Commissioning of the X-band RF Transverse Deflector at the Linac Coherent Light Source

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Outline

- Motivation/background
- Principle and design
- Implementation at LCLS
- Commissioning progress

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Motivation

- X-ray FELs, such as LCLS, provide x-ray pulses typically from 100s femtoseconds (fs) to 10s fs;
- At LCLS, two short-pulse operation modes – low-charge and slotted-foil – have been established to generate <10-fs x-rays (Poster TUPEA086);
- The pulses of <10fs are too short to be measured by the present diagnostics at LCLS;
- Developing new schemes for temporal diagnostics with fs-resolution is critical and challenging.

Recent developments at LCLS

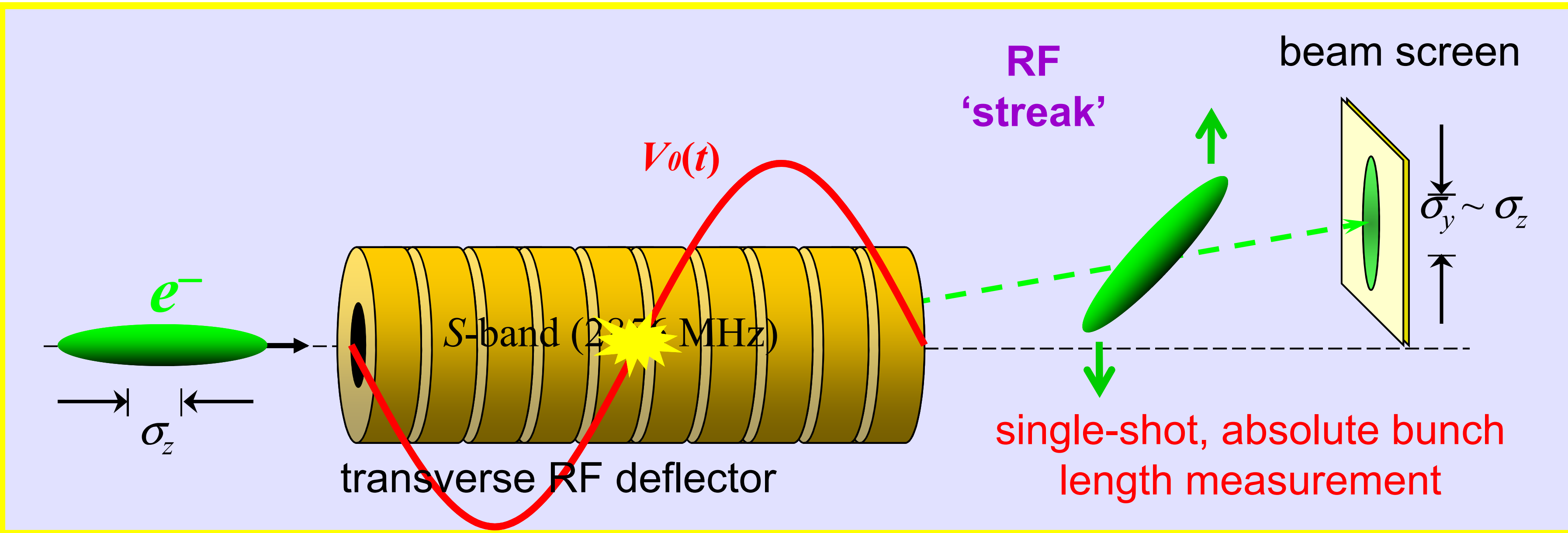
- e-beam
  - Longitudinal mapping (Huang et al, PRSTAB2010)
  - Prism-based THz spectrometer (Maxwell et al, IBIC12)
- x-rays
  - Cross-correlation (Ding et al., PRL2012)
  - Statistical spectral (Lutman et al., PRSTAB2012)
  - THz-streaking (A. Cavalieri et al.)

➢ **X-band transverse deflector (XTCAV)**

(Ding et al., PRSTAB2011)

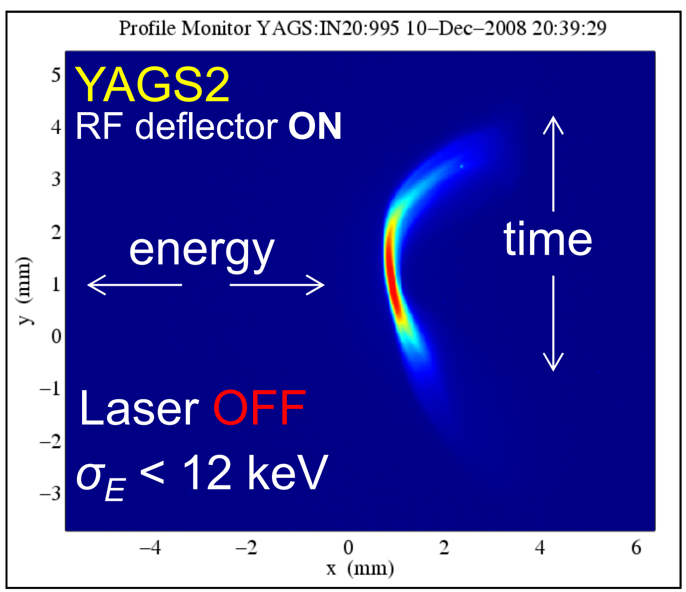
→ to measure e-beam and x-rays simultaneously, single-shot.

