ASTA *Standard* Beam Diagnostics

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ASTA User's Meeting
July 23, 2013

Outline

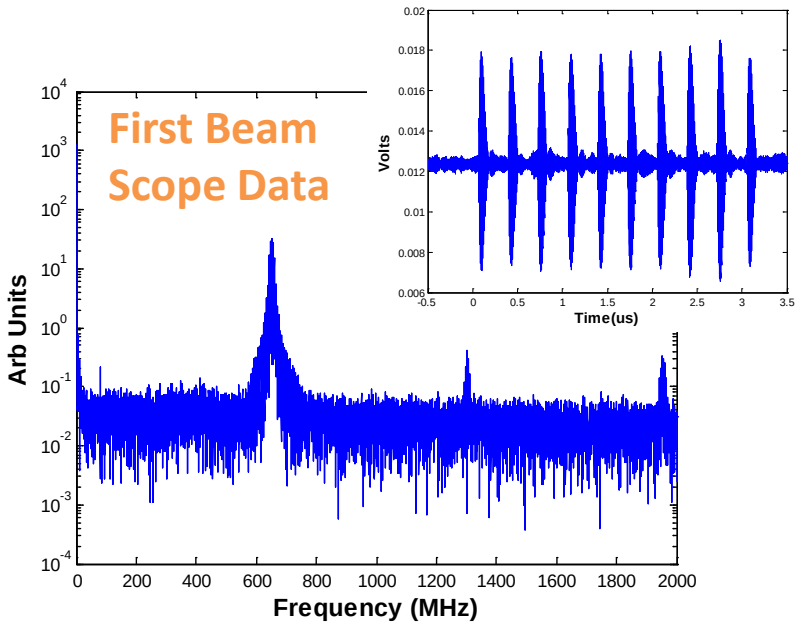
- Beam Position Monitors
- Intensity Monitors
- Transverse Profile Monitors
- Longitudinal Profile Monitors
- Bunch Arrival-time Monitor

Beam Position Monitors

- 11mm button electrode with sma feedthru in 47.5mm inner diameter housing
- 4 Button electrodes provide horizontal and vertical measurement
- 36 pickups in LE beamlines
  - 23 in straight ahead to CM2 (LE1)
  - 13 in diagnostic dump line (LE2)
- 27 pickups in the HE beamlines
  - 8 in HE 4
  - 19 in HE5-7
- 63 total pickups

