Experimental Effort for Alternative Schemes

ILC2007 at DESY Hamburg

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Introduction

Laser-Compton scattering experiments, as an alternative schemes for polarized positron source of ILC, have a good potential to be expanded into very wide, various, and interesting field. For example, not only for physics and accelerator applications, medical and industrial applications are expected. In addition to high power laser and external cavity developments, recently, **fiber laser** becomes an important clue for this field. According those point of view, we want to introduce some experimental topics presented in PosiPol 2007, LAL-Orsay.

- Contents of this talk

◇ **Compton ILC source based on a CO2 laser and a 4 GeV linac** (I. Pogorelsky , BNL)

◇ **Fabry Perot resonators program in LAL-Orsay**

(Y. Fedala , LAL)

◇ **Compton gamma-ray generation experiment by using an optical cavity in ATF** (H. Shimizu , ATF)

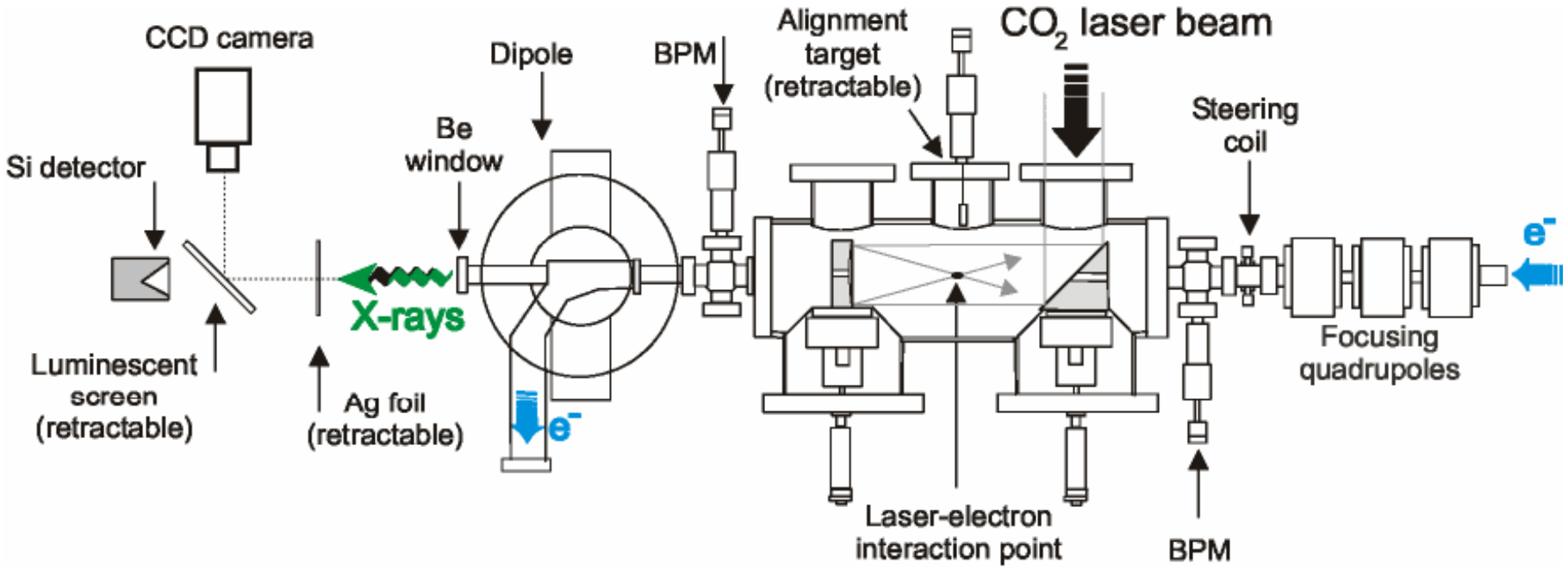
◆ **about Fiber Laser**

Compton Exp. at BNL

- Using 60MeV electron beam.
- 1TW CO_2 laser in 50mHz frequency.
  (※ 1-path experiment)
- Scattering with 0-deg. angle.
  (head-on scattering achieved with holed mirror)
- Heighten $N_\gamma/N_e \Leftrightarrow$ Nonlinear effect

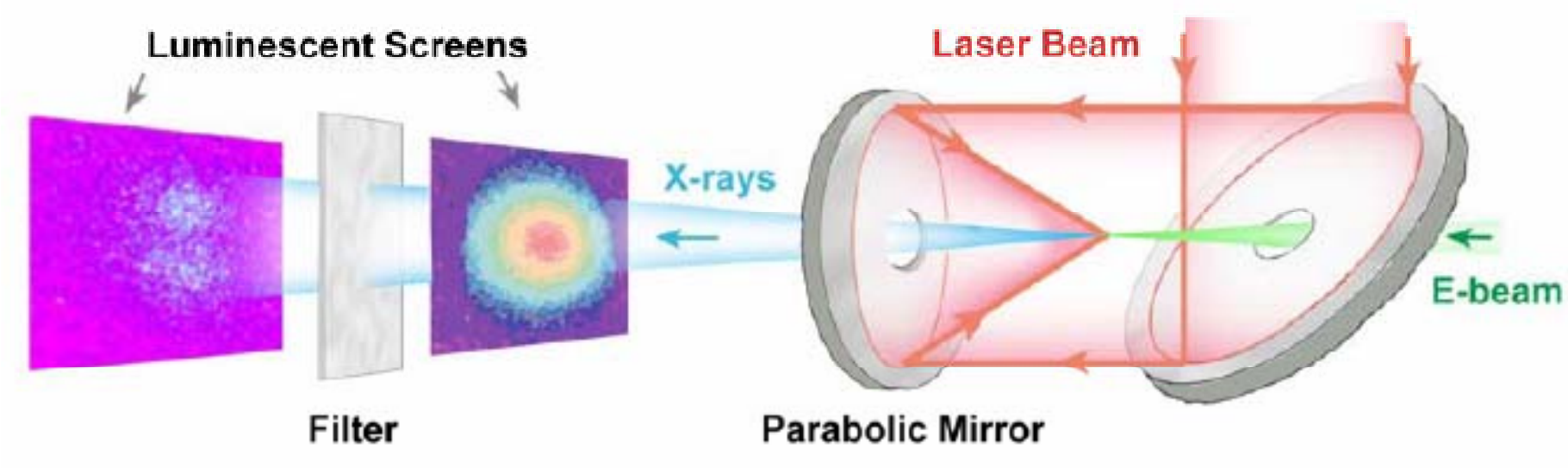
Electron beam:
energy 60 MeV,
bunch charge 0.2 nC,
duration 3.5 psec (FWHM),
transverse size 45×80 μm^2(RMS).

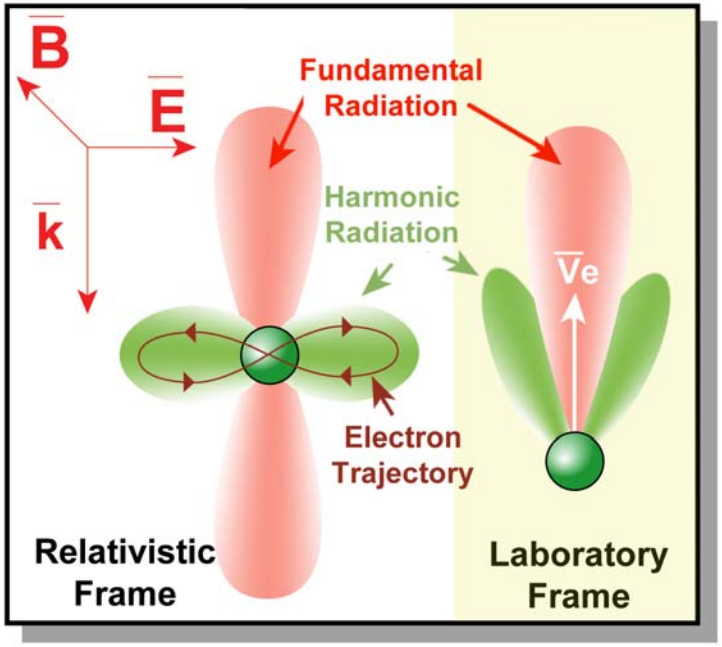
Laser pulse:
wavelength 10.6 μm
energy 2 J,
duration 5 ps (FWHM),
focal spot size 35 μm (RMS).

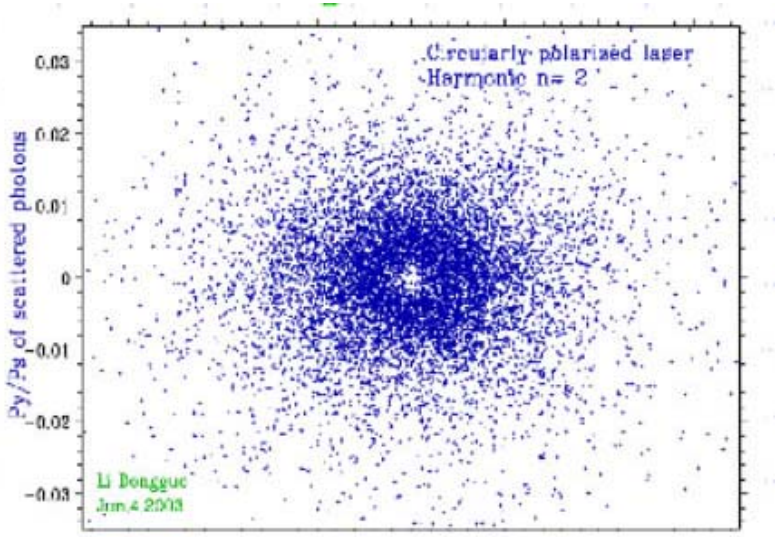


γ-ray production efficiency N_γ/N_e ~1

Observation of Nonlinear Thomson Scattering







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Quantitative agreement of the BNL experiment results

e-beam - size 60 μm (RMS), charge 0.2 nC, duration 3.5 ps (FWHM);
laser - energy 2 J, size 35 μm (RMS), duration 5 ps (FWHM).

