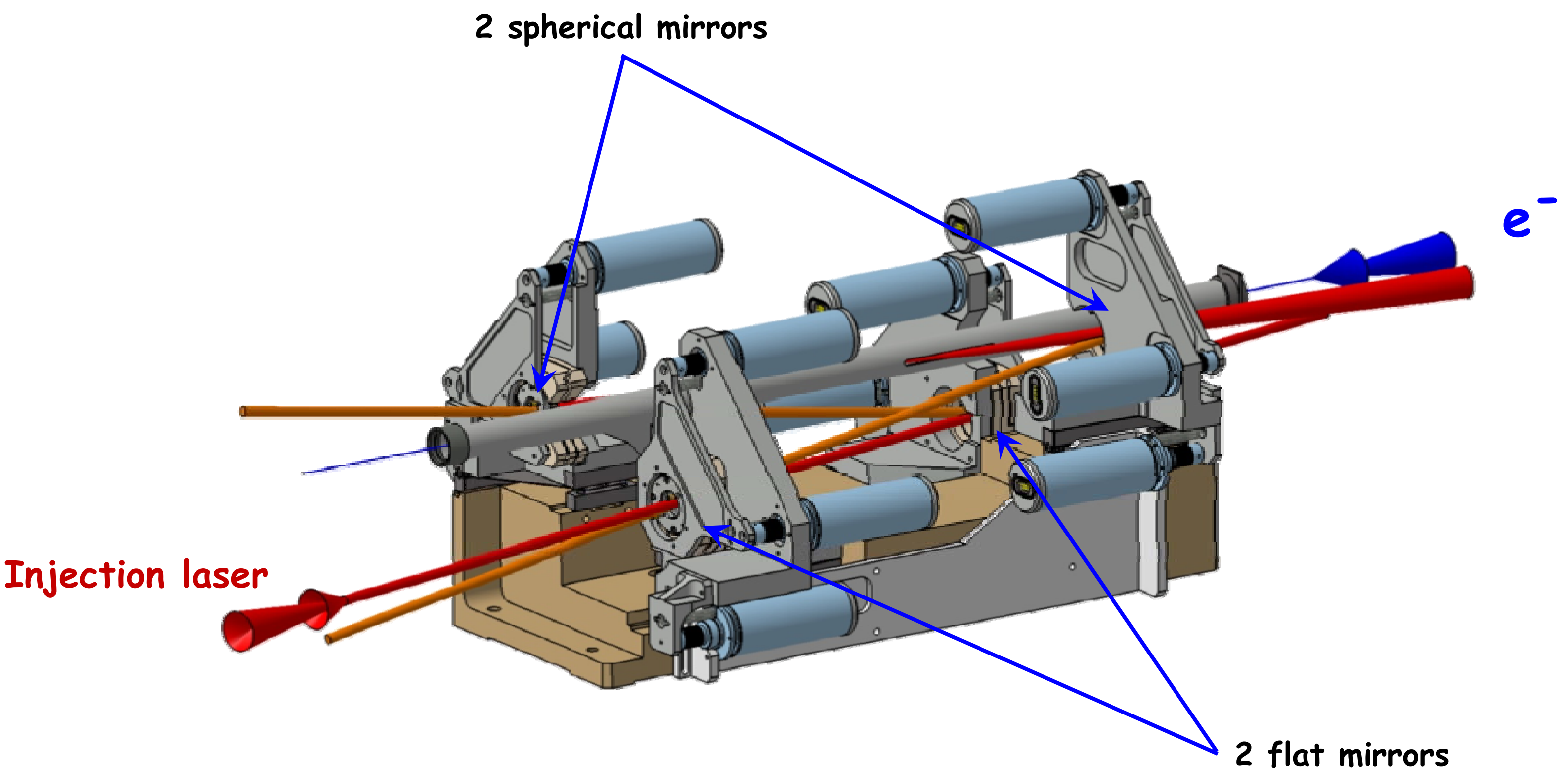
