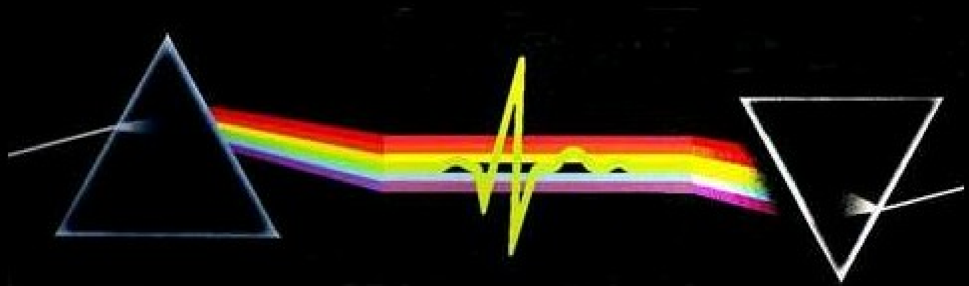


PLIC

Pulsed Laser Injected Cavity

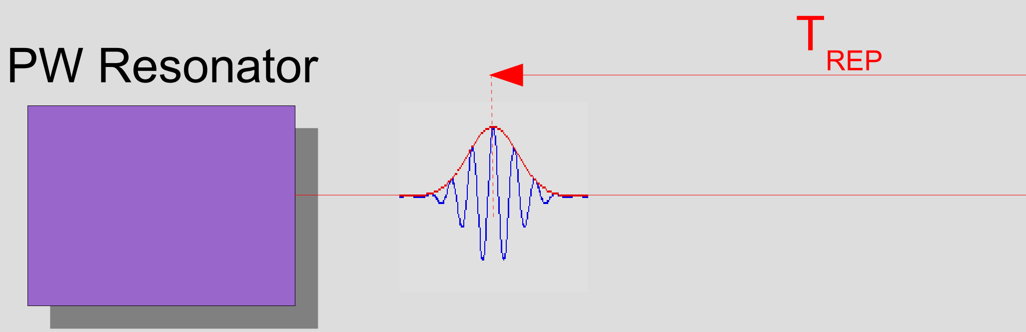
R&D goals summary

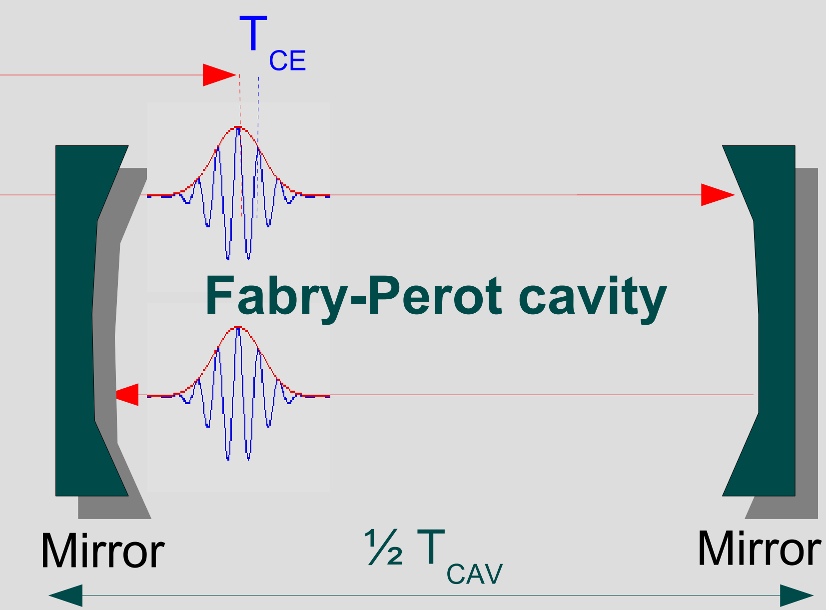
- Use of a 2m Fabry-Perot optical cavity to amplify pico-second laser pulses
  - Finesse = 1000 then 30 000
- 800 mW (mean power) resonator @ λ=800 nm
  - Pumped by a 6W CW laser
  - Repetition rate : 76 Mhz (2m cavity matching)
  - Achievable Finesse of 1 000 000 limited by spontaneous emission @800mW
- Particular studies to put the laser & cavity on an accelerator (part of the experiment presented by Yasmina Fedala)