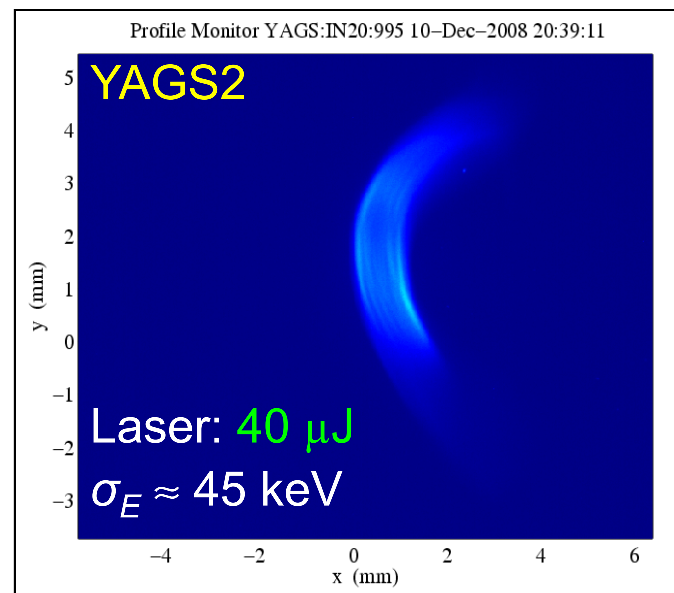
TCAV: an RF "streak" camera for e-beam



Deflector + energy spectrometer

Longitudinal phase space

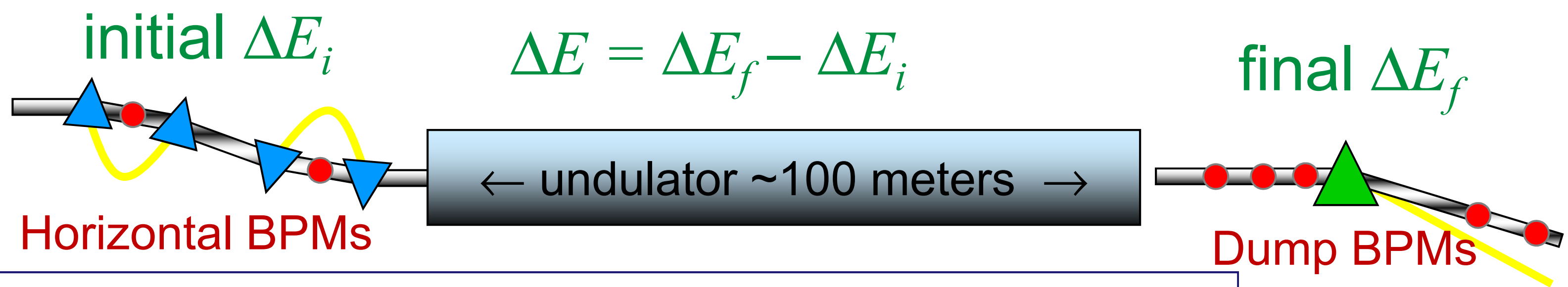




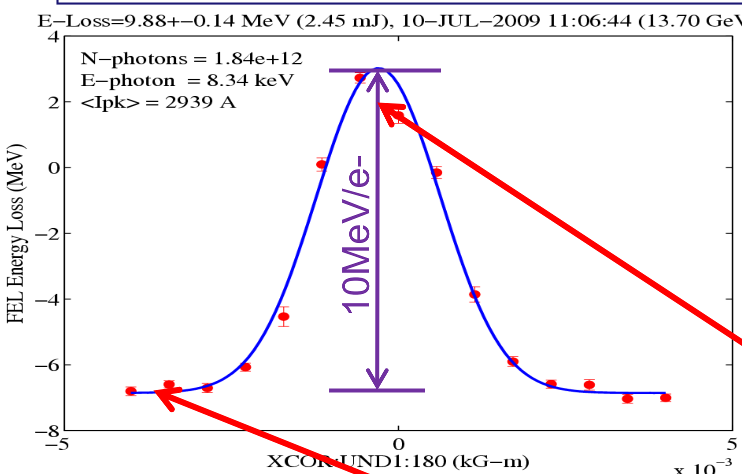
(Huang et al, PRSTAB2010)

How to retrieve x-ray temporal profile?

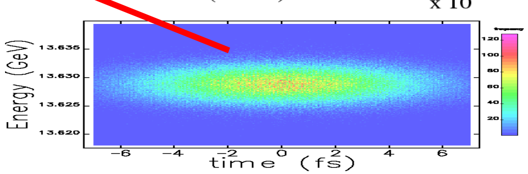
- The E-loss scan for measuring x-ray pulse energy:

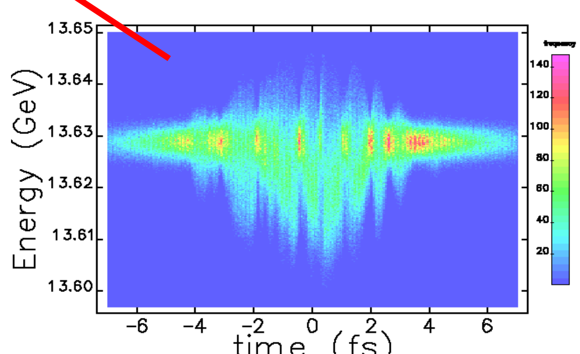


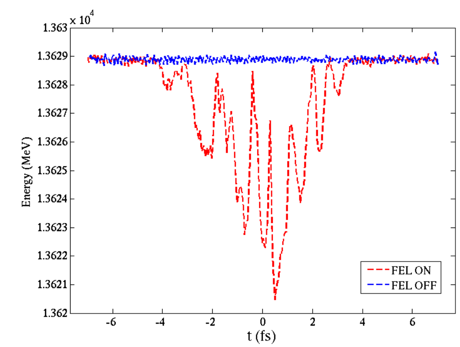
vary FEL power with oscillations & record e⁻ energy loss



We propose to streak the beam in time to measure the ***time-resolved*** energy loss, or energy spread, where the x-ray profile has been imprinted in the e-beam time-energy phase space.







