Activités expérimentales autour des cavités Fabry-Perot au LAL

But de cette activité

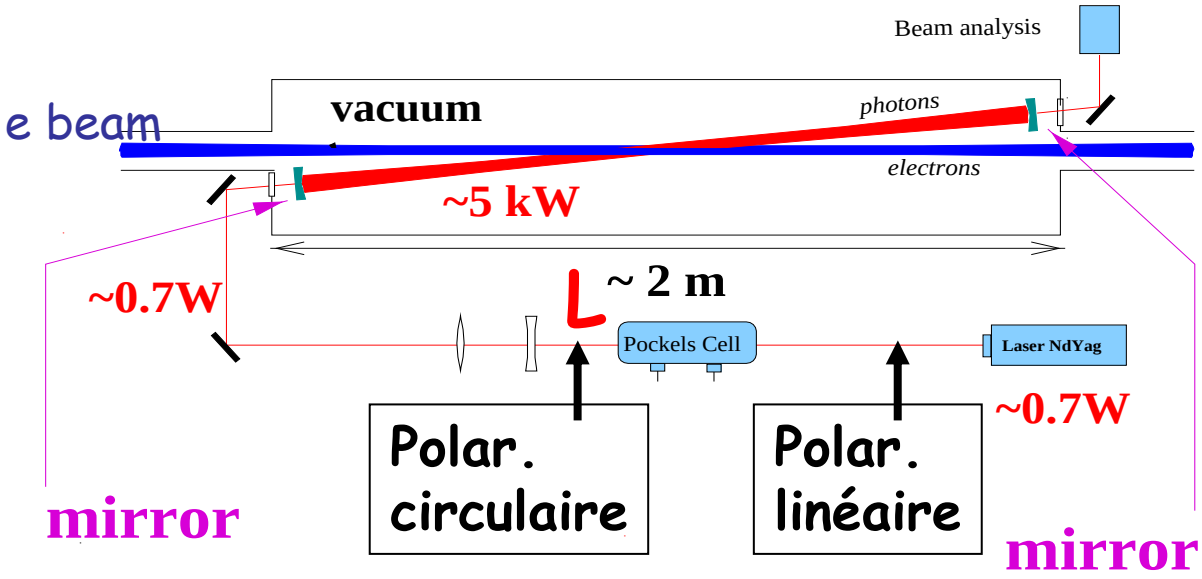
Obtenir un faisceau laser de forte puissance moyenne au point d'interaction laser-électron ← c.f. présentation A. Variola

Plan

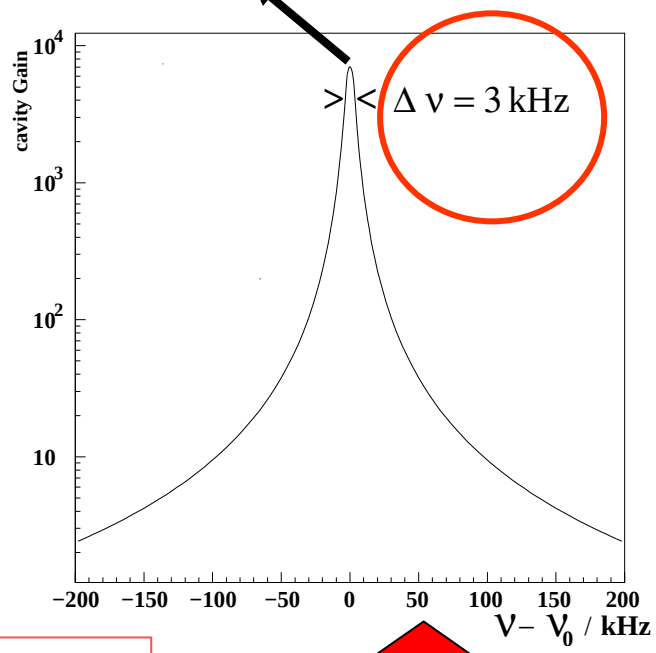
- Introduction : la cavité Fabry-Perot
- R&D passée, présente & future

F. Zomer LAL/IN2P3/Université Paris 11

Cavité Fabry-Perot : principe



Gain ~9000



Quand $\nu_{Laser} \propto c/2L \Rightarrow$ résonance

- Mais : $\Delta\nu/\nu_{Laser} = 10^{-11} \Rightarrow$ asservissement laser/cavité
  - Effectué en `jouant' sur la fréquence du laser

$\Rightarrow$ Laser Nd:YAG (infra-rouge, λ =1064 nm)

R&D passée : 2000-2007
Polarimétrie Compton à HERA

Diffusion Compton :

$e+\gamma_L \rightarrow e+\gamma$

Section efficace :

$d\sigma/dE_\gamma = \sigma_0(E_\gamma) - P_e S_\gamma \sigma_1(E_\gamma)$

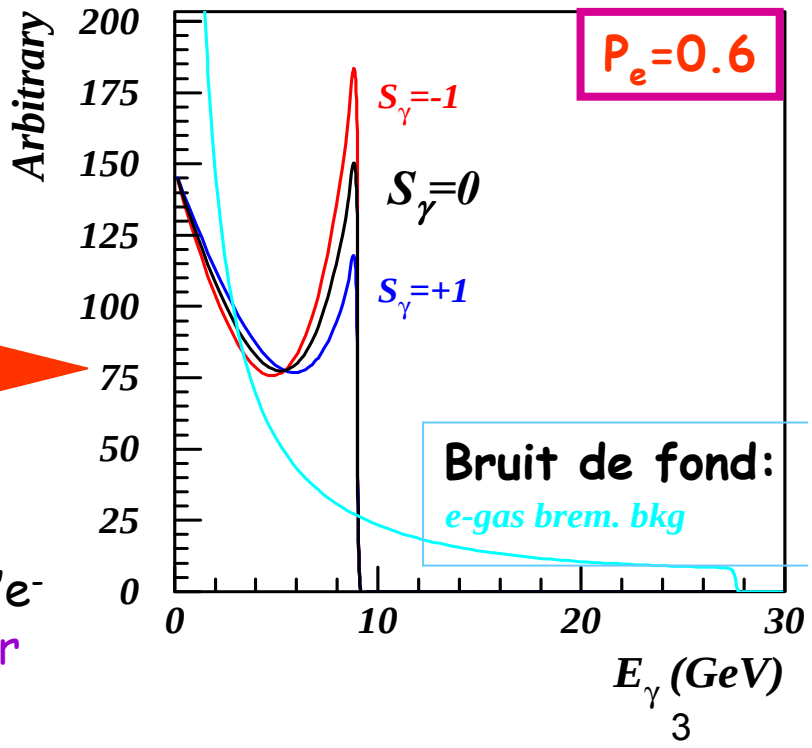
σ_0, σ_1: connues (QED)

S_γ: degré de polarisation circulaire faisceau laser (±1)

P_e: Polarisation des e^- déterminée par un fit

E_γ

Photon detector



Luminosité (électron-laser):

$$Lumi \propto \frac{\lambda P_L I_e}{\sqrt{\sigma_{e,\gamma}^2 + \sigma_{\gamma,\gamma}^2}}$$

I_e: intensité faisceau d'e^-

λ : longueur d'onde laser

P_L: puissance du laser

Lumi$\propto P_{Laser}$ ➔ résonateur Optique pour accroître la puissance moyenne

ELSEVIER Nuclear Instruments and Methods in Physics Research A 459 (2001) 412–425 Section A
www.elsevier.nl/locate/nima