- Brief experiment principles
- Technical details
- Status & Prospects

Brief experiment principles

PW laser amplifying principle in time domain



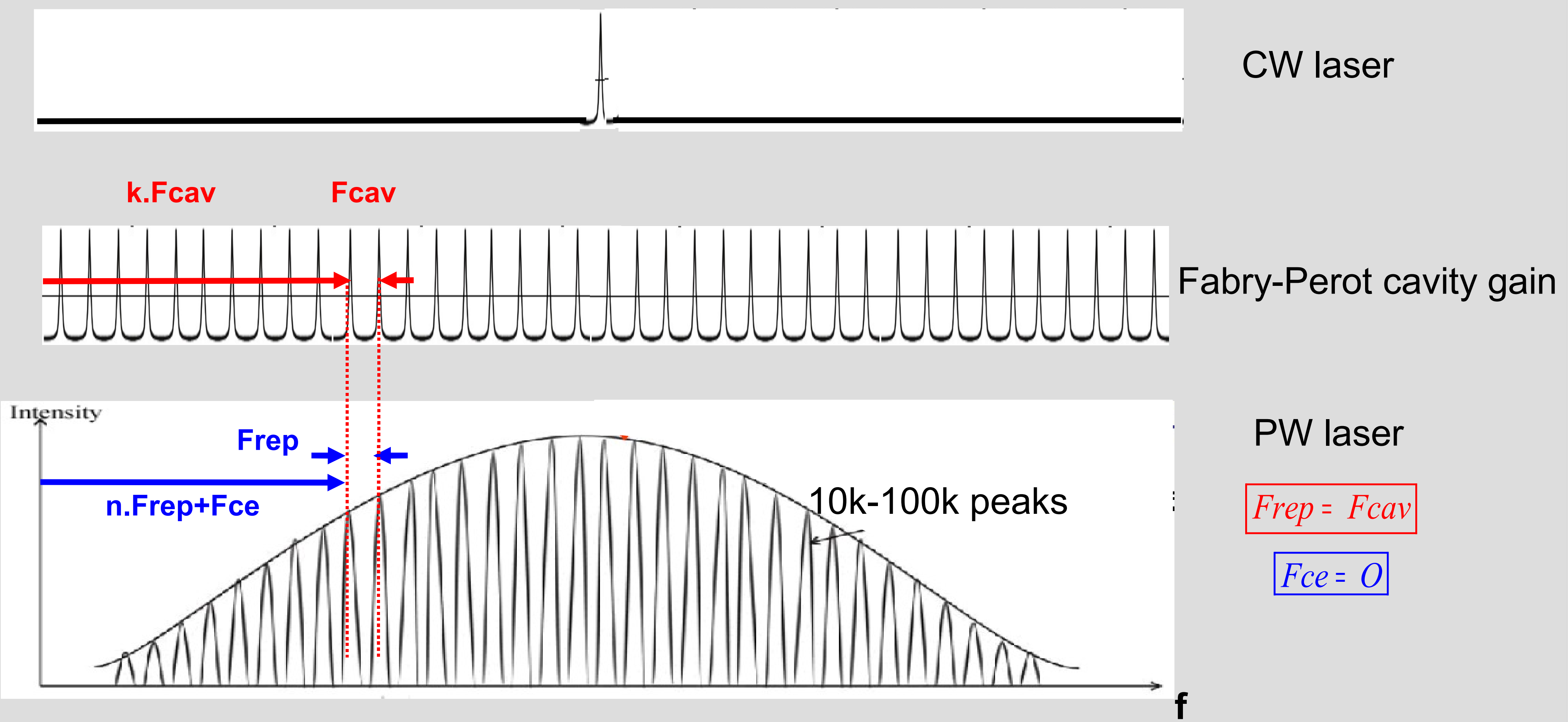


Laser pulses are amplified
if laser field can overlay with FP cavity field :

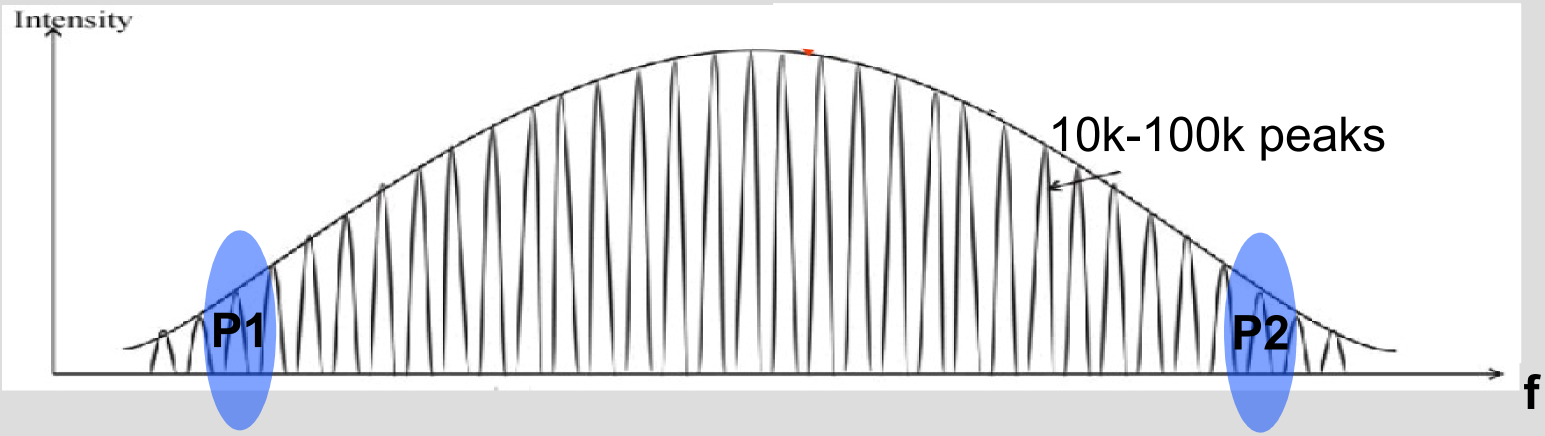
$$Trep \triangleq \frac{Lrep}{Vg} = Tcav \triangleq \frac{Lcav}{Vg} \Rightarrow \boxed{Lrep = Lcav}$$

$$Tce \triangleq Lrep\left(\frac{1}{Vg} - \frac{1}{V\varphi}\right) = 0 \Rightarrow \boxed{Vg - V\varphi = 0}$$

