



High finesse Fabry-Perot cavity for a pulsed laser

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Fabry-Perot cavity & pulsed laser

Klaus's talk:

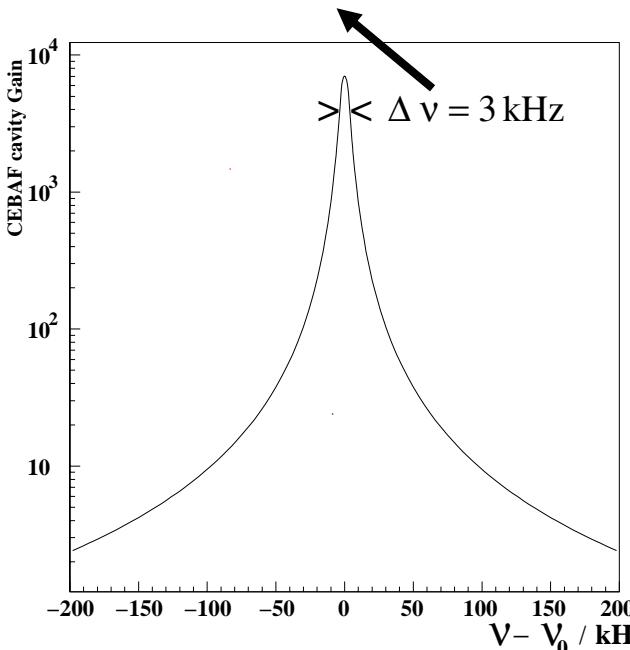
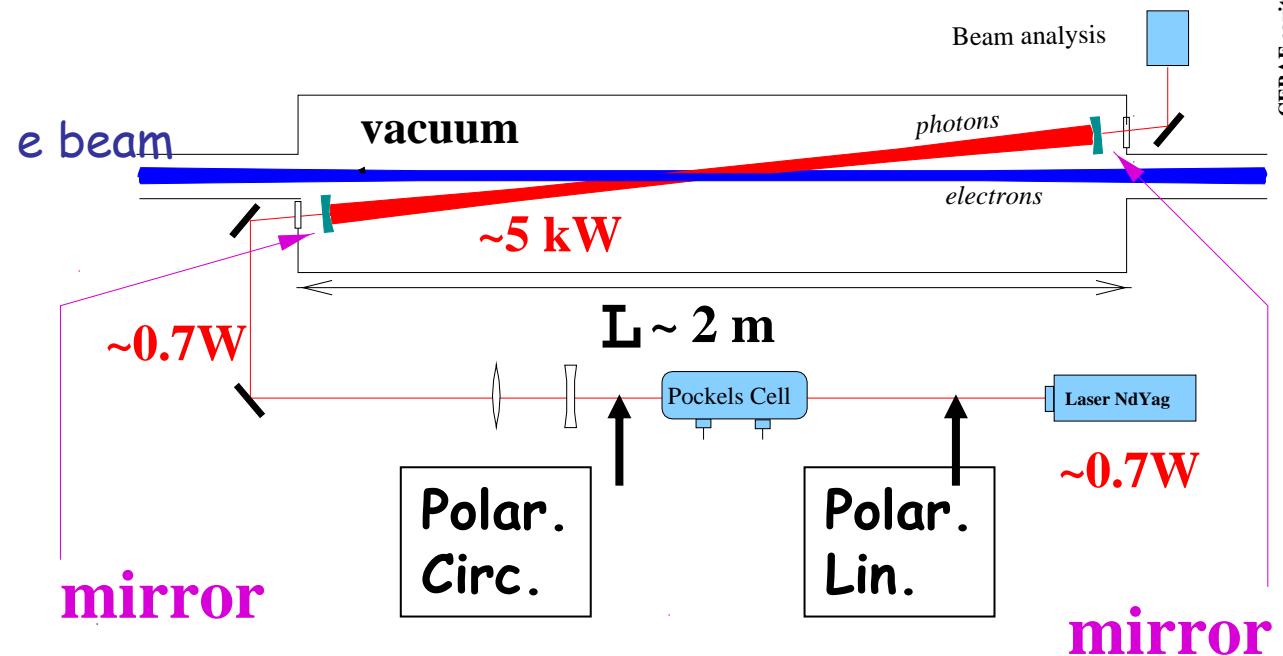
LASER: 1ps pulsed with
 $\sim 0.1\text{J/pulse}$ @ $\sim 300\text{MHz}$
& Smallest beam waist

Solution:

Concentric Fabry-Perot resonator in
pulsed regime

Fabry-Perot cavity: Principle (HERA cavity, cw laser)

