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Beam Diagnostics of SDUV-FEL

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FEL2010 Malmo,Sweden 2010.8.27

Outline

- Overview of diagnostics
- FEL experiments
- Summary

Goal of SDUV FEL experiments

- SASE FEL experiment

  262nm-400nm, expected gain, 103-104,
  with 9m undulator. (saturation length is ~20 m)

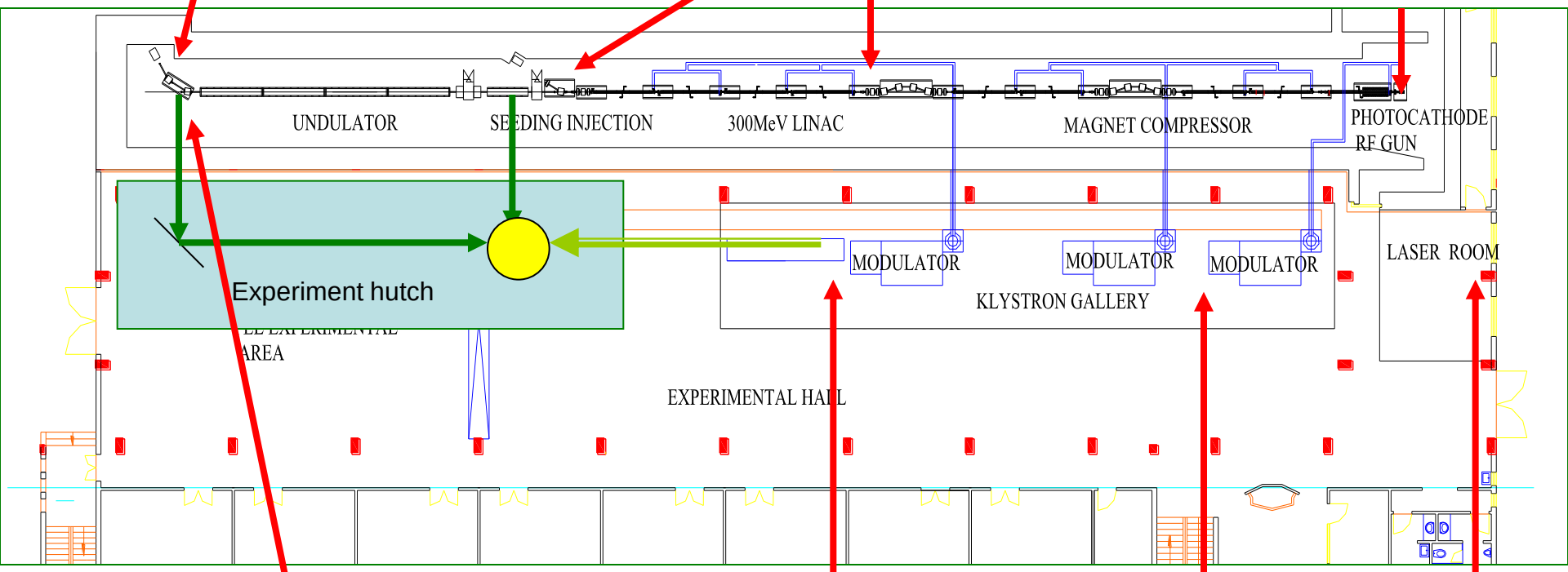
- HGHG experiment

  1047nm => 349nm (h =3, correspond to ~137MeV)
  1047nm => 262nm (h=4, correspond to ~160MeV)
  able to reach saturation with 9m undulator

- Echo (EEHG) experiment

  proof-of-principle experiment (low harmonics, 523nm)
  high harmonics experiment (Ehco's ultimate advantage) at 149nm(7^{th}) and 116nm(9^{th}) etc.

Facility layout

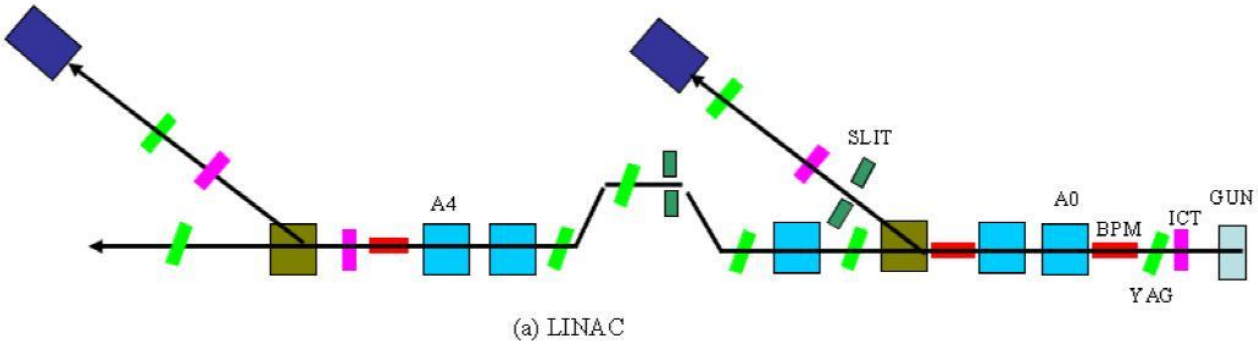


Tasks & solution

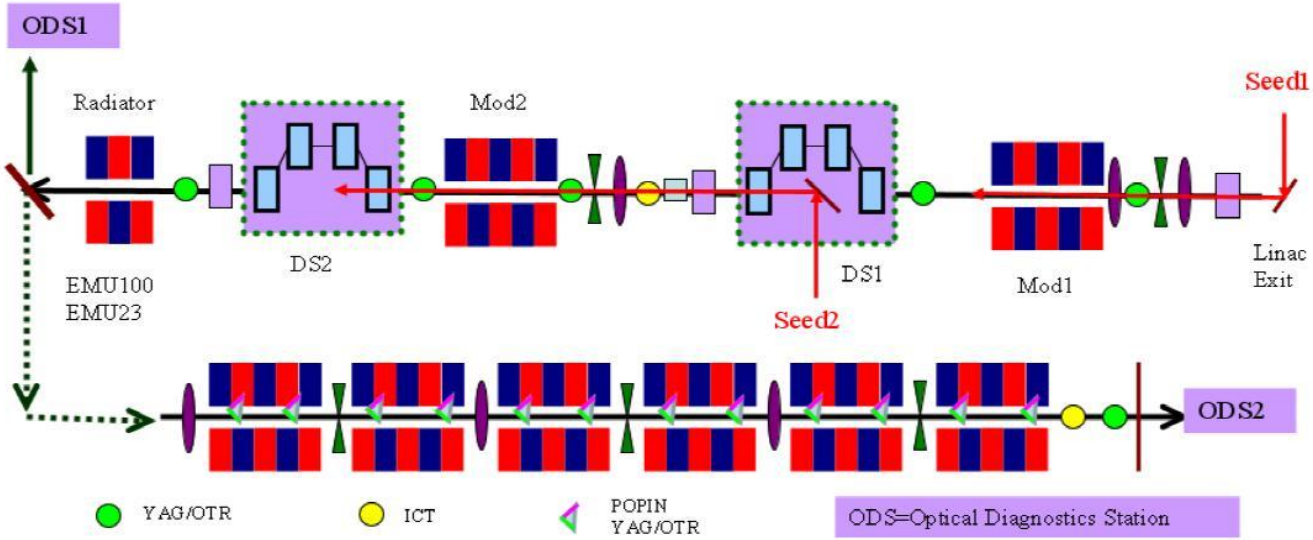
	Parameter	Solution	Remark
Electron beam quality	Intensity	ICT + scope	
	Position	RF BPM + Libera	
	Profile	YAG / OTR	
	Emittance	OTR + Q scan	
	Bunch length	Deflecting cavity + YAG	No Power / correlation
	Energy spread	YAG + B magnet	
Commissioning tools for FEL experiments	Orbit	Pop-in YAG	Repeatability
	Overlap in space	YAG	
	Overlap in time	OTR + PD + scope	Bunch length
FEL quality	Intensity	PD, CCD	Visible light
	Spectra	Spectrometer	

Diagnostics layout

- 3 stripline BPMs at Linac
- 4 ICTs at Linac
- 2 scrapers at Linac
- 2 energy spectrometer
- 7 YAG/OTR at Linac



