Status and update plan of the ATF DR

Nobuhiro Terunuma, KEK

European Linear Collider Workshop ECFA LC2013, May 28, 2013

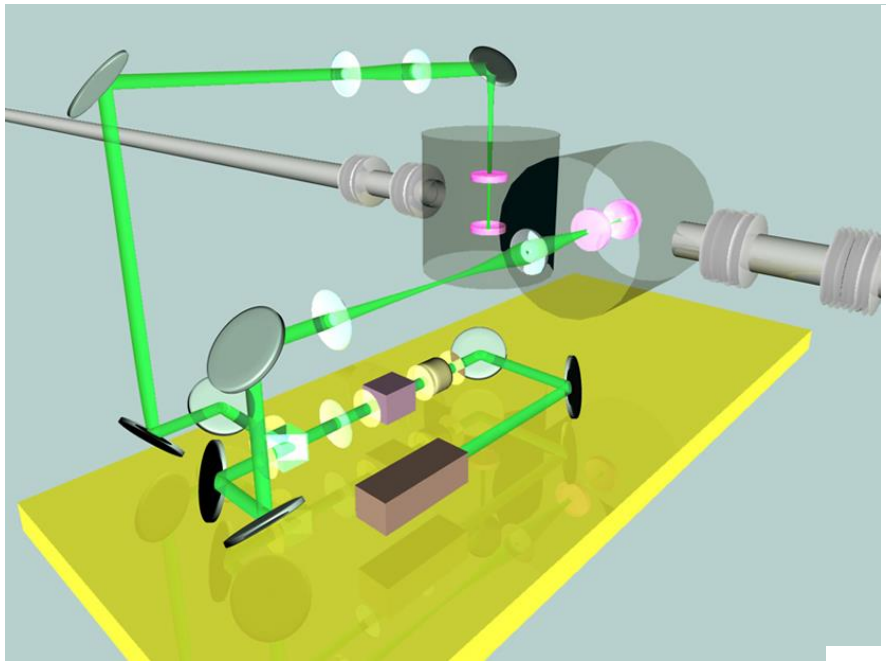
ATF DR status

- Present users on ATF DR
  - Cavity Comptons
  - ATF2
- Low emittance for ATF2 (~10pm)
  - Maintained in each startup of the beam weeks
  - Usually done in a shift
- Studies for the smaller emittance (2pm)
  - It has not been done in 2012 because of the ATF2 priority.
  - It should be re-scheduled from now on.

Emittance

- Measured in DR
  - XSR monitor
  - ATF2
- Measured in EXT
  - wire scanners (Tungsten 10 um, Carbon 6 um)
  - Multi-OTR monitor

Laser Wire with Optical Cavity (DR)



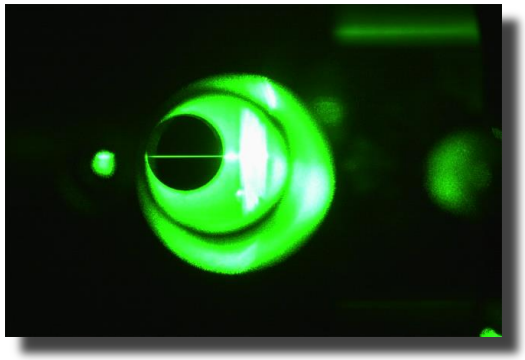
The most accurate emittance monitor in ATF DR.

14.7μm laser wire for X scan
5.7μm for Y scan

But the measurement is

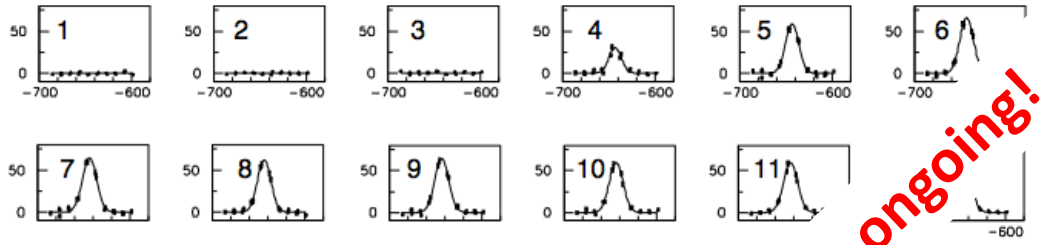
time consuming.

(scan: 15 min for X, 6 min for Y)



300mW 532nm Solid-state Laser fed into optical cavity

Multi-bunch separated measurement



Two mirror cavity

- **Difficult to maintain**
- **low signal intensity**

Not in function in recent years

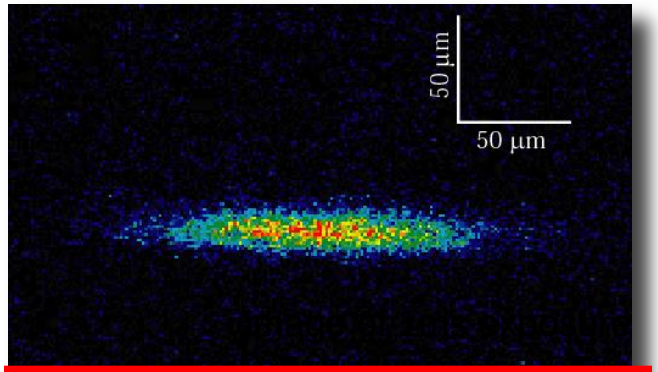
Upgrade is ongoing!

X-ray SR Monitor (XSR)

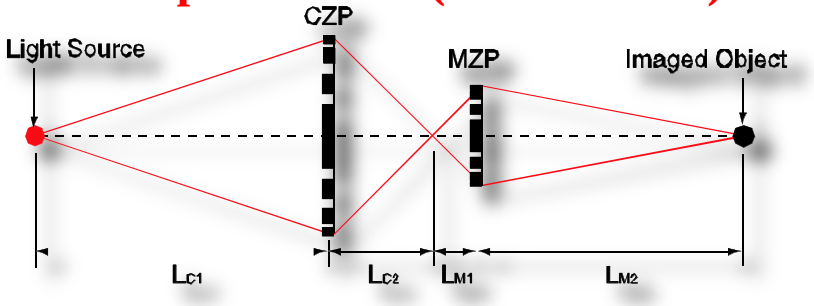
Real-time monitor for emittance tuning in DR

X-Ray Telescope using Zone Plate at 3.2KeV
magnification : 20

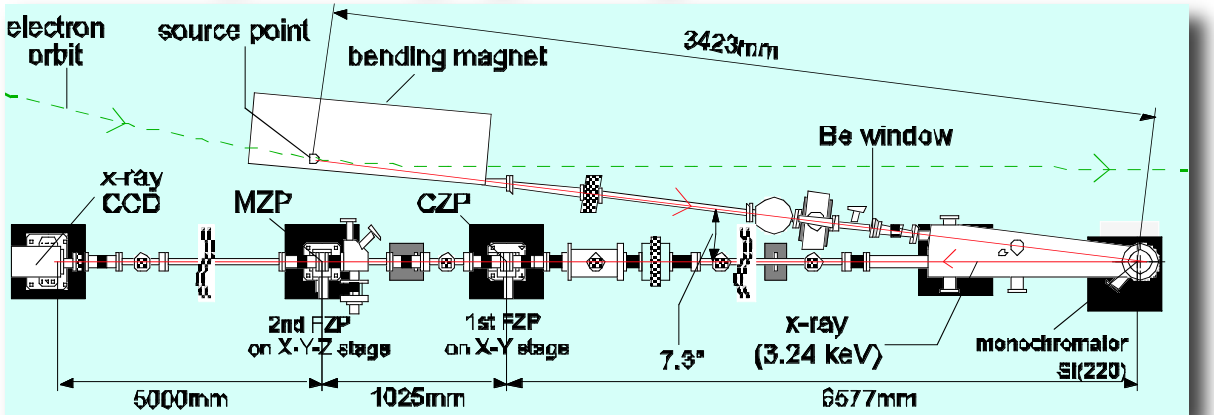
- **Non destructive measurement**
- **High resolution (< 1μm)**
- **2D direct imaging of the electron beam**
- **Exposure time (1 ms ~ 20 ms)**

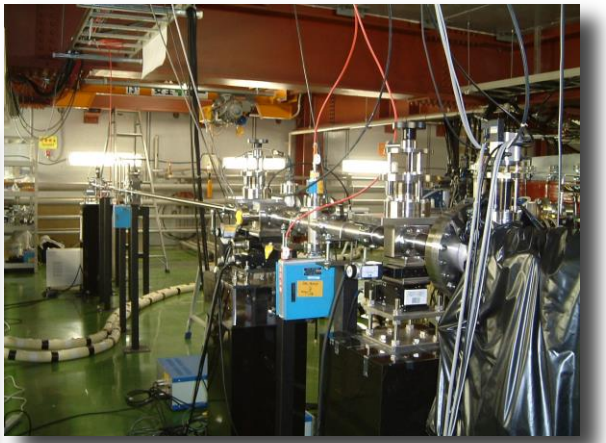


σ_x = 48.2 ± 0.5 [μm]
σ_y = 6.4 ± 0.1 [μm]



