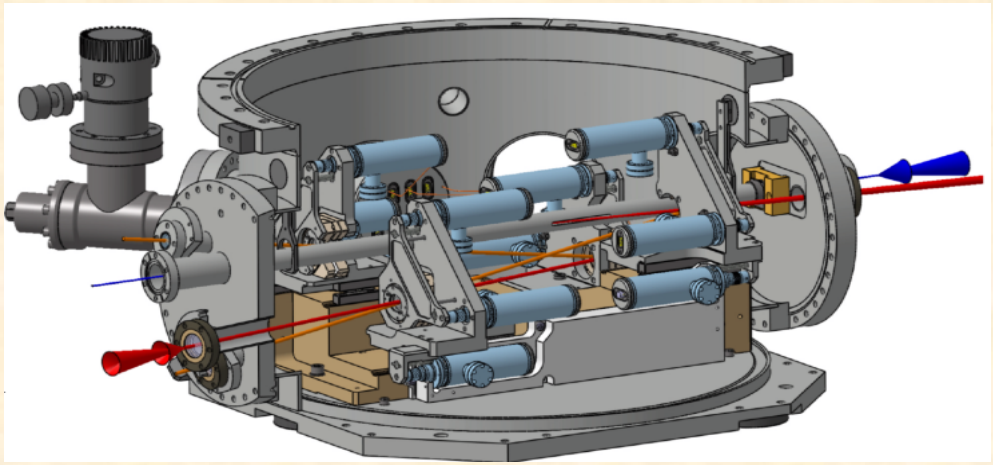
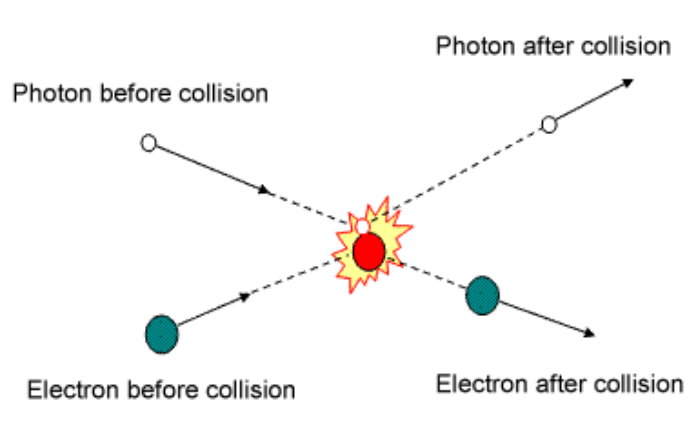


Recent results on Fabry-Perot cavities R&D in Japan and in France

Nicolas Delerue
LAL (CNRS and Université de Paris-Sud)
On behalf of the collaboration

Gamma ray production by Compton scattering



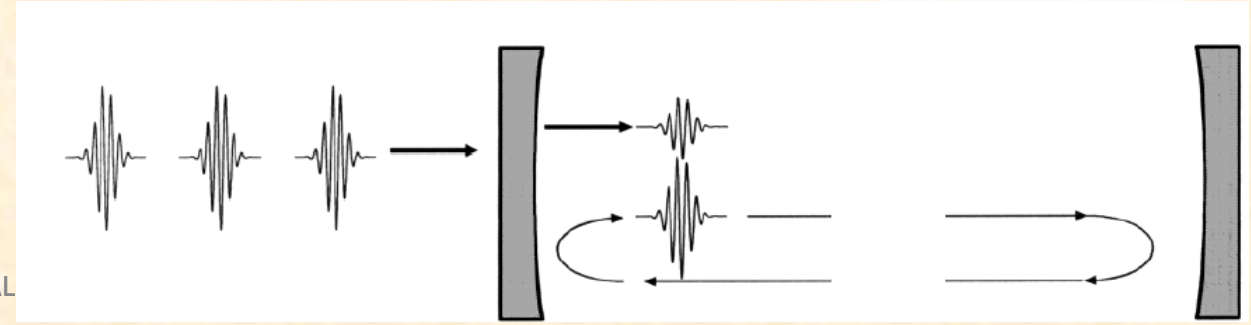
$$Flux_{cw} \propto \frac{\lambda P_L I_e \sigma_T}{\sqrt{\sigma^2_{electron} + \sigma^2_{laser}}}$$

I_e: electron beam intensity
P_L: laser power
λ: laser beam wavelength
$\sigma_{electron}$=electron beam size r.m.s
σ_{laser}=laser beam size r.m.s

- Compton (Thomson) scattering is the exchange of energy that occurs when a photon collides with an electron.
- It can be used to boost low energy (IR) photons to X-rays energy by colliding them with high energy electrons.
- The source of photons is typically a laser (IR => eV).
- The cross-section for this process is very low.

Fabry-Perot cavities: Laser pulses stacking

- Small Compton cross-section
  => important to recycle laser and electrons
  => Use of a Fabry-Perot cavity to accumulate and recycle the laser power.
- Allows significant enhancement factors on the laser power (1000-10000).
- This is very difficult
  => frequency combs
  => demonstrated in an accelerator with a CW laser by LAL at HERA
  => current prototype with pulsed laser tested by LAL at KEK in Japan.