Compton scattering off polarized electrons with a high-finesse Fabry–Pérot Cavity at JLab

N. Falletto[a], M. Authier[a], M. Baylac[a], M. Boyer[a], F. Bugeon[a], E. Burtin[a], C. Cavata[a], N. Colombel[a], G. Congretel[a], R. Coquillard[a], G. Coulloux[a], B. Couzy[a], P. Deck[a], A. Delbart[a,*], D. Desforges[a], A. Donati[a], B. Duboué[a], S. Escoffier[a], F. Farci[a], B. Frois[a], P. Girardot[a], J. Guillotau[a], C. Henriot[a], C. Jeanney[a], M. Juillard[a], J.-P. Jorda[a], P. Legou[a], D. Lhuillier[a], Y. Lussignol[a], Ph. Mangeot[a], X. Martin[a], F. Marie[a], J. Martino[a], M. Maurier[a], B. Mazeau[a], J.F. Millot[a], F. Molinié[a], J.-P. Mols[a], J.-P. Mouly[a], M. Mur[a], D. Neyret[a], T. Pédrol[a], S. Platchkov[a], G. Pontet[a], T. Pussieux[a], Y. Queinec[a], Ph. Rebourgeard[a], J.C. Sellier[a], G. Tarte[a], C. Veyssière[a], A. Zakarian[a], P. Bertin[b], A. Cosquer[b], J.P. Chen[c], J. Mitchell[c], J.-M. Mackowski[d], L. Pinard[d]

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[b]*LPC/IN2P3, Clermont Ferrand, France*
[c]*Thomas Jefferson National Accelerator Facility, Newport News, VA 23606, USA*
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Received 28 June 2000; accepted 5 August 2000

Même cavité à HERA (Projet LAL/DESY)

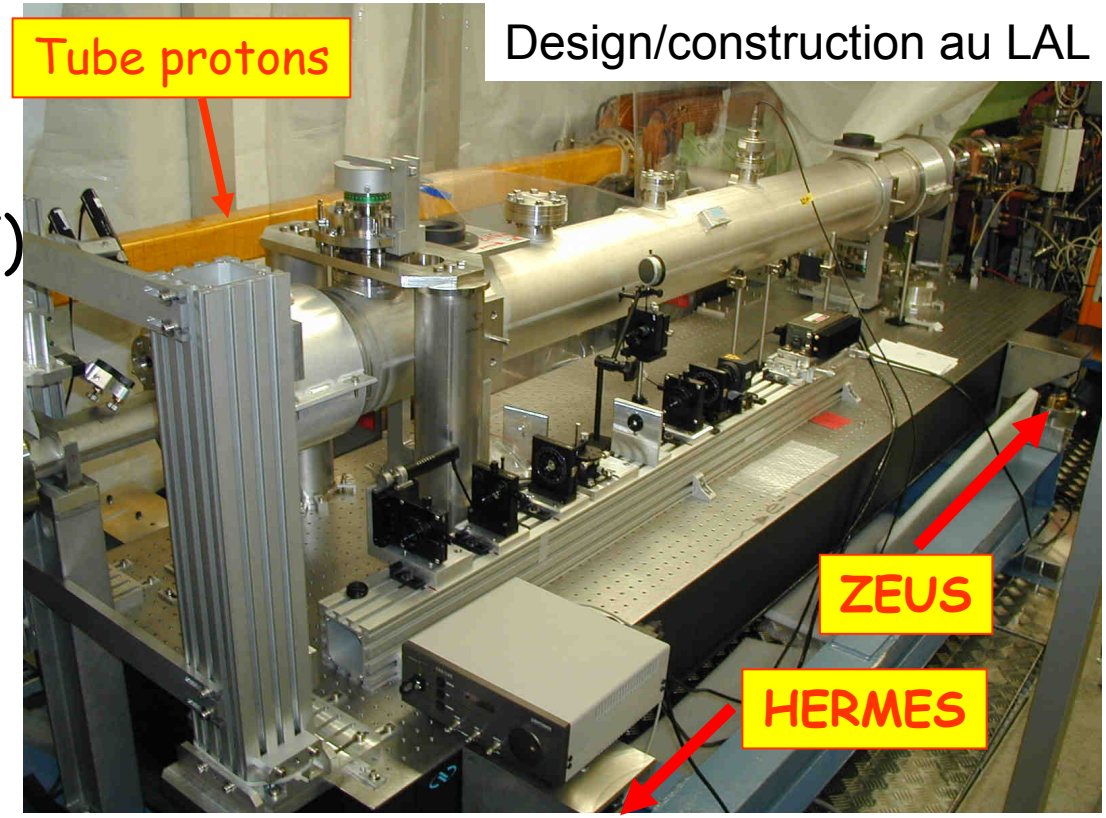
~200 bunchs d'e± (27.5GeV)