Zone plate





SR X-ray beam line

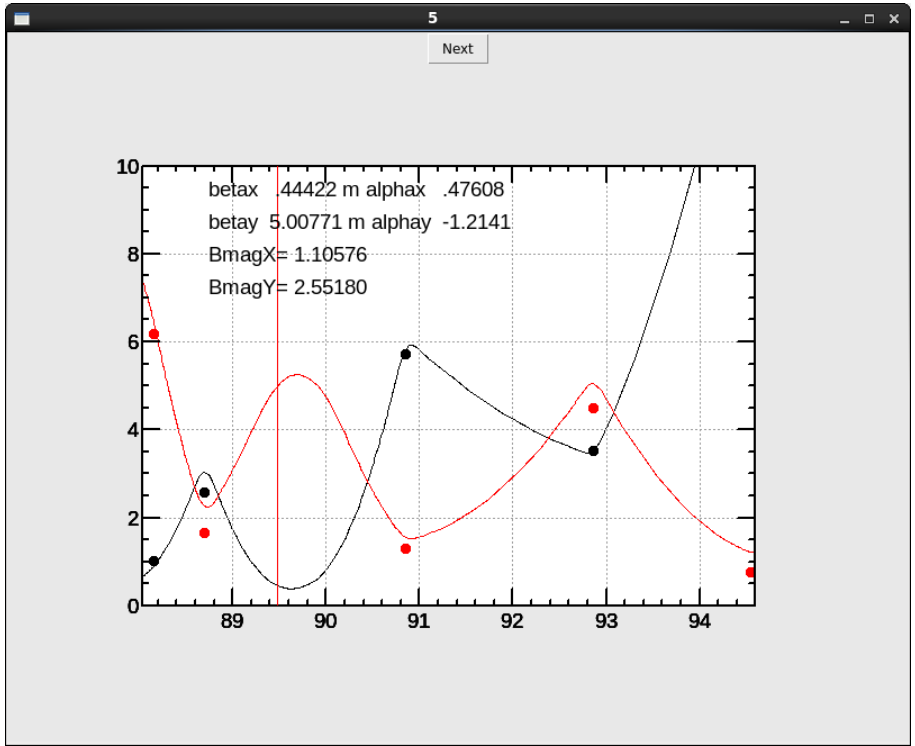
Beta Measurement

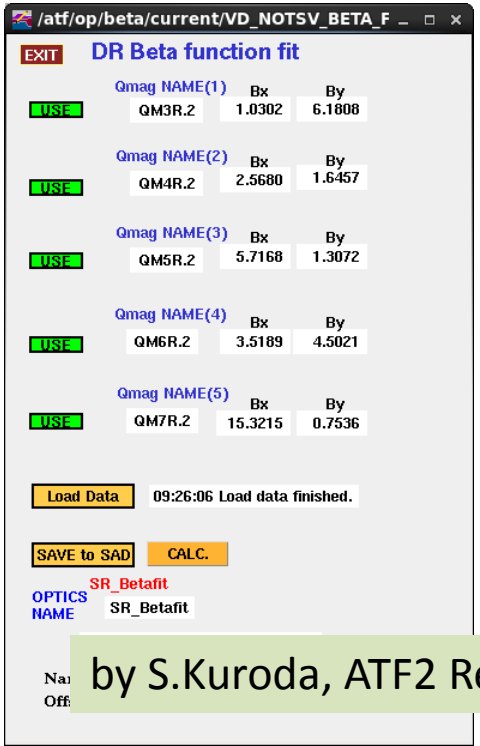
- Emittance is calculated by the formula;

$$\sigma_y^2 = \beta_y \varepsilon_y$$

β is calculated by fitting the β s at near Qs, which are measured by tune slope.

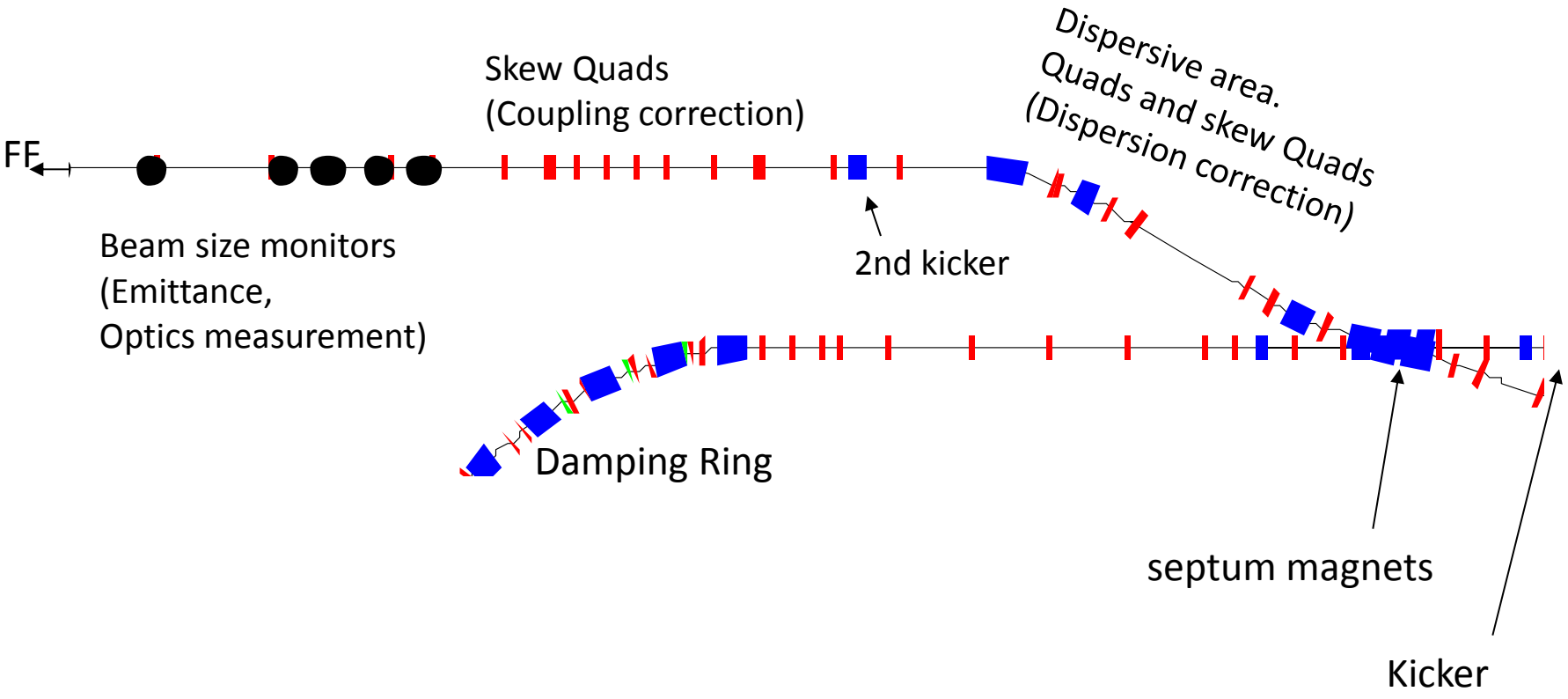
ex.)->





by S.Kuroda, ATF2 Review

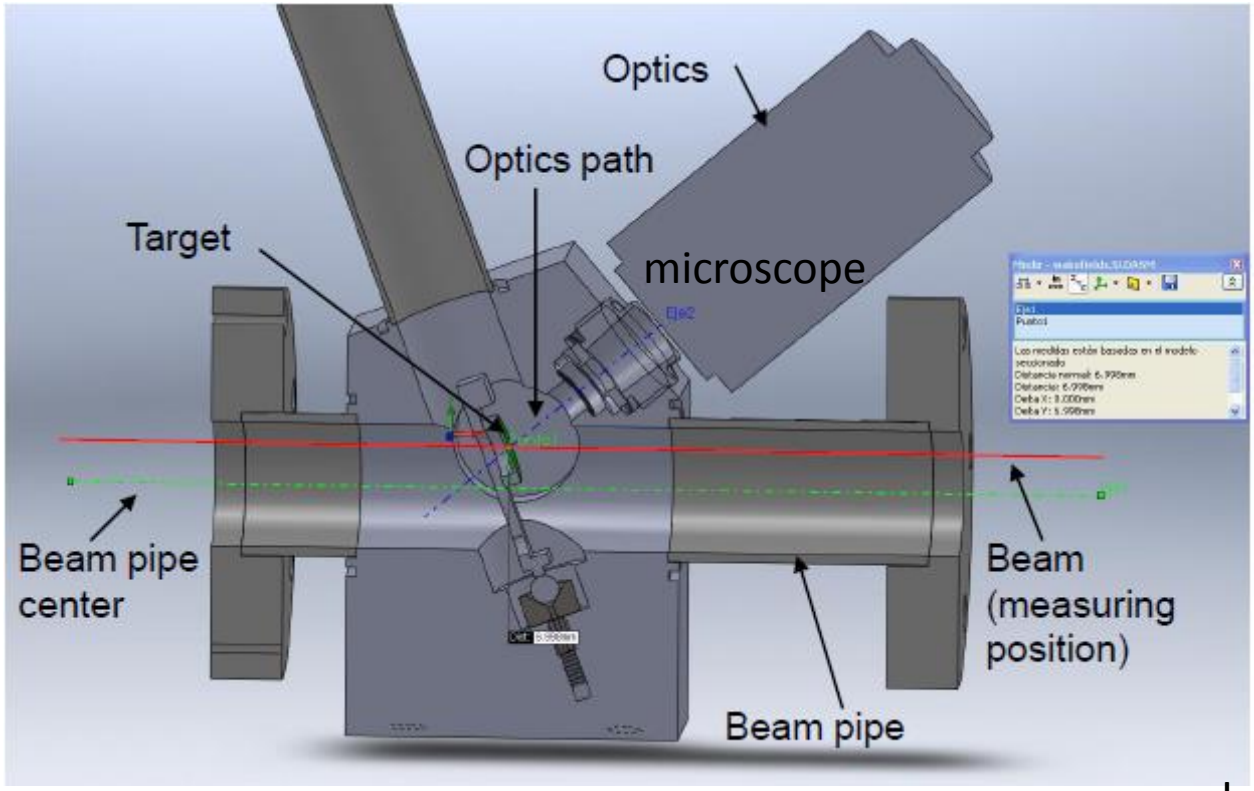
Layout of Extraction Line



Modified from figure in 13th ATF2 Project Meeting, January 12 2012, by Mark Woodley