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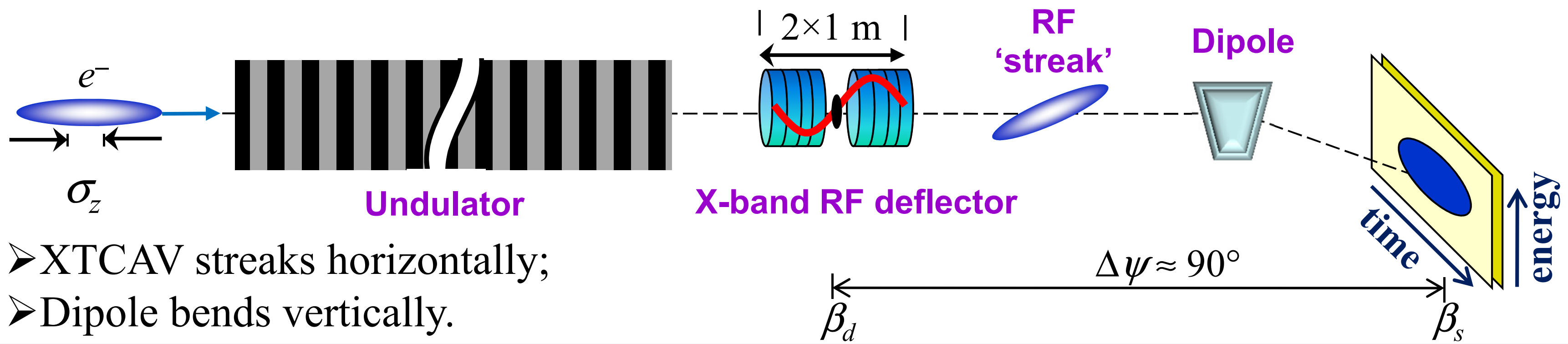
Layout and deflector parameters



- ➢XTCAV streaks horizontally;
- ➢Dipole bends vertically.

Frequency	11.424 GHz
Maximum kick	48 MV@40MW

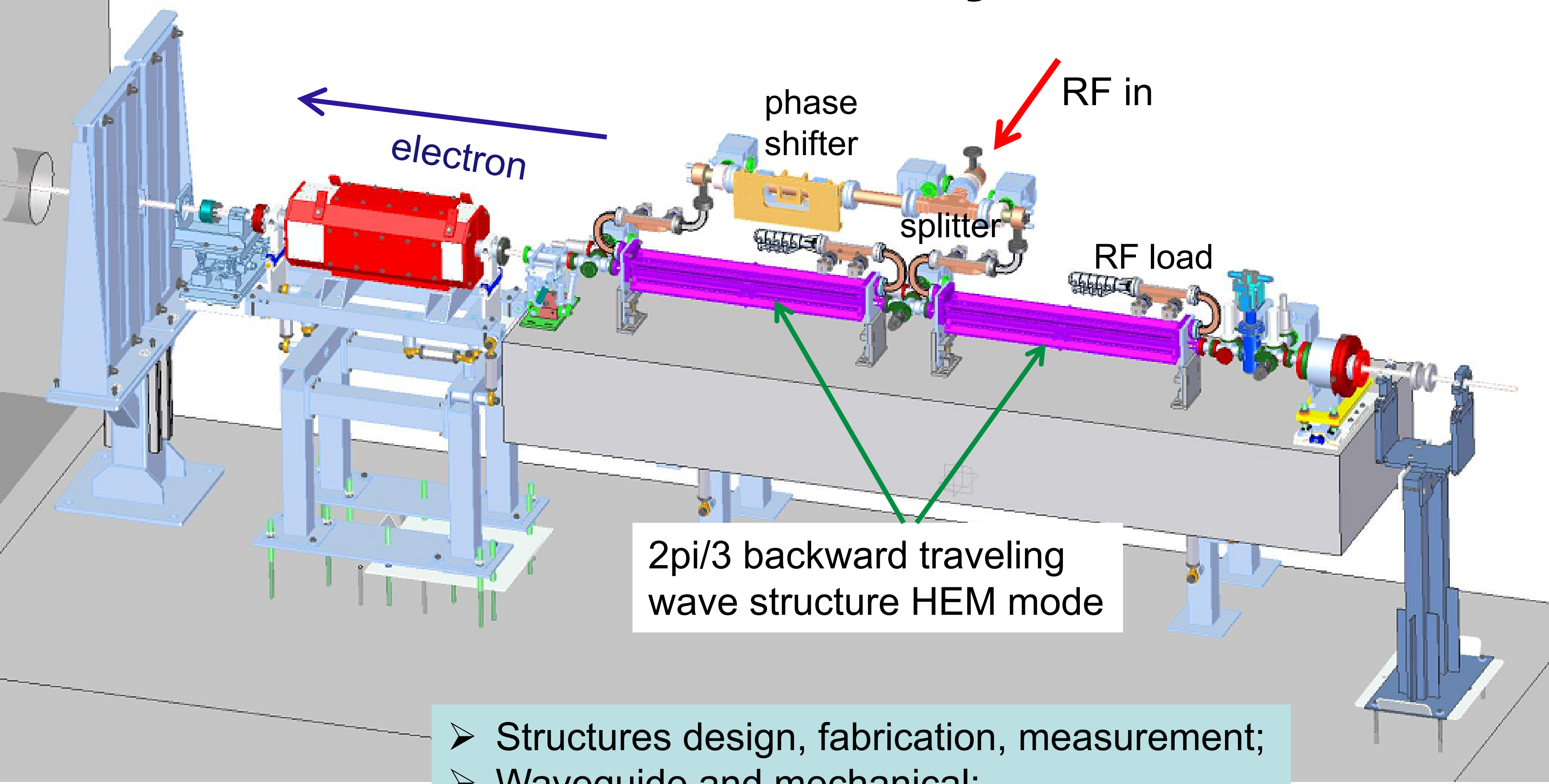
- $S = \sqrt{\beta_x(s_0)\beta_x(s)} \cdot \frac{eV_0 k}{E} \cdot \sin(\Delta\Phi_x)$

