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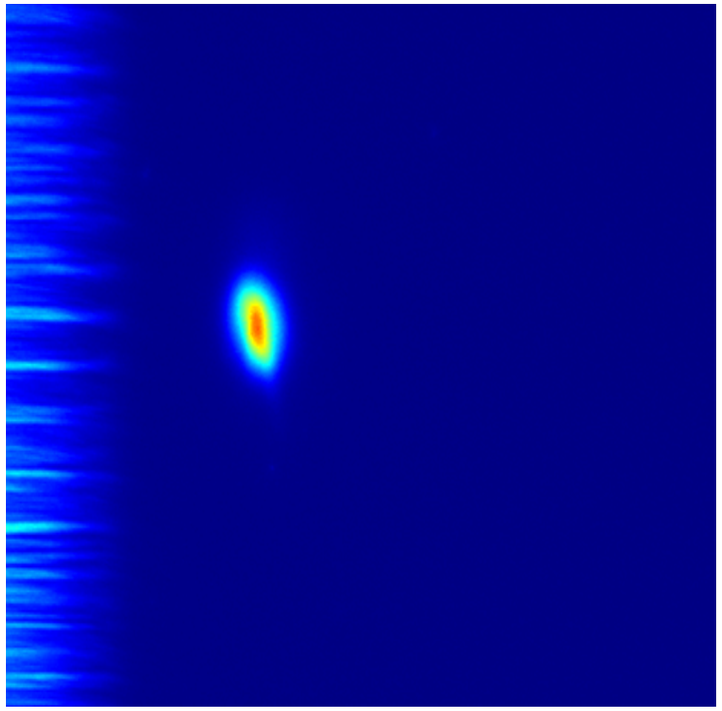
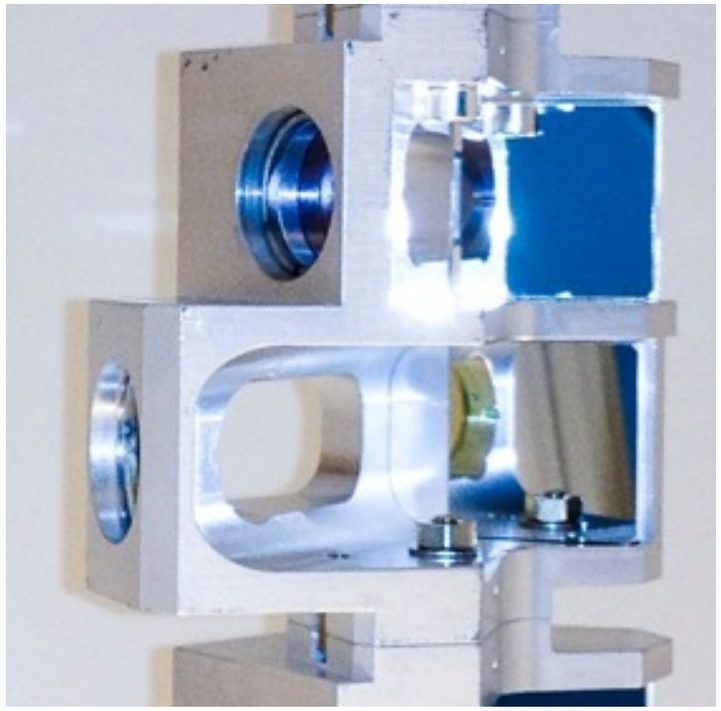
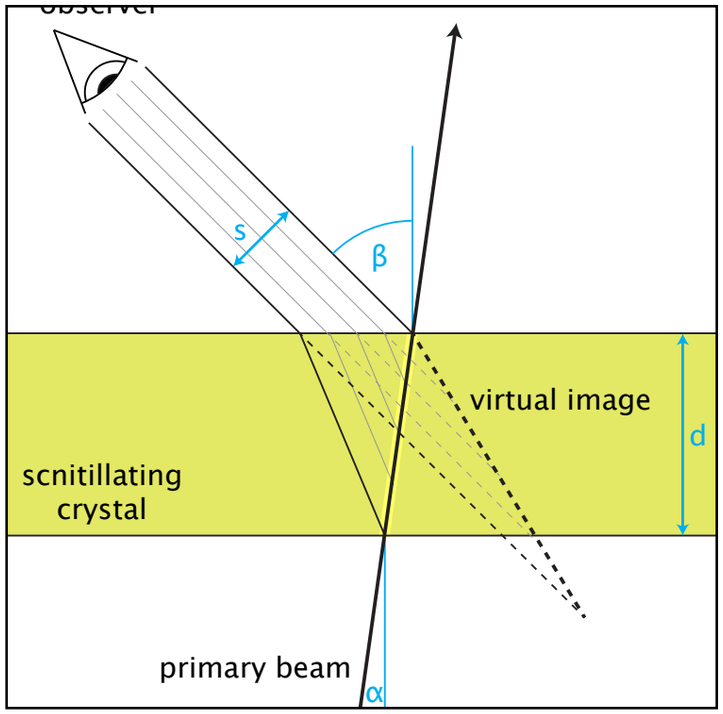
PSI

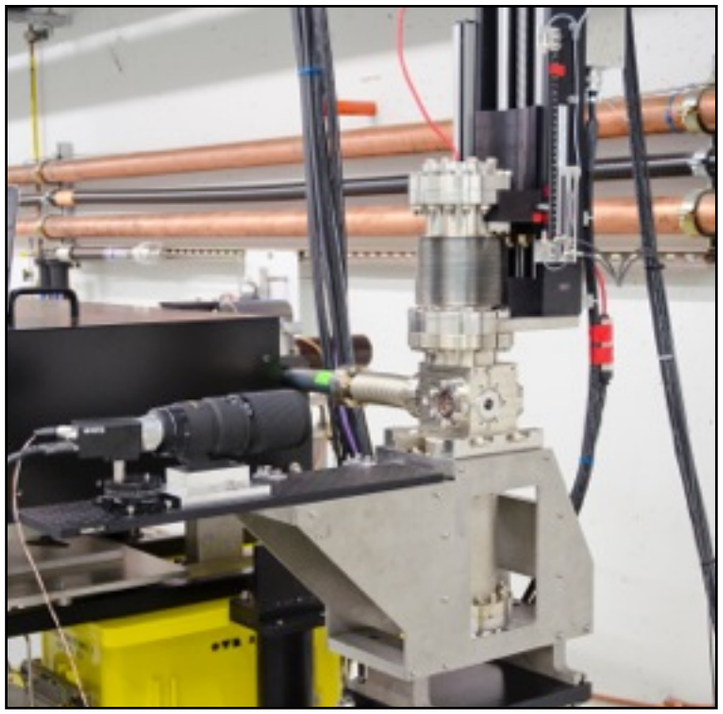
SLAC NATIONAL ACCELERATOR LABORATORY

DESY









Measurements with SwissFEL Transverse Profile Imager at LCLS

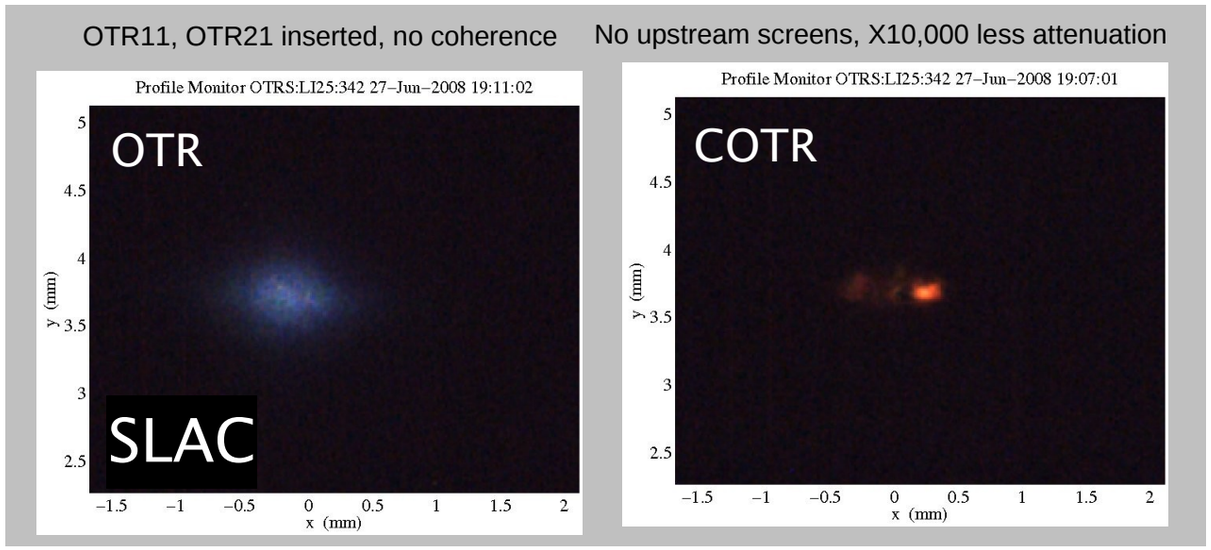
Rasmus Ischebeck, Patrick Krejcik, Henrik Loos, Minjie Yan

Problem: Coherent Optical Transition Radiation (COTR)

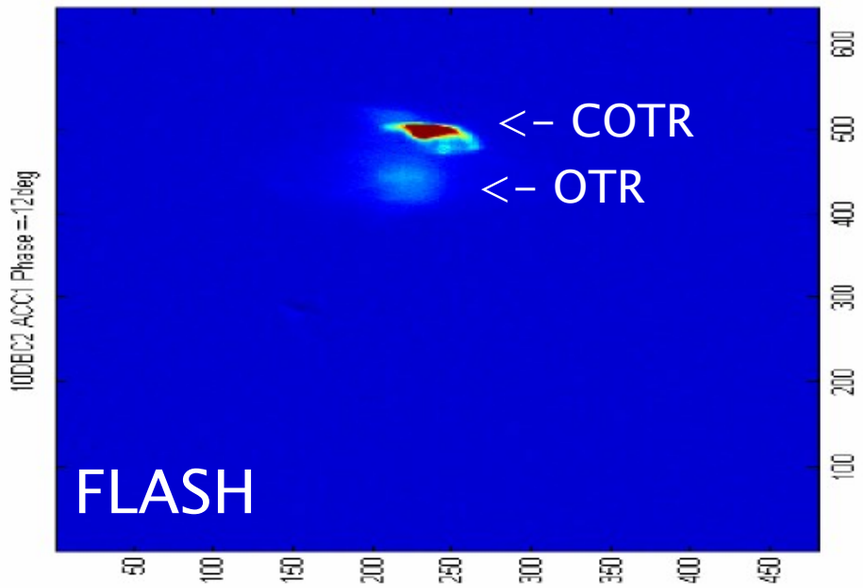
> Traditionally, we use optical transition radiation monitors to measure beam profile