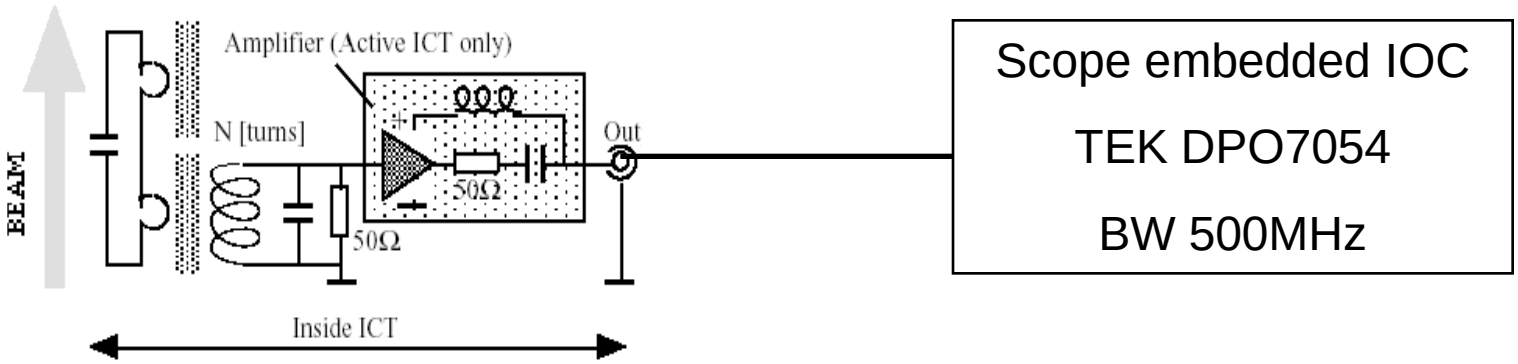
(a) LINAC



(b) Undulator

- 7 YAG/OTR at undulator
- 2 ICTs at Undulator
- 12 pop-in probe in undulator
- 2 optical diagnostics station

Bunch charge measurement: ICT

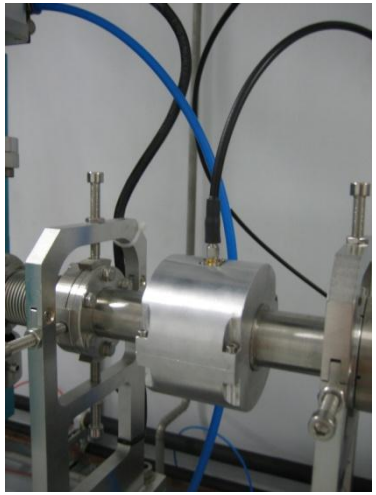


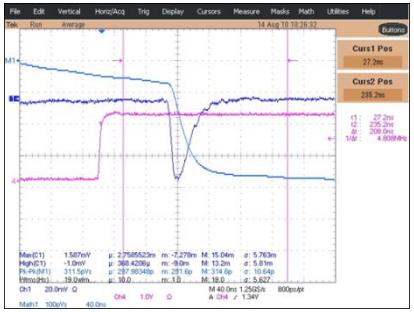
Scope embedded IOC

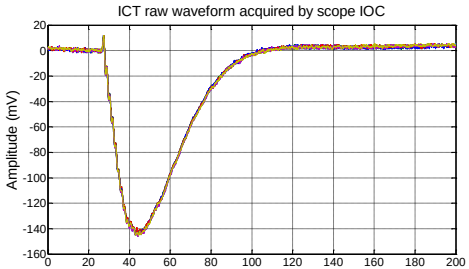
TEK DPO7054

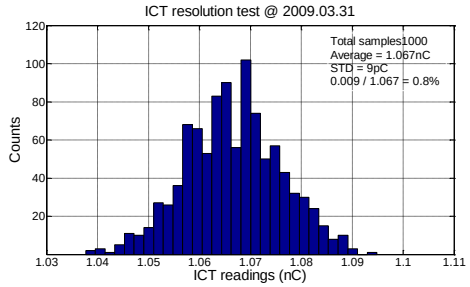
BW 500MHz

Bergoz ICT



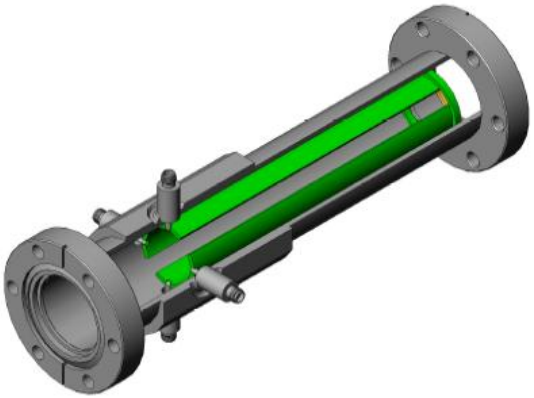


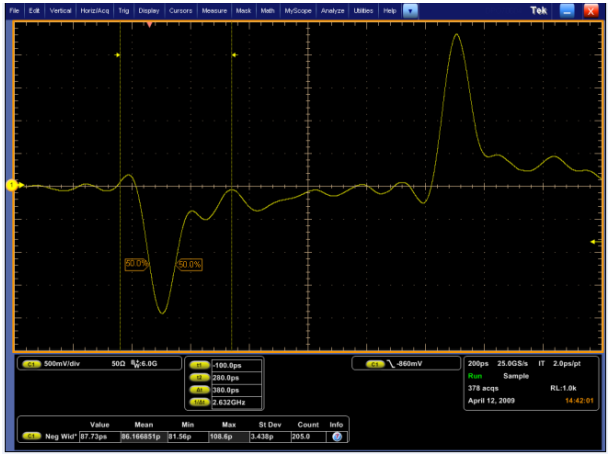


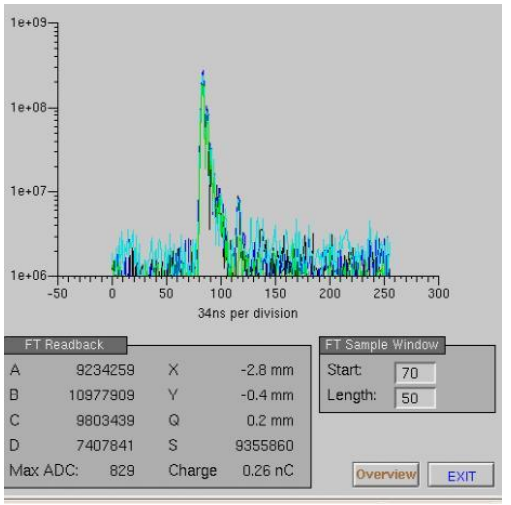


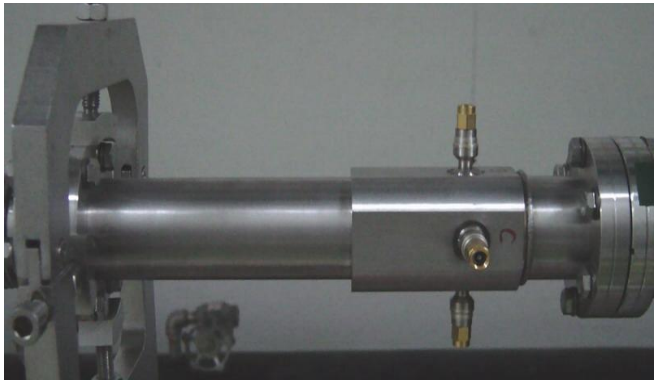
1000 samples **RMS: 1.6pC/200pC = 0.8%** **P-P: 10/200 = 5%**