Amplifying principle in frequency domain



Locking principle

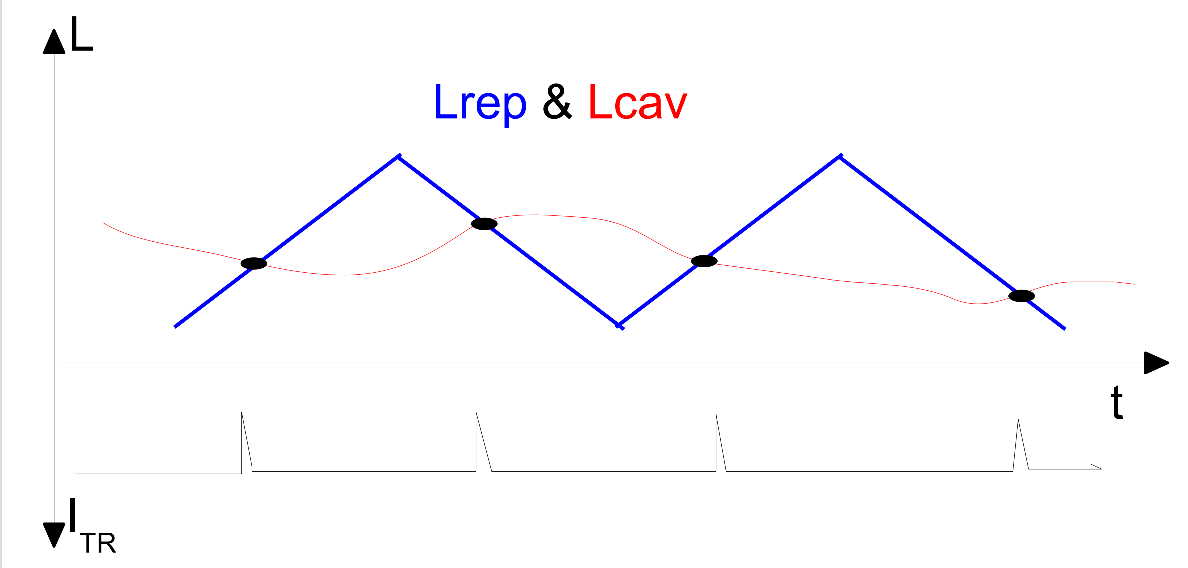


1) Ramping Lrep

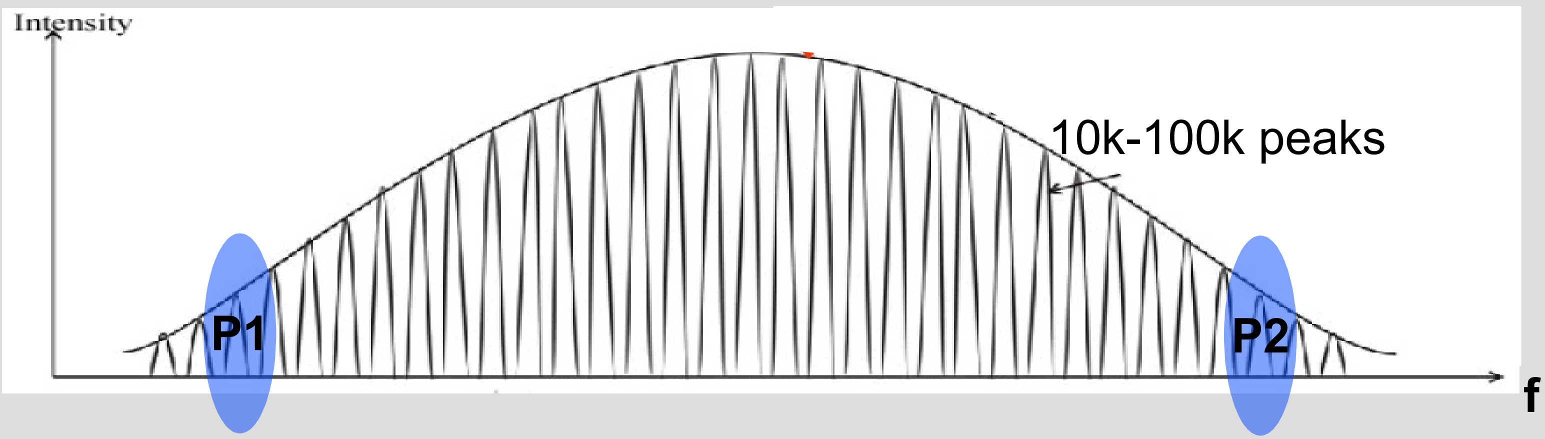
2) I_{TR}>0 & PDH=0 => Lrep = Lcav

3) Trigger to hold Lrep
   (Lcav is free)

4) Measurement & feedback
to cancel phase shift @P1 & P2



Locking principle



1) Ramping Lrep

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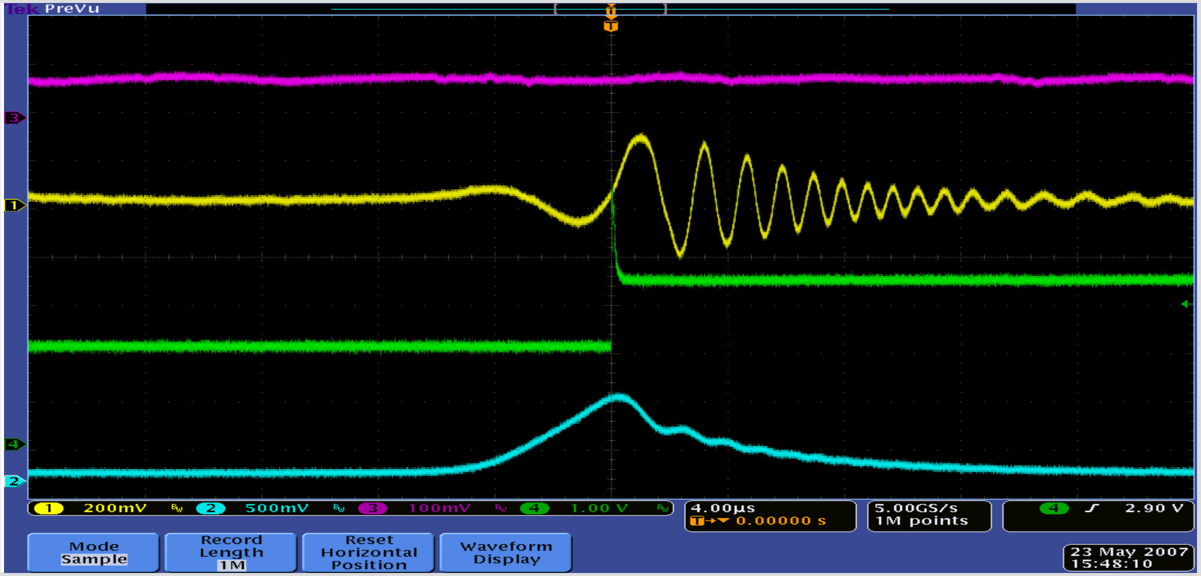
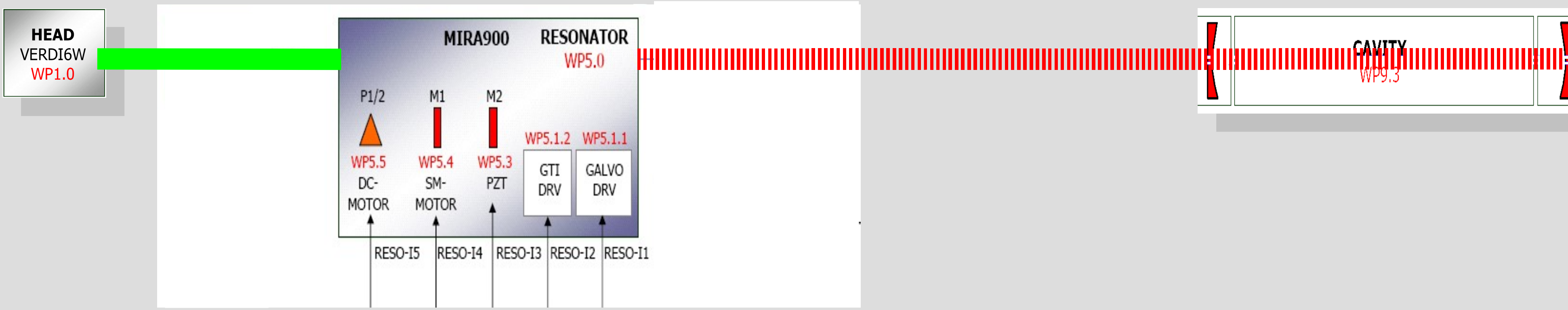


Locking bricks

- One needs signals sensitive to frequency difference to control Frep=Fcav and Fce=0 => 3 Pound-Drever-Hall measurement blocks
- One needs actuators to allow feedback on LASER parameters Lrep, Vg-Vφ => Motors, PZT, AOM, Shifter, GTI & starter
- One needs a system to acquire, make a feedback and output analog signals : we chose a digital system with ADC, FPGA, DAC => Lyrtech DAQ board

Technical details

Main optical elements



Coherent Verdi :