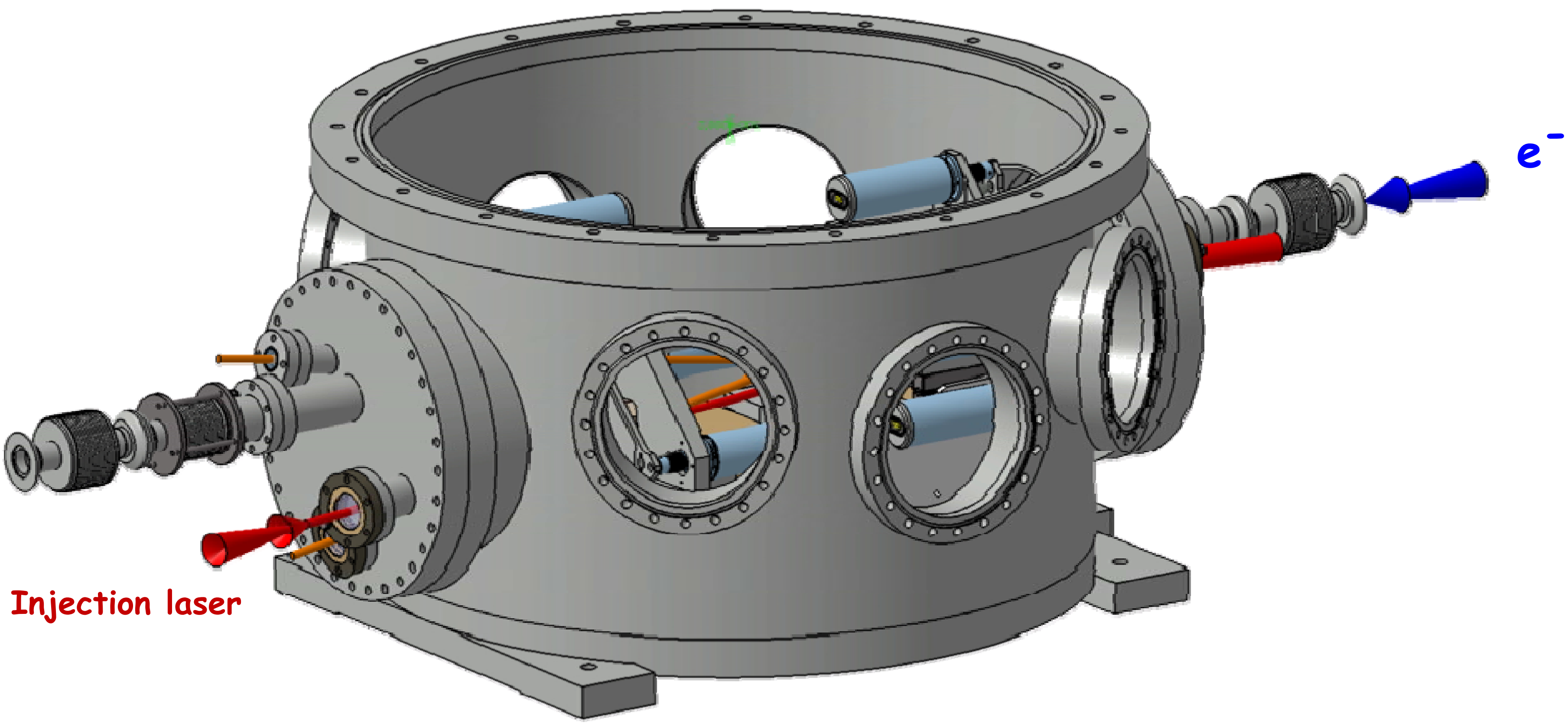
Mirror positioning system



