Lasers in FEL Science

Bringing ultrafast to x-ray experimental stations

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The SwissFEL Photonics : Pump Laser Workshop

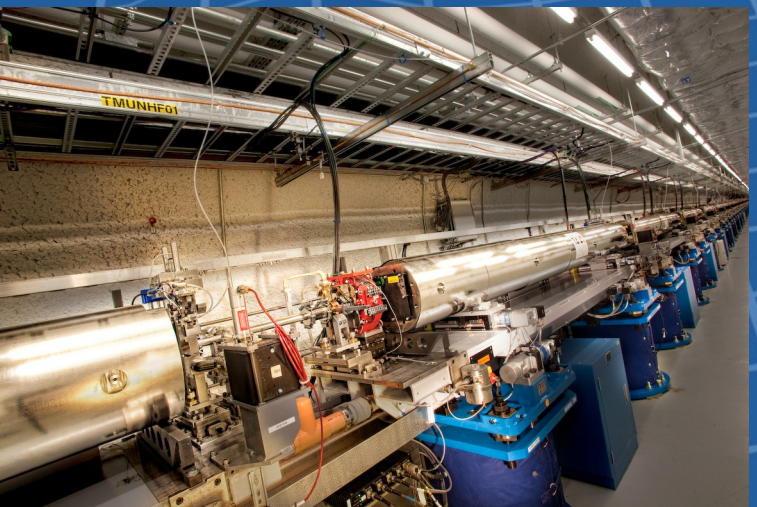
16 November 2012

U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

Outline

- Laser use at LCLS
- Foreseeing User Desires
- Current R&D
- Keeping good people



Stability, reliability … and triage

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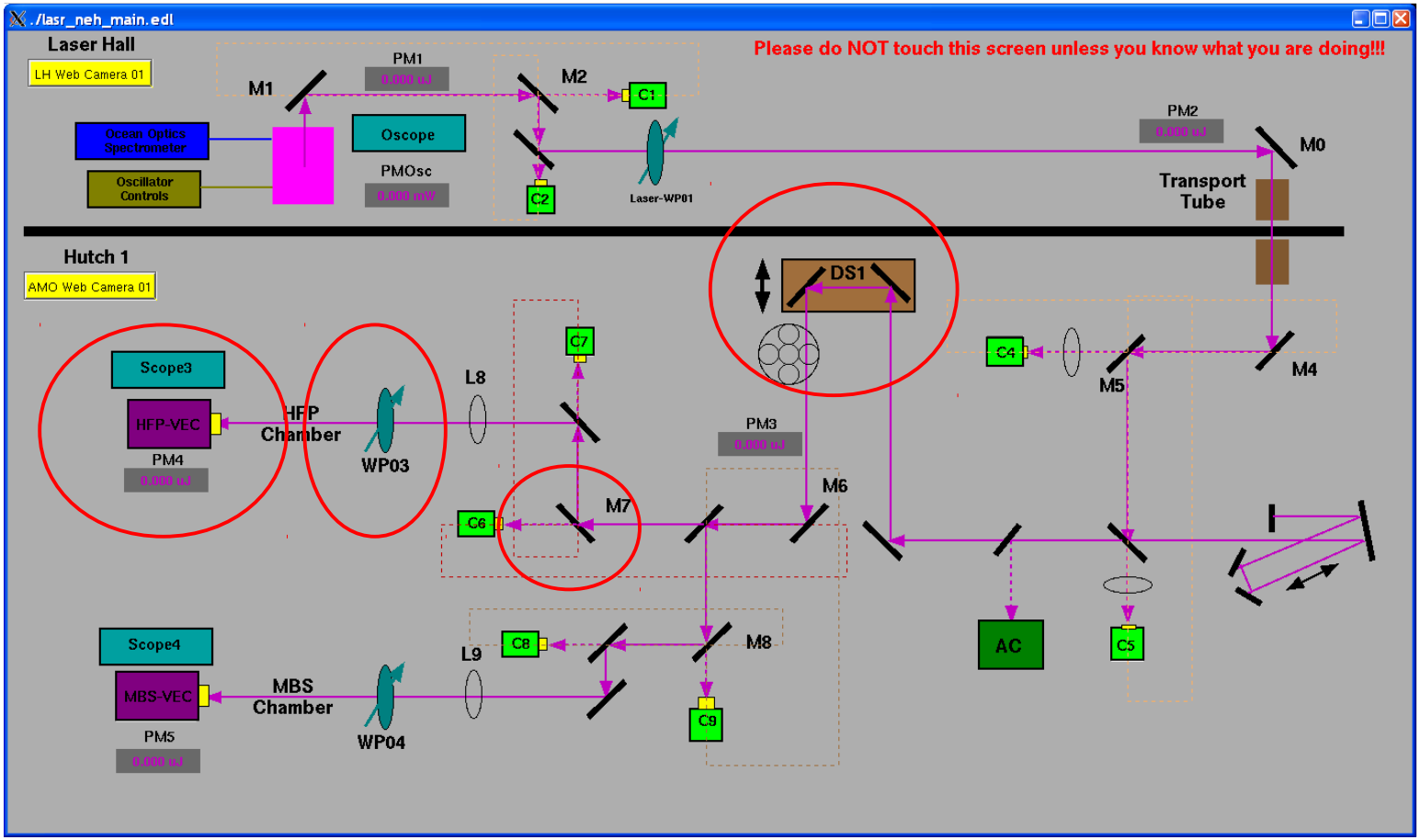
- Avoid “Rolling blackouts”
  - Single system that is multiplexed cannot be used for development
  - Hot-spares allow running lasers to the ground
  - We're likely to get 20K hours from EVO diodes according to Edstrom
  - Optical path from one system to the other allows timing debugging
- Relay imaging is critical, possibly joined with spatial filtering
  - Relay image to the experiment
  - Relay image the output/equivalent plane to a CCD
- Avoid flash lamps
  - They cost whole beamtimes at $44K/hour
  - They also may fail the spectral timing scheme

Less is more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Laser Hall
LH Web Camera 01
Please do NOT touch this screen unless you know what you are doing!!!
M1
PM1
M2
C1
Ocean Optics Spectrometer
Oscillator Controls
Oscope
PMOsc
C2
Laser-WP01
PM2
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Transport Tube
Hutch 1
AMO Web Camera 01
DS1
C7
L8
Scope3
HFP-VEC
PM4
HFP Chamber
WP03
C4
M5
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PM3
M6
M7
C6
Scope4
MBS-VEC
PM5
MBS Chamber
WP04
L9
C8
M8
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AC
C5

