High finesse Fabry-Perot cavity for a pulsed laser

F. Zomer

F. Zomer
Orsay-LAL/IN2P3-CNRS
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Fabry-Perot cavity & pulsed laser

Klaus's talk:

LASER: 1ps pulsed with

~ 0.1J/pulse @ ~300MHz

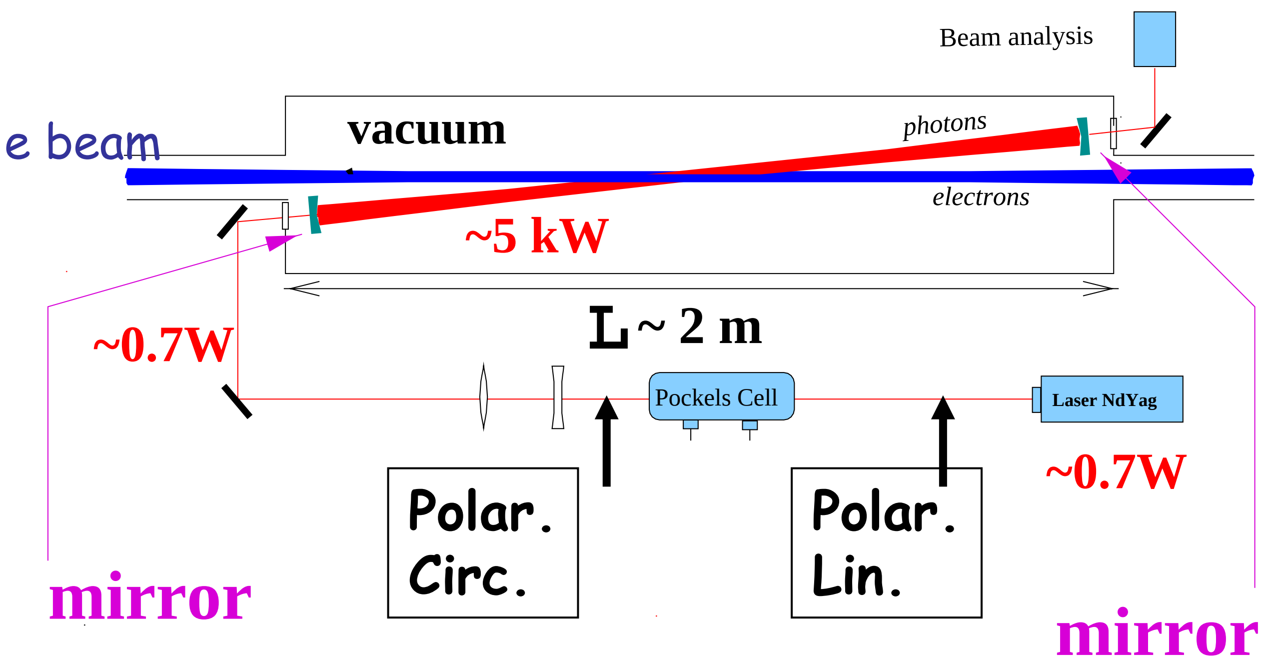
& Smallest beam waist

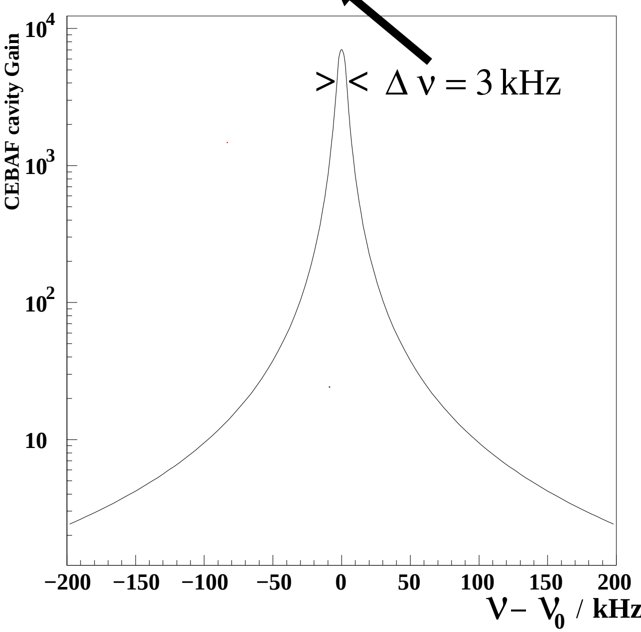
Solution:

Concentric Fabry-Perot resonator in pulsed regime

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

Gain ~10000

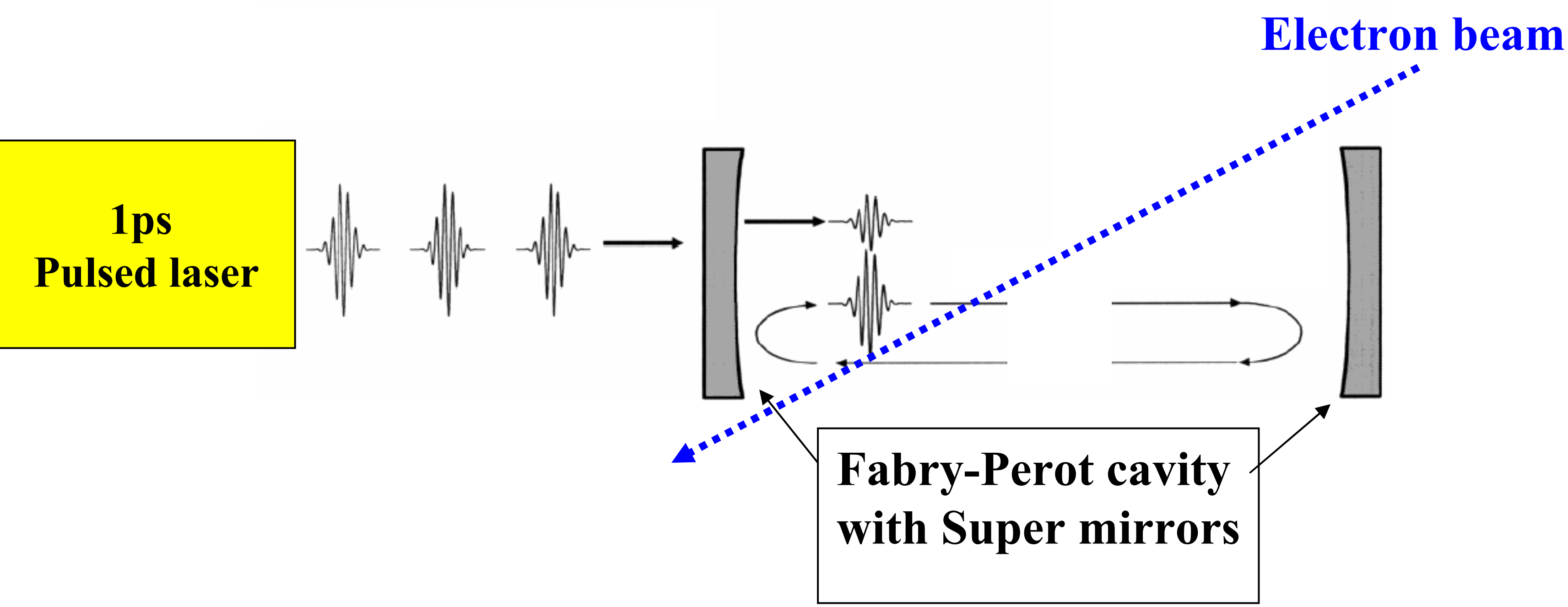




When $\nu_{Laser} = \nu_0 \propto$ c/2L $\Rightarrow$ resonance

- But: $\Delta\nu/\nu_{Laser} = 10^{-11}$ for Gain=10^4 $\Rightarrow$ laser/cavity feedback
  - Done by changing the laser frequency

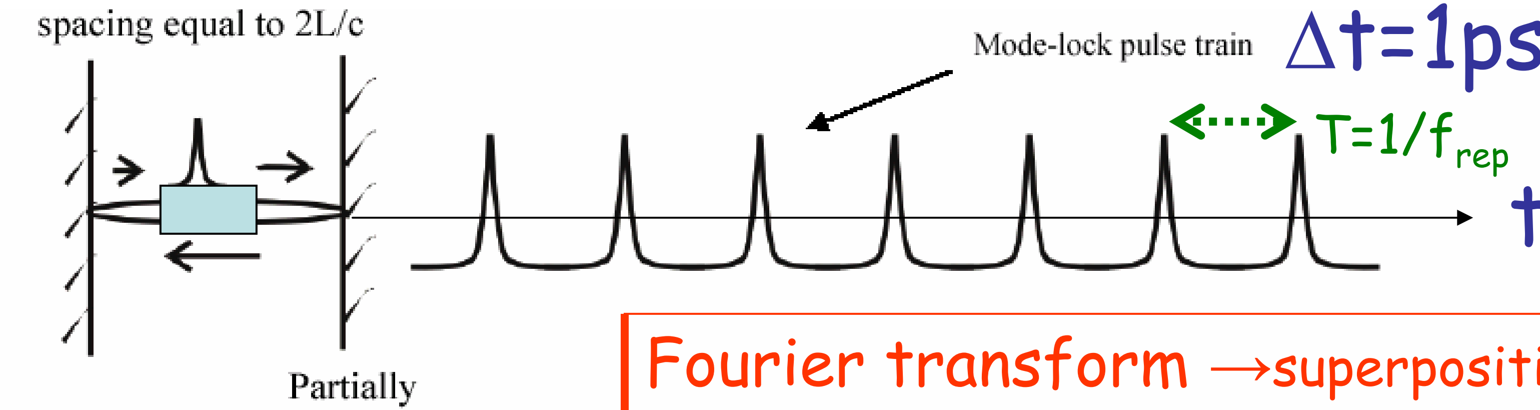
Fabry-Perot cavity filled with a pulsed laser