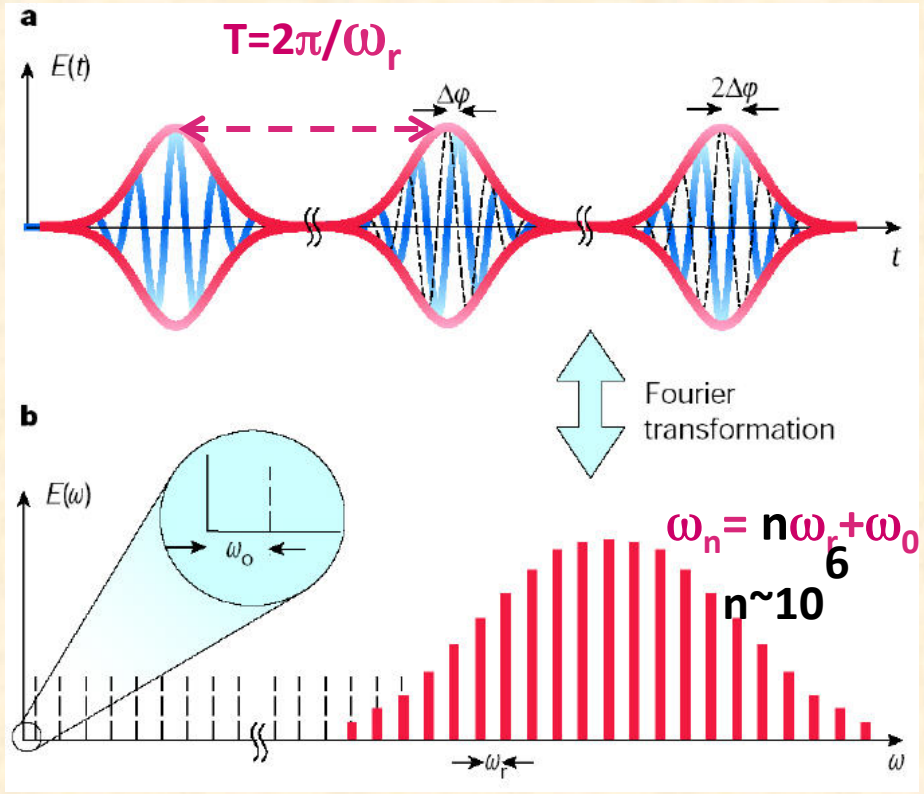


Pulsed_laser/cavity feedback technique

Specificity ➔ properties of passive mode locked laser beams

Frequency comb ➔ all the comb must be locked to the cavity

➔ Feedback with
2 degrees of freedom :
control of the
Dilatation & translation (PZT)

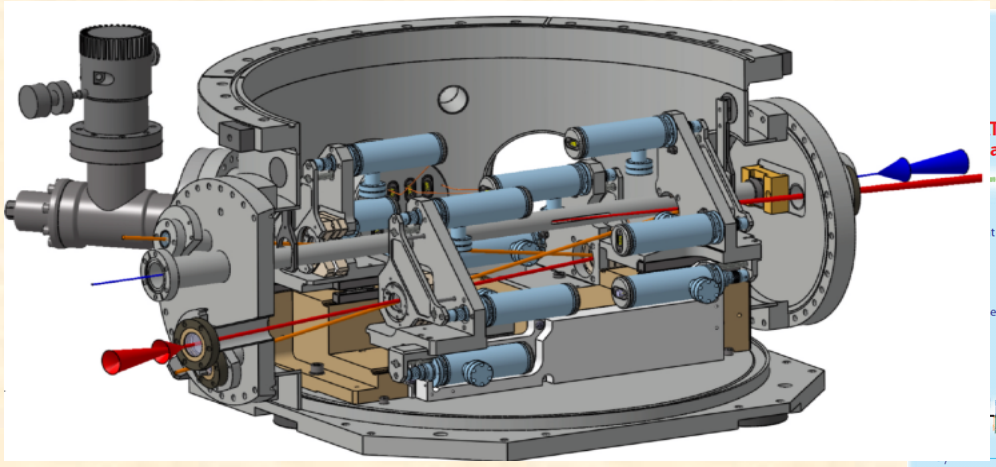


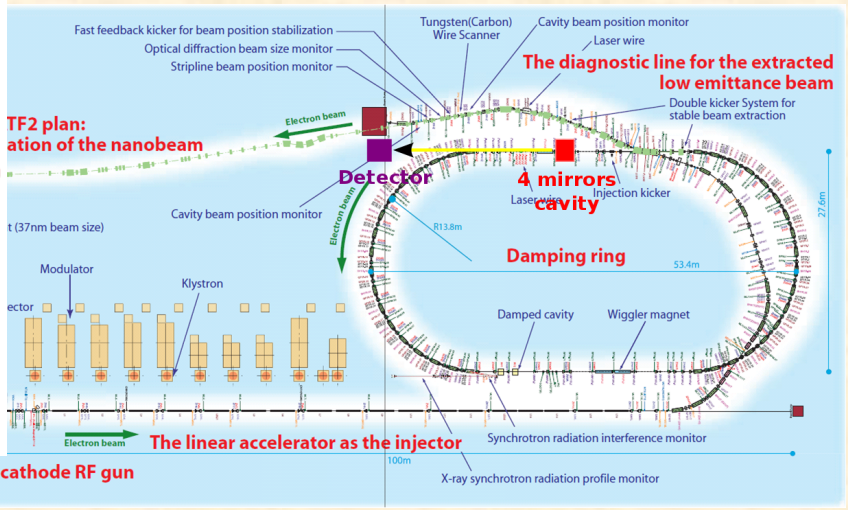
T. Udem et al. Nature 416 (2002) 233

State of the art (Garching MPI) : **~70kW,** 2ps pulses @78MHz, stored in a cavity
(O.L.35(2010)2052) **~20kW,** 200fs pulses @78MHz

France-Japan collaboration on Fabry-Perot cavities

- Cavities installed at KEK on the ATF.
- Use different cavities to explore slightly different designs.
- Gamma detector is shared.
- Both groups have demonstrated high gamma flux.