Remote location for stability and redundancy

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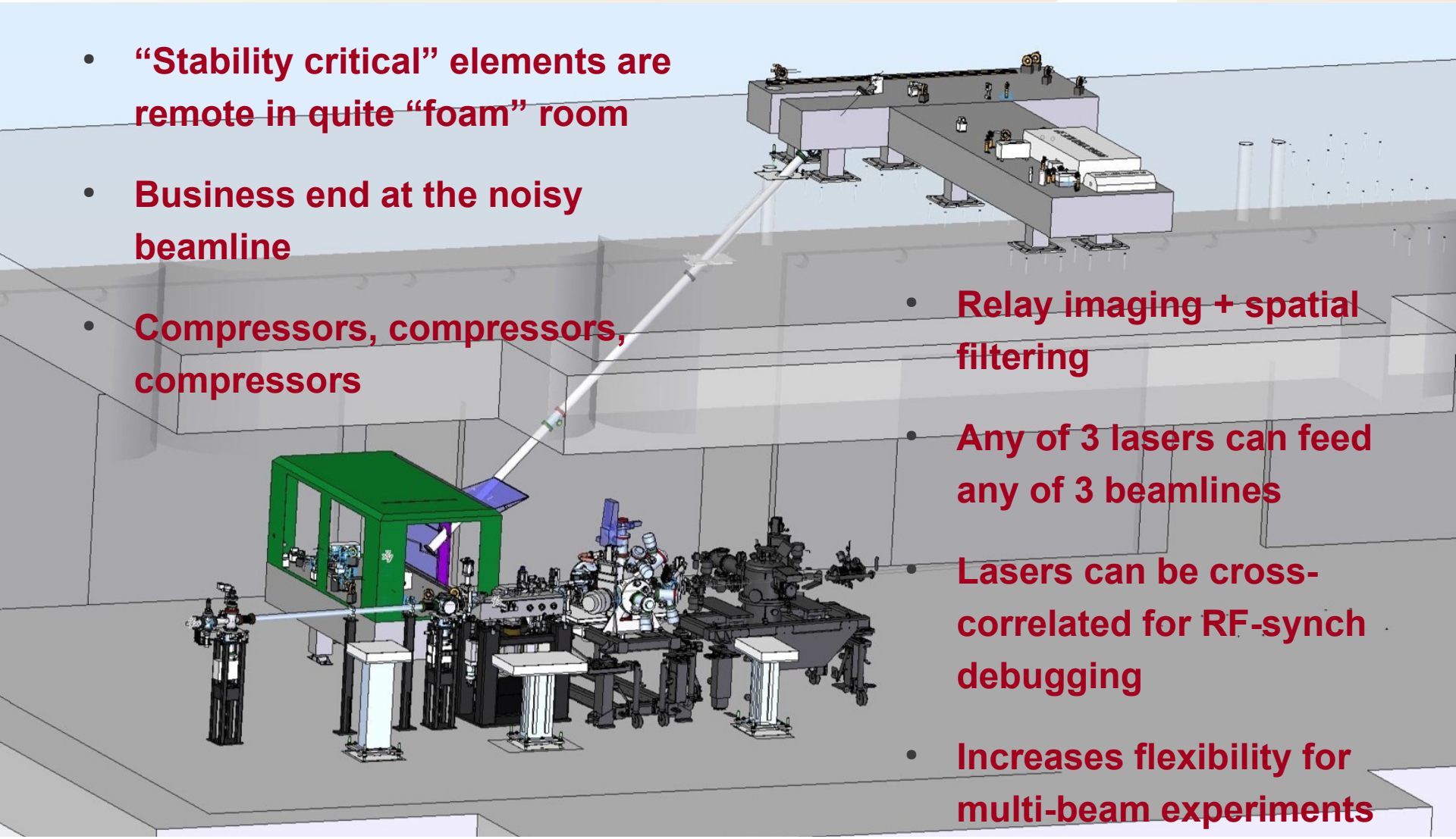
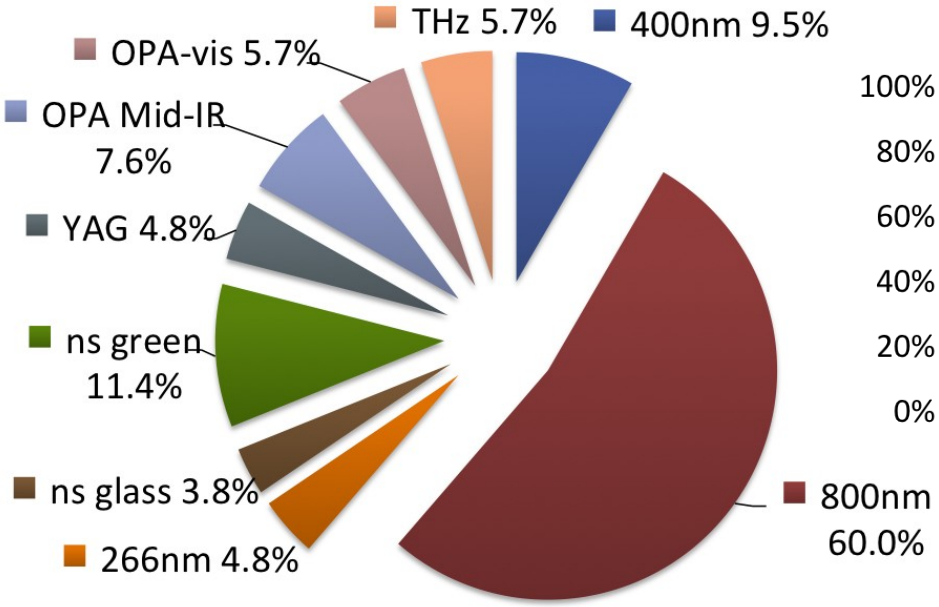
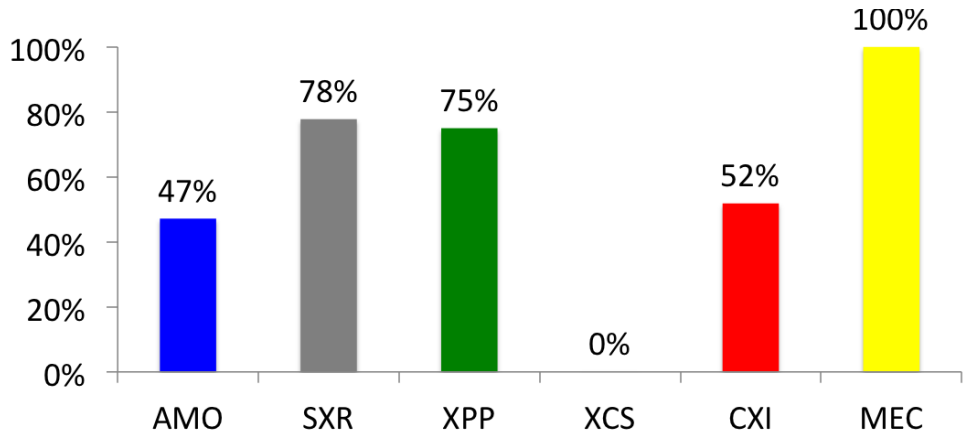
- "Stability critical" elements are remote in quite "foam" room
- Business end at the noisy beamline
- Compressors, compressors, compressors