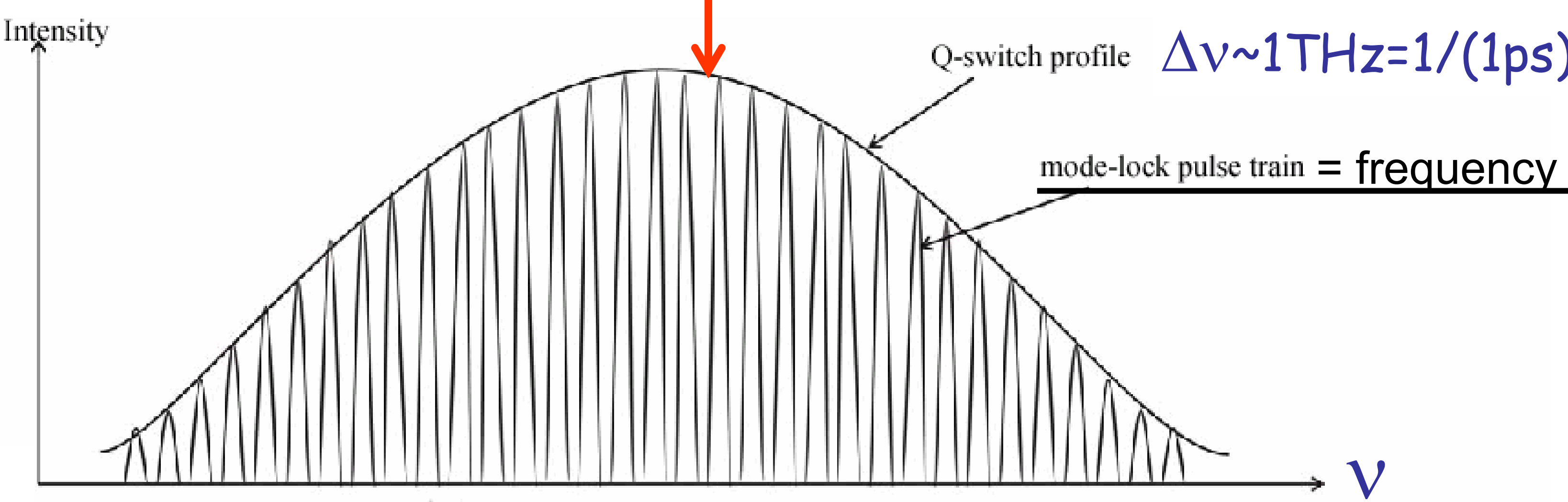
•A priori impossible because of the laser frequency width:
$\Delta\nu \approx$1/(1ps)=1THz for picosecond laser (c.f. 3kHz cavity banwidth for a gain of 10^4)