Temp. resol. $\sigma_{t,R} \propto \frac{\lambda_{rf}}{V_0}\sqrt{E\frac{\varepsilon_{N,x}}{\beta_x(s_0)}}$

- ✓ High resolution, ~ few fs;
- ✓ Applicable in all FEL wavelength;
- ✓ Beam profiles, single shot;
- ✓ No interruption with operation;
- ✓ Both e-beam and x-ray profiles.

HXR: (14GeV)	**SXR:** (4.3GeV)
$S = 42$,	$S = 136$,
$\sigma_{t,R} \sim$ **3 fs**;	$\sigma_{t,R} \sim$ **1 fs**;

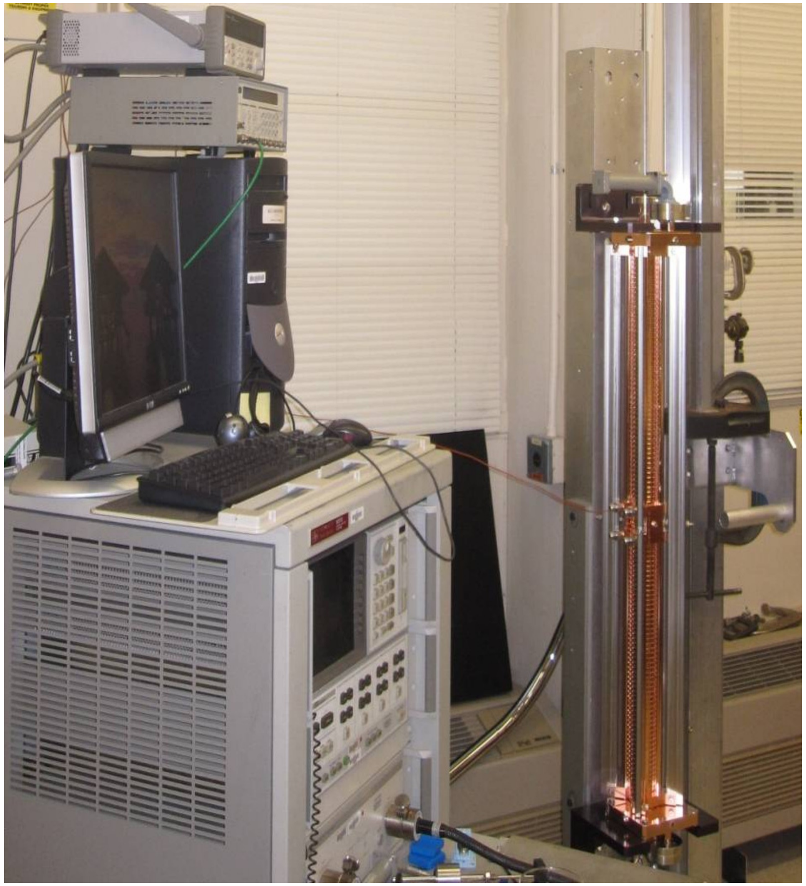
Mechanical Layout



(Courtesy of Eric Bong)

- Structures design, fabrication, measurement;
- Waveguide and mechanical;
- Klystron and modulator;
- LLRF and controls;
- Safety and protection;
- Electrical AC power and cooling.
- etc.

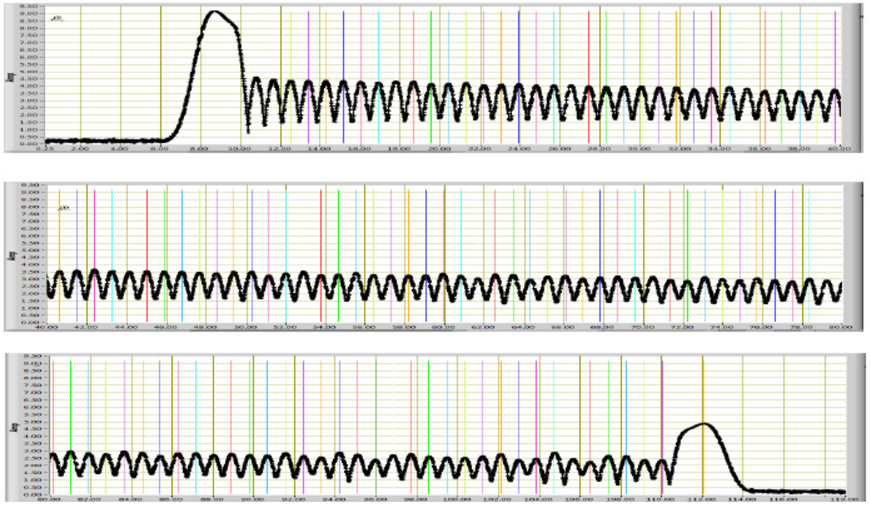
Microwave tuning of the structures



Microwave Tuning Using Nodal Shift Method with a Metal Rod

(Juwen Wang)

