ATF Introduction, Instrum. R&D

Shigeru KURODA (KEK)

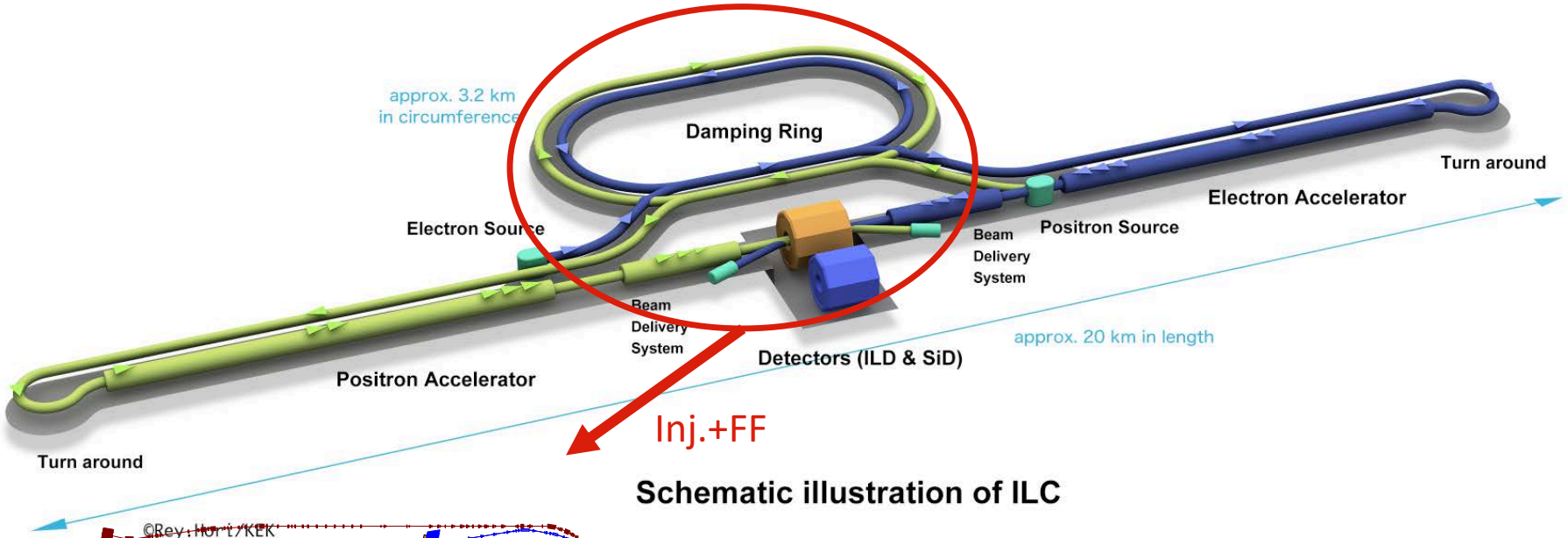
ATF Review Meeting - September 29th 2020

Contents

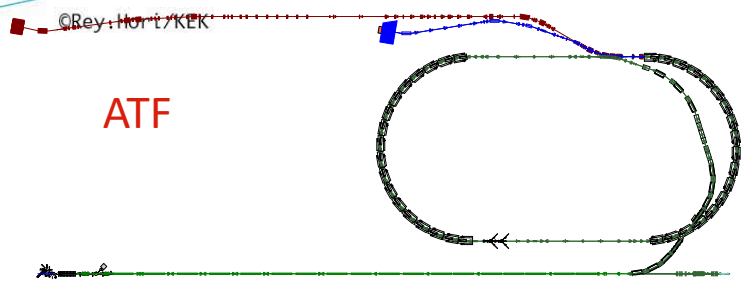
- Brief history of ATF
- Accelerator components
- ATF2 project
- Brief report of instrumentation R&D

ATF
(Accelerator Test Facility)

