Bunch Length Measurements at SPEAR3

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for the SPEAR3 Accelerator Group

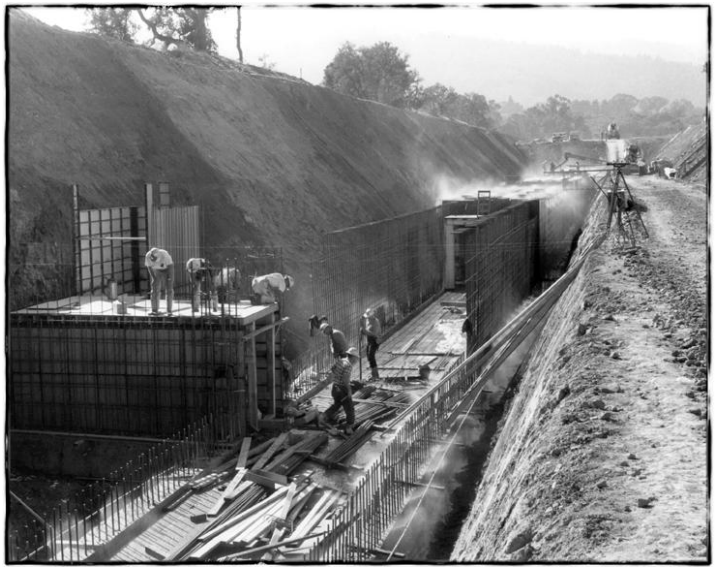
Outline

1. SLAC, LCLS, SPEAR3 and short bunch operation (low-α)
2. Streak camera measurements
3. Cross-correlation measurements
4. Summary