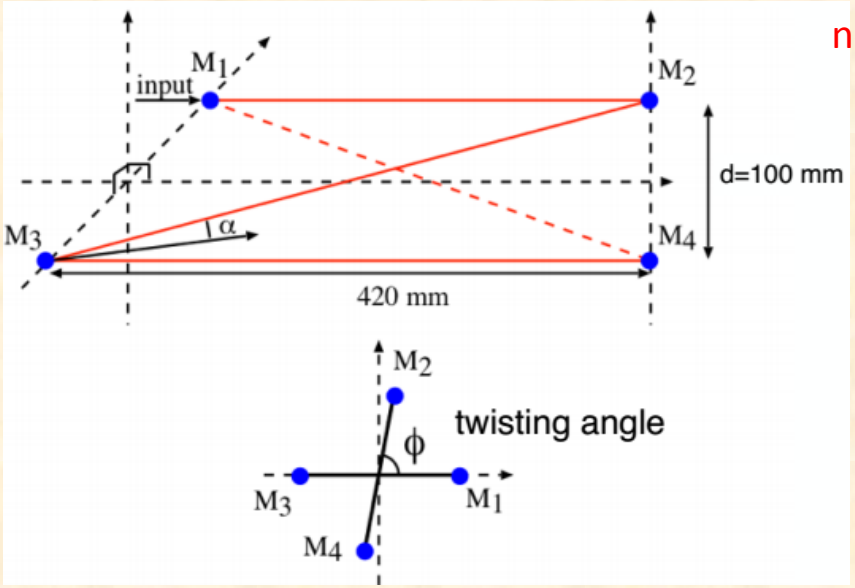


Recent result of 2013 (KEK)

- Our goal is to achieve laser-beam collision with the laser of
- small beam size (15μm x 15μm (RMS))
- high average power (100kW (=10W x 10,000))
- In the beam experiment time of 2012, there turned out to be two problems.
- laser profile does not agree with what we designed (mode puzzle)
- laser profile deforms as stored power increases (heat issue)
- This year, we focused on these beam profile problems

our 3D cavity

(trying to make a round spot by introducing a small twisting angle)



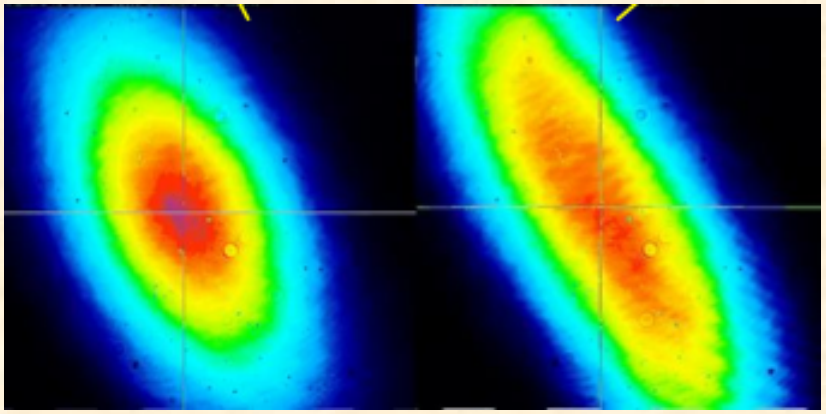
measured profile

low power

not round !

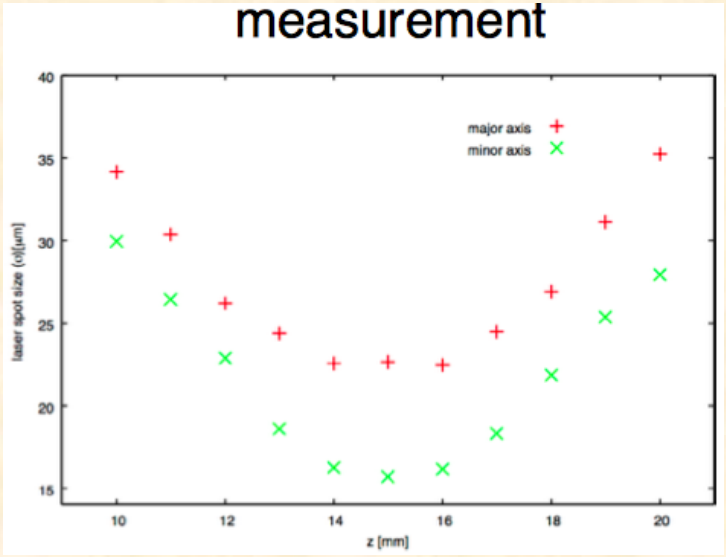
high power

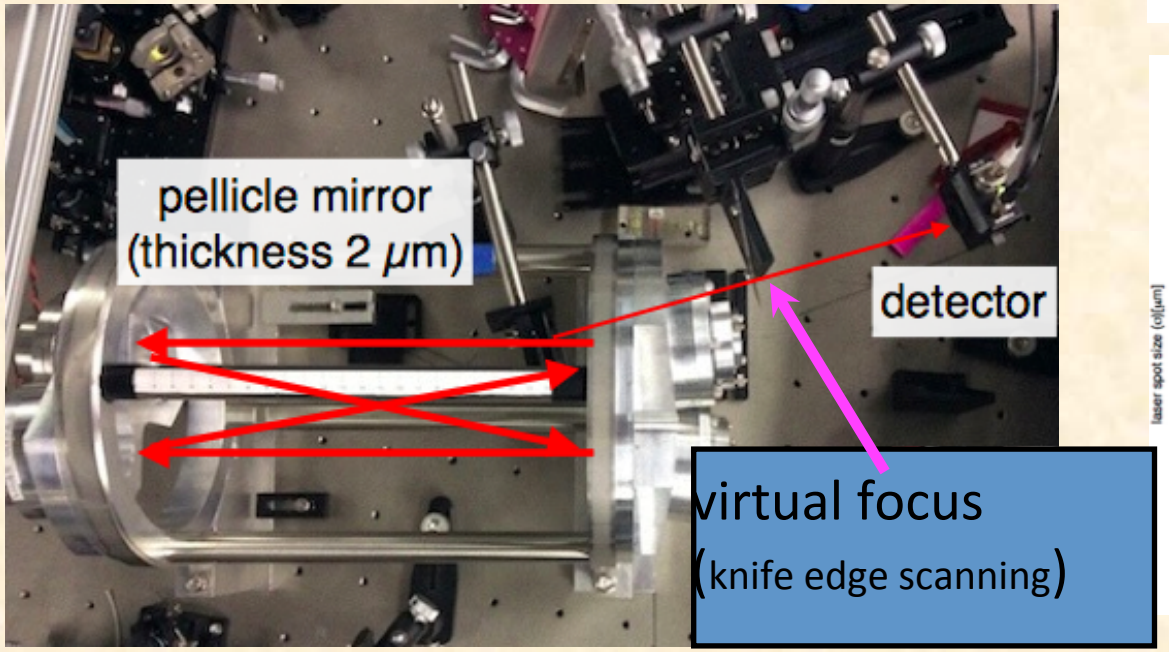
heat deformation !