ATF/ATF2 Introduction



Schematic illustration of ILC



History

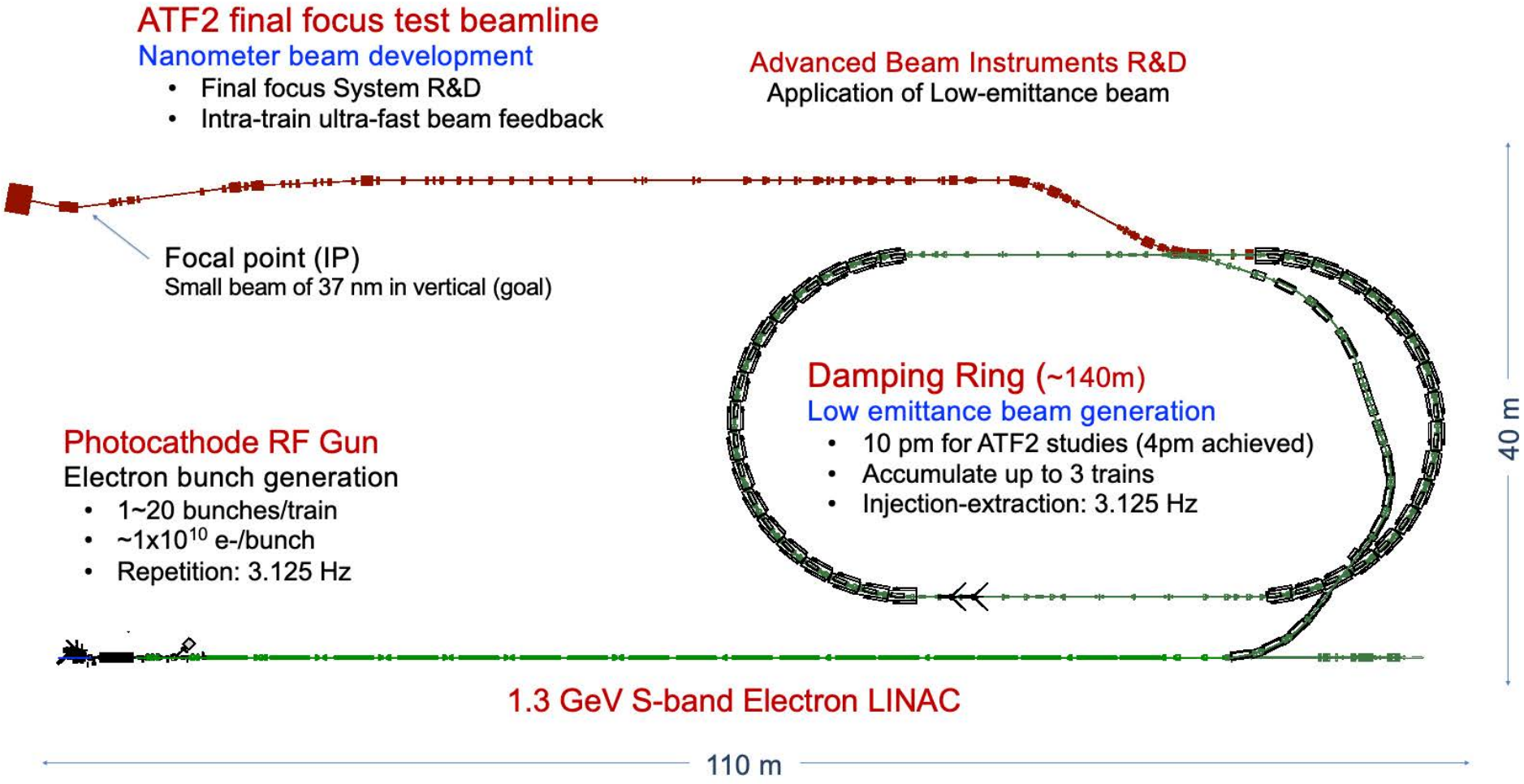
~1990 design started
1997 beam operation started
~2000 εy<5pm
2002 photo-cathode RF gun
2004 ITRP recommendation
2008 ATF2 commissioning

Accelerator R&D
Main goal

1. Low emittance generation
   Done in ~2000
2. Multi-bunch operation
   Multi-bunch generation is OK by RF Gun.
   Still study is needed for instabilities.