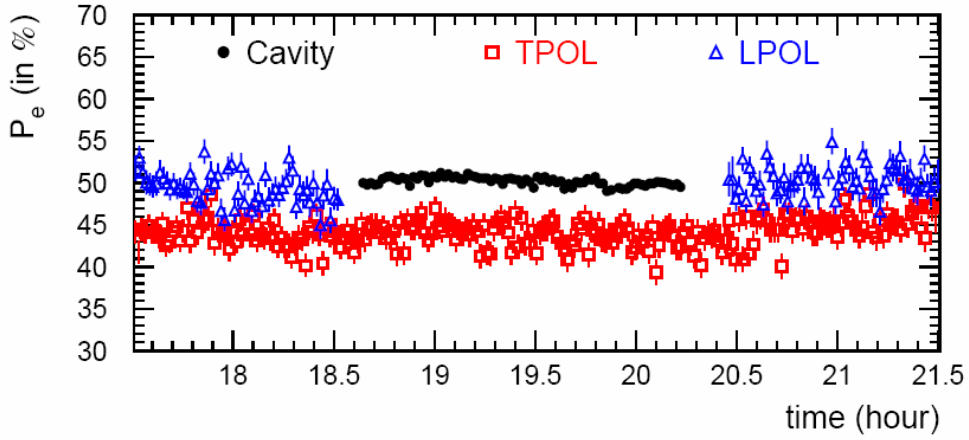
But : Δ_{stat}~1%/bunch/mn

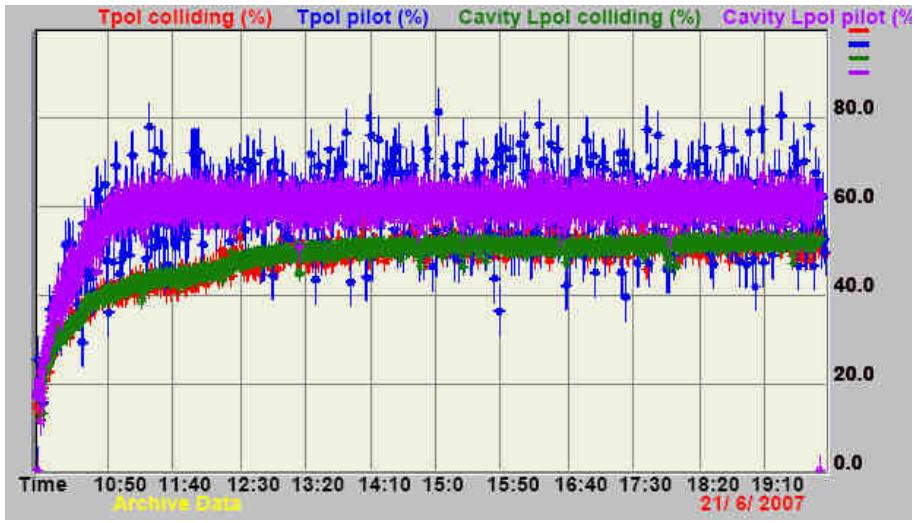
➔DAQ sans trigger à 10MHz

➔ P_{laser} (cw)~5kW

➔ Gain cavité ~10000

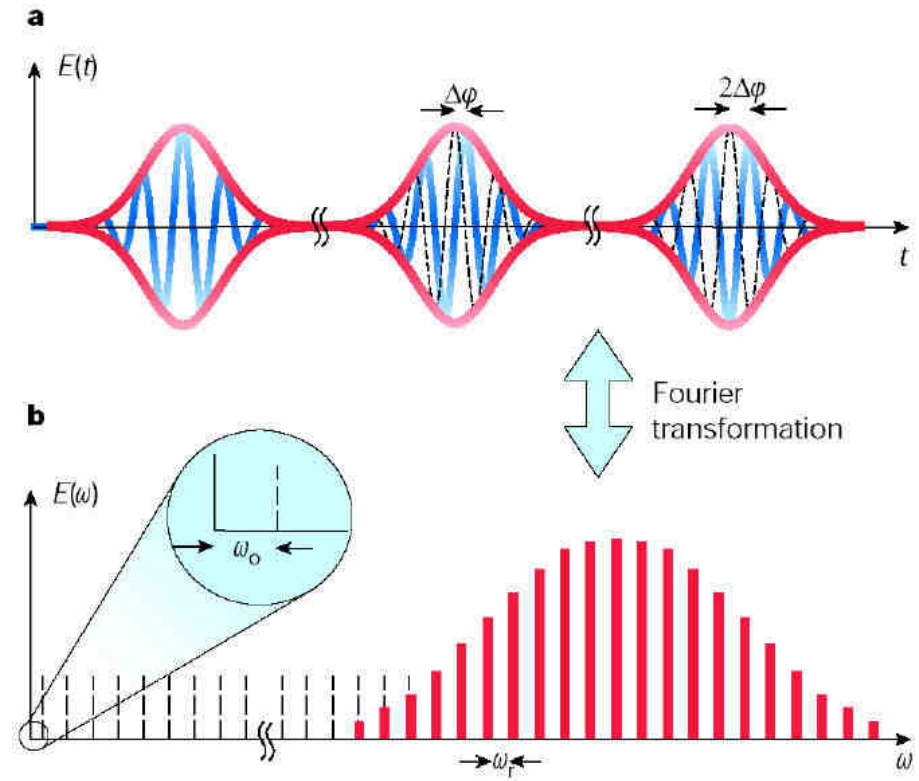






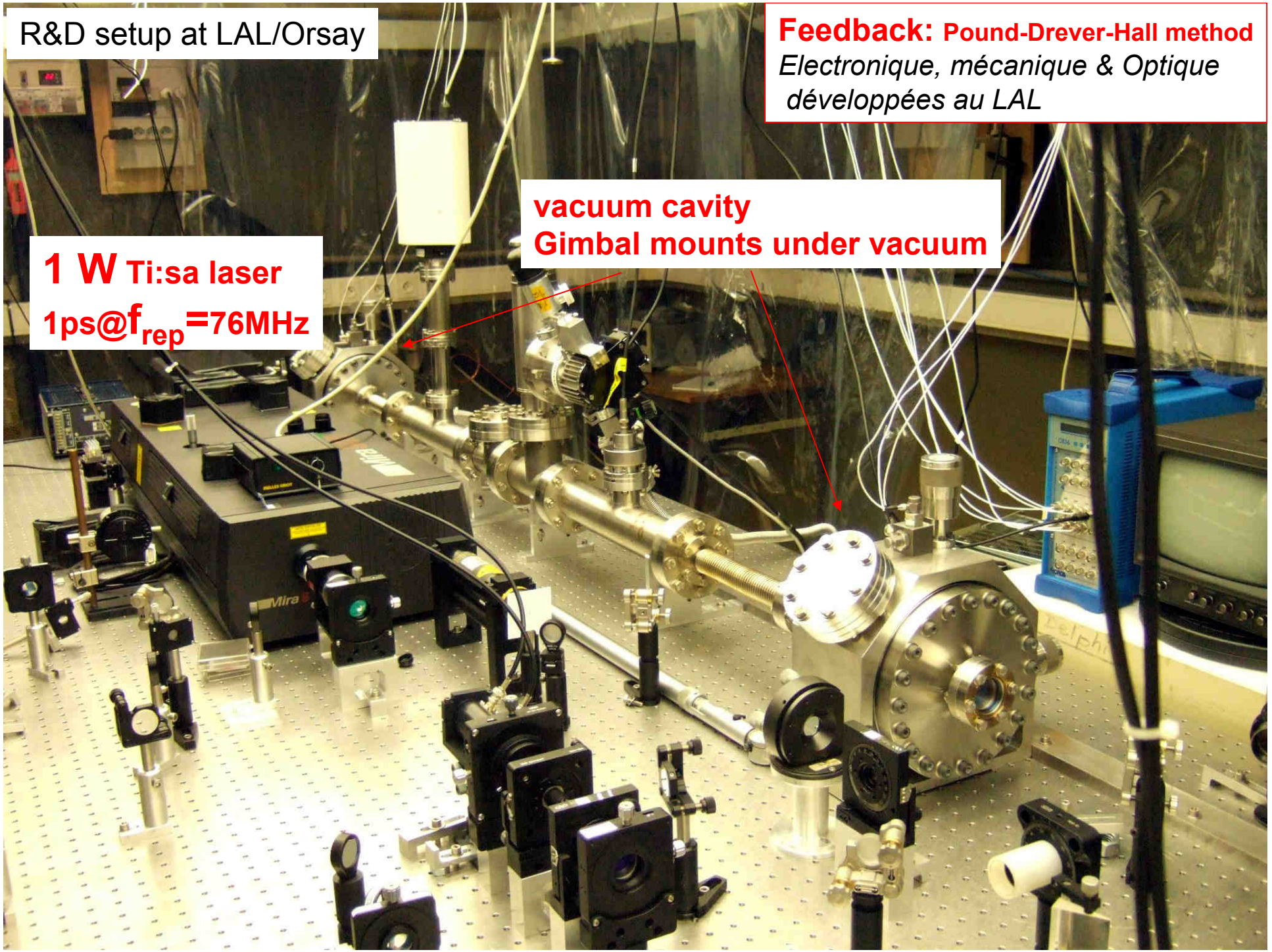
R&D actuelle: 2005-2008
asservissement laser pulsé/cavités hauts gains
Financement: Europe/Eurotev, IN2P3