Electron beam position measurement



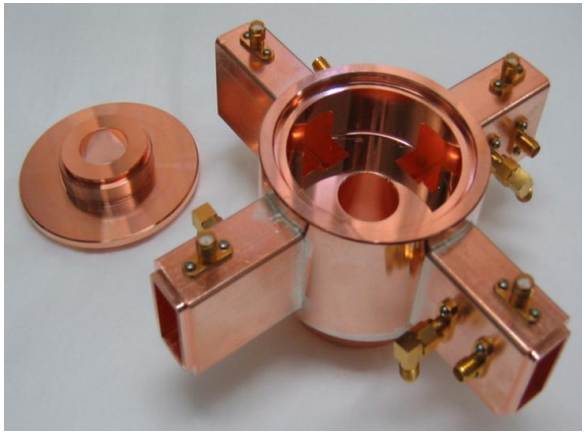


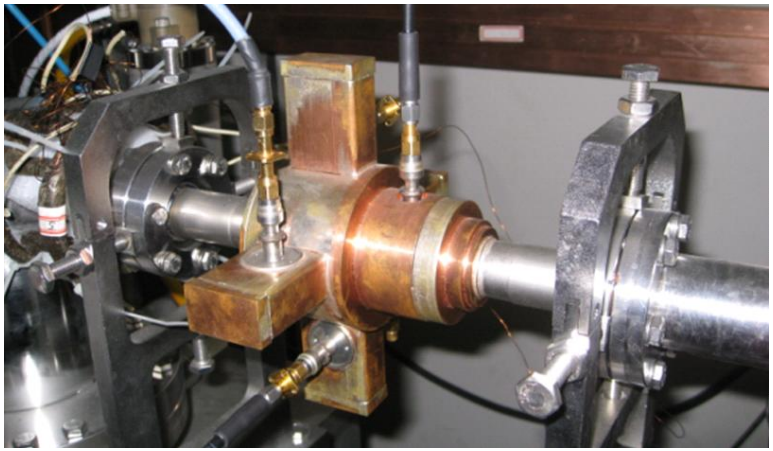




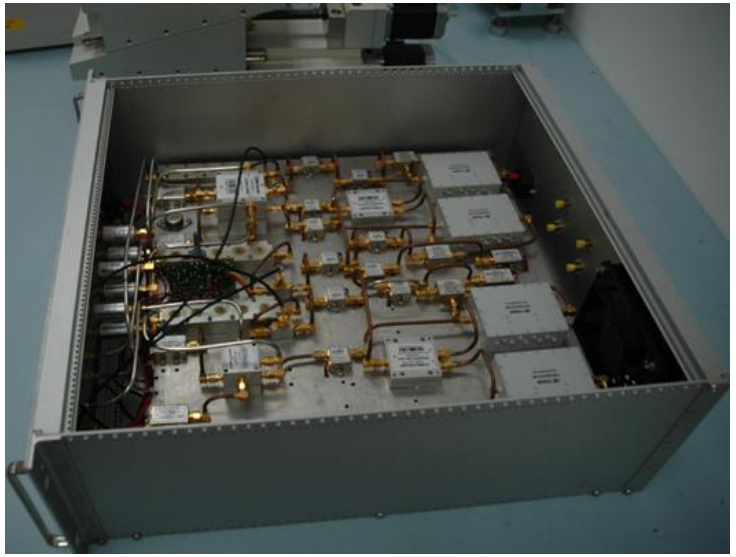
- Stripline RF BPM 60 degree, 150mm
- Libera Electron processor
- Typical deviation (with beam moving) ~ 30um

Electron beam position measurement

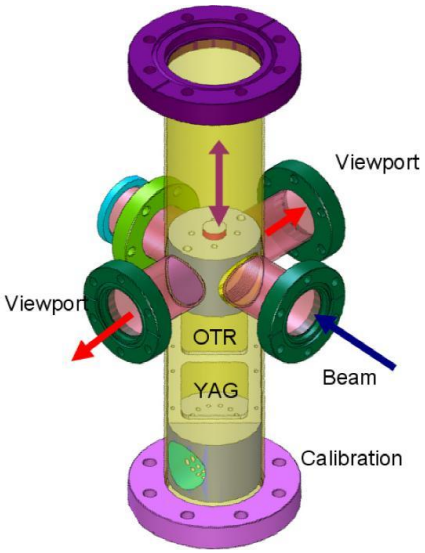




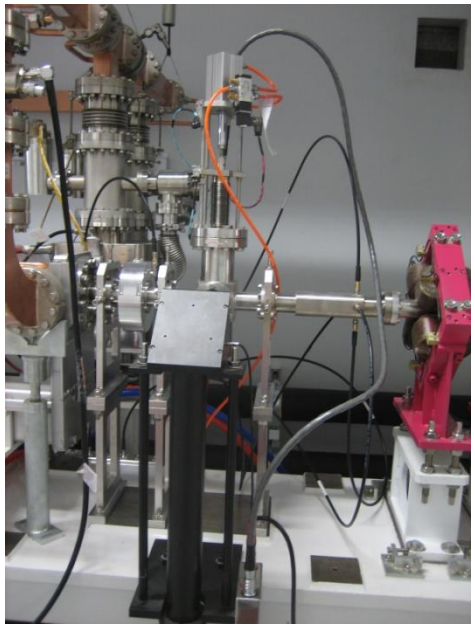
- C band, 5712MHz
- Tested in photon RF Gun test bed

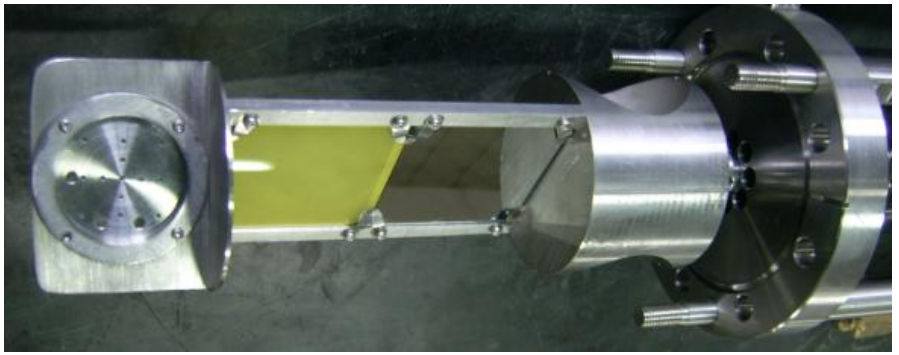


Electron beam transverse profile observing



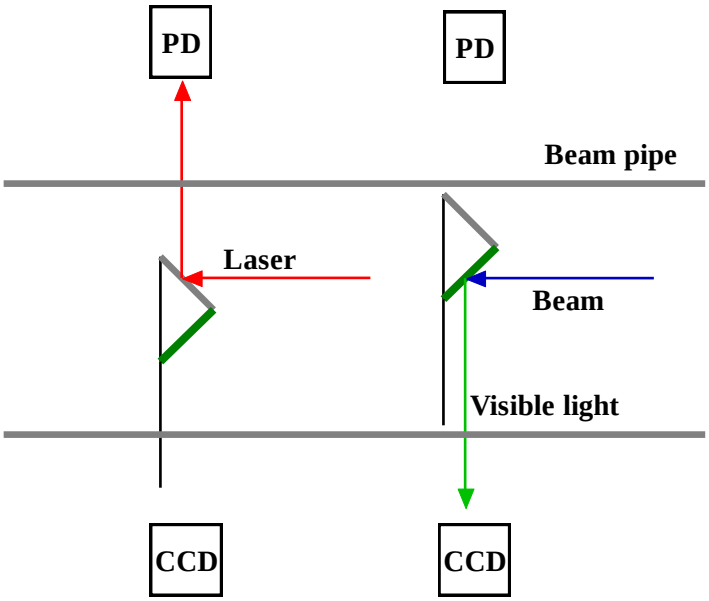
- Multi stages profile monitor (30mm X 50mm)
  - 1st stage Beam bypass
  - 2nd stage YAG screen
  - 3rd stage OTR screen (mirror)
  - 4th stage Calibration plate
- 20:1 magnification with 7.4μm pixel size
- Optical assembly
- GigE CCD camera, 12bit





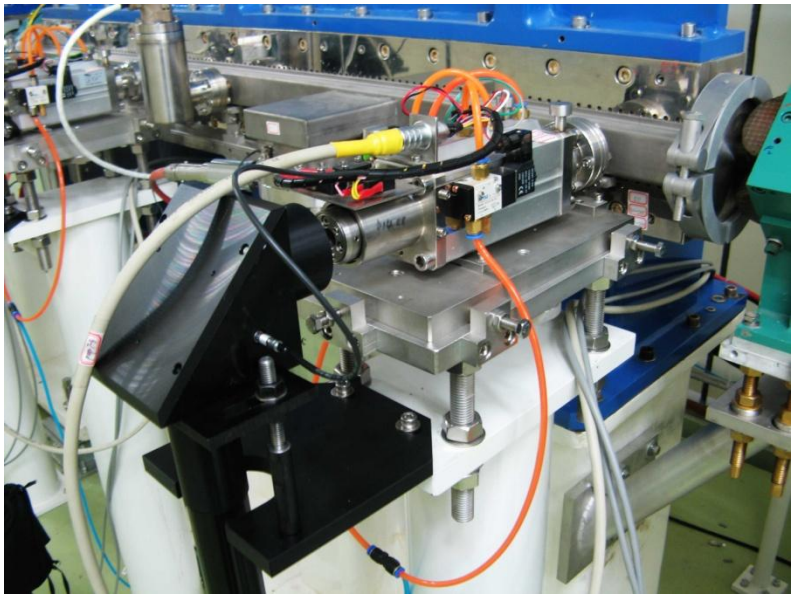
Electron beam transverse profile measurement

- Multi stages profile monitor (4.5mm X 6.5mm)
  - 1st stage Mirror for laser
  - 2nd stage YAG screen
- 1:1 magnification with 7.4μm pixel size
- Optical assembly
- GigE CCD camera, 12bit