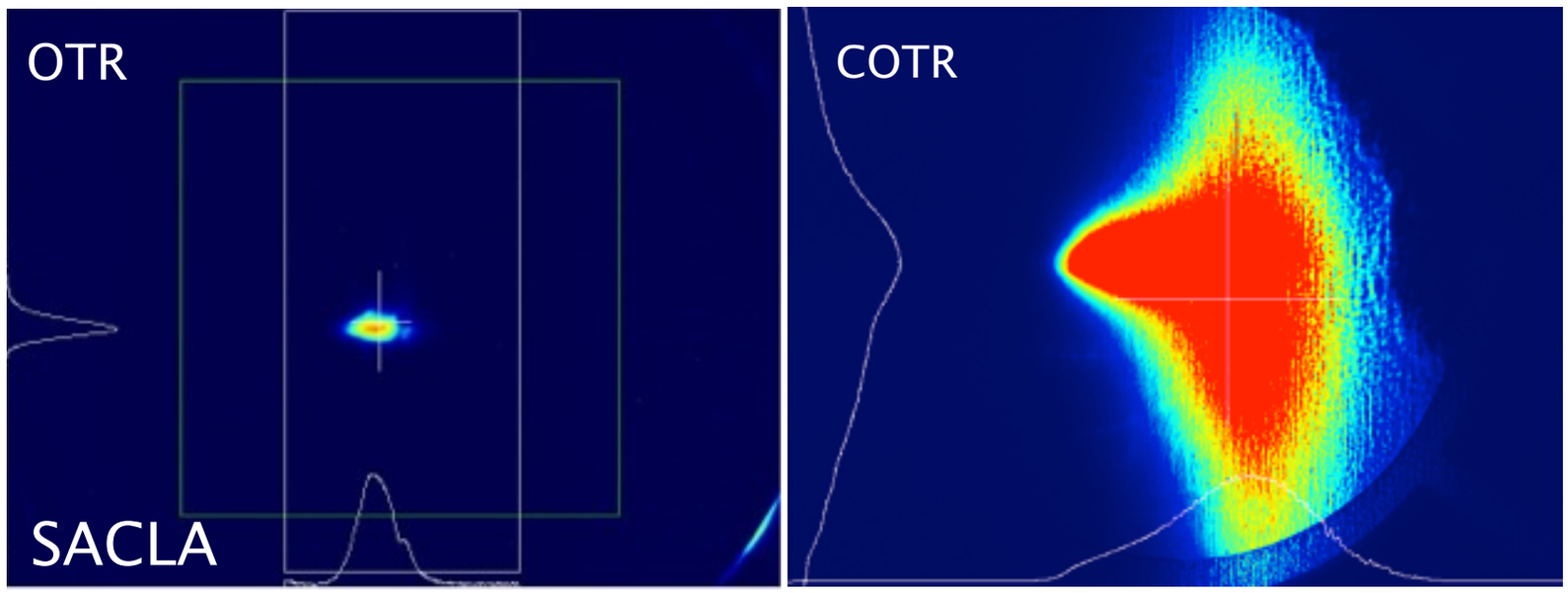
> Highly compressed beams emit coherent radiation that disturbs the measurement

> First observed at LCLS, meanwhile also at FLASH and SACLA:



Joe Frisch, SLAC

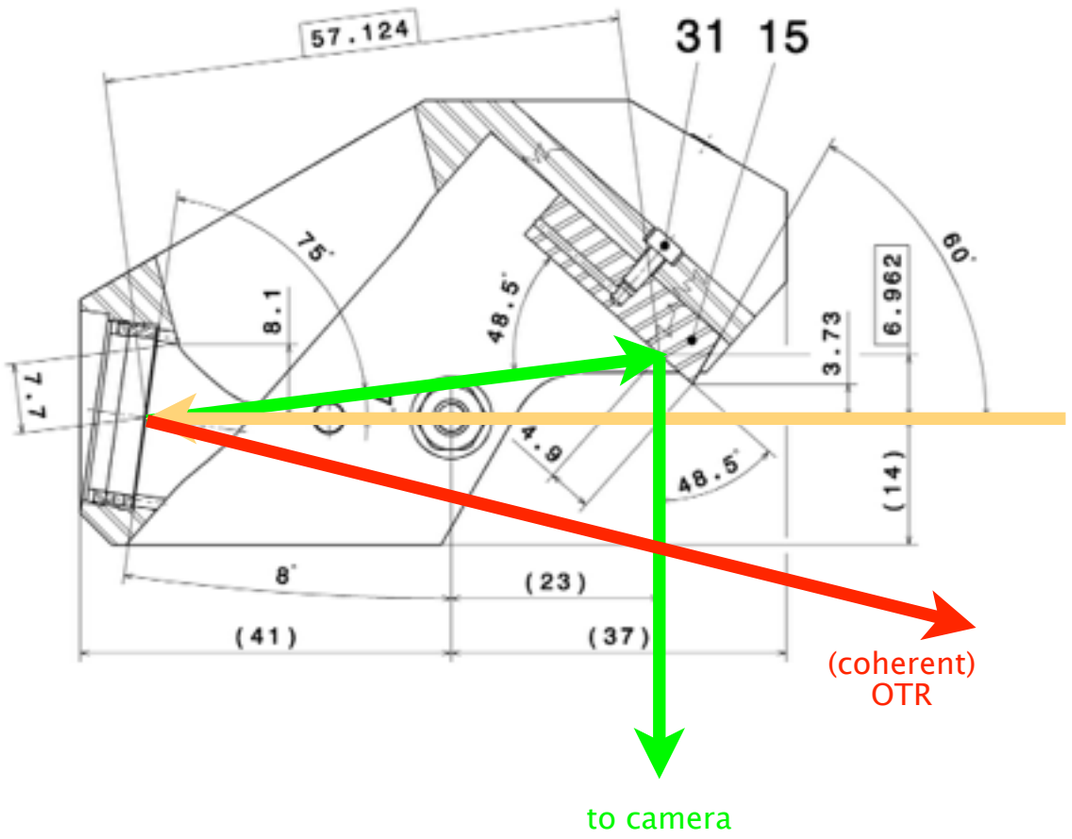


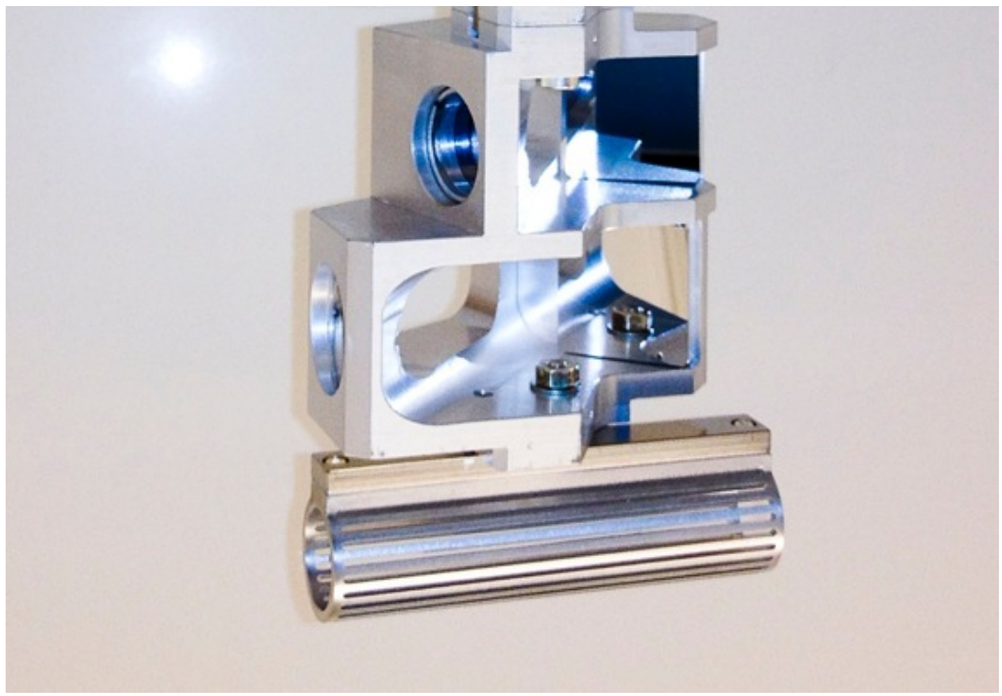


Yuji Otake, SACLA

Solution: Use Scintillator, Direct COTR Away from Camera

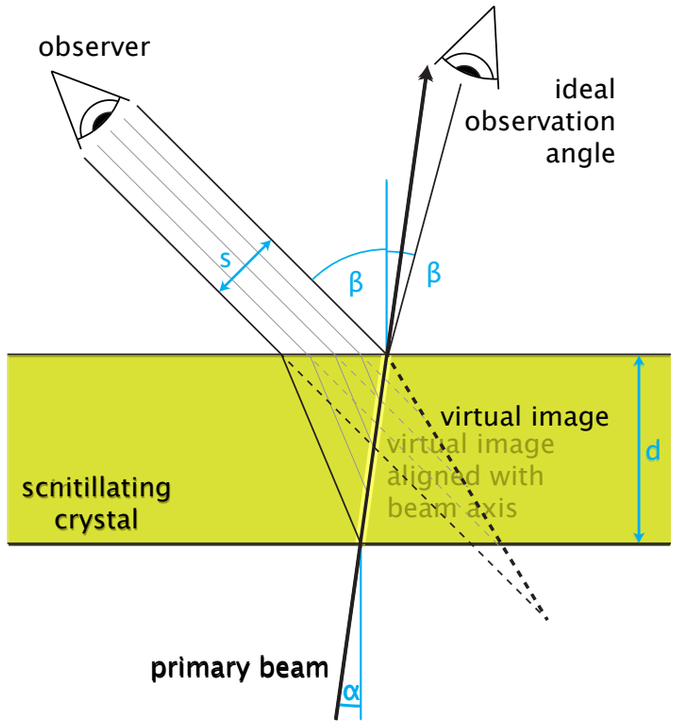
> Transverse profile imager developed at PSI directs COTR away from the camera:



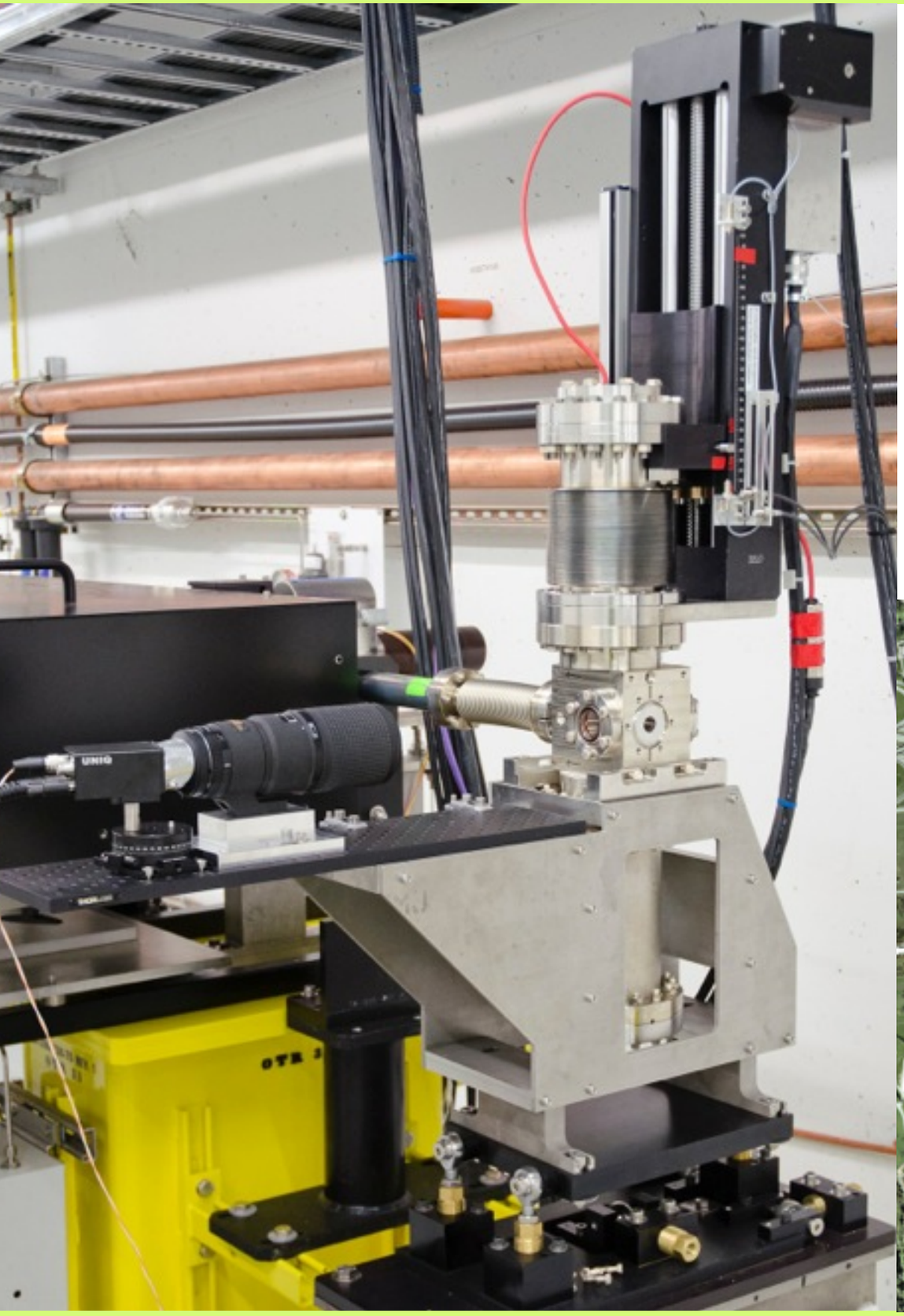


> At the same time, it achieves a good spatial resolution:

The YAG / LuAG scintillators are observed at such an angle that Snell's law of refraction is observed. As a consequence, we can image beams that are smaller than the thickness of the scintillator. (Patent pending)



Measurements Performed in December 2013



LCLS Linac-to-Undulator Line

> Beam energy: up to 14.7 GeV

> Bunch charge: 20…250 pC

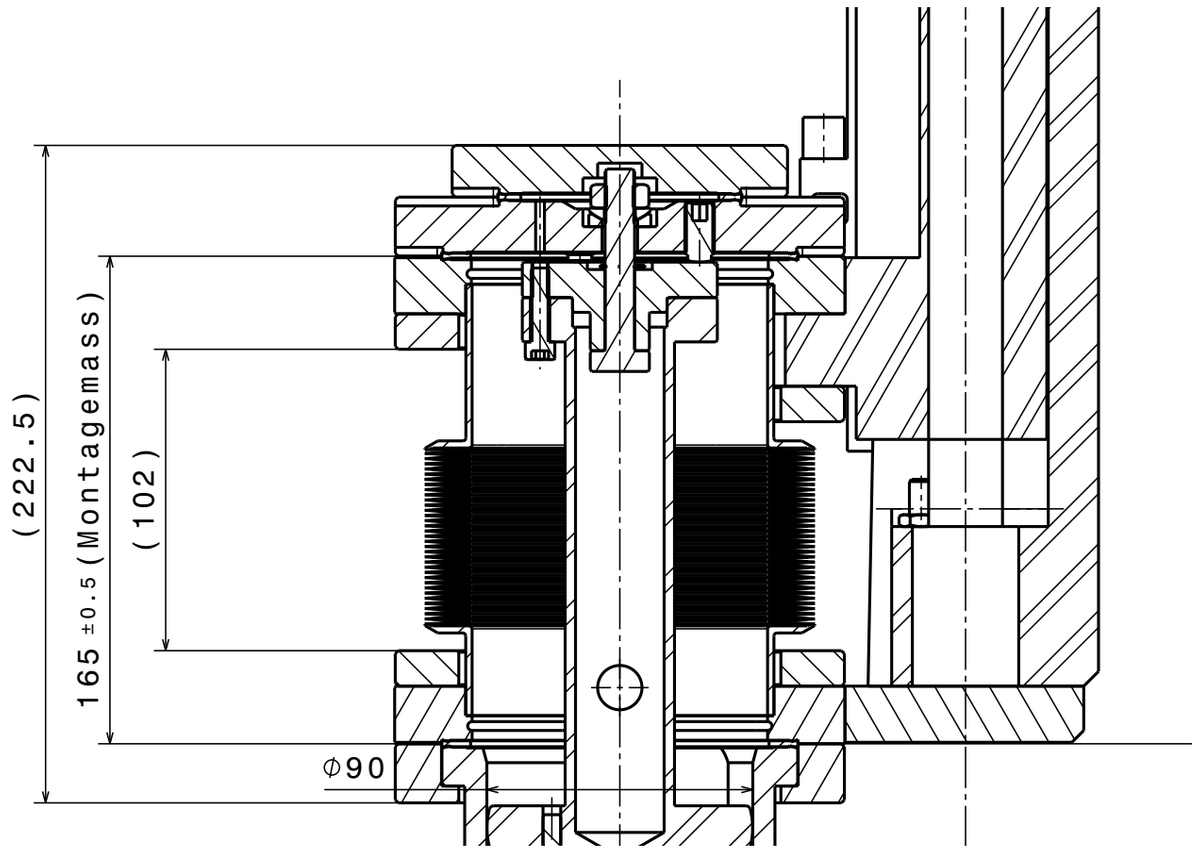
> Bunch length: 3…70 fs

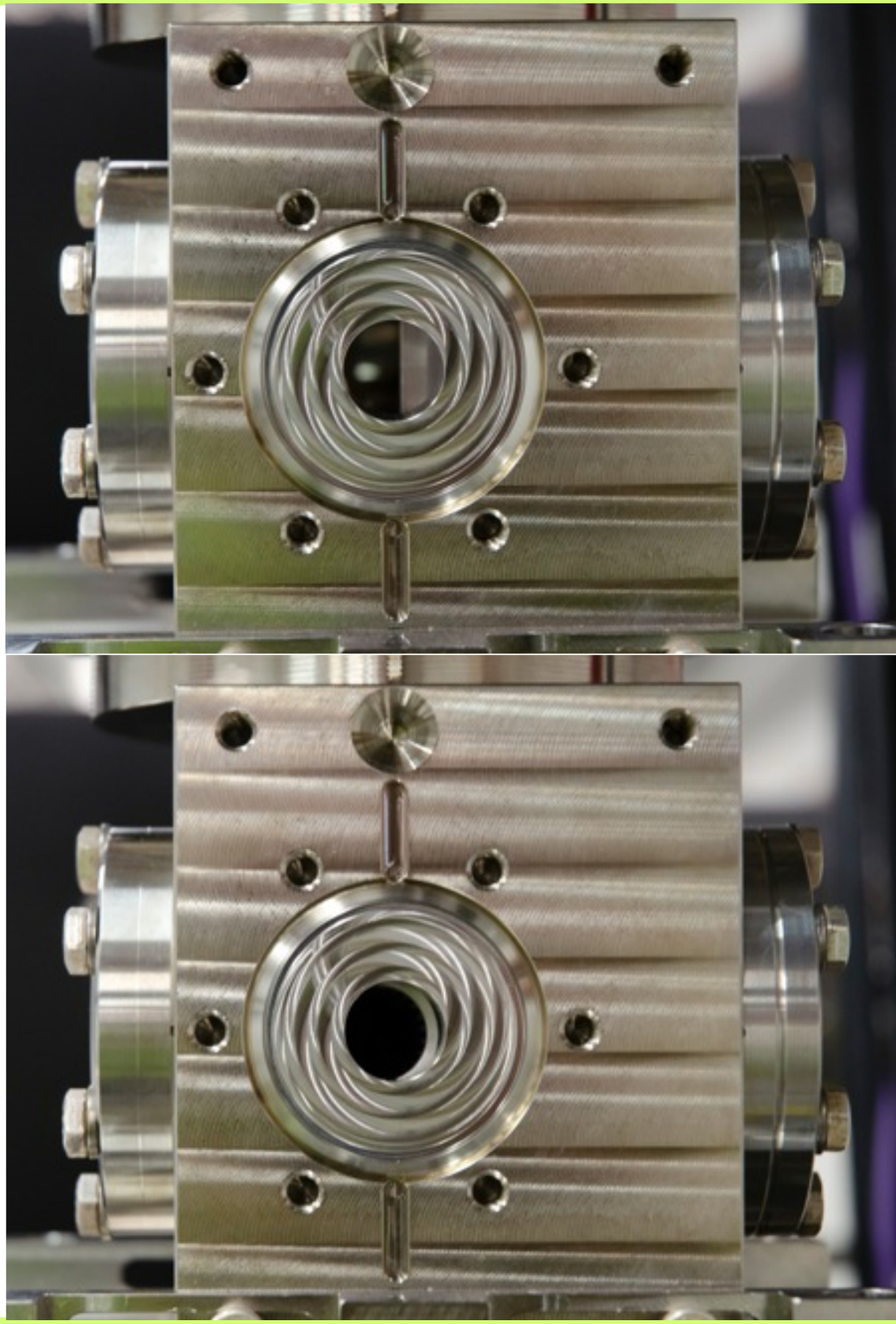
> Normalized emittance: 300…1600 nm

> Repetition rate: 1…120 Hz

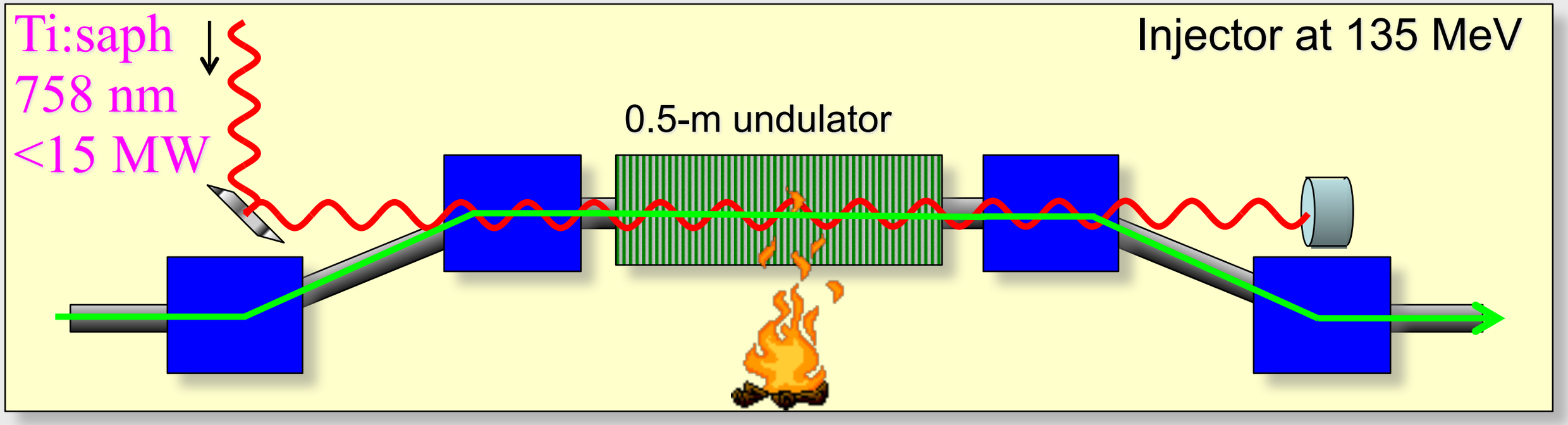
Alignment was Improved

- > Mis-alignment resulted in large losses when screen was inserted
- > Could be corrected with adjustment screws