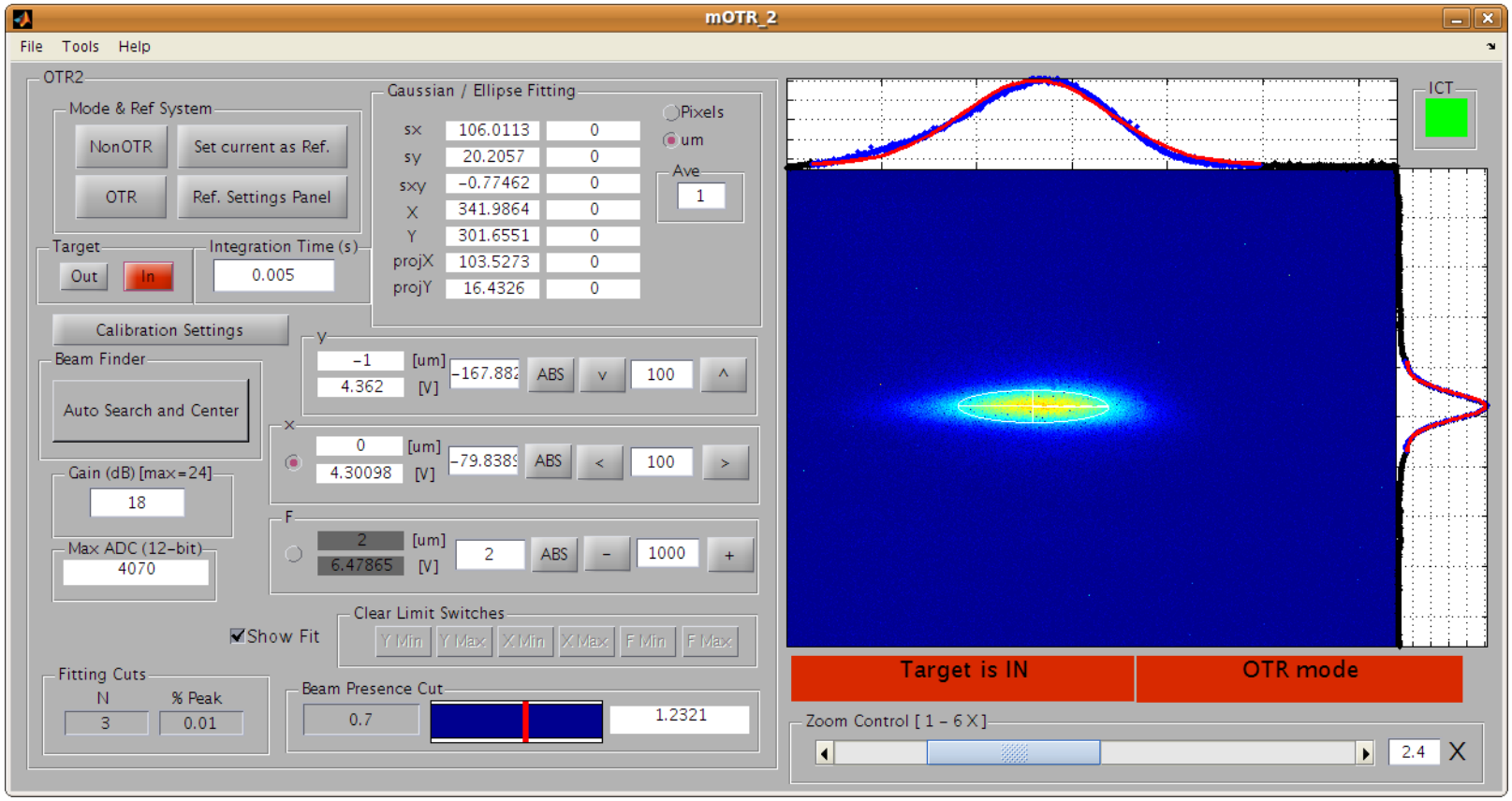
OTR beam profile monitor

- Measure Single pulse beam size (faster than wire scanner).
- We have 4 monitors → Evaluate projected x, y emittance
  - Could evaluate normal mode emittance (4-D analysis)



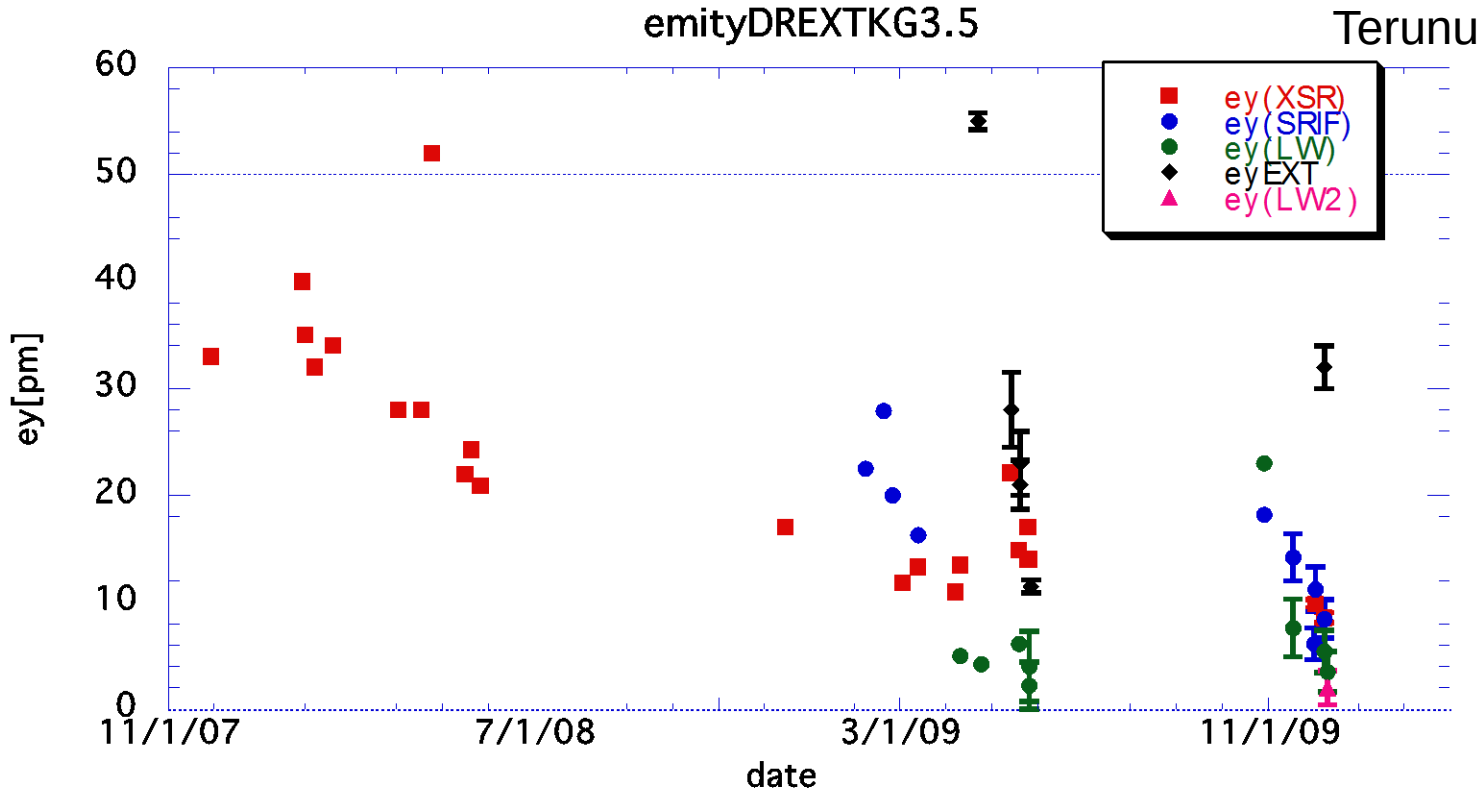
J. Alabau, et.al.