Parameter	*total*	*harmonics*
Number of x-ray photons at IP	3×10^{8}	1.6×10^{7}
Integral x-ray energy at IP (eV)	10^{12}	1.5×10^{11}
Number of x-ray photons at detector	7×10^{7}	1.5×10^{7}
Energy on detector (eV)	4×10^{11}	4×10^{10}
Filtered energy on detector (eV)	3.1×10^{10}	3.0×10^{10}

⇐ *Agrees with experiment*

Conclusions:

- 15% of the x-ray energy goes into harmonics
- The x-ray signal filtered by the 10-μm Ag foil consists primarily of harmonics
- 0.2 nC bunch contains 1.25×10^{9} electrons, i.e. 4 times the number of photons generated at IP. However, due to the approximately two times bigger cross-section of the *e*-beam compared with the laser focus, only ~¼ of the total electrons in the bunch participated in scattering.
- Thus, we conclude that x-ray yield is close to $N\gamma/Ne$~1, as is required for ILC.

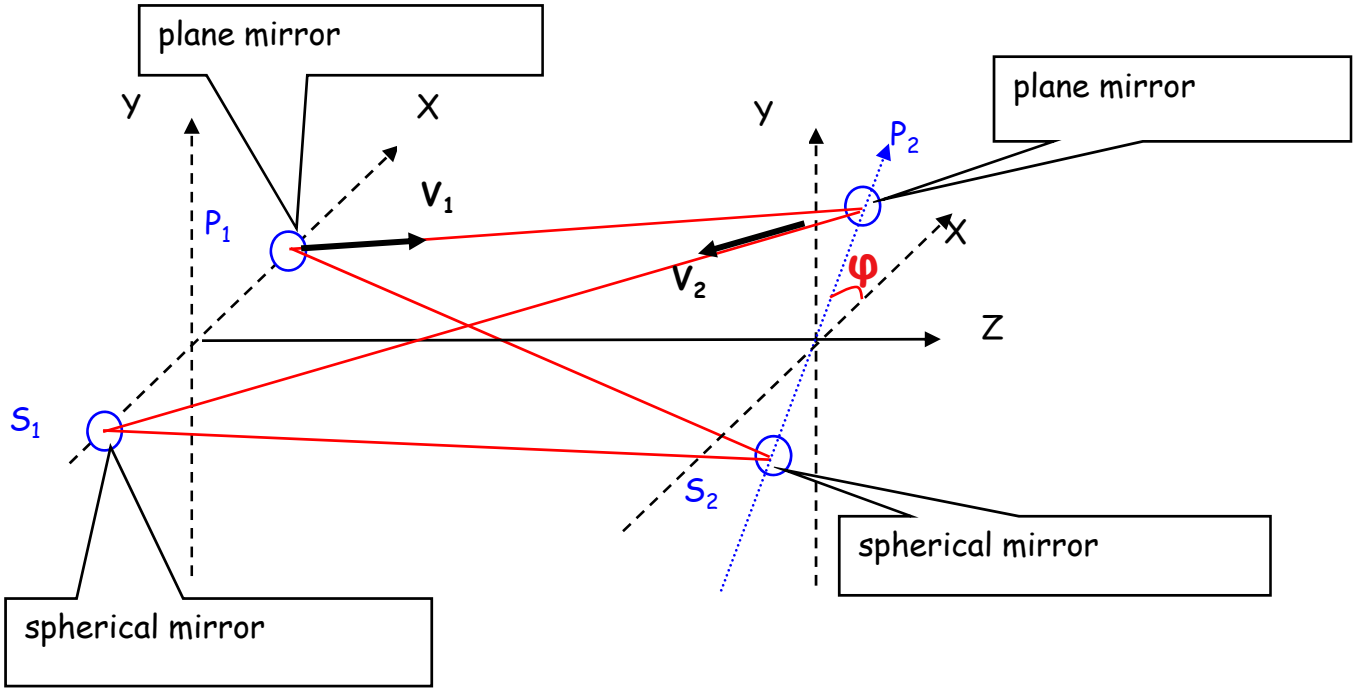
Exp. at LAL and ATF

- Both group design for Compton scat. with external cavity to stack laser beam.
- Goal is to achieve high enhancement & small beam spot size.

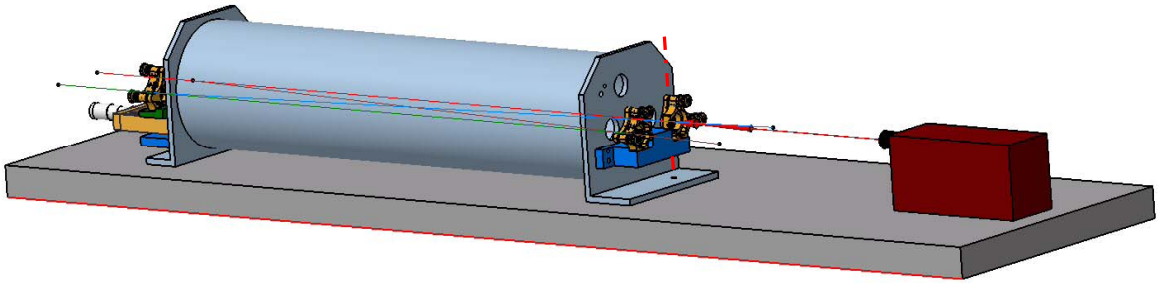
	LAL	KEK
Structure	4-Mirror Cavity (confocal)	2-Mirror Cavity (concentric)
Finesse	～10000	～1000
Waist Size (2σ)	＜ 20μm	60μm
beginning	without e-beam (Exp. to verify high quality cavity)	with ATF beam (Exp. aimed at getting γ-rays)