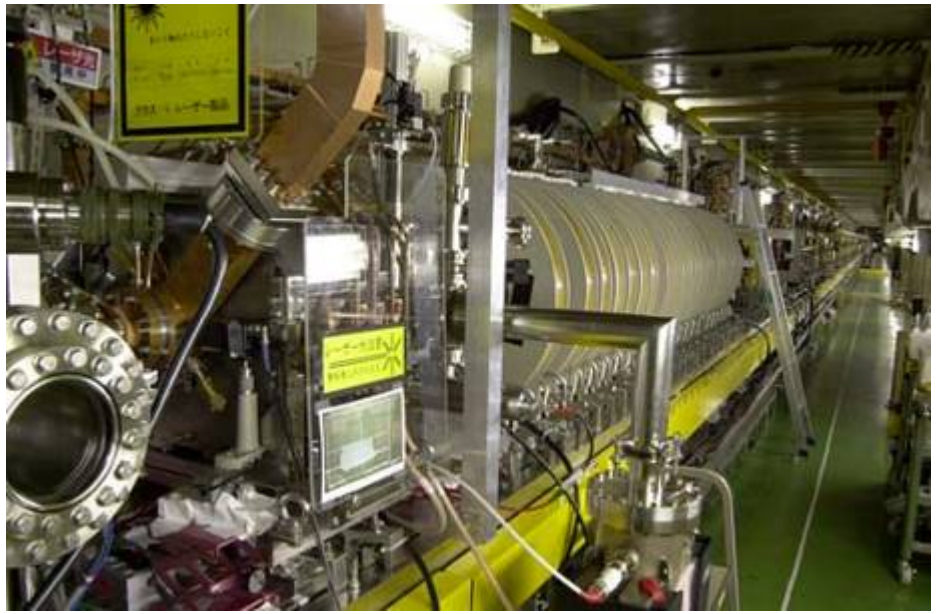
Other studies, e.g. LW, e+,…
ATF2 goal
small beam size as 37nm and its stable operation

ATF Accelerator Complex



ATF Injector Linac

- Beam Energy 1.3 GeV
- Up to 4E10 e-/bunch (usually 1E10)
- Up to 10 bunches/pulse
- Rep. rate ~6.25 Hz (usually 3.125 or 1.5625 Hz)
- Acceleration system
  - RF frequency 2.856 MHz (S- band, same as SLAC)
  - 19 accelerating structures + 2 energy compensation structures,
  - 3 m long each