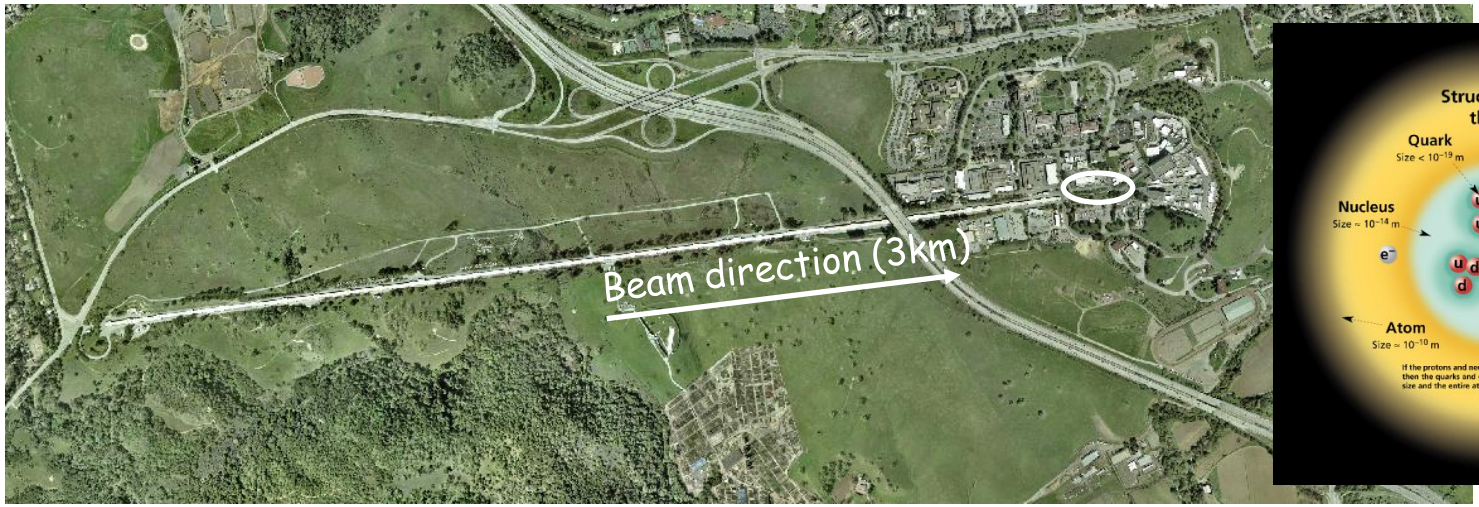
SLAC Project M circa 1962

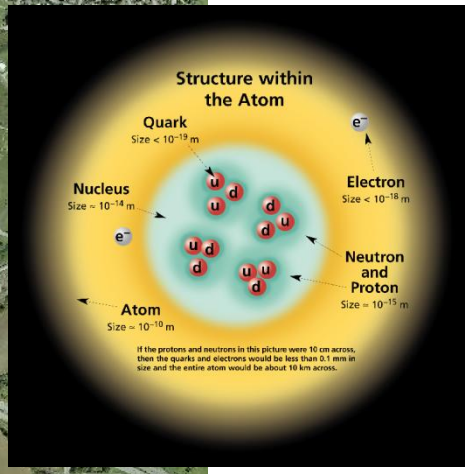
W. K. H. "Pief" Panofsky, 1919 - 2007

SLAC Professor and Director Emeritus



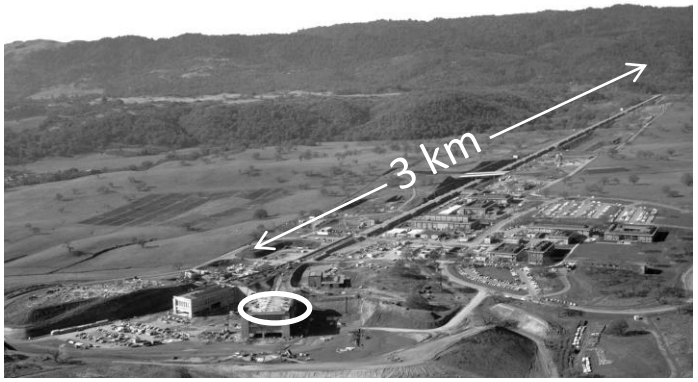
Stanford Linear Accelerator Center



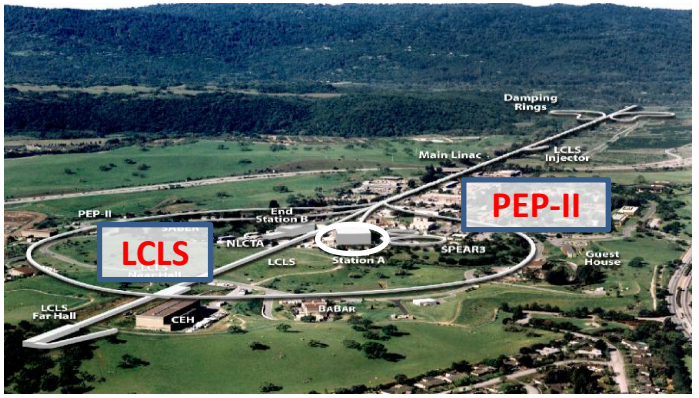


SLAC 2-mile accelerator and SPEAR storage ring

Early view of SLAC

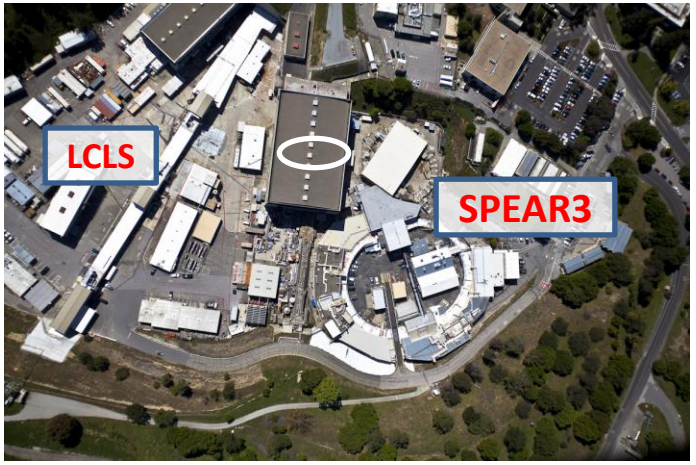


SLAC with LCLS

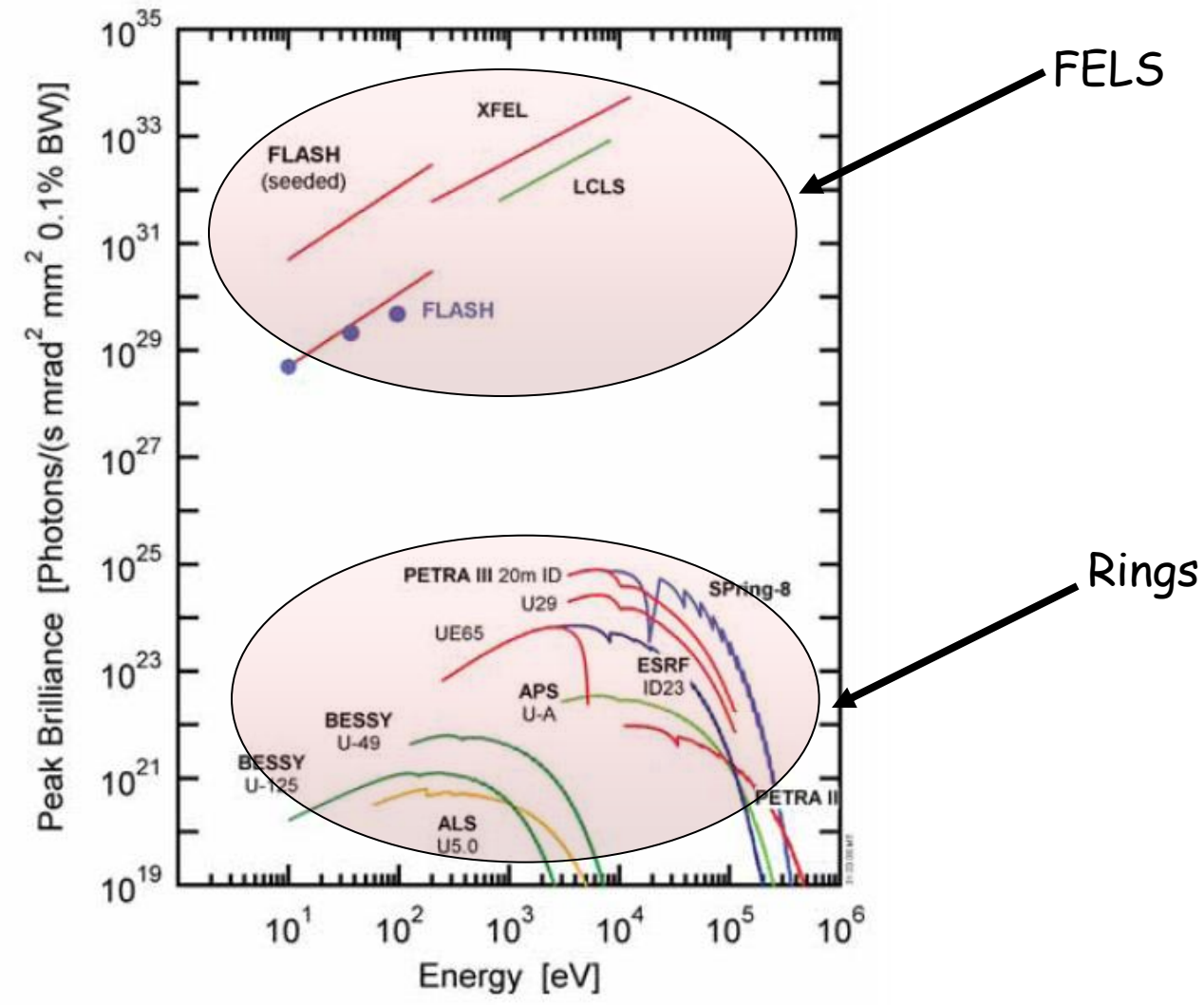


SPEAR circa 1972

SPEAR3 circa 2009

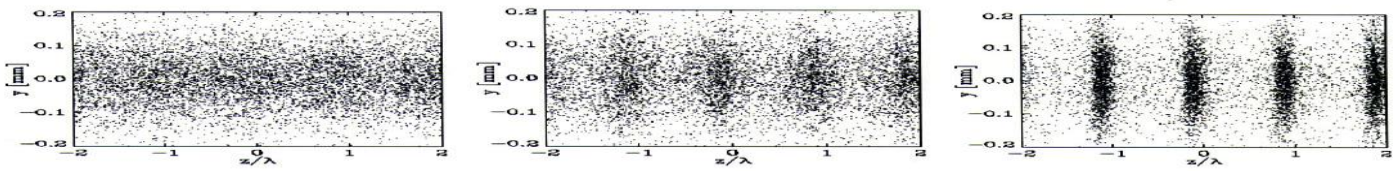


Free-Electron Lasers
- short pulse, high power, coherence



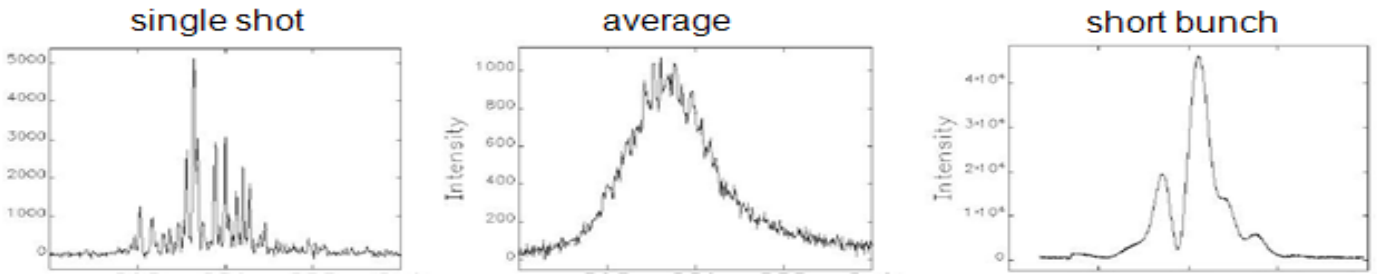
Electron and Photon Pulse Structure: SASE

Electron



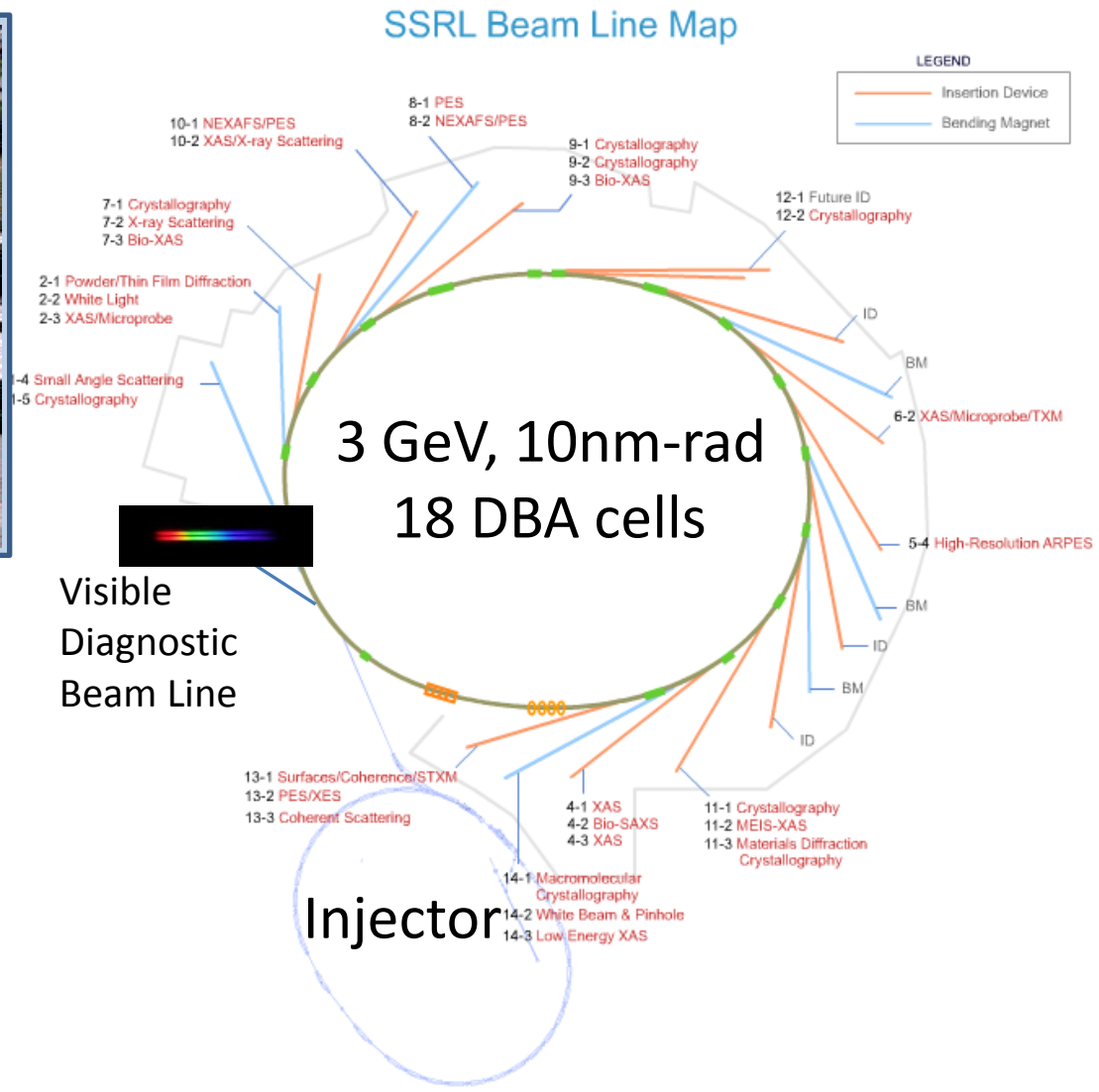
START MIDDLE END

Photon

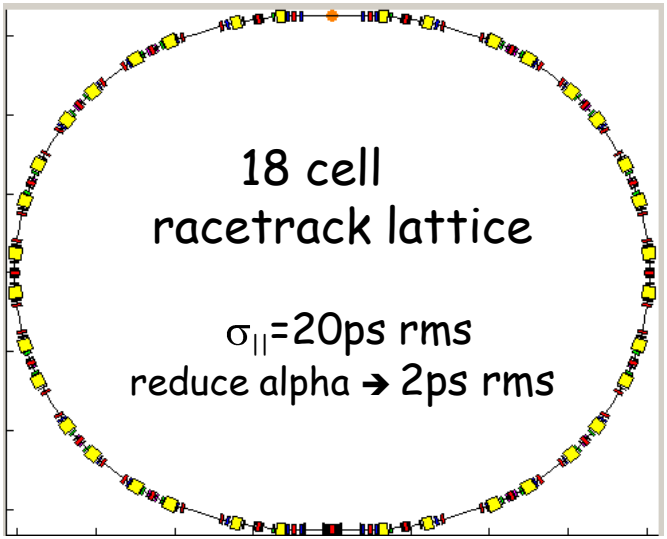


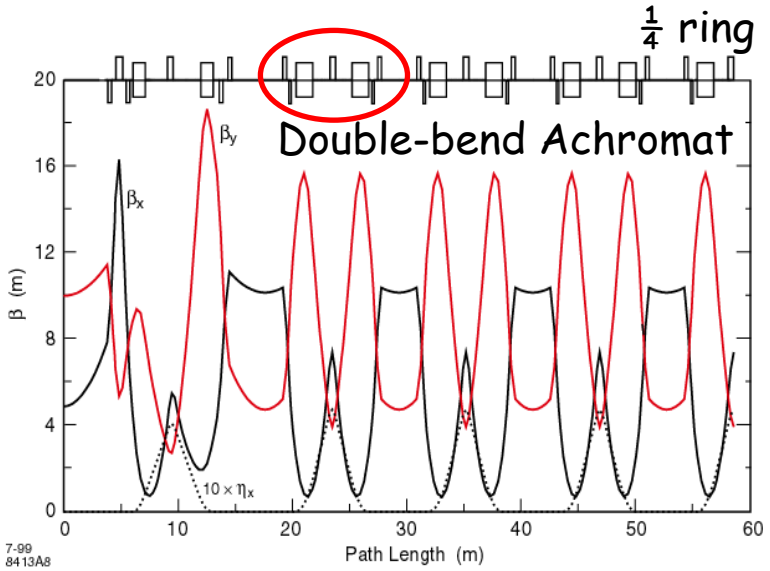
…the (LCLS) X-ray pulse duration appears much shorter than the nominal 80 fs (bunch)
…the 80fs mode of operation actually produces X-ray pulses of ~20-40fs
(L. Young, et al, Nature 446,1 July 2010)