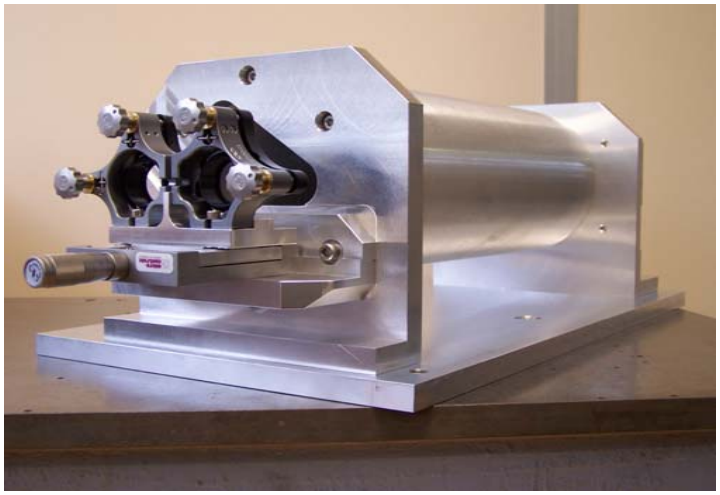
R&D Report from LAL

Four mirrors 2D or 3D cavities

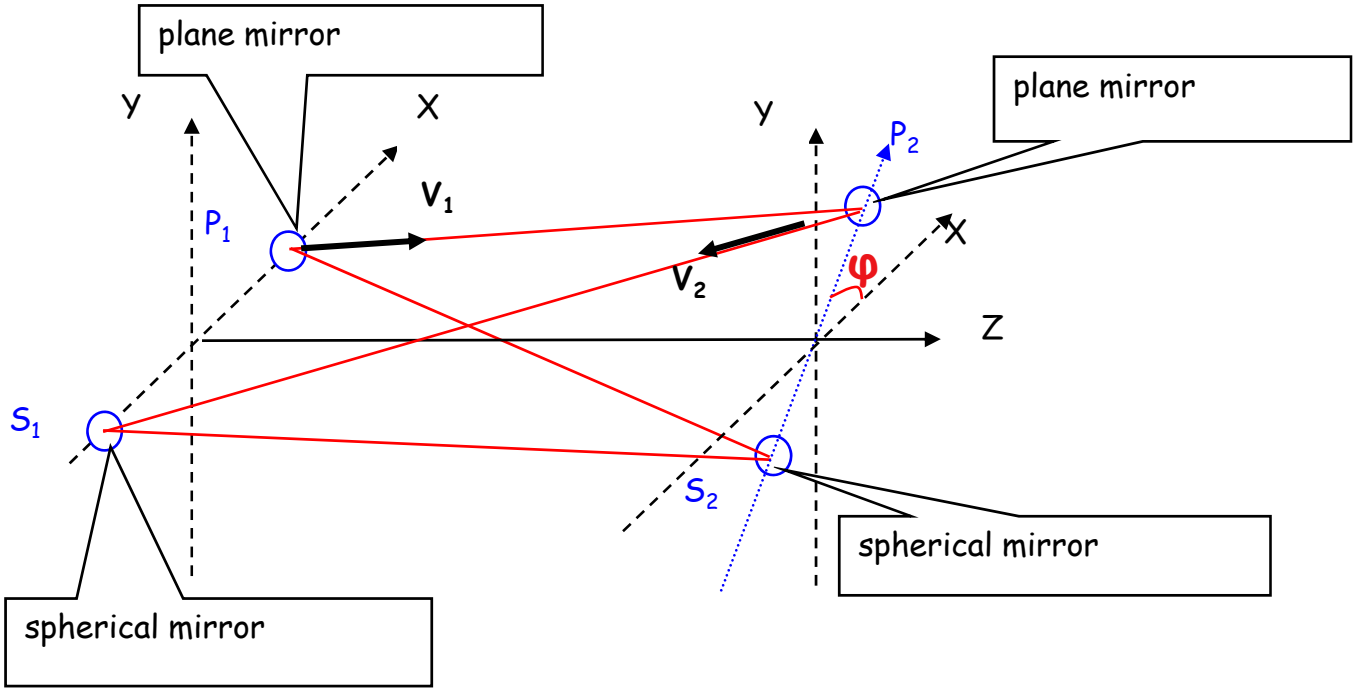


φ=0 ➔ 2D cavity

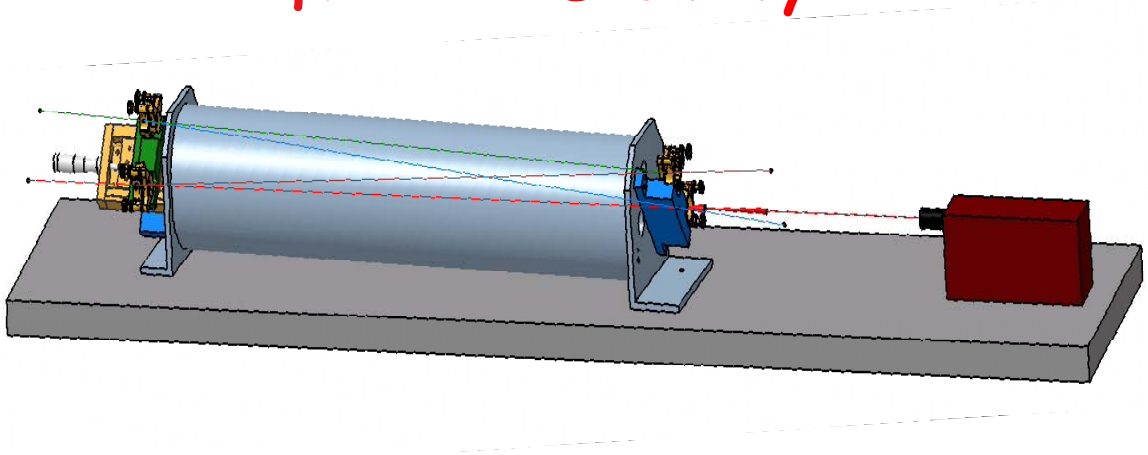


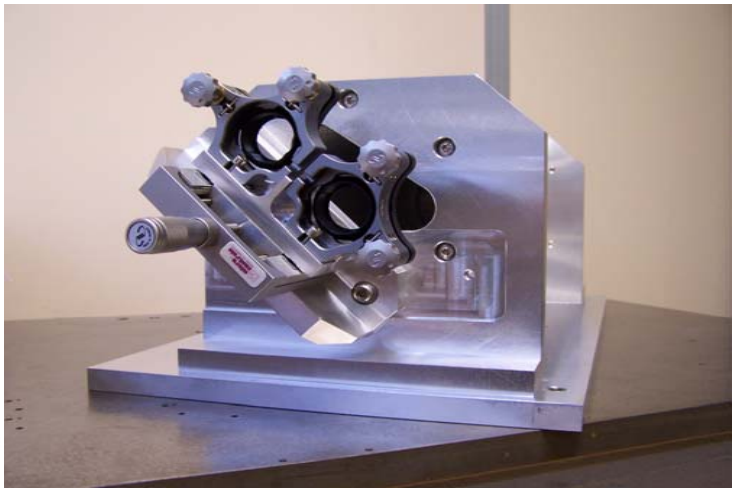


Four mirrors 2D or 3D cavities



φ≠0 ➔ 3D cavity

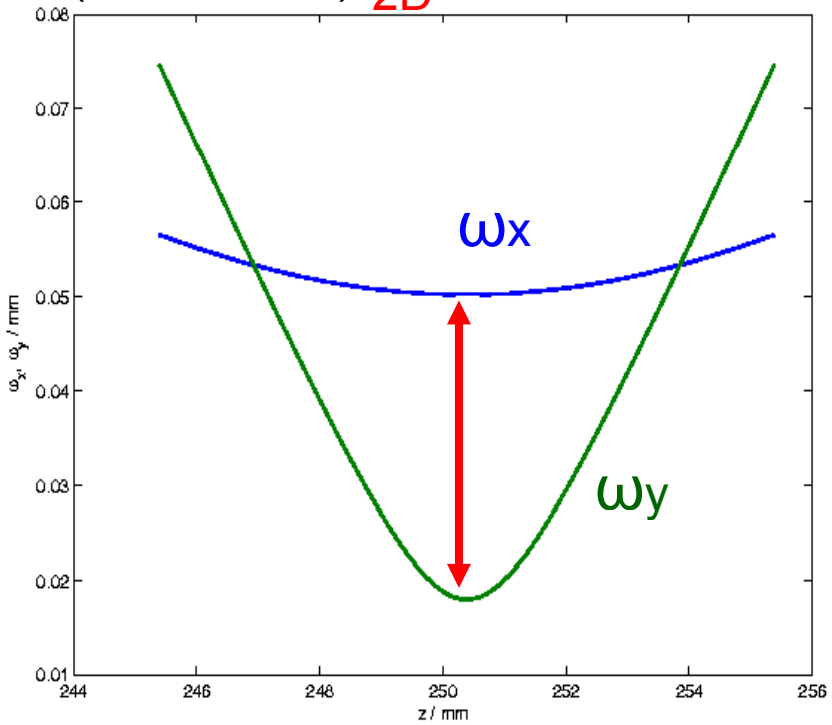




Comparison of Astigmatism in 2D & 3D Configuration

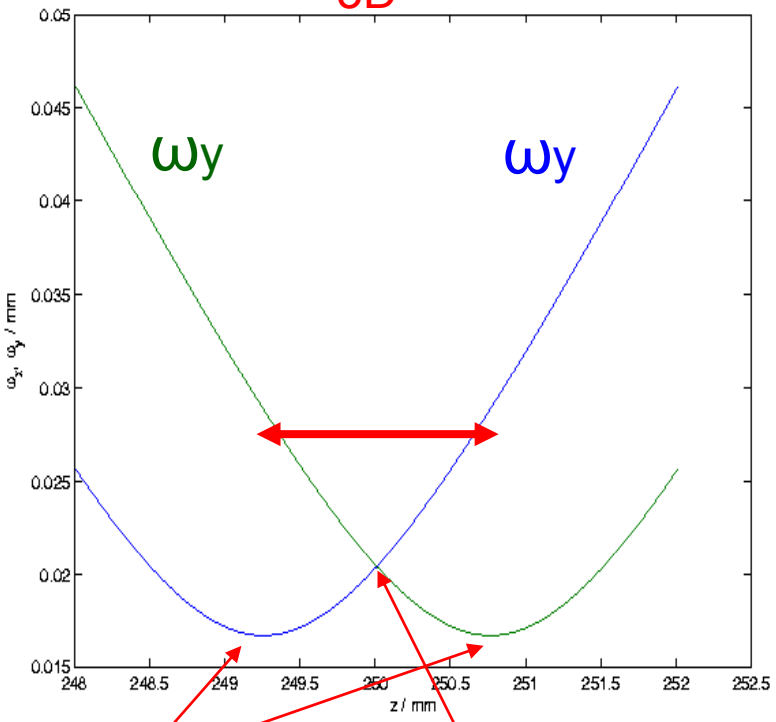
Zoom around the waist position (calculations)