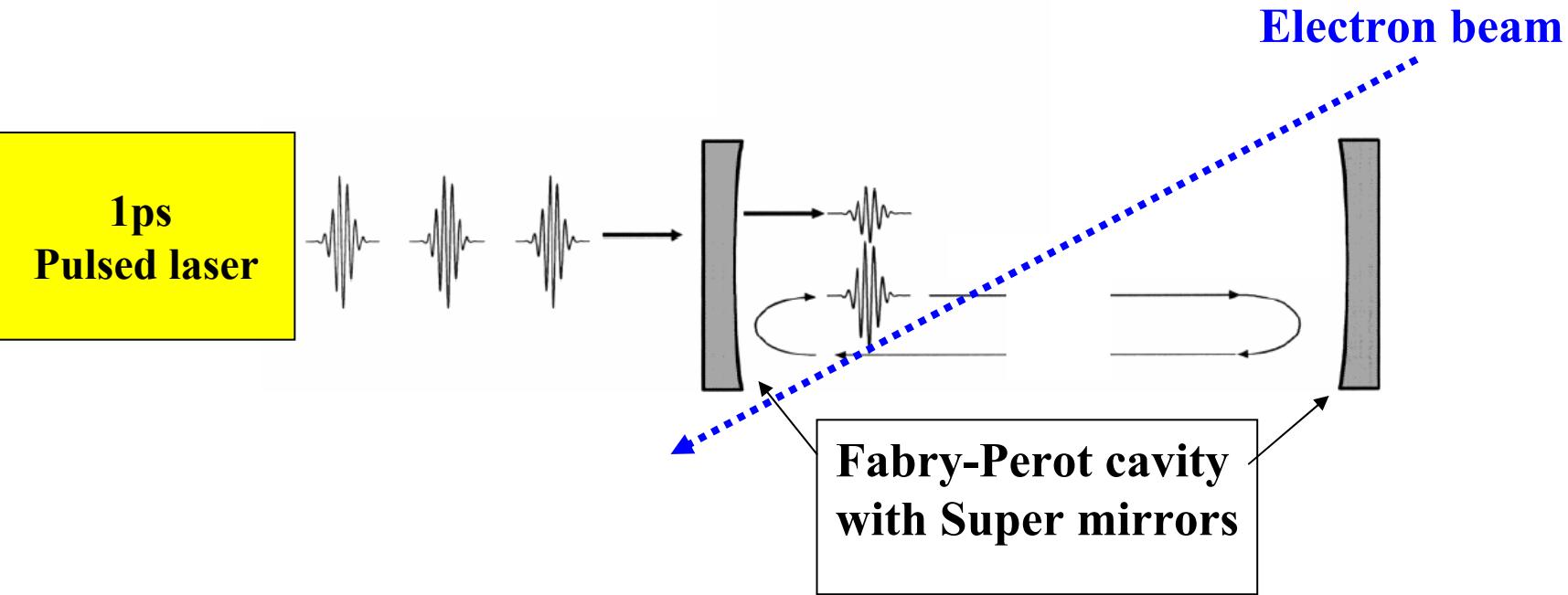
Gain ~10000



When $v_{\text{Laser}} = v_0 \propto c/2L \Rightarrow \text{resonance}$

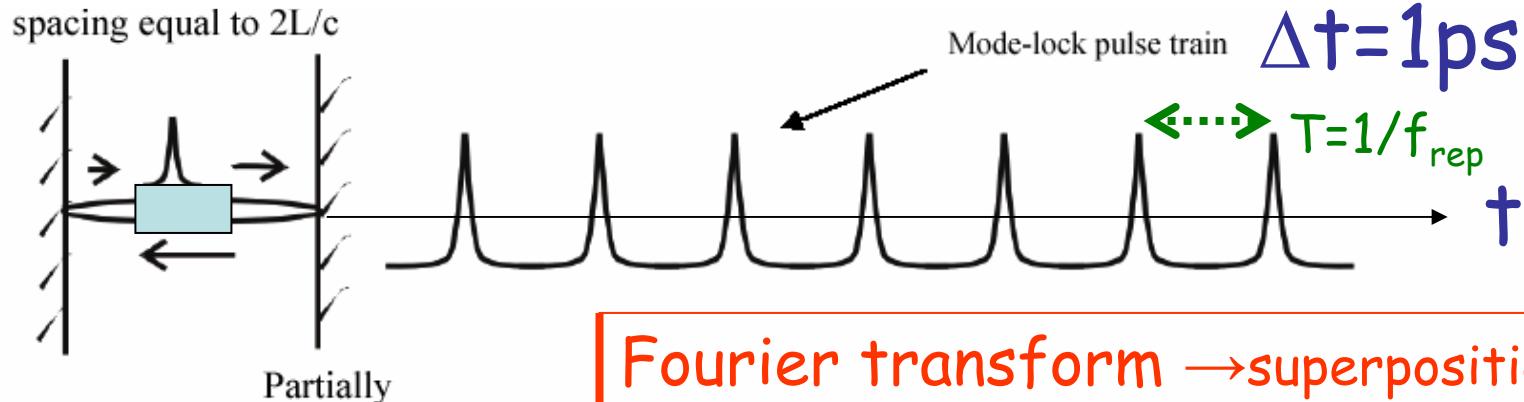
- But: $\Delta v/v_{\text{Laser}} = 10^{-11}$ for Gain=10⁴ \Rightarrow laser/cavity feedback
- Done by changing the laser frequency