- CW DPSS
- Power : 6 W
- Wavelength : 532 nm

LAL made FP cavity :

- Length : 2 m
- Finesse : 1000 then 30000

Coherent Mira :

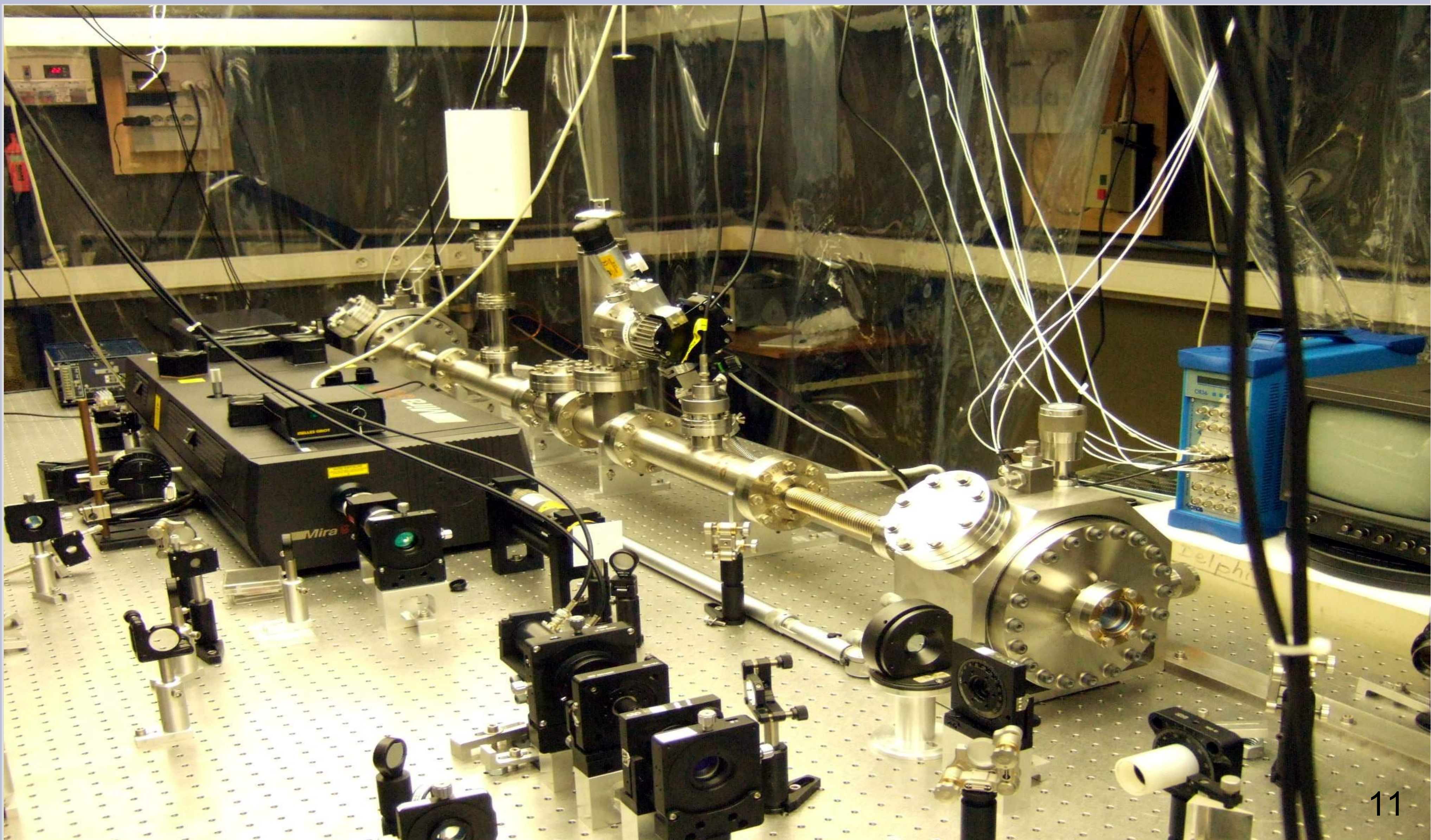
- Ti:Al_2O_3 pulsed resonator by Kerr effect
- Repetition rate : Frep = 76 MHz
- Energy per pulse : E = 10 nJ / pulse
- Pulse width : T_{FWHM} = 1 ps / 100 fs
- Wavelength : λ = 800 nm