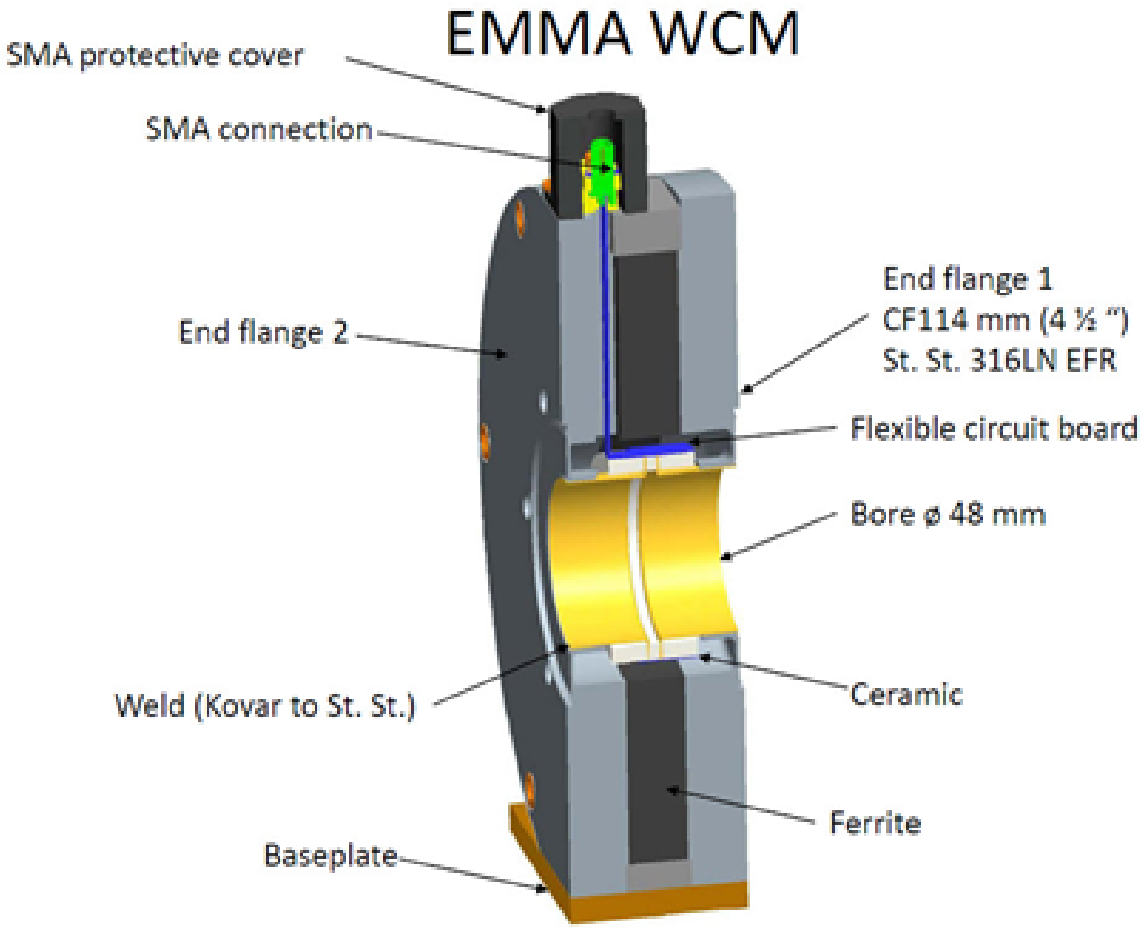
Beam Position Monitors

- In tunnel signal conditioning and downmix electronics for 650MHz
- Digital signal processing via custom 12 channel 250MS/s VME/VXS digitizers
- Upgrade of system developed for the ATF damping ring at KEK
- For nominal bunch charge (3nC)
  - <50μm micropulse (single bunch) resolution
  - ~1μm full 1ms macropulse (3000 bunches) resolution
  - Provide relative intensity and beam phase
- Will provide sensitivity down to ~50pC per bunch



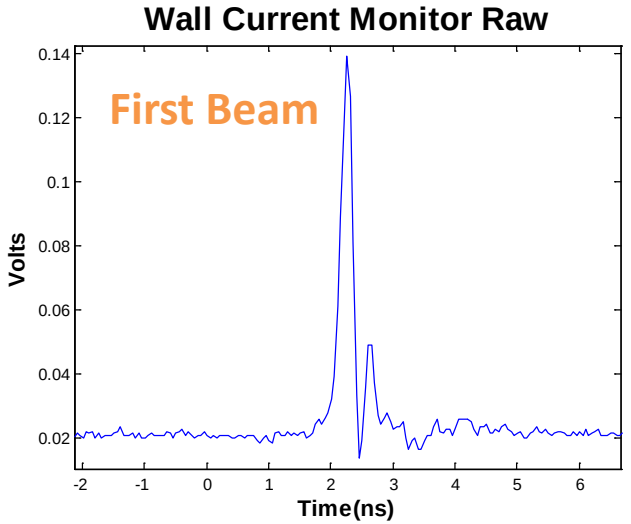
Intensity Monitor

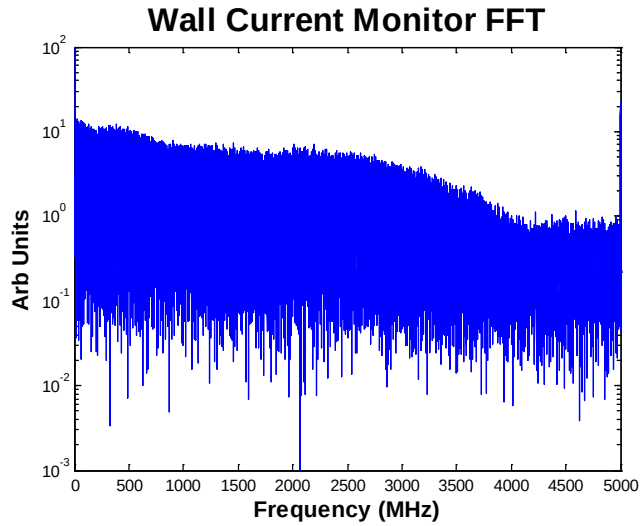
- Use high bandwidth Wall Current Monitor developed for EMMA
- Compact 50mm design including flanges with 48mm diameter bore
- Low frequency cutoff of ~16kHz due to gap resistance and ferrite inductance
- High frequency range of ~4GHz limited by microwave cutoff of high order modes
- 5 monitors total
  - 2 in LE1, 1 LE2, 1 HE4, 1 HE5-7