2D



Strong astigmatism

3D

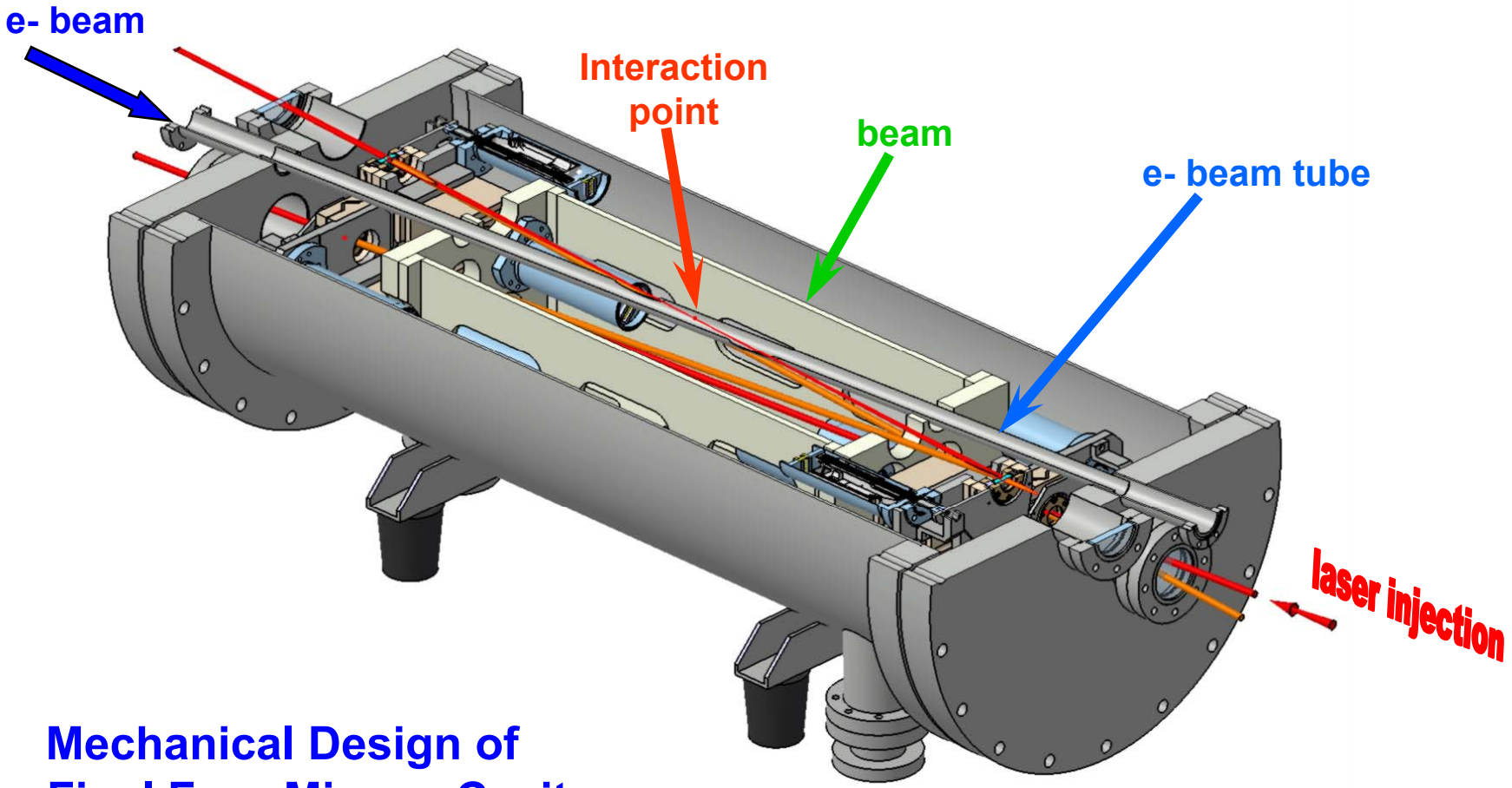


2 waist positions inside the cavity

Third position➔ circular beam with small waist

astigmatism compensated in 3D config. ➔ results reproduced with measured data .

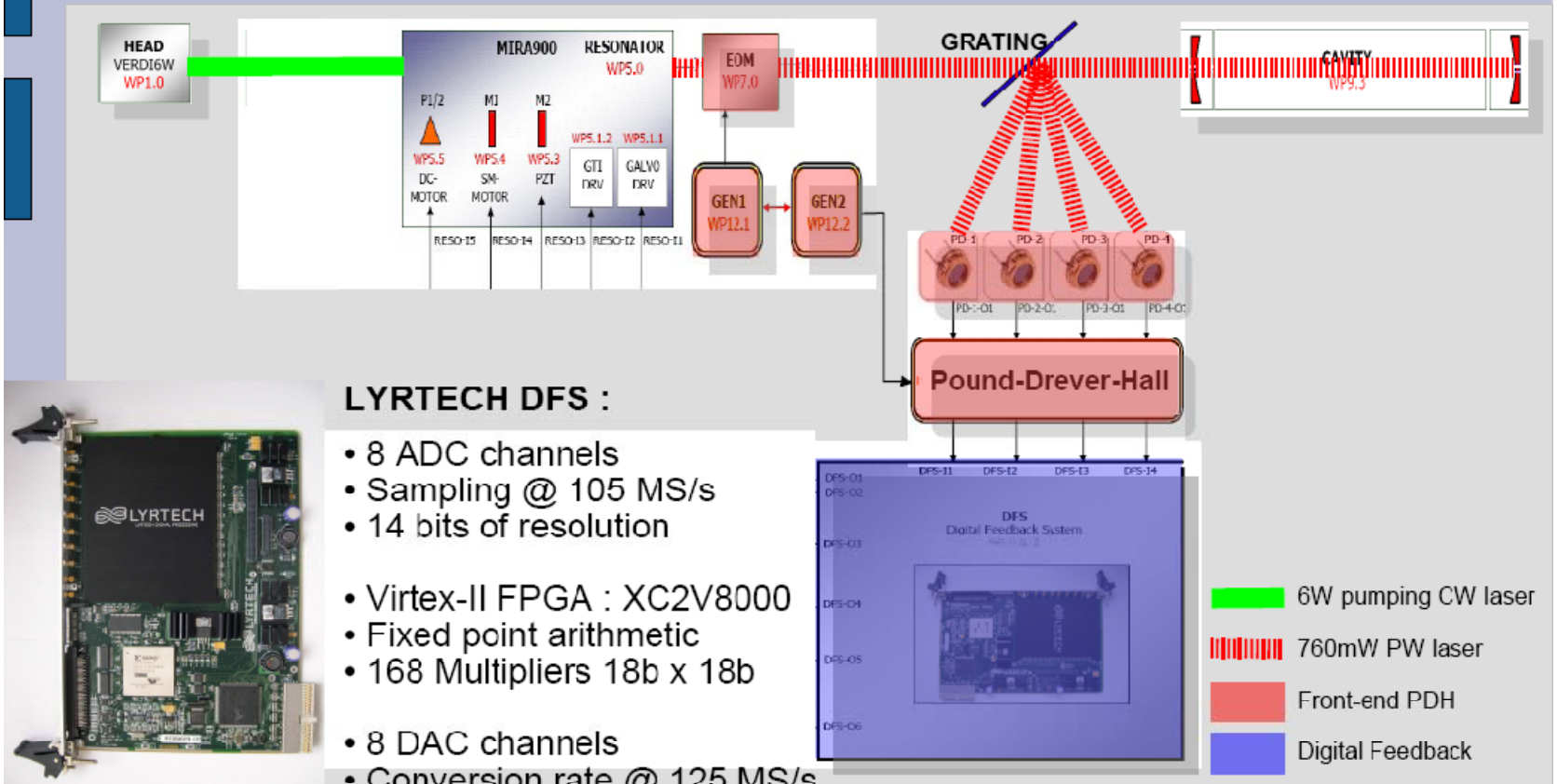
LAL group is also preparing exp. with e-beam



Mechanical Design of Final Four Mirrors Cavity

R. Cizeron (LAL)

Digital Feedback System (DFS)



LYRTECH DFS :

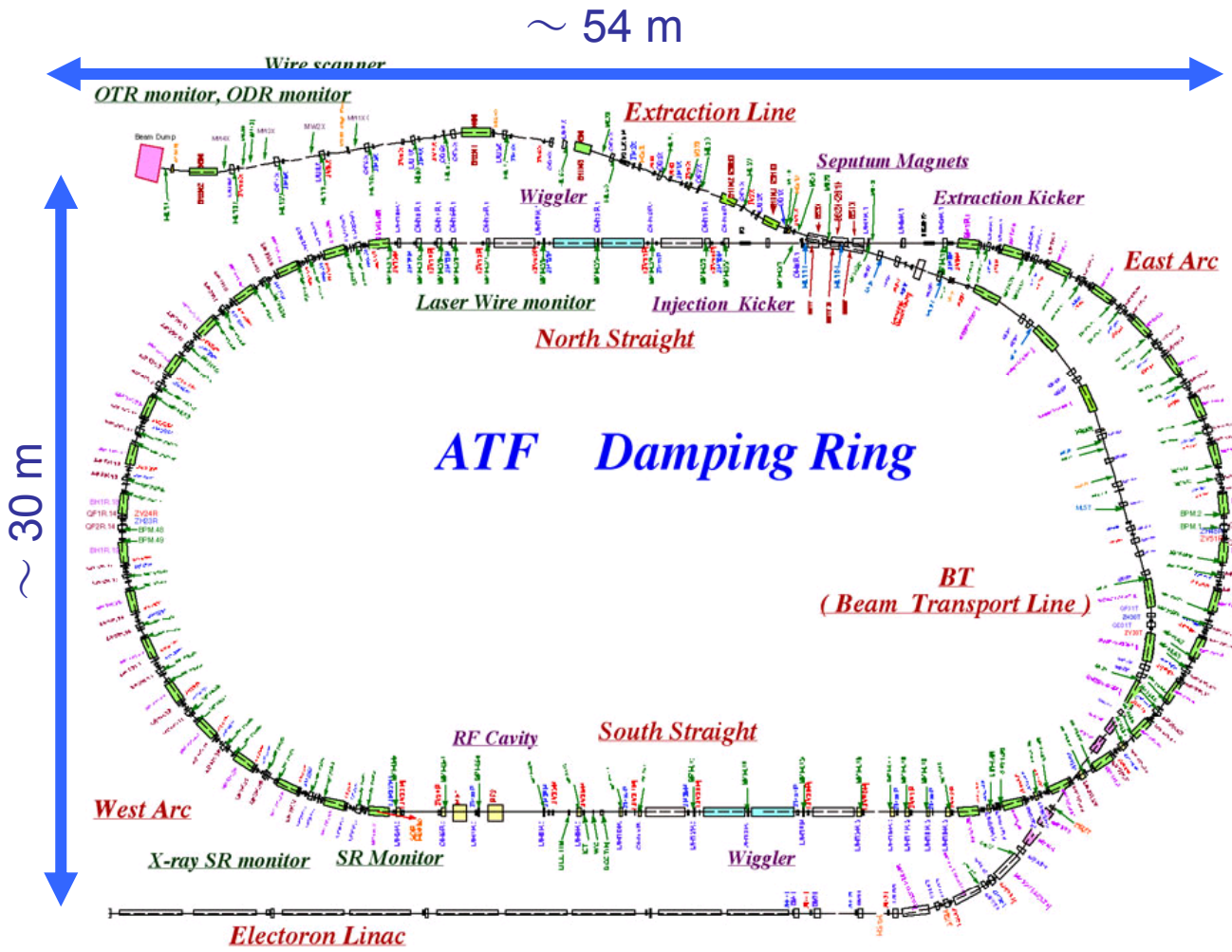
- 8 ADC channels
- Sampling @ 105 MS/s
- 14 bits of resolution