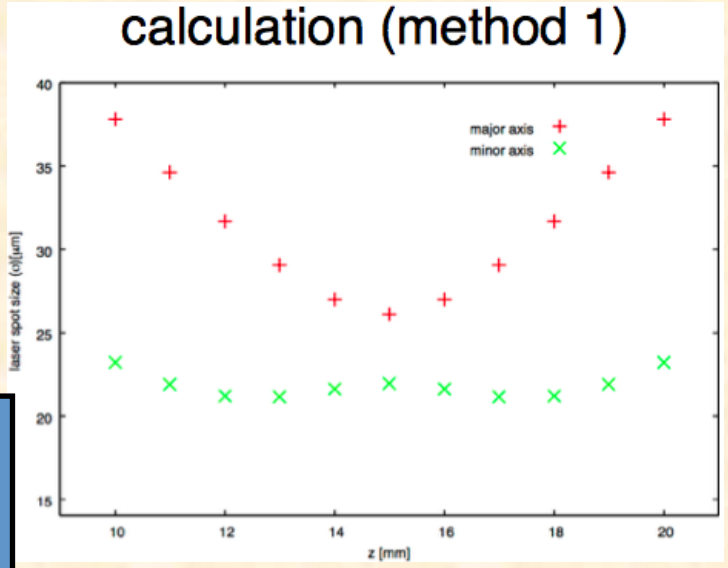


Recent result of 2013 (KEK)

- Go back to the test bench
- Detail measurement with a prototype cavity
- By inserting a thin mirror in the cavity, we could reproduce a virtual focus at outside of the cavity.
- Direct profile measurement by knife edge scanning proved that our model was not correct. (need to make a new model…)





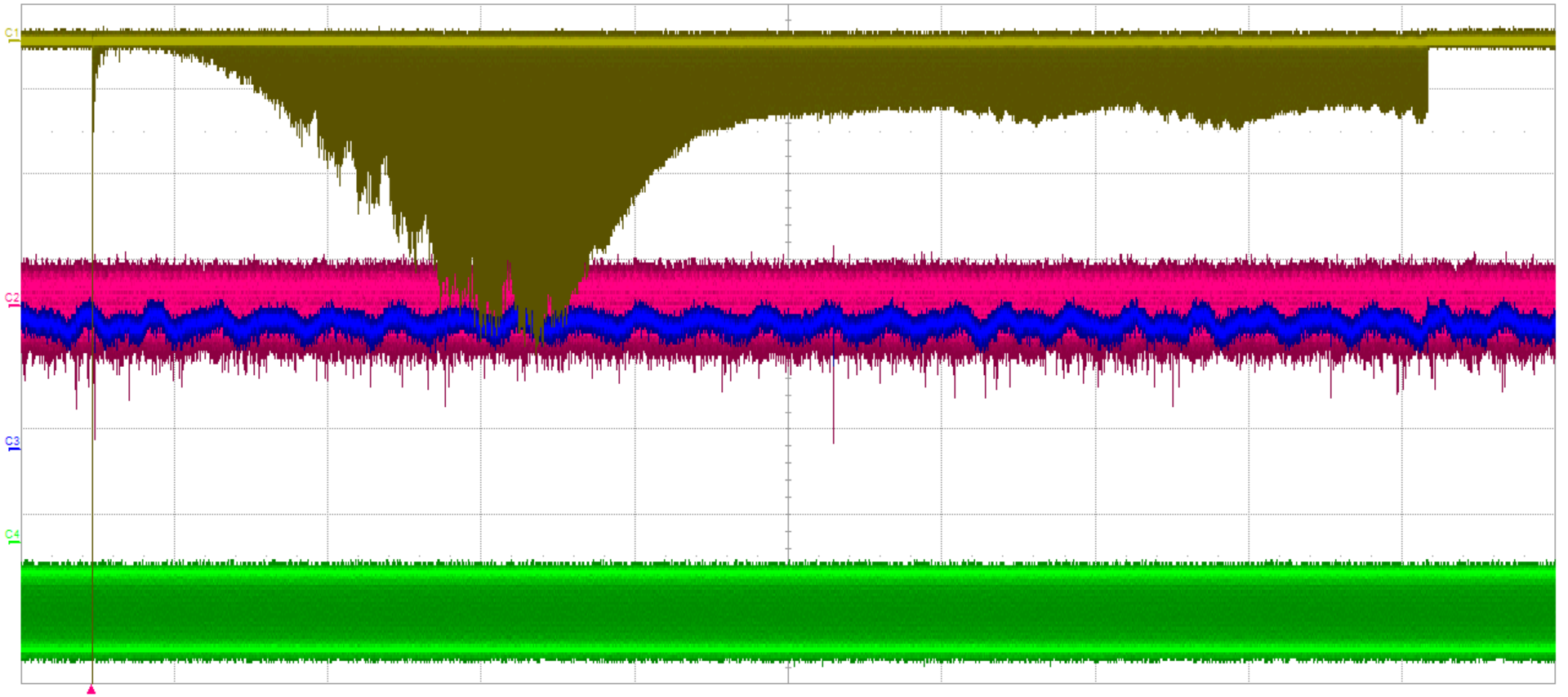


LAL results for 2013

- Setup significantly improved wrt 2011
  (new laser, new mirrors, improved feedback, new DAQ…).
- Mirrors finesse: 40k
- Best stored power (locked):
  81kW (test bench) / 40 kW (ATF)
  => limited by thermal effects
- Data taking run in December 2013 at the ATF.