•In fact possible with mode-locked lasers

Mode-locked laser



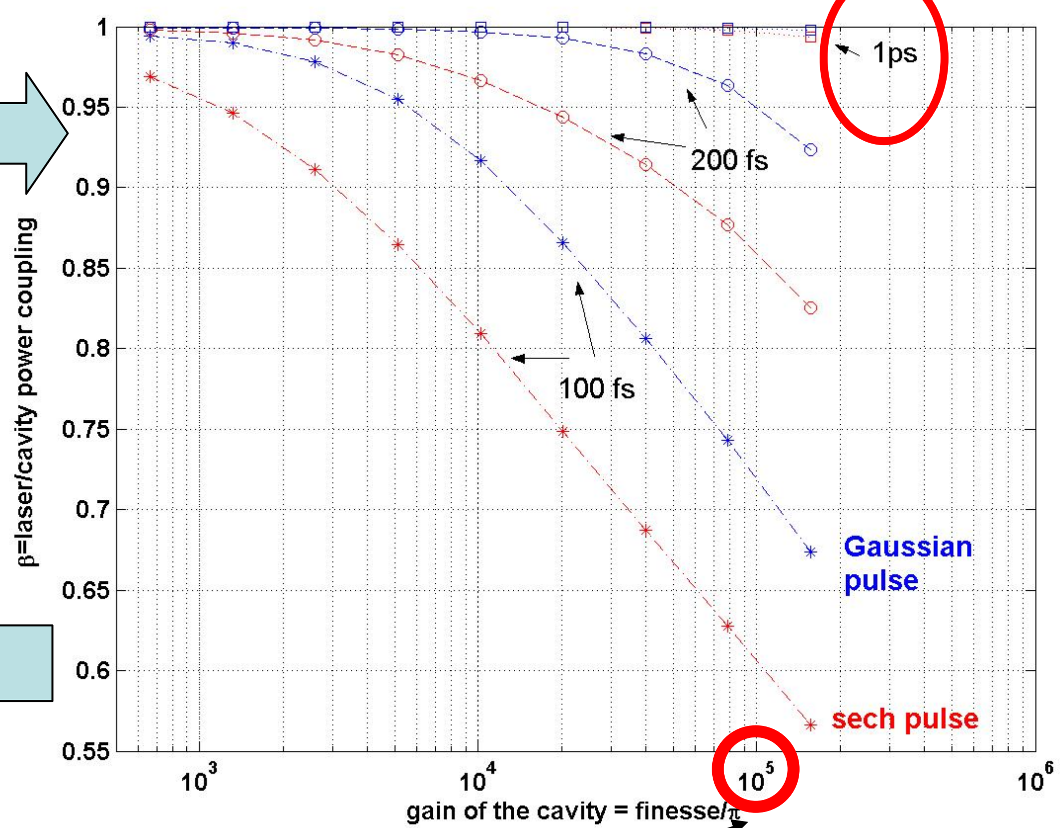
Fourier transform →superposition of N longitudinal laser mode - in phase



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 ≈10^4
    - Falleto et al. (NIMA459(2001)412)