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

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

R&D Report from ATF

The Clue is Accelerator Test Facility (ATF)



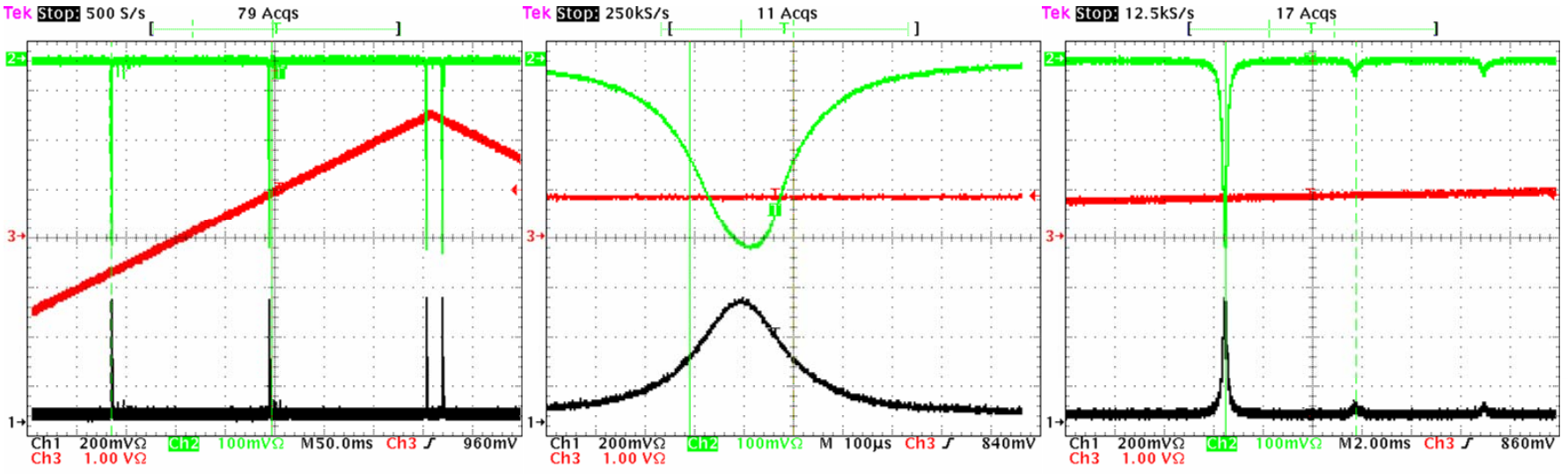
Proof of Principal Exp. have **DONE.**

Fukuda *et al.* [Polarized γ]
PRL91(2003)164801

Omori *et al.* [Polarized e+]
PRL96(2006)114801

※ Both Exp. above are in 1-path

Typical examples of observations



- With training configuration, 800～900 finesse can be reached constantly.
- Also, observed beam waist achieved inside the cavity is stably about 60µm.

- With 10W mode-lock laser, achieved finesse is 200 and beam waist size is 67μm.

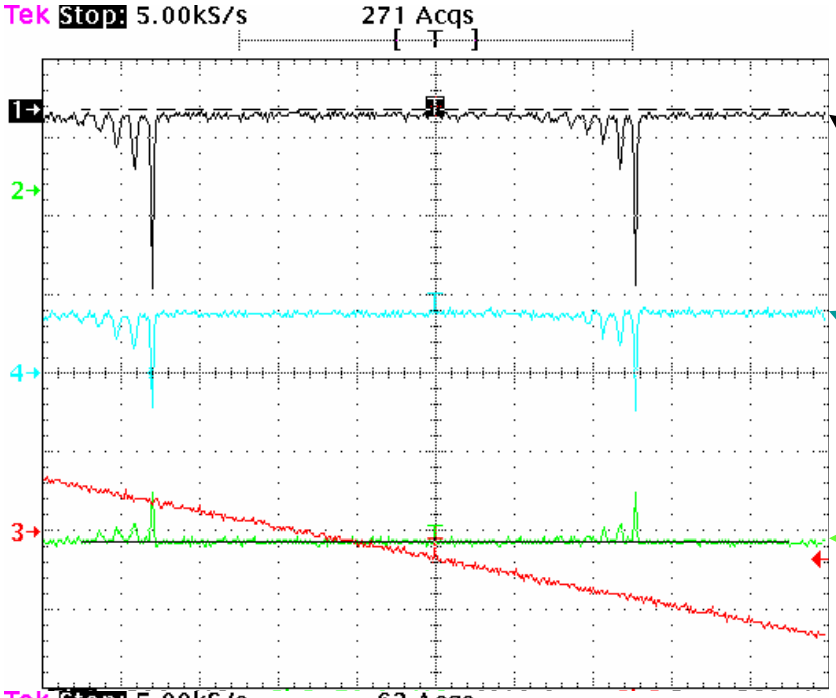
  → Mode matching is still imperfect.

- First try to take a feed-back

  → CW laser case, it works well

  → Pulse laser case, jitter is still large

Feed-Back study results (Pulse)



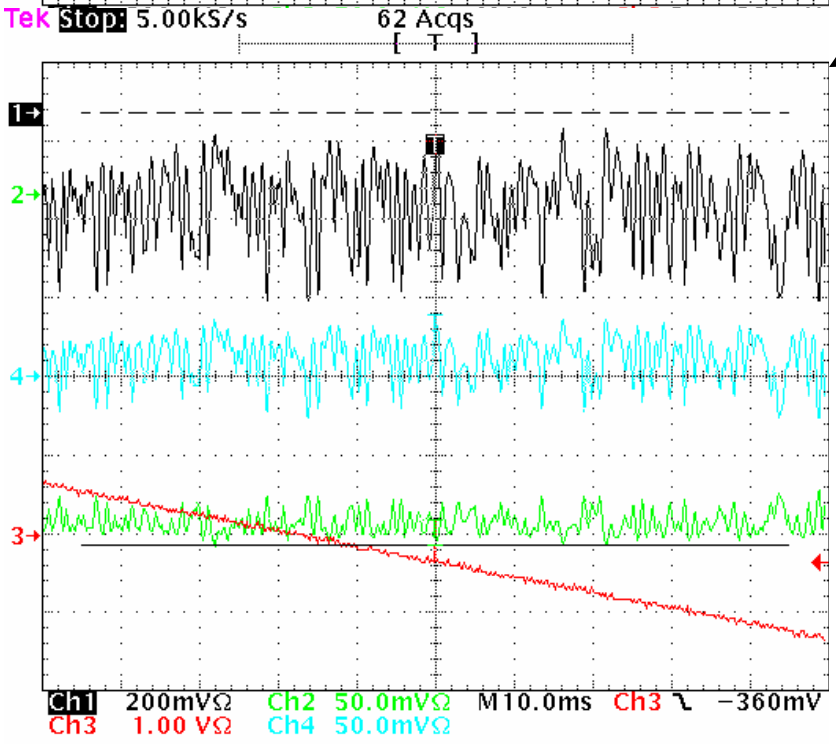
Transmission Light

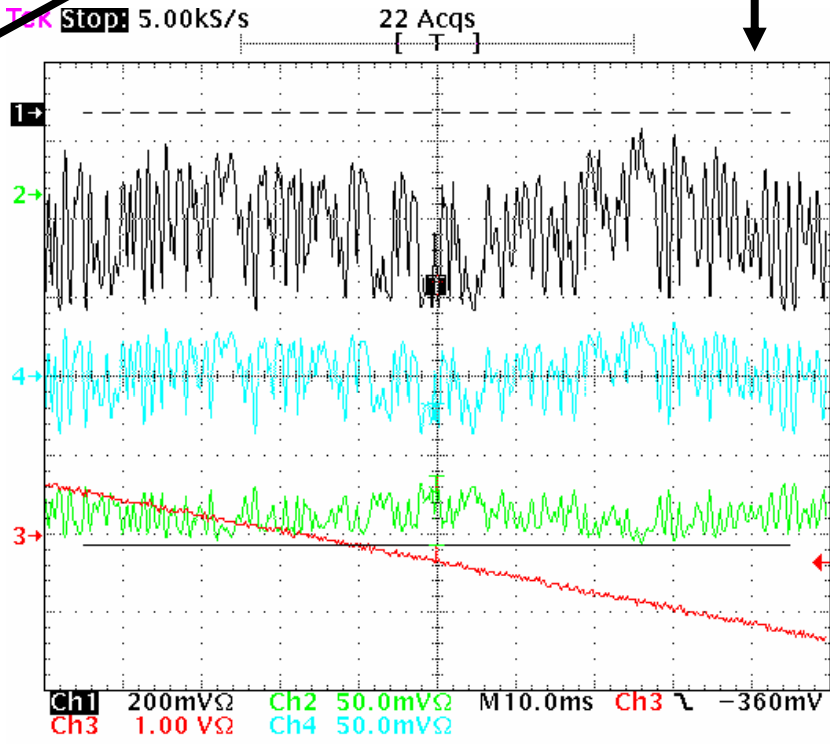
Error Signal

Reflected Light

Integration (1ms)