} $\overline{P}$ = 760 mW

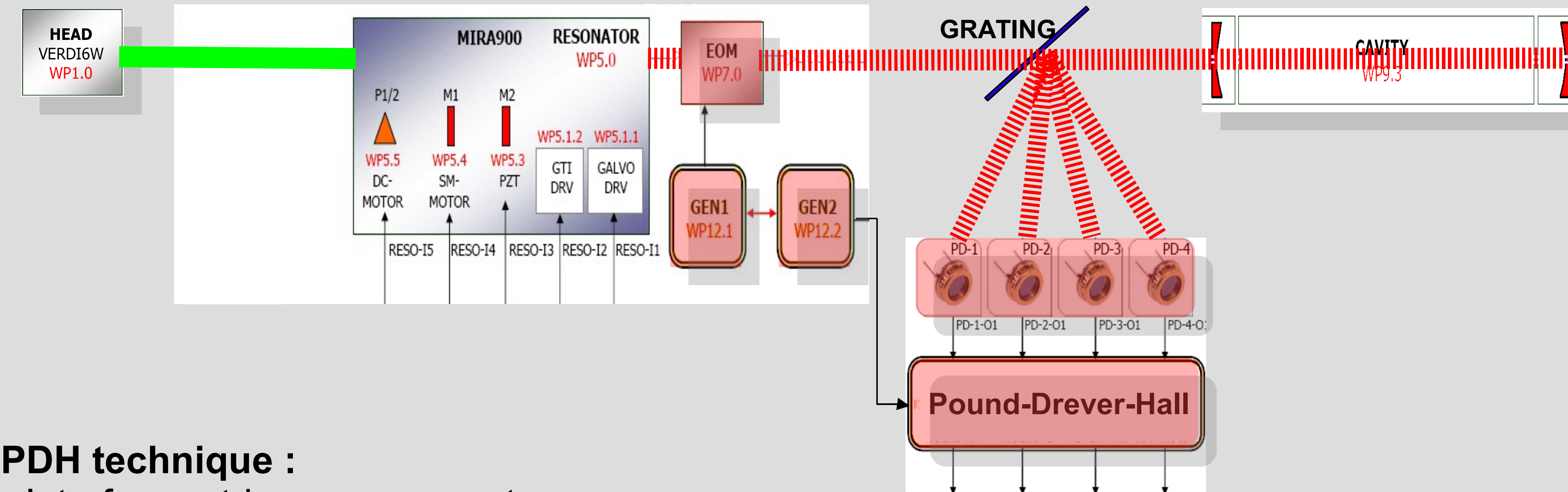
6W pumping CW laser

760mW PW laser

Laser, resonator & cavity picture



Pound-Drever-Hall phase detection technique



6W pumping CW laser

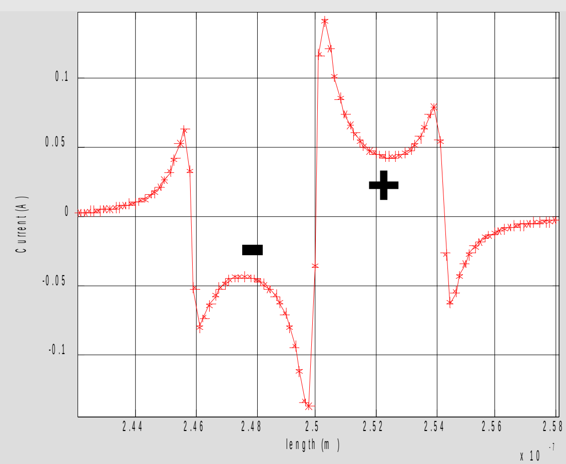
760mW PW laser

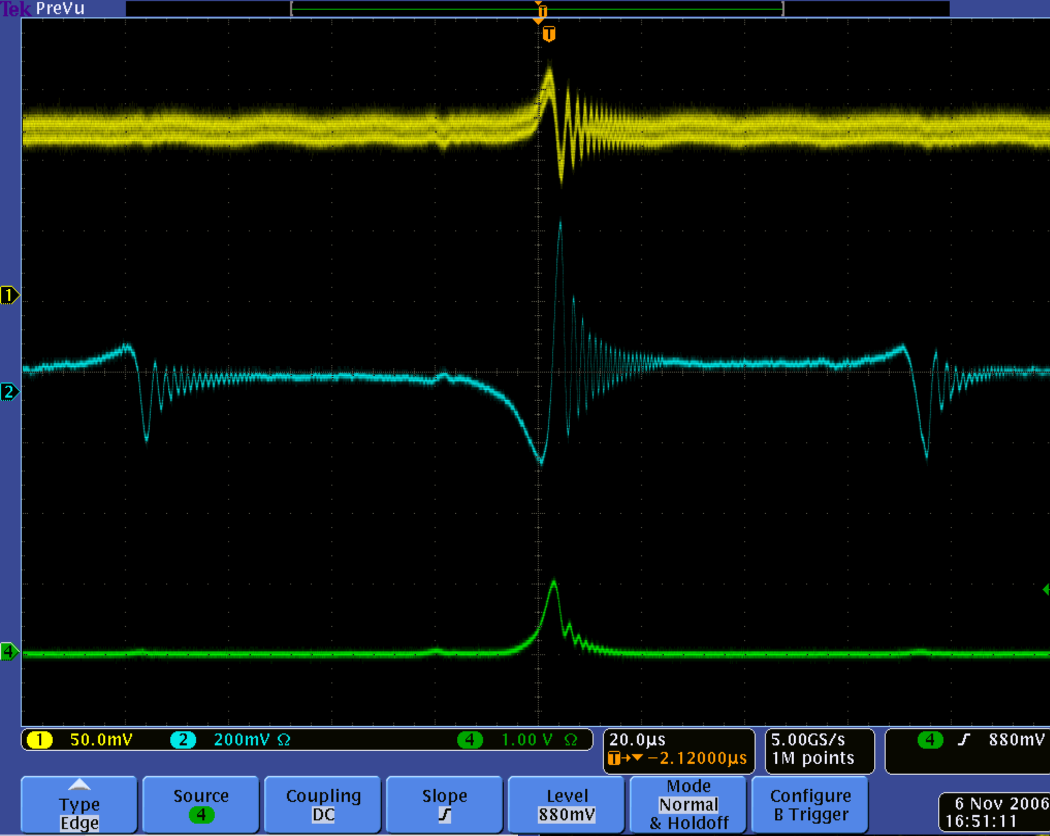
Front-end PDH

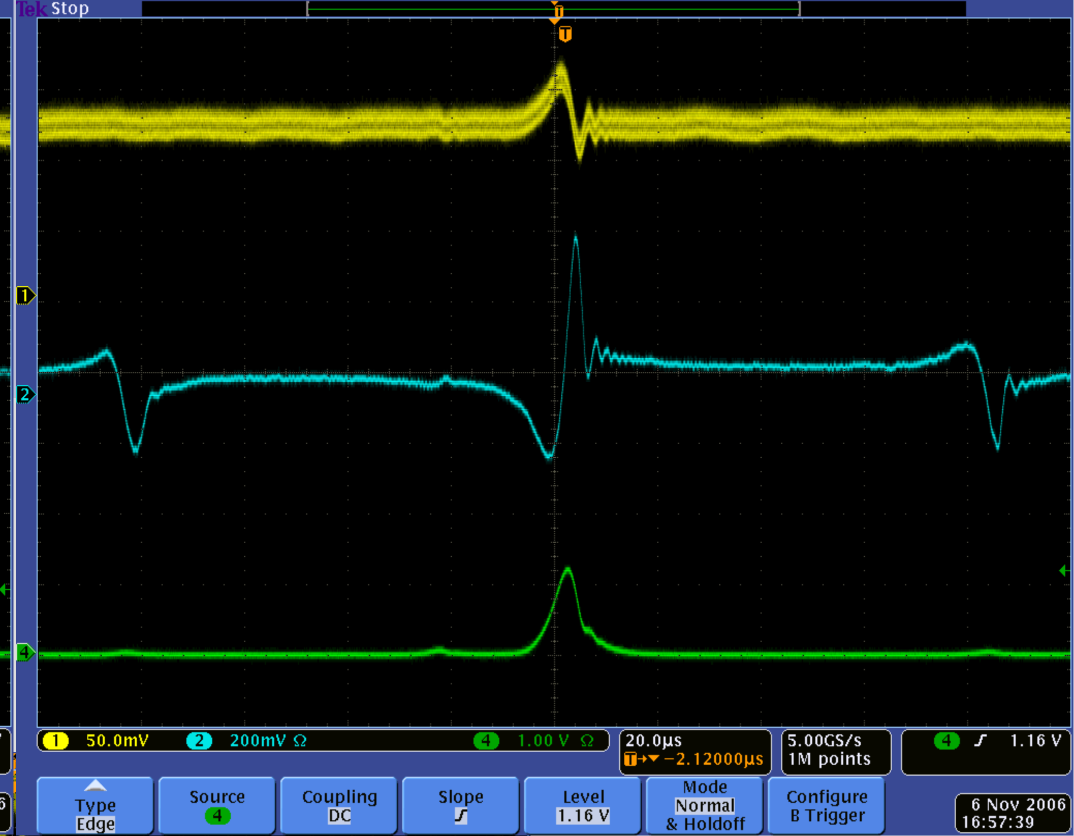
PDH technique :