Intensity Monitor

- Provide bunch by bunch intensity via analog integrator and custom digitizer
- Use dual channels to sample signal and background for each bunch
- For nominal 3nC bunch charge will provide 1% relative bunch intensity
- Absolute calibration under study
  - May include Toroid to facilitate calibration



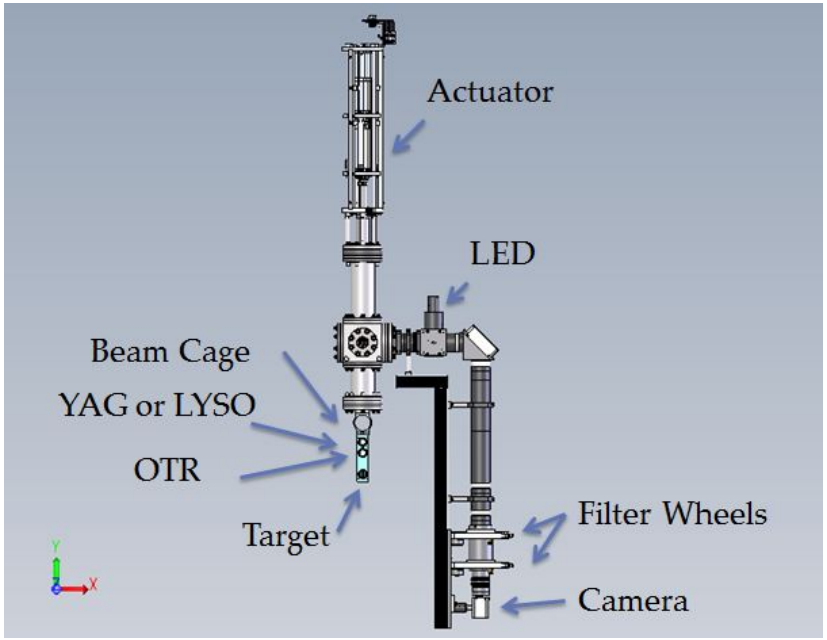


Transverse Profile Monitors

- 22 Crosses with 18 OTR and 20 YAG
  - 8 LE1, 5 LE2, 2 HE4, 7 HE5-7
- Optics: 150mm, mirror, 150mm, 200mm (achromats), 75mm machine lens
- Filter Wheels:
  - A: Blank, ND0.3,ND1.0, ND2.0, ND3.0
  - B: Blank, 400±35nm, 550±35nm,

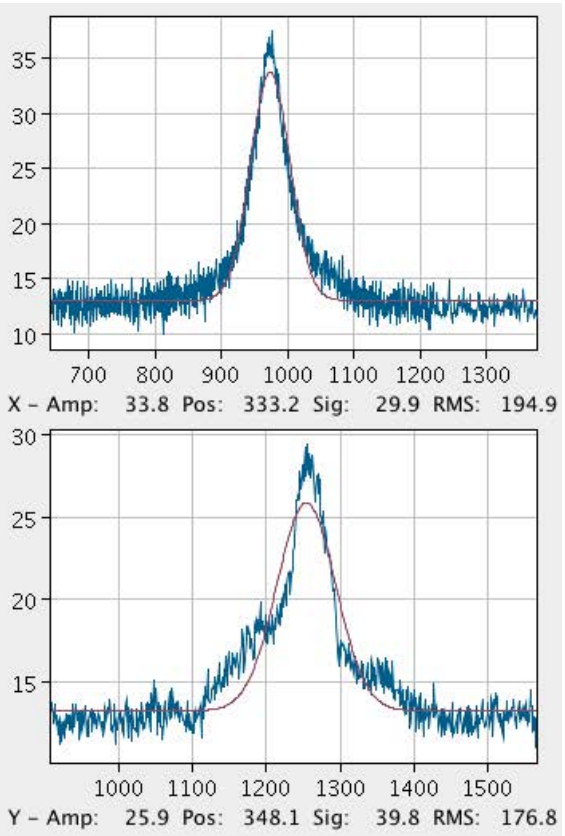
    Horizontal Polarizer, Vertical Polarizer
- Camera
  - Prosilica GC2450: 5MegaPixel, GigE, 25µsec shutter,

RadiaBeam Cross



- Single crystal, oriented normal to beam
  - Reduce depth-of-focus and powder resolution effects
- OTR and Crystal cover wide charge range
  - 20pC-3.2nC