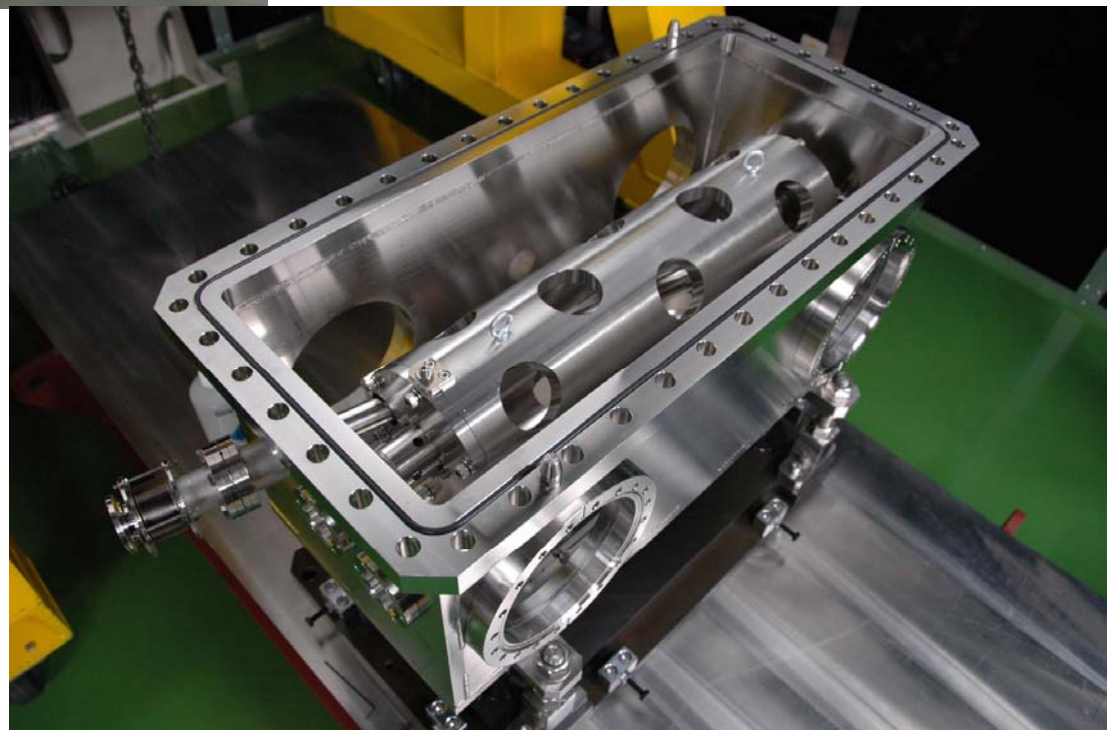
Integration (10ms)





Real Cavity constructed in ATF

Cavity fixed inside of
the real vacuum chamber



Talks about Fiber Laser

- 4 talks (title includes “fiber”) in the conference.
  - ◇ **Fiber technology for high average powers lasers**

    M. Hanna (Institut d’Optique-Palaiseau)
  - ◇**High power fiber lasers perspectives**

    Y. Zaouter (CELIA/Amplitude Systemes)
  - ◇**The laser wire fiber laser**

    N. Delerue (Oxford)
  - ◇**Multi kW fiber laser**

    M. Kuriki (KEK)

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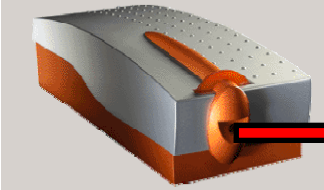
Outline of the talk

- Interests of Yb-doped fibers as amplifier medium
  - How to use the advantages of fibers ?
  - How to handle or avoid disadvantages of fibers?
  - The double-clad yb-doped fiber concept
  - The micro-structured fibers
- High power / High energy fiber amplifiers
  - Existing systems
  - Perspectives
- **The ANR project LAL / Amplitude Systemes**

ANR LAL / Amplitude Systemes

Femtosecond oscillator	Grating stretcher
Compressor	**Fiber amplifiers**

1. PM-LMA fiber ampli.
   - High pump absorption
   - Polarized output beam
2. PCF-Fiber amplifier
   - High launch power
   - >800W pump power
   - Reduced non-linearities

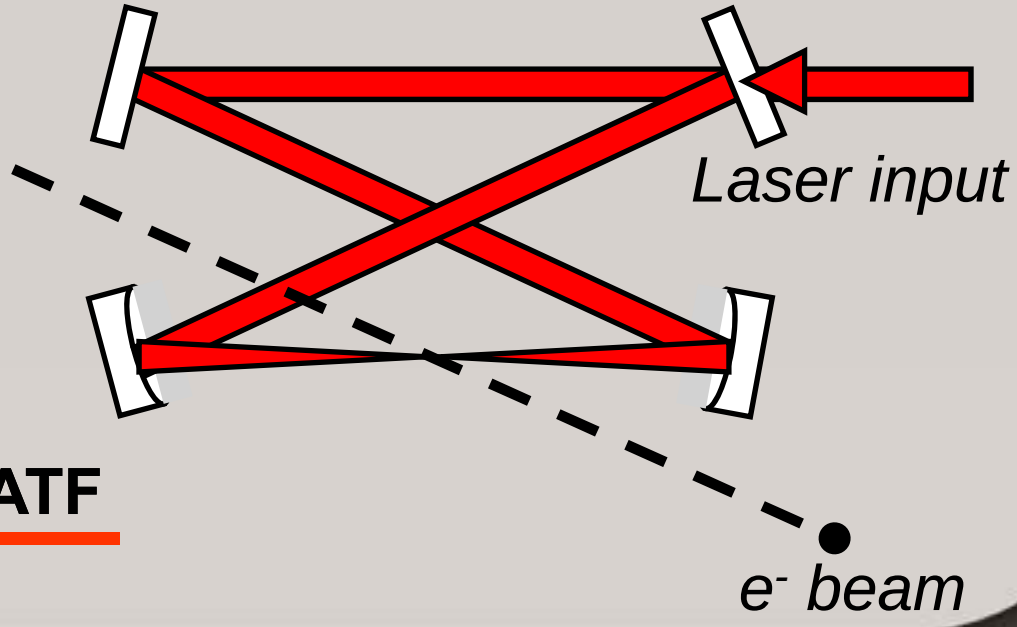


- > 300W average power
- Linearly polarized beam

ANR LAL / Amplitude Systemes

Laser system designed by Amplitude Systemes

- Injection in a super high finess FB-cavity
  - Gain ~ 10^4 – 10^5
- Small interaction region
  - **Multi-MW** pulses stacked
- Non-planar geometry
  - Circular polarization
  - Polarized positrons source



Installation at KEK / ATF

For more information,

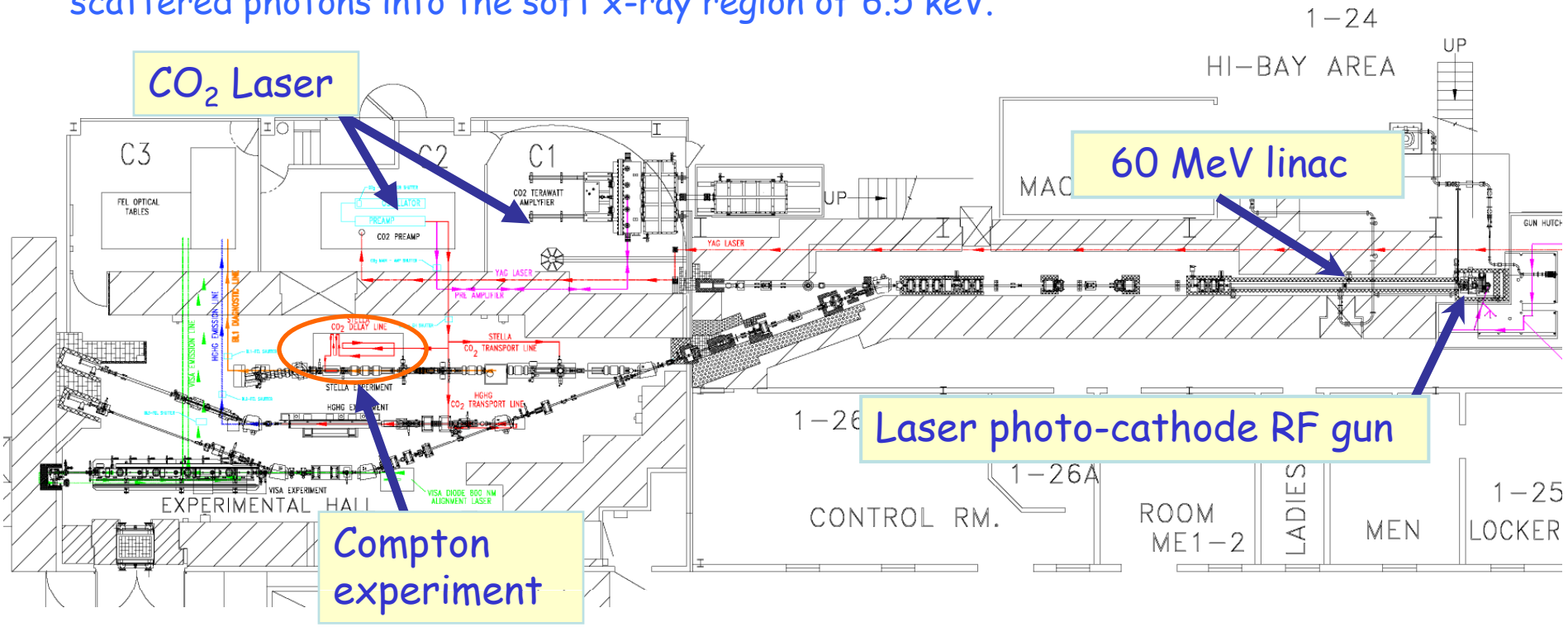
Conclusion

- **Presented the best performances to date**
  - High power fibre-CPA
  - High energy fibre-CPA
- **Design of the project submitted to ANR**
  - Very high power 1-ps amplifier with a synchro-locked laser seed
  - Non-planar FP-cavity
  - FPGA global control of the experiment
- **Installation at KEK / ATF**
  - Production of polarized positrons