Vacuum vessel for KEK



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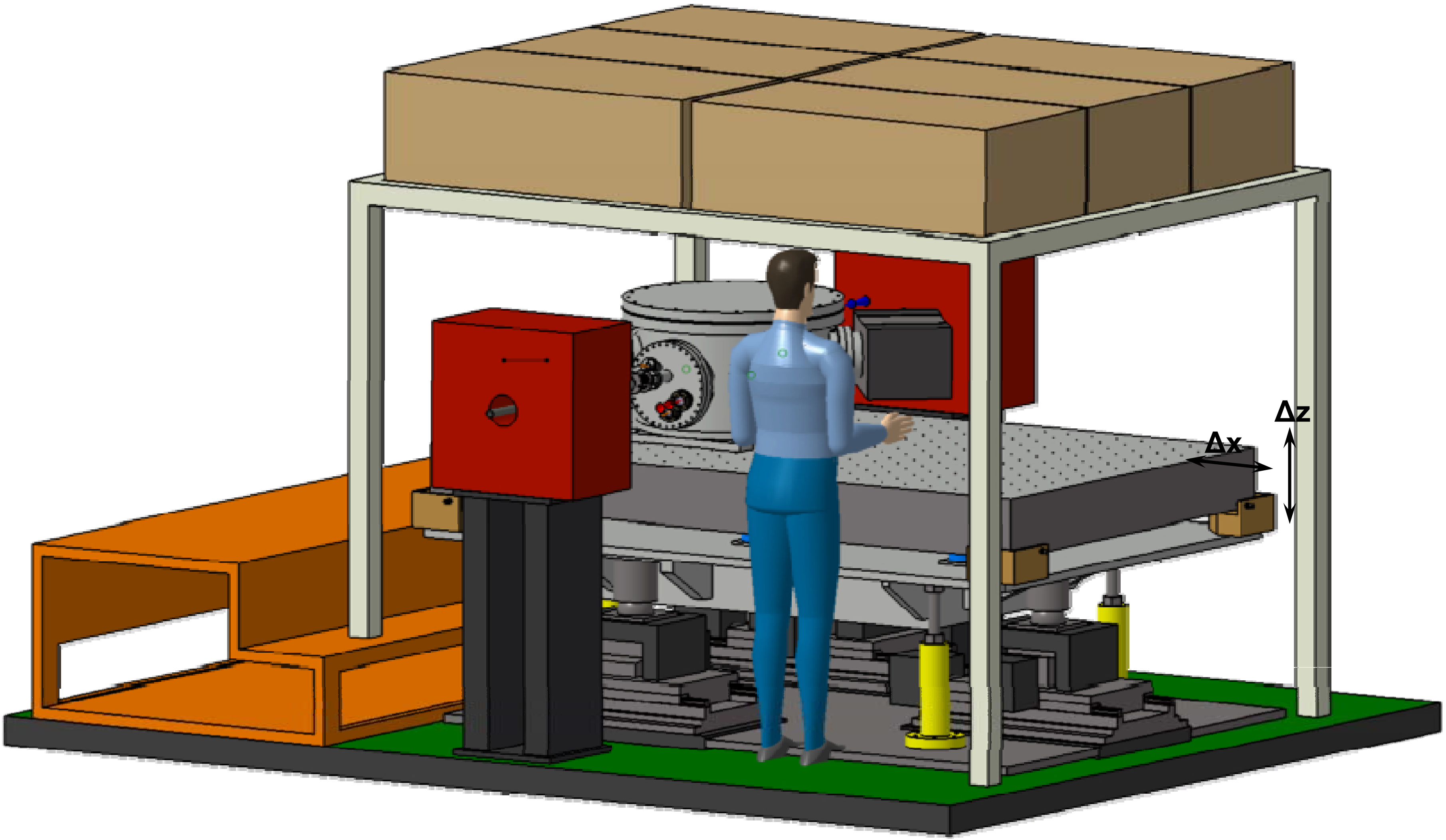
Implantation at ATF



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Summary

- LAL is involved in different programs involving lasers, FP cavities etc…
- 1 GOAL => store the maximum power with a very short pulse for Compton applications
- First goals successful: (@ low power) we locked at 30000 finesse, we produced waists of the order of few tenths of microns and we studied the best 4 mirrors cavity configurations due to the polarization effects on modes.

- Next steps

a) increase the finesse
b) implement the locking on the second degree of freedom (to maintain the locking with short pulses)
c) develop a high power high frep fiber laser
d) study the behavior of mirrors coatings under high power regime
e) try to store more than 100kW (and why not 1 MW) in a FP resonator
f) Install the system @ ATF KEK and have a first principle demonstration (and the first world gamma factory…)

The results will be rescaled and dimensioned for the proposal of the polarized positron source for the CLIC based on Compton scattering