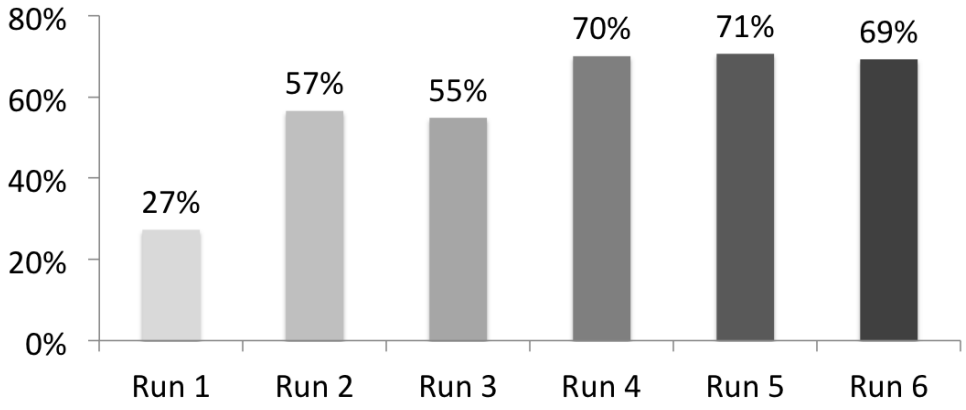


- Relay imaging + spatial filtering
- Any of 3 lasers can feed any of 3 beamlines
- Lasers can be cross-correlated for RF-synch debugging
- Increases flexibility for multi-beam experiments

“If you build it... they will come”







Foreseeing User Desires – soft x spectroscopy

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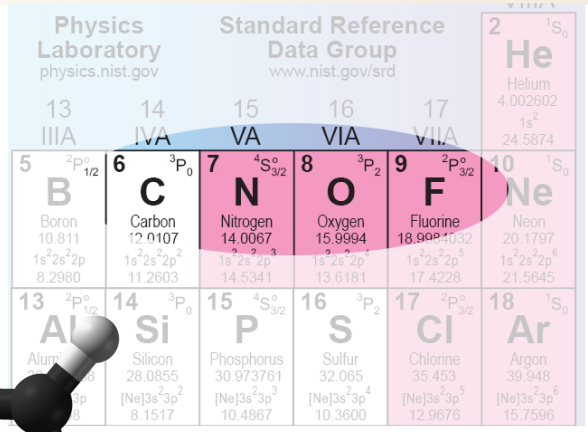