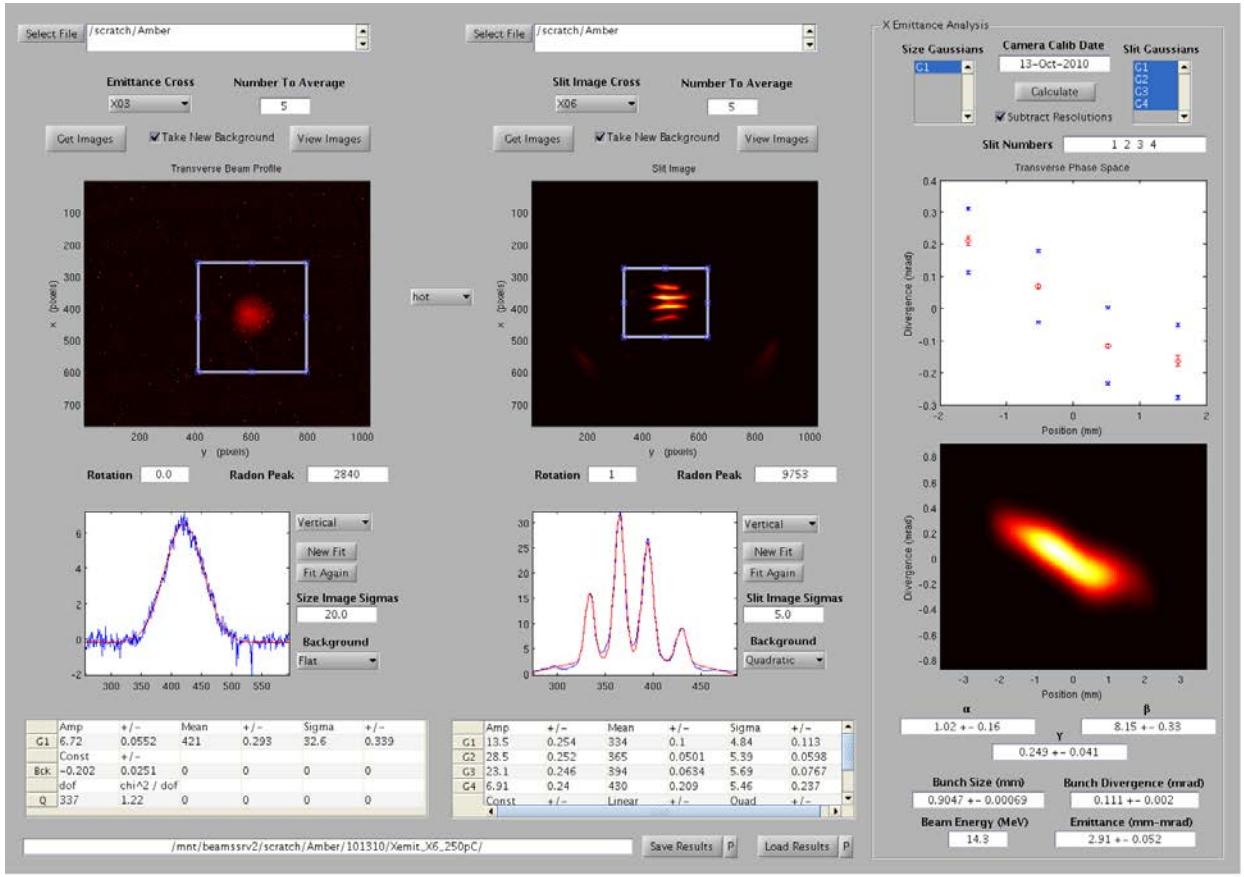
First Beam at ASTA
July 11, 2013



No data
Position: 0.0px, 88.0px Intensity: 0
ROI is: 640.0, 906.0 - 1376.0, 1567.0 Height: 661.0um Width: 736.0um Active