Collisions achieved very easily!

- Very strong & clear signal (after adjusting the movers)

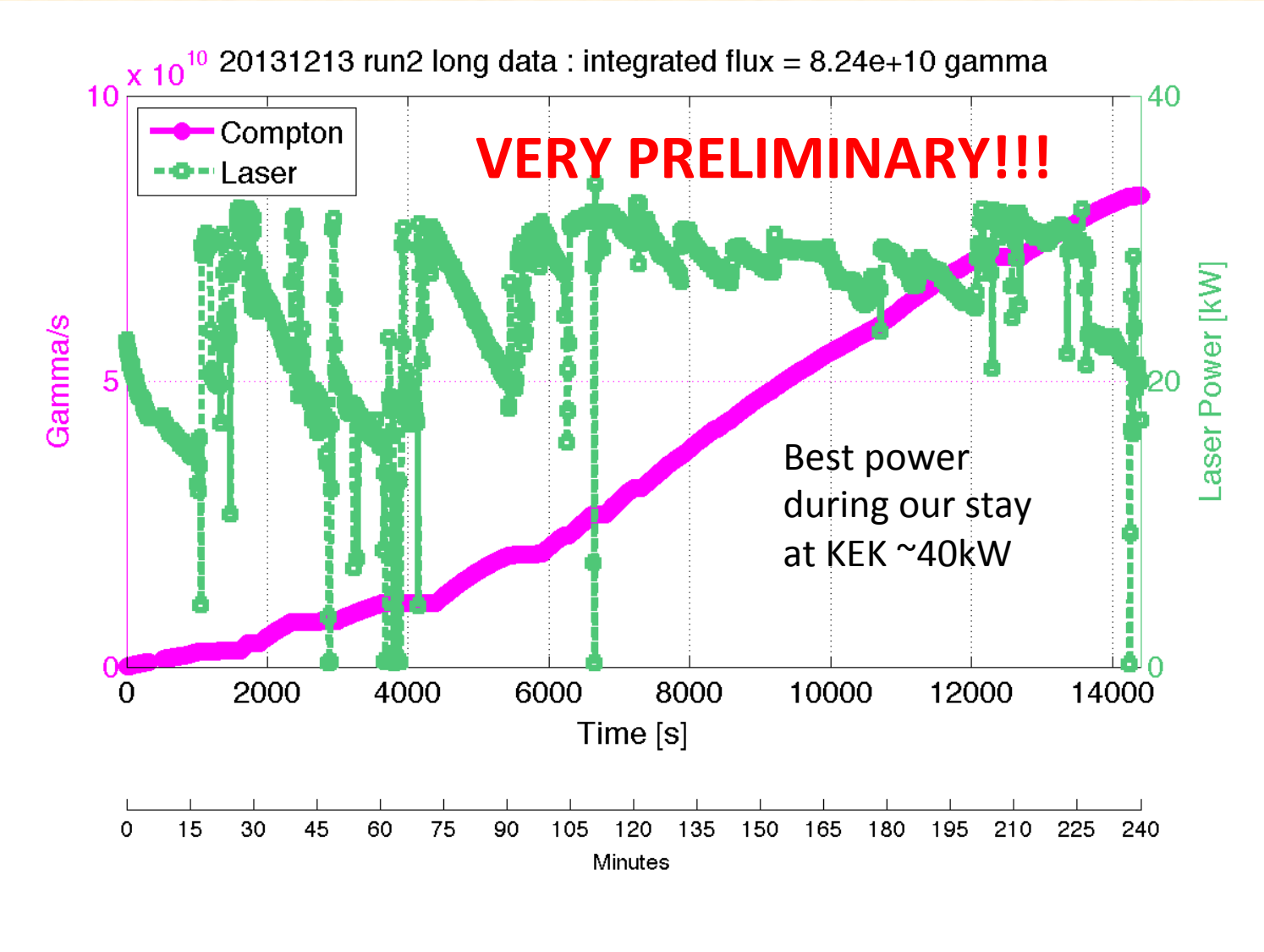


Measure	P1:area(C1)	P2:mean(C3)	P3:Rescale(P2)	P4:- - -	P5:- - -	P6:- - -	P7:- - -	P8:- - -
value	-12.546107150 mVs	73.4 mV	29.35 kW					
mean	-5.94207922978 mVs	67.544 mV	27.0175 kW					
min	-15.771320502 mVs	57.3 mV	22.90 kW					
max	603.163061 µVs	75.8 mV	30.32 kW					
sdev	5.66748991845 mVs	5.255 mV	2.1021 kW					
num	394	400	400					
status	✔	✔	✔					

C1 DC50 500 mV/div 1.780 V | C2 DC1M 500 mV/div 220 mV | C3 DC1M 50.0 mV -62.0 mV | C4 DC50 500 mV/div -1.165 V