Back to the SPEAR3 Light Source

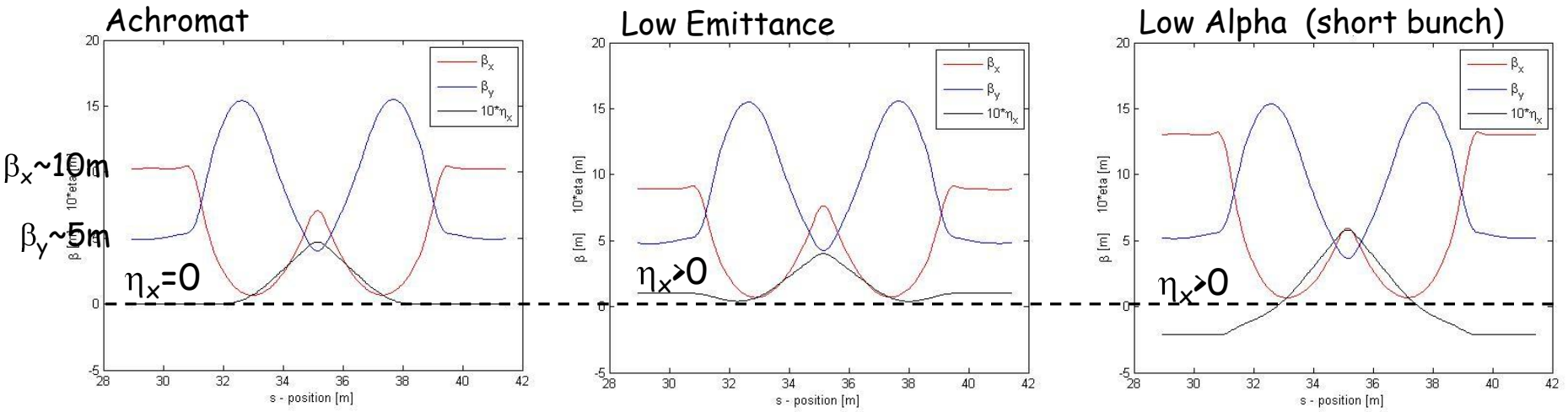


SPEAR3 Accelerator Optics



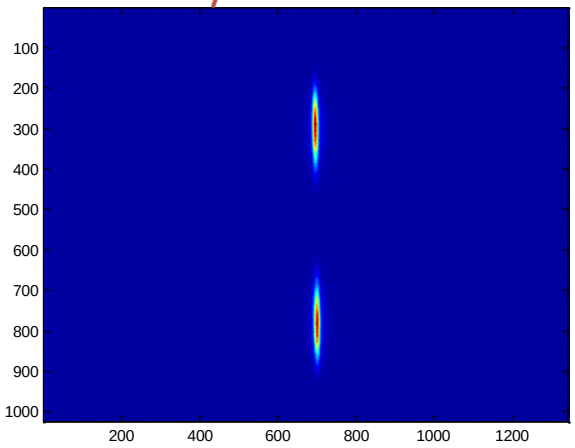


Single cell optics

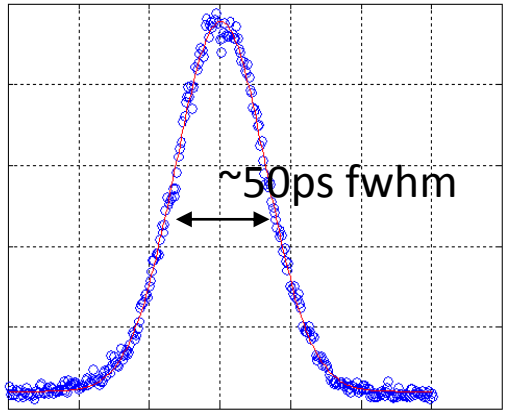


Typical streak camera data

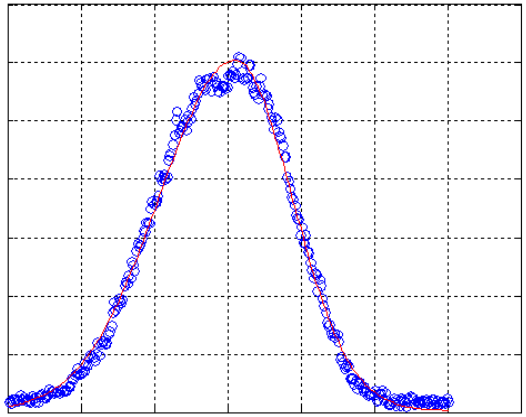
R2 synchroscan



1mA Symmetric Gaussian Fit



20mA Asymmetric Gaussian Fit

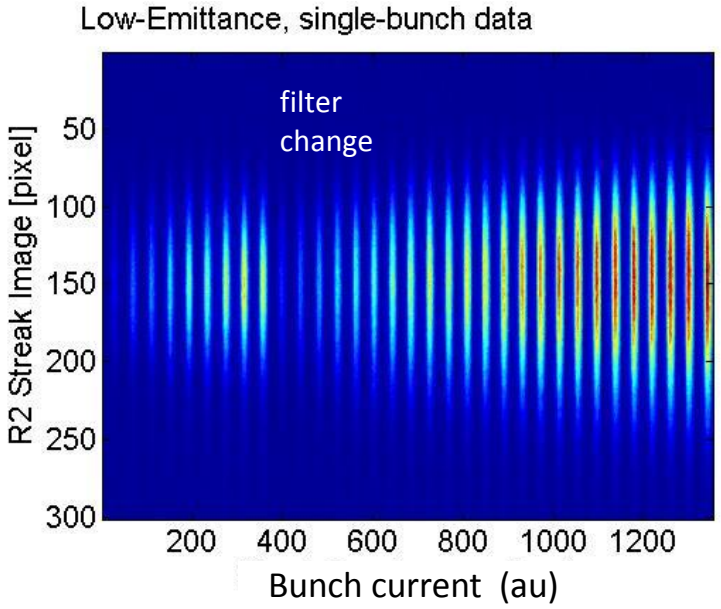


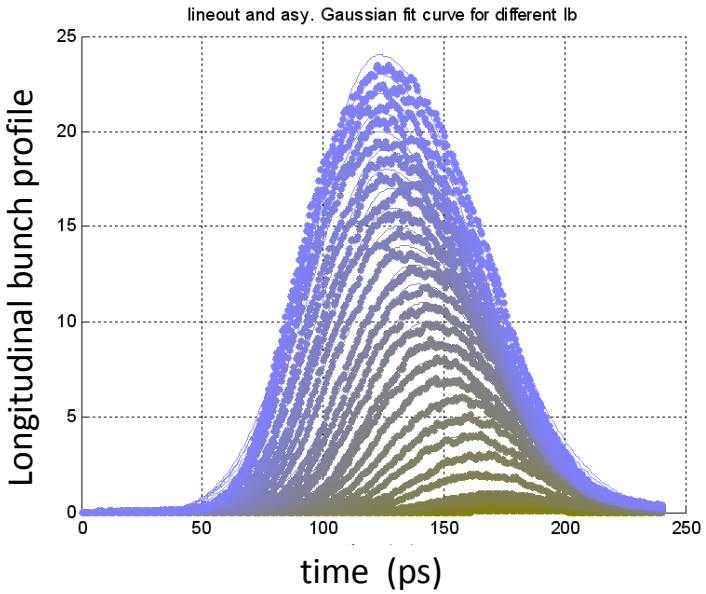
screen height	ps/px
R1: 157.45ps	0.1538ps/px
R2: 704.41ps	0.6879ps/px
R3: 1214.60ps	1.1861ps/px
R4: 1686.50ps	1.6470ps/px

$$I(z) = I_1 + I_0 \exp\left\{-\frac{1}{2}\left(\frac{z-\bar{z}}{\sigma(1+A\,\mathrm{sgn}(z-\bar{z}))}\right)^2\right\}$$

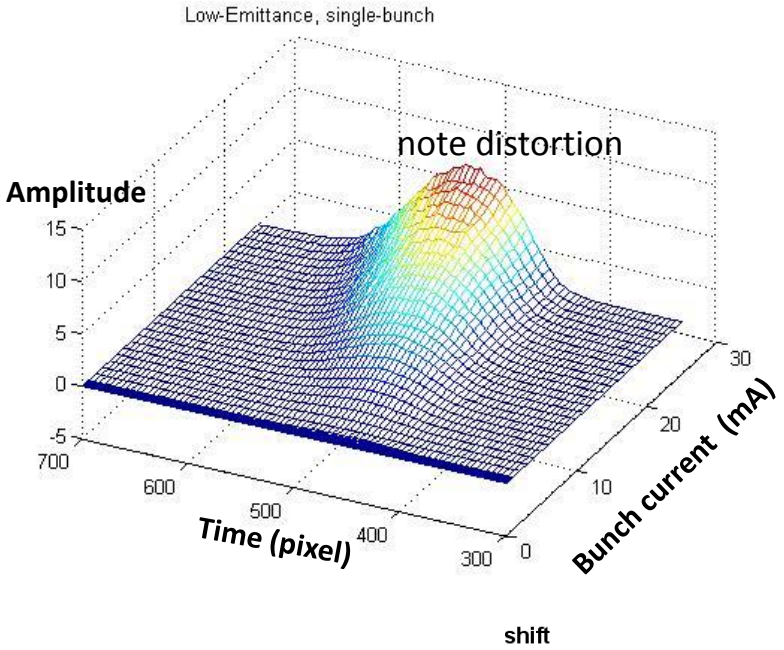
asymmetry term

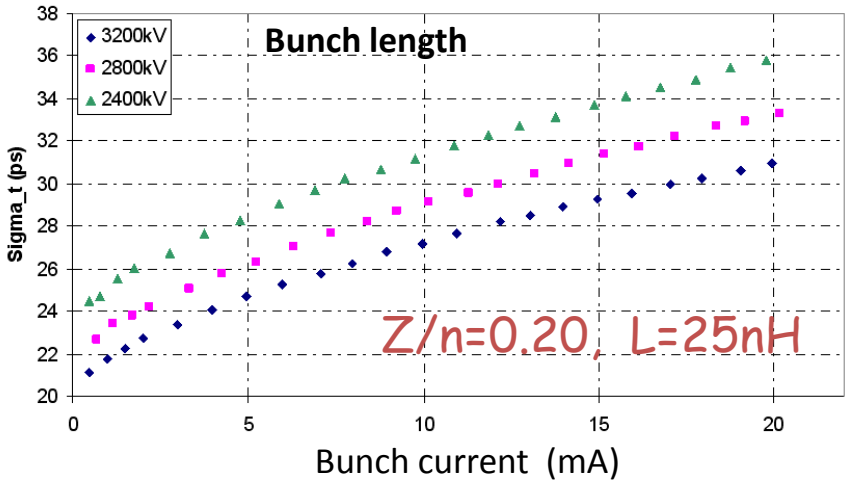
Low-emittance optics: bunch length vs. current