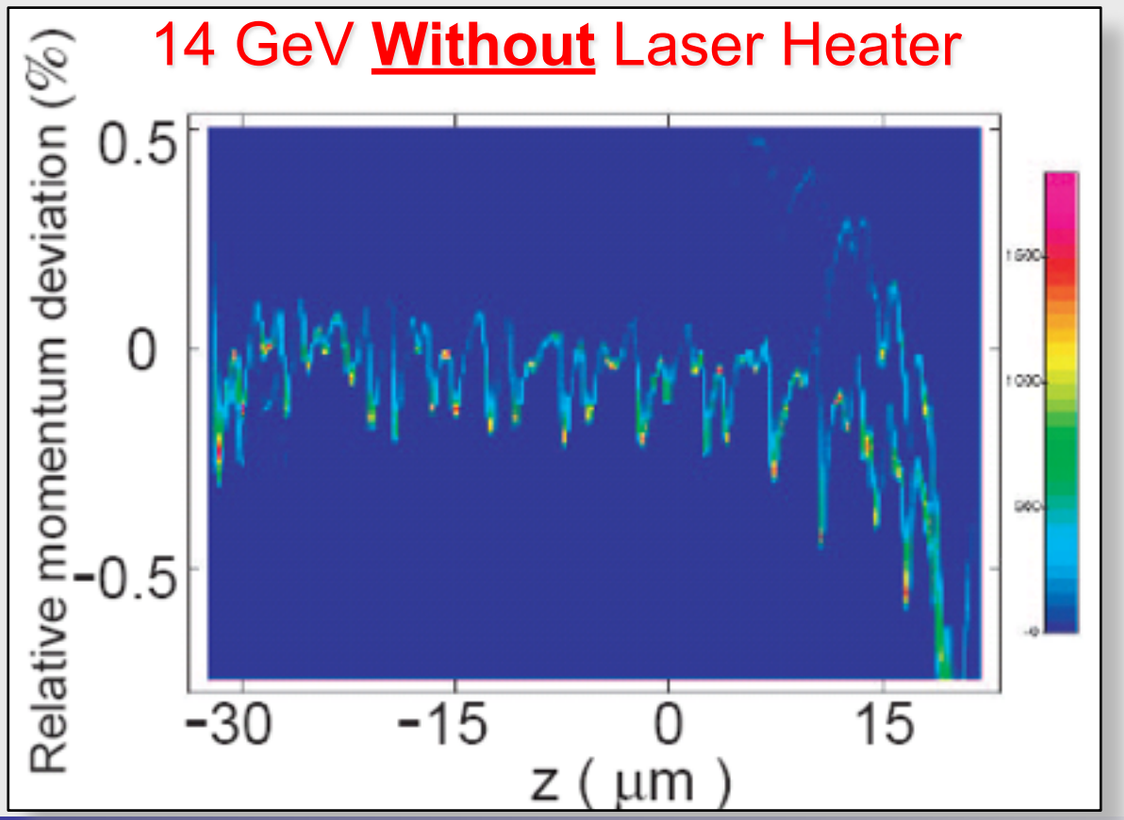




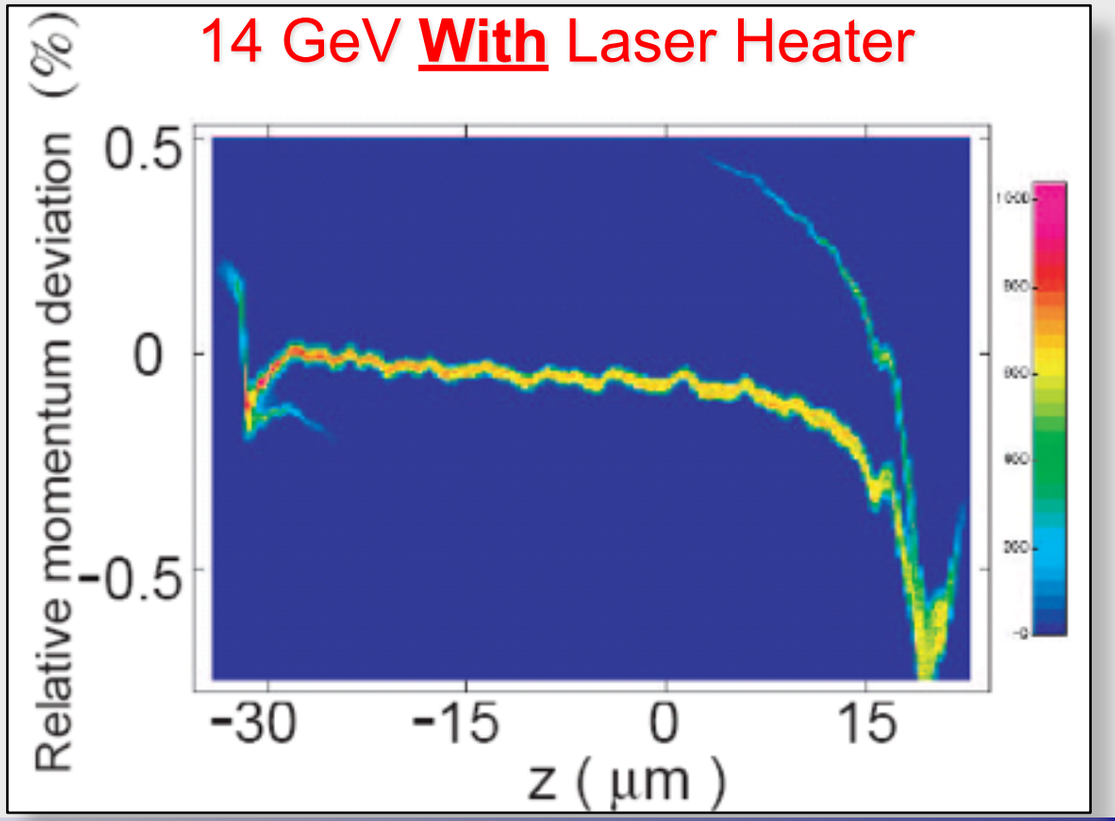
μ-Bunching Landau Damped by Laser Heater



'Laser heater' suggested by Saldin et al., NIMA, 2004; independently by J. Galayda



LCLS design study: Z. Huang et al., PRST 2004 (chicane suggested by T. Smith)