Example of OTR profile



from ATF Log Book

DR Emittance Summary



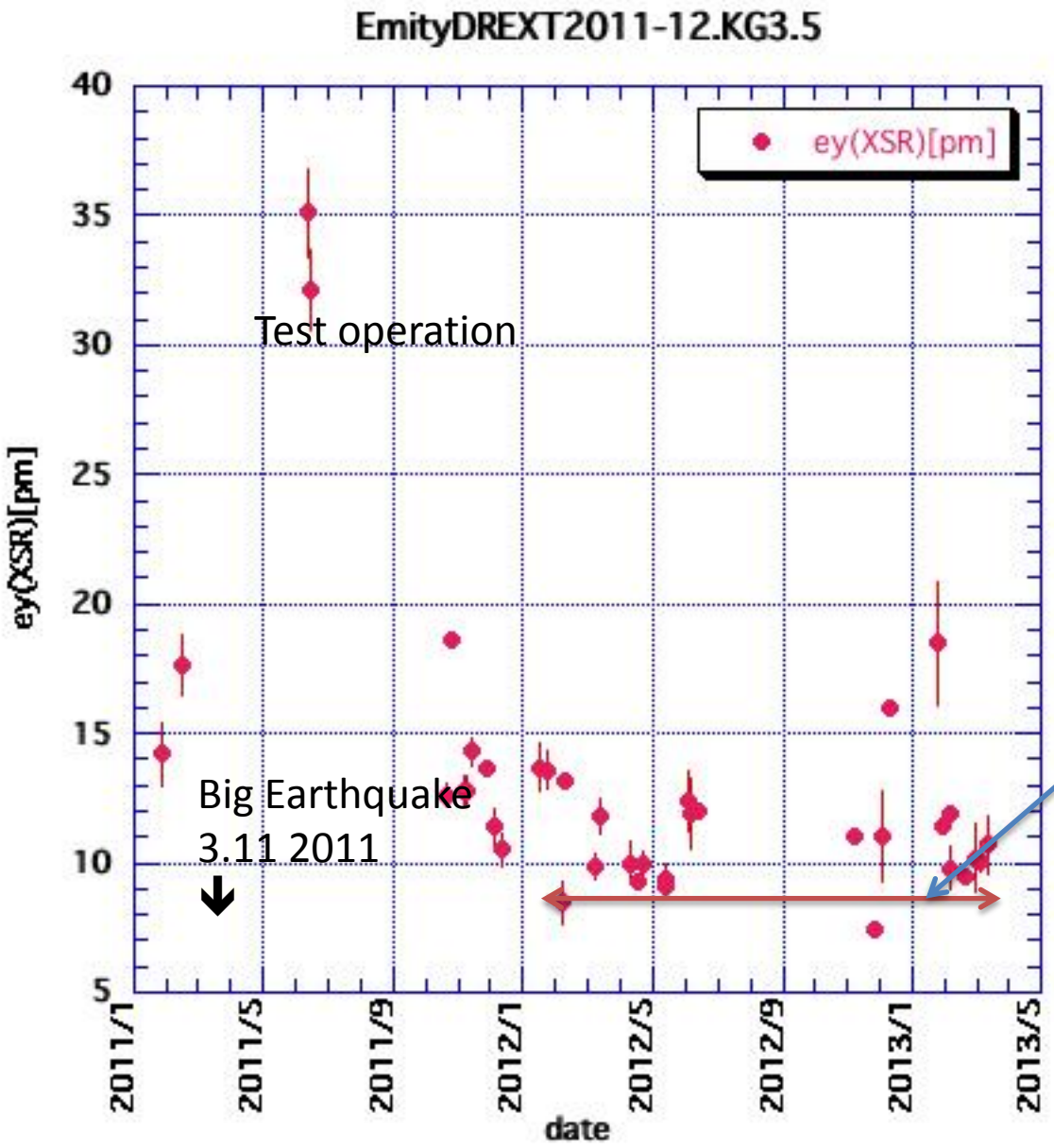
2009 spring
I=5-6x10^9

2009 autum
I=4-5x10^9

Low emittance was recovered in the operation 2008-2009.
Measured ε_y=8.56±0.46/ 8.43±1.79/ 3.50±1.78/ 2.00±1.61pm by XSR/ IF/ LW00/ LW01.
Study for the discrepancy is still on going.

by S.Kuroda, ATF2 Review

Emittance Summary 2011-2013



Emittance in DR is around 10-12 pm

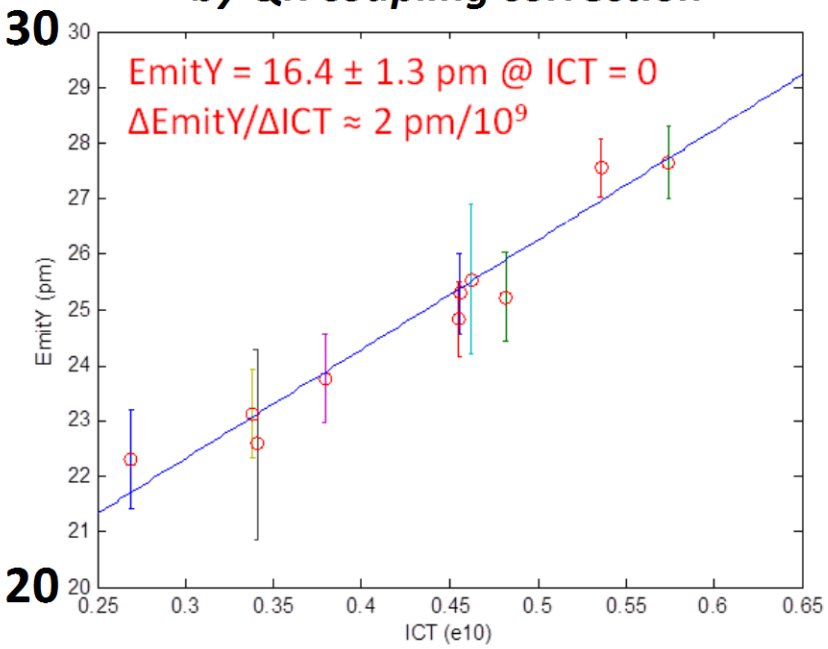
by S.Kuroda, ATF2 Review

Emittance of extracted beam

- Extracted emittance before May 2013 was bigger than that of DR about twice or more.
- Is the DR emittance 10 pm?
- Change of the coupling-correction scheme in May 2013, seems to remove the discrepancy between EXT and DR.

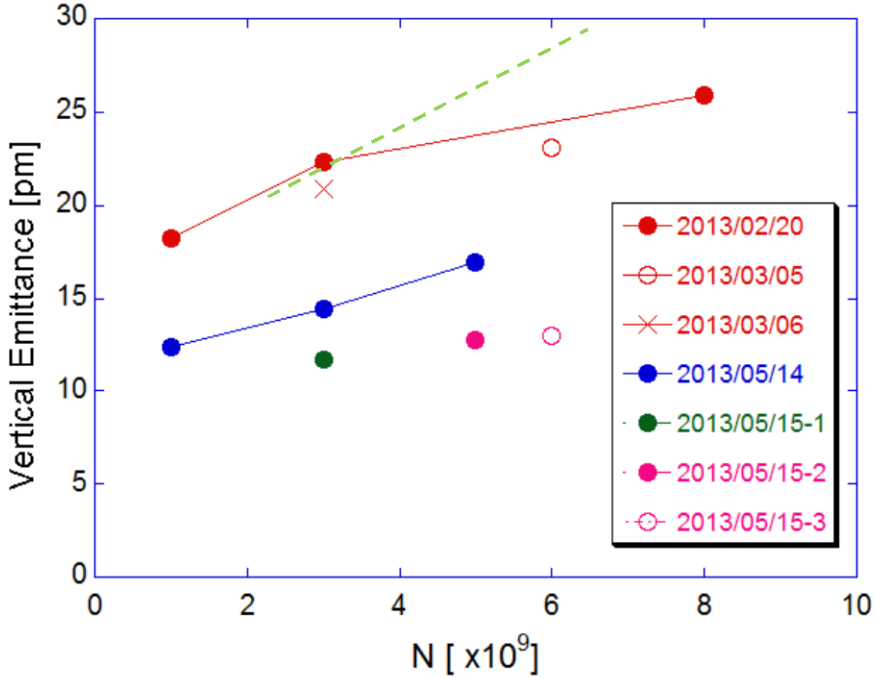
Summary of the emittance measurement by OTR

OTR emittance measurement by QK coupling correction



at 2012 December by M.Woodley at ATF2 review

OTR emittance measurement by QS difference knob coupling correction



Red ; 2013 March
Blue ; 2013 May
Green ; 2013 May with QK correction
Pink ; 2013 May with QK correction with CCD tilt correction

by T.Okugi , ATF operation meeting

The reason of the small emittance in 2013 May operation

Settings of skew quadrupole magnets in the extraction line

Magnet	2012/12/21	2013/05/15
QS1X	-0.140	-1.500
QS2X	-0.140	0.600
QK1X	-11.097	-1.456
QK2X	0.005	-0.341
QK3X	-3.019	1.929
QK4X	7.276	-1.327

The most of the coupling was corrected in upstream of beamline in 2013 May.