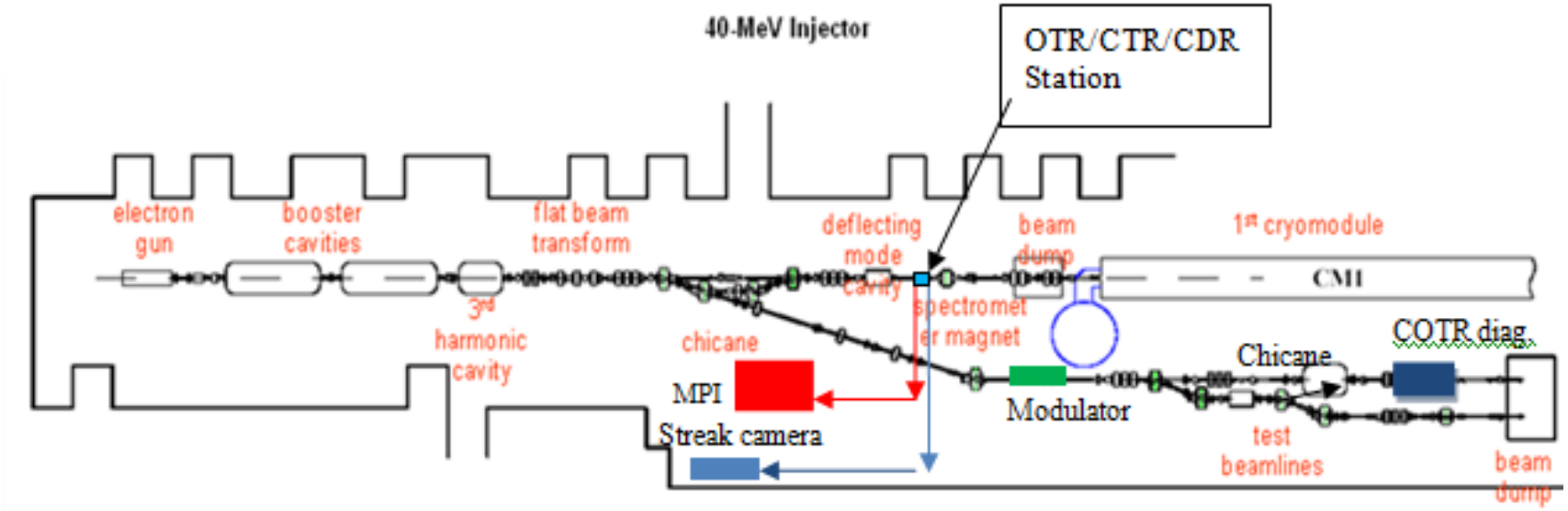
Emittance Measurement

- MATLAB Application tool at A0PI provided online emittance and C-S parameter calculations to facilitate operations.
- Analogous version being developed for ASTA using 3 slit crosses – 2 in LE1 and 1 in LE2

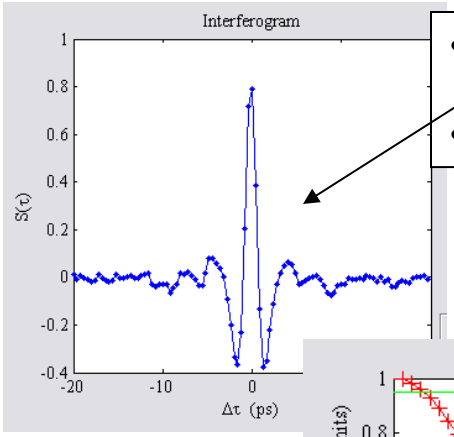


Longitudinal Monitors

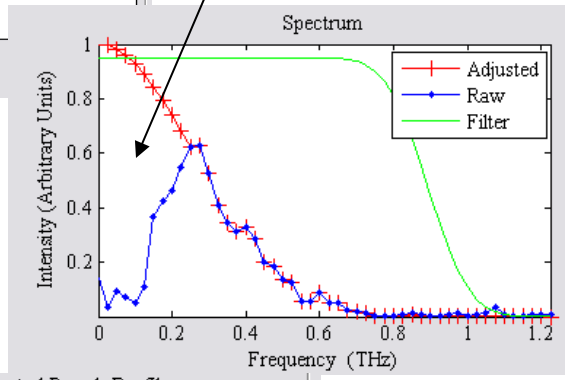
- Hamamatsu C5680 dual-sweep streak camera (resolution of 0.6 ps (sigma)) viewing optical transition radiation (OTR). Synchroscan vertical sweep unit phase locked to 81.25 MHz. Optical synchrotron radiation (OSR) from a chicane dipole might also be used at high beam power.
- Martin-Puplett Interferometer (MPI) viewing FIR coherent transition radiation (CTR) or the proposed coherent diffraction radiation (CDR).
- If the chicane is unpowered, the input bunch length can then be measured.
- A second station may be installed in the high energy end after the upstream dipole.