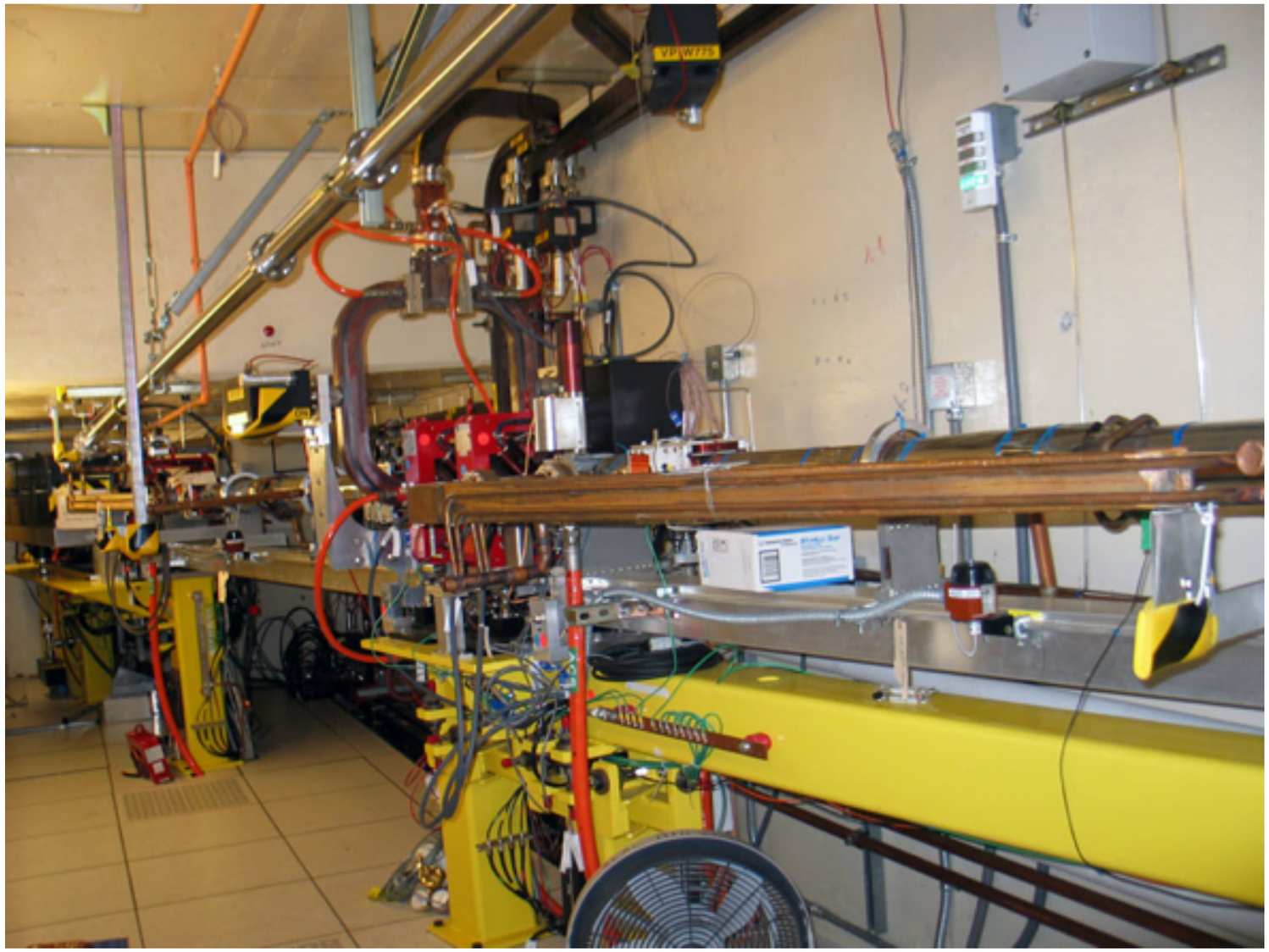


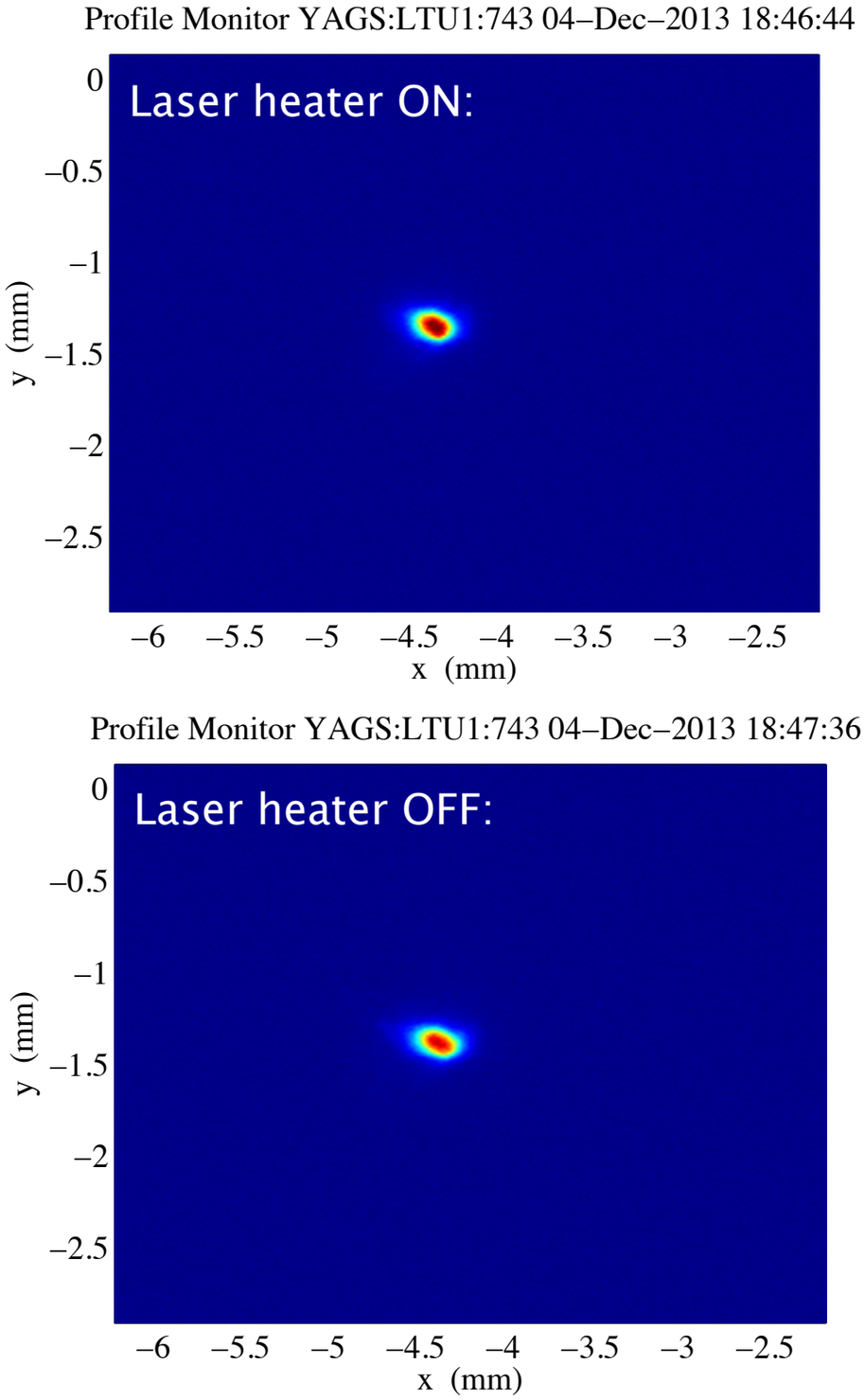
Elegant simulations

Zhirong Huang
zrh@slac.stanford.edu

Measurements — December 2013

> First Measurements at LCLS show no sign of coherent OTR on the camera:



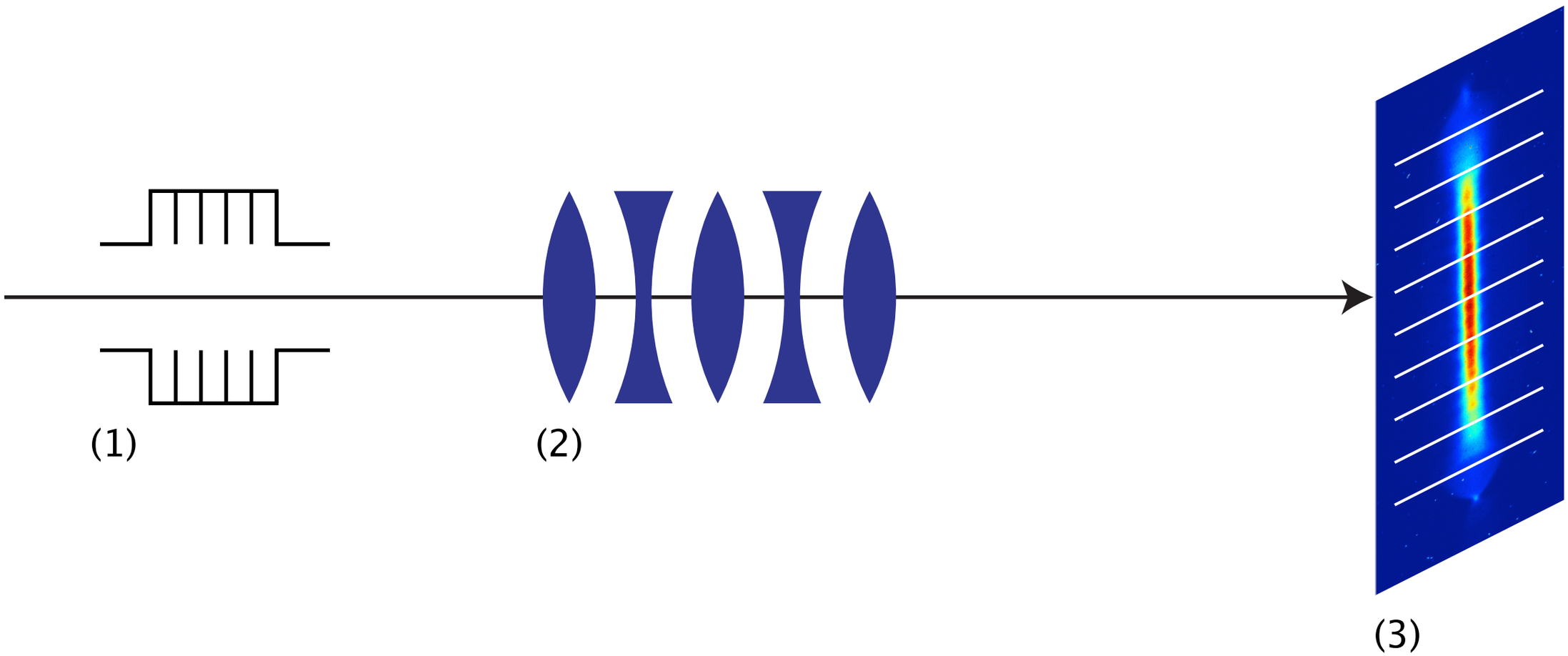


More Measurements — March 2014

> Patrick Krejcik, Henrik Loos (SLAC), Minjie Yan (DESY)

> Quadrupole scans to measure emittance

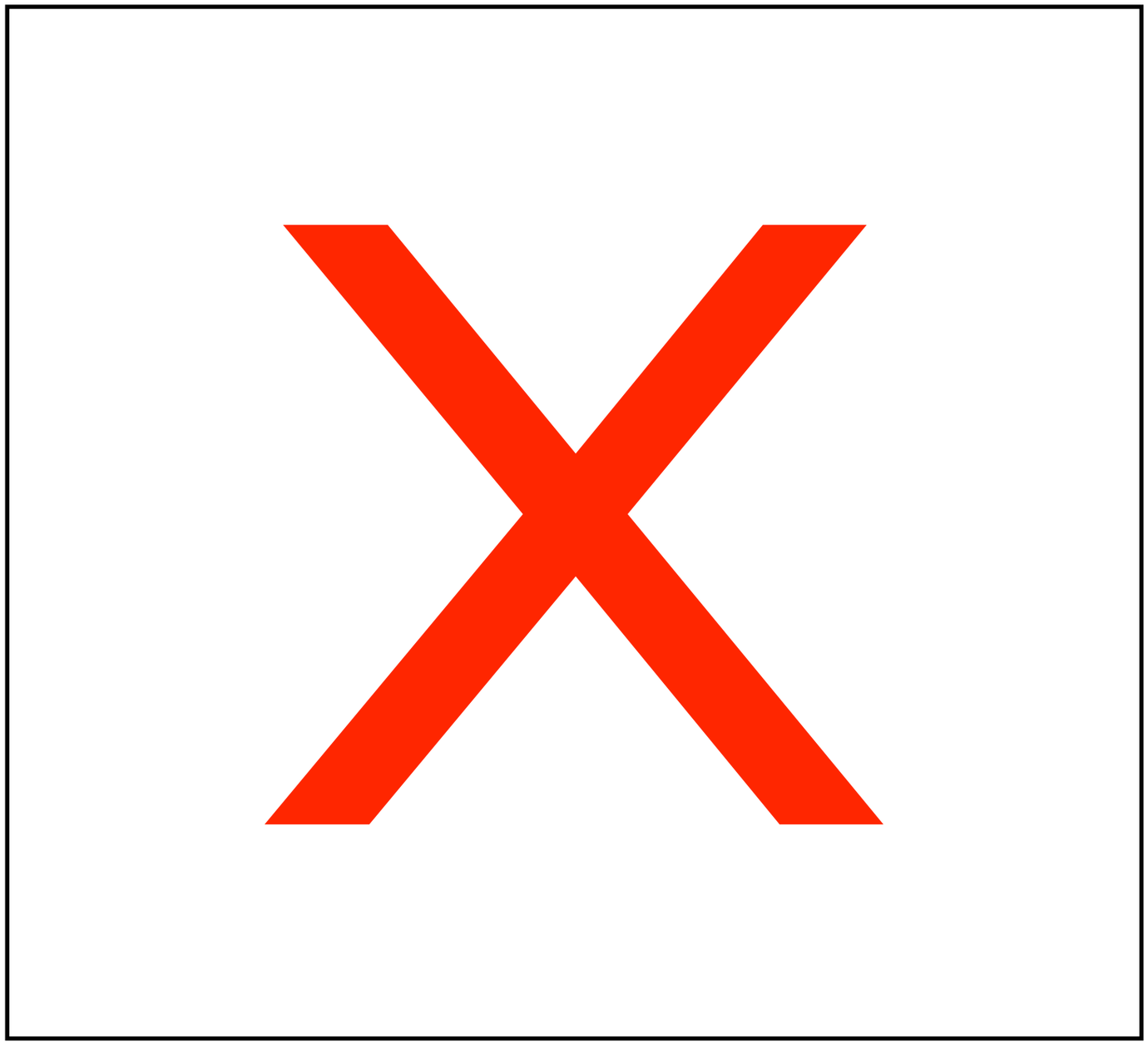
> First attempt at slice emittance measurement



Emittance quad scan at screen

Use tweaker quad

for scan



FODO lattice off

Beta match X and Y waist at screen (almost)