Deflector Electric Field Amplitude



RF Parameters and Analysis

- S11=0.03
  (only 0.1% RF power reflection due to no perfect match)
- S22=0.02
  (only 0.04% RF power reflection due to no perfect match)
- S12=0.532
  (Theoretical value S12=0.54, it shows the perfect tuning and high quality diffusion bonding and brazing)
- Fill Time with WR90 arms: T_f=108ns
  (Theoretical value T_f =106ns without arms, it shows the perfect fabrication)

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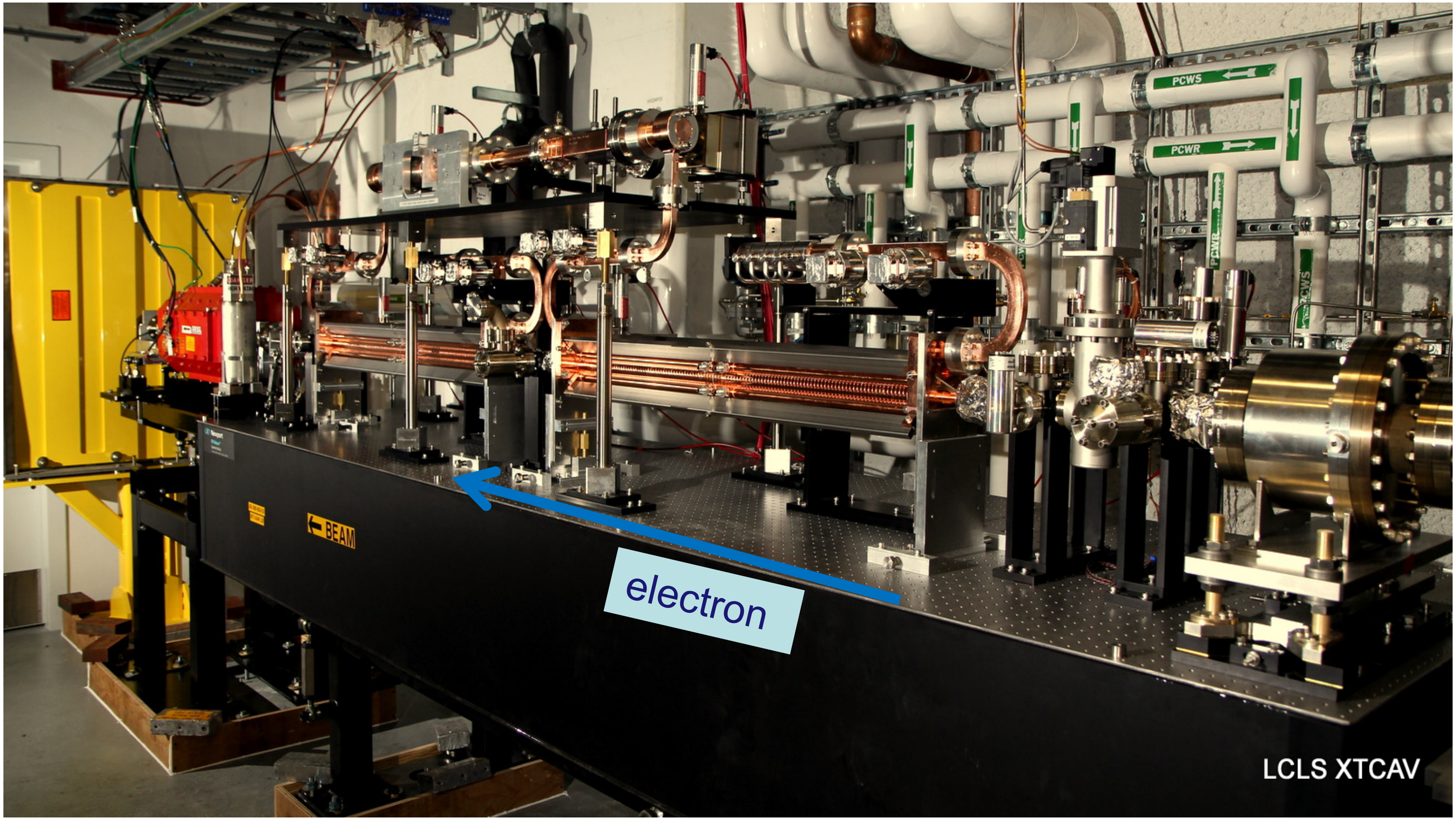
Structures installed in 2012 summer



Structures installation; magnets and BPMs re-configuration; safety and protection system re-configuration.