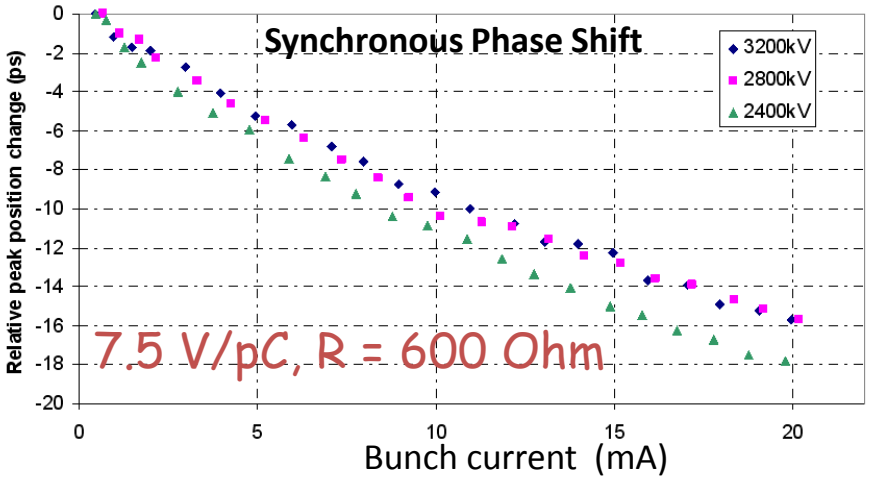


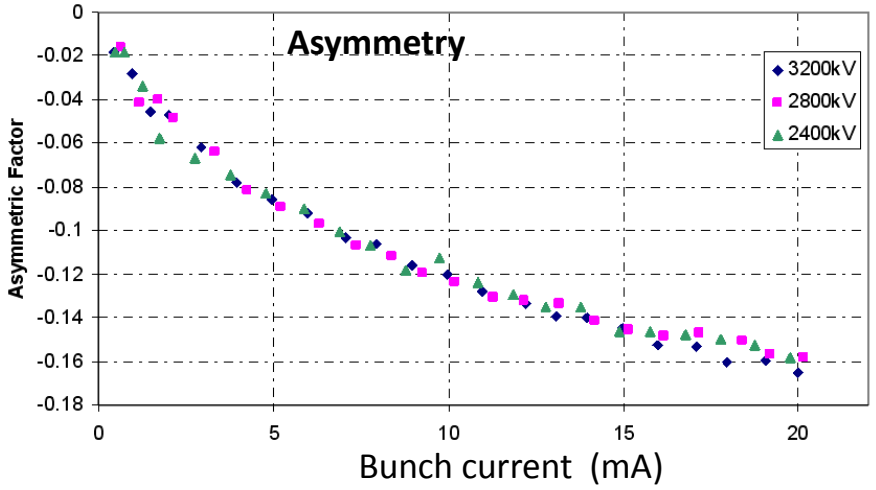


Current scan and ring impedance

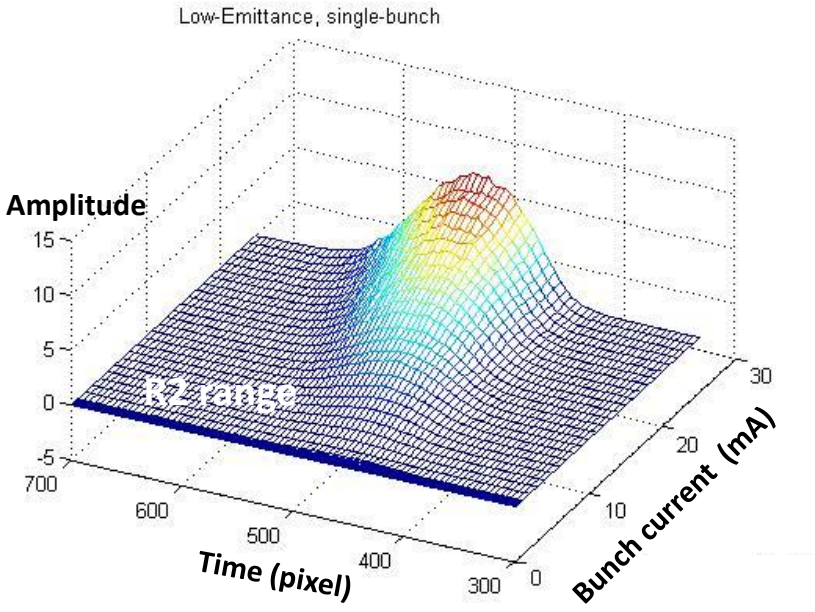


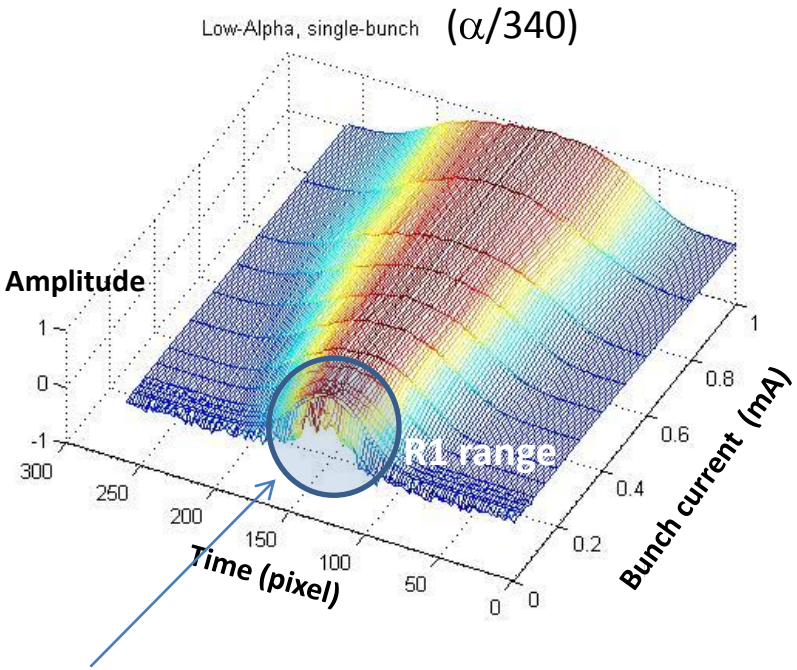


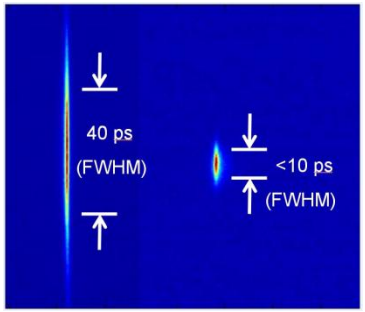




Bunch length measurements in low-alpha mode



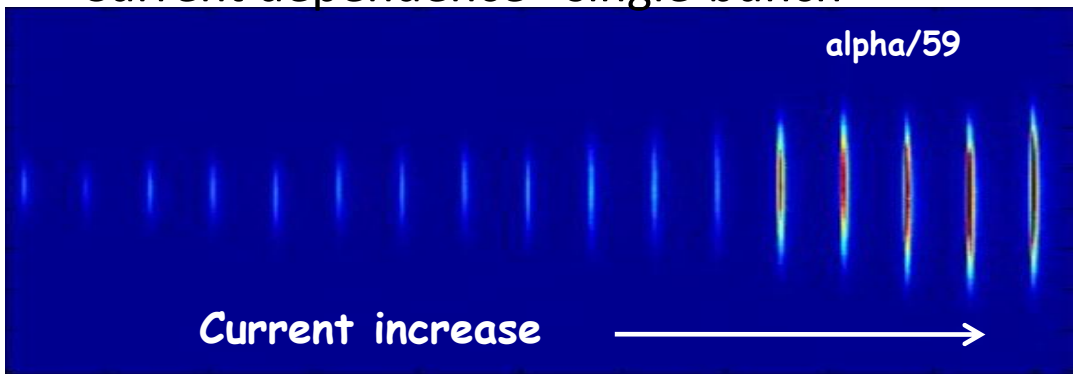




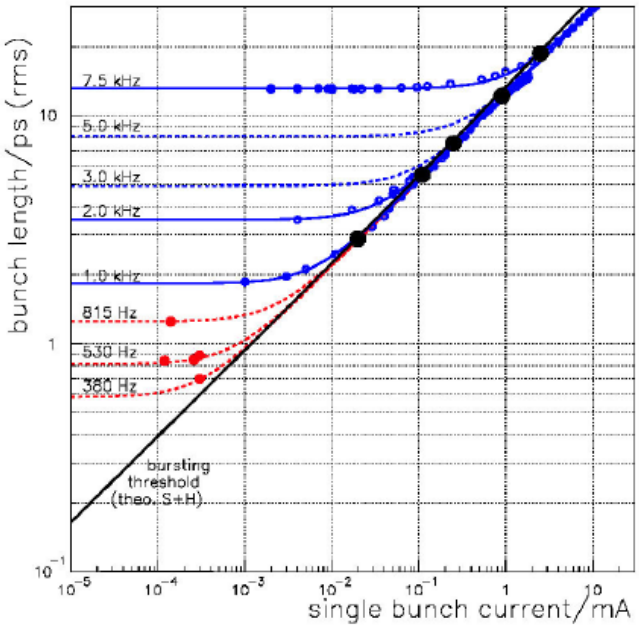
Low beam current (~10-20pc , SR emission)
Streak camera resolution limit ~2.4ps rms

Bunch length scaling in low-α mode (cont'd)