Différence mode pulsé / mode cw



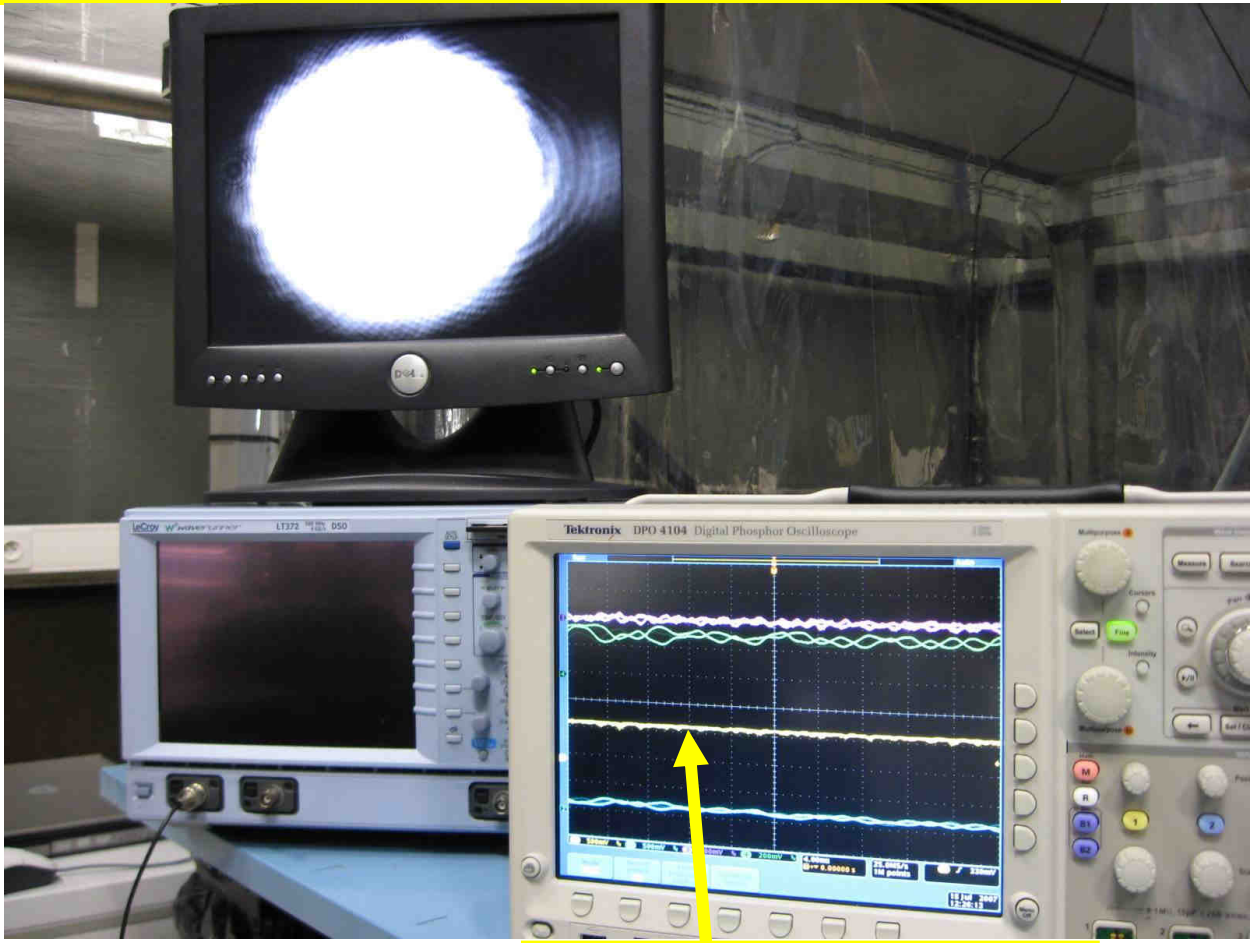
T. Udem et al. Nature 416 (2002) 233

Peigne de fréquence
➔ tous les pics doivent résonner
➔ Feedback à 2 degrés de liberté :
control de la Dilatation & translation du peigne


R&D setup at LAL/Orsay
Feedback: Pound-Drever-Hall method
Electronique, mécanique & Optique
développées au LAL
vacuum cavity
Gimbal mounts under vacuum
1 W Ti:sa laser
1ps@f_{rep}=76MHz

Status : Cavity locked (*low gain* ~ 1200)

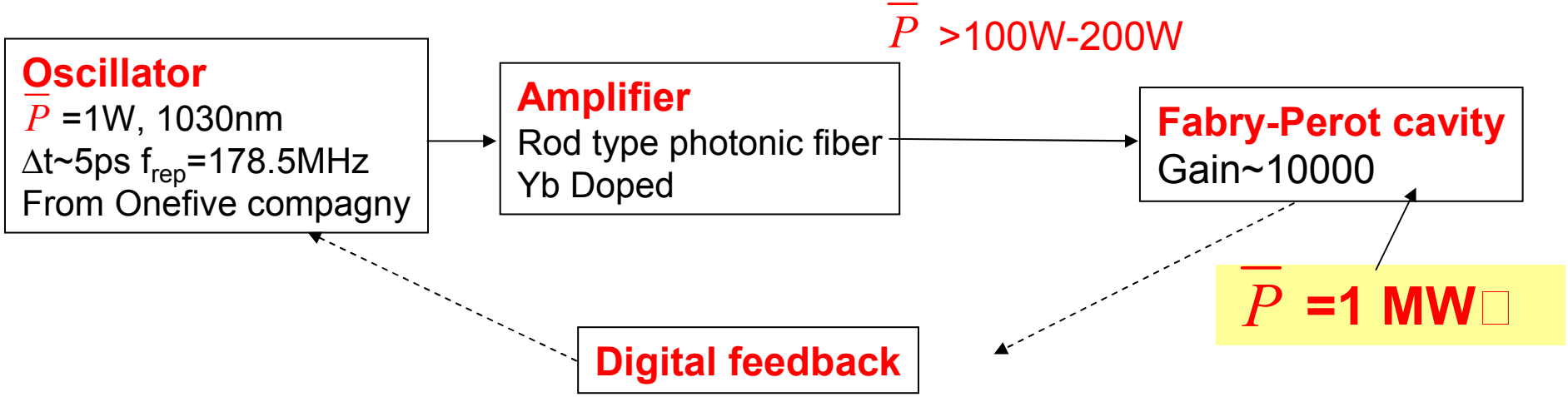
- **Digital feedback (VHDL programming)**
- **Already $\Delta f_{rep}/f_{rep} \sim 10^{-10}$ ➔ $\Delta f_{rep} \sim 76$mHz for $f_{rep} \sim 76$MHz**
- **New mirrors asap ! ➔ gains 10^4-10^5**



Cavité lockée :
Signal transmis « stable »

New R&D : started february 2008
Funds: GIS P2I+IN2P3 (+ANR ?)