Fabry-Perot cavity filled with a pulsed laser

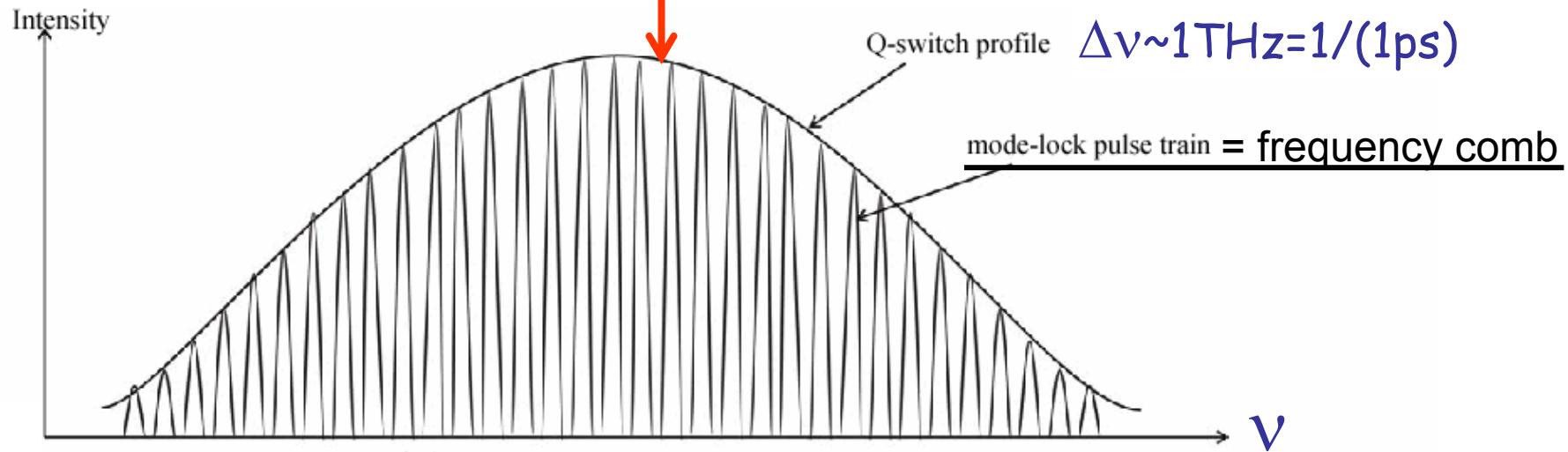


- **A priori impossible** because of the laser frequency width:
 $\Delta\nu \approx 1/(1\text{ps}) = 1\text{THz}$ for picosecond laser (c.f. 3kHz cavity bandwidth for a gain of 10^4)
- In fact possible with mode-locked lasers