Brookhaven National Laboratory

Accelerator Test Facility

- The BNL-ATF is the only facility in the world equipped for testing the Compton scattering process close to these optimum conditions outlined above.
- The main equipment for the test includes a 5-ps CO_2 laser and a 60-MeV high-brightness photocathode RF electron-linac. A relatively low *e*-beam energy does not change the underlying physics of the Compton interaction, but merely shifts the scattered photons into the soft x-ray region of 6.5 keV.



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Quick Summary of LAL & ATF

- LAL
  - → astigmatism study (2D&3D)
  - → stability check of beam size
  - → new design report for scattering exp.
  - → fast digital feedback
- ATF
  - → basic study with pulse laser
  - → feedback study with CW laser
  - → feedback study with pulse laser
  - → construction report

This talk is…

as a brief summery report of some experimental talks and also closely related topics given at LAL, Orsay.

Contents

- Experimental Report

  ◇ **Compton ILC source based**
  on a CO2 laser and a 4 GeV linac (I. Pogorelsky , BNL)
  ◇ **Fabry Perot resonators program in LAL-Orsay**

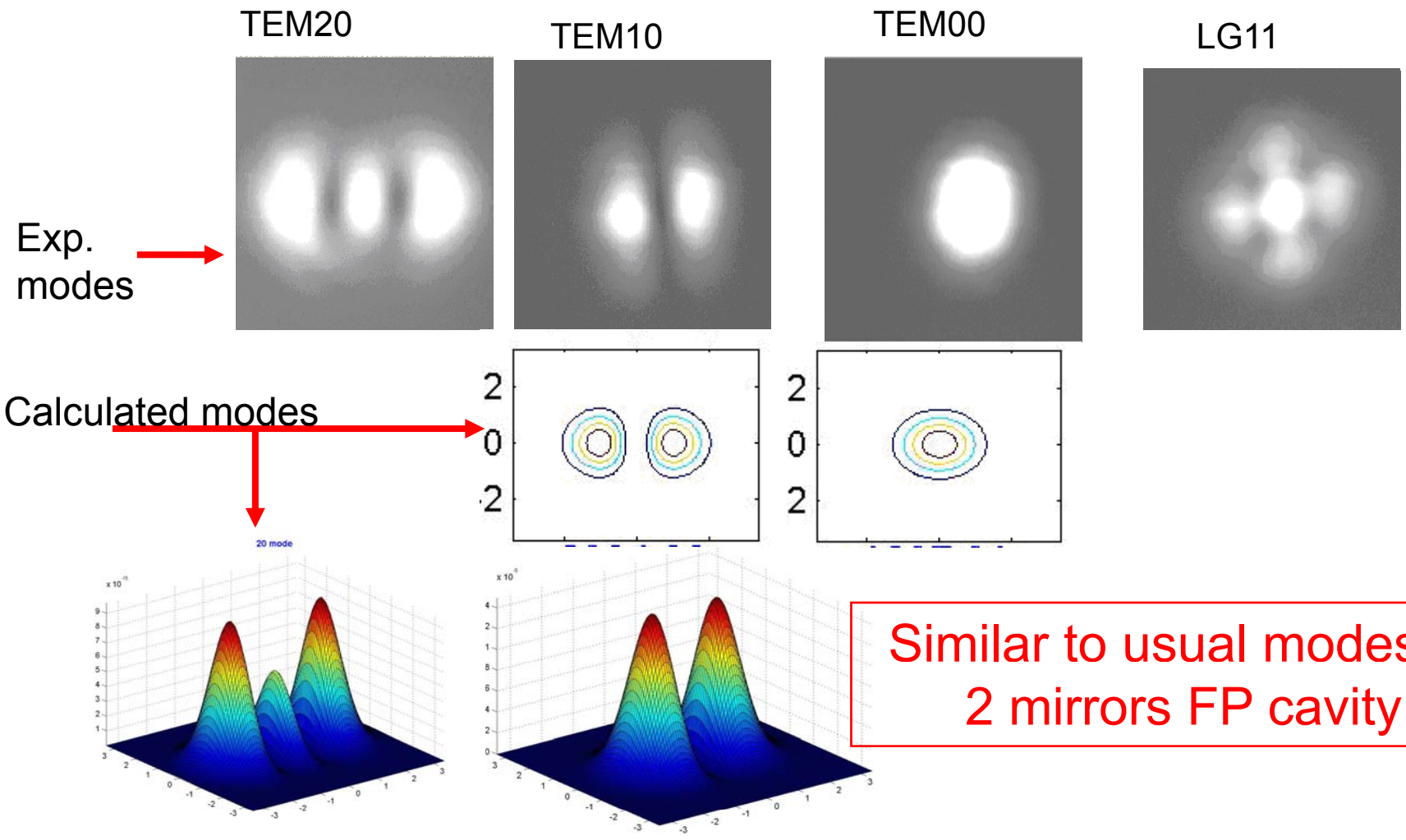
  (Y. Fedala , LAL)

  ◇ **Compton gamma-ray generation experiment**
  by using an optical cavity in ATF (H. Shimizu , ATF)