ATF Damping Ring

$E=1.3GeV, C=140\ m$

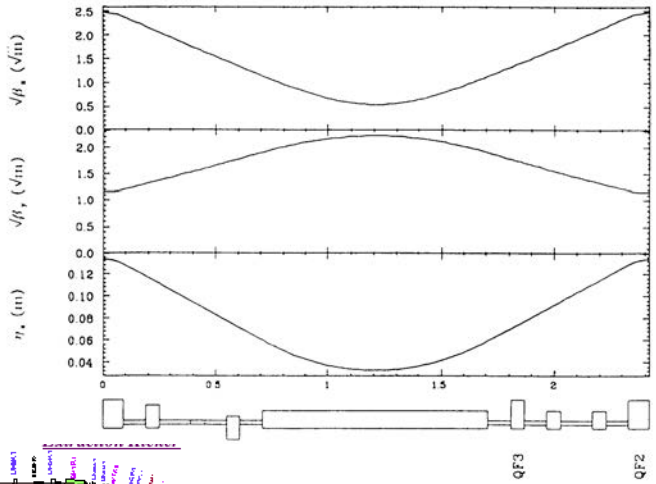
$Ne=0\sim2x10^{10}$ e-/bunch

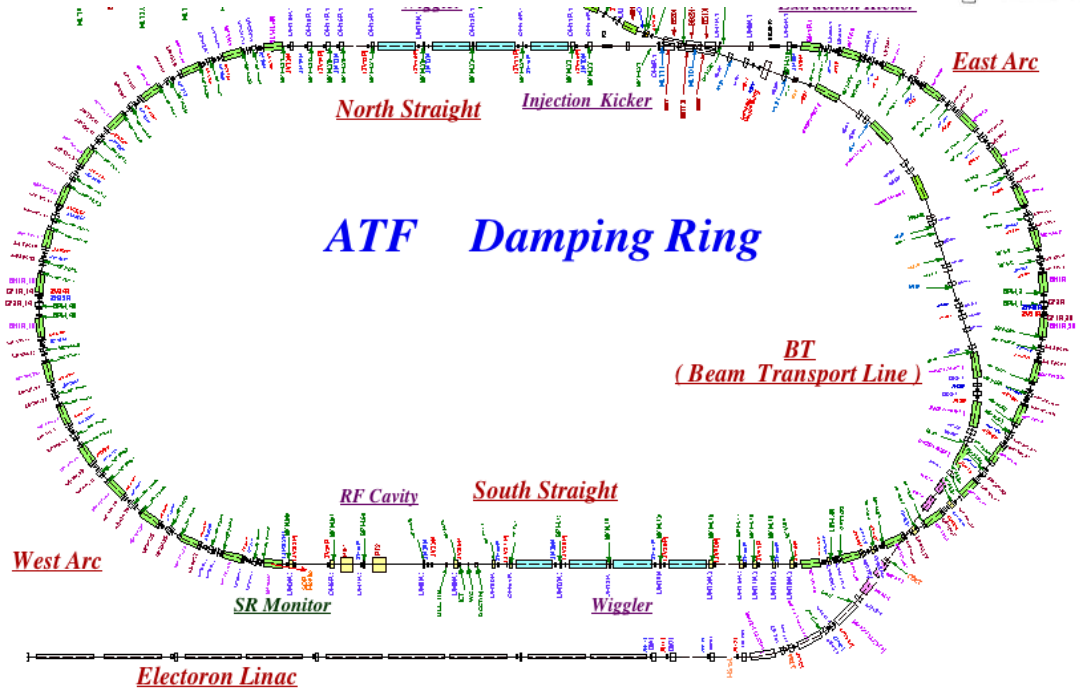
1 ~ 10 bunches/train

1~3 trains/ring

$\gamma\varepsilon_x = 2.5E\text{-}6$ **(at 0 intensity)**

$\gamma\varepsilon_y < 2.5E\text{-}8$ **(at 0 intensity)**





Low vertical emittance beam production was one of the main goal of ATF.

Much effort has been done for emittance tuning(including monitor R&D).