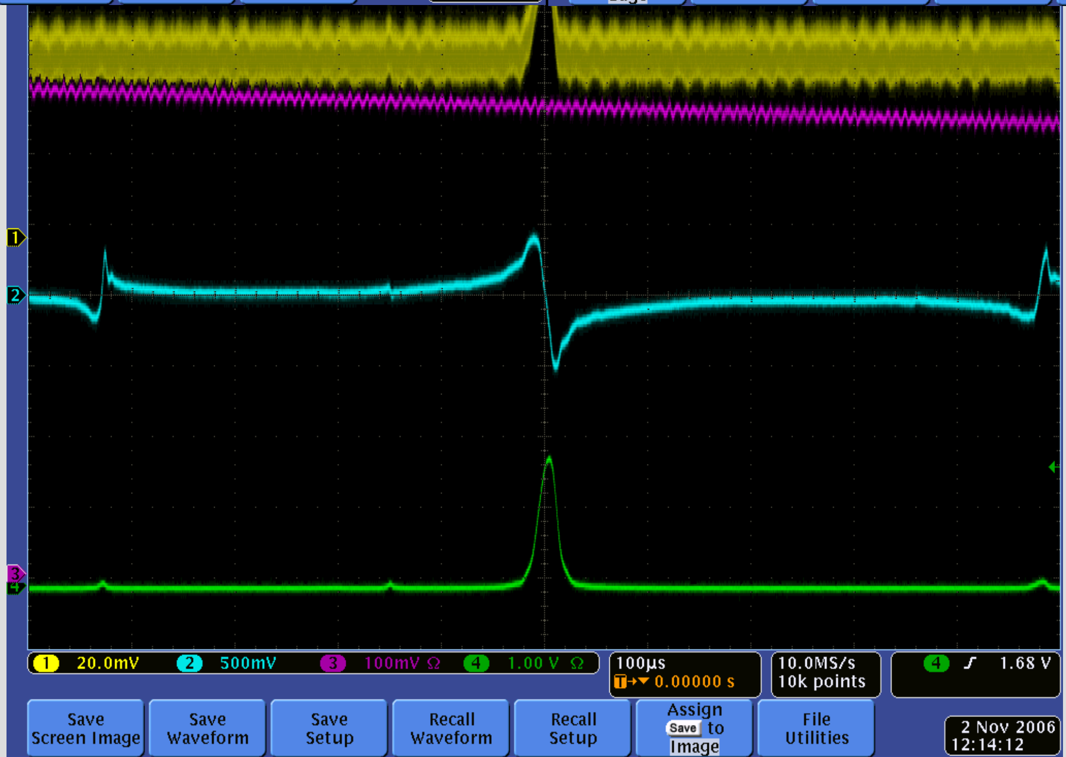
- Interferometric measurement
- Very high sensitivity only limited by spontaneous emission noise converted to phase noise
- Sidebands produced by EOM
- Quadrature demodulation
- Grating + slits
- Linear region for linear feedback corresponding to FP cavity linewidth
- « wider » non linear region

Pound-Drever-Hall transfer function

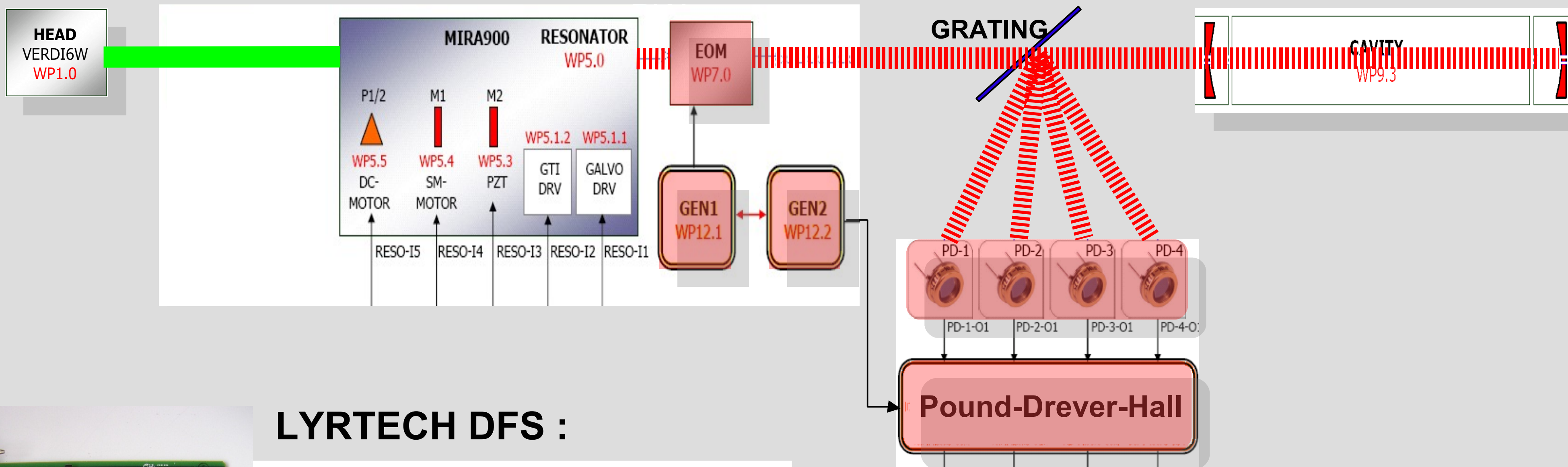



Tek PreVu
50.0mV
200mV Ω
1.00 V Ω
20.0µs
−2.12000µs
5.00GS/s
1M points
880mV
Type
Edge
Source
Coupling
DC
Slope
Level
880mV
Mode
Normal
& Holdoff
Configure
B Trigger
6 Nov 2006
16:51:11


Tek Stop
50.0mV
200mV Ω
1.00 V Ω
20.0µs
−2.12000µs
5.00GS/s
1M points
1.16 V
Type
Edge
Source
Coupling
DC
Slope
Level
1.16 V
Mode
Normal
& Holdoff
Configure
B Trigger
6 Nov 2006
16:57:39


20.0mV
500mV
100mV Ω
1.00 V Ω
100µs
0.00000 s
10.0MS/s
10k points
1.68 V
Save
Screen Image
Save
Waveform
Save
Setup
Recall
Waveform
Recall
Setup
Assign
Save to
Image
File
Utilities
2 Nov 2006
12:14:12