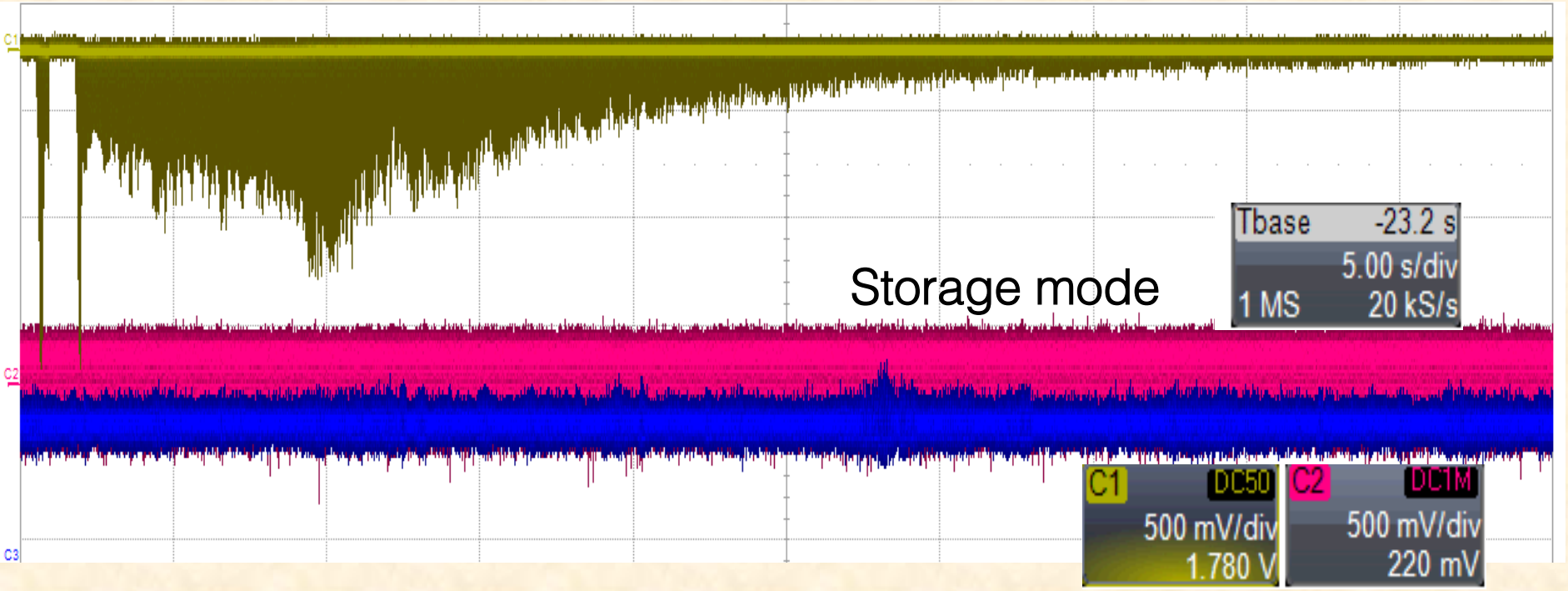
Tbase -227 ms 50.0 ms/div 1 MS 2 MS/s | Trigger Ext DC Stop -200 mV Edge Negative