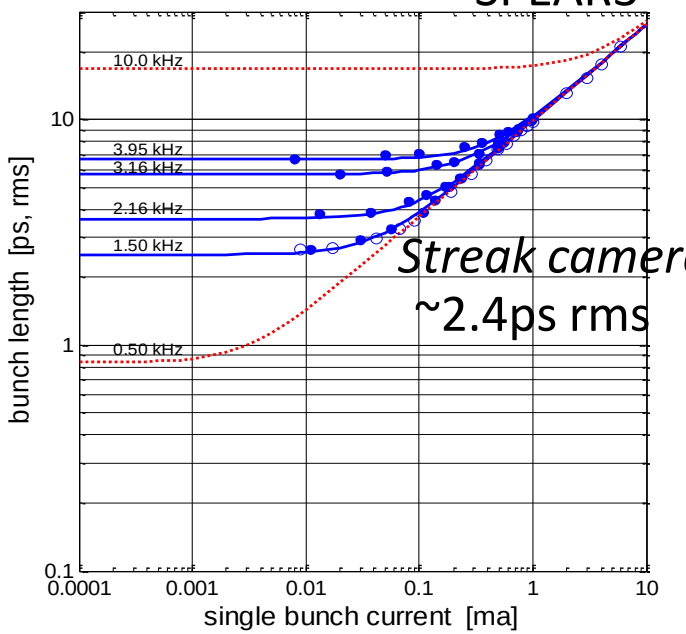
Current dependence - single-bunch



BESSY-II

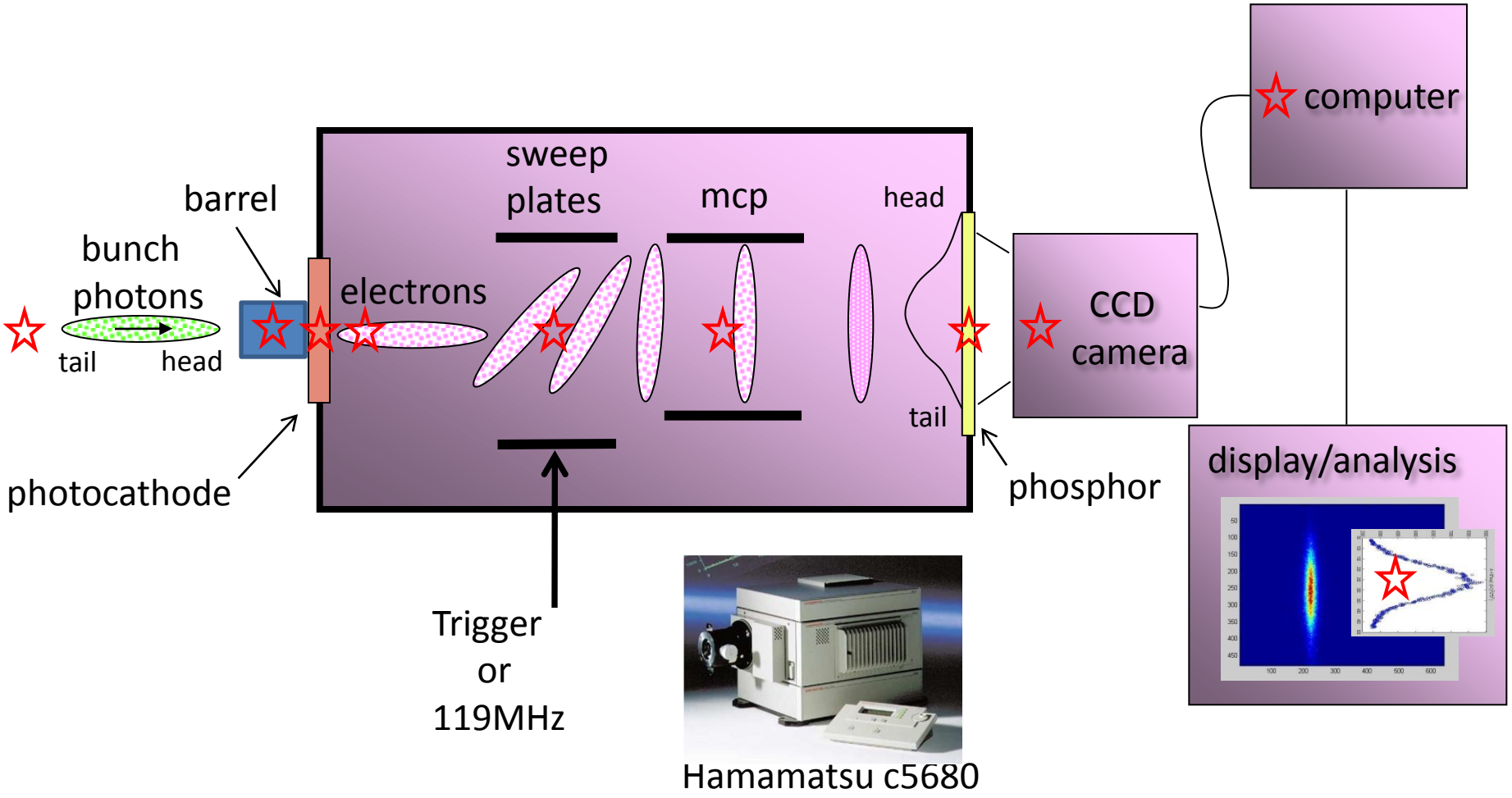


SPEAR3



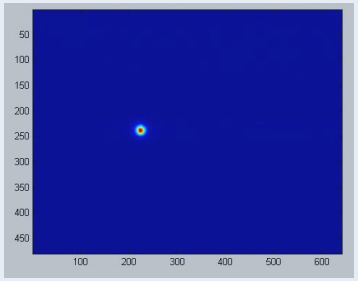
Streak camera limit
~2.4ps rms

Streak camera resolution issues



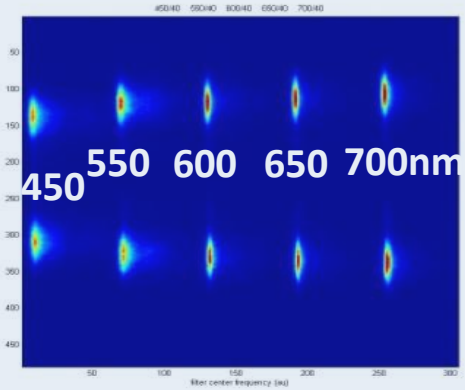
System Calibration

Focus mode



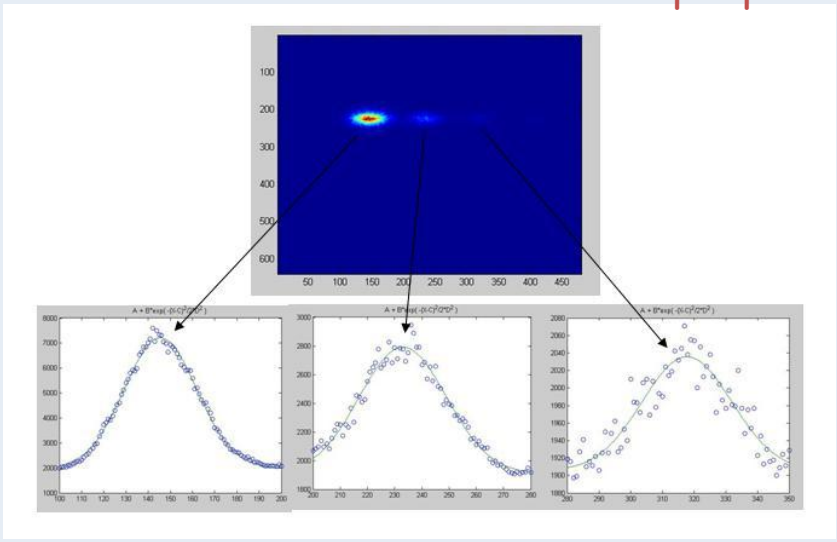
5-6 pixel FWHM

Chromatic dispersion



Glass Etalon

Use 2L/c echo to determine px/ps



screen height	ps/px
R1: 157.45ps	0.1538ps/px
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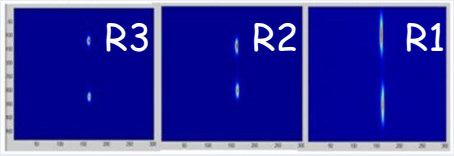
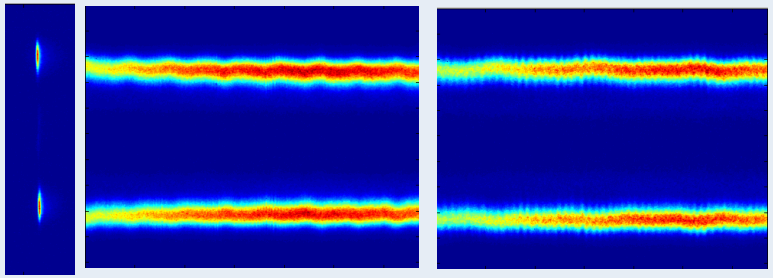


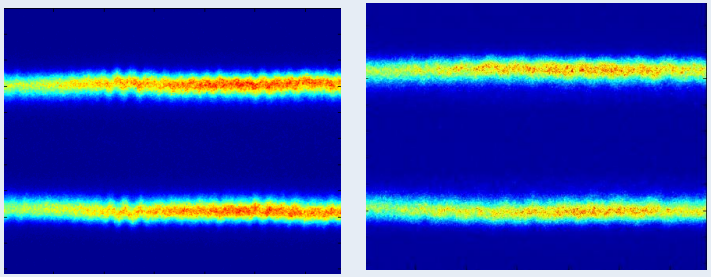
Synchroscan, dual-scan, triggered-scan operation

Synchroscan integrates but has ripple

50ms horizontal **20ms**



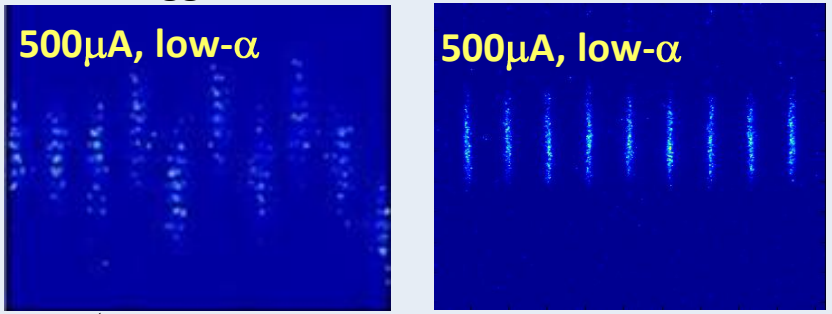
10ms **5ms**



deconvolve ripple, ~1ps phase noise

Triggered-scan isolates but has noise

triggered **dual-scan**



fit Gaussians,
histogram statistics

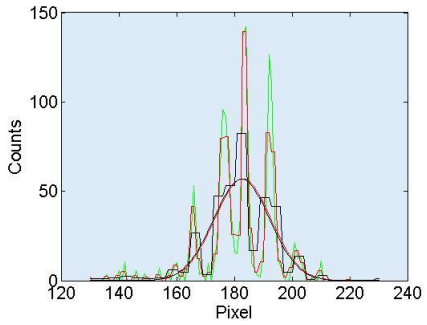
Statistical evaluation of triggered-scan data