The maximum strength of skew quadupole magnets in 2013 May were very small to those in 2012 December.

by T.Okugi , ATF operation meeting

DR BPM Upgrade for 2 pm emittance

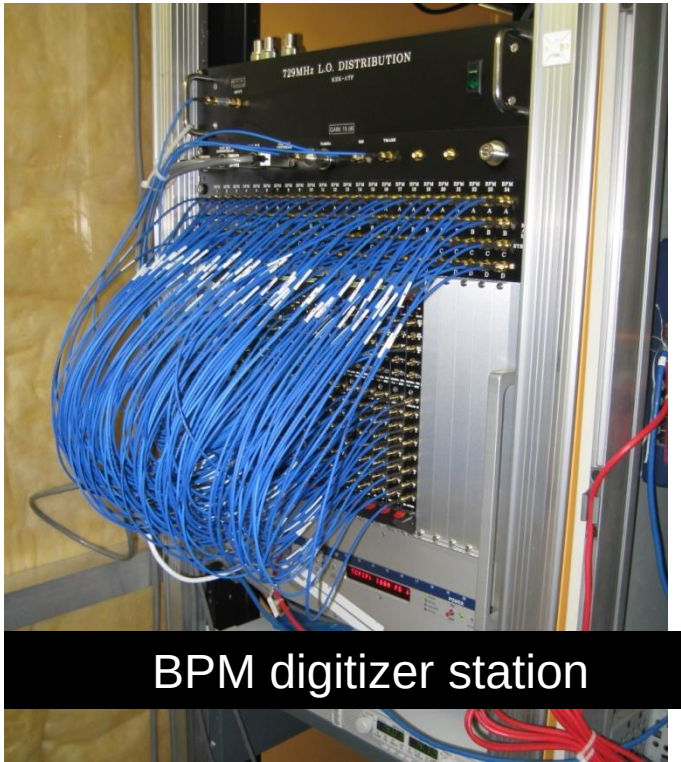
The original read-out system designed for the **single path** position measurement has a 10 μm resolution.

Upgraded BPM readout system:
FNAL-KEK collaboration

- **Broadband turn-by-turn mode** (< 10 μm resolution)
  - Injection 1,000 turns
  - Extraction 64 turns
- **Narrowband mode with high resolution** (~ 100 nm range)
  - 160 ms, 500,000 turns after injection

Installed in 2010 for all DR BPMs (96)

Downmix box at the beamline



BPM digitizer station

Summary: Emittance in Damping Ring

- We achieved minimum vertical emittance ~4pm in 2002~2003.
- Recently, we have kept (nearly) the best condition.
- For smaller vertical emittance (~ 2pm, ILC DR design),
  - New beam size monitor for confirmation.
  - Keep good alignment.
  - Keep good BPM performance.
- However, present priority is ATF2 study (Final focus test, demonstration).
  - Damping Ring emittance is small enough for ATF2

by K.Kubo, ATF review, August 2012

Optical Cavities in ATF DR

- High intense gamma-ray generation
- Optical cavities: 2-mirror → 4-mirror
- for the polarized positron source (Hiroshima/KEK)
- for other application (LAL)
- for the upgrade of Laser Wire scanner

Laser-Compton-Scheme & Laser Pulse Stacking for pol. e+ generation

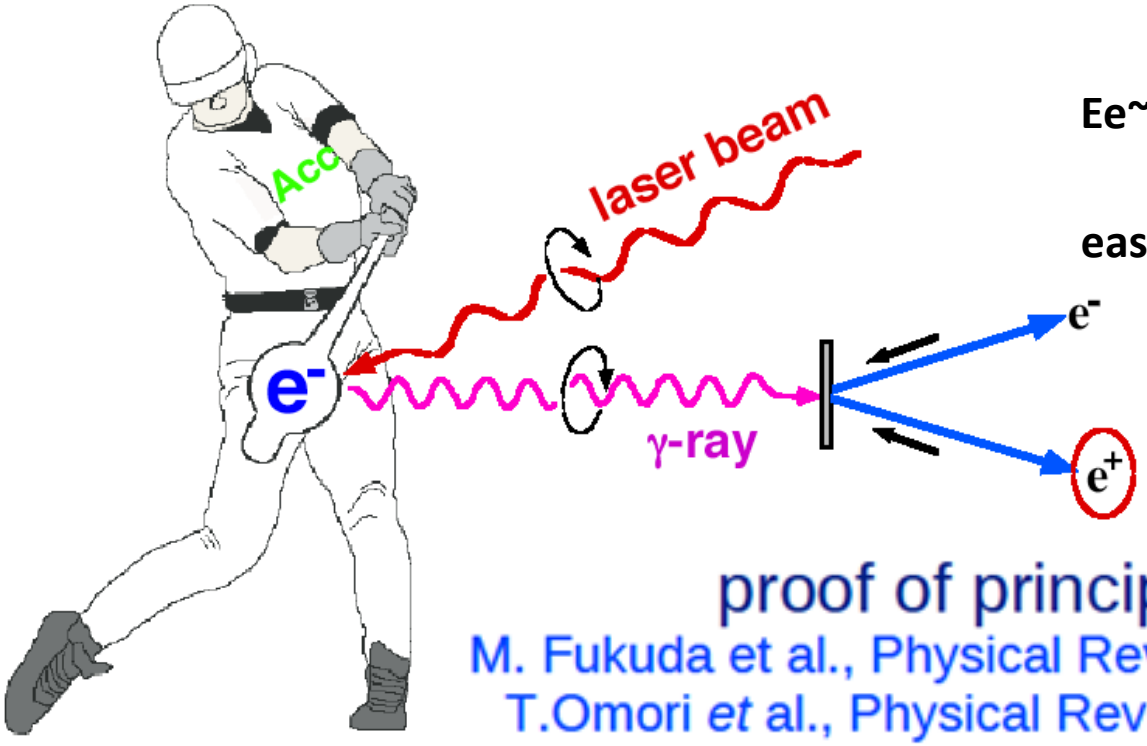
France-Japan collaboration

French Labs. : LAL (Orsay) in Collaboration with
CELIA (Laser lab., Bordeaux) and
LMA (mirror coatings Lab., Lyon)
Japanese Labs. : KEK, ATF group,
Hiroshima University

by T.Omori

Introduction

- **Polarized e+ by laser Compton Scheme**



Ee~1GeV for 10MeV gammas

easy to control polarization

proof of principle experiment

M. Fukuda et al., Physical Review Letters 91, 164801 (2003)

T.Omori *et* al., Physical Review Letters 96, 114801(2006)

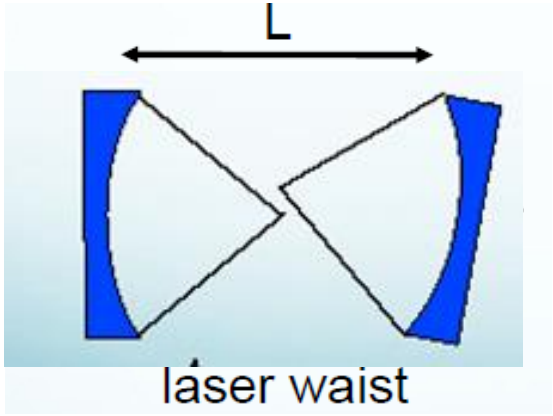
Toward the positron sources

-> increase intensity of gamma rays

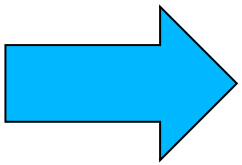
-> Laser Pulse stacking cavity

by T.Omori

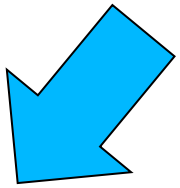
Way 4-mirror Cavity?
get small sport size

