Development of an optical cavity system for ILC and advanced photon source (A_RD_01)

FJPPL workshop
2013.6.4 Seoul
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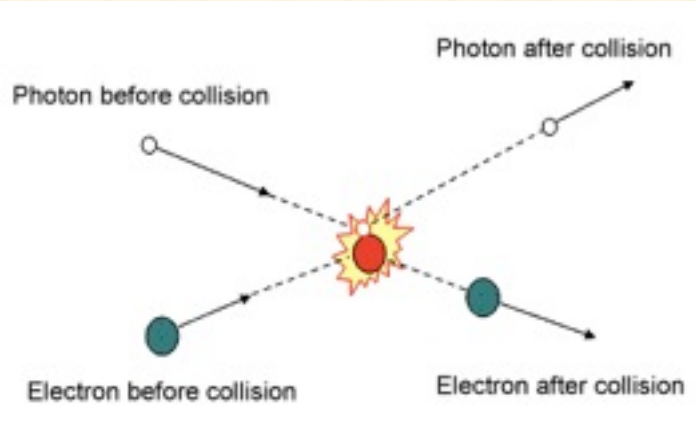
(KEK)

- Optical cavity system for Compton source
- Cavity development by two individual groups of Japan and France communicating each other.
- Both groups install the system at ATF
- Further upgrading with new system and new ideas based on our present establishment.

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

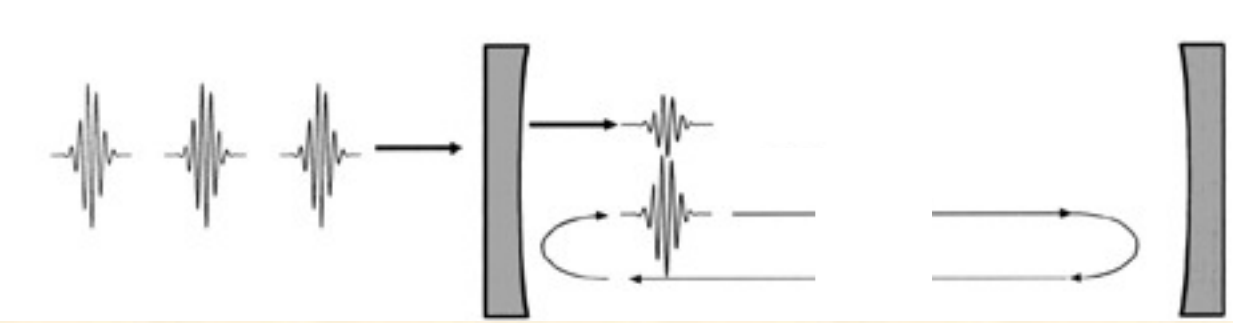
$\sigma_{electron}$=electron beam size r.m.s

σ_{laser}=laser beam size r.m.s

- Compton 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.

Laser pulses stacking

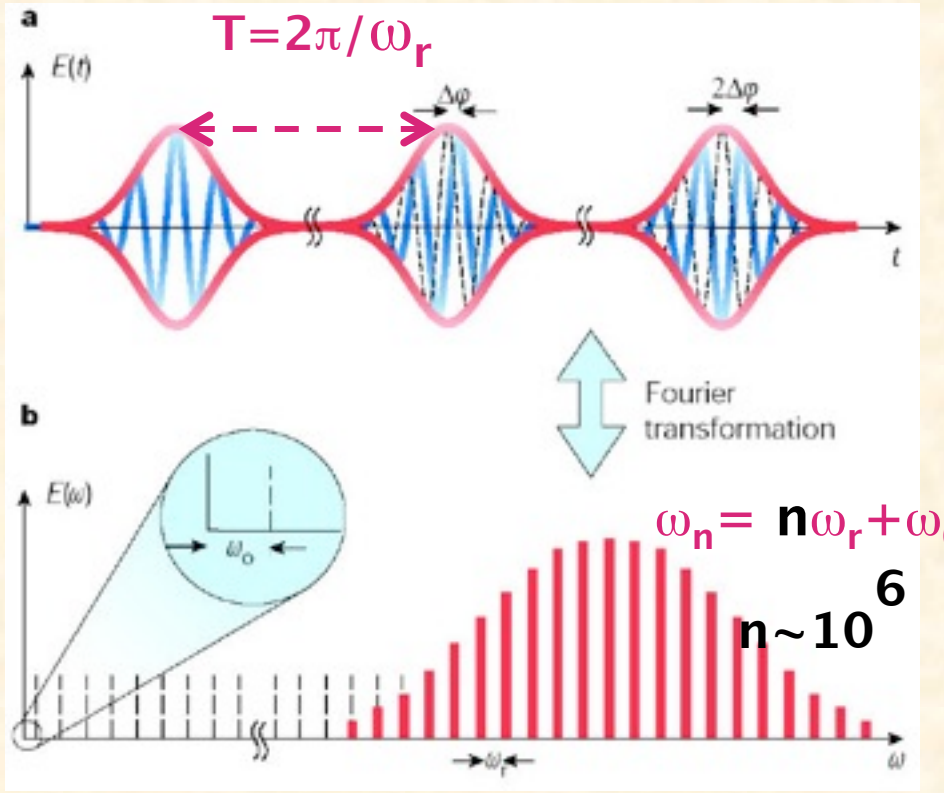
- Small Compton cross-section
  => important to recycle laser and electrons
  => Use of a Fabry-Pérot cavity to accumulate and recycle the laser power.
- Allows significant enhancement factors on the laser power (1000-10000).
- This is very difficult
  => frequency combs
  => demonstrated in an accelerator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

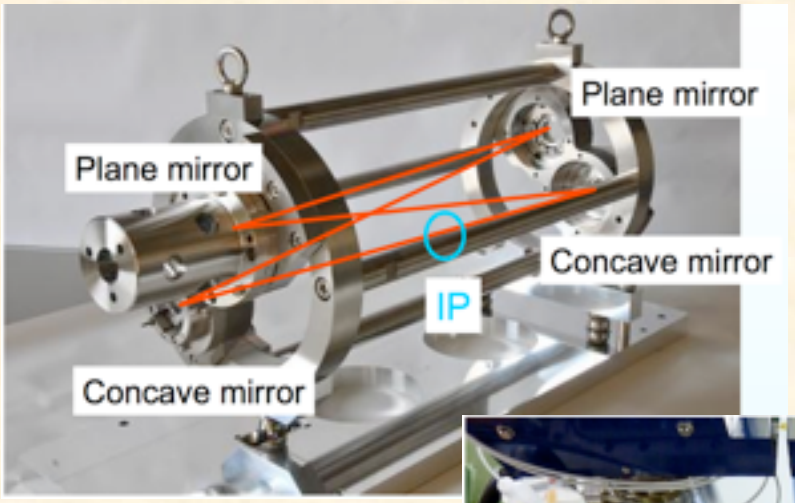
State of the art (Garching MPI) : ~**70kW,** 2ps pulses @78MHz, stored in a cavity
(O.L.35(2010)2052) ~**20kW,** 200fs pulses @78MHz