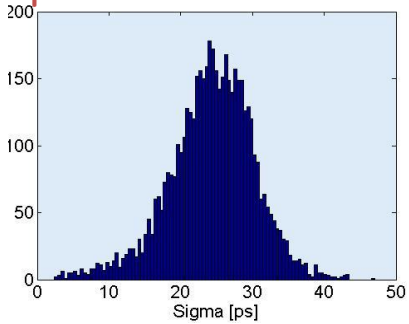
Single-shot fits

Histograms

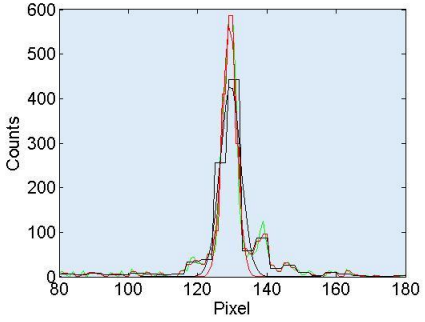
Centriod, Sigma and Sum

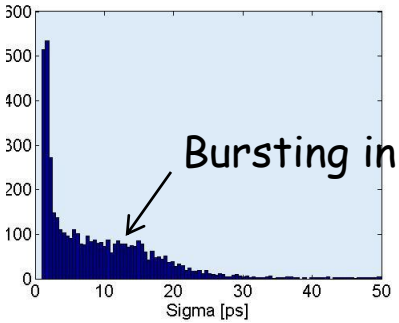
Nominal optics

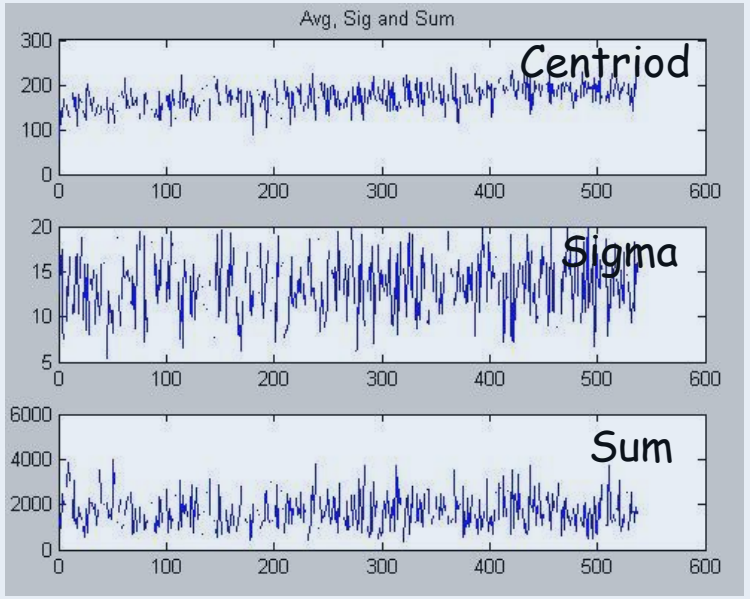




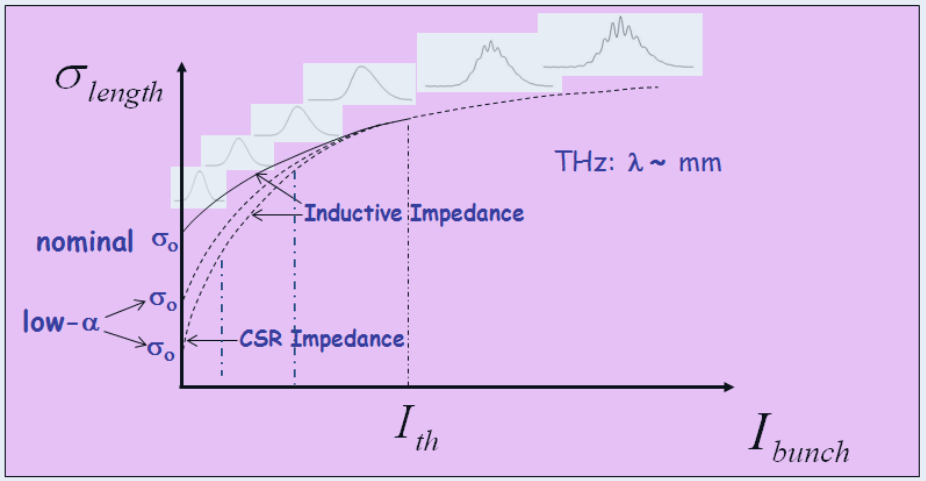
Low-alpha optics

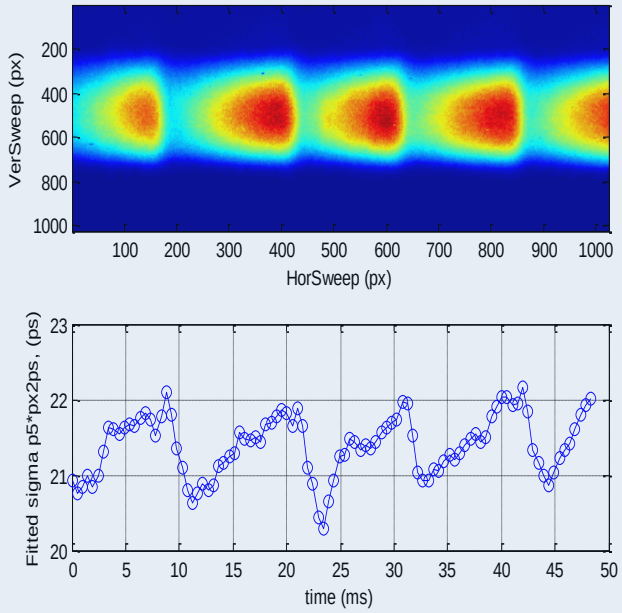




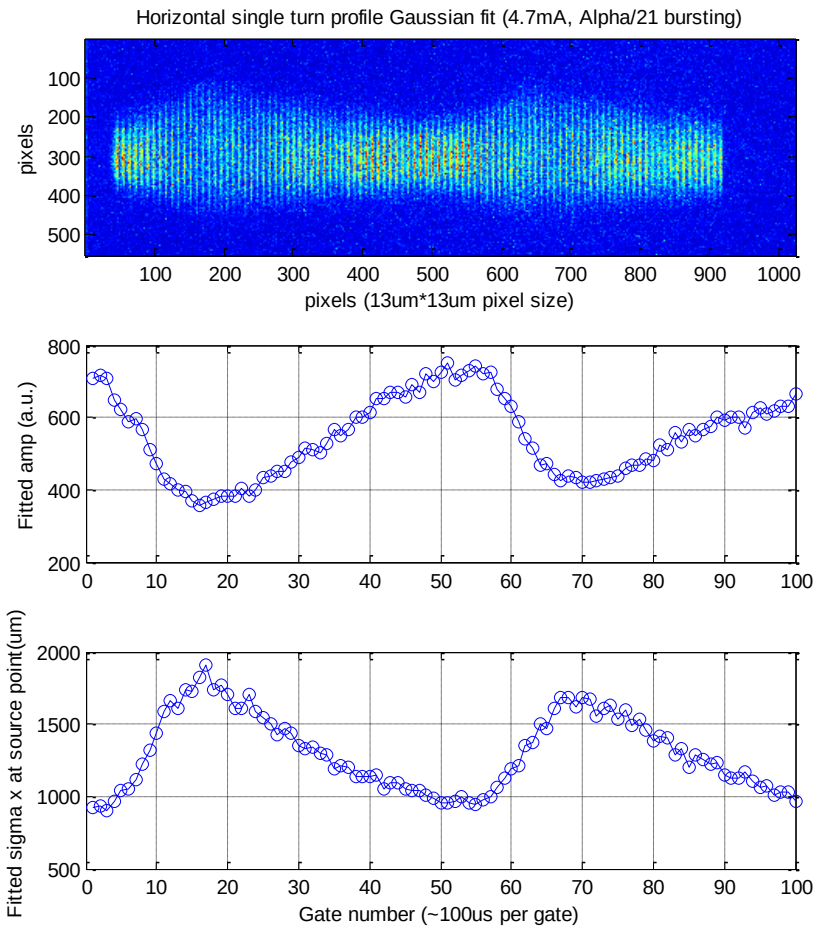


Bursting as seen on the streak camera





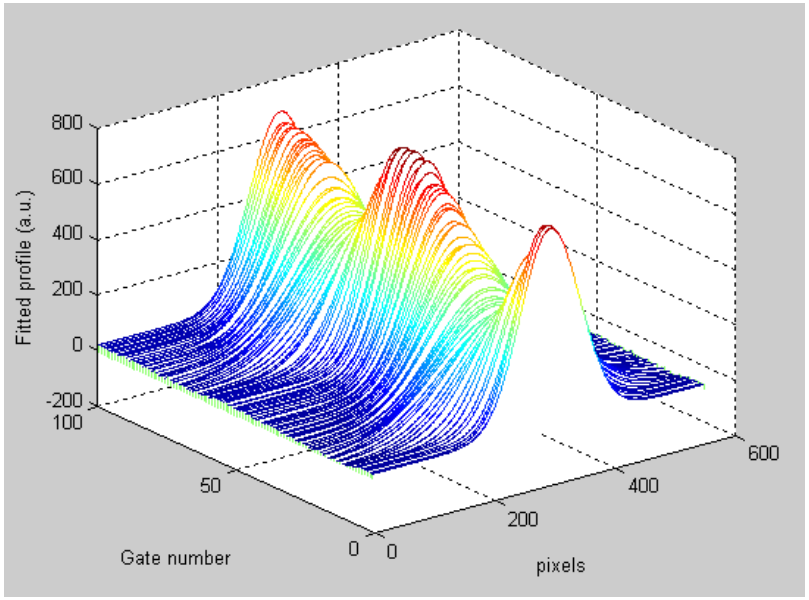
Bursting as seen on fast-gated camera



$\alpha/21$ 4.7mA

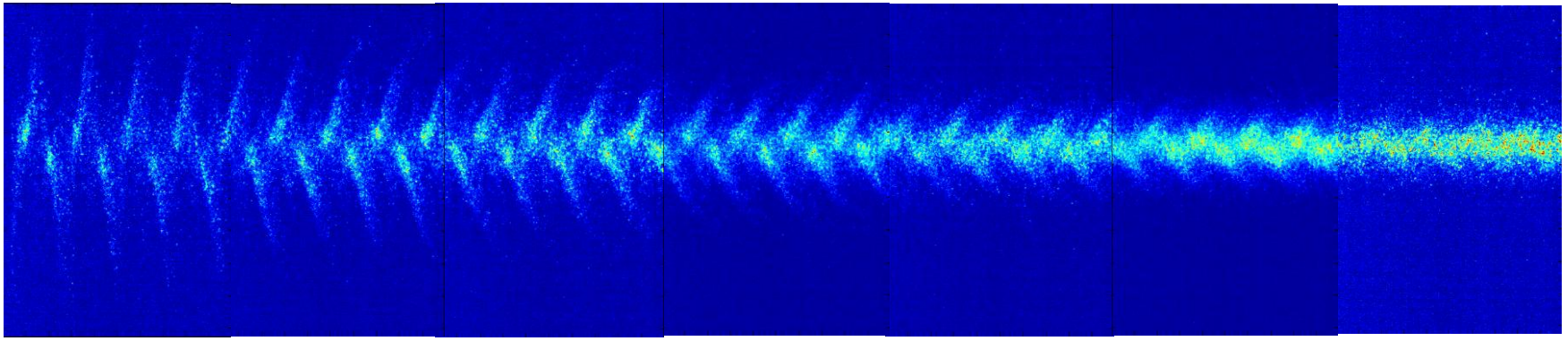
Gate trigger freq: ~10kHz

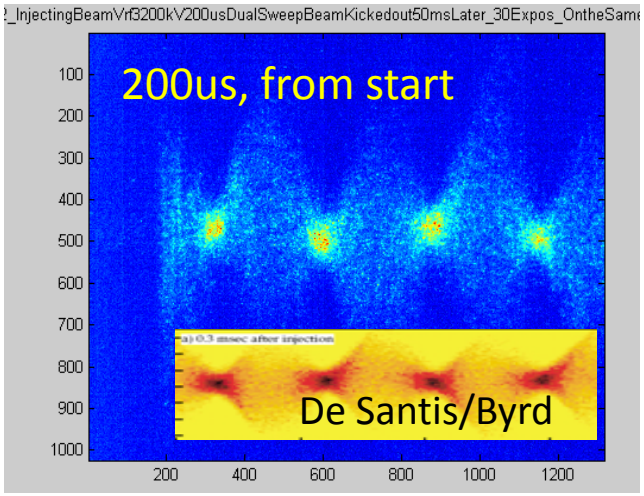
100 gates per exposure

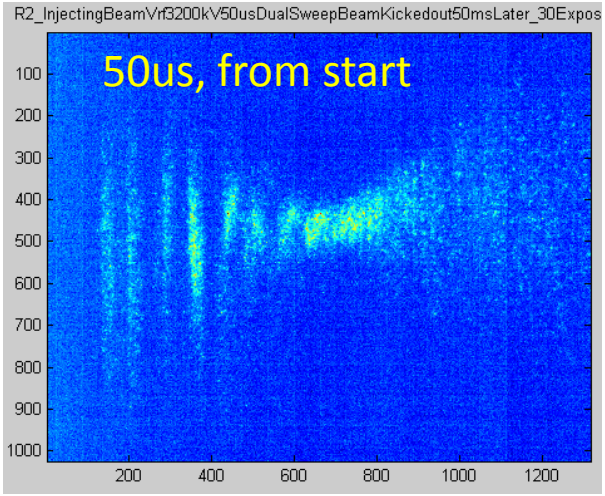


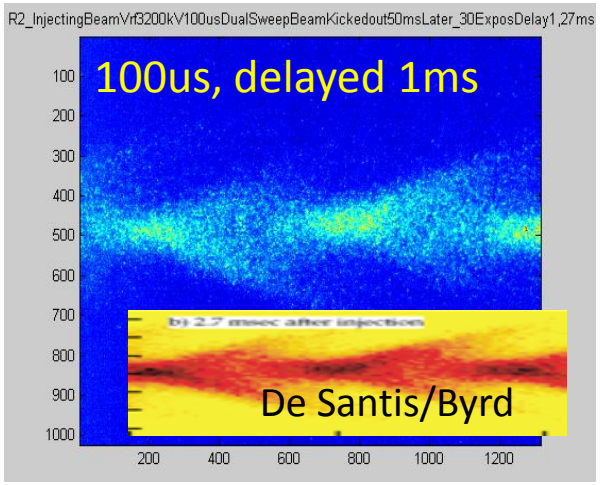
Injection damping transients – longitudinal plane

500us per frame

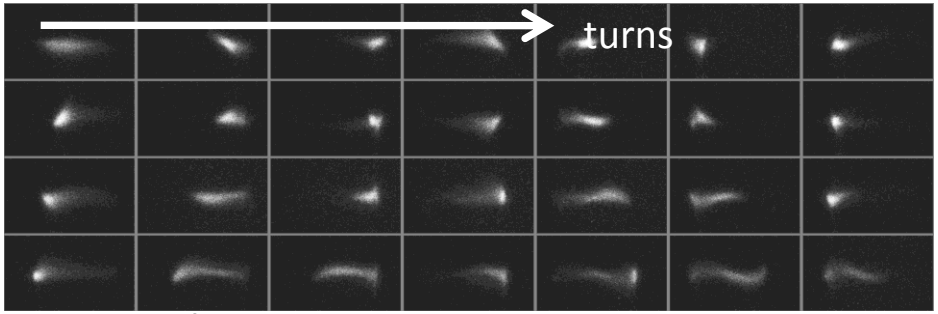




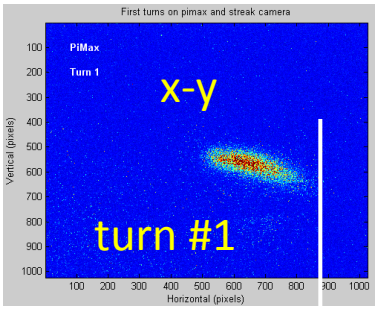


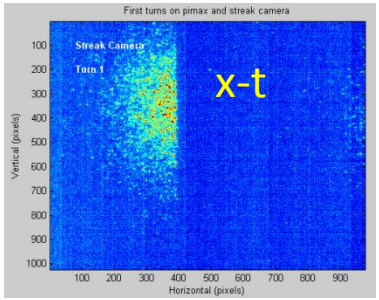


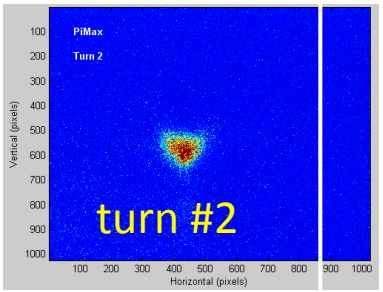
x-y projection and x-t projection of injected beam

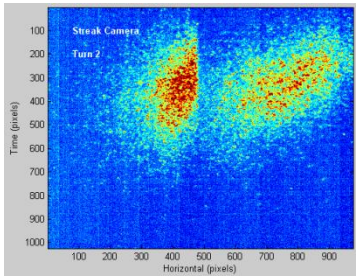


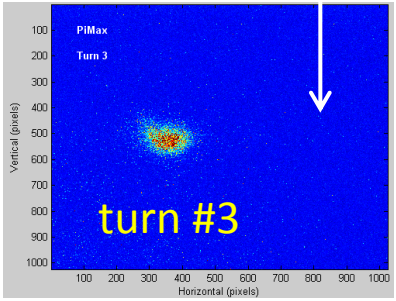
Fast Gated Camera Streak Camera Fast Gated Camera Streak Camera

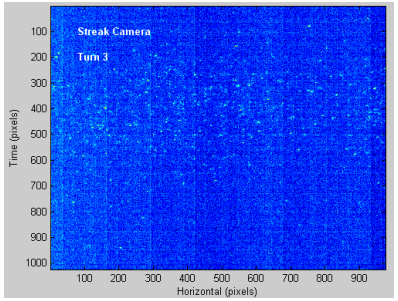


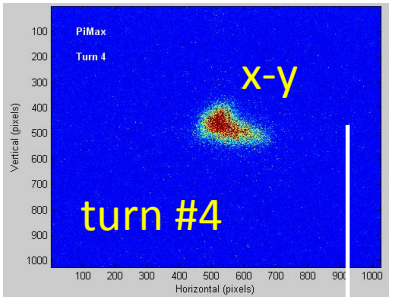


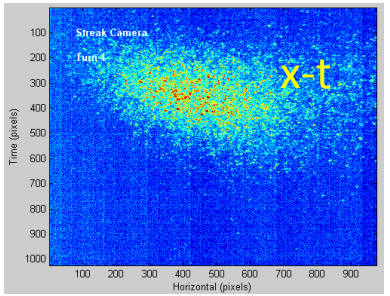


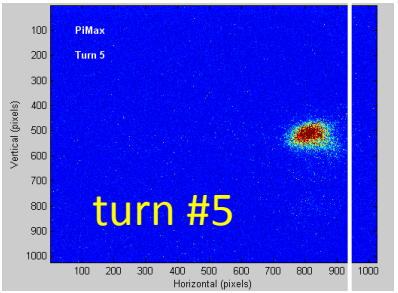


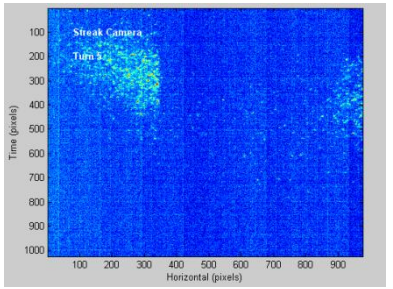


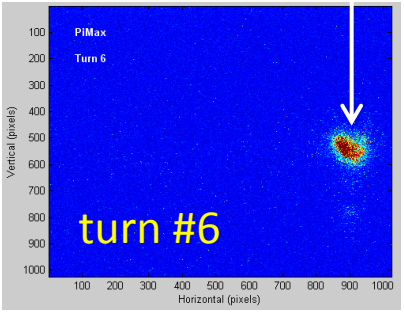


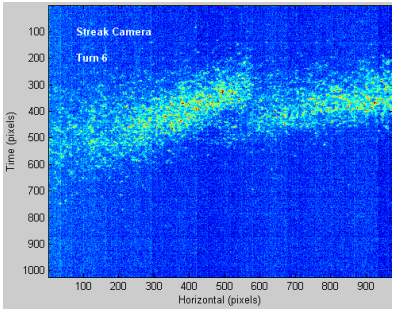












Laser/SR cross-correlation bunch length measurements

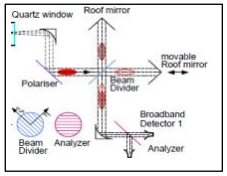
Goal is to produce ps x-ray pulses at MHz rates for pump/probe