Mode-locked laser



Fourier transform → superposition of N longitudinal laser mode - in phase

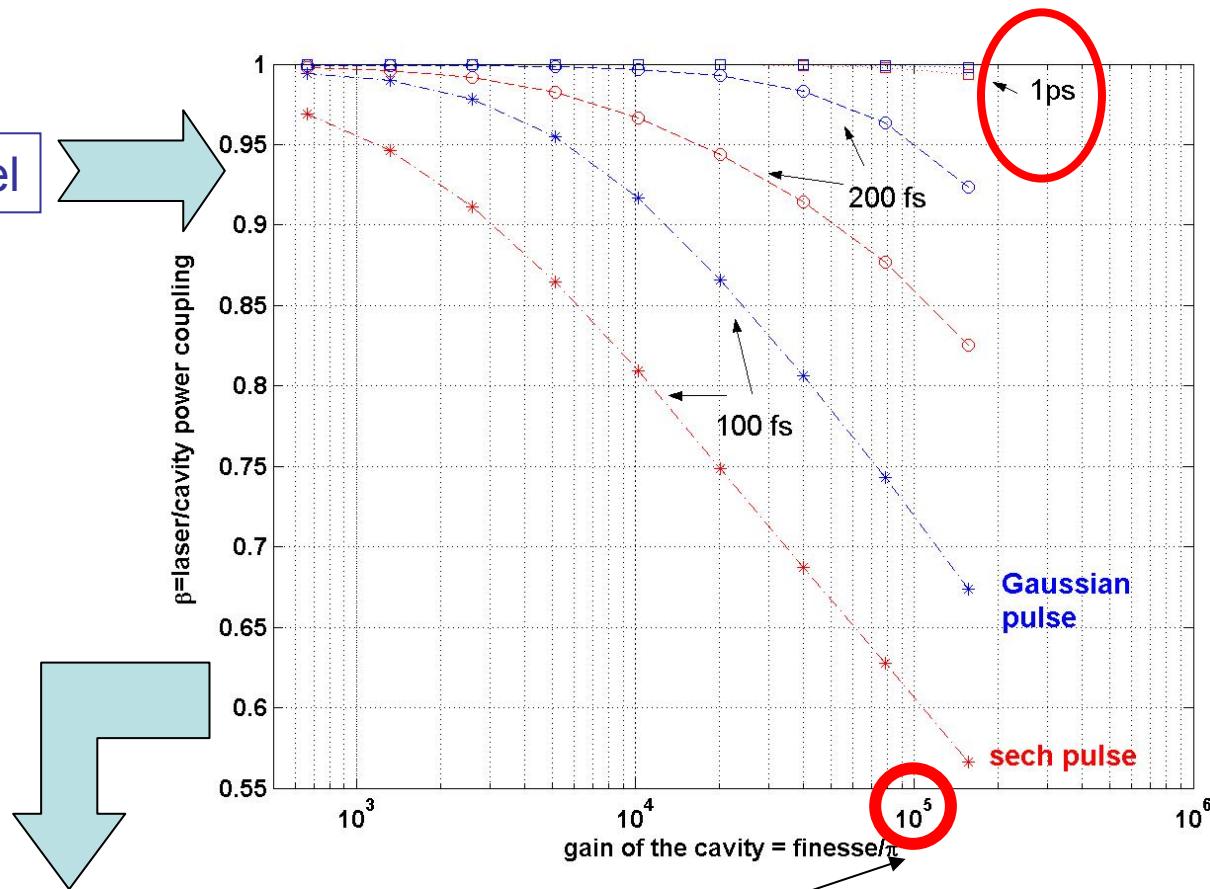


If F.P. cavity length = laser cavity length
→ all modes are also resonant modes of the FP cavity

Maximum Cavity Gain achievable in pulsed regime:

- limited by the dispersion (=pulse time width broadening) & chromatic dependence of the reflection coefficient of the cavity mirror coatings

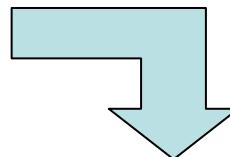
Multilayer model



No effect for a pulse width of 1ps: gain up to 10^5 can - *a priori* - be envisaged

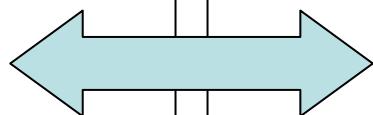
Existing FP cavities in HEP

- Continuous laser beam
 - CEBAF (polarimeter) - gain $\approx 10^4$
 - Falleto et al. (NIMA459(2001)412)
 - HERA (polarimeter) - gain $\approx 10^4$
- Pulsed laser beam
 - 25ps pulses & gain ≈ 3000
 - Loewen (Slac-R-632)
 - 7ps @350MHz, R&D in progress
 - Nomura et al. (EPAC-2004)
 - **4 mirrors cavity → reduction of the laser beam size**