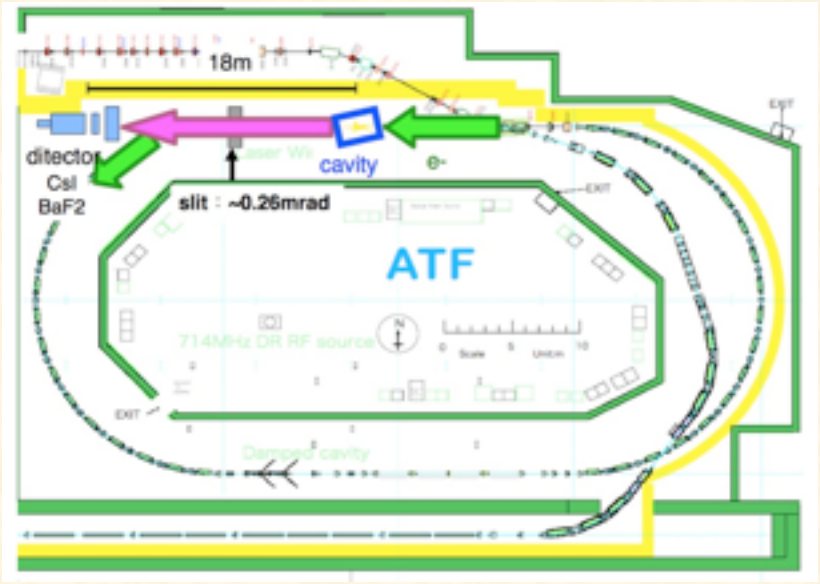
Japanese group

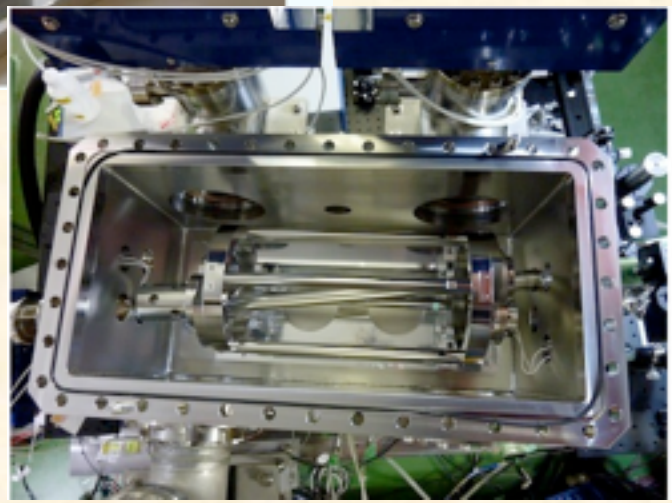
- What we have done
  3 activities (Ring, NC linac, SC linac)
- Planned development

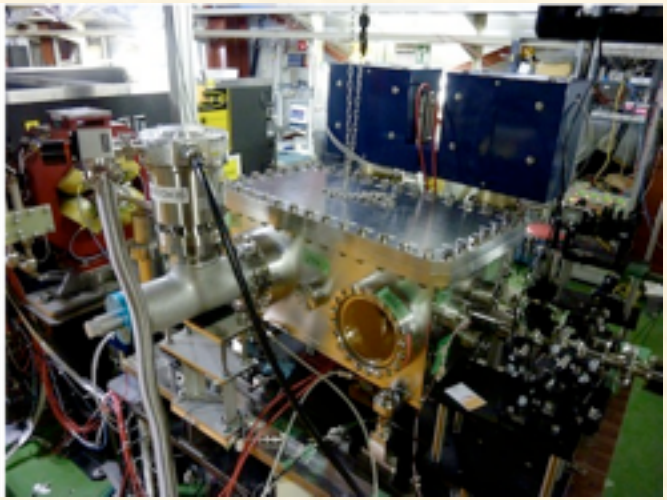
Ring accelerator

- High average flux gamma-ray generation for polarized positron source.
- 3D-4mirror cavity







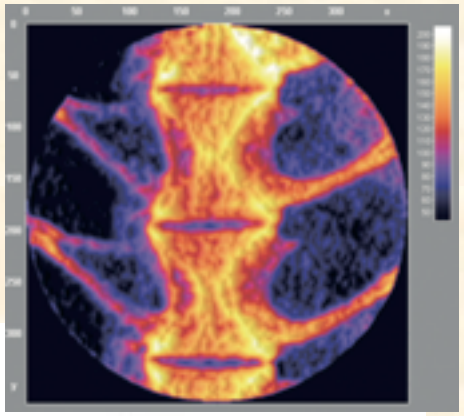


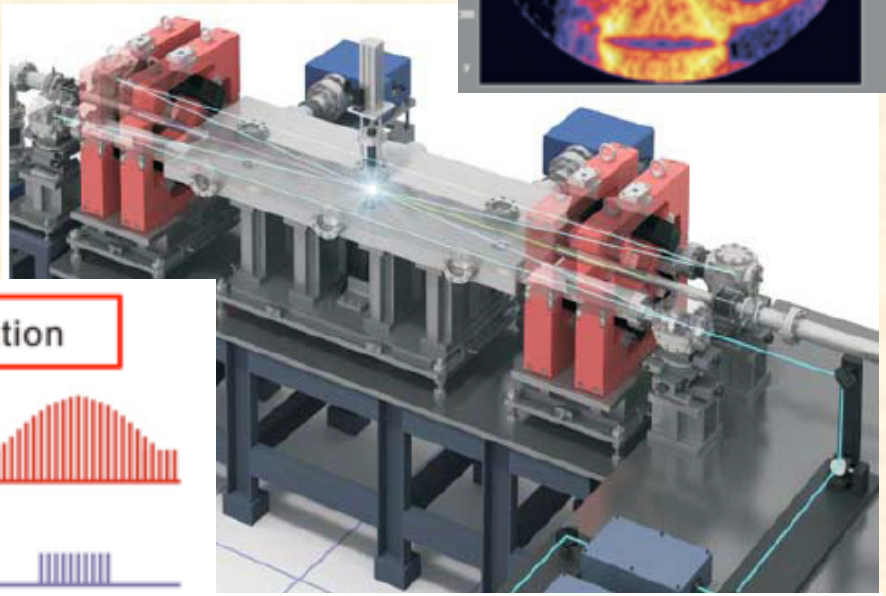
Ring accelerator

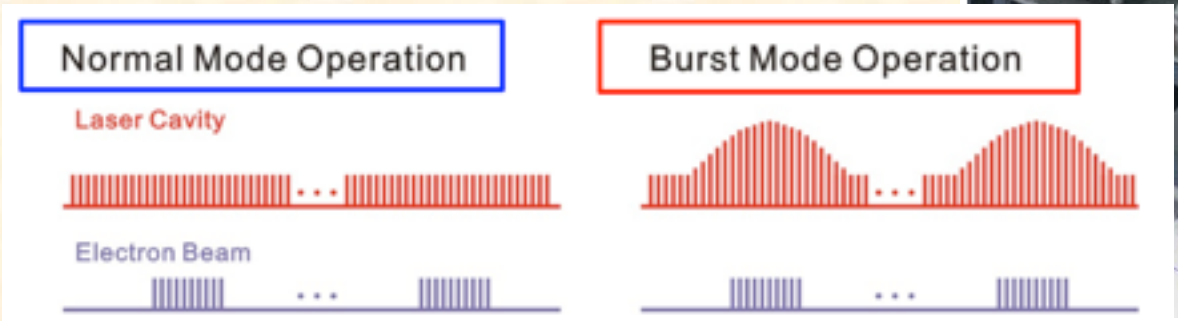
- Achievement
  - 2.6kW power in the cavity (finesse 5000)
  - 13μm laser spot size at collision point
  - gamma-ray yield : 2.6x10^8 /sec
- Next step
  - higher finesse (to 26000)
  - solve thermal effect problem that limits stored power
  - high quality mirror