Comparative wire scans less accurate in non-FODO lattice with waist at screen

X

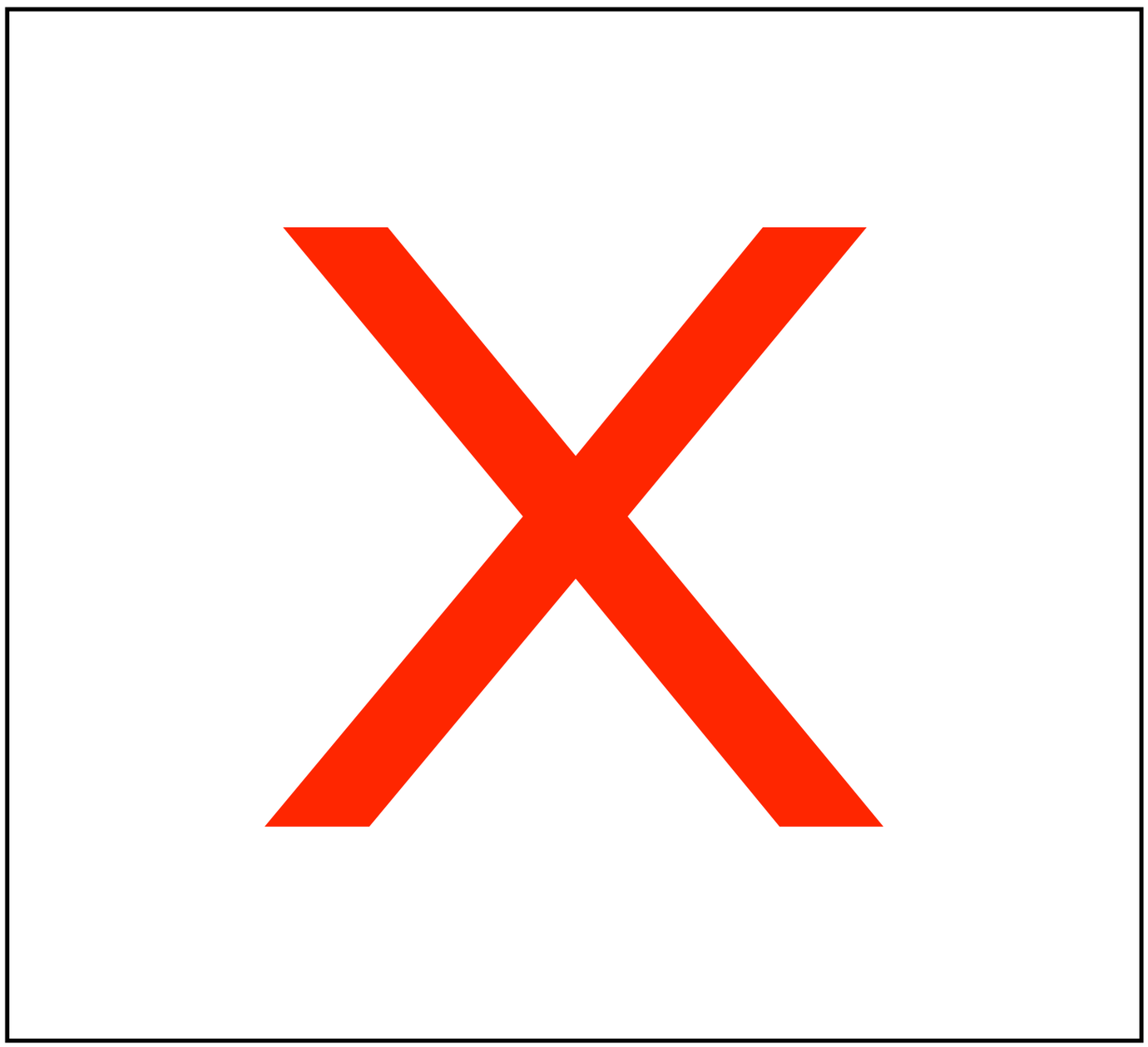
Screen 2.4

Wire 1.2

Y

Screen 1.6

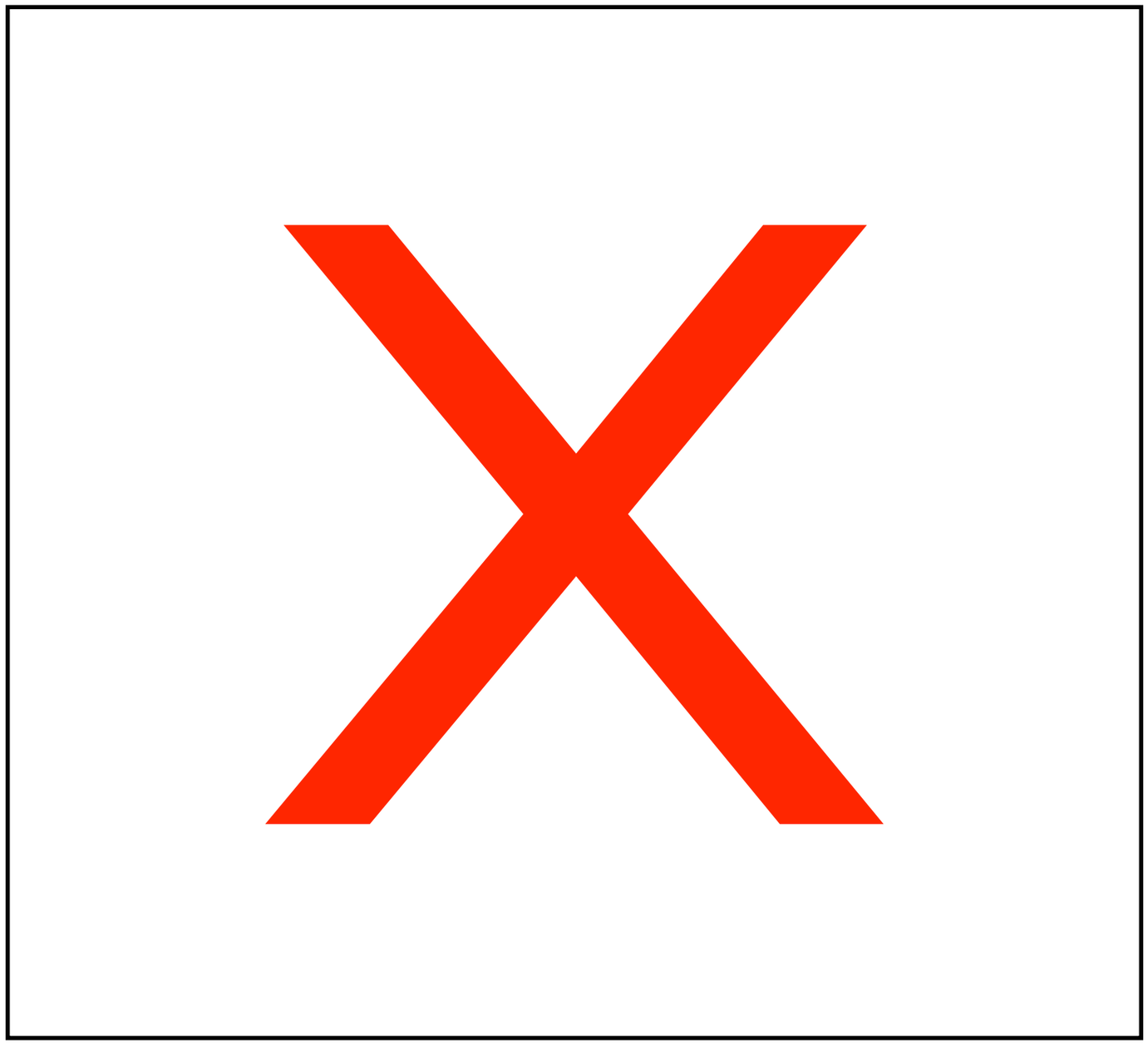
Wire 1.2



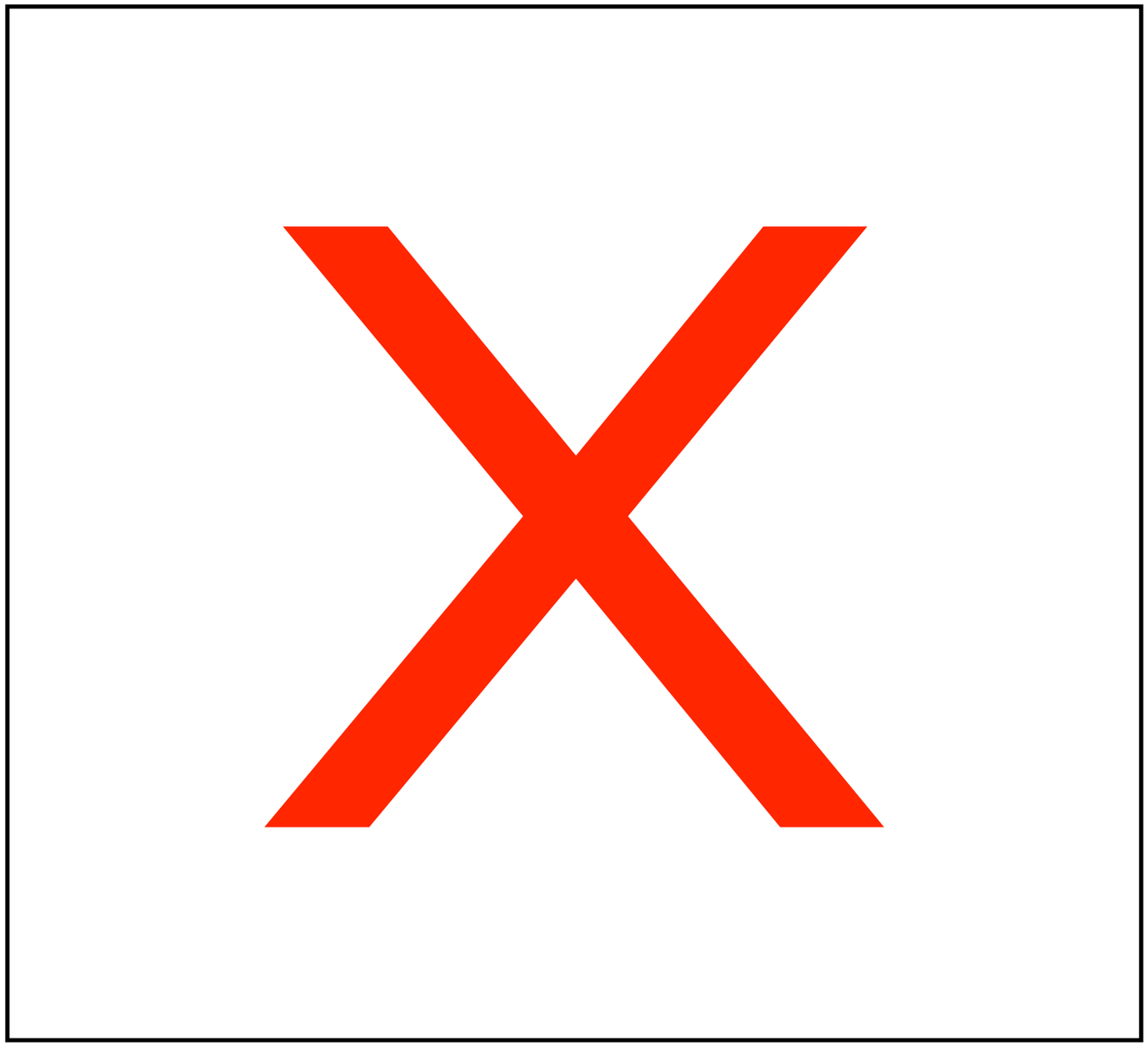
Camera Intensity during waist scan

Camera intensity constant versus beam area $\sigma_x * \sigma_y$

Looks okay with LH on and under compressed



Camera intensity versus laser heater power



Fixed spot size

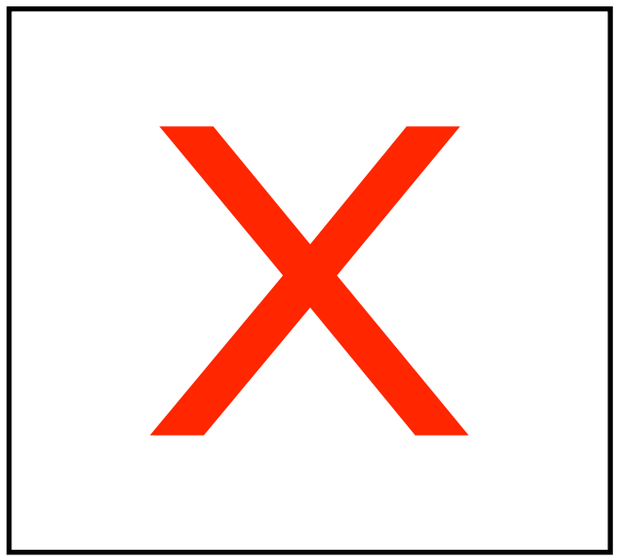
10% change in camera intensity with LH off