R&D to match Klaus's requirement

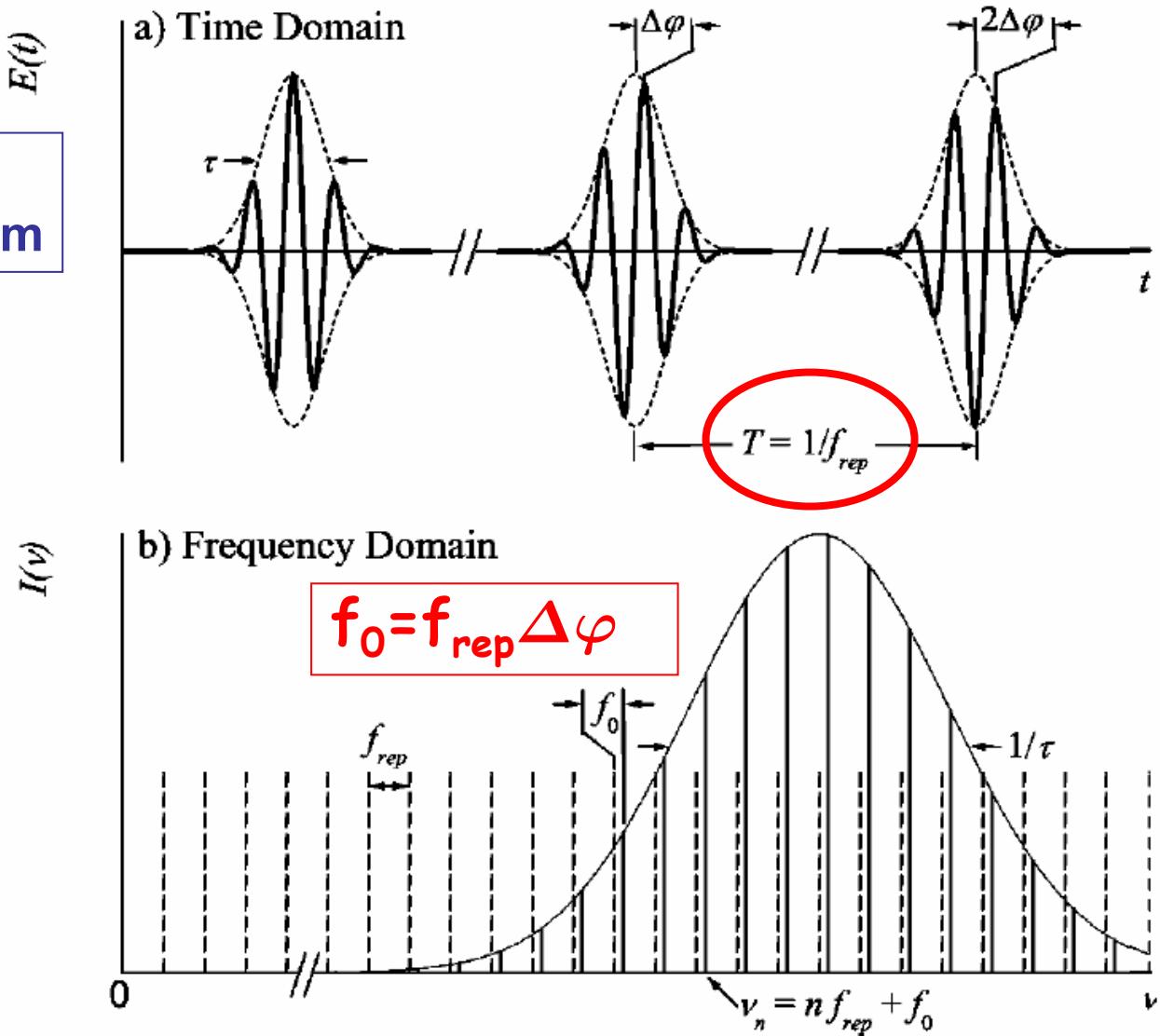
- Moderate cavity gain (Urakawa et al. KEK)
 - Very small laser beam waist ($\approx 5\mu\text{m}$) to increase de laser-e luminosity
 - 4 mirrors cavity
 - High input laser power
- KEK R&D
- Very high cavity gain $\approx 10^4\text{-}10^5$
 - Moderate laser beam waist ($\approx 50\mu\text{m}$)
 - 2 mirrors cavity
 - Concentric cavity
 - Moderate input laser power
 - Orsay (Eurotev) R&D