  - HERA (polarimeter) - gain ≈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

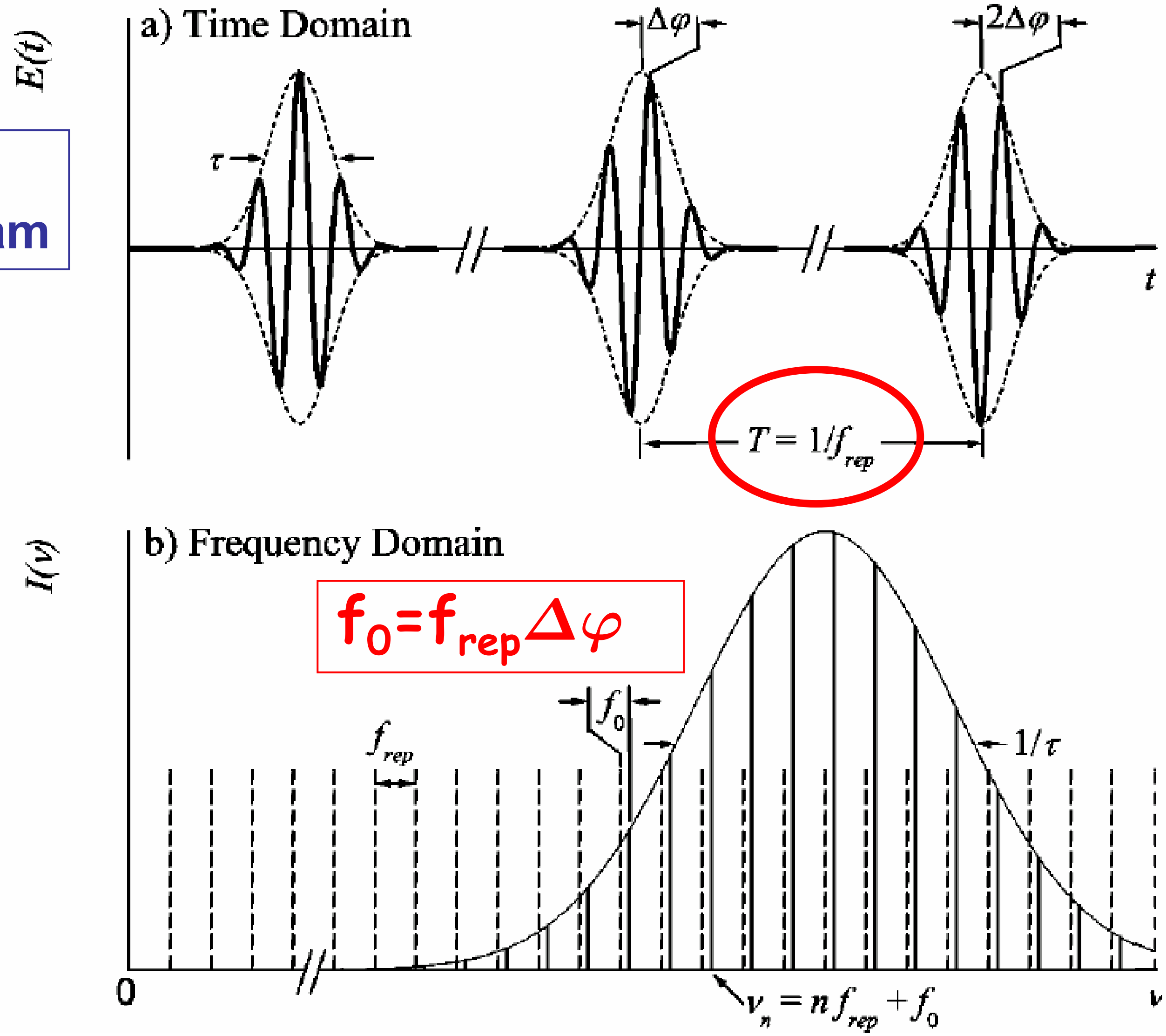
- Moderate cavity gain (Urakawa et al. KEK)
  - Very small laser beam waist (≈5μm) to increase de laser-e luminosity
    - 4 mirrors cavity
  - High input laser power
- KEK R&D