1. Setup the following system at CELIA (Bordeaux)/LAL

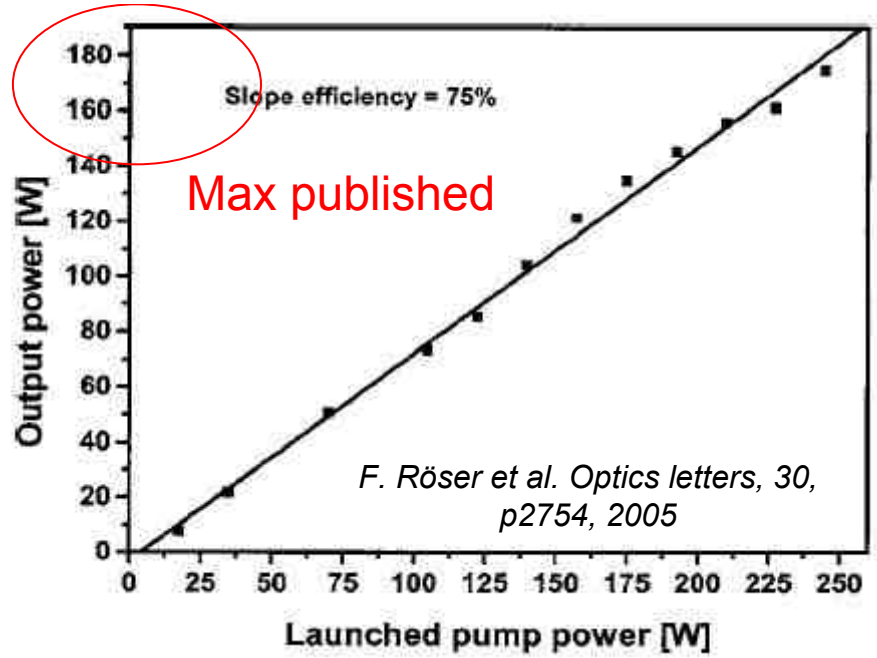


2. Optics studies: phase noise (CPA or not CPA), power stability, cavity mirror heating (CELIA/LMA)

3. Installation of the system at ATF/KEK (with KEK)

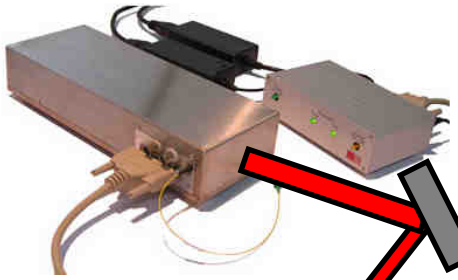
The laser amplification R&D

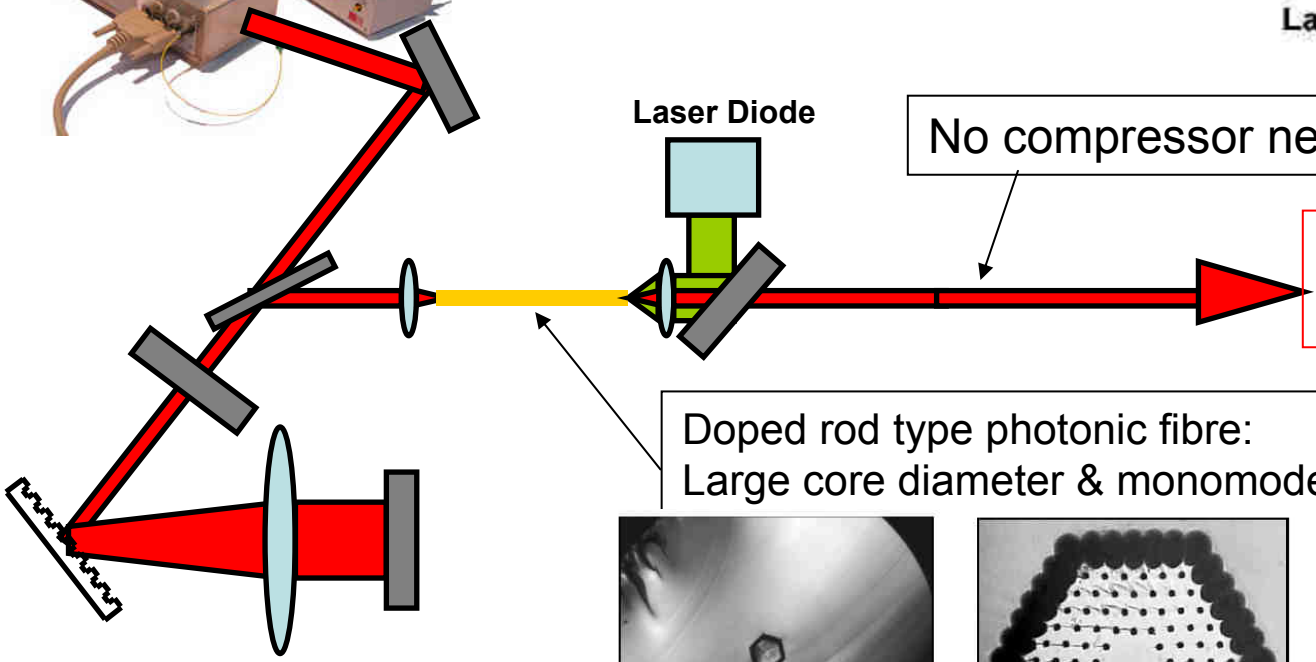
➔E. Cormier (CELIA)



OneFive laser

Δt=2-5ps, 178.5 MHz, 1W

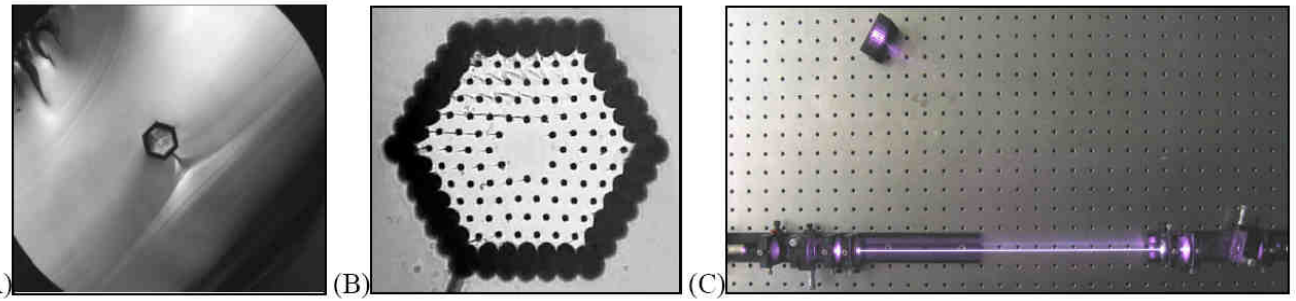




No compressor needed a priori

Possible average power 100W-300W (simulation)

Doped rod type photonic fibre:
Large core diameter & monomode developed for CELIA