Orsay R&D within Eurotev

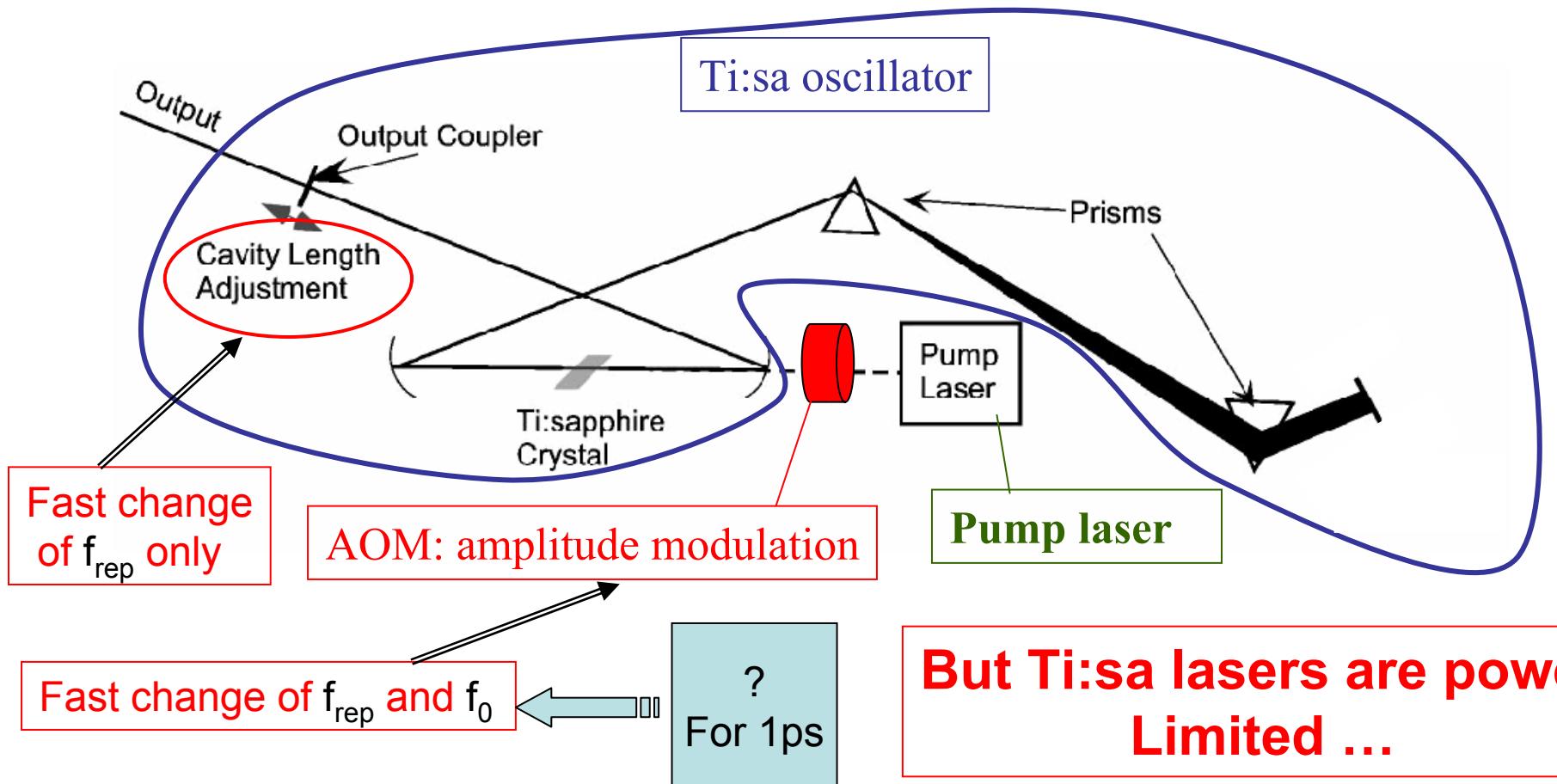
- Locking of a Ti:sa laser (MIRA-Coherent pumped by a 6W VERDI) to a high finesse linear cavity (=2 spherical mirrors):
 - Feedback difficult & never done for 1ps pulses + very high finesse
- Schedule
 - Years 2005-2007 : Finesse=30000-300000
 - Years 2007-2008 : Operation in the concentric mode

Feedback for mode-locked laser beam



Jitter $\Delta f_0 \approx 1 \text{ MHz} \rightarrow [f_0 \text{ or } \Delta\varphi] \& f_{rep}$ must be controlled even for 1ps pulses if the cavity finesse is very high

- Feedback technique
 - Fabry-Perot cavity taken as the reference
 - f_{rep} & f_0 are changed inside the laser(s)
 - Error signals: taken at different values of $\lambda \rightarrow$ to lock the full frequency comb to the cavity



Possible laser for Klaus's scheme

Opt. & Phot. News 2003

Rüdiger Paschotta and Ursula Keller

Ever Higher Power from Mode-Locked LASERS

The available output power of passively mode-locked lasers has recently been boosted to levels of up to 60 W in femtosecond pulses. This achievement is based on an improved understanding of various limiting factors. A number of applications are expected to benefit.

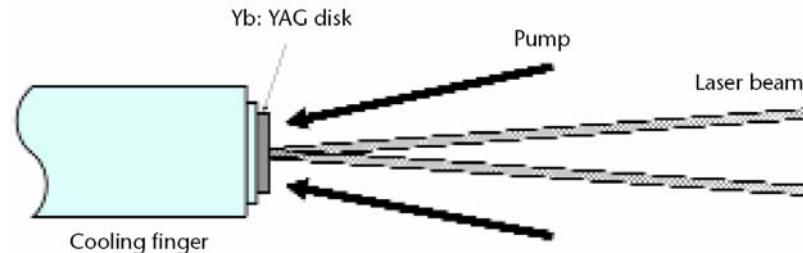


Figure 3. Thin-disk laser head (without multipass pump optics).