↓

Quick tuning(≈ 1 shift) with

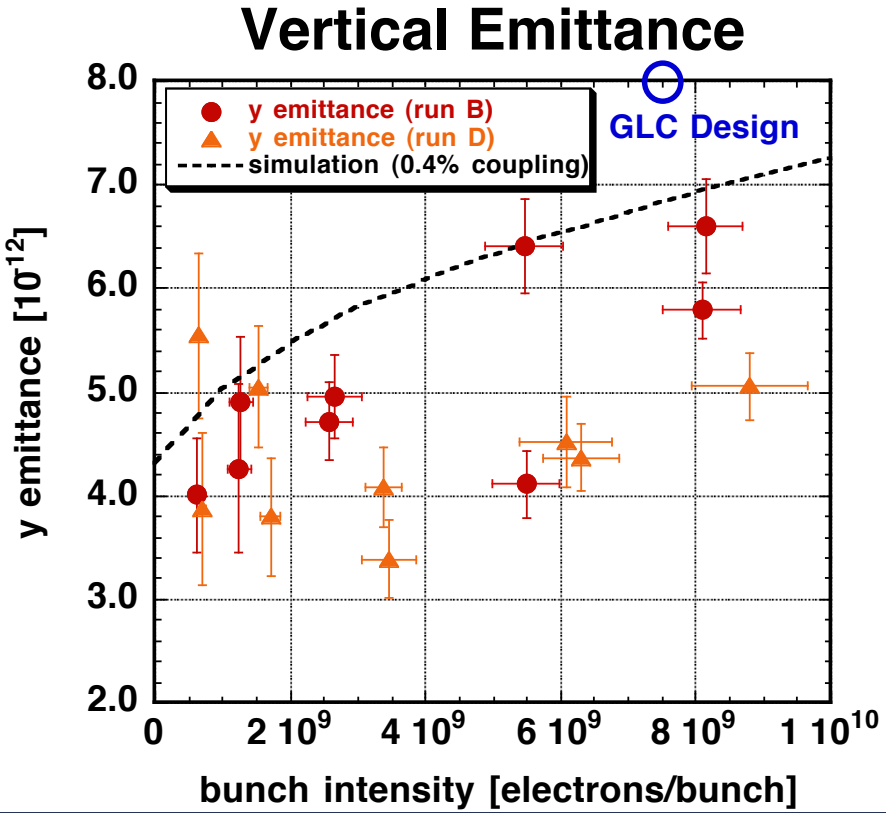
vertical dispersion correction

x-y coupling correction

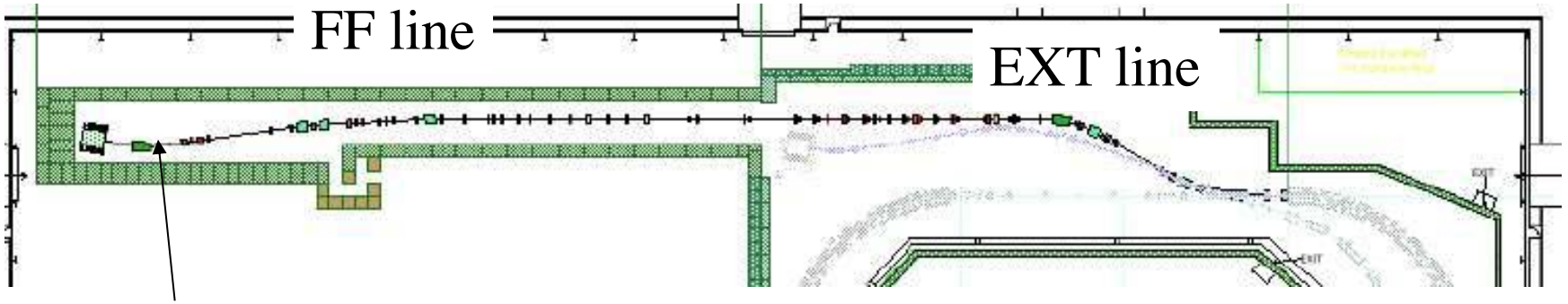
→ ≈ 10 pm vertical emittance

Emittance Study in DR

- There were great efforts to achieve low vertical emittance since DR commissioning.
- From the end of 2000 to 2002, we observed very low vertical emittance in DR about 10 pm.
- After further improvement of hardware, with software and simulation works, we constantly achieved lower than 5 pm at low intensity (N →0), and lower than 8 pm at high intensity (N~1E10)., which was lower than "designed" emittance. (2003)



Extraction line and Final Focus line (ATF2)



Final focal point
$\sigma_y \sim 40$ nm

Test of final focus scheme of Linear Collider

Development of various instrumentations
e.g. Beam position monitors, Beam size monitors, Orbit feedback

ATF2 Project

- 2005 International collaboration started
- Construction and study of final focus beam line
- Instrumentation R&D with international collaboration
- The collaboration might develop into ATF3

Table A.1: Institution that has concurred and signed the Memorandum of Understanding for the ATF2 project.

Region	Institution
Asia	Advanced Research Institute for Science and Engineering, Waseda University
	Department of Physics, Kyoto University
	Department of Physics, Nagoya University
	High Energy Accelerator Research Organization (KEK)
	ICEPP, the University of Tokyo
	Graduate School of Advanced Sciences of Matter, Hiroshima University
	Institute of High Energy Physics, Beijing (IHEP)
	Pohang Accelerator Laboratory (PAL)
Europe	Department of Physics and Astronomy, University College London
	Deutsches Elektronen-Synchrotron (DESY)
	European Organization for Nuclear Research (CERN)
	John Adams Institute for accelerator science
	Physics Department, Queen Mary, University of London
	Royal Holloway, University of London
	Applied Physics Department, Tomsk Polytechnie University
	Institut National de Physique Nucléaire de Physique des Particules (IN2P3)
	Instituto Nazionale de Fisica Nucleare (INFN)
North America	Fermi National Accelerator Laboratory (Fermilab)
	Laboratory for Elementary-Particle Physics, Cornall University (LEPP)
	Lawrence Berkeley National Laboratory (LBNL)
	Stanford Linear Accelerator Center (SLAC)