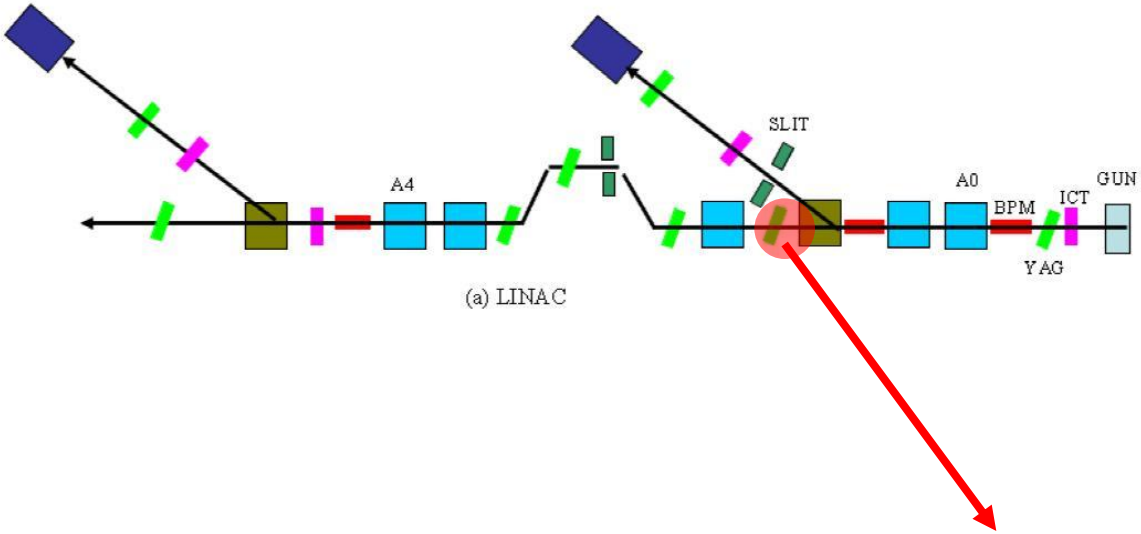


Design borrowed from BNL

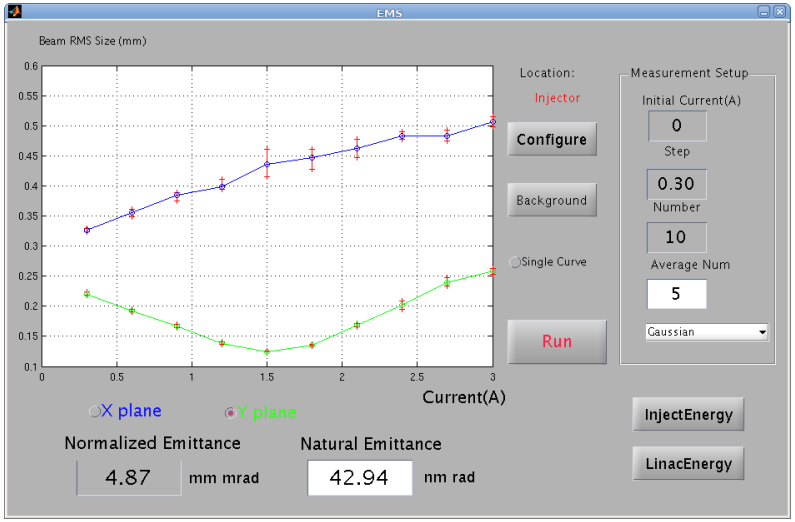
- Vacuum chamber deformation
- Poor repeatability
- Not good for orbit reference

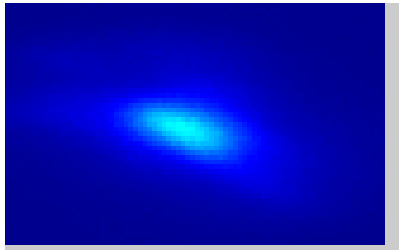


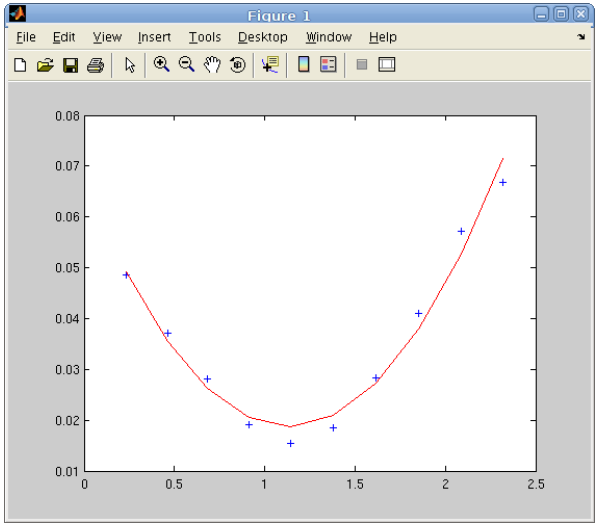
Electron beam emittance measurement



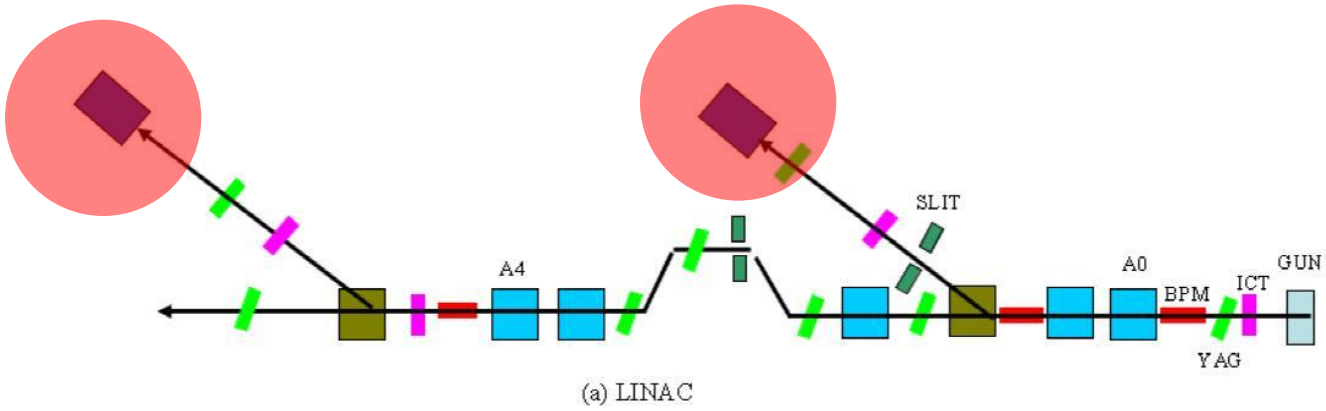
- Quad scan
- OTR screen
- Spatial resolution 25um
- Matlab based routine