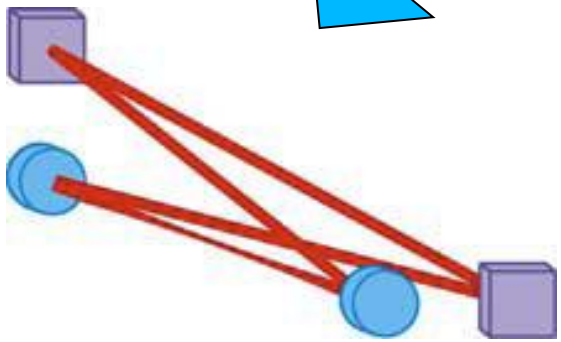


2 mirrors is not stable
for small spot size



2d 4M has astigmatism

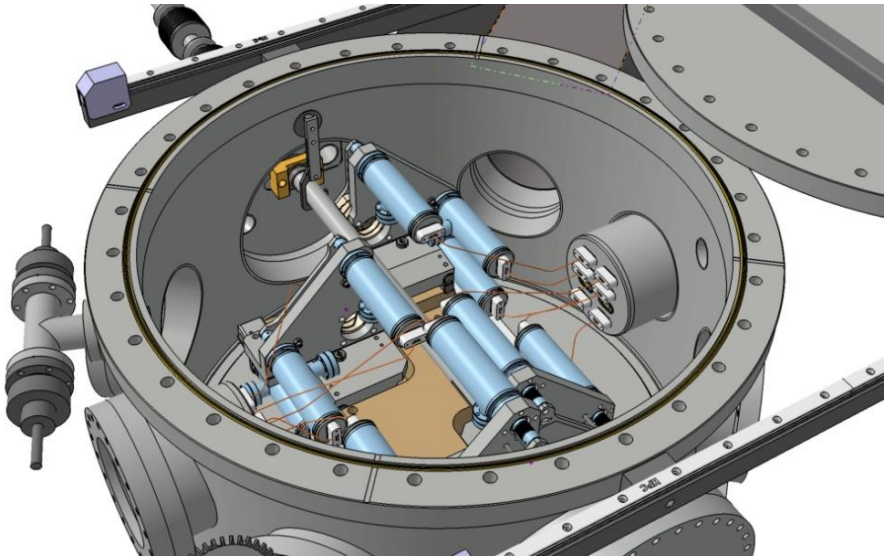




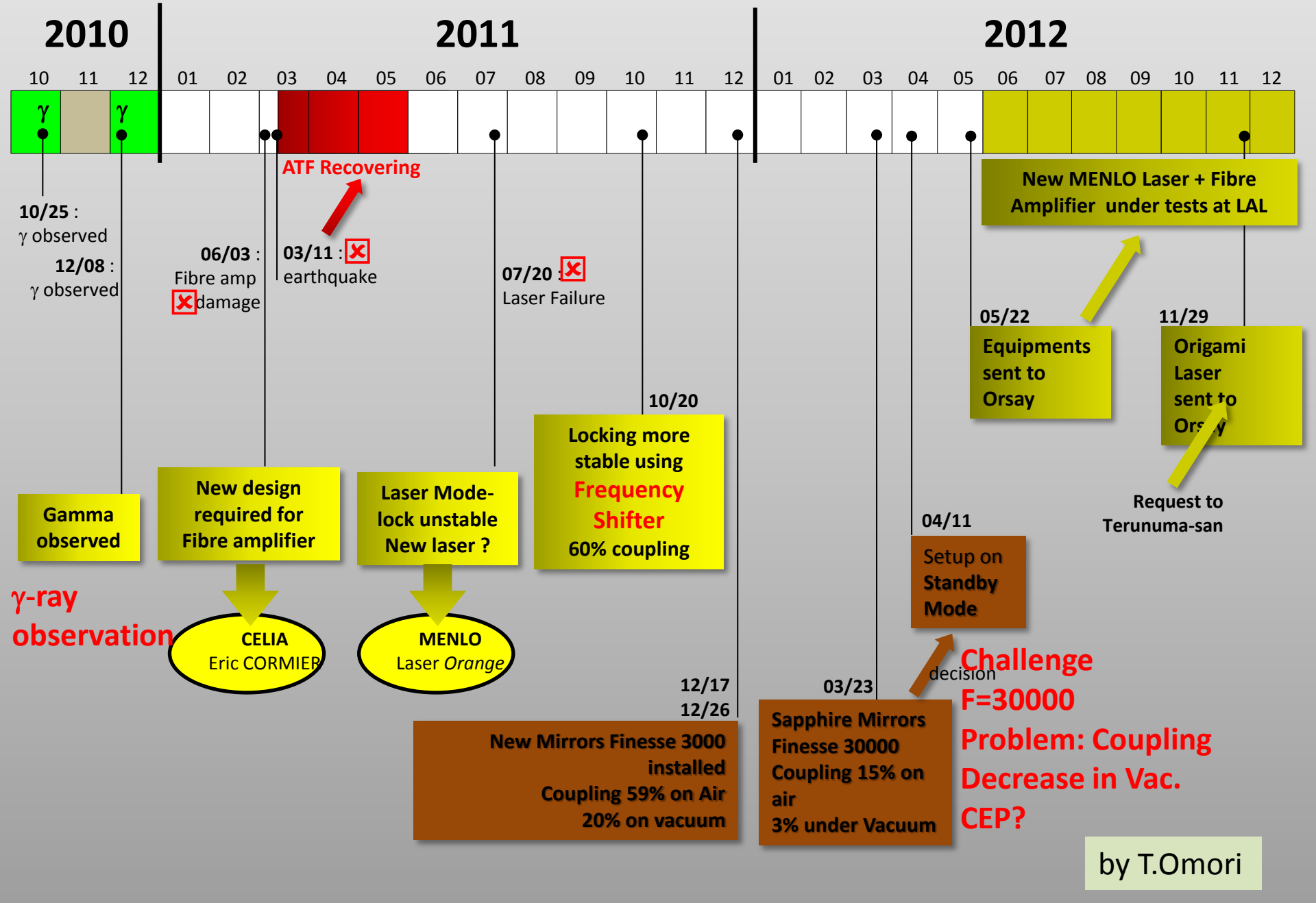
3D (or twisted)
4M ring cavity

by T.Omori

2010 Summer: French cavity Installation



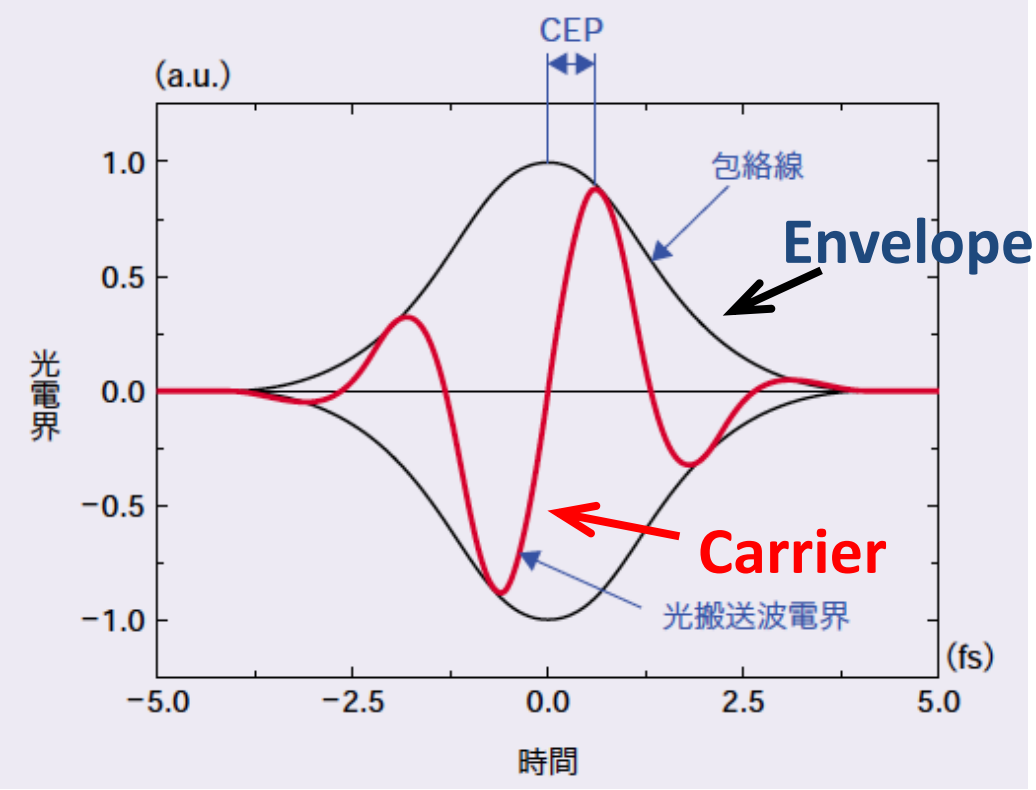
by T.Omori


2010
2011
2012
10 11 12 01 02 03 04 05 06 07 08 09 10 11 12 01 02 03 04 05 06 07 08 09 10 11 12
γ
γ
ATF Recovering
10/25 : γ observed
12/08 : γ observed
06/03 : Fibre amp damage
03/11 : earthquake
07/20 : Laser Failure
New MENLO Laser + Fibre Amplifier under tests at LAL
05/22
Equipments sent to Orsay
11/29
Origami Laser sent to Orsay
Request to Terunuma-san
Gamma observed
New design required for Fibre amplifier
Laser Mode-lock unstable New laser ?
10/20
Locking more stable using Frequency Shifter 60% coupling
04/11
Setup on Standby Mode
γ-ray observation
CELIA Eric CORMIER
MENLO Laser Orange
12/17
12/26
New Mirrors Finesse 3000 installed
Coupling 59% on Air
20% on vacuum
03/23
Sapphire Mirrors
Finesse 30000
Coupling 15% on air
3% under Vacuum
decision
Challenge
F=30000
Problem: Coupling Decrease in Vac.
CEP?
by T.Omori

French Cavity aiming very high finesse.

Issue: Lost stacking when goes vacuum.

Carrier Envelope Phase (CEP)