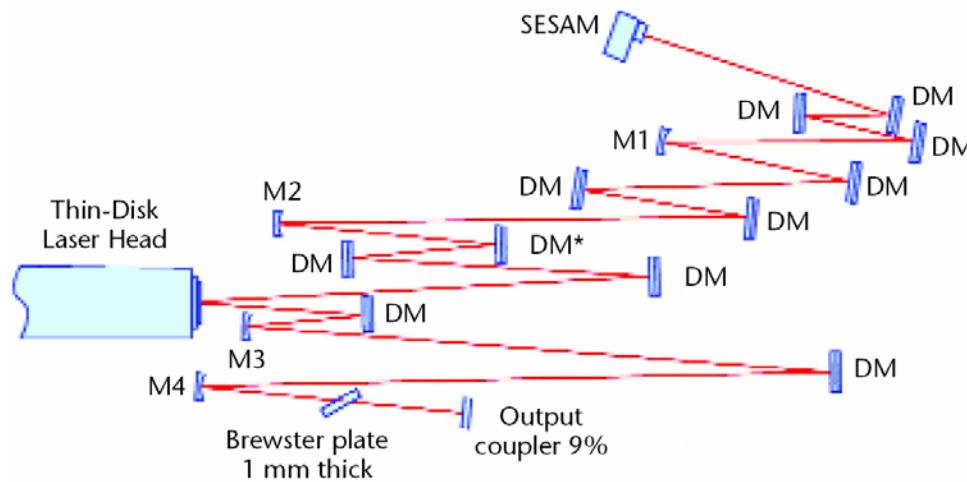


Figure 4. Cavity of mode-locked 60-W laser.
DM = dispersive mirror; M2, M3, M4 = highly reflecting mirrors;
SESAM = semiconductor saturable absorber mirror.

Yb:YAG, $\Delta t=810\text{fs}$ @ 33MHz

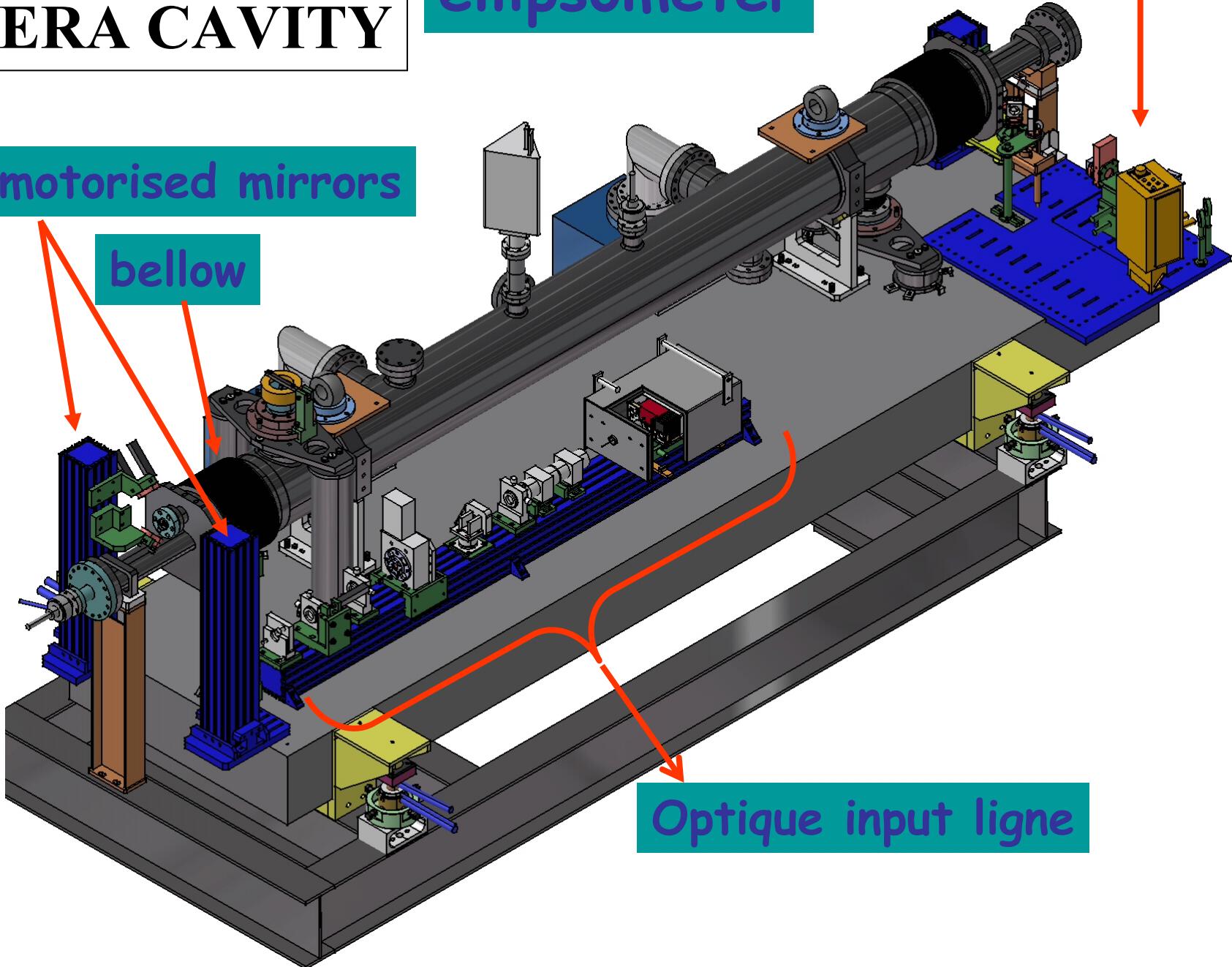
• $1.7\mu\text{J}/\text{pulse} \{\times 10^5 \text{ (cavity)} \rightarrow \approx 0.1\text{J}/\text{pulse}\}$