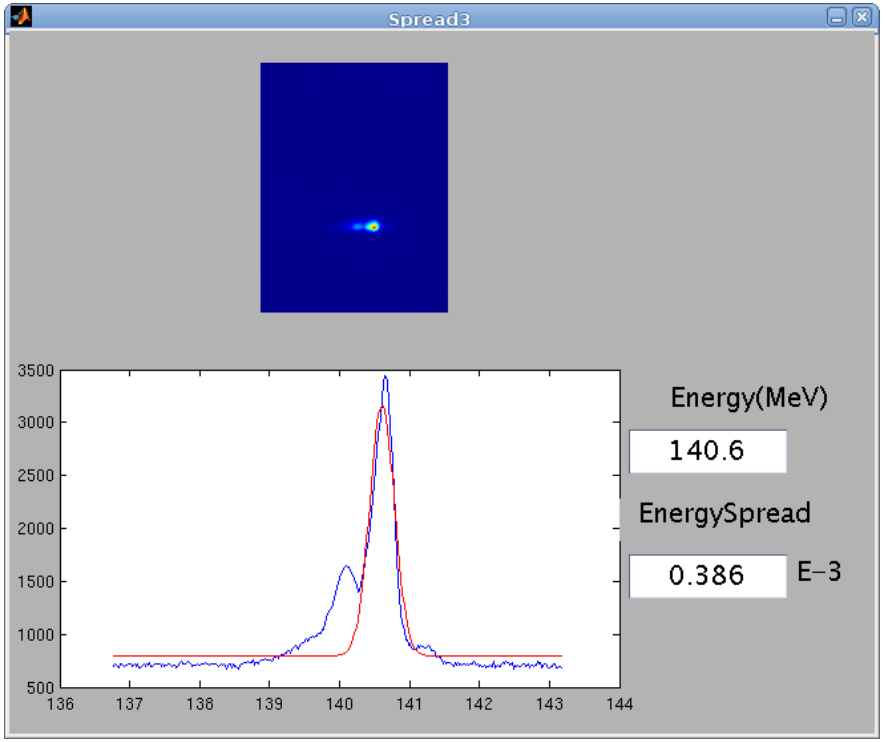




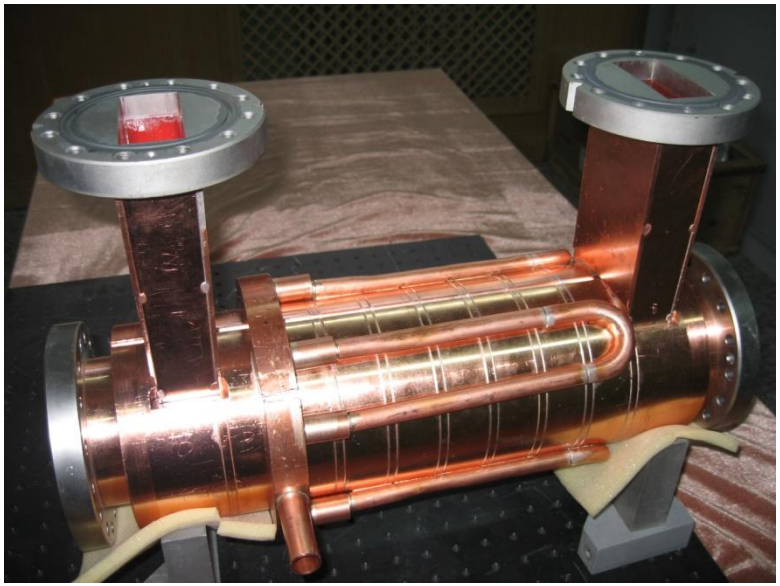
Electron beam energy spread measurement

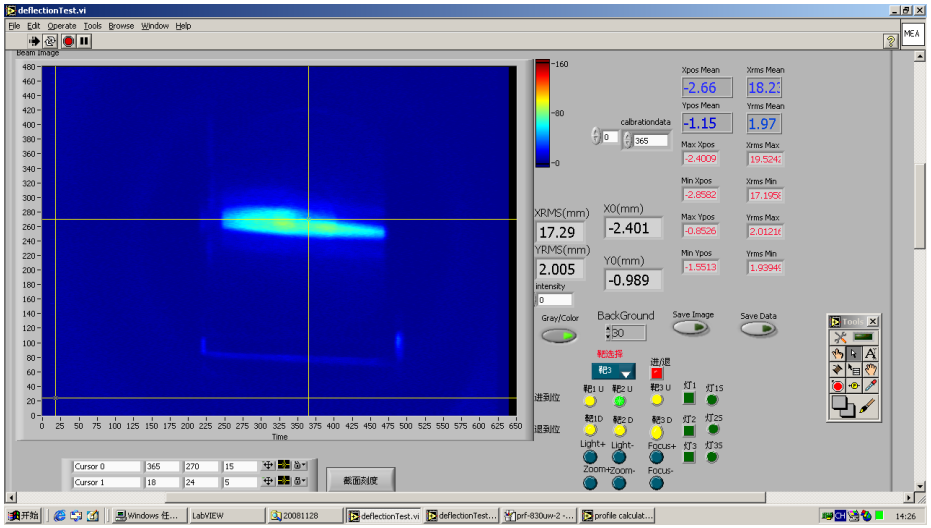


- Two energy spectrometers
  - 60MeV
  - 140MeV
- YAG screen was used due to good sensitivity
- Spatial resolution ~ 50um



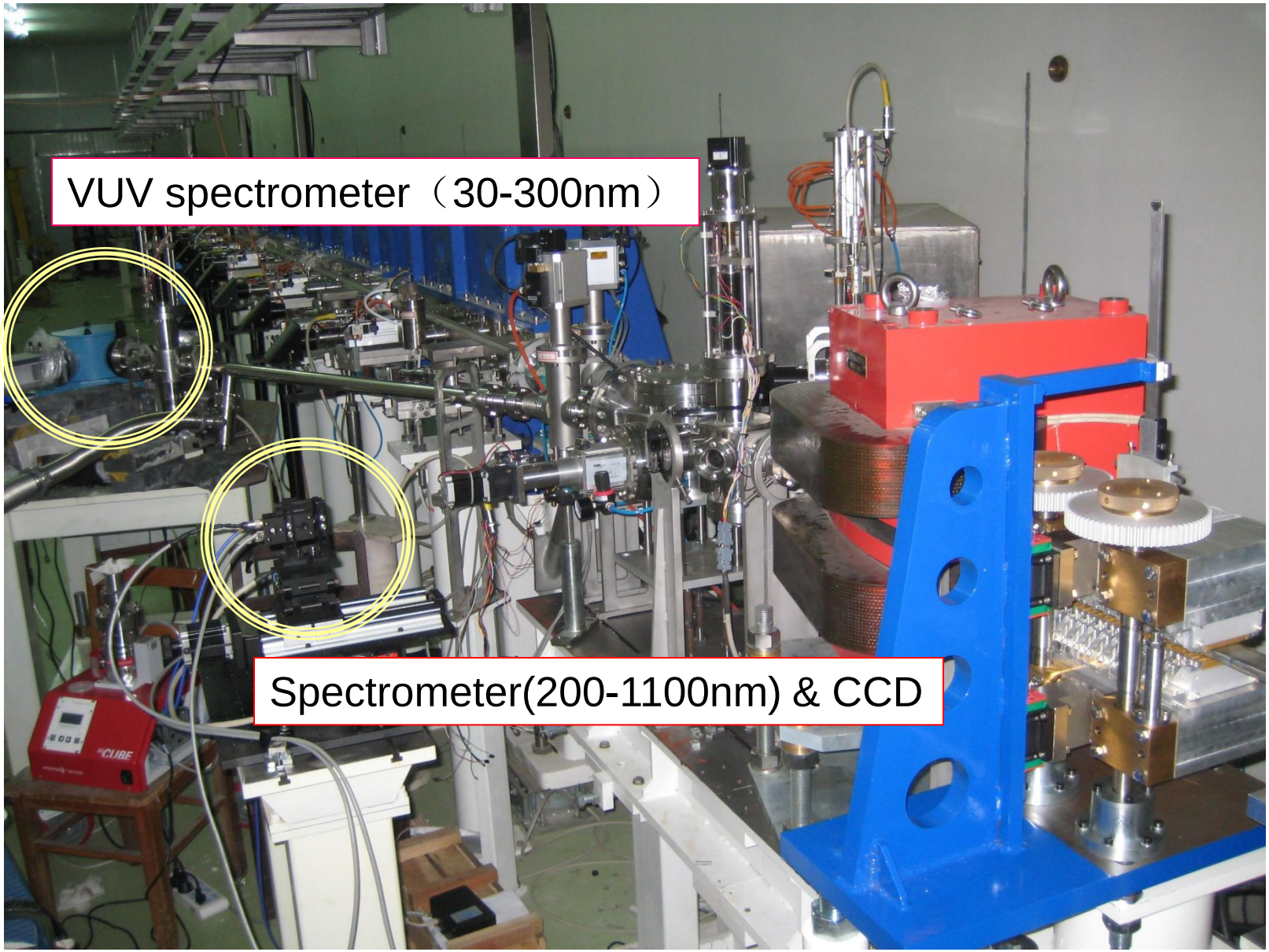
Electron beam bunch length measurement





- Deflecting cavity + YAG
- Demonstrated at photo Gun test bed
- Not applied here due to absence of RF power

Optical diagnostics station

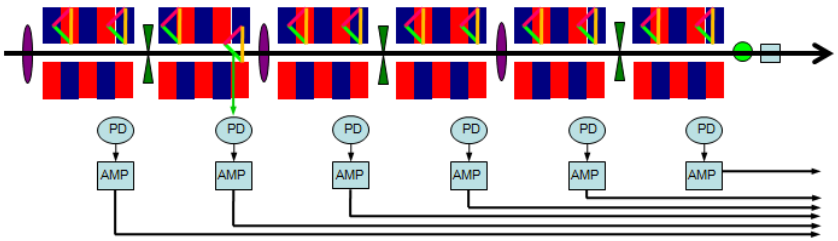


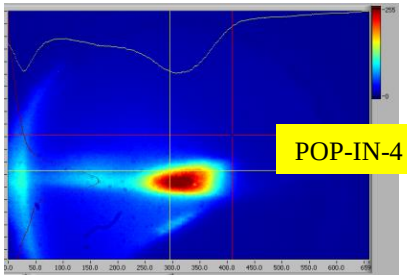
Milestones of FEL experiment

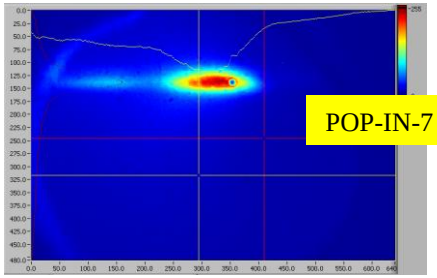
- 2009.04-08: Linac commissioning
- 2009.09-12: SASE experiment
- 2010.01-03: Seeded FEL Installations
- 2010.05: Seeded FEL experiments start
- 2010.05.17: HGHG signal
- 2010.05.22: First Echo signal (‘double-peak’)
- 2010.07-08: Install. for high harmonics EEHG