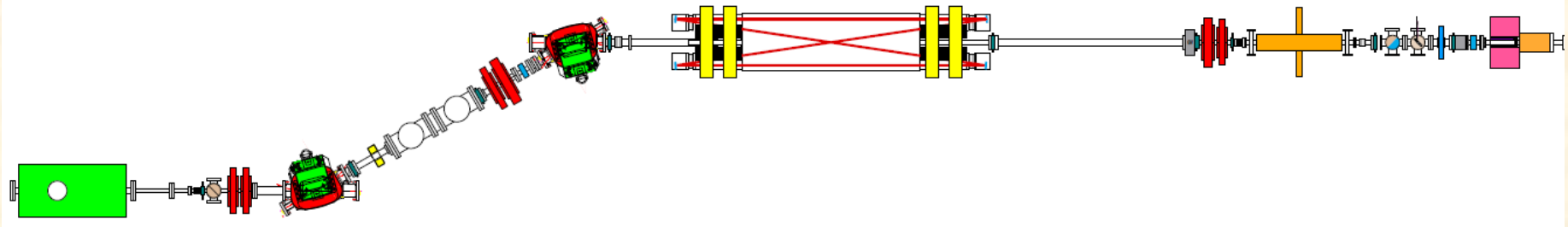
NC linac small accelerator

- Compact X-ray source for imaging
- Pulsed amplification
- Large size 4-mirror cavity, trying to decrease peak power on mirrors.



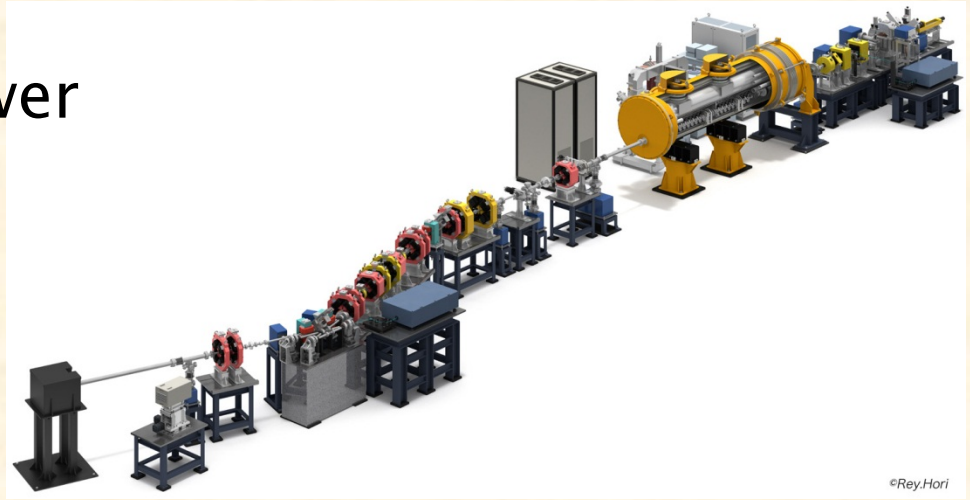


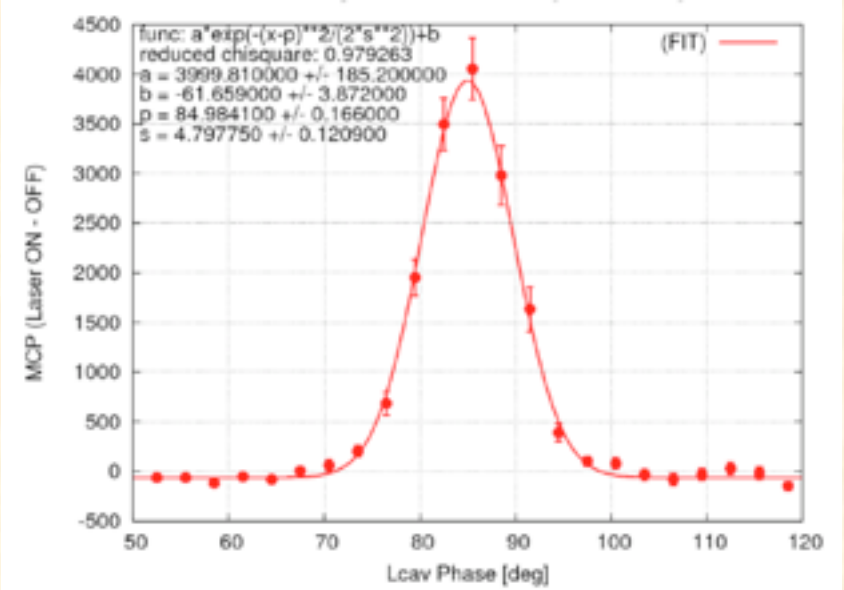


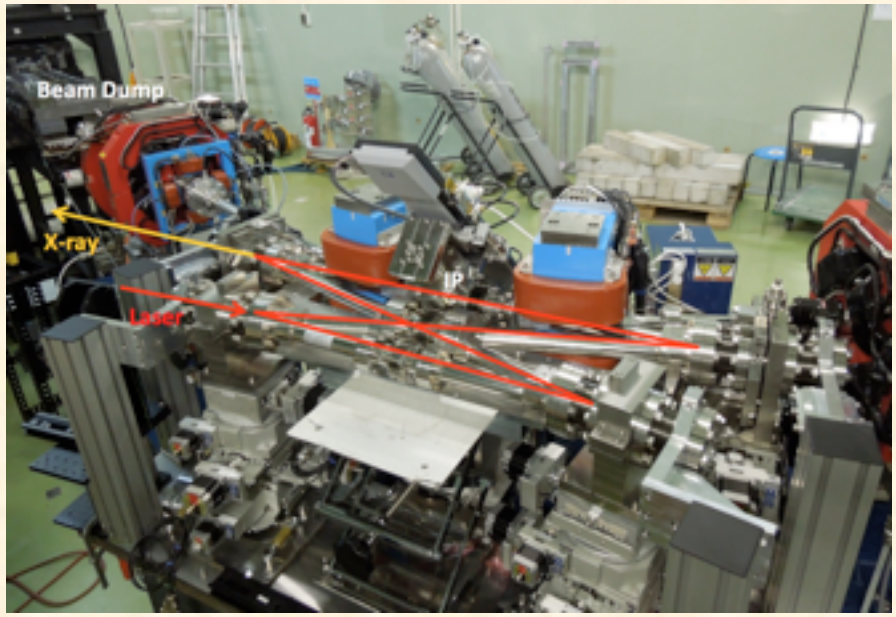


SC linac

- Long bunch train linac
  - aiming high average power
- Flexible optical cavity
- Achievement
  - laser spot size 80μm
  - stored power 2.7kW