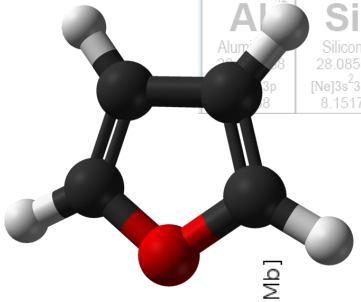

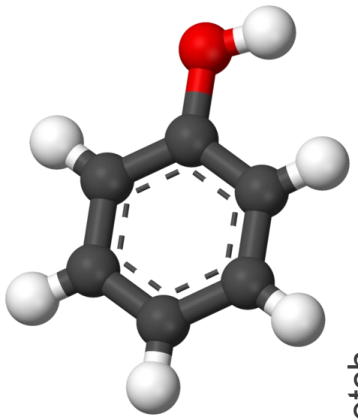

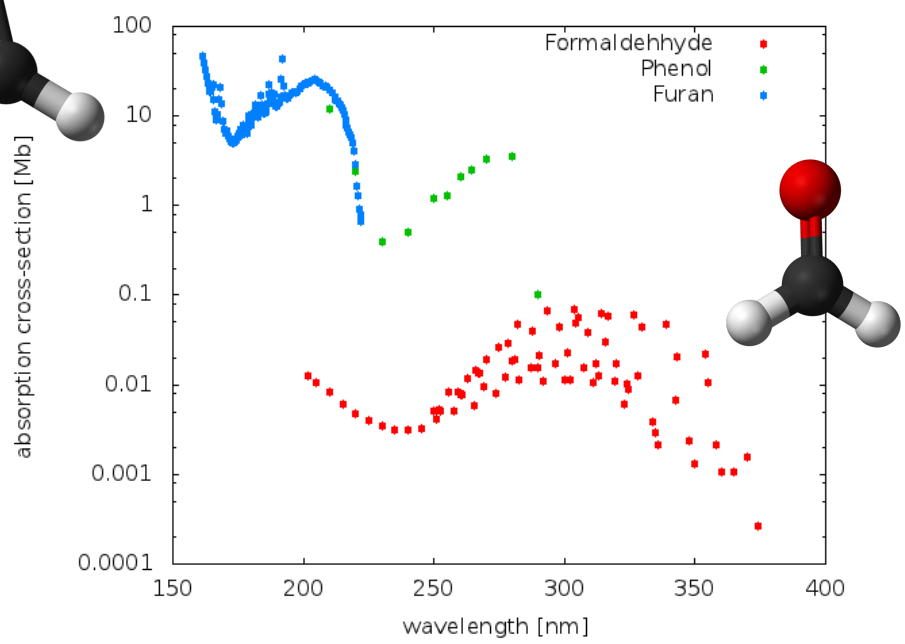

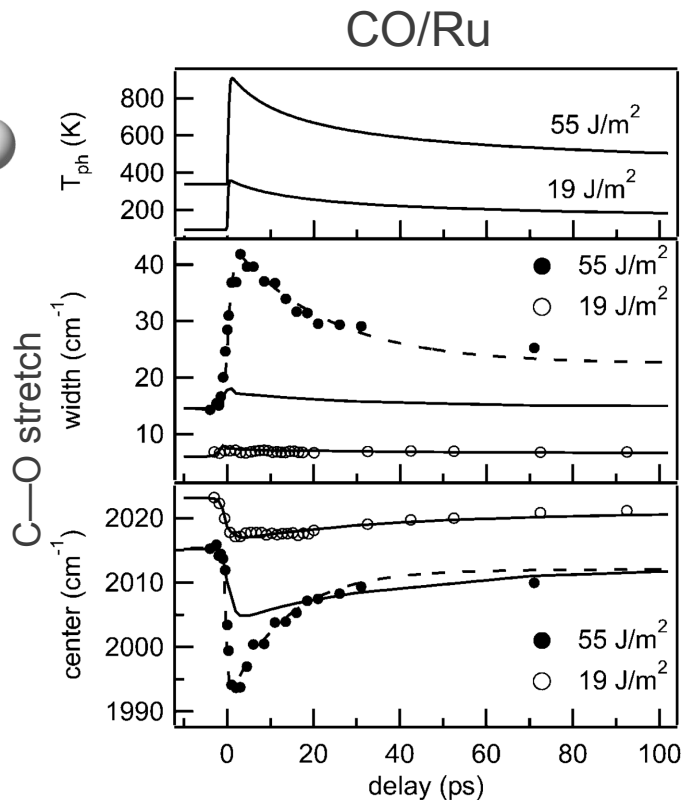

Bonn *et al.*, PRL **84 4653 (2000)**

Today's cutting edge is tomorrow's bread-and-butter

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“Can we use electronic delay rather than a motor?”

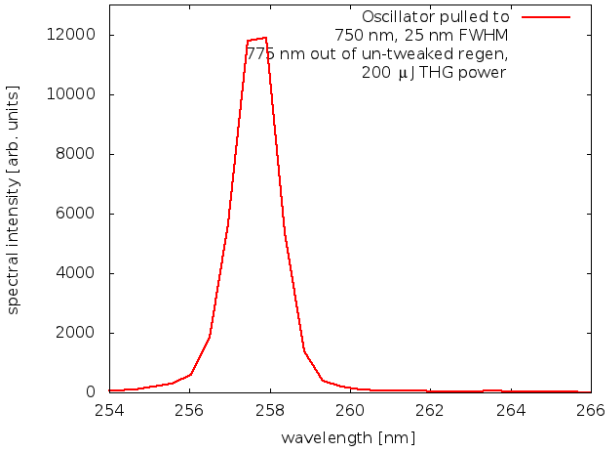
“Can we make the rf synchronization a bit worse?”

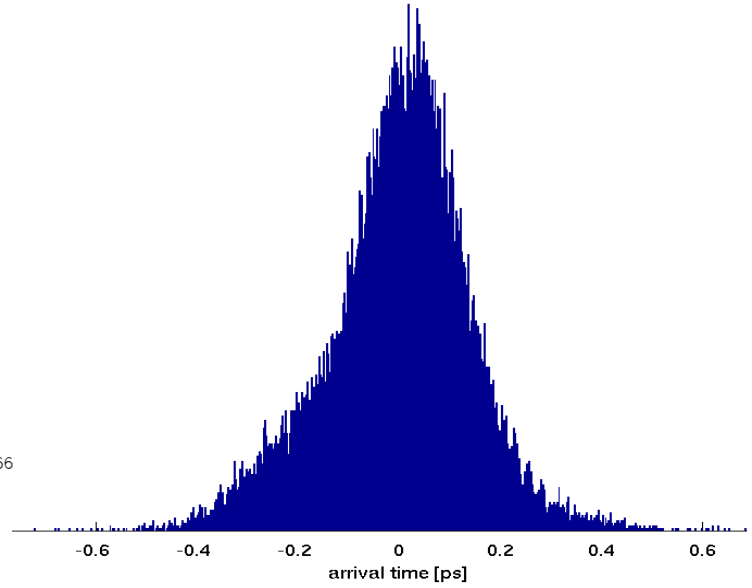
“Can we feed-back on the time tool?”

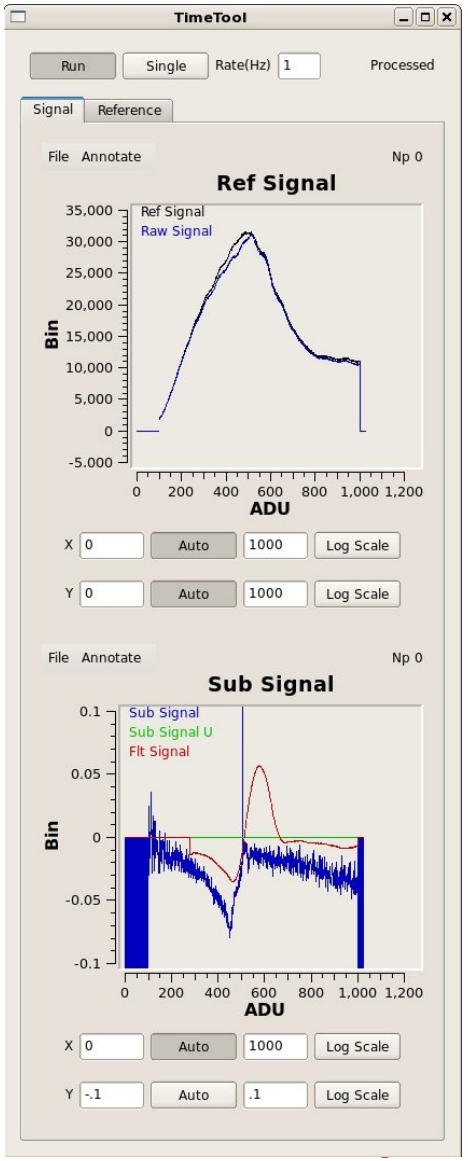
“Oh my God... event code 84 is disabled!”

“Can we switch rapidly between 266 nm, and 258 nm?”

"I want delays out to a millisecond!”