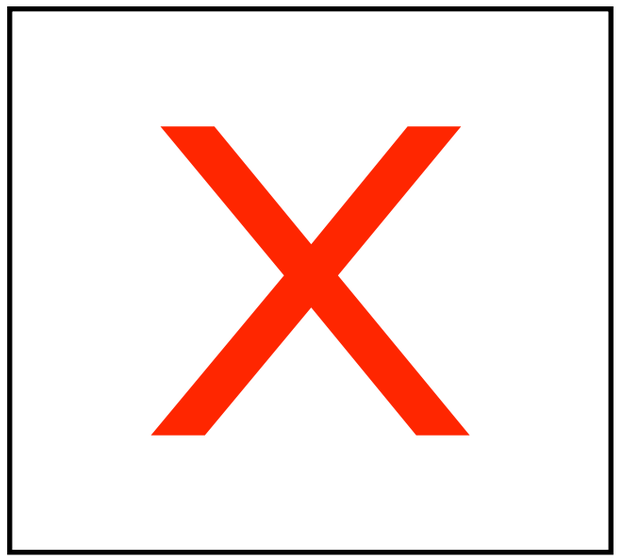
Looks good, so far.

Chirp Scan

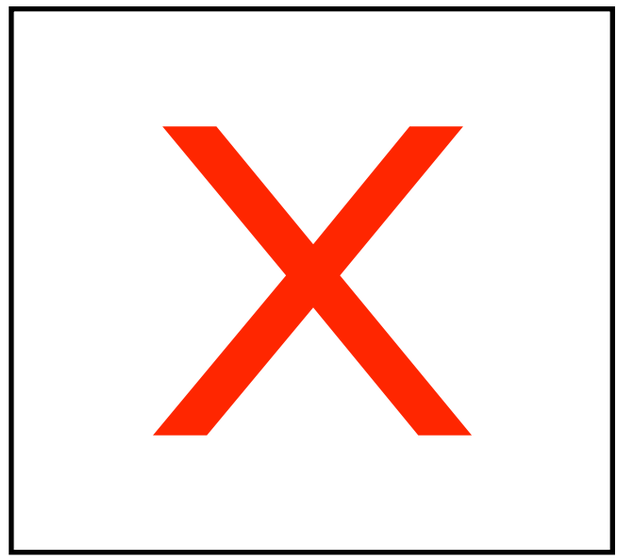
Setting A: 20pC, 4.18GeV Setting B: 20pC, 13.1GeV Setting 3: 150pC, 13.1GeV

Chirp Scan: Laser Heater ON vs. OFF





Normalized to mean(Icamera)



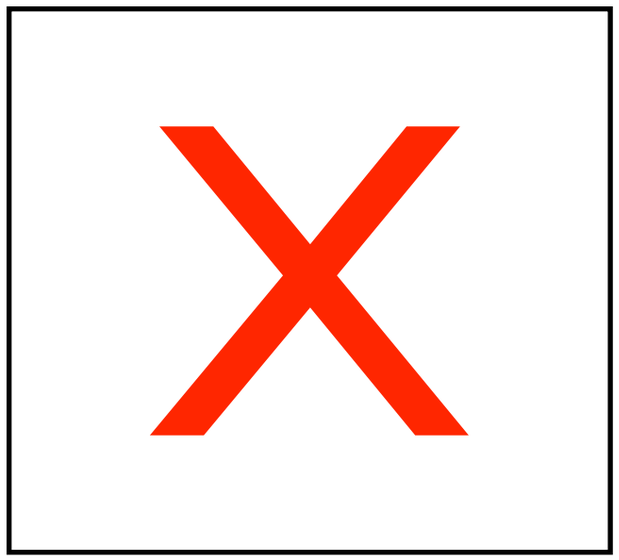
Normalized to mean(Icamera)

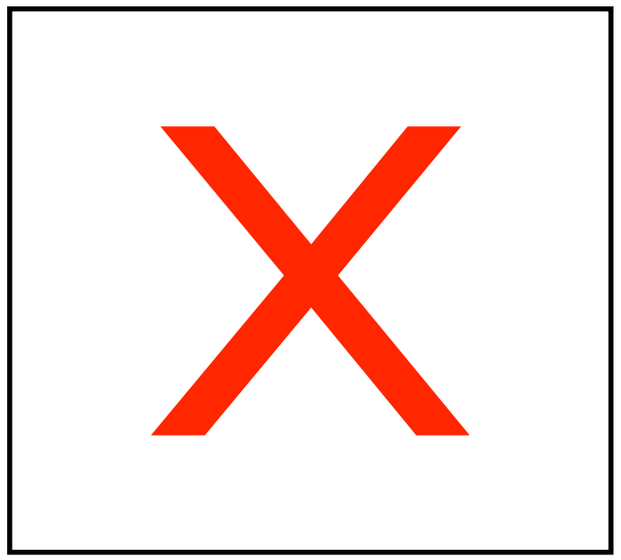
- Scanned from under compression to over compression
- Camera intensity in the same level for both LH ON/OFF, when the bunch was longer
- Small enhancement in camera intensity @ Peak compression of -2900
- LaserHeater ON: no COTR (maximum enhancement of ~5%)
- LaserHeater OFF: maximum enhancement of ~10% @ peak compression

Chirp Scan

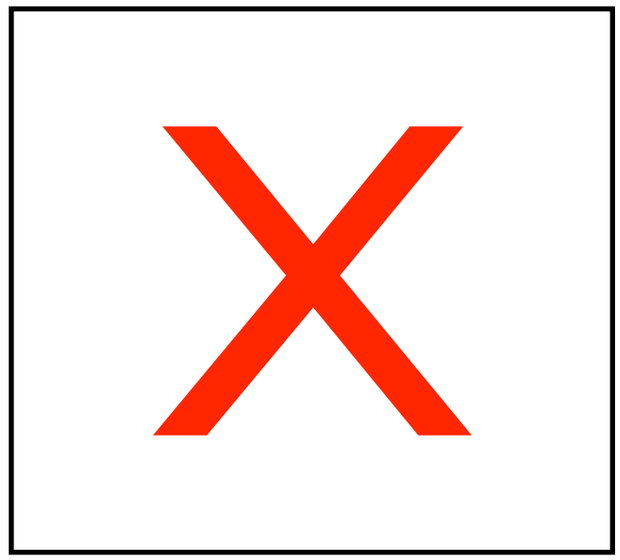
Setting A: 20pC, 4.18GeV | Setting B: 20pC, 13.1GeV | Setting 3: 150pC, 13.1GeV

Chirp Scan: Laser Heater ON vs. OFF





Normalized to mean(Icamera)



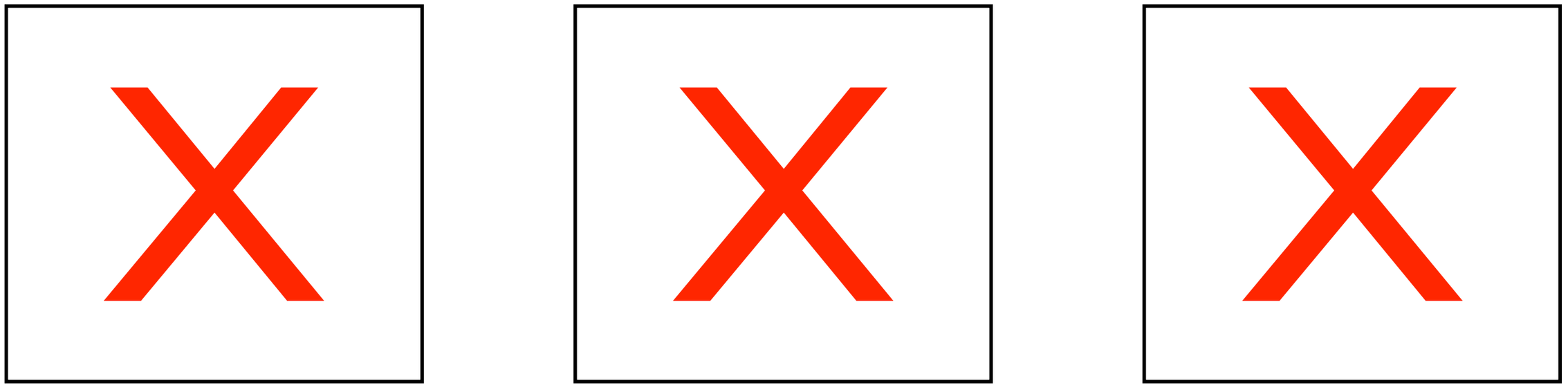
Normalized to mean(Icamera)

- LH on: no COTR
- LH off: only enhancement of factor ~1.2 at peak compression

Chirp Scan

Setting A: 20pC, 4.18GeV Setting B: 20pC, 13.1GeV Setting 3: 150pC, 13.1GeV

Chirp Scan: Laser Heater ON vs. OFF
(ROI is reduced to a smaller area excluding the stripe pattern)