HERA CAVITY

ellipsometer

4 motorised mirrors

bellow



Optique input ligne

2003 installation
shielding (3 mm pb)



HERA CAVITY

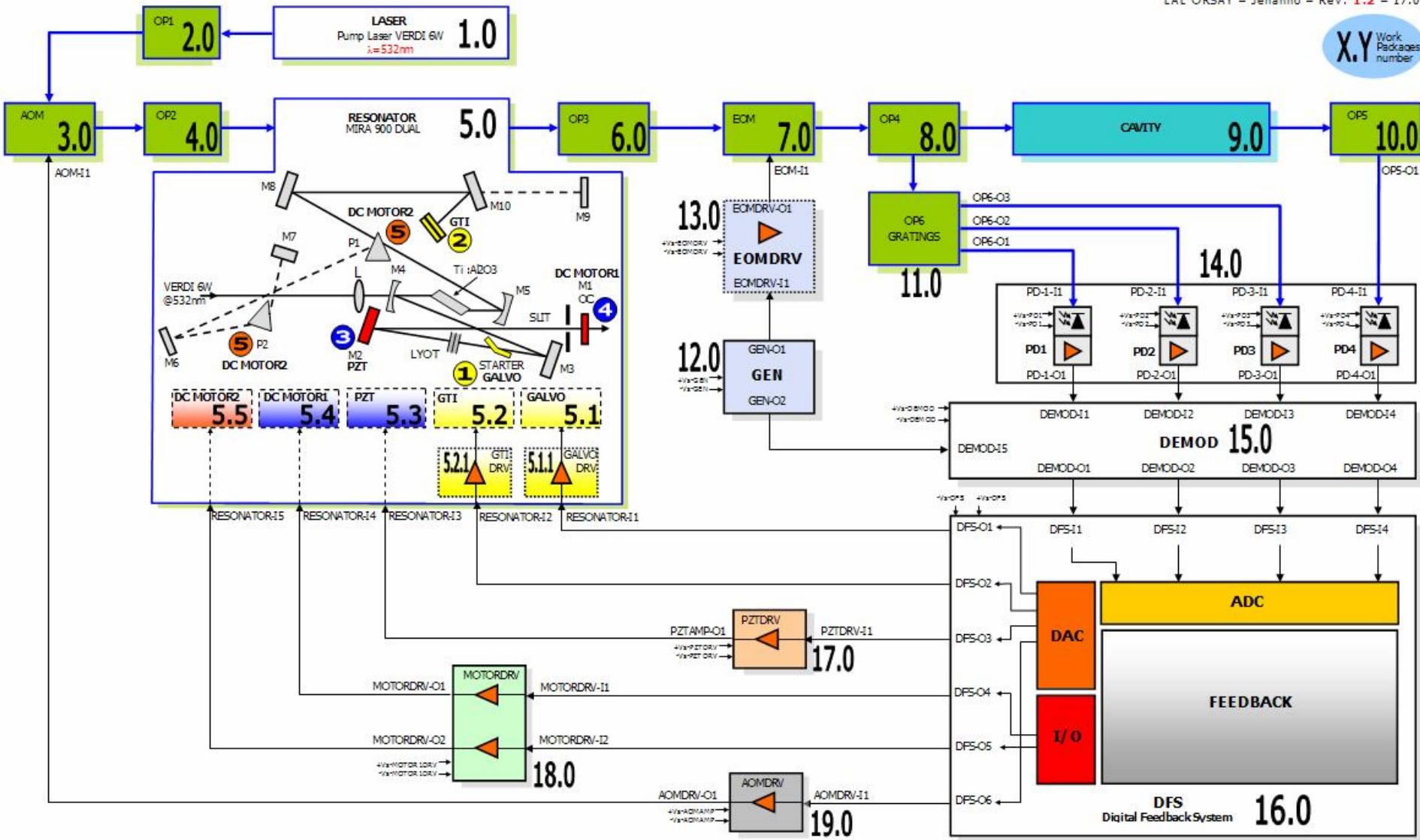
Summary

- 2 ways of R&D
 - Moderate cavity finesse **but** very small laser beam waist
 - Feedback on f_{rep}
 - Moderate input laser beam power **but** very high cavity finesse
 - Feedback on f_{rep} & f_0 [need for a high quality mode-locked laser beam]
- *A priori* feasible

Feedback scheme

LAL ORSAY - Jehanno - Rev. 1.2 - 1/03/0

X.Y
Work
Packages
number



Reduction of the laser beam size at the IP

- To get a **laser beam size $< 50 \mu\text{m}$** at the electron-laser beam IP
 - Use of a quasi-concentric cavity
(mirror curvature radius \approx half cavity length)
 - BUT, **mechanical tolerance $<\mu\text{m}$ & μrad**
needed on relative mirror positions
 - Active feedback on relative mirror position & laser beam pointing