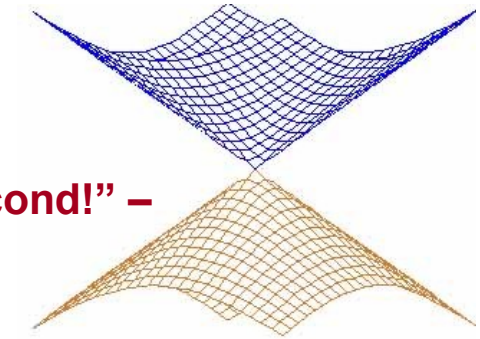


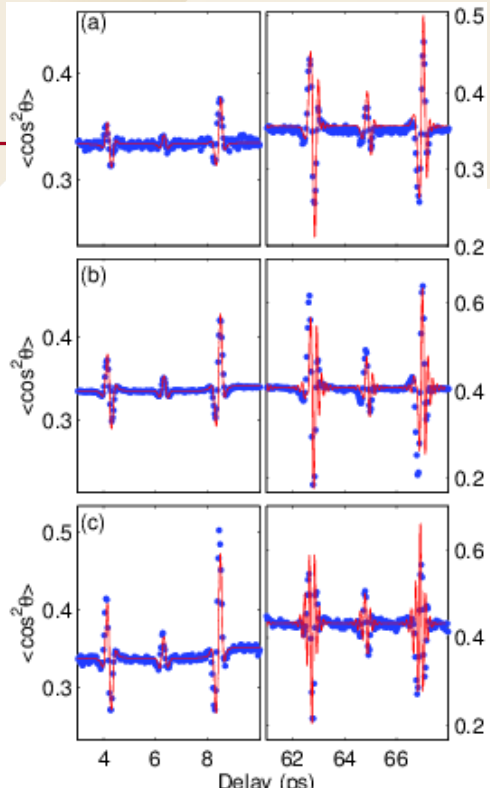


Tomorrow's cutting edge will be...

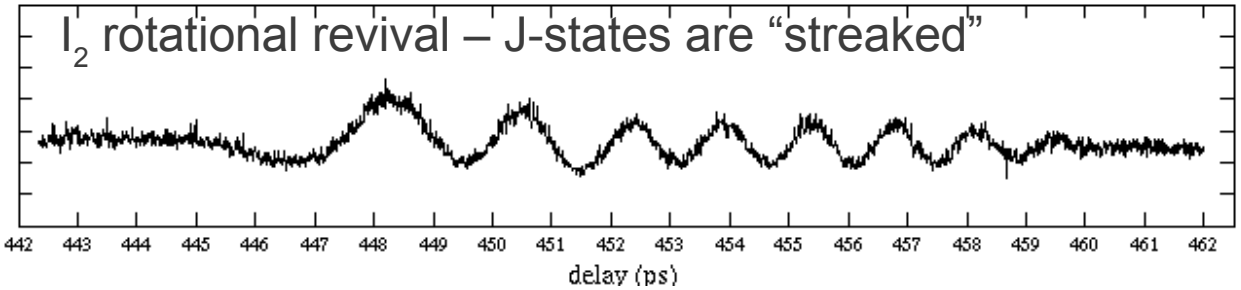
- **Stochastic Sampling of Quantum revivals?**
  - **Conical Intersections versus J-state?**
  - **10 fs resolution at 1 ns delay**

"I want delays all the way to a millisecond!" – Henrik Lemke

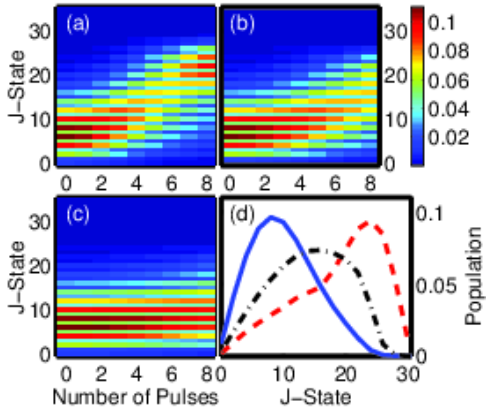




Flexibility is key



Broege *et al.*, PRA **78** 035401 (2008)



Cryan *et al.*, PRA **80** 063412 (2009)

Current R&D – Letting science drive scientists

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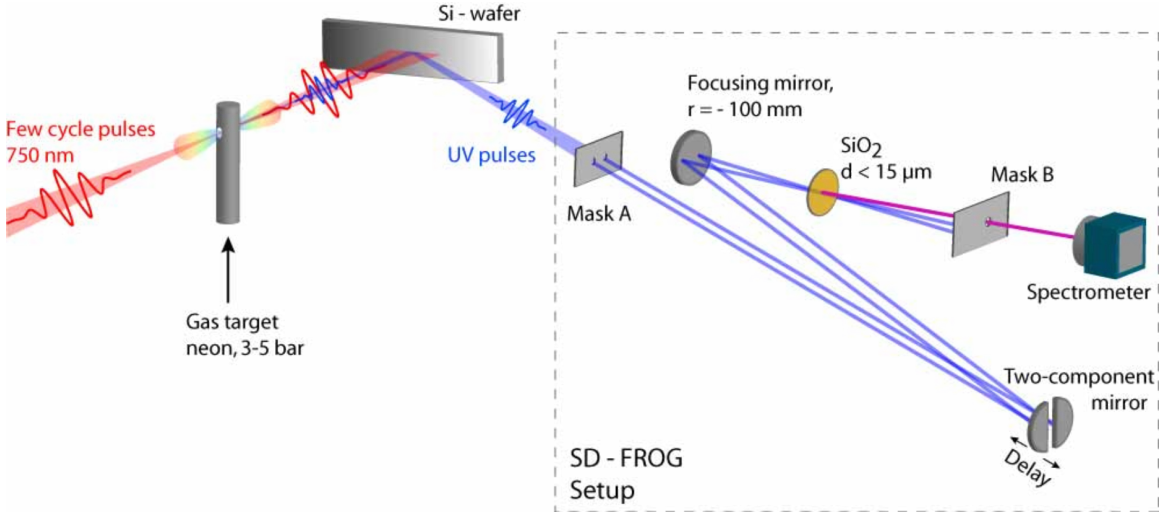
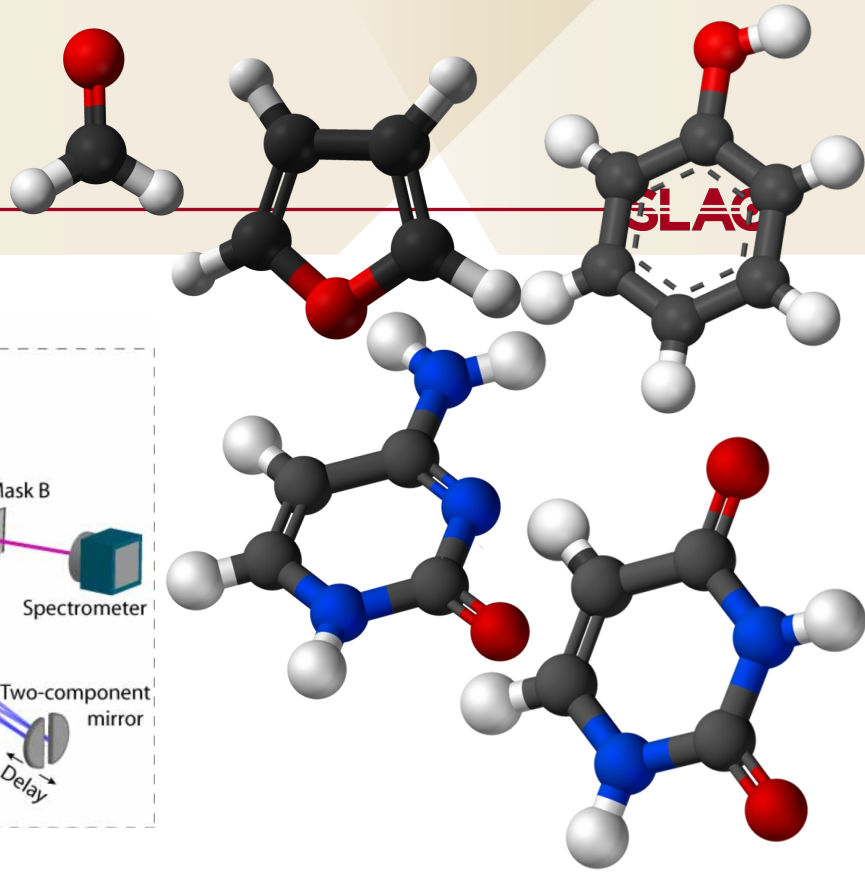
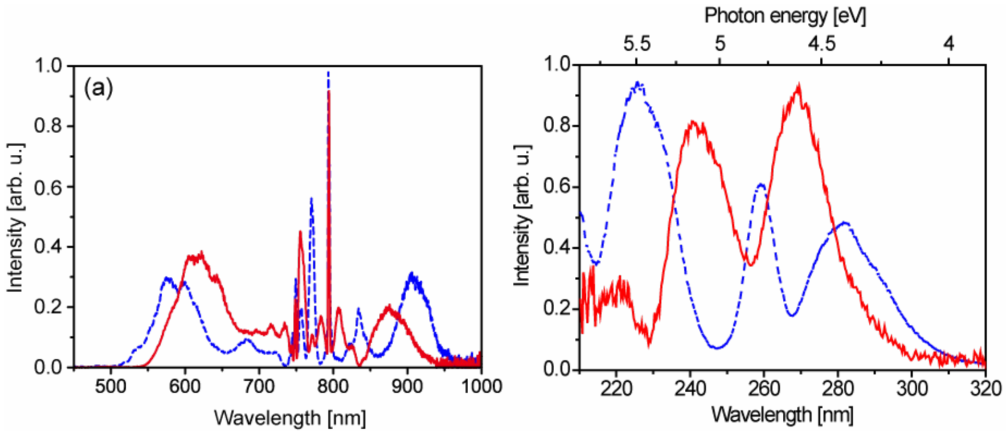
- Keeps scientists engaged
- Brings new capabilities to facility
- Solving their own problems, typically solves other's problems:
  - Short deep uv pulses
  - Plasma THz generation
  - Timing
  - X-ray pulse characterization
  - Double x-ray pulses