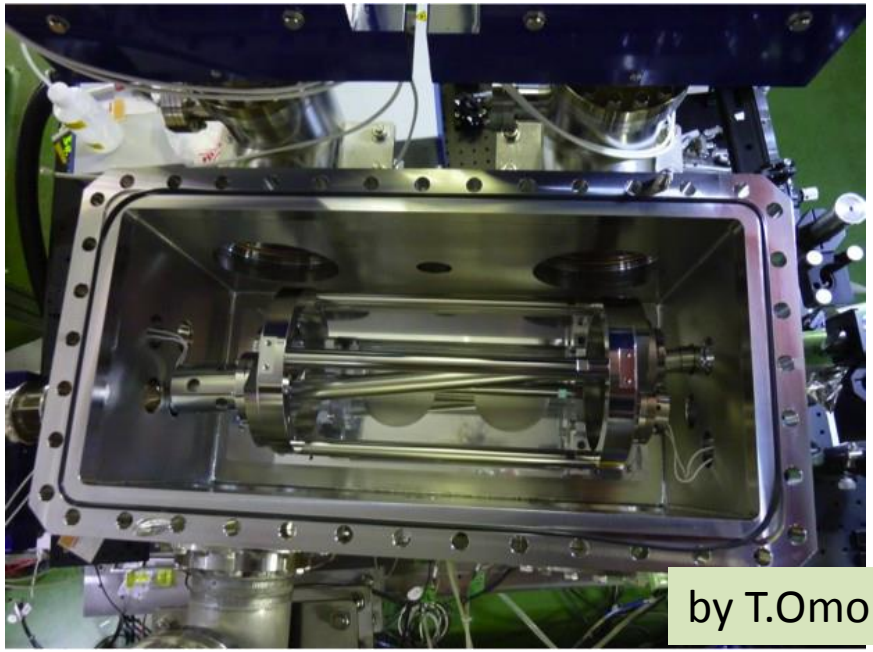


Cure is on going at LAL

by T.Omori

-> Cavity back to KEK this summer

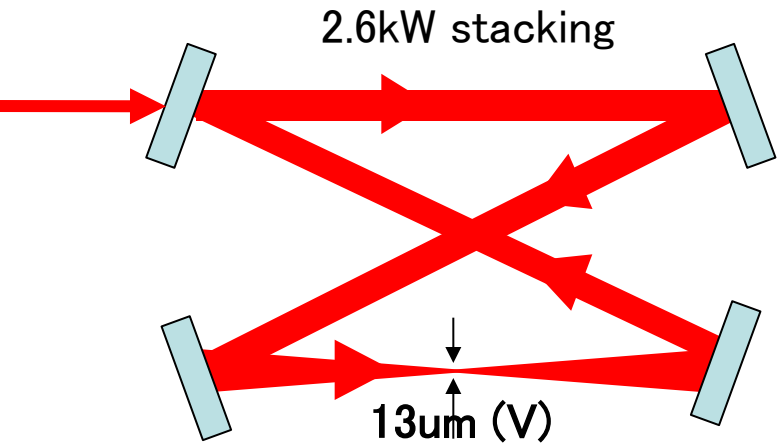
2011 Autumn: KEK-Hiroshima 4M Cavity Installation

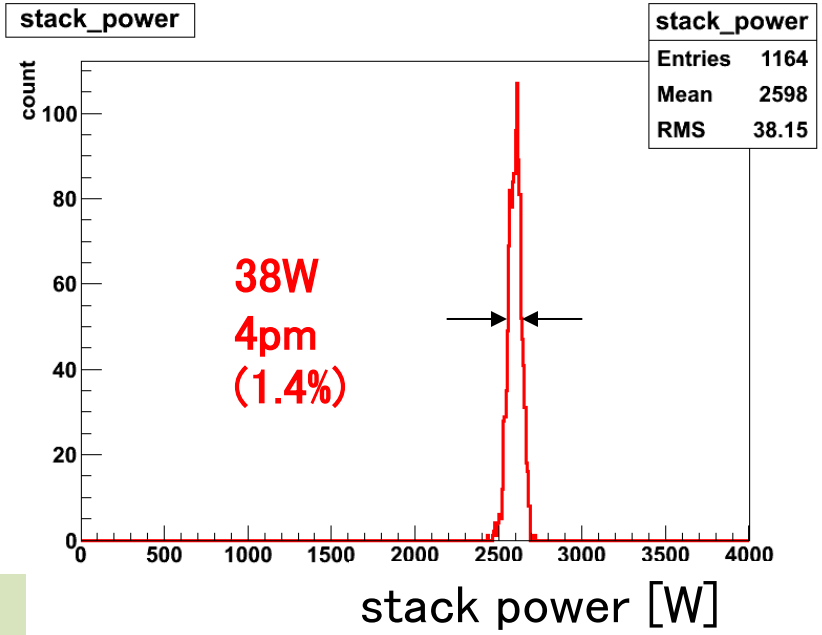


by T.Omori

Stable resonance with small spot size

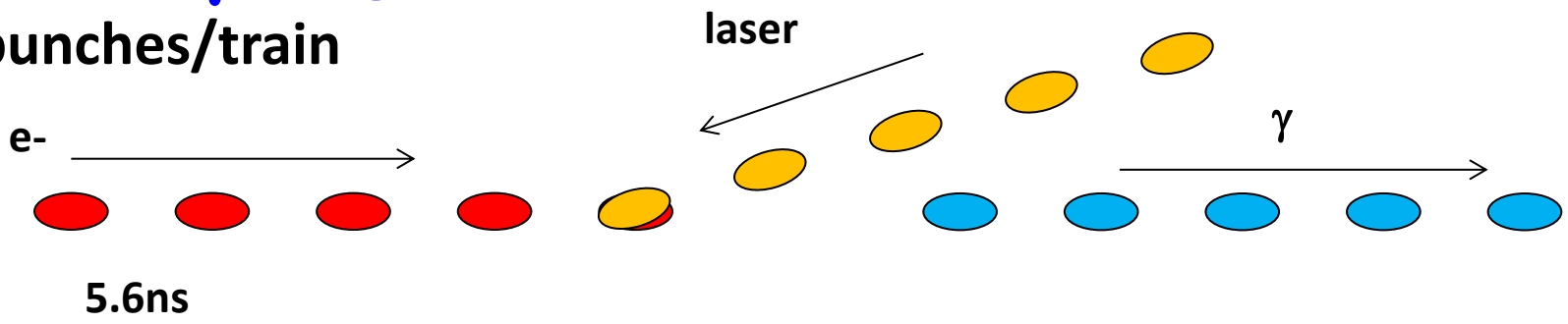
- Stable resonance by new feedback sys. (analog)
- 2.6kW average power w/ 1.4% fluctuation
- laser waist size at IP(σ)=13um (vertical scan)
- Finesse 4040+−110 (Enhance = 1200)





by T.Omori

γ-ray Generation / electron

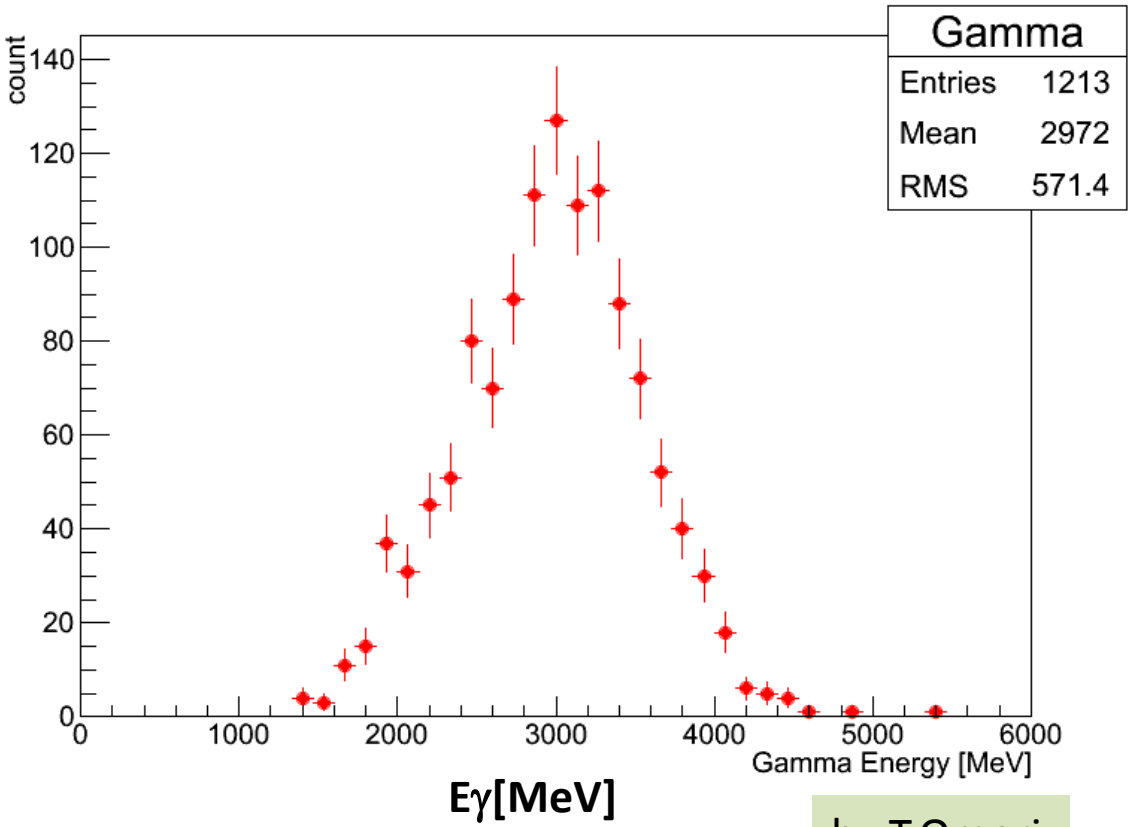


2970±20 MeV

⇒ ~128γs/trainのガンマ線に相当

ATF 2.16MHz

~2.6×10^8/sec



Eγ[MeV]