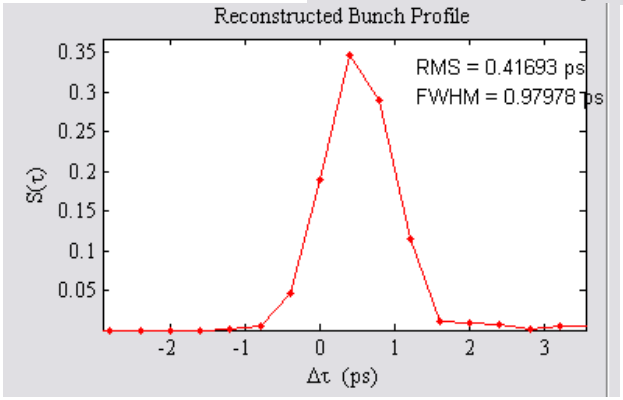
Martin-Puplett Interferometer



- Bunch shape is related to autocorrelation trace, $S(\tau)$, of either CTR or CSR
- Missing low frequencies have to be filled in



Data from A0 Emittance Exchange Experiment

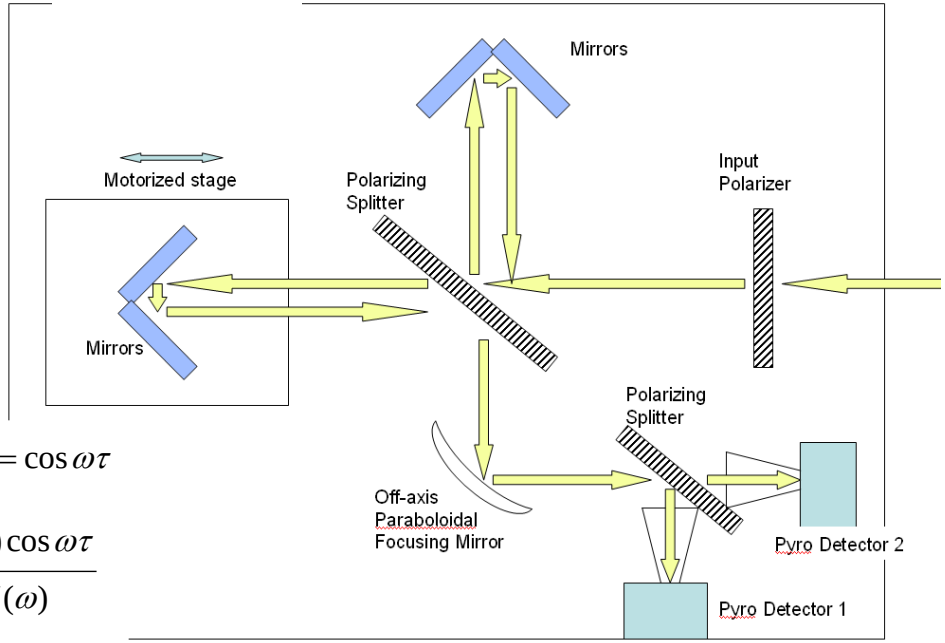


Incoherent Coherent

$$I(\omega) = I_0(\omega)\left(N + N(N-1)\left|F(\omega)\right|^2\right)$$

$$F(\omega) = \frac{1}{Q}\int d^3x \rho(\vec{x}) e^{-i\omega(\vec{x}\cdot\hat{n})}$$

Bunch Size



$$I_1 \propto \frac{E_0^2}{2}\cos^2\frac{\omega\tau}{2}$$

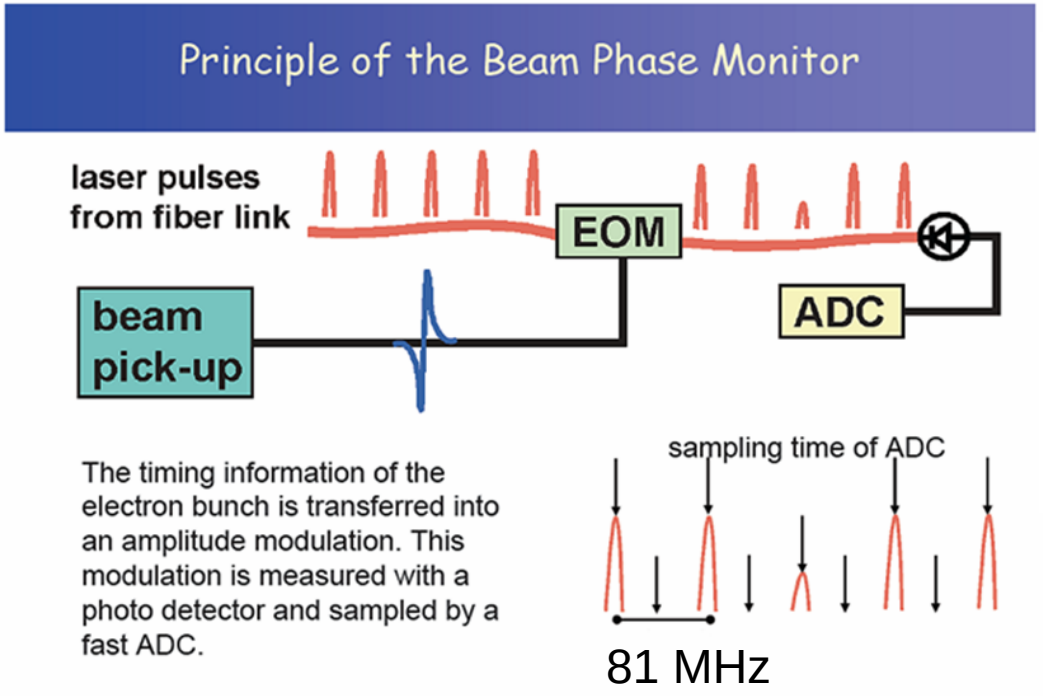
$$I_2 \propto \frac{E_0^2}{2}\sin^2\frac{\omega\tau}{2}$$