Gold grating-based strectcher gives negative chirp for spectral compression

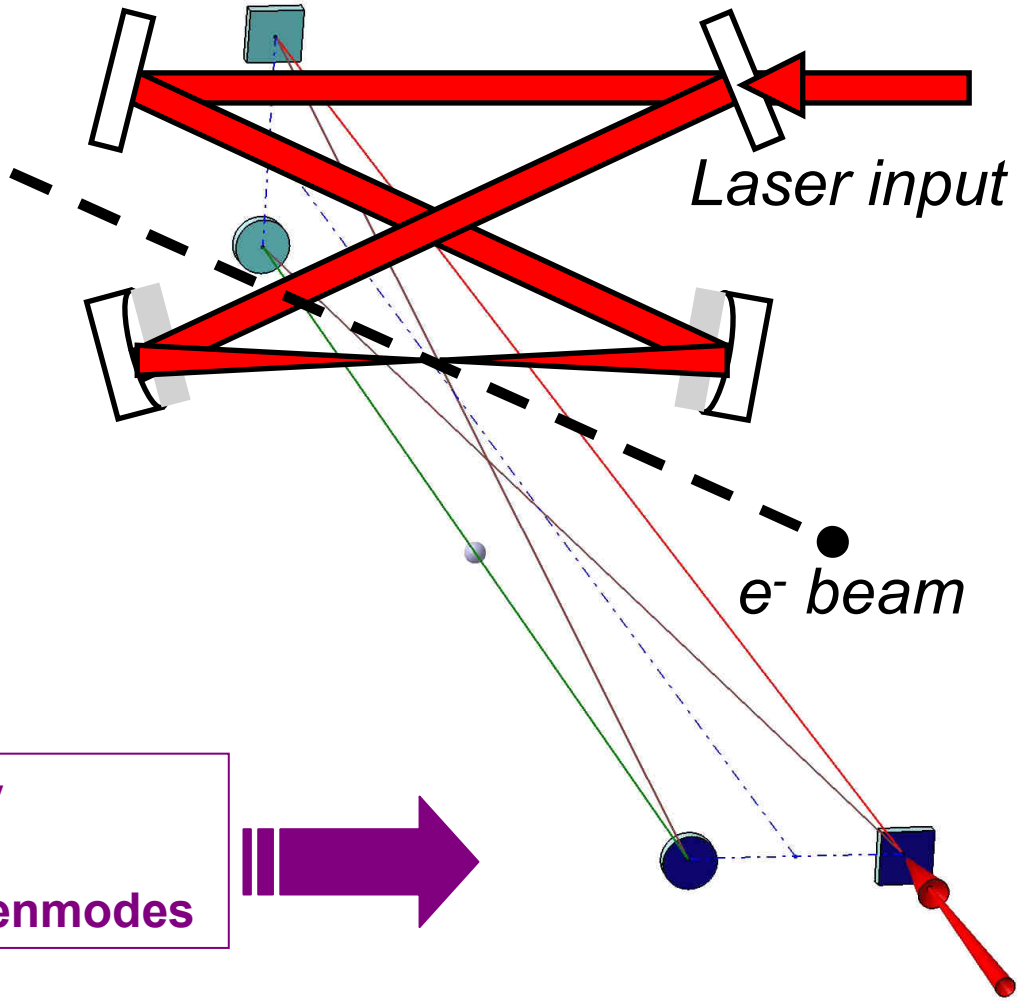
Toward small laser spot size

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 & ~circularly polarised eigenmodes