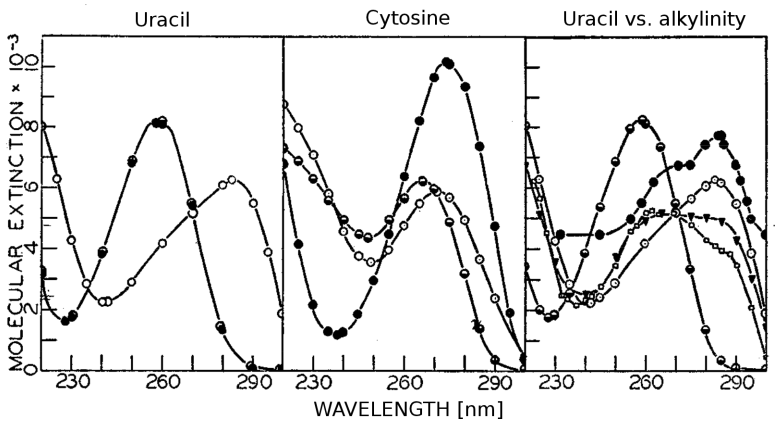
The push to uv







Graf *et al.*,Opt. Exp. **16** 18956 (2008)



Ploeser & Loring J. Bio. Chem. (1948)

Plasma THz generation – 5-20 THz, 2-4THz FWHM

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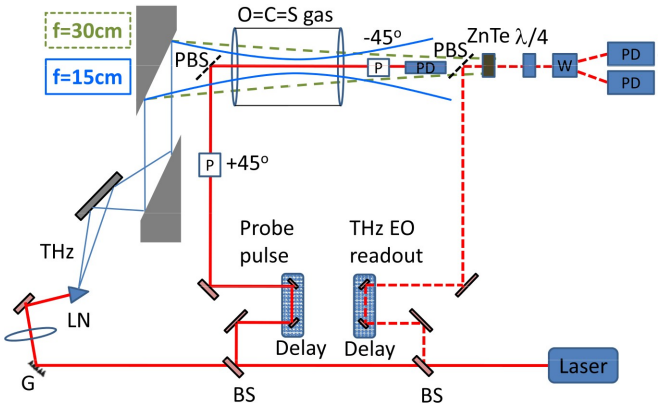
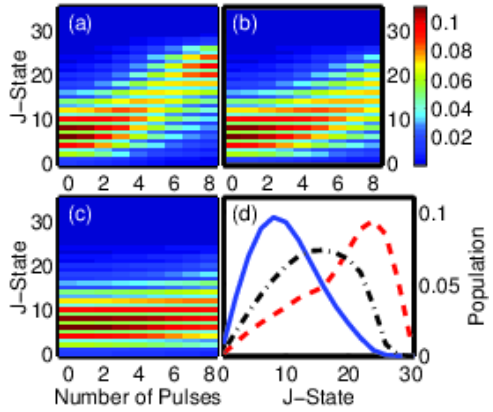
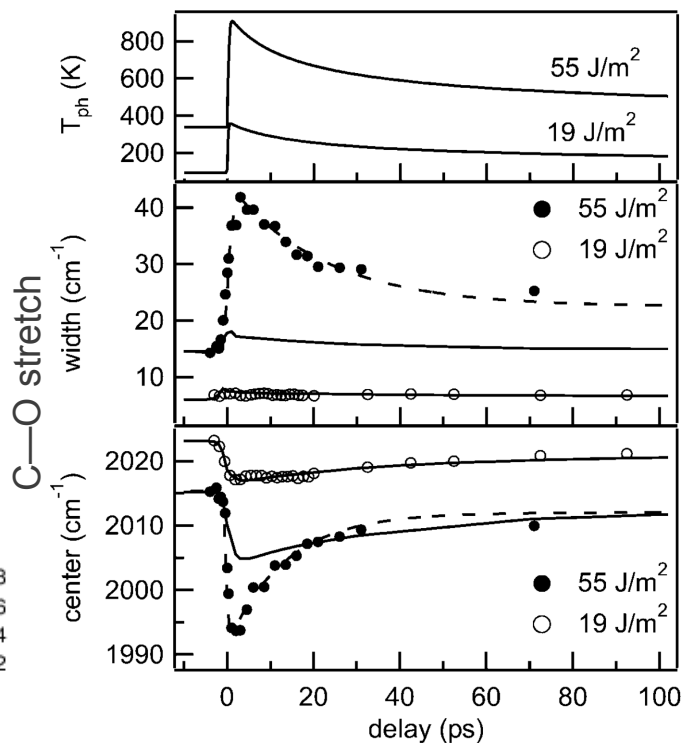
- H-bonding network in liquid water
- Phonon excitations in dielectrics
- Surface Chemistry, e.g. CO/Ru
  - 800 K : 19 μm : 16 THz
  - 300 K : 50 μm : 6 THz