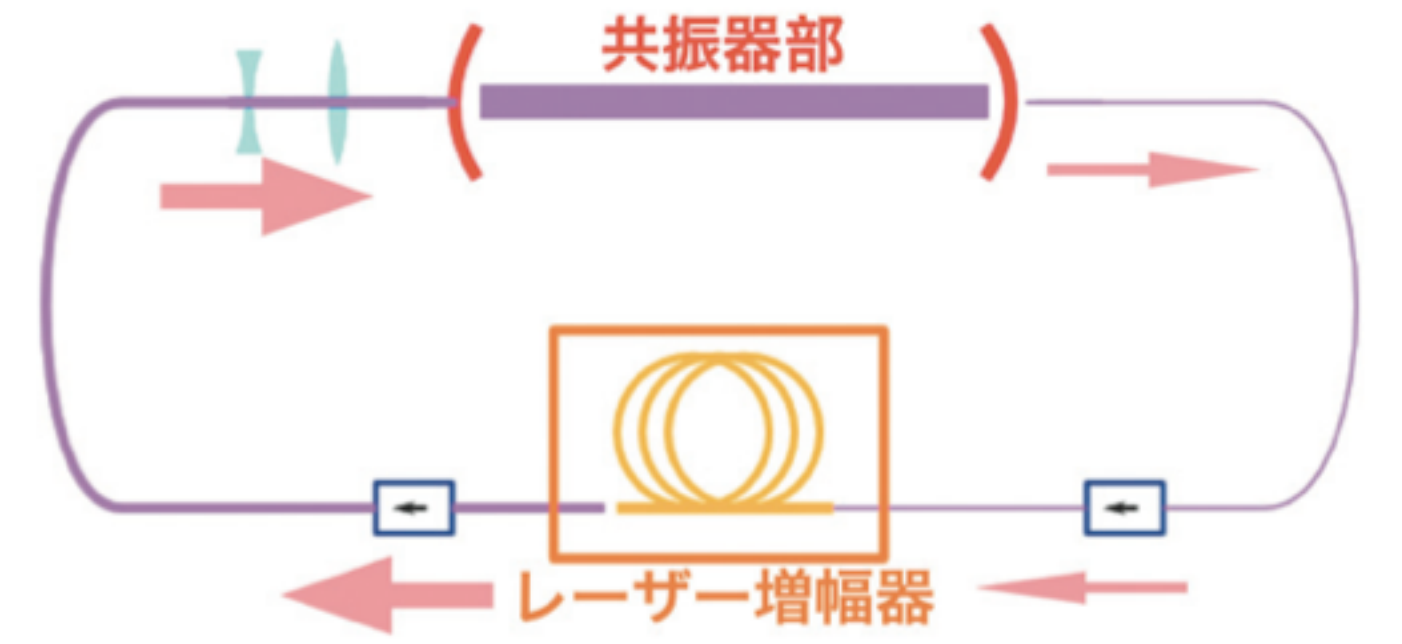






Planned development

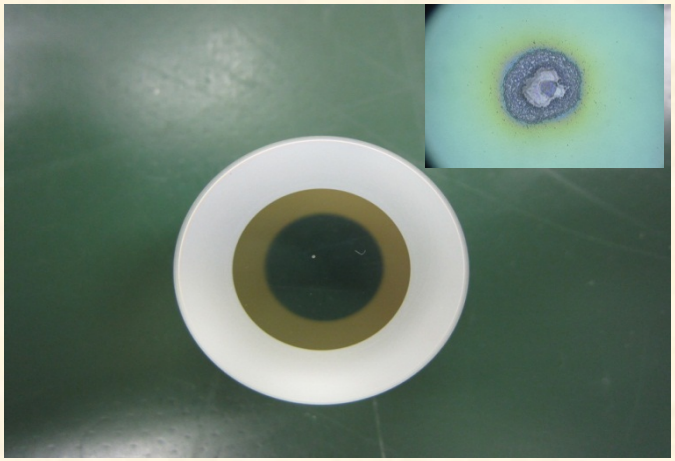
- Self start system
  - automatic resonance realization for higher finesse

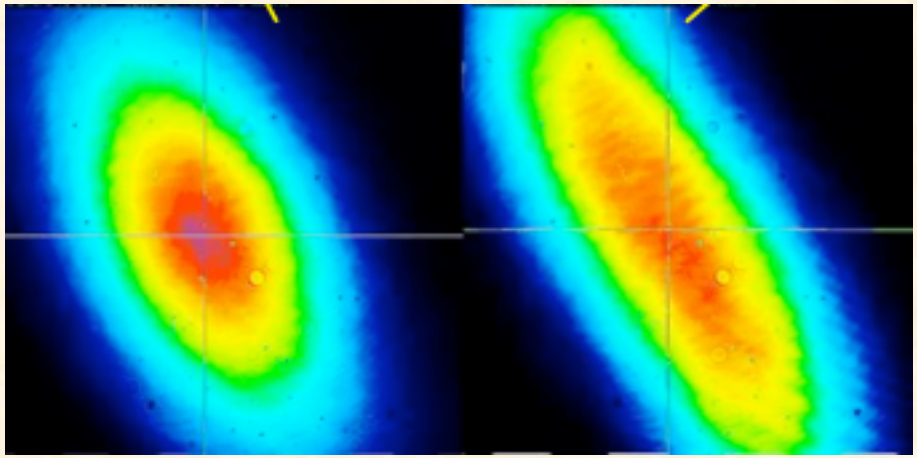


Planned development

- Higher finesse
  - 5000 (present) to 30,000
  - high quality mirror and its treatment
- Experienced problem
  - peak power damage
  - average power deformation