Past Studies at ATF(Before ATF2)

Beam Physics…

- Multi-bunch beam production (RF Gun)
- Low emittance beam
- Coherent synchrotron radiation (CSR)
- Polarized positron(Pol.Pos.) production

Instrumentations…

- DR BPM (submicron resolution)
- Optical cavities (DR LW, Pol. Pos. production)
- XSR, Interferometer
- Double Kicker System
- Wire scanner, Cav. BPM, OTR

Instrumentation R&D (international collaboration)

Main issue of ATF2 is FF study.
Many R&D of instr. also have been done with the collaboration

- Fast kicker
- Cavity BPMs
- Collimator
- Laser wire
- Optical radiation monitors

Details can be found in the review report

Fast Kicker

- Bunch spacing of ILC DR < 6 ns, while > 300ns in main linac.
  → Kicker magnet with fast rise/fall time

Figure 46: Side view of the stripline kicker

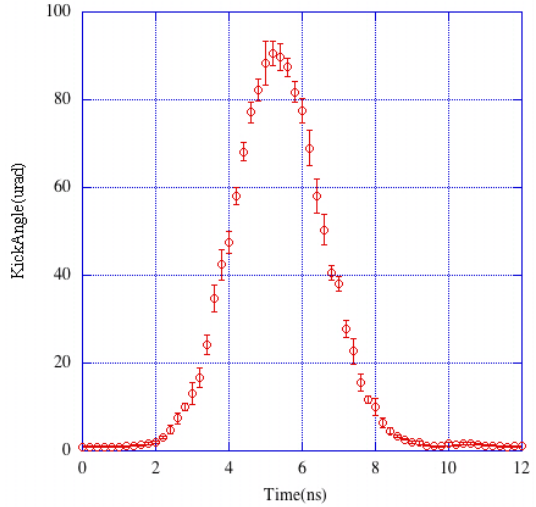
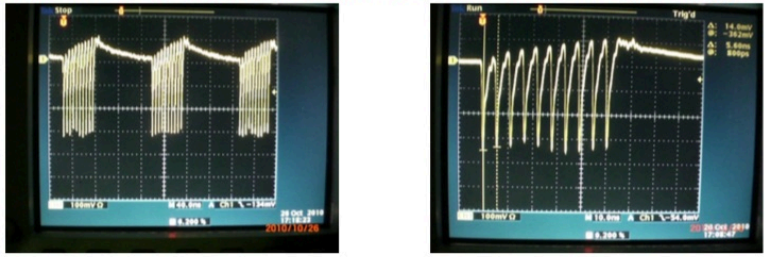


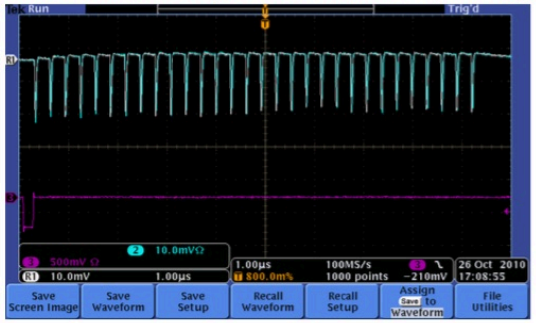
Figure 47: Beam kick angle as a function of time

DR bunches(3train, 10bunches, 5.6ns bunch spacing)



→

Extracted bunches(308ns bunch spacing, 30 bunches)



Cavity BPMs

- Cavity BPM is attached to each Q magnet in ATF2 beam line.
- Stability and submicron resolution was shown.

- There is also cavity BPM at the focal point(IPBPM).
- Low Q property is required for measurement of beam with 150ns bunch spacing.
- Resolution of about 20nm was measured.