Digital Feedback System (DFS)

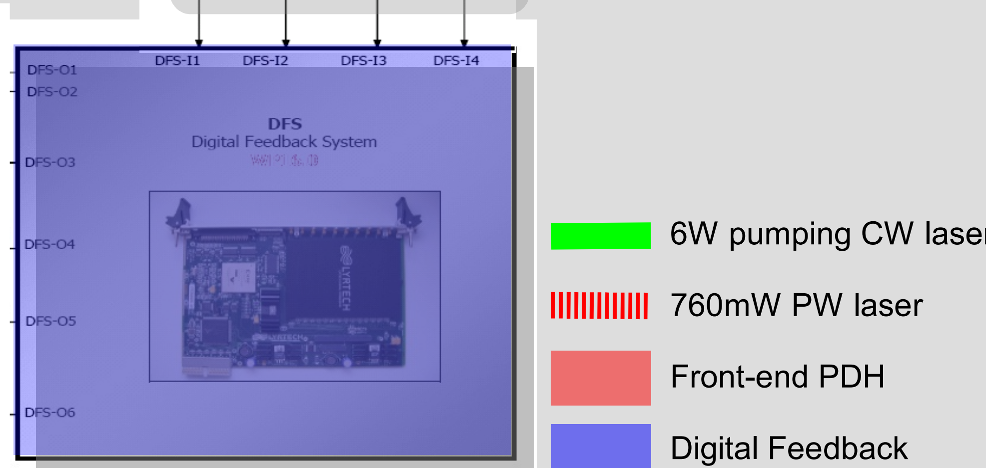


LYRTECH DFS :

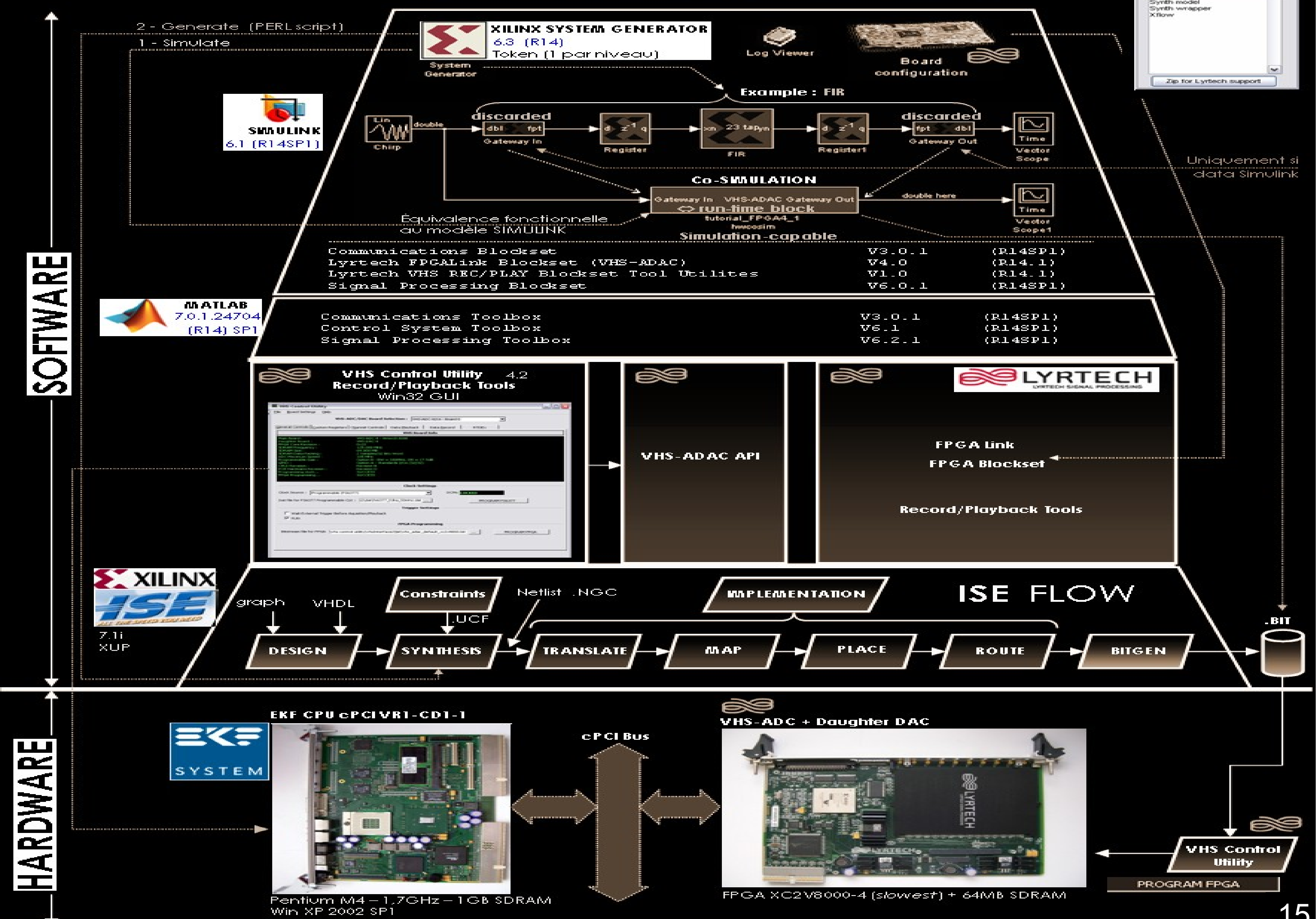
- 8 ADC channels
- Sampling @ 105 MS/s
- 14 bits of resolution