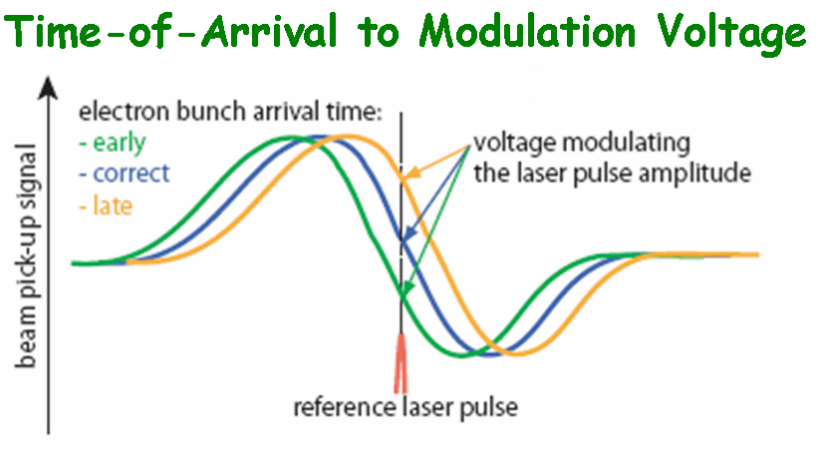
$$S(\tau,\omega) = \frac{I_1 - I_2}{I_1 + I_2} = \cos\omega\tau$$

$$S(\tau) = \frac{\int d\omega\, I(\omega)\cos\omega\tau}{\int d\omega\, I(\omega)}$$

Bunch Arrival-time Monitor

- ASTA requirement to measure bunch-by-bunch time-of-arrival to sub-ps levels
- Utilize femtosecond laser and electro-optical modulation to sample bunch time-of-arrival relative to accelerator master oscillator