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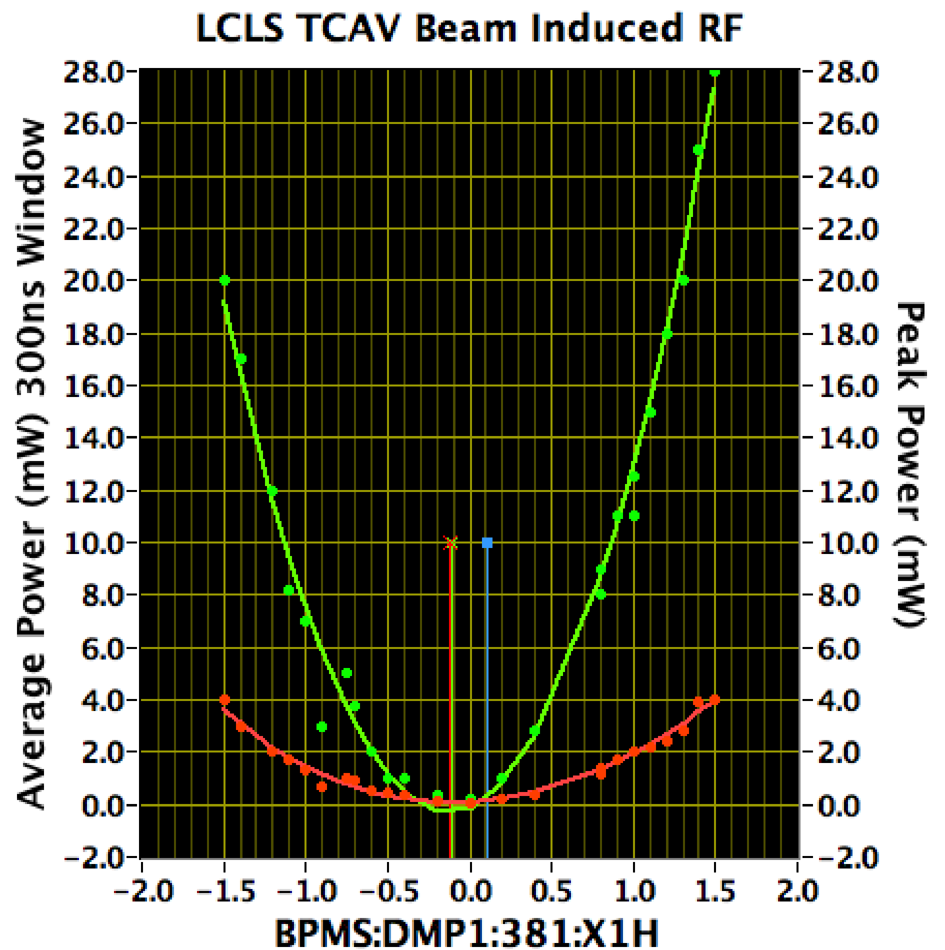
Transverse alignment measurements

- Measured beam excited rf signal while steer the beam horizontally.
- Beam excites 11.4GHz HEM dipole mode, travels to the klystron port.
- If the beam is in the center, no energy exchange → no excited signal.

→ Mechanical alignment is measured about 100 um accuracy, consistent with design requirements.



(J. Lewandowski, J. Wang)

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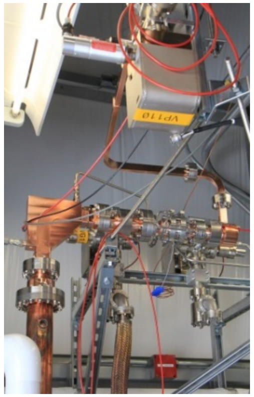
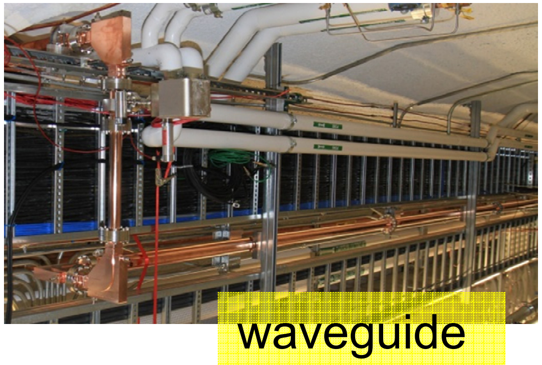
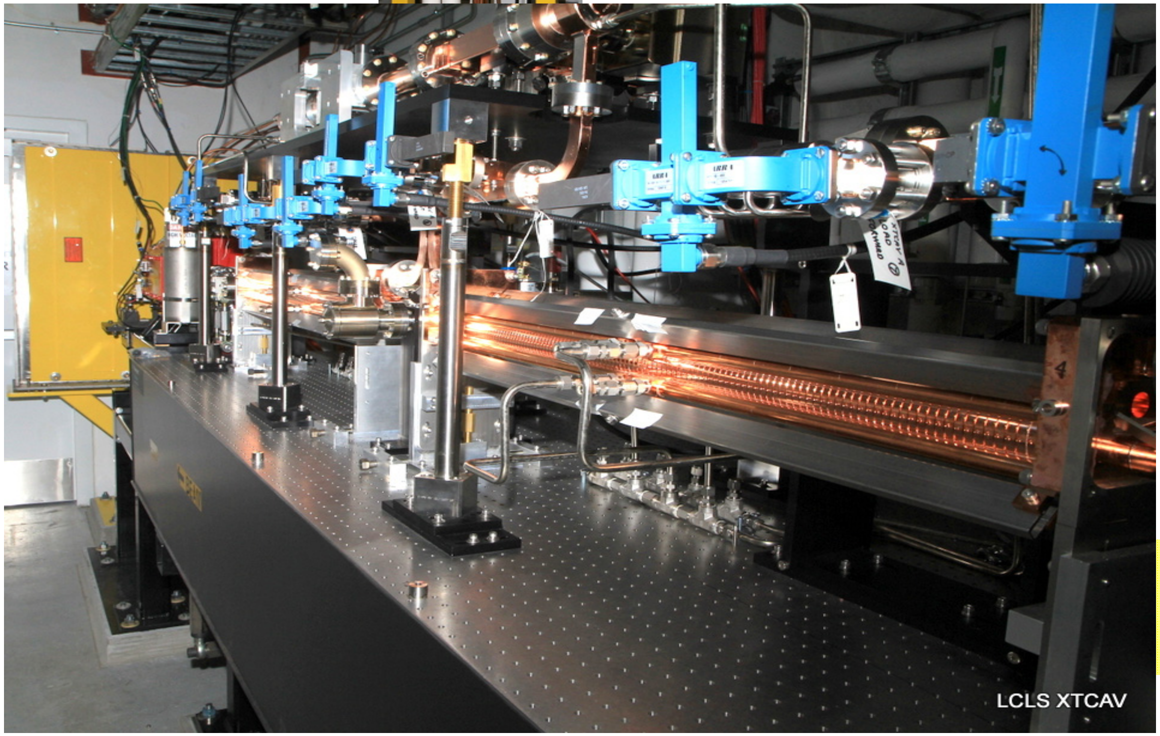
The whole system is ready in April 2013, RF conditioning started in May.