- Very high cavity gain ≈10^4-10^5
  - Moderate laser beam waist (≈50μm)
    - 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

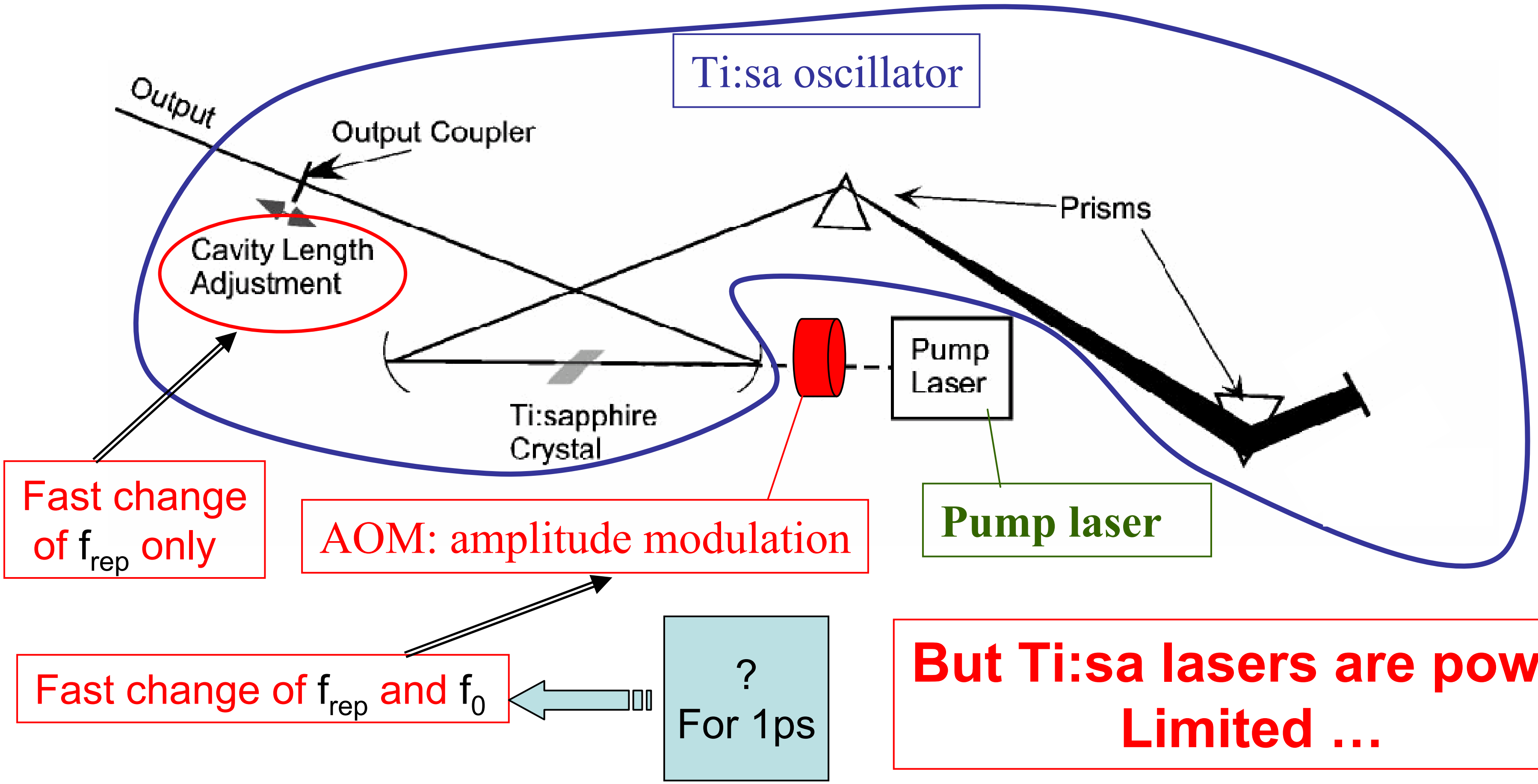
Feedback for mode-locked laser beam



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

[*Femtosecond optical frequency comb technology*, Ye&Cundiff, Springer 2005]

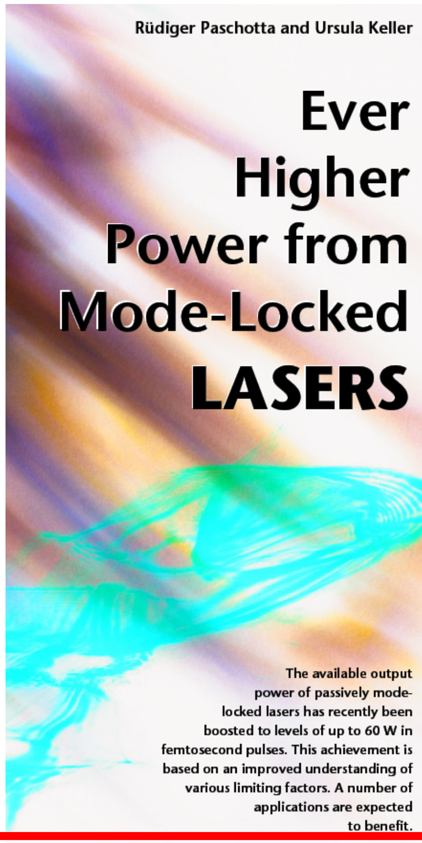
- Feedback technique
  - Fabry-Perot cavity taken as the reference
  - f_{rep} & f_0 are changed inside the laser(s)
  - Error signals: taken at different values of $\lambda \rightarrow$ to lock the full frequency comb to the cavity



But Ti:sa lasers are power Limited …

Possible laser for Klaus's scheme

Opt. & Phot. News 2003



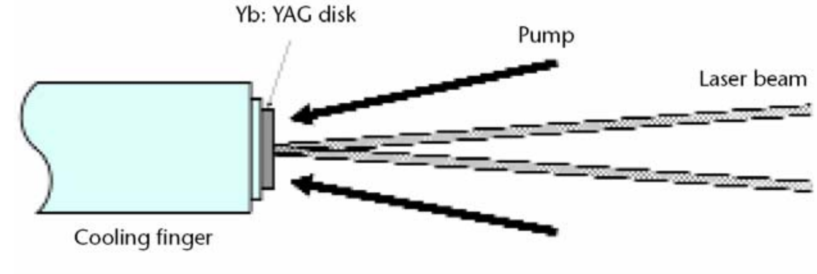


Figure 3. Thin-disk laser head (without multipass pump optics).