Long run with high power

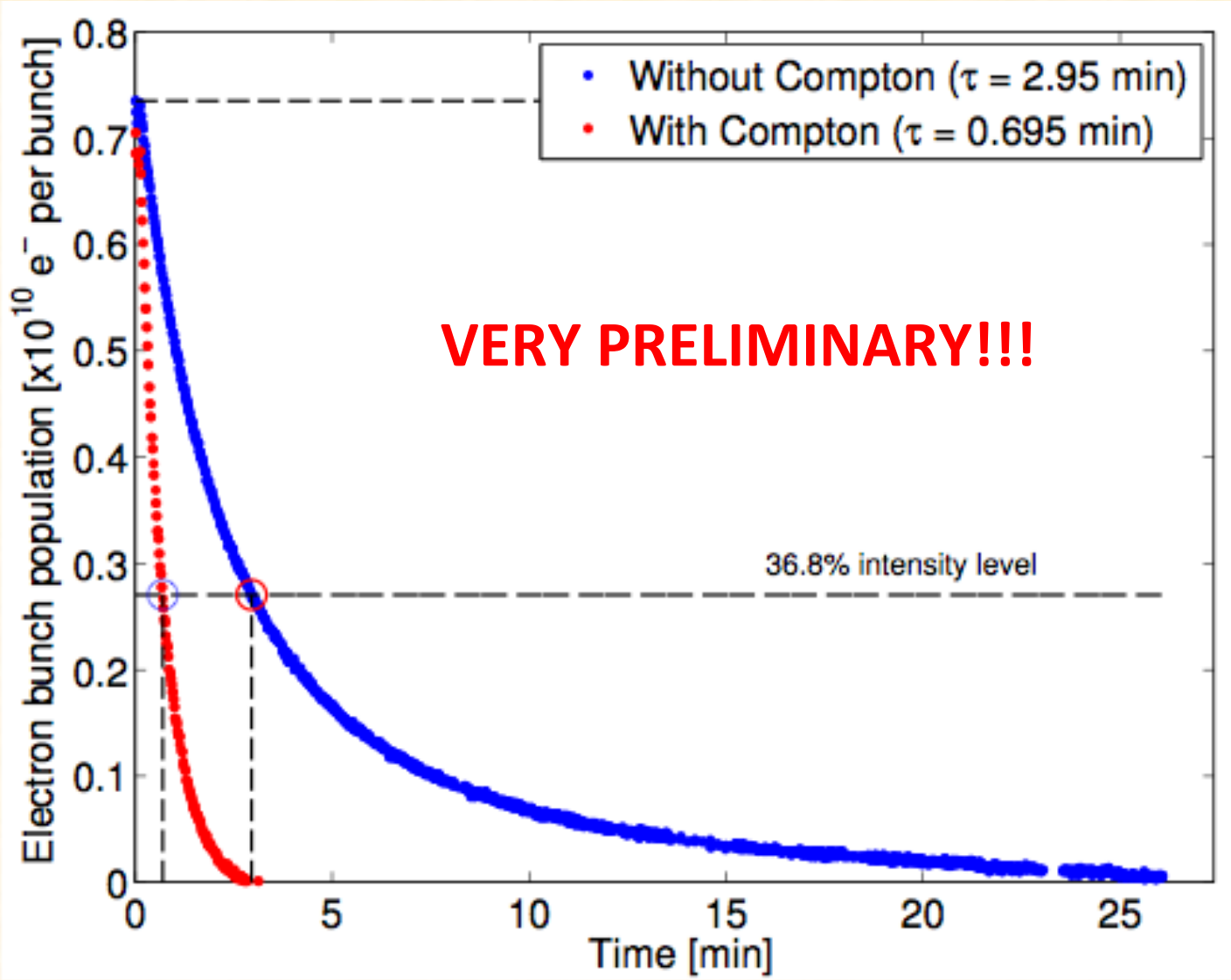


Long beam storage

- We did use long storage period to study flux stability and impact on the beam lifetime.
- In storage mode we observed an expected « peak » in Compton flux after ~7s at full laser power.

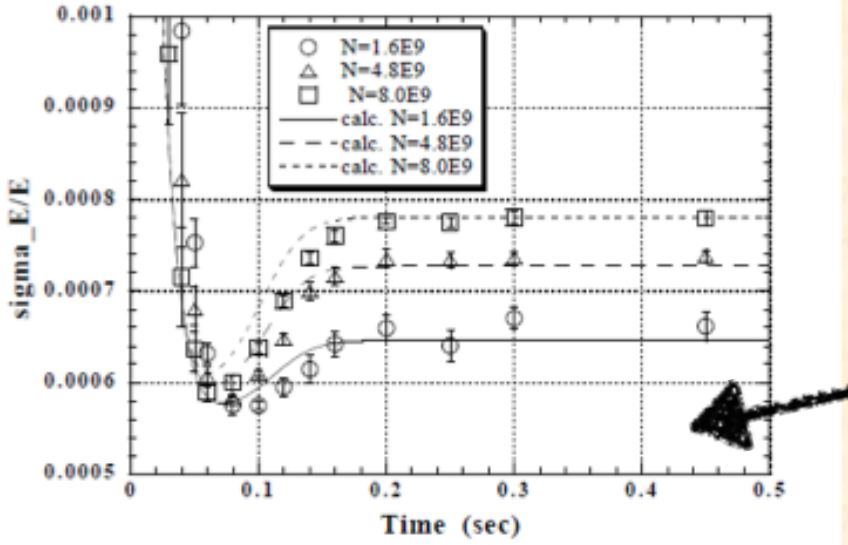


Beam lifetime decrease



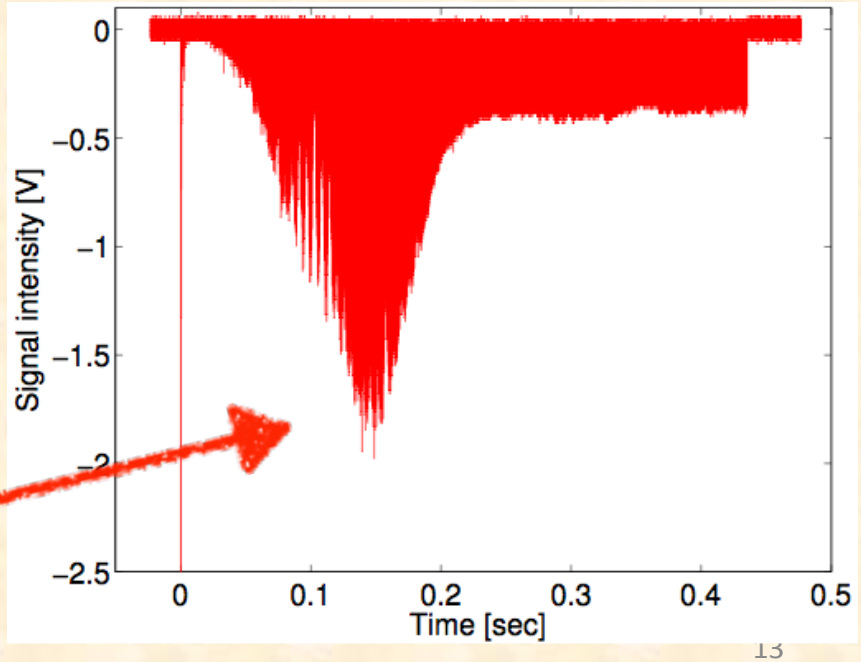
Effect of intrabeam scattering

K. Kubo et al., Phys. Rev. Lett. 88, 194801 (2002).



Measured energy spread as function of time after injection, for three different currents.

Measured Compton signal intensity ~number of scattered gamma rays ~ (electron bunch size at the IP)$^{-1}$ as function of time after injection.