- Other Related Topics

  ◆ **Fiber Laser**

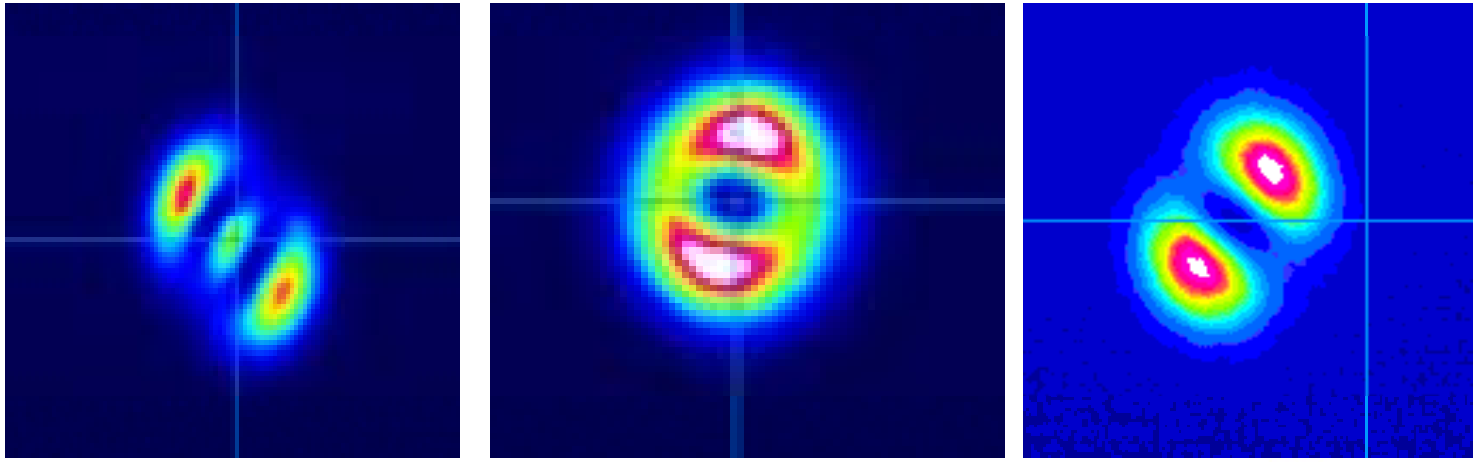
2D cavity modes



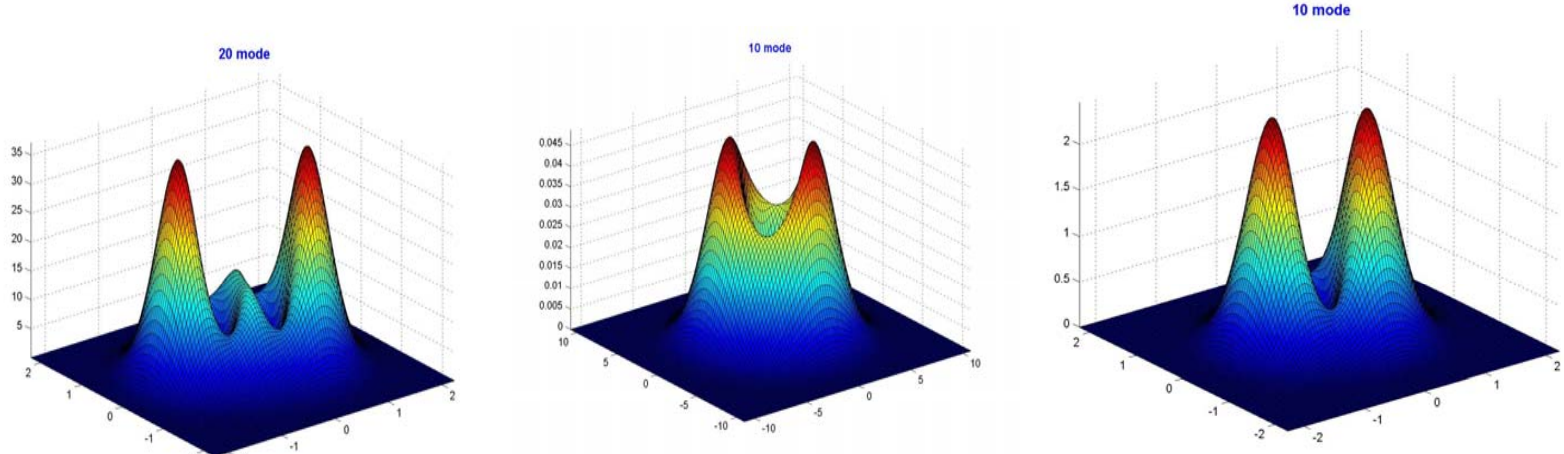
Similar to usual modes of 2 mirrors FP cavity

3D cavity modes

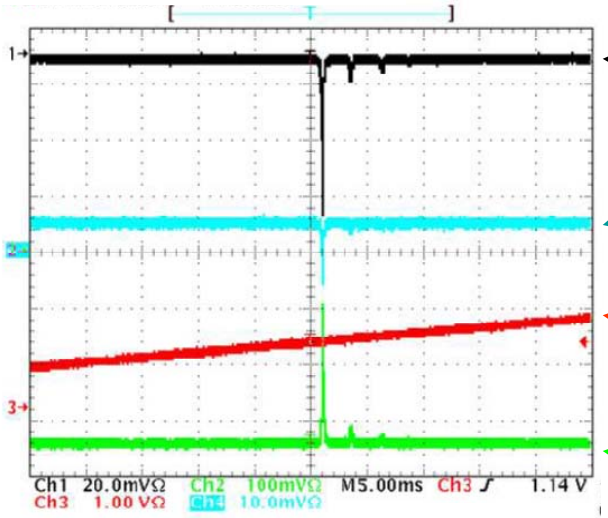
Exp.
Higher order
Modes



Th. results



Feedback Study Results with CW case



Transition Light

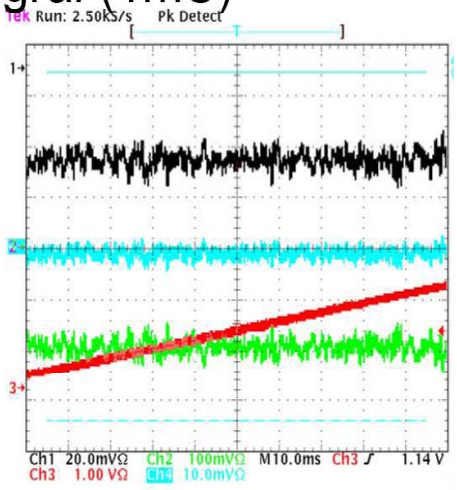
Error Signal

Piezo Modulation

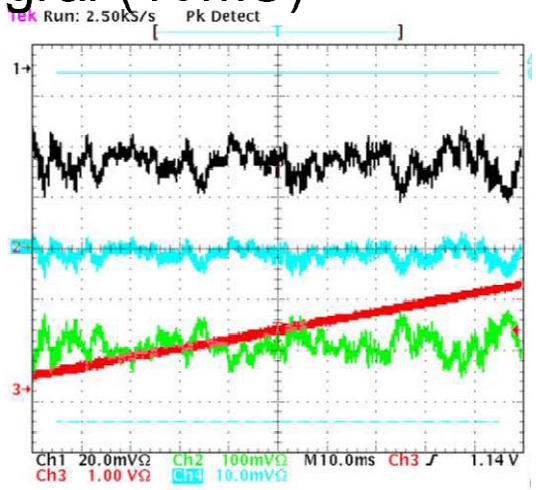
Reflected Light

- Those results are obtained with each time constant (parenthetic).

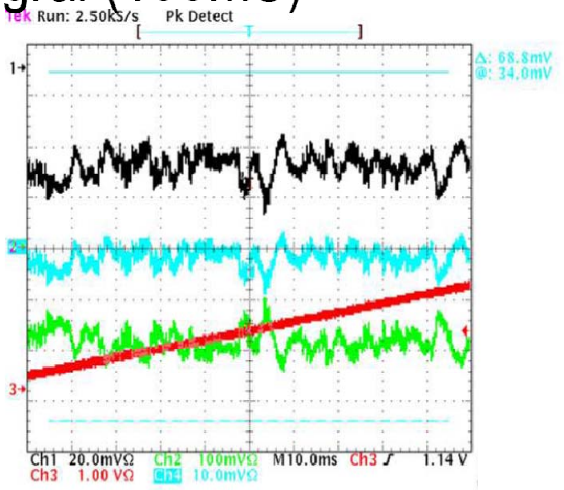
Integral (1mS)



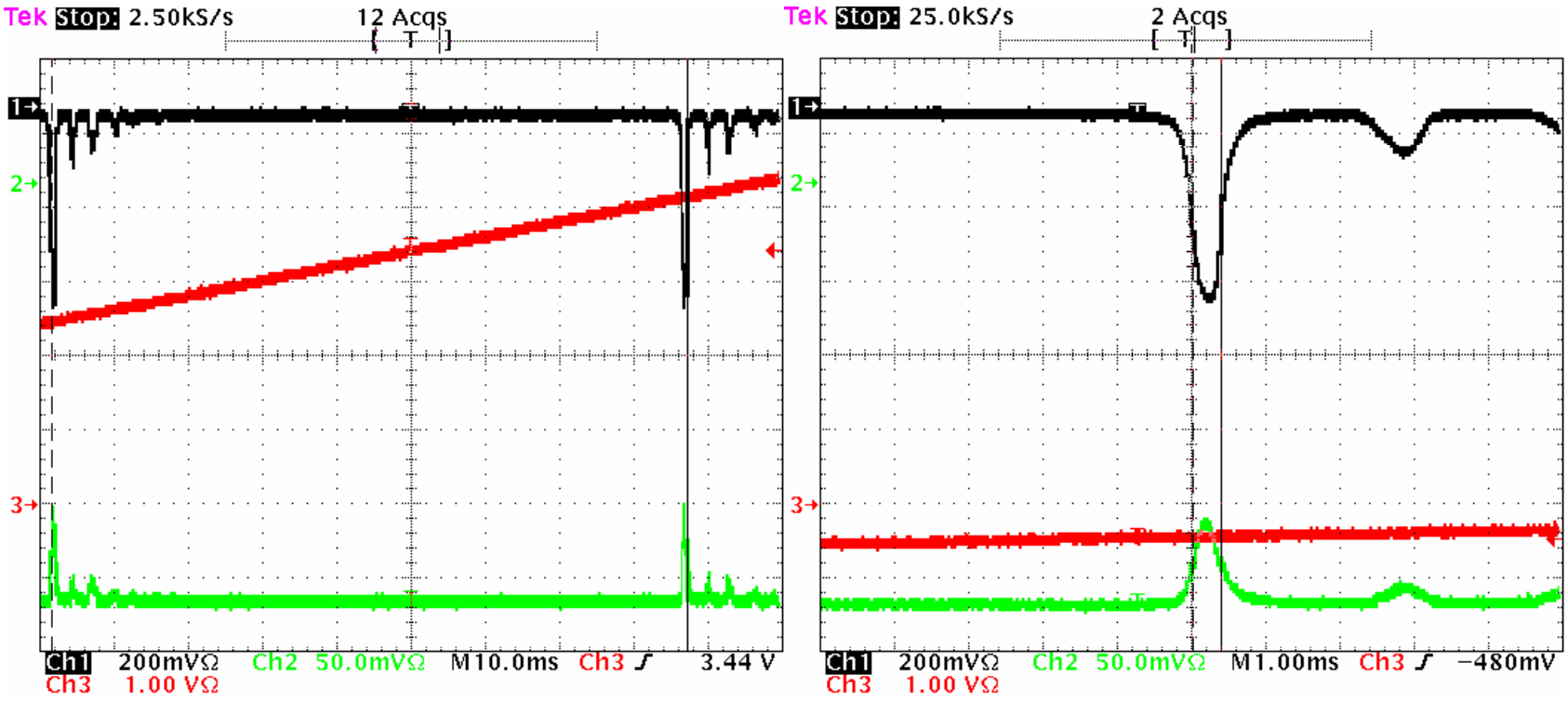
Integral (10mS)



Integral (100mS)



first try with pulse laser



- Have not reached to the best matching condition yet.
  - → achieved finesse ∼ 200
  - → beam waist size ∼ 67μm
- Need more practice to erase higher mode peaks, and to get more high finesse value.
-