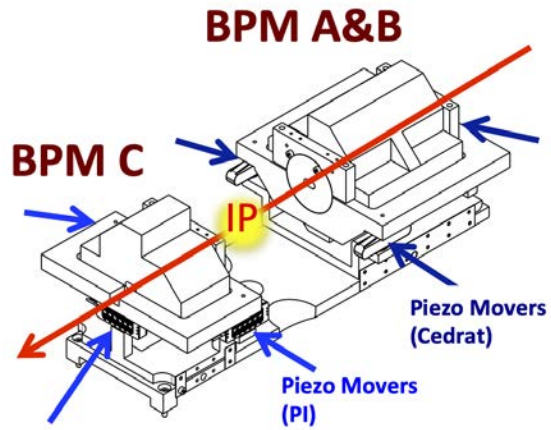
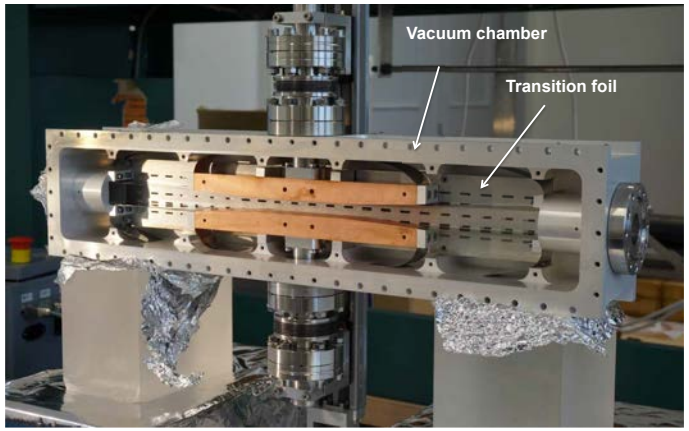


Figure 53: Layout of the three Cavity BPMs at ATF2-IP.

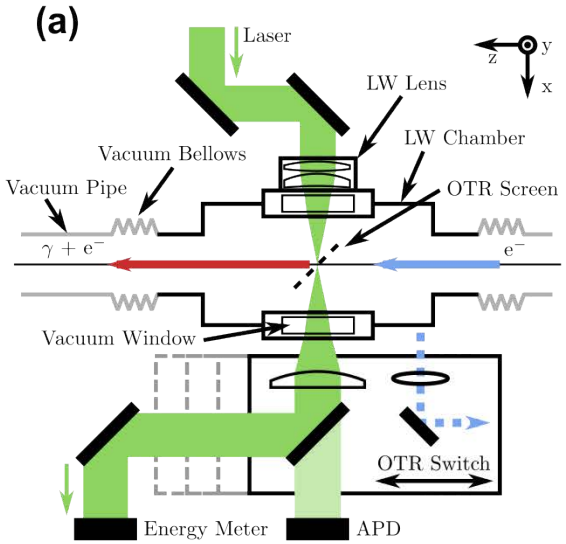
Collimeter

- Reduction and control the beam halo



Laser wire

- Demonstration of beam size measurement of ≈ 1um



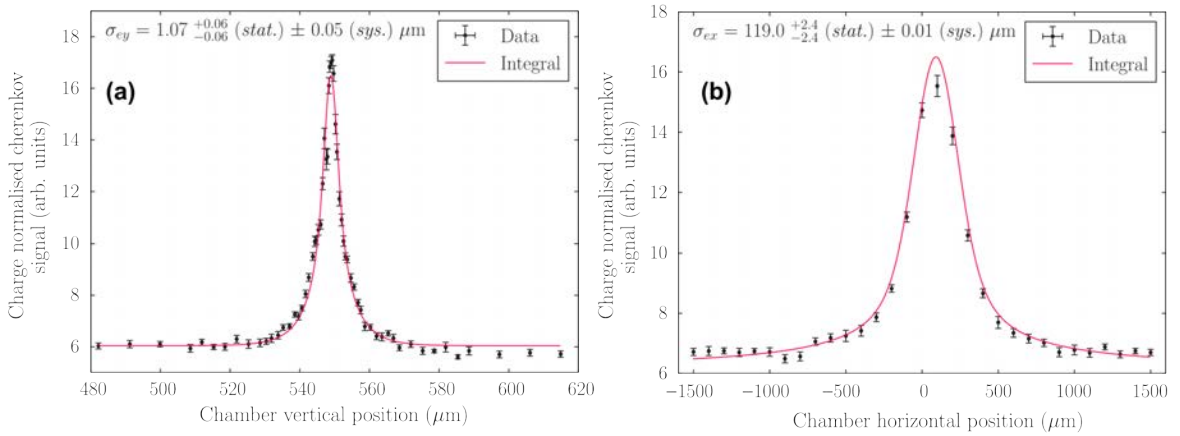


Figure 60: Vertical laserwire scan with nonlinear step size and the smallest measured electron beam size (*a*). Horizontal laserwire scan for the smallest vertical scan (*b*).