by T.Omori

Summary by T.Omori

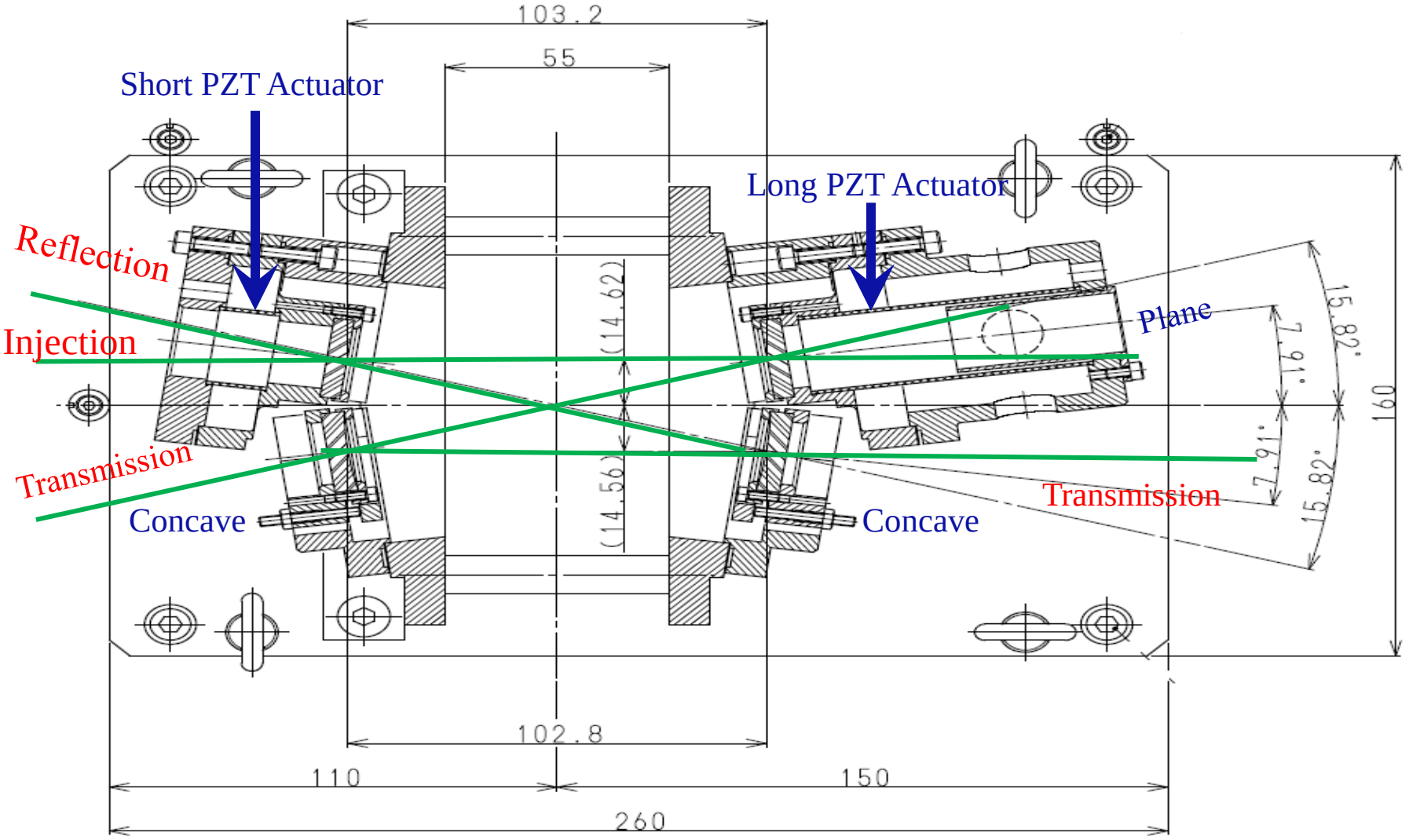
- **Optical Cavity at the ATF is in progress for Polarized positron source for the ILC**
  - Good collaboration between France – Japan team
    - **information / technology exchange**
- **R&D of 4 mirror ring cavities are in progress**
  - Sophisticated mechanism aminig very high laser power enhancement ,,, French team
  - Relatively simple but new cavity control practical experience w/ the ATF ,,, Japanese team
- **Next Step (2013 and ,,,)**
  - France : Laser with CEP control (ongoing@LAL)
    - Summer: Re Install whole system
  - Japan: Finesse 48,000 (16600 enhancement)
  - Japan: Digital Feedback (ongoing)

Application for the DR Laser Wire

2-mirror → 4-mirror

- Improve the reliability of system
- Pulsed laser→ increase intensity→ faster measurement

Design Of Mirror holders & Mirror Alignment scheme



Cavity length is 102.8 mm only , and side by side mirror distance is kept to 29.2 mm

by R.Arpit, ATF2 project meeting

Parameters of Compact 4 mirror laser wire in comparison to old 2 mirror laser wirer system

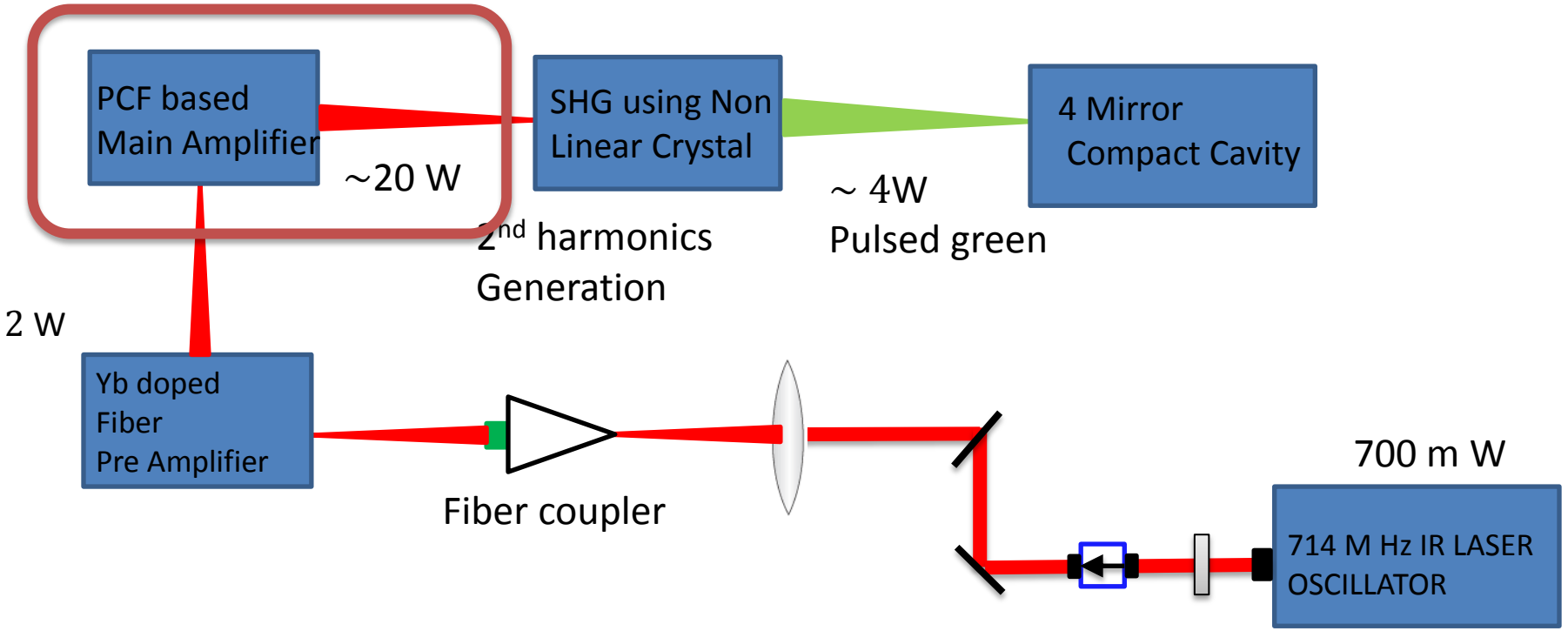
Parameter	2 mirror Horizontal wire	2 mirror Vertical wire	4 mirror laser wire
Reflectivity of mirrors	99.1%, 99.9%	99.8%, 99.9%	99.9%,99.99%,99.99%,99.99%
Mirror curvature	20 mm	20 mm	101.81 mm
Finesse (measured)	620	1700	4126.6
Power gain	660	1300	2000
Waist size (value)	5.7 um	14.7 um	(6 um,14 um)
Wavelength	532nm (CW green)	532 nm (CW green)	532 nm (Pulsed green, 714 M Hz)

MERITS

1. Four mirror resonator reduces the sensitivity to the misalignment of mirror compared to two mirror resonator, thus more stable.
2. CW laser wire system takes more time in scanning of electron beam compare to Pulsed laser. Pulsed Compact resonator will take less than one minute to scan electron beam profile
3. With pulsed laser wire, more efficient laser-beam collision can be realized
4. High Finesse and high enhancement factor is achieved in 4 mirror pulsed laser wire system in comparison to 2 mirror laser wire system

by R.Arpit, ATF2 project meeting

Preparation of Pulsed Green Laser oscillator



We are now working on development of fiber amplifier in order to obtain high power green laser beam.

We achieved 2 W IR power after Yb doped fiber amplifier.

Conversion efficiency of Non linear crystal for 2nd harmonics generation is 15 -20 %, so we have to achieve good amount of IR pulsed power after Photonic crystal fiber based main amplifier system.

by R.Arpit, ATF2 project meeting

New Laserwire in ATF DR

- It was installed in January 2013.
- Unfortunately the cavity was out of the range for the possible DR frequency changes.
- Removed from DR in May 2013.

- Re-optimization of cavity and re-installation wil be done in this summer
- The improvement of the laser amplifier is also ongoing.

- Hope to run in following autumn runs.

Summary

- Emittance of the ATF DR is typically 10 pm recently.
  - It is tuned within a shift in every startup of ATF.
  - No more tuning had not been done in recent years because of the ATF2 priority.
- Small emittance study toward 2 pm should be resumed.
- Cavity Compton studies are also resumed.
- Others
  - TBT by Yevs (next talk)
  - CLIC issues will be planned but mostly at EXT/ATF2.

Schedule? of ATF-DR since 2013