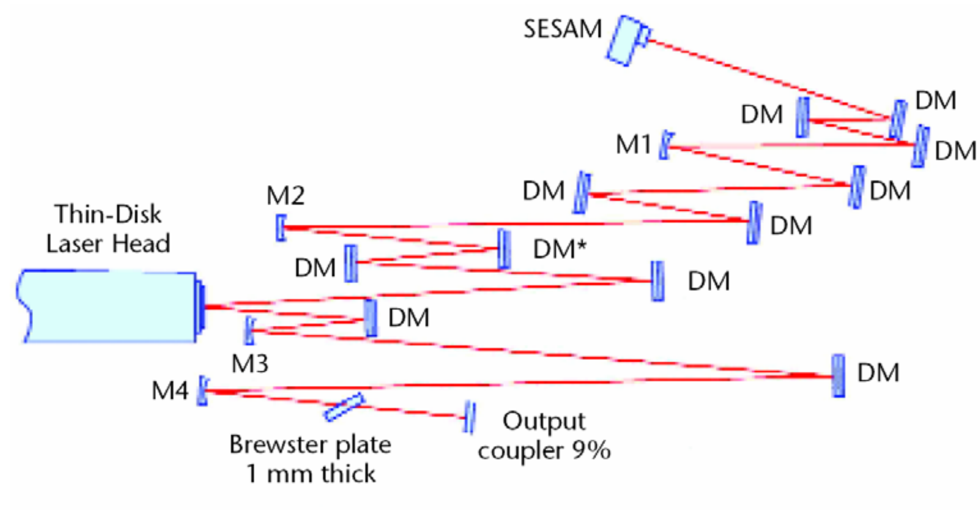
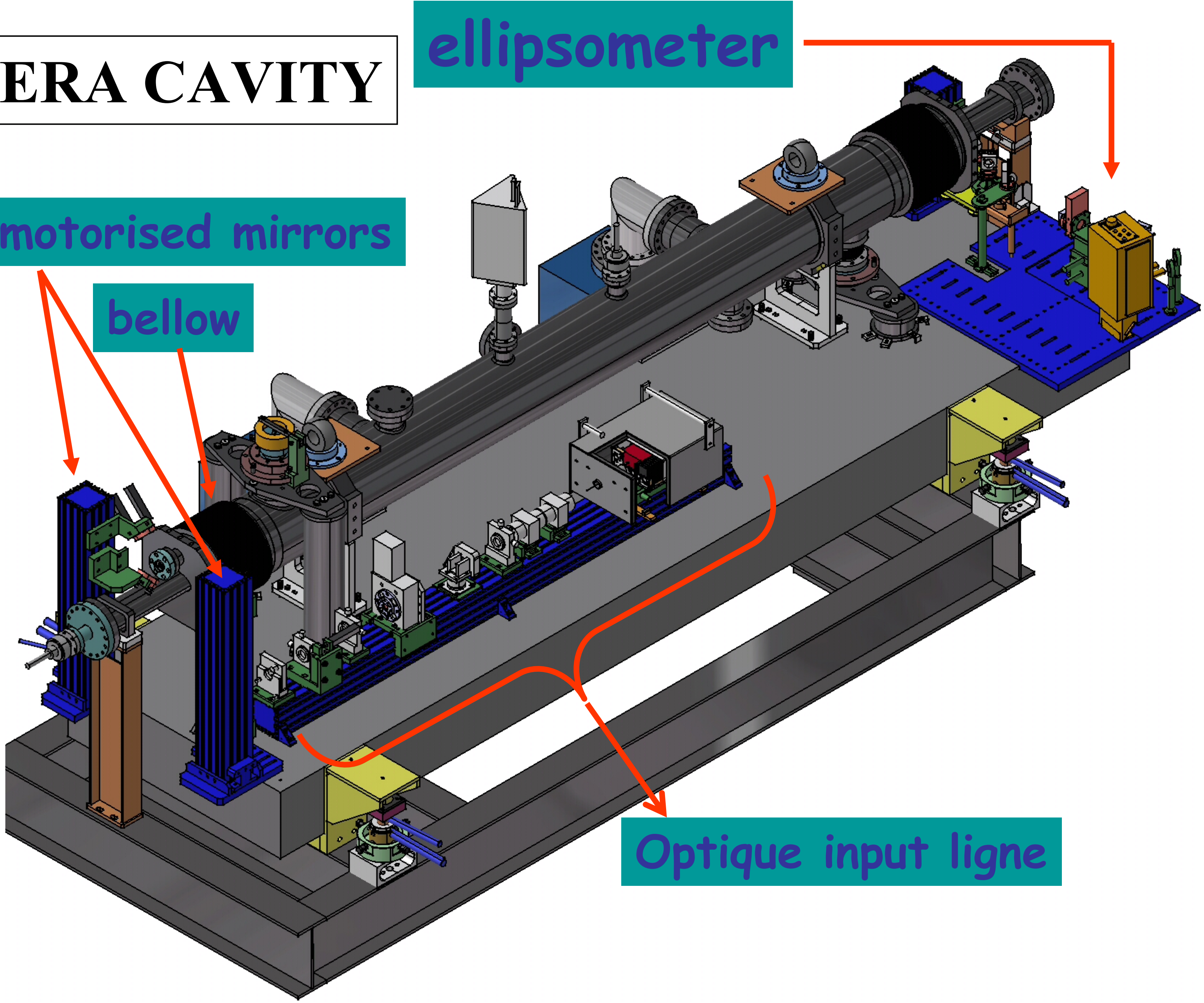


Figure 4. Cavity of mode-locked 60-W laser.
DM = dispersive mirror; M2, M3, M4 = highly reflecting mirrors;
SESAM = semiconductor saturable absorber mirror.