Optical Radiation Monitors

- Milti-OTR system → emittance & Twiss parameter measurement
- OTR/ODR with submicron resolution
- ChODR
  Cherenkov radiation ← beam goes in parallel to a dielectric interface

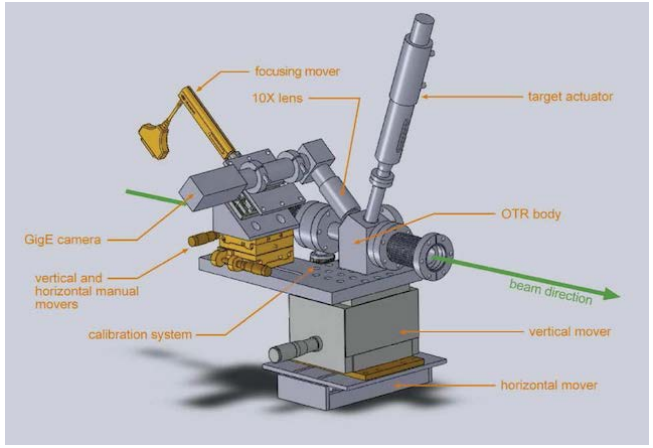


Figure 61: Schematic of the OTR station: The four OTR stations have the same configuration.

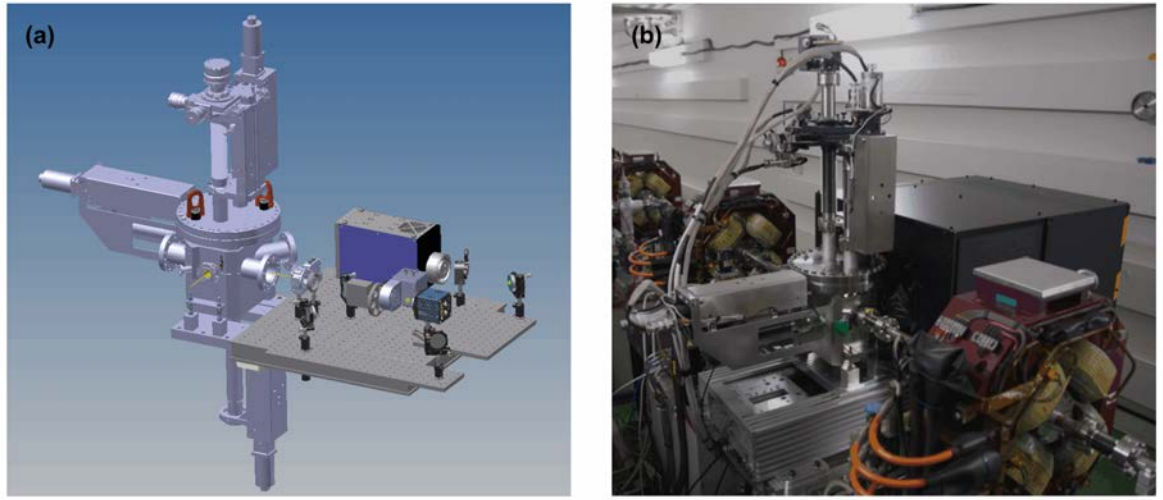


Figure 64: Schematic illustration of the tank and optical instrument (*a*), and the tank and optical instrument installed in the extraction line of ATF2 (*b*).

Summary

- ATF is a test accelerator mainly for LC R&D.
- ATF DR provides low emittance beam for the studies.
- ATF2 studies final focus system including its instrumentations.
- Some instrumentation R&D are briefly reported here.