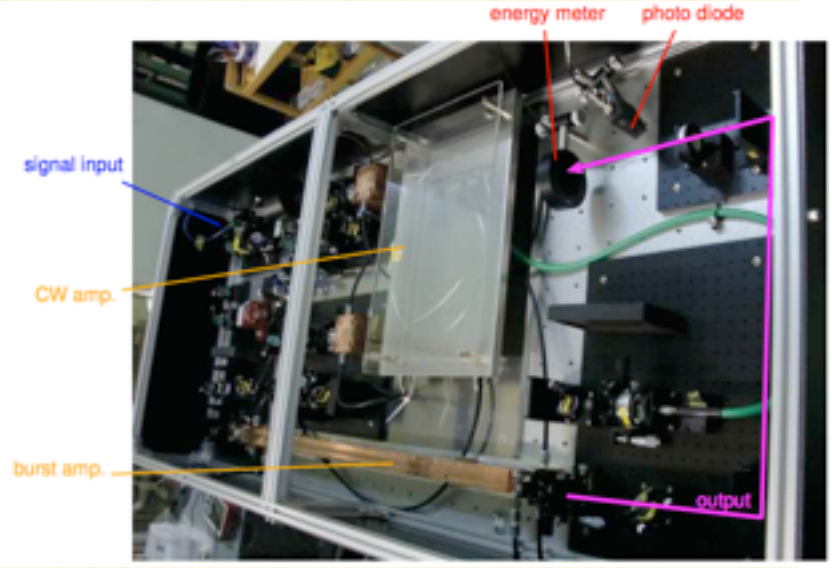
2011

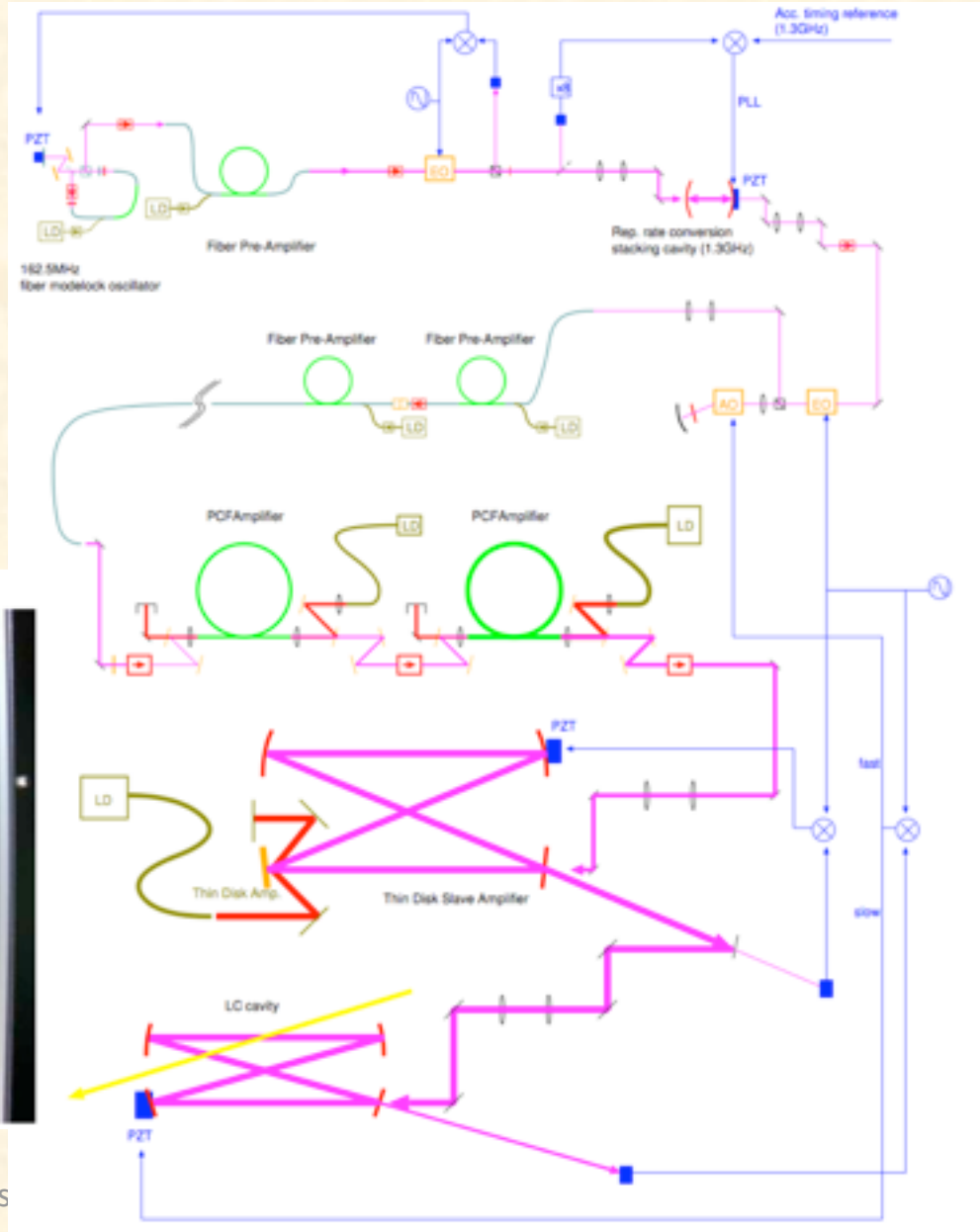




Planned development

- Higher input power
  - Fiber amplifier
  - Disk amplifier





MightyLaser update

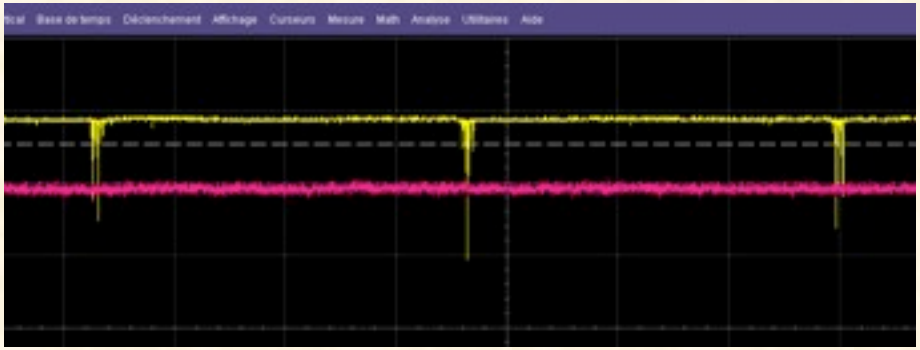
- What is MightyLaser
- Status before the 2011 earthquake
- Earthquake recovery
- Current status
- Plans

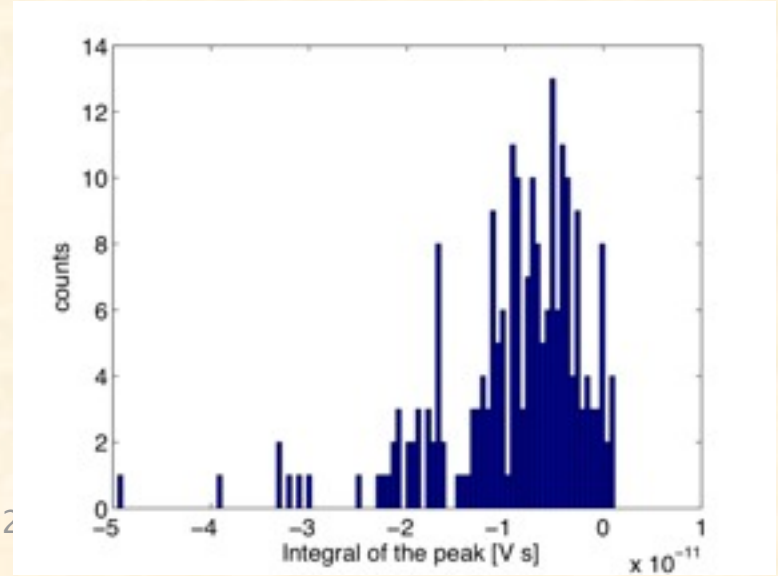
R&D at LAL on Fabry-Perot cavities

- LAL has been working on Fabry-Perot cavities for about 10 years.
  => Polarimetry measurement at HERA
  => High flux positrons source for the ILC
  => Mighty laser / ThomX
- We have several Fabry-Perot cavities installed in our lab for R&D and training (eg: feedback studies, alignment training…)
- We have developed a digital feedback system to control the length of the cavities.