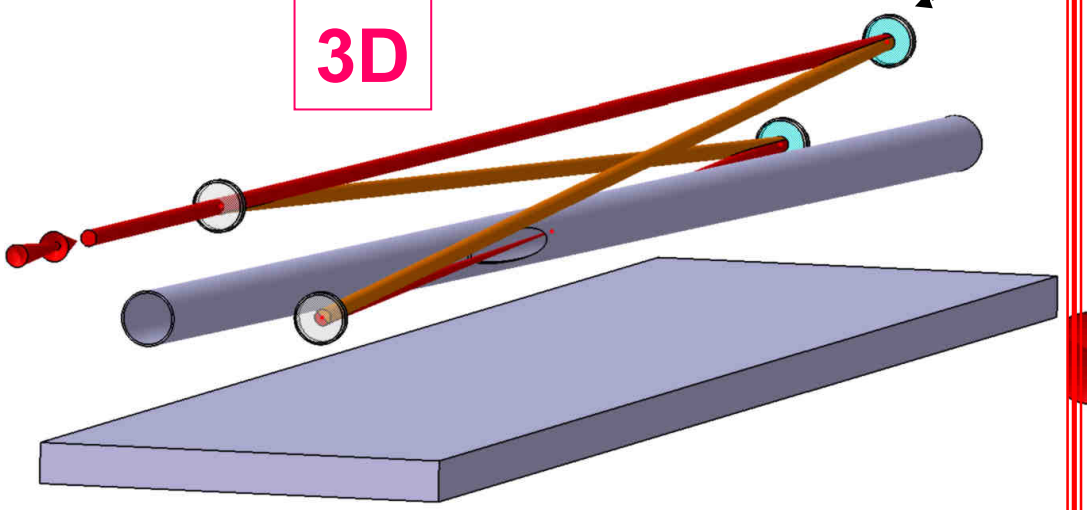


Choice of the cavity geometry
Interaction plane must be horizontal

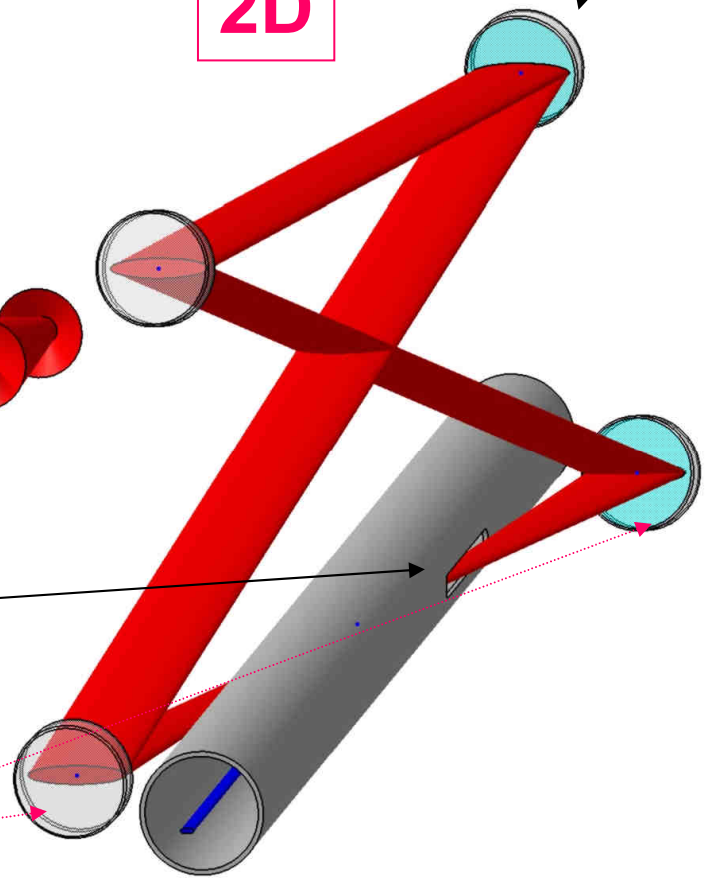
2 choices

Valorisation en cours :
monture motorisées
Gimbal sous ultra-vide

3D



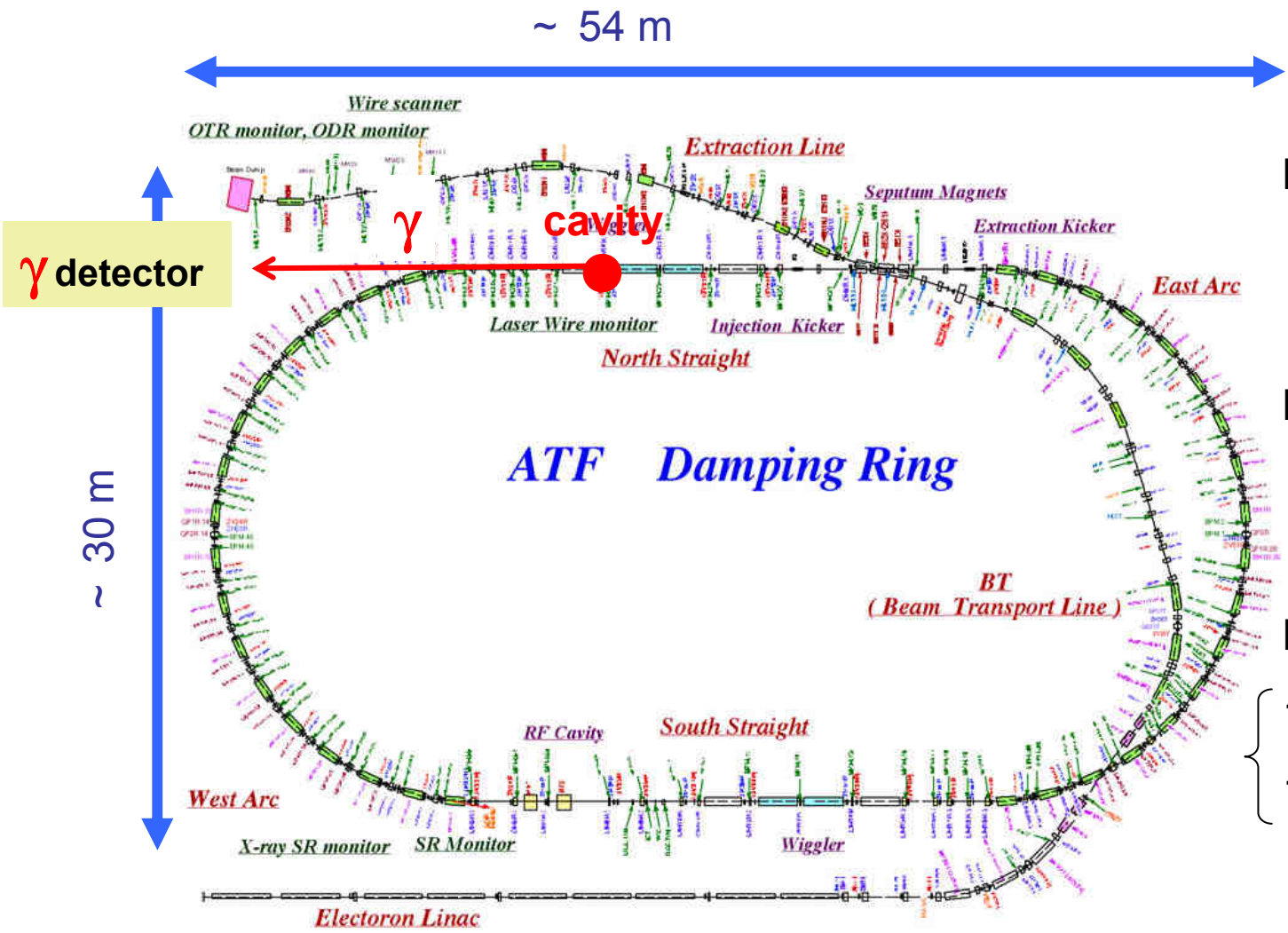
2D



Main constraint: 5mm vertical slit width

- Optical path length = c/178.5MHz~1.6m
- 2 sperical mirrors with R=500mm

Cavity installation on the Accelerator Test Facility (ATF) at KEK



Beam Energy

→ 1.28GeV

Beam Size

→ 100μm×10μm

Emittance →

1.0×10^{-9} rad.m

1.0×10^{-11} rad.m

(Ultra Low !!)

(H. Shimizu)

Résumé

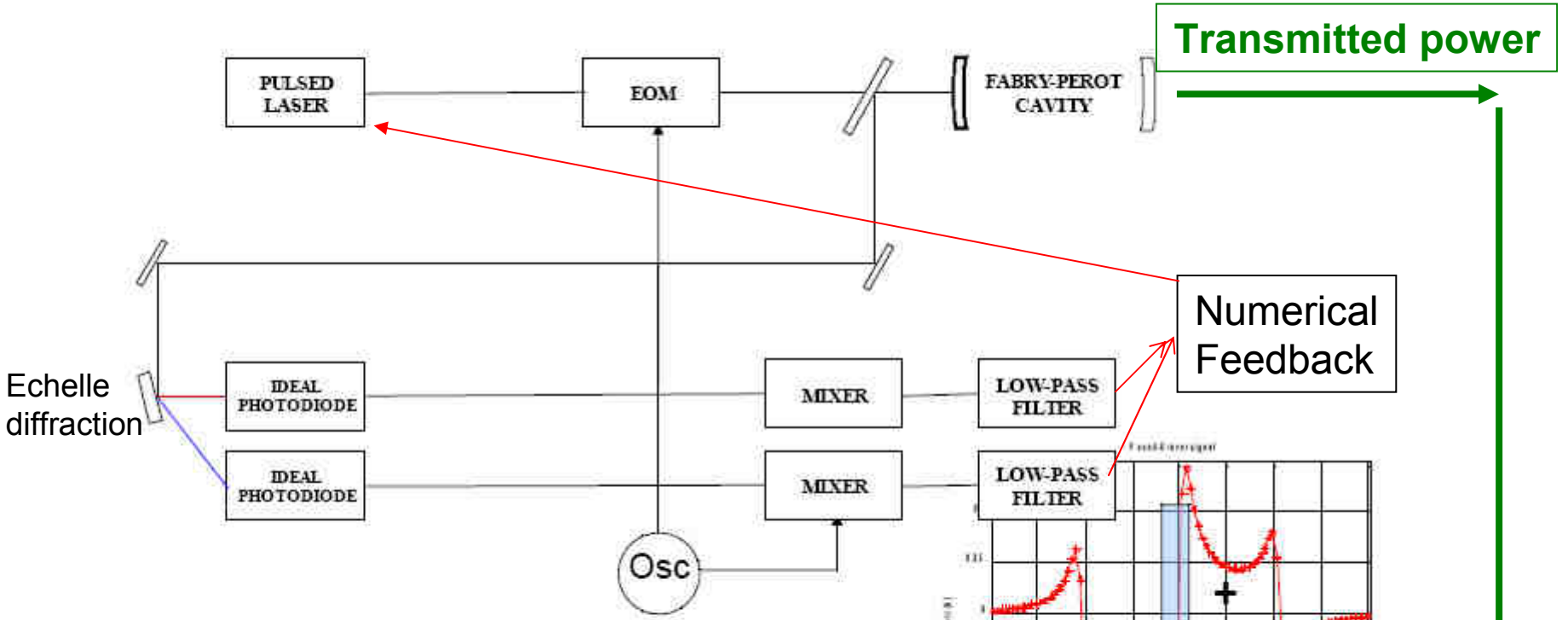
- Passé : 2000-2007
  - Mise en œuvre d'une cavité finesse 30000 à HERA pour la polarisation
- Présent : 2005-2008
  - Cavité finesse 3600 en mode pulsé (1W1ps@76MHz)
  - Finesse 30000 en cours de montage
- Futur : 2008-2011/ Collaboration avec CELIA/LMA/KEK
  - Amplification par fibre dopée et installation d'une cavité à 4 miroirs sur ATF (design mécanique complexe)