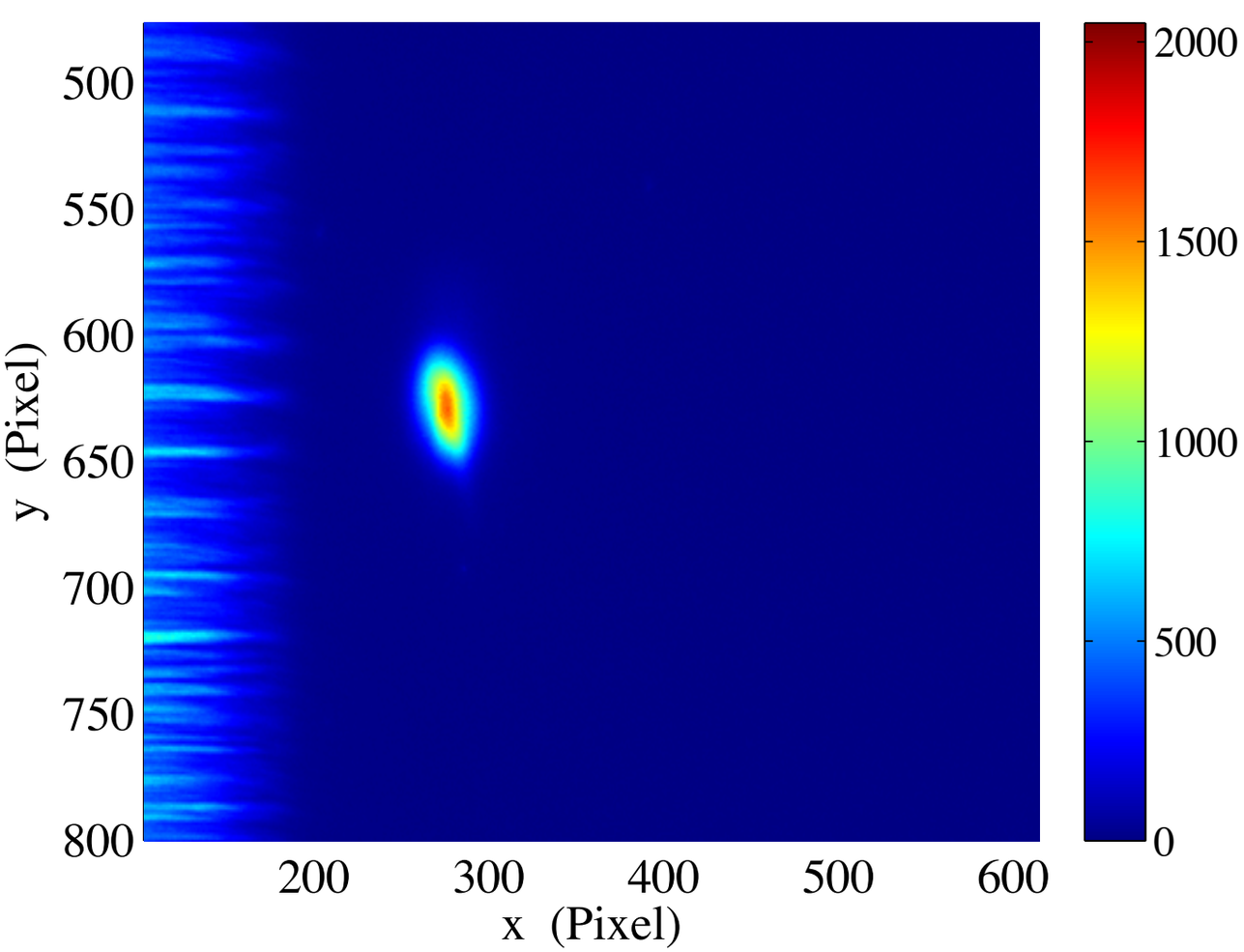


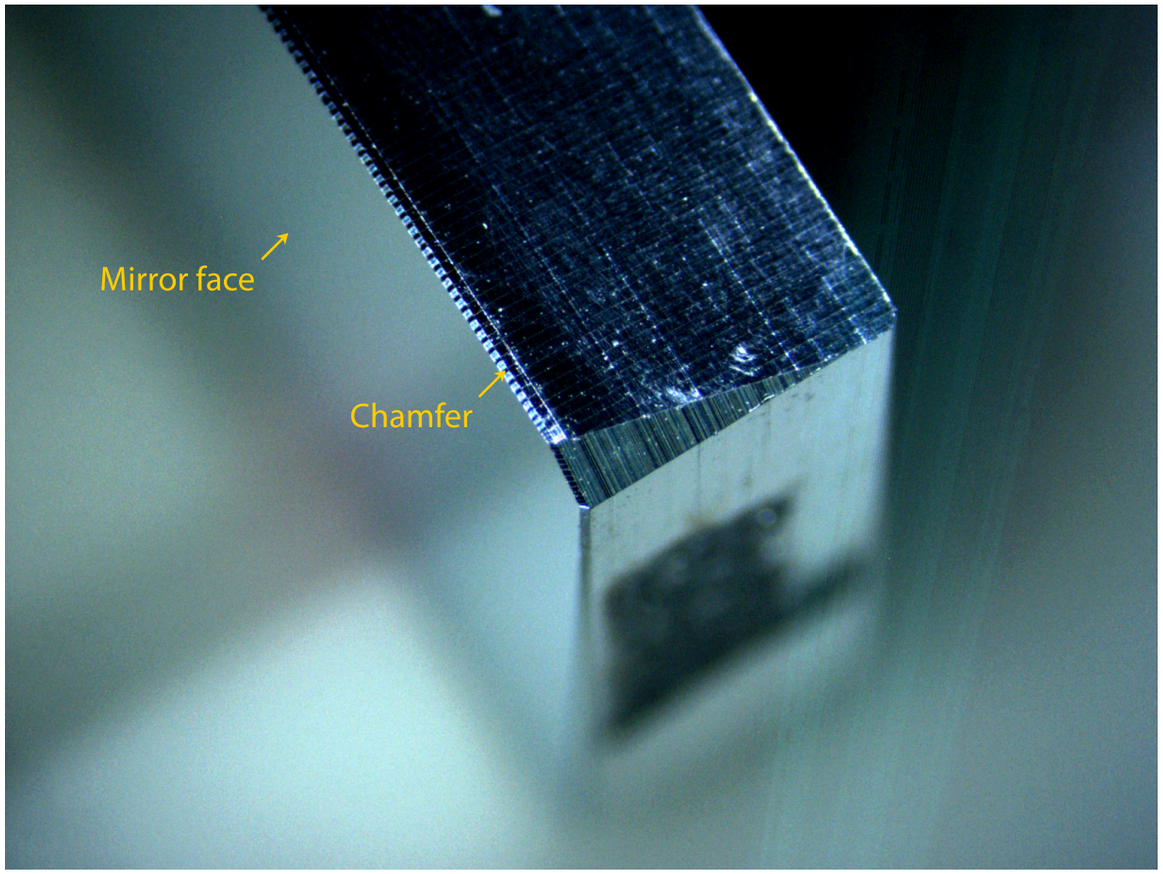
- With reduced ROI, beam sizes can be determined more precisely.
- Up to Ipeak=5000A, no COTR and good agreement with LH off and on.
- LH on: in the worst case at peak compression, an enhancement of factor ~2

A More Detailed Look at the Images

> Features observed to the left of the beam

> Possibly coherent optical diffraction radiation from the mirror edge





Summary

- > SwissFEL transverse profile imager prototype has been successfully installed at LCLS linac-to-undulator line
- > Alignment issues could be fixed in December 2013
- > More systematic measurements performed in March 2014
- > Possible COTR contribution under nominal conditions (nominal compression, laser heater on):
  - > Low charge (20 pC): not more than 5%
  - > High charge (150 pC): factor 2 when beam size is minimum
    - > (Compare to factor 10^5 with OTR profile monitor)
- > Stripes beside the beam could be coherent diffraction radiation from the mirror chamfer

Thank You…

> Hansueli Walther for the technical design

> The AMI team for manufacturing the components

> Markus Baldinger for the assembly

> Patrick Krejcik for setting up an installation of the PSI profile monitor at LCLS

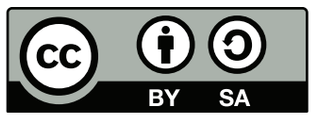
> Gene Kraft for coordinating the installation

> Henrik Loos for support with software and operation of the monitor

> Minjie Yan for measurements

> Zhirong Huang for the slide on the laser heater

> The entire LCLS Operations crew



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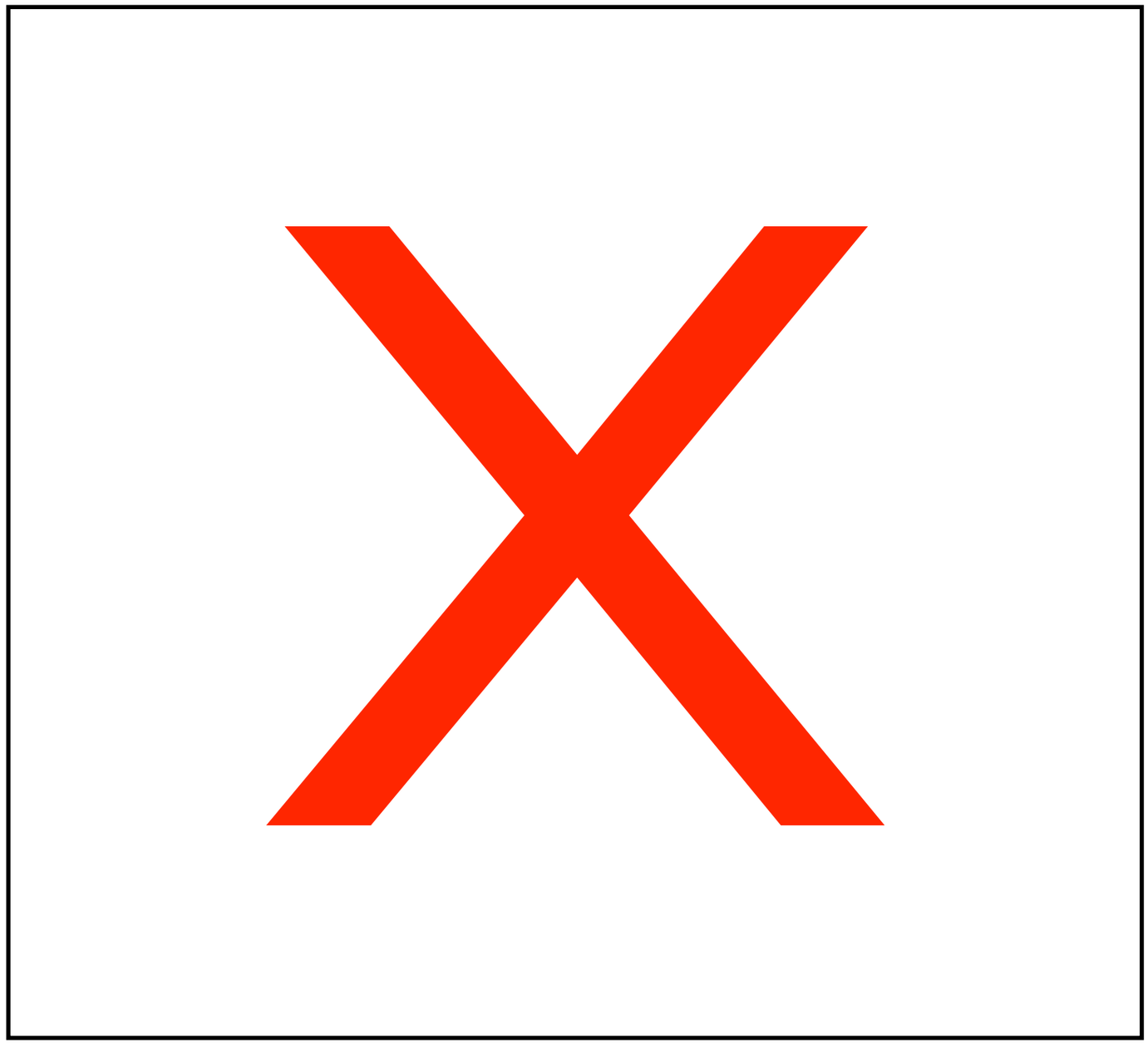
One More Thing…

> Slice Emittance with TCAV3, Laser Heater off, I_{pk} = 750 A



Preliminary!