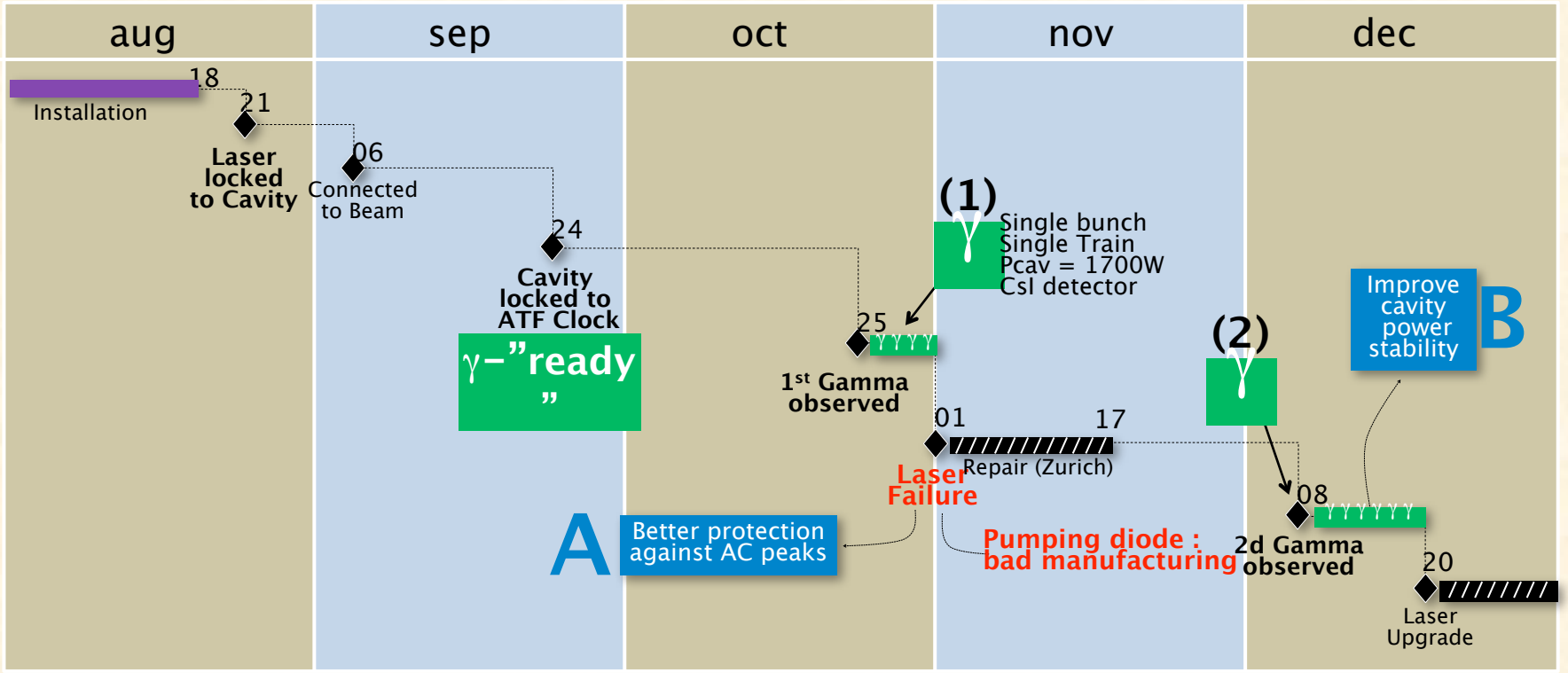
Status before the 2011 earthquake

- In October 2010 we had a very fast commissioning of the cavity.
- Gamma ray production was confirmed.
- 2 papers published on initial results.
- Upgrade planned for 2011.