SASE experiment: plan

- Six photodiodes are used to measure FEL energy in undulators
- SXUV photodiode from IRD company is used
- The deviation of signal of photodiodes is much large due to the poor alignement and vacuum chamber deformation of pop-in monitors

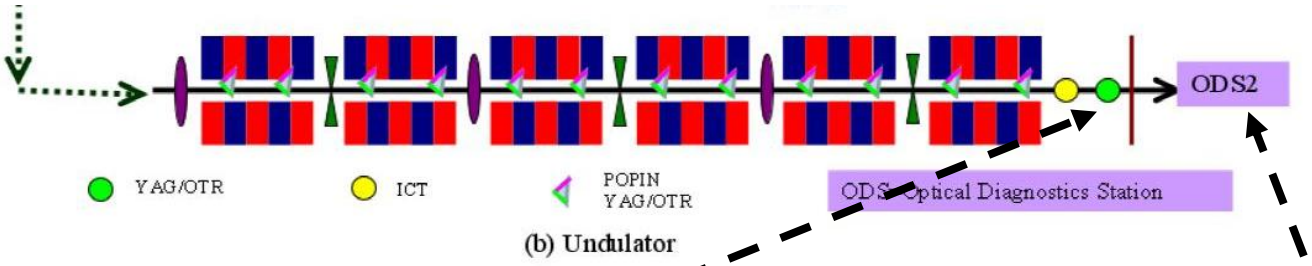


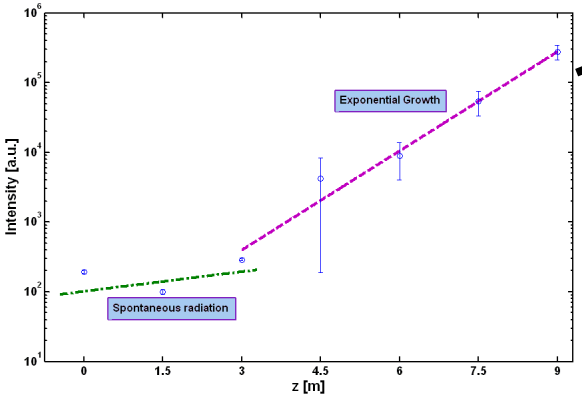


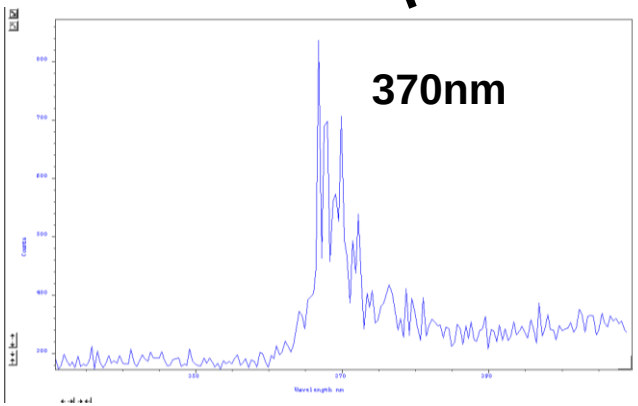


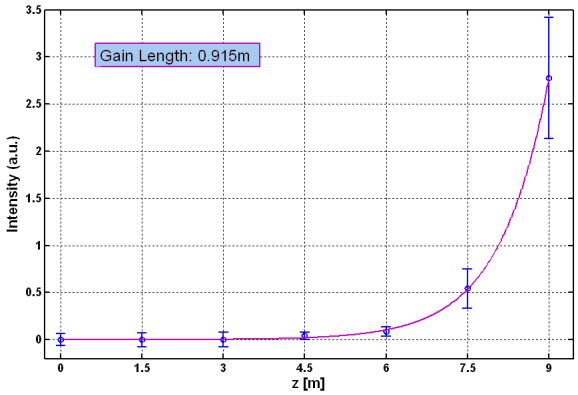
Observe electron beam
Difficult to be orbit reference
Difficult to measure growth curve