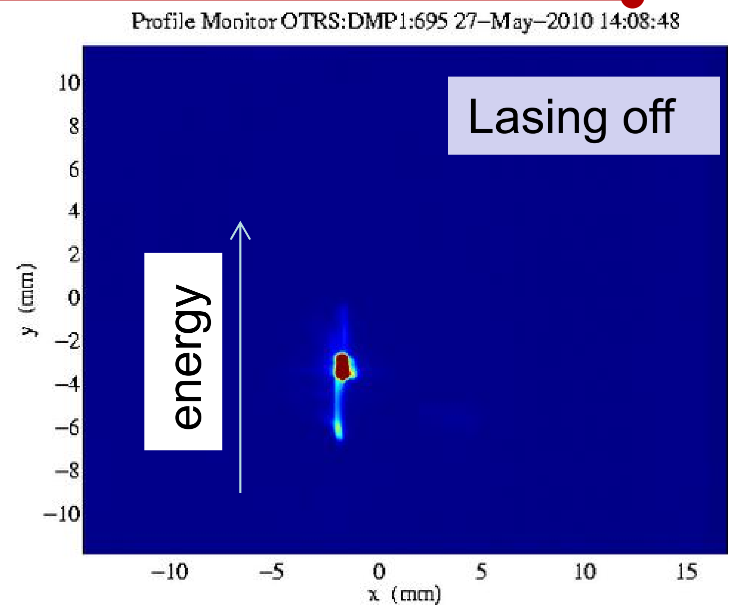
(Pictures courtesy of P. Krejcik)