Fleischer *et al.*, PRL **107** 163603 (2011)



Cryan *et al.*, PRA **80** 063412 (2009)

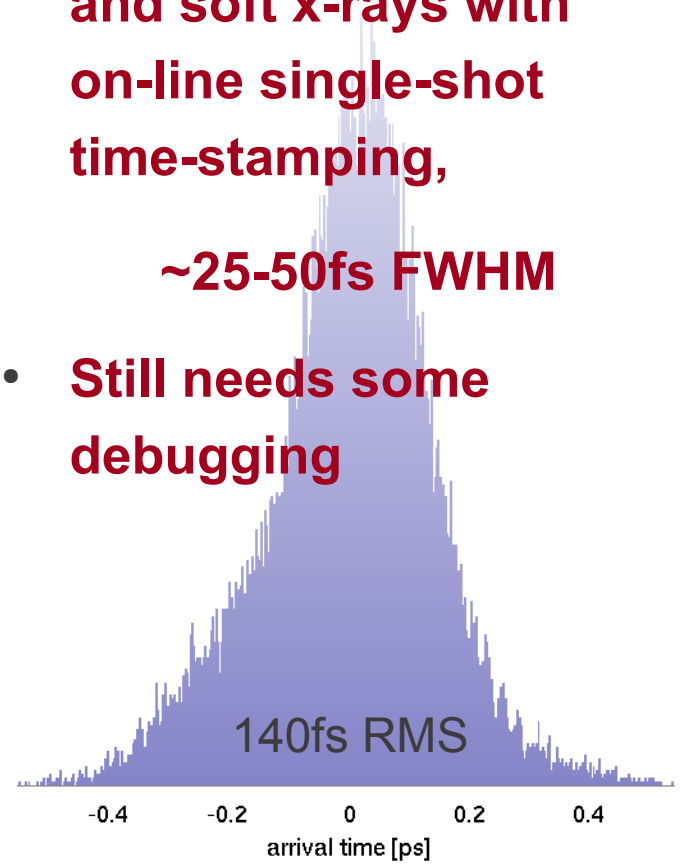


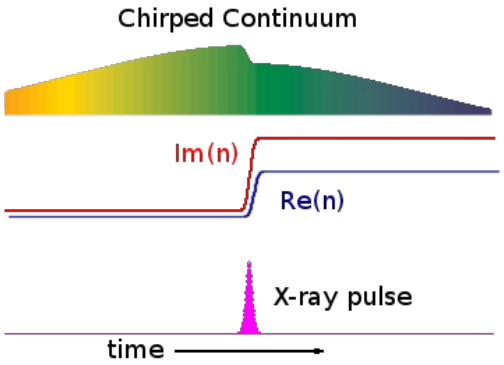
Bonn *et al.*, PRL **84 4653 (2000)**

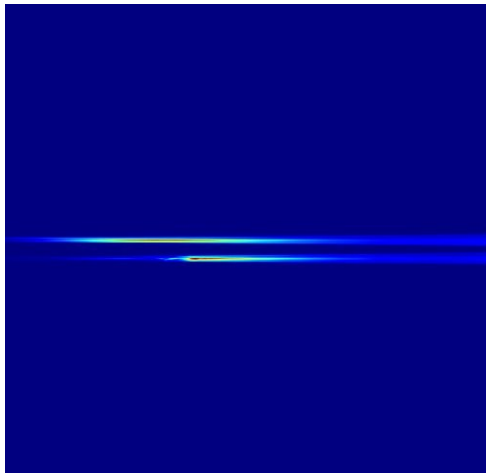
Timing – almost there now

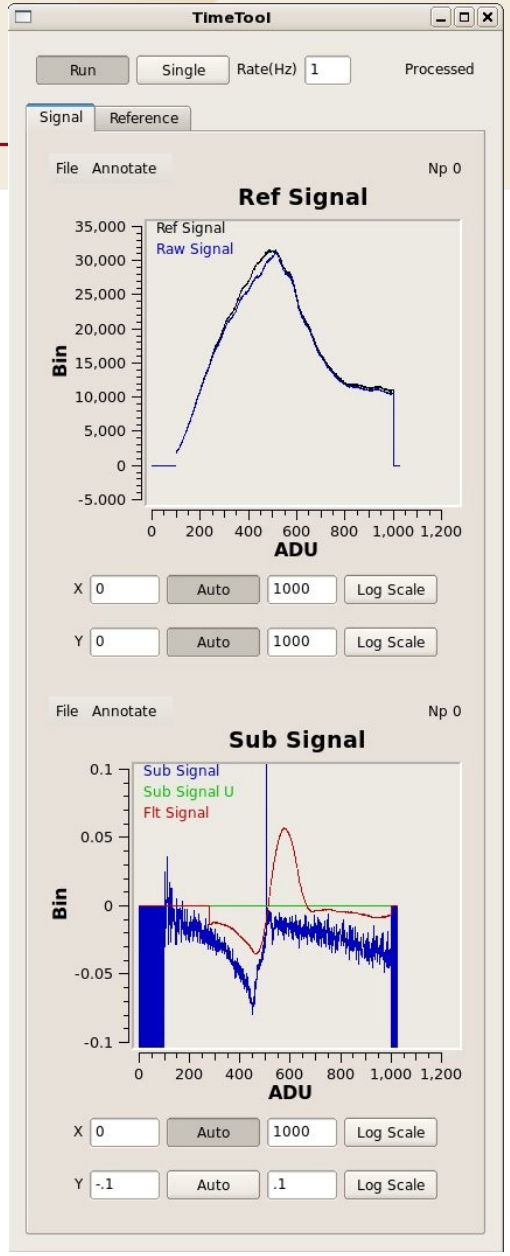
- **2011 demonstration**
- **2012 available at hard and soft x-rays with on-line single-shot time-stamping,**