SASE experiment: practical



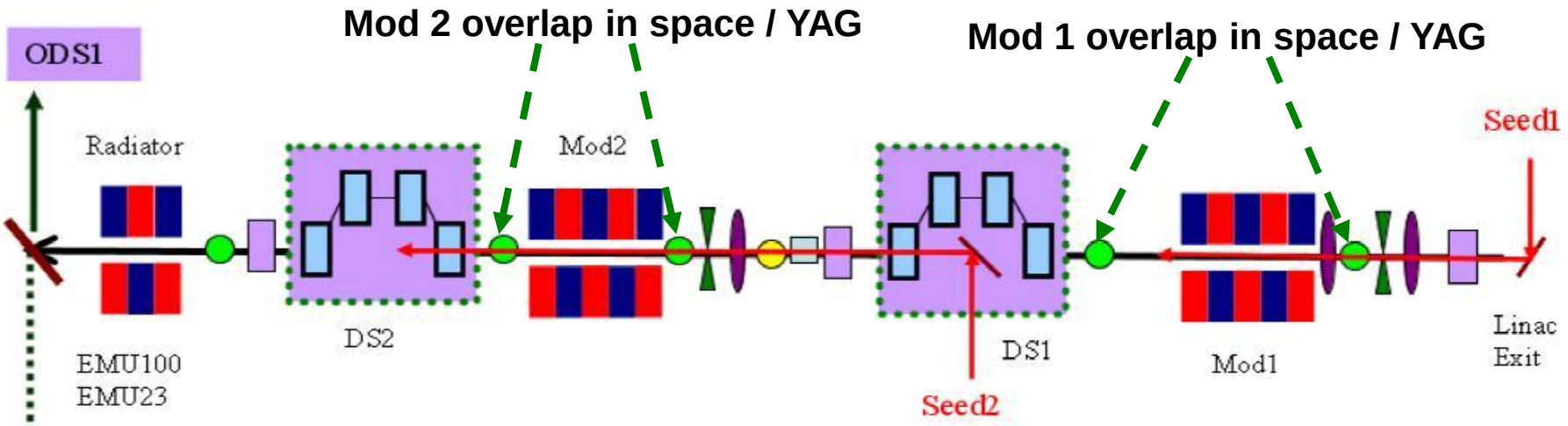


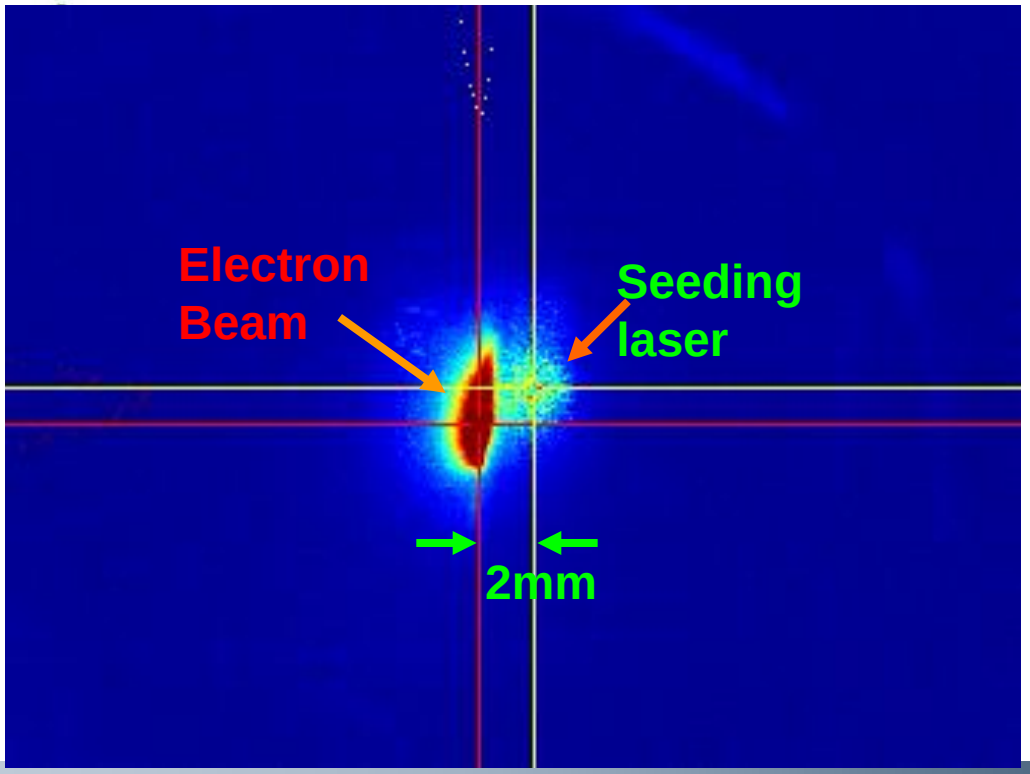


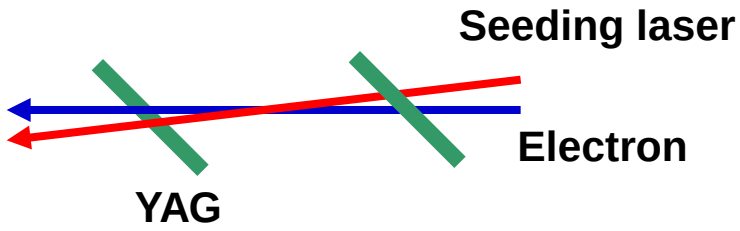


- Measure the FEL intensity (370nm) with CCD via mirror (OTR screen)
- Kick out the electron beam with Quads and Correctors
- The linearity of CCD was test with 262nm laser