Yb:YAG, Δt=810fs @ 33MHz

- **1.7μJ/pulse {×10^5 (cavity)→ ≈ 0.1J/pulse}**

HERA CAVITY

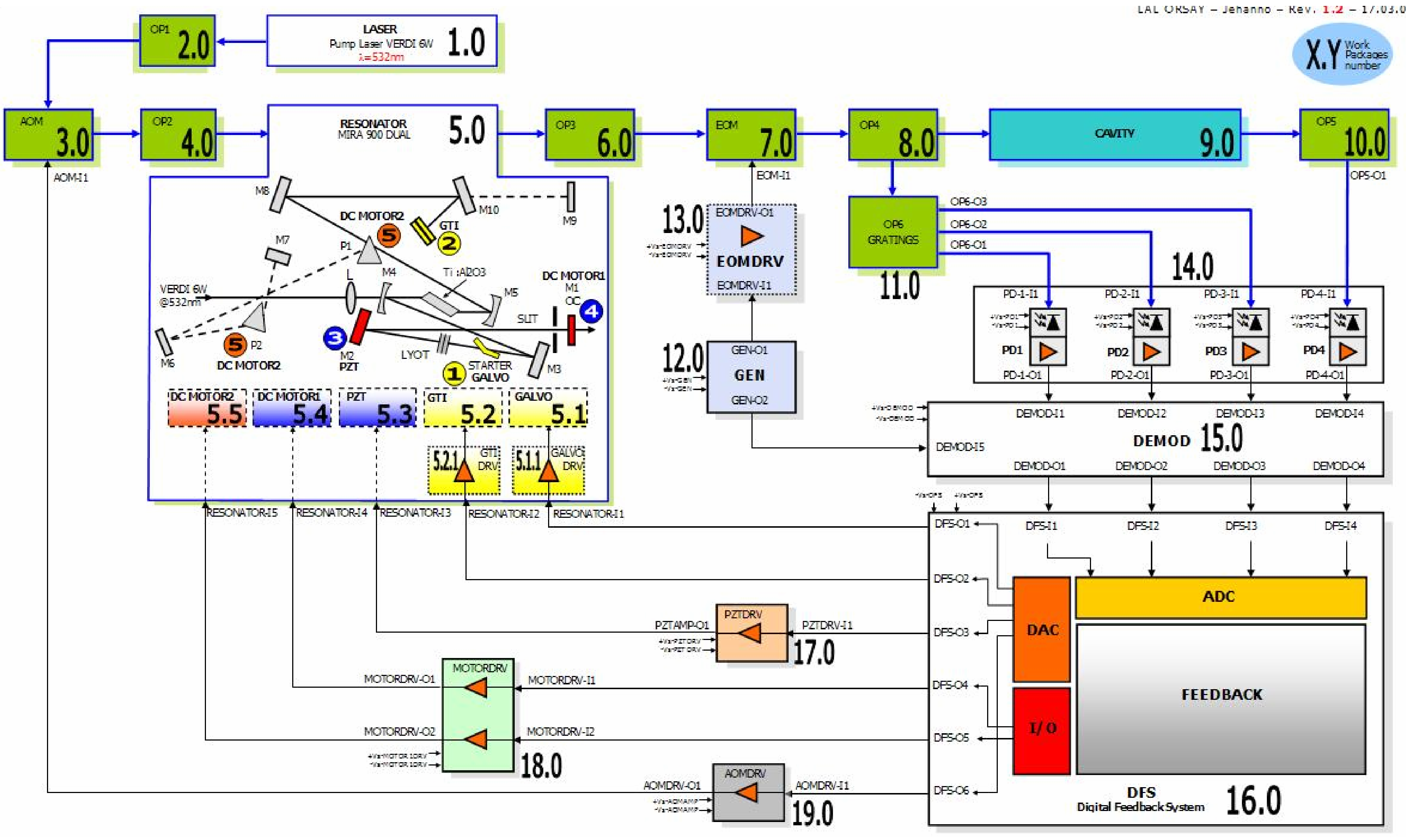

ellipsometer
4 motorised mirrors
bellow
Optique input ligne


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



Reduction of the laser beam size at the IP

- To get a laser beam size < 50 μm at the electron-laser beam IP
  - Use of a quasi-concentric cavity

    (mirror curvature radius ≈ half cavity length)
  - BUT, mechanical tolerance <μm & μrad needed on relative mirror positions
    - Active feedback on relative mirror position & laser beam pointing