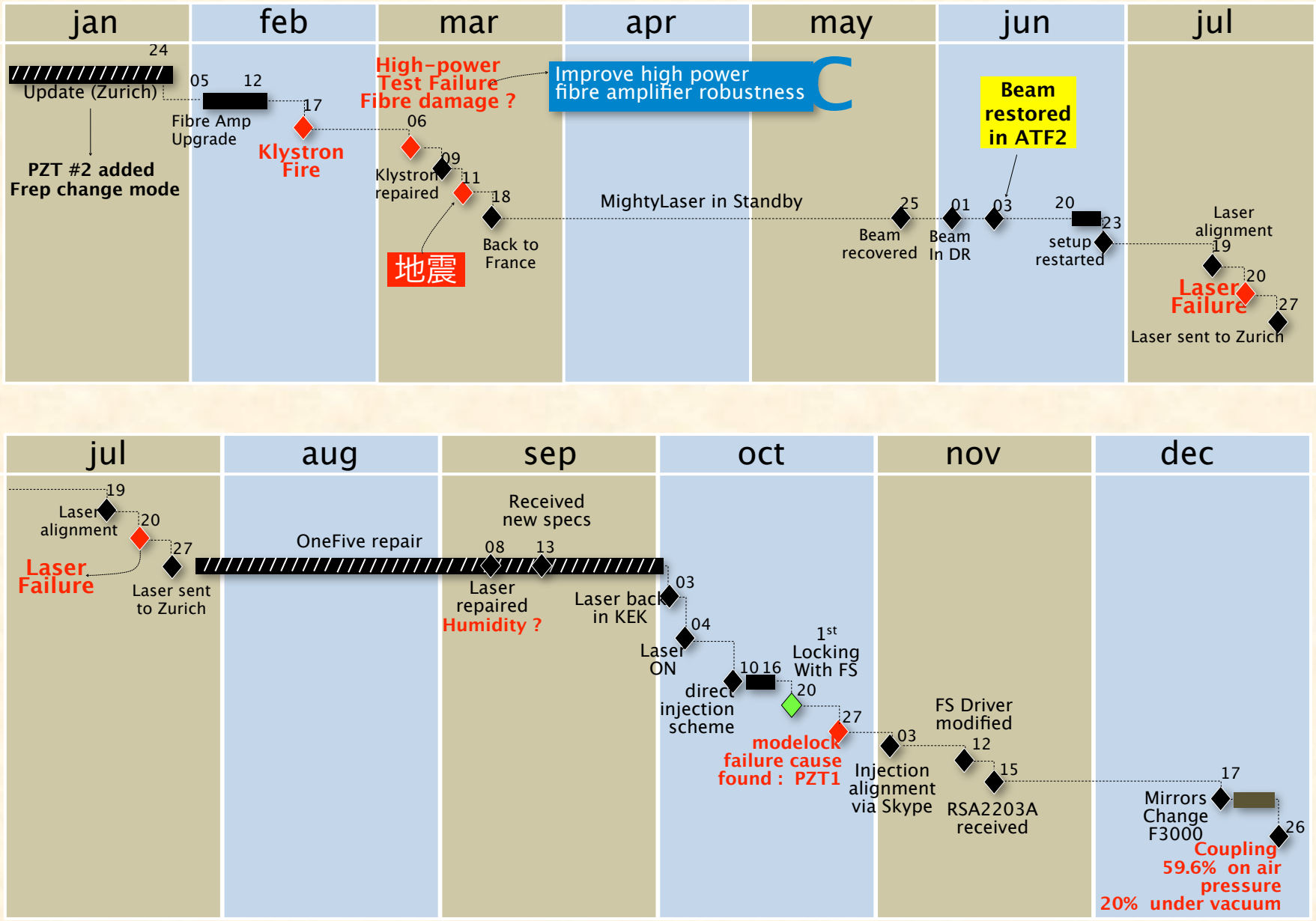
MightyLaser Milestones 2010



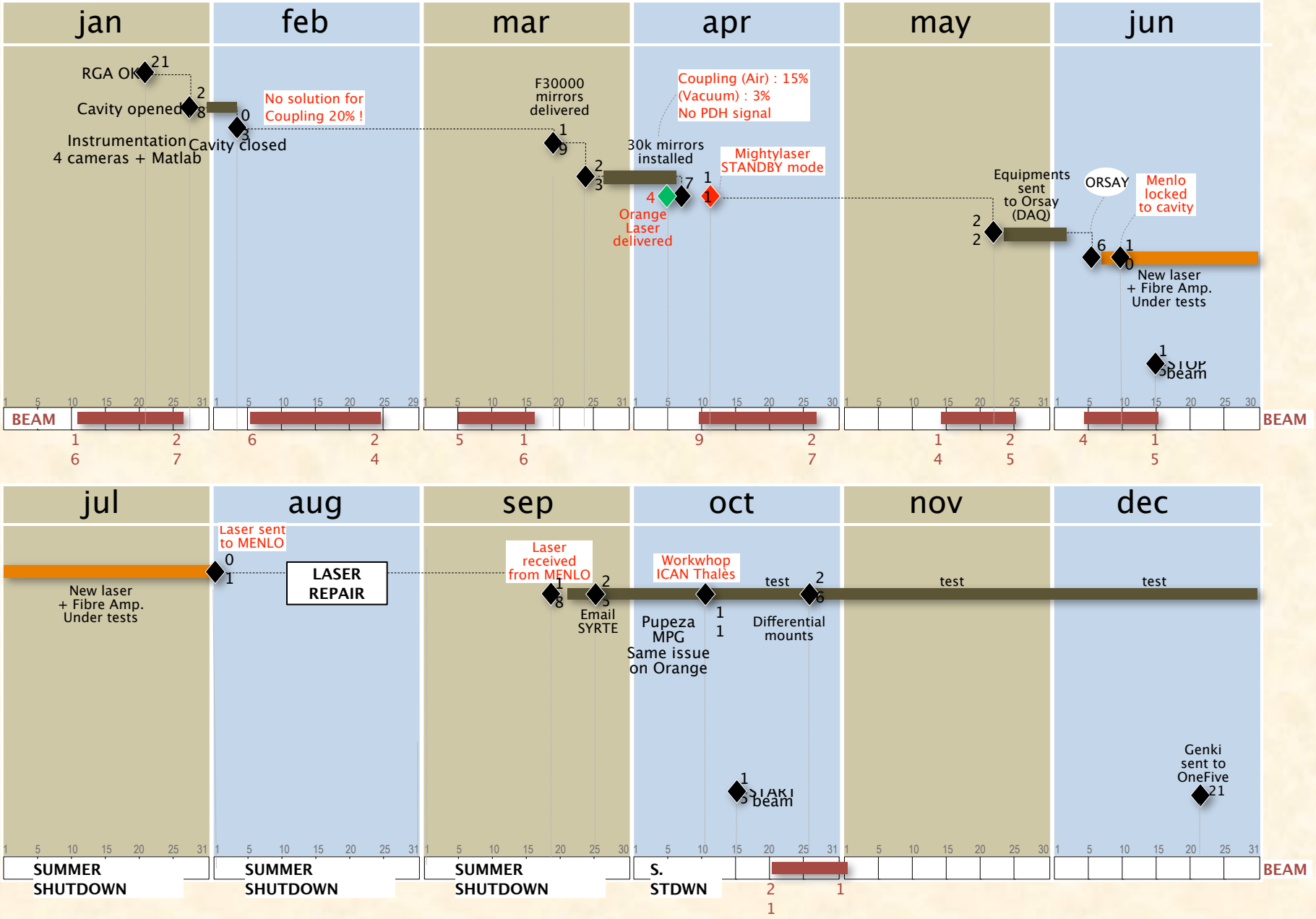
Damages in 2011

- After the 2011 earthquake the power delivered by the laser dropped significantly.
- Some problems were also found on the mirrors: the finesse of the cavity was much lower than before.
  => decision (April 2012) to continue the recovery work at LAL.