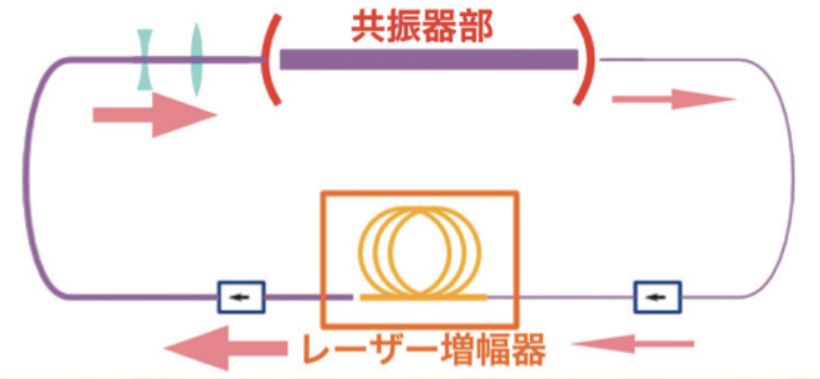


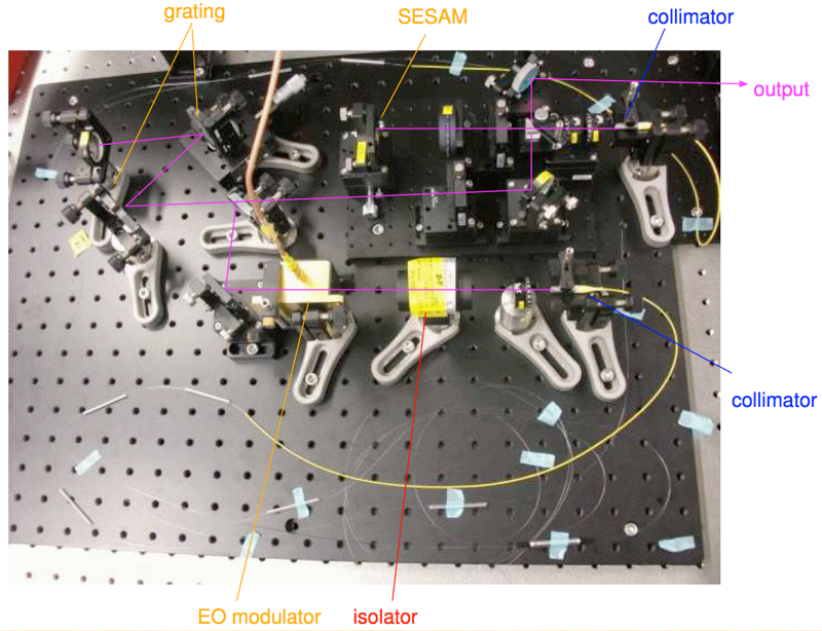
Limitations

- Several effects limited the power stored in the cavity:
  - Thermal effects at the beam compressor (CVBG) & wavefront changes => bad coupling
  - Mirrors thermal deformation => mode changes
  - 80Hz oscillations in the signal (due to a nearby pump?)
- The laser amplifier was able to deliver much more power than what was used because we could not inject more power in the cavity.

Plan of 2014 (KEK)

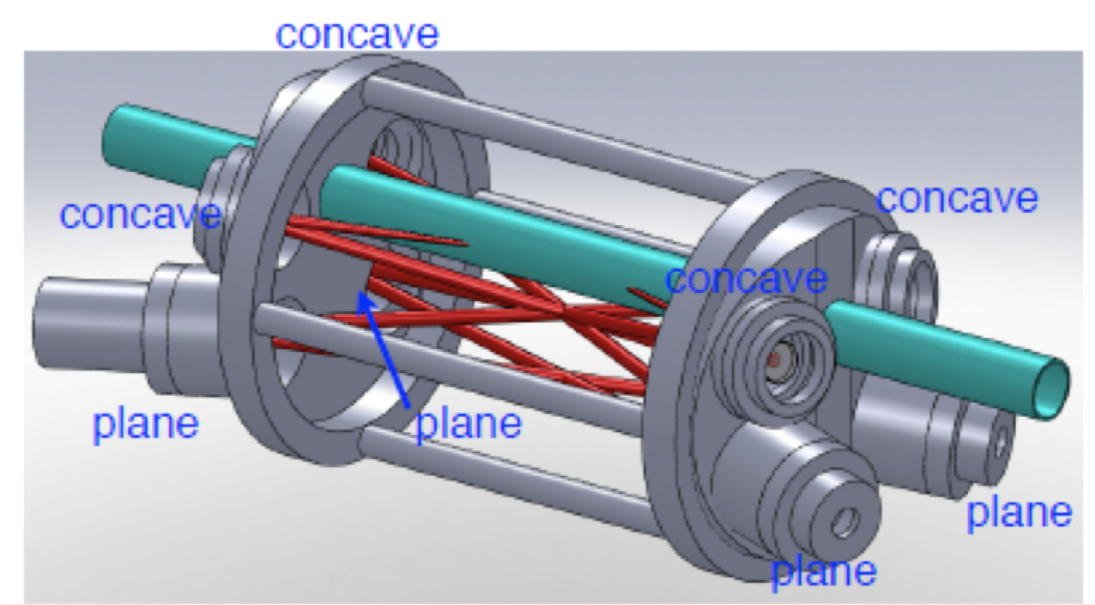
- Higher enhancement factor (target: mirror loss 10ppm/mirror)
- A clean booth has been prepared for handling mirrors in a clean environment.
- Testing mirror cleaning (first contact).
- Hope these will reduce mirror heating, improve deformation.
- Digital feedback system development
- Started with a new FPGA board.
- For even higher enhancement system, a new scheme “self-start” system.
- Basic tests are planned for pulsed oscillation at low power.





Plan of 2014 (KEK)

- Laser-Compton user line construction is on going at cERL
- Schedule: cavity system installation Nov.2014, beam test Feb.2014.
- New optical cavity has been designed in the last year
- planer 4-mirror cavities
- 2 cavities stacked in a flame with a common collision point



R&D 2014+ at LAL

- Understand thermal effects in the cavity!
  => Test new mirrors (ULE substrate)
  cost: > 20k€
- Investigate on test bench (at LAL) how these mirrors perform.
  => need to install at LAL a cavity like that at KEK.
- A graduate student (Pierre Favier) will start on this topic in October.

Outlook and Future plans

- Both groups have had good results in the past year.
- Significant R&D, especially on thermal effect, is needed for further progress.
- FP cavities are part of key project both at LAL and KEK. This R&D is necessary to achieve our goal in these projects.
- Regular meetings of the two groups are necessary to discuss each other's findings.