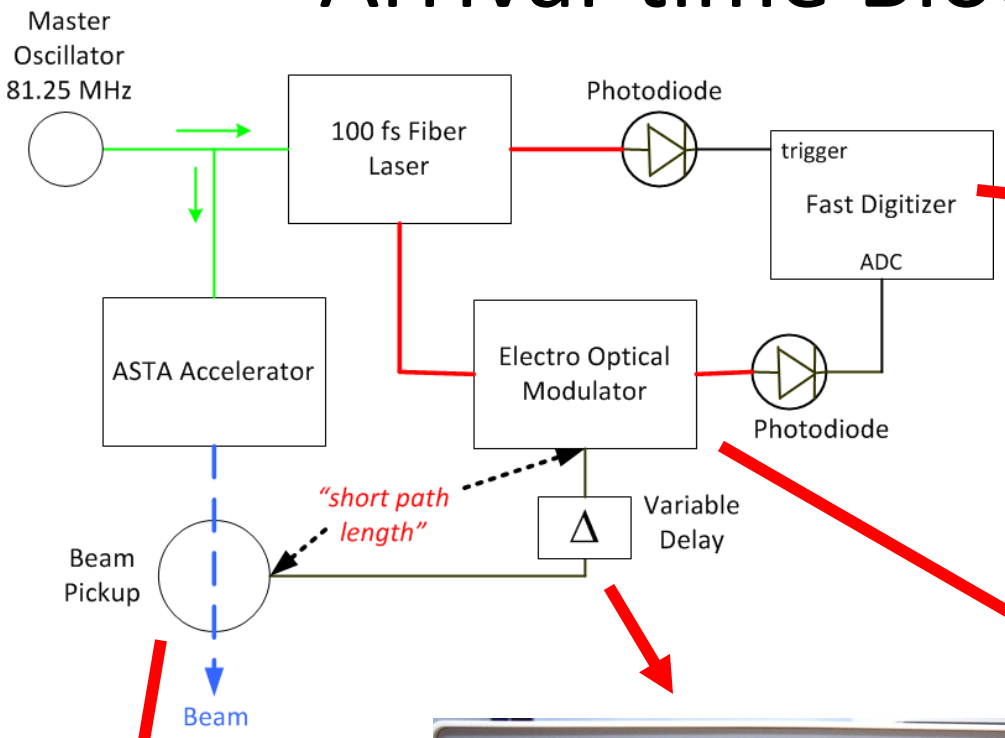


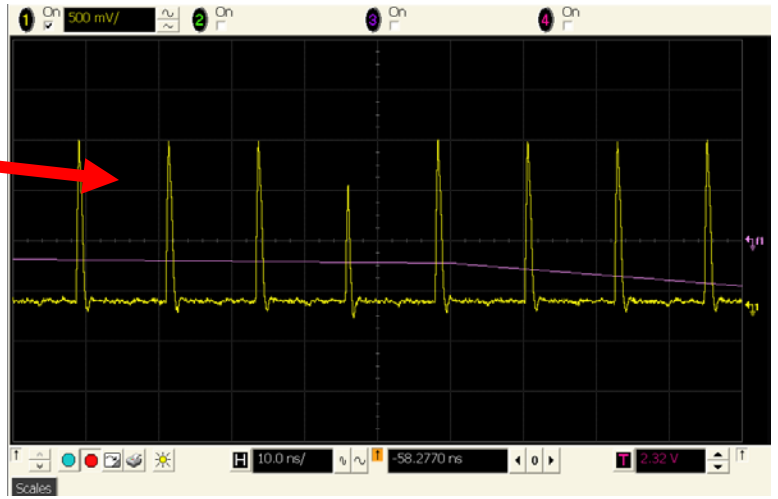


courtesy *F. Loehl, DESY*

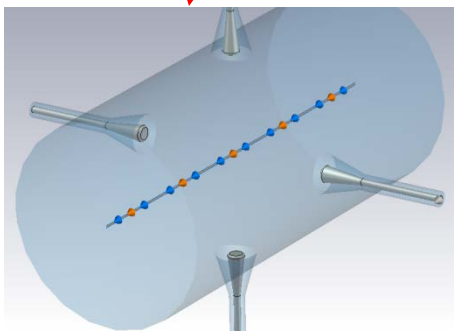
Modulate laser pulse with zero-crossing voltage from beam pickup.

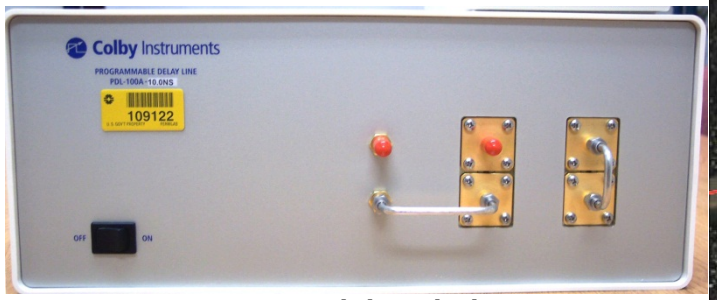
Arrival-time Block Diagram



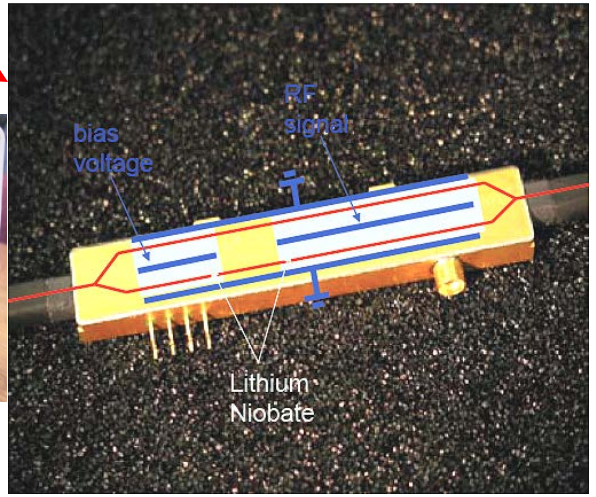


Modulated Laser Pulse





Programmable delay
0.5 ps steps; 10 ns range



Commercial EOM; 10 GHz BW

Please contact eddy@fnal.gov with questions or requests

Thanks for your attention!