ECHO experiment: overlap in space

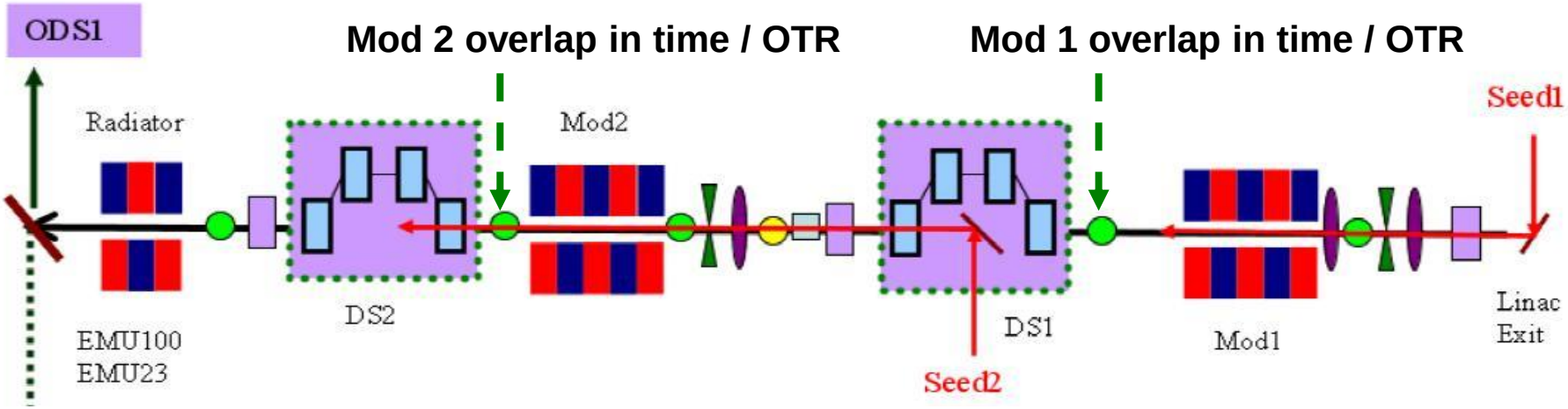


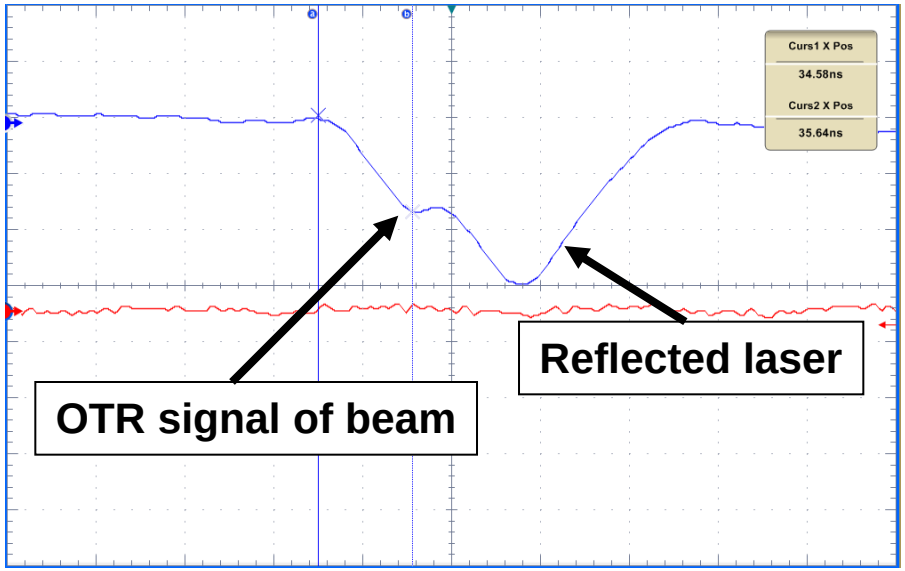




- Align beam and laser transversely through YAG images

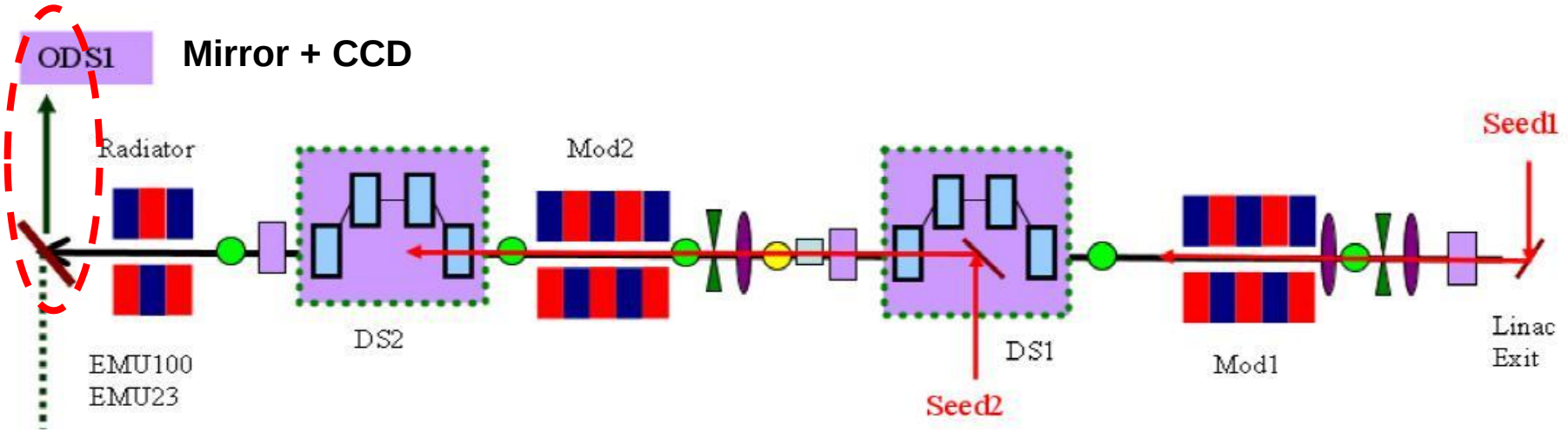
ECHO experiment: overlap in time

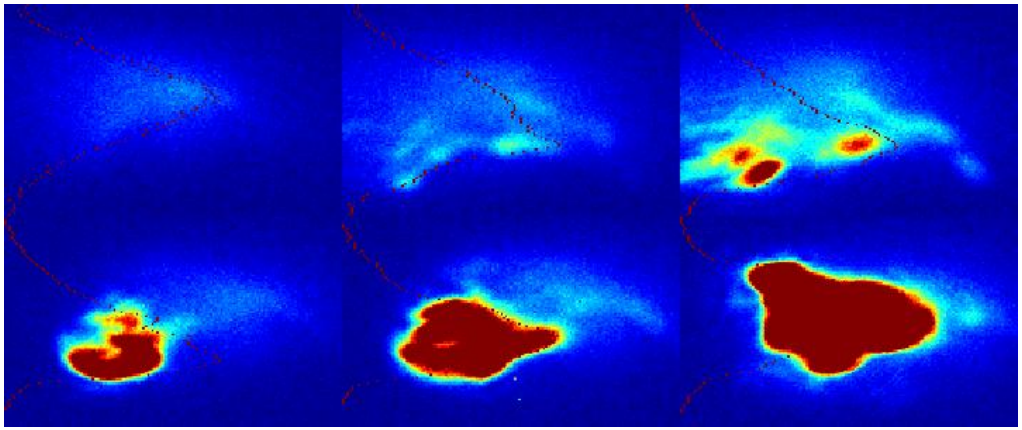


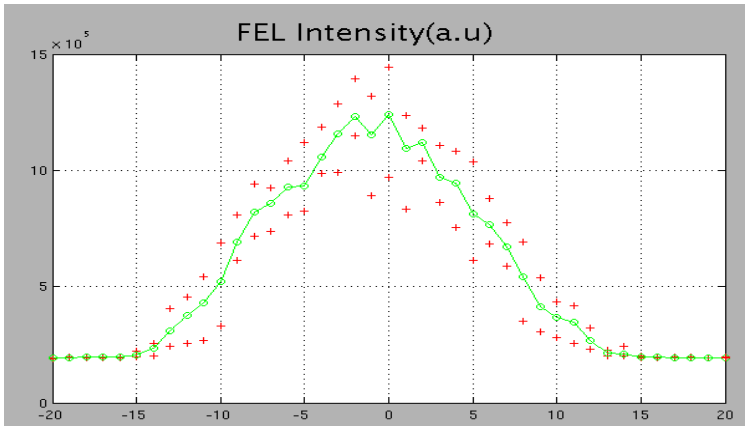


- OTR signal for electron beam
- OTR as mirror for laser
- Fast PD (2GHz) + scope to sample optical signal
- Adjust optical delay and power of laser to merge two peaks together
- $\Delta t \sim 200ps$

ECHO experiment: overlap in time (fine tuning)



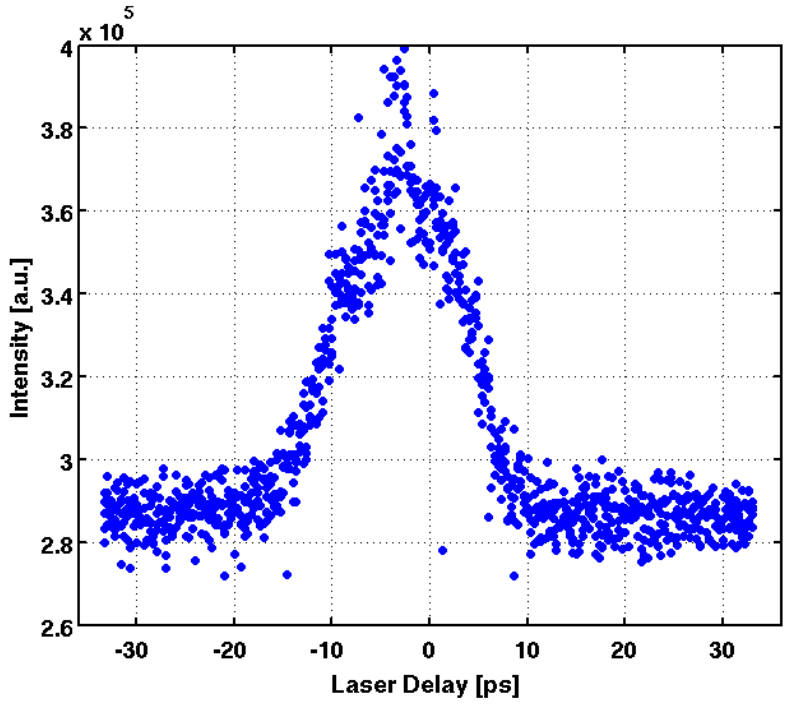




- Scan optical delay of laser within 200ps
- Monitor radiation intensity
- Peak position indicates the optimized delay

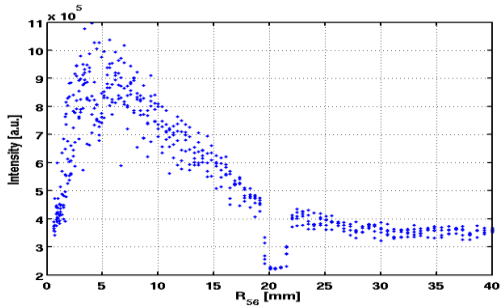
ECHO experiment: bunch length measurement

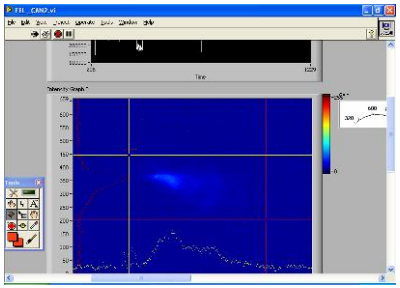
- Correlation of seeded laser and electron beam
- Scan the optical delay of laser
- Observing the intensity of undulator radiation
- Laser pulse : ~ 8ps (lab measured)
- Electron pulse : ~ 10ps



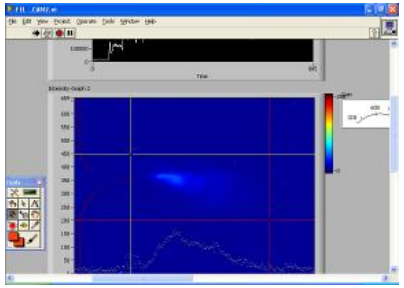
ECHO experiment: double peaks

First modulator: scan R56_1



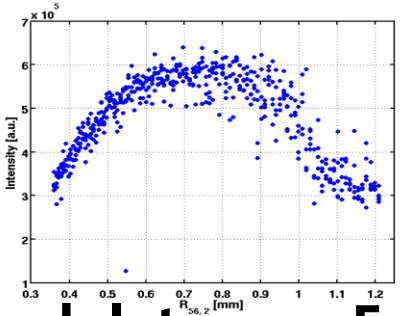


Seed Laser-1 OFF

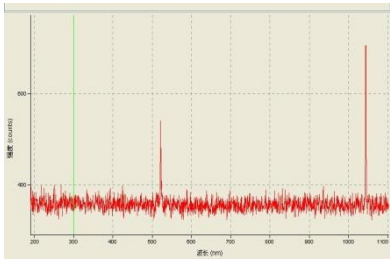


Seed Laser1 ON

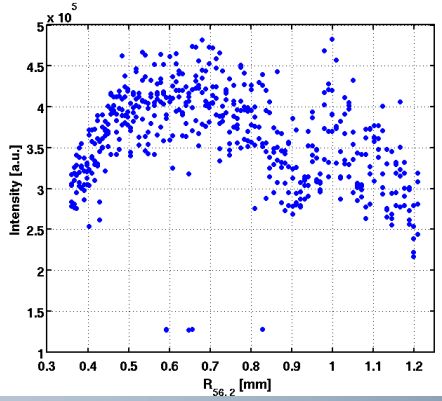
Second modulator: scan R56_2



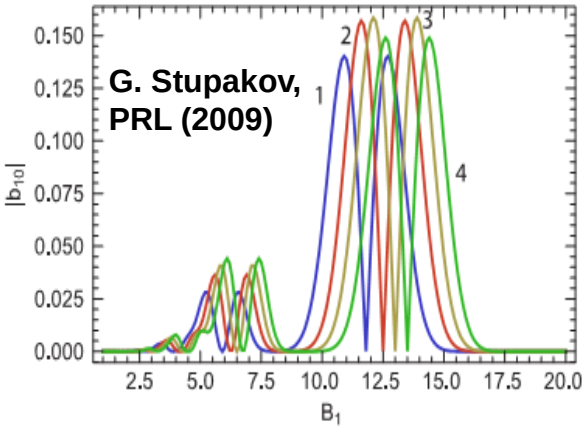
1,Tune first modulator to no-gain.
2, both laser-on, scan R56_2



Both modulator on: Echo at work



- "Double peaks" are observed with EEHG setup, which agrees well with echo theory.



Summary

- SDUV Diagnostics has proved quite helpful for machine commissioning and experiments
- SASE and seeded FEL experiments have been carried out with these electron and optical diagnostics.
- Echo signal was observed by direct measurement of bunching through coherent undulator radiation. The bunching pattern ‘double peaks’ was clearly seen and agree with theoretical predictions.
- Future plan

  Fix pop-in probes

  Add more RF BPMs in FEL section

  Cavity BPM (prototype) online

  Wire scanner (prototype) online

  Deflecting cavity online

Thanks for your attention