  ~25-50fs FWHM
- **Still needs some debugging**

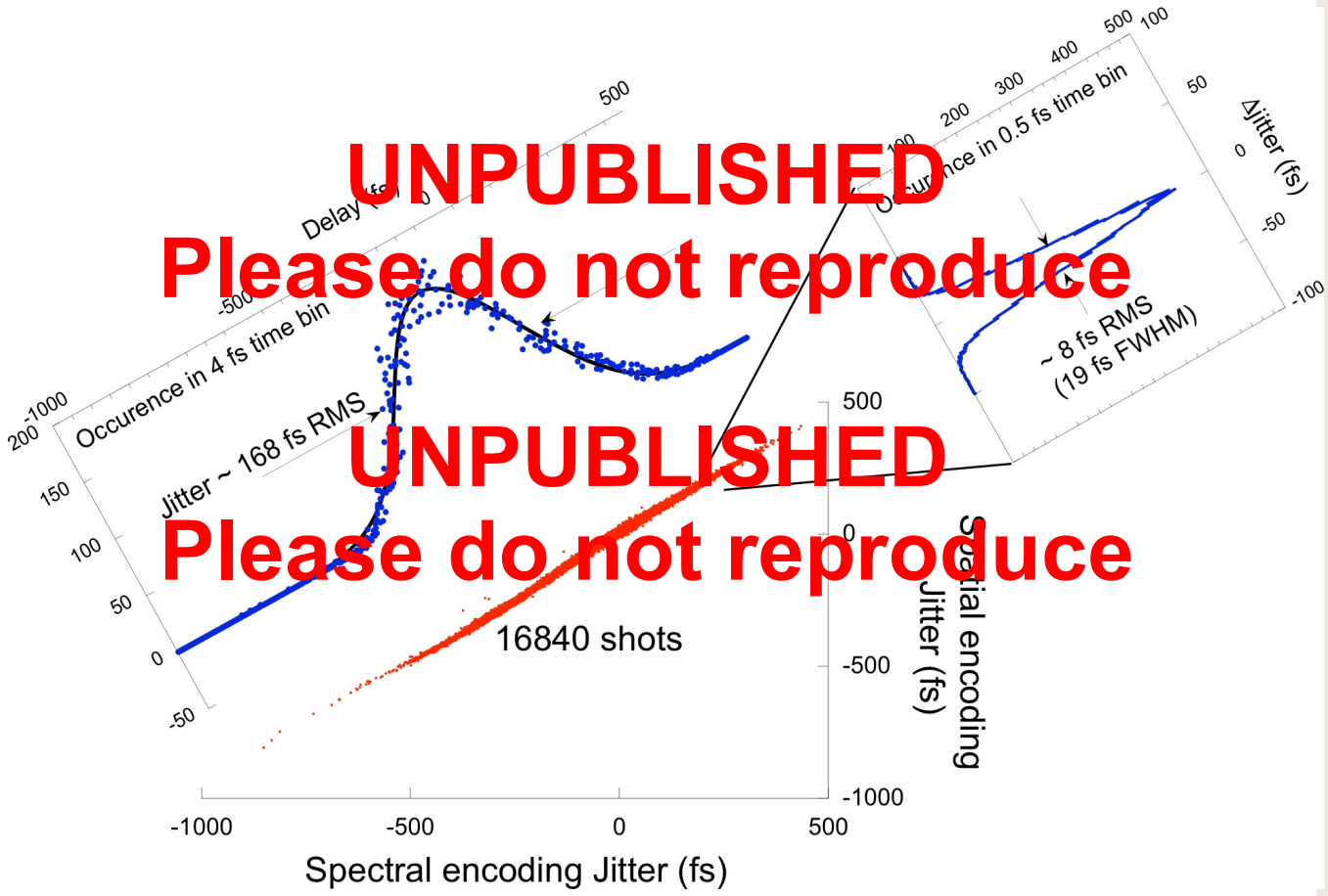




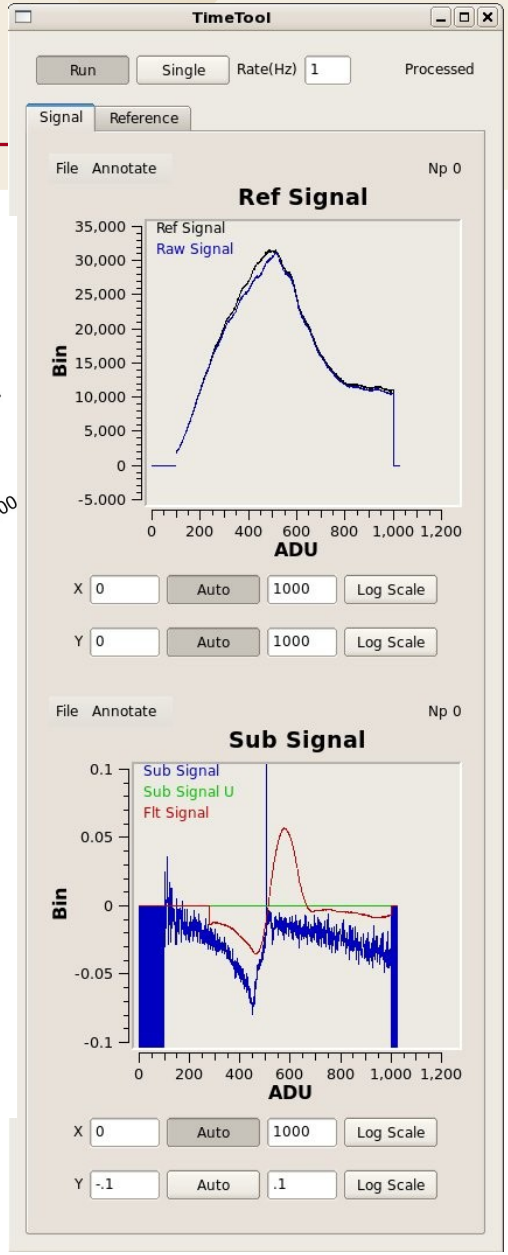