- Virtex-II FPGA : XC2V8000
- Fixed point arithmetic
- 168 Multipliers 18b x 18b

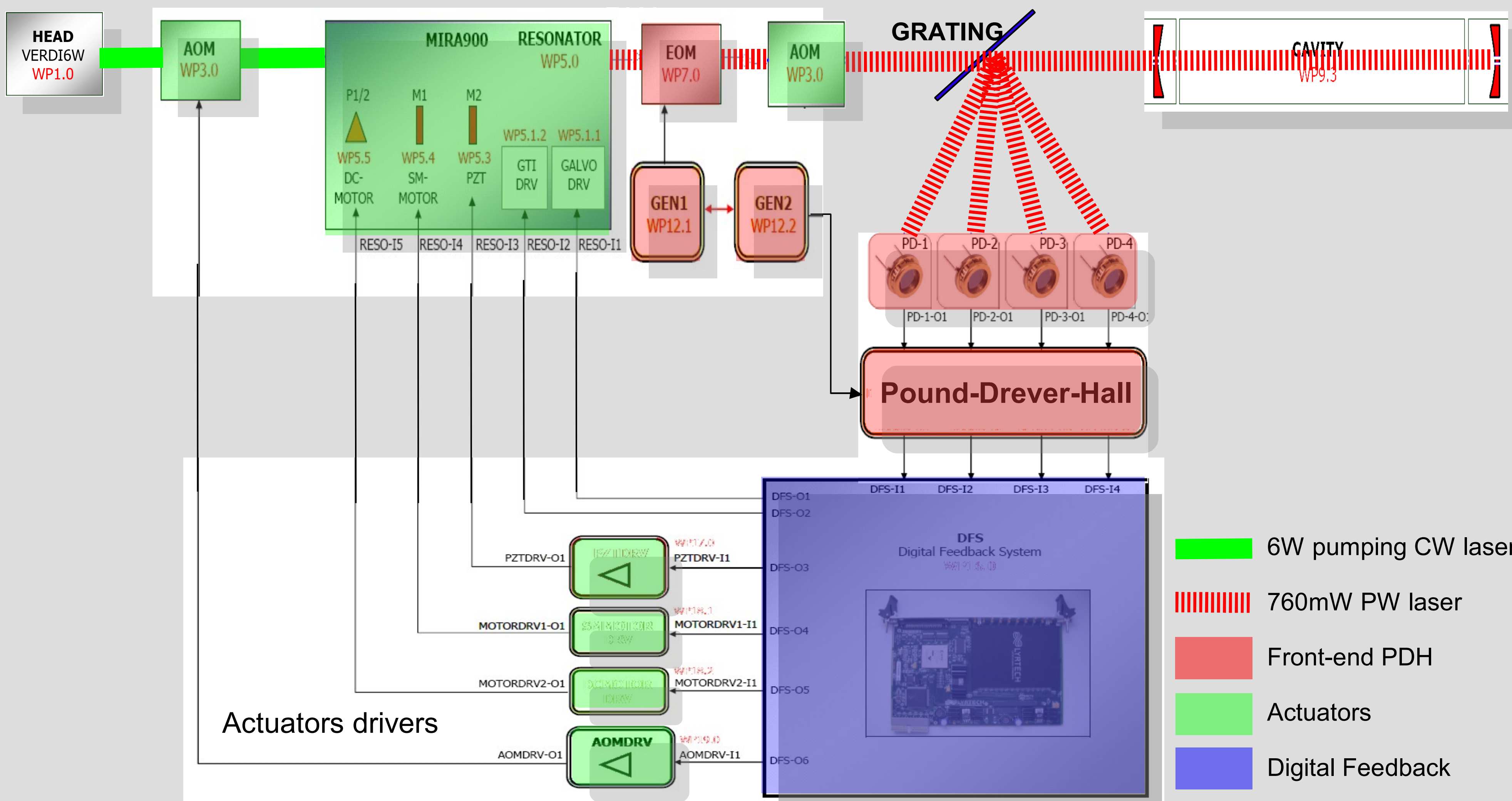
- 8 DAC channels
- Conversion rate @ 125 MS/s
- 14 bits of resolution



SOFTWARE TOOLS FLOW



Actuators



1) PZT, motor **change laser path length** : Lrep, ~~Vg-Vφ~~ => Frep, ~~Fce~~

2) AOM & Frequency shifter **change local refractive index** : Vg-Vφ => Fce

Status & Prospects

Status (1)

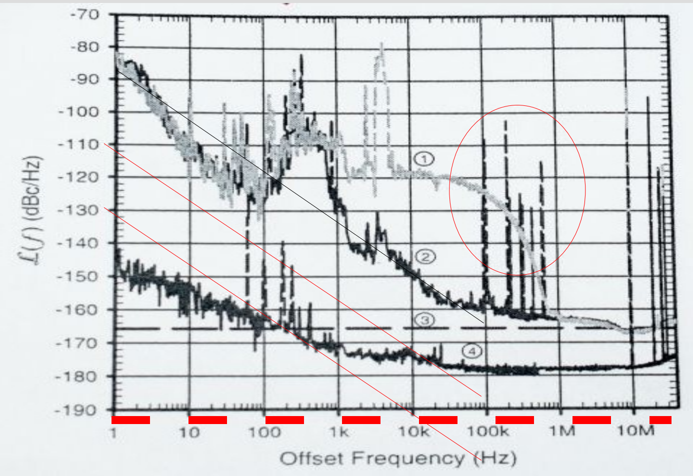
- Laser, resonator & cavity installed on optical table with vibration damping feet.
- Cavity is now with a vacuum tube & vacuum is done
  - Finesse is presently about 1000 but 30000 finesse mirrors are on the shelf
  - For the present finesse the short term stability of the laser cavity should be better than the FP cavity
  - Then one only needs to compensate (long term) low frequency drifts $< <$ kHz
- Phase measurement with the PDH technique gives good results.
  - Max signal of 1V with 750µV RMS of noise means a precision better than 0,1% inside the cavity linewidth and this precision is independant of the finesse.
  - 1MHz PDH bandwidth ensures a low phase delay @ kHz
  - 1 block produced for the global spectrum measurement
  - 2 blocks are designed with gain 10x and same output noise for P1 & P2
- Used actuators are a mirror motor and mirror PZT.
  - PZT driver and signal transmission need to be improved (differential scheme for PZT driving and signal transmission)

Status (2)

- Digital feedback conception flow is now masterized (Simulink/Matlab/ISE/VHDL/Synthesis)
  - IIR SOS structure has a double loop scheme on output data to improve the precision
  - Digital ramping signal produced then hold when resonance is reached
  - Linear feedback is triggered in same time (currently under definition for PZT)
  - First feedback loop on motor gave good result but was not fast enough to keep locking
  - Working on PZT with the global frequency offset only (we are waiting 2 more PDH blocks)
- Many measurements & simulations are under way
  - Gain calibration of the system
  - Noise sources measurement (Seismic / accoustic / electronics / phase noise) & coupling reduction
  - Simulink simulation to predict feedback & cavity behavior

Prospects

- Lock the 1000 finesse cavity at short term
- Use 30000 finesse mirrors => increase Feedback bandwidth @ 1MHz
- PDH :
  - Needs optimization for delay response to prevent from stability problems with the feedback system.
  - Increase PDH bandwidth => increase noise



- Feedback :
  - Need of a non-stationnary cavity model
  - 100ns of structural delay (10 clock counts for ADC+DAC) => predictive model ?
  - Fixed point => Filters coefficients generation algorithm needs improvement
- Actuators :
  - Need of several actuators for dynamics – bandwidth trade-off
  - Need of improved drivers noise