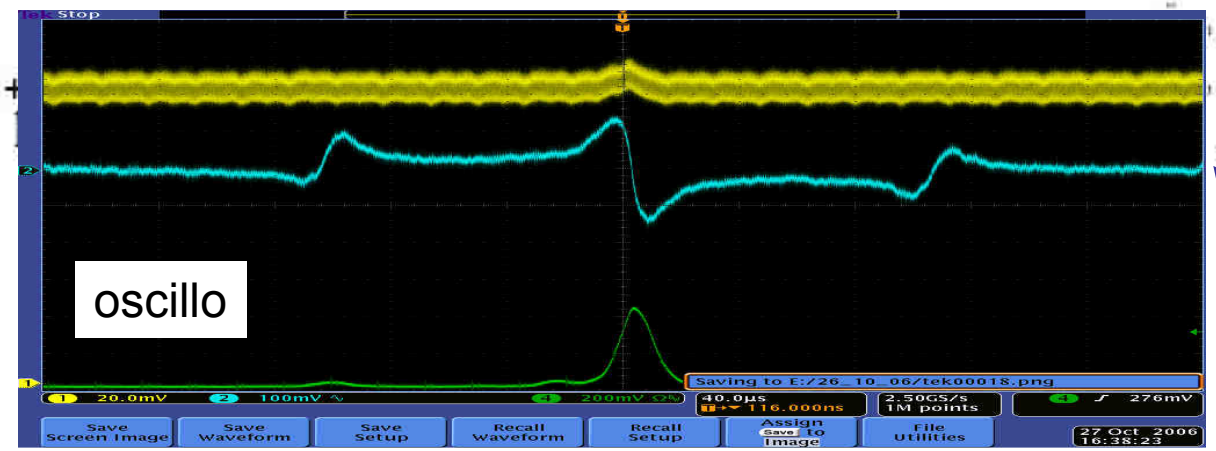
Membre de l'équipe pour la R&D future

- CELIA(Laser Lab. In Bordeaux)
  - J. Boullet, E. Cormier, Y. Zaouter (Physique ampli/fibre)
  - P. Balcou, S. Montant,MC Nadeau (Physique effets thermiques)
- LAL (Orsay)
  - J. Bonis, R. Cizeron, J. Colin, G. Guilhem, M. Lacroix, R. Marie (mécanique)
  - R. Chiche, D. Jehanno (électronique)
  - , Y. Fedala, V. Soskov, A. Variola, F. Zomer (Physique/optique)
- LMA
  - R. Flaminio, C. Michel, L. Pinard,
- In close collaboration with KEK (T. Omori, J. Urakawa) and Hiroshima Uni. (M. Kuriki, T. Tohru)

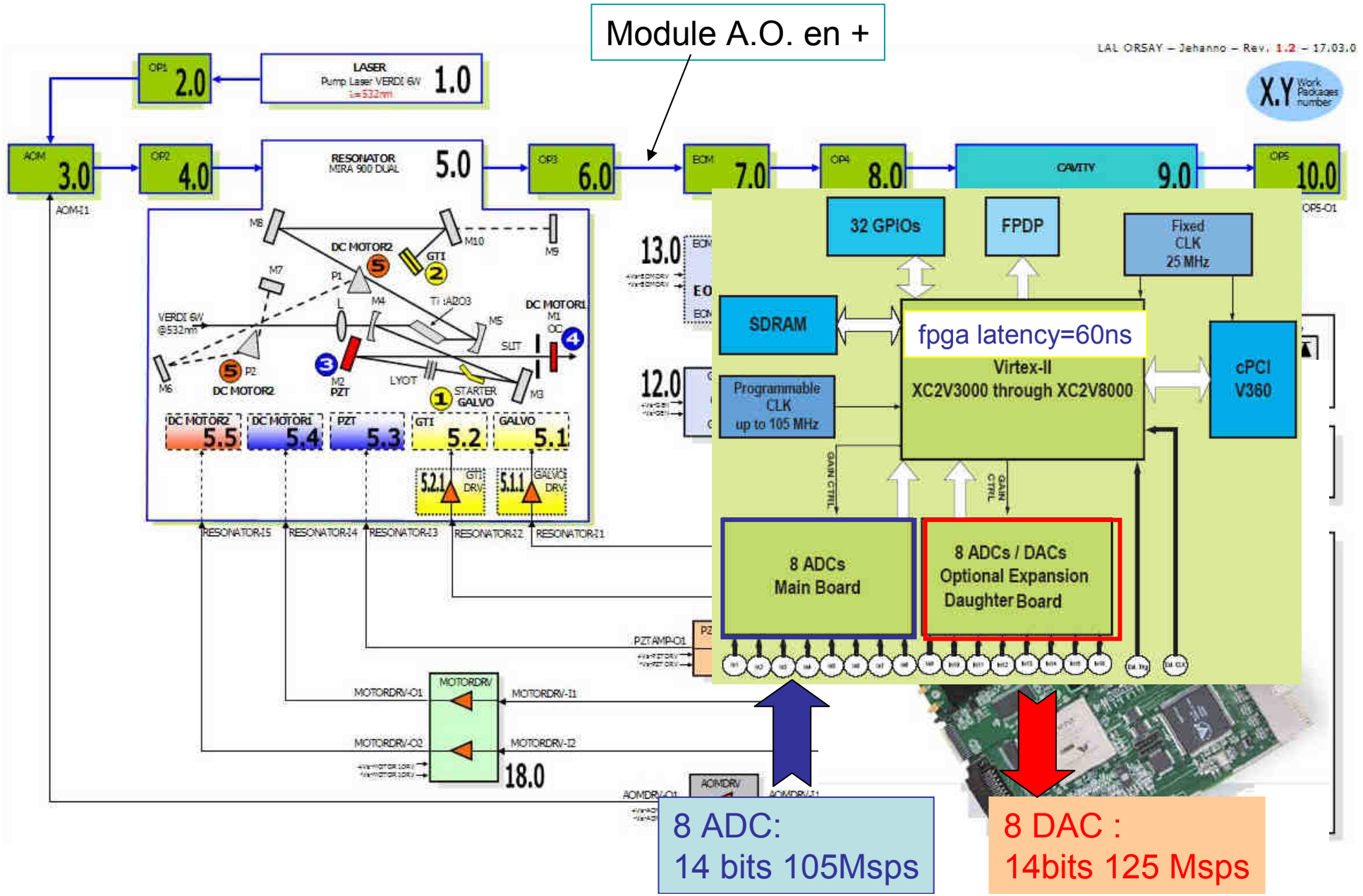
Feedback : Pound-Drever-Hall method

Electronique, mécanique & Optique développées au LAL





Feedback


Module A.O. en +
LAL ORSAY – Jehanno – Rev. 1.2 – 17.03.0
X.Y Work Packages number
OP1 2.0
LASER
Pump Laser VERDI 6W
1.0
AOM 3.0
OP2 4.0
RESONATOR
MIRA 900 DUAL
5.0
OP3 6.0
EOM 7.0
OP4 8.0
CAVITY 9.0
OP5 10.0
AOM-I1
OP5-O1
13.0
12.0
18.0
DC MOTOR2 5.5
DC MOTOR1 5.4
PZT 5.3
GTI 5.2
GALVO 5.1
5.2.1 GTI DRV
5.1.1 GALVO DRV
RESONATOR-I5
RESONATOR-I4
RESONATOR-I3
RESONATOR-I2
RESONATOR-I1
PZT AMP-O1
MOTORDRV
MOTORDRV-O1
MOTORDRV-I1
MOTORDRV-O2
MOTORDRV-I2
AOMDRV
AOMDRV-O1
AOMDRV-I1
32 GPIOs
FPDP
Fixed CLK 25 MHz
SDRAM
fpga latency=60ns
Virtex-II
XC2V3000 through XC2V8000
cPCI V360
Programmable CLK up to 105 MHz
GAIN CTRL
8 ADCs Main Board
8 ADCs / DACs Optional Expansion Daughter Board
8 ADC:
14 bits 105Msps
8 DAC :
14bits 125 Msps