MightyLaser Milestones 2011



MightyLaser Milestones 2012

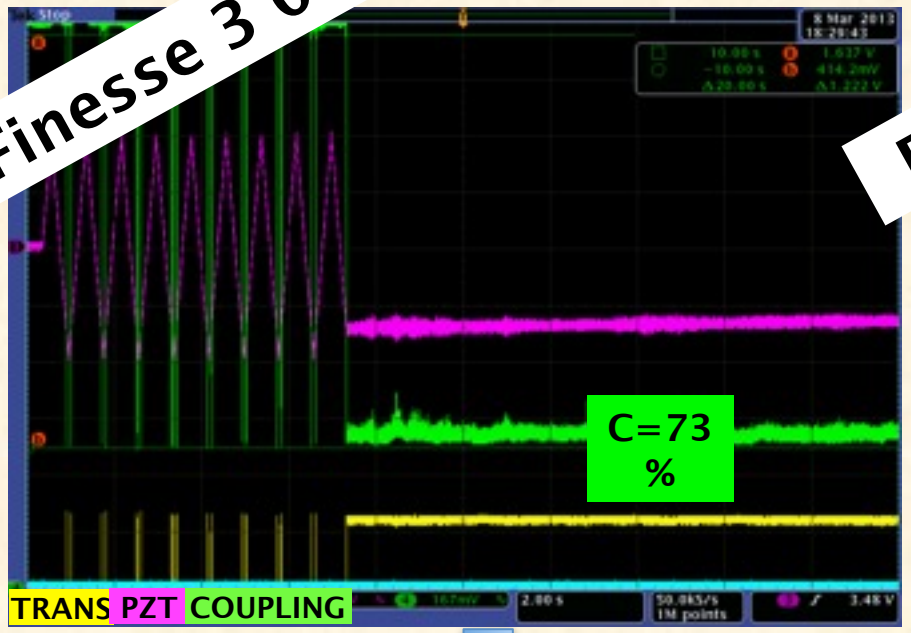


Current status

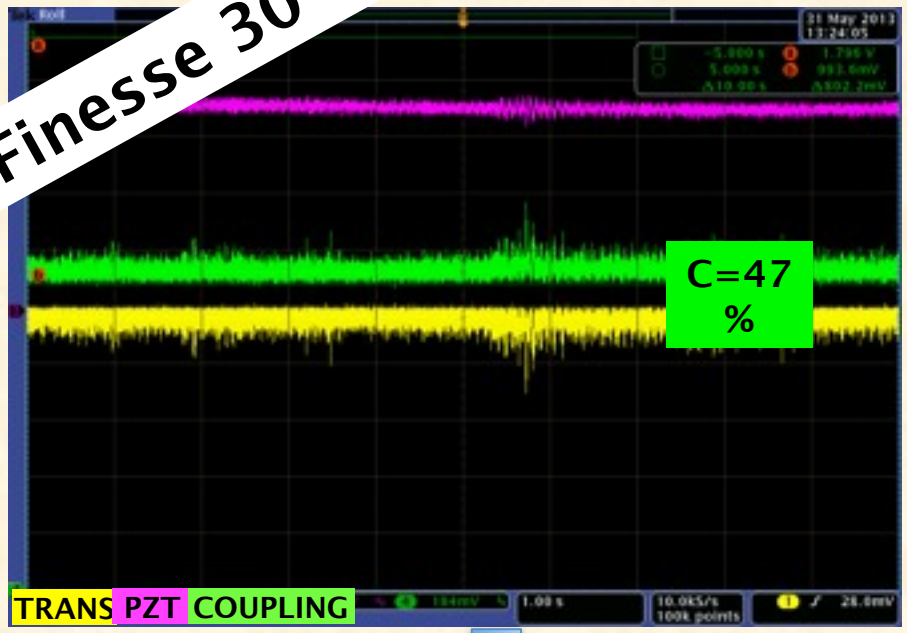
- Laser has been fixed.
- New laser amplifier, higher output power, more stable, connectorized fiber (less alignment).
- Working on phase (CEP) control.
- Lock with better mirrors (F=30000)

Current Results on 2013.05.31

Finesse 3 000



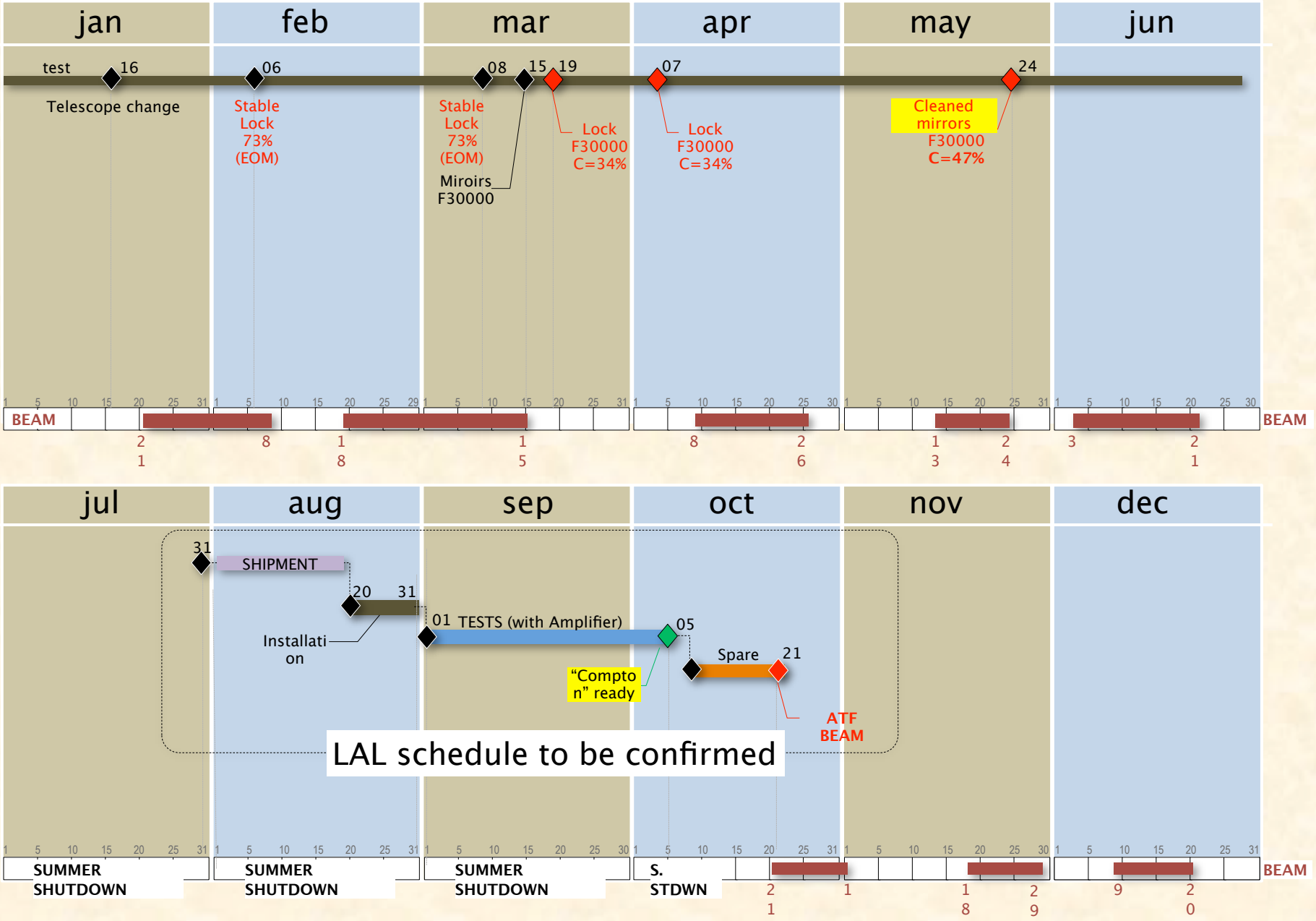
Finesse 30 000



Estimated Power in cavity with Injected Power P_{IN}

P_{IN} = 10W	7.3kW	47kW
P_{cav} = 50W	36.5kW	235kW

MightyLaser Milestones 2013



Future plans

- Reinstallation of the setup at KEK at the end of the summer.
- New data taking in October and December
  => hope to take advantage of the full possibilities of the system.

Outlook

- MightyLaser has already demonstrated the use of a 4-mirror Fabry-Perot cavity to produce polarised Compton photons before the 2011 earthquake.
- 2 publications, 2 PhD thesis.
- We now want to measure the flux that can be delivered by the system at full power.
- Important for future high flux polarised positron sources based.