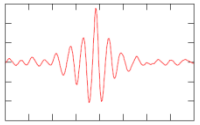
SLAC/Stanford PULSE Institute

Short Bunch Measurements with SR

IR/THz beam line

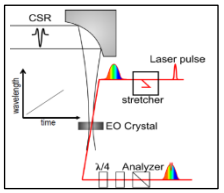
- Ø FIR interferometer/form factor





Fröhlich

- Ø CSR component/electro-optic

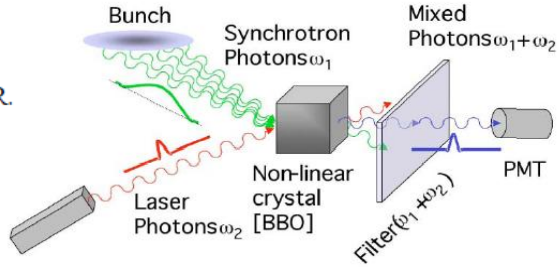


Steffen/Müller/Peier

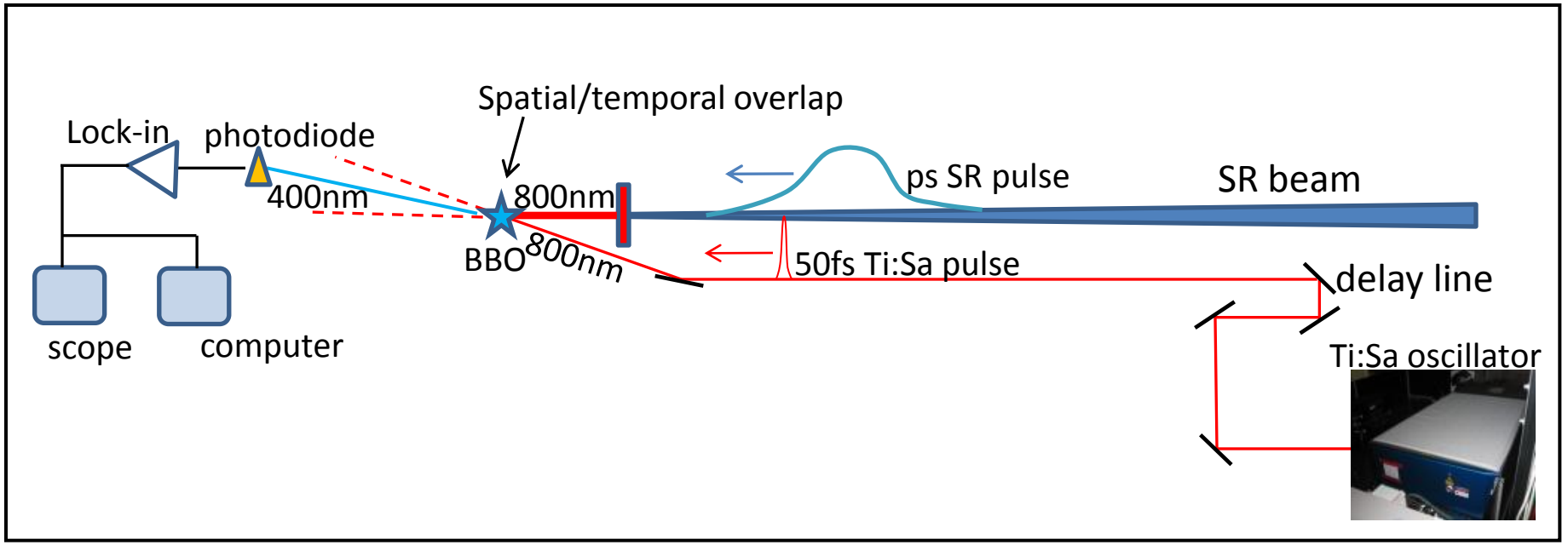
'optical sampling' in the visible (*Zolotorev, et al, ALS*)

DEVELOPMENT OF A LONGITUDINAL DENSITY MONITOR FOR STORAGE RINGS*

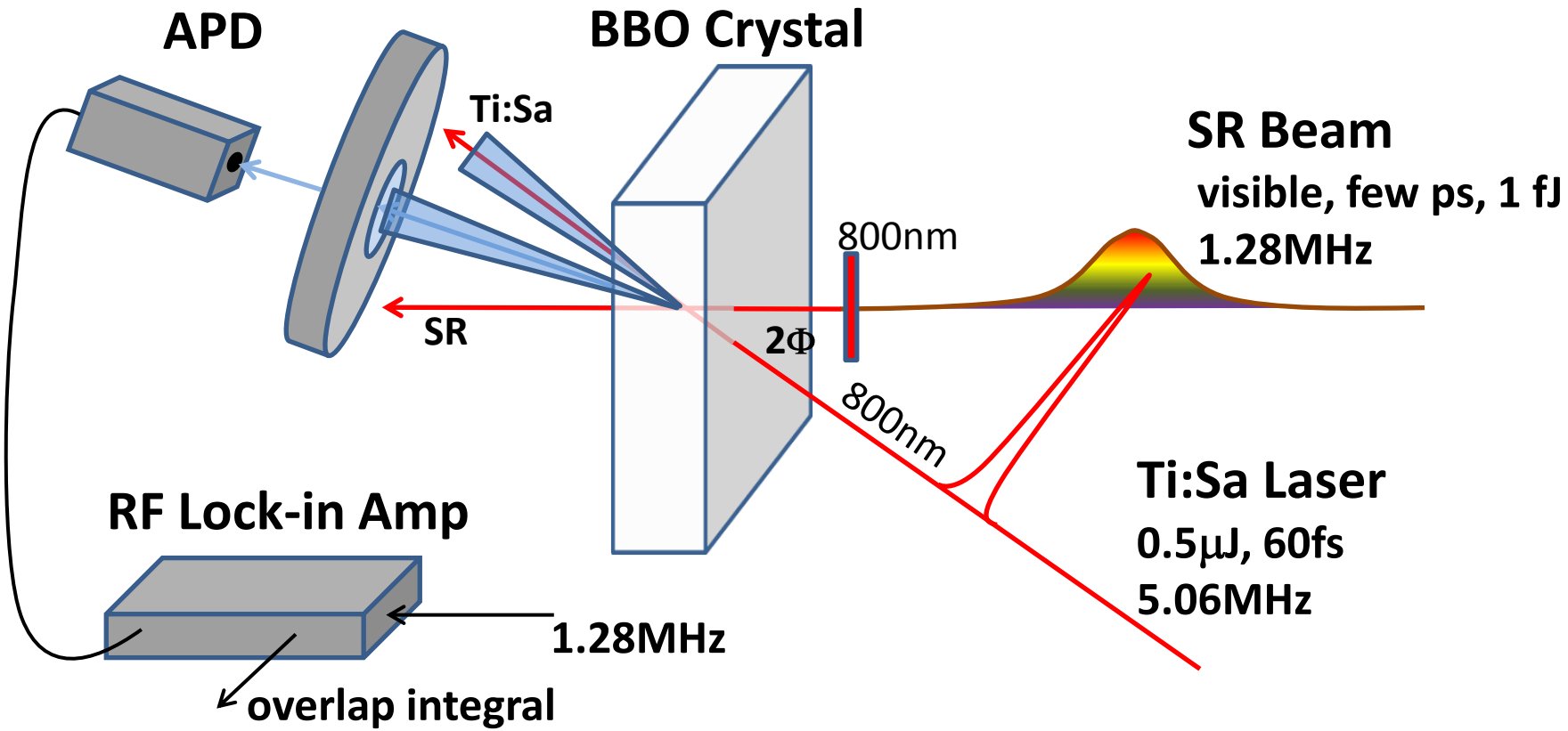
M. Zolotorev, J.-F. Beche, J. Byrd, P. Datte, S. De Santis, P. Denes, M. Placidi, A. Ratti, V. Riot, R. Schoenlein and W. Turner, Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA



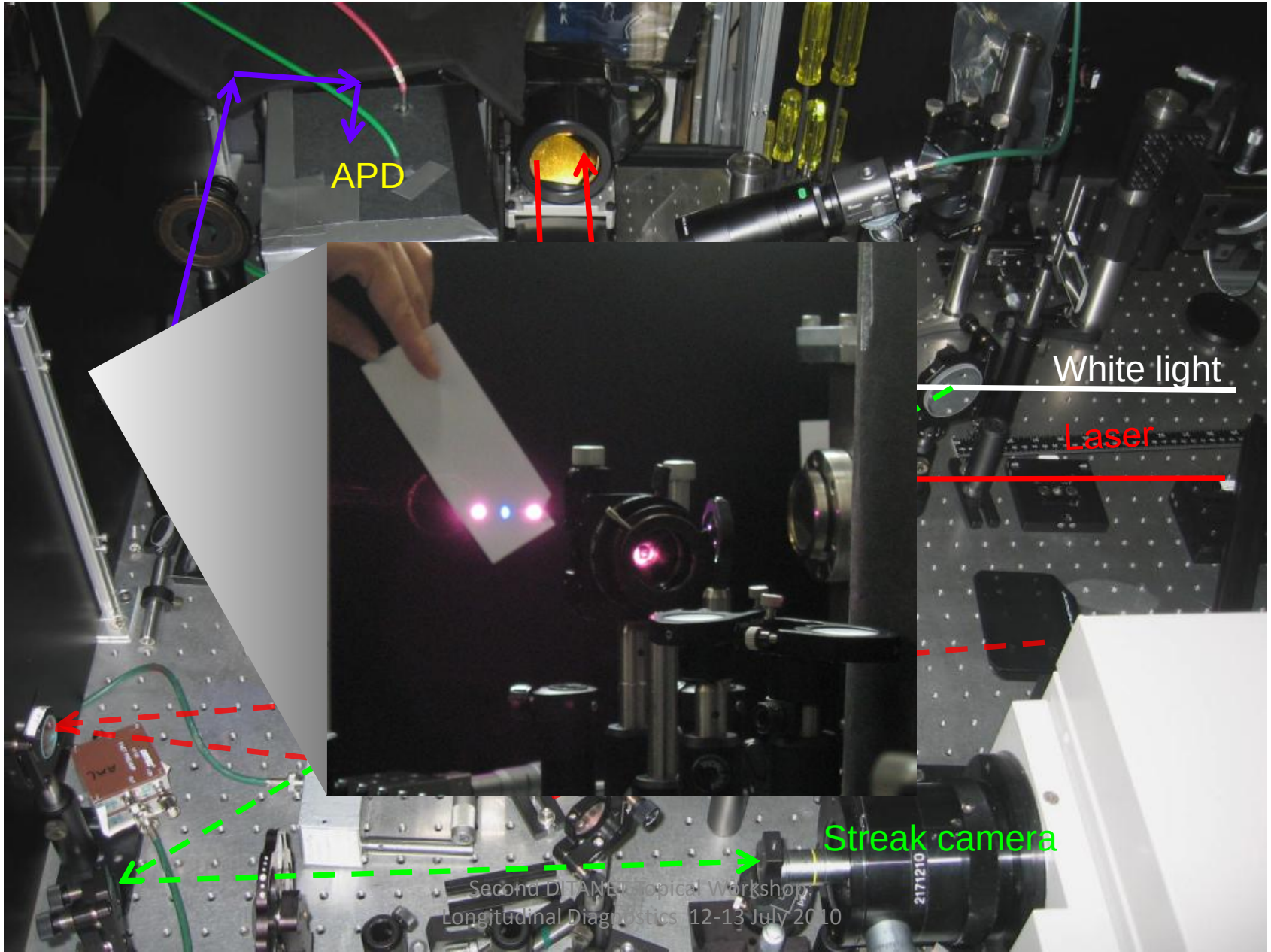
Laser/ SR Cross-correlation Geometry



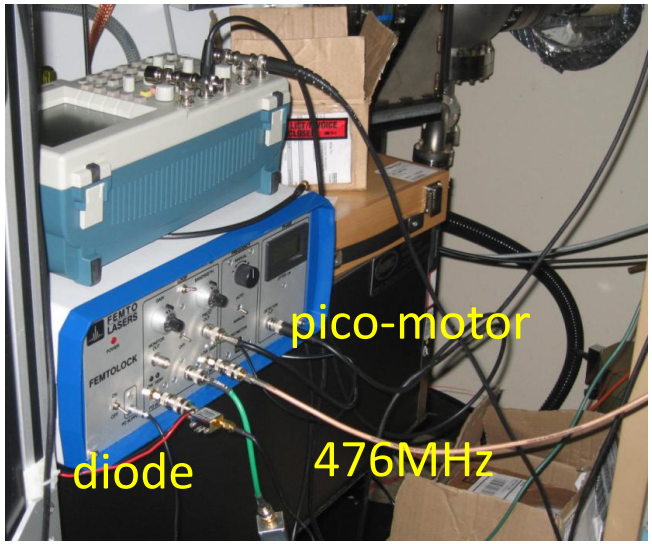
Second-Harmonic in a BBO

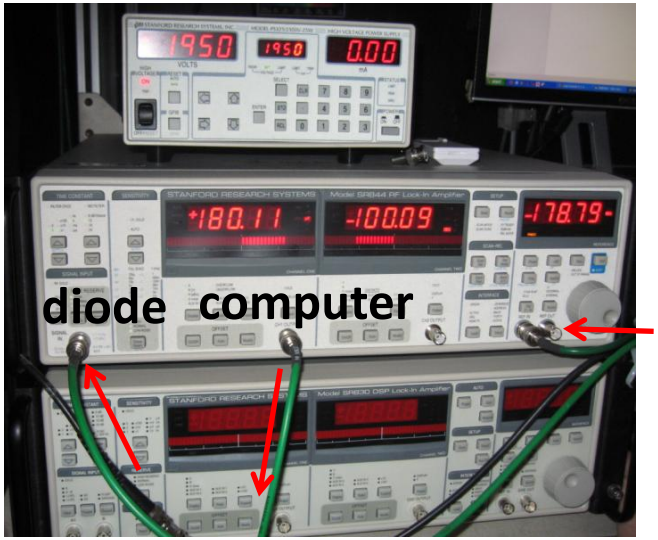


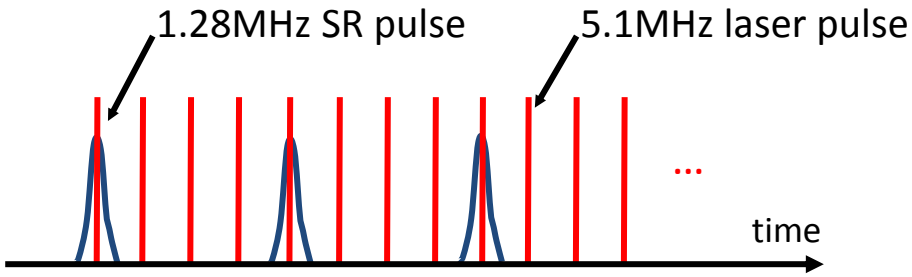
Plan View of Optical Bench



Laser timing and Lock-in Measurement

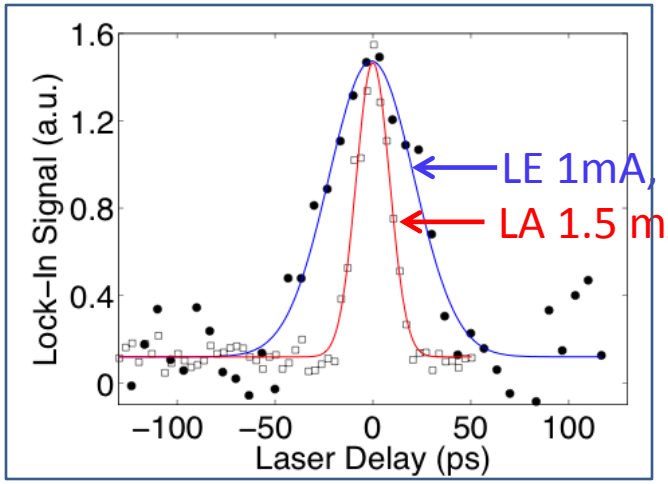


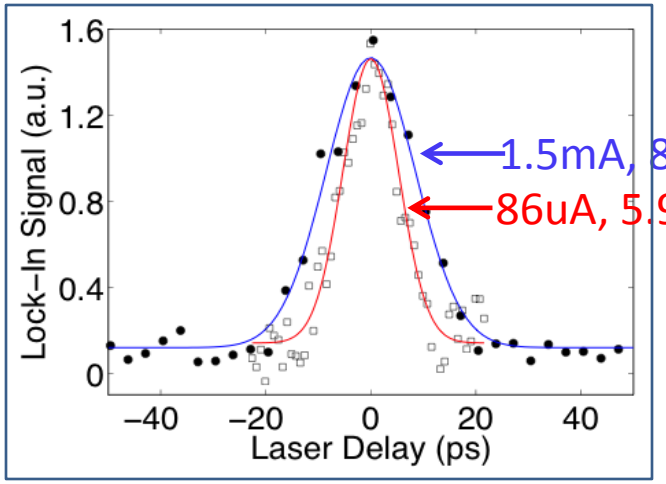


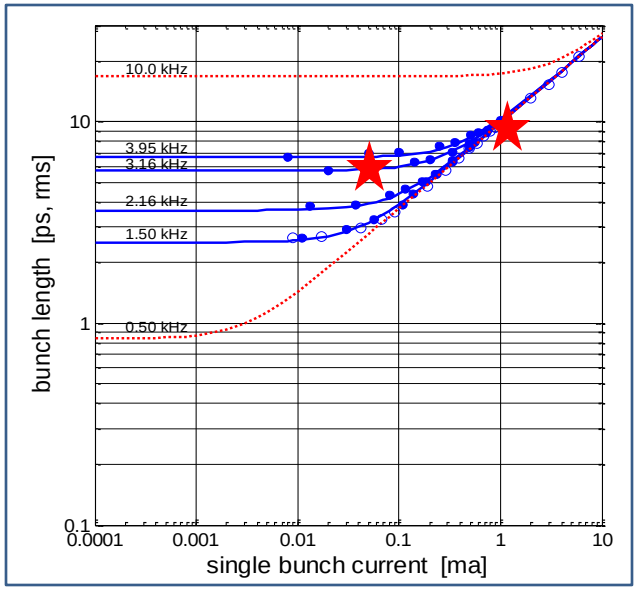


Lock-in to 1.28MHz signal
400nm component

Bunch Profile in Low-α Optics

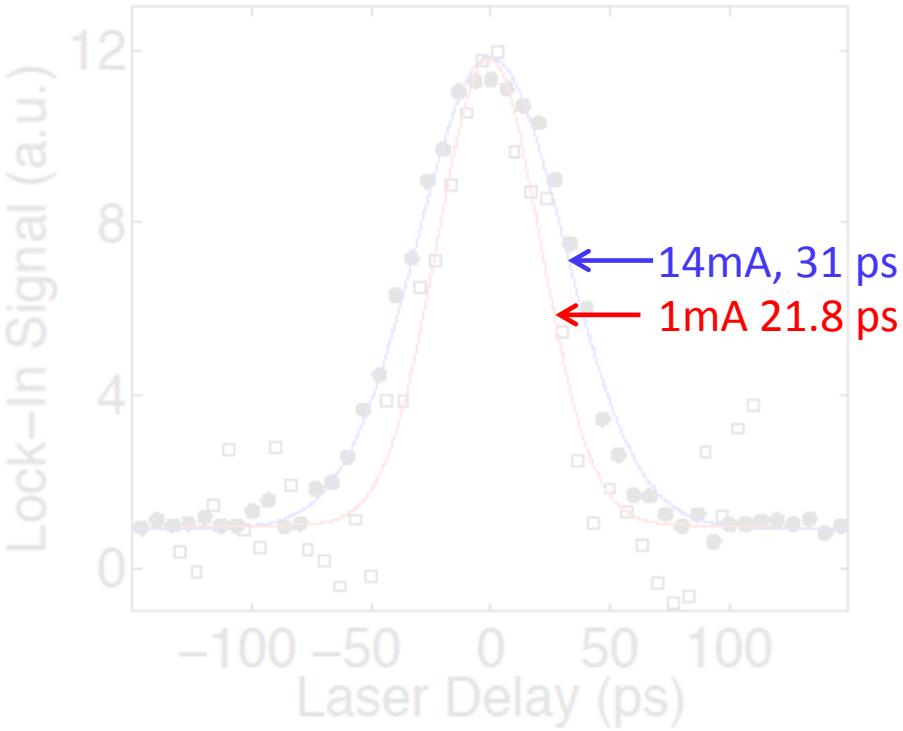


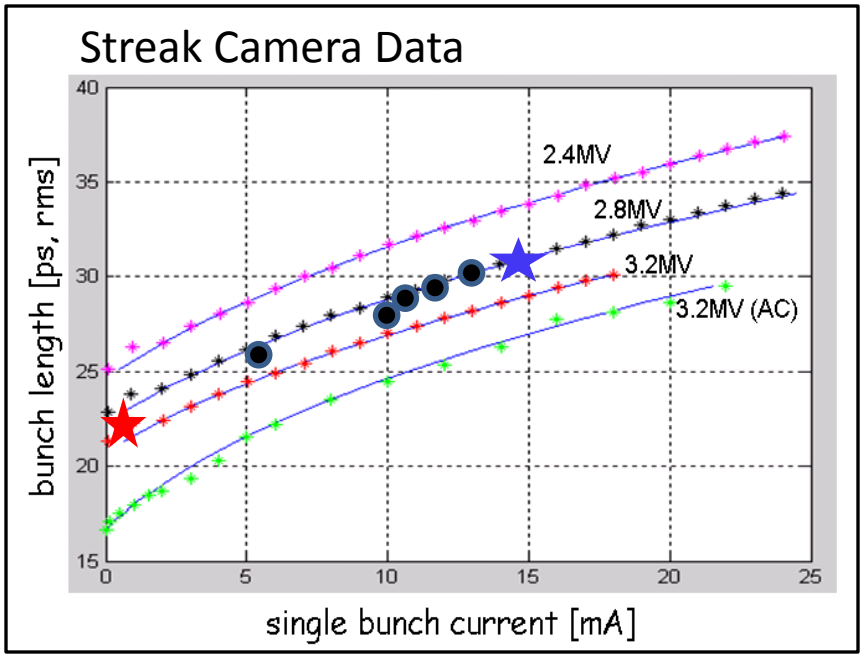




Comparison with SC data

Profile Measurements in Low-Emittance Optics





Summary and Future Improvements

- Low-α operation for short-pulse, high rep-rate x-ray beam
- Streak camera measurements of bunch length scaling law
- Streak camera limited by low flux, ~2.4ps synchroscan resolution
- Developing laser/SR cross-correlation measurements (no IR port)
- Testing different EO crystals, fiber laser
- Use visible diagnostic beam to provide timing for pump/probe stations

Thank you!