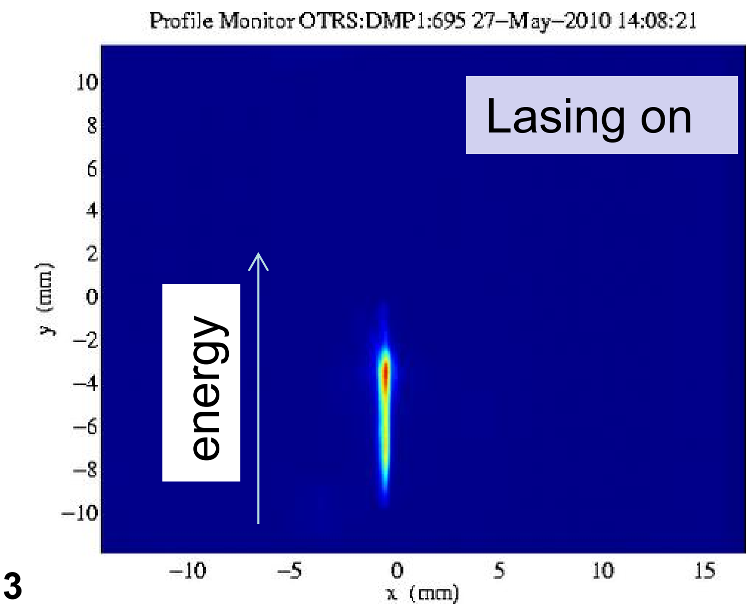
Optics commissioning

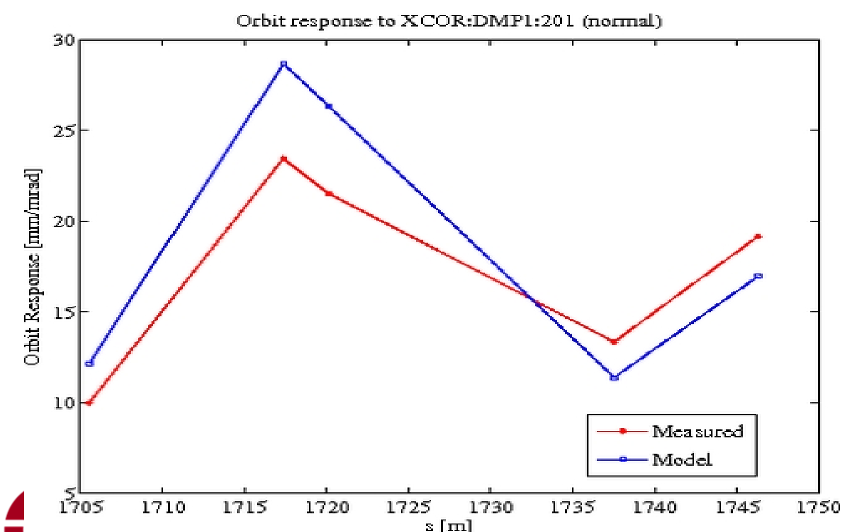
- Optics optimization at different energies:

phase advance, beta functions, dispersion.

- measured orbit response.
- Lasing suppression with a closed bump.

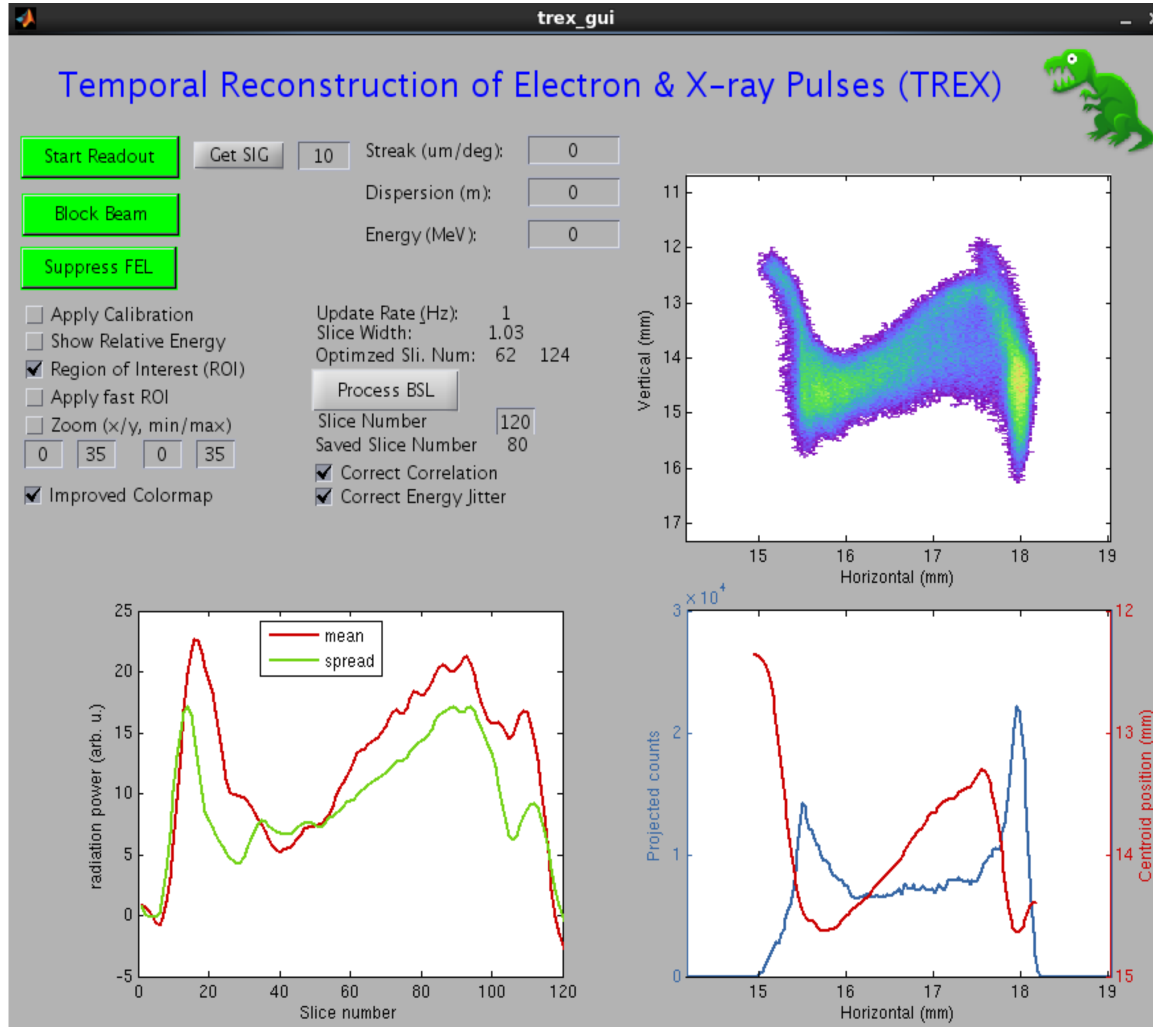






Jitter and data analysis

- Jitter corrections: energy jitter, current jitter, arrival jitter, deflector phase jitter.
- Matlab-based GUI has been developed.
- Scheduled first beam-based commissioning within two weeks.



(C. Behrens)

Summary

- Good progress in the past two years;
- The whole system is ready, rf conditioning started;
- Beam-based commissioning and measurements will start in two weeks;
- More fun is coming…

- Thanks the project manager P. Krejcik;
- Thanks **all my colleagues** from SLAC engineering, controls, operations, safety, and rf support groups;
- Thanks the supports from LCLS FEL R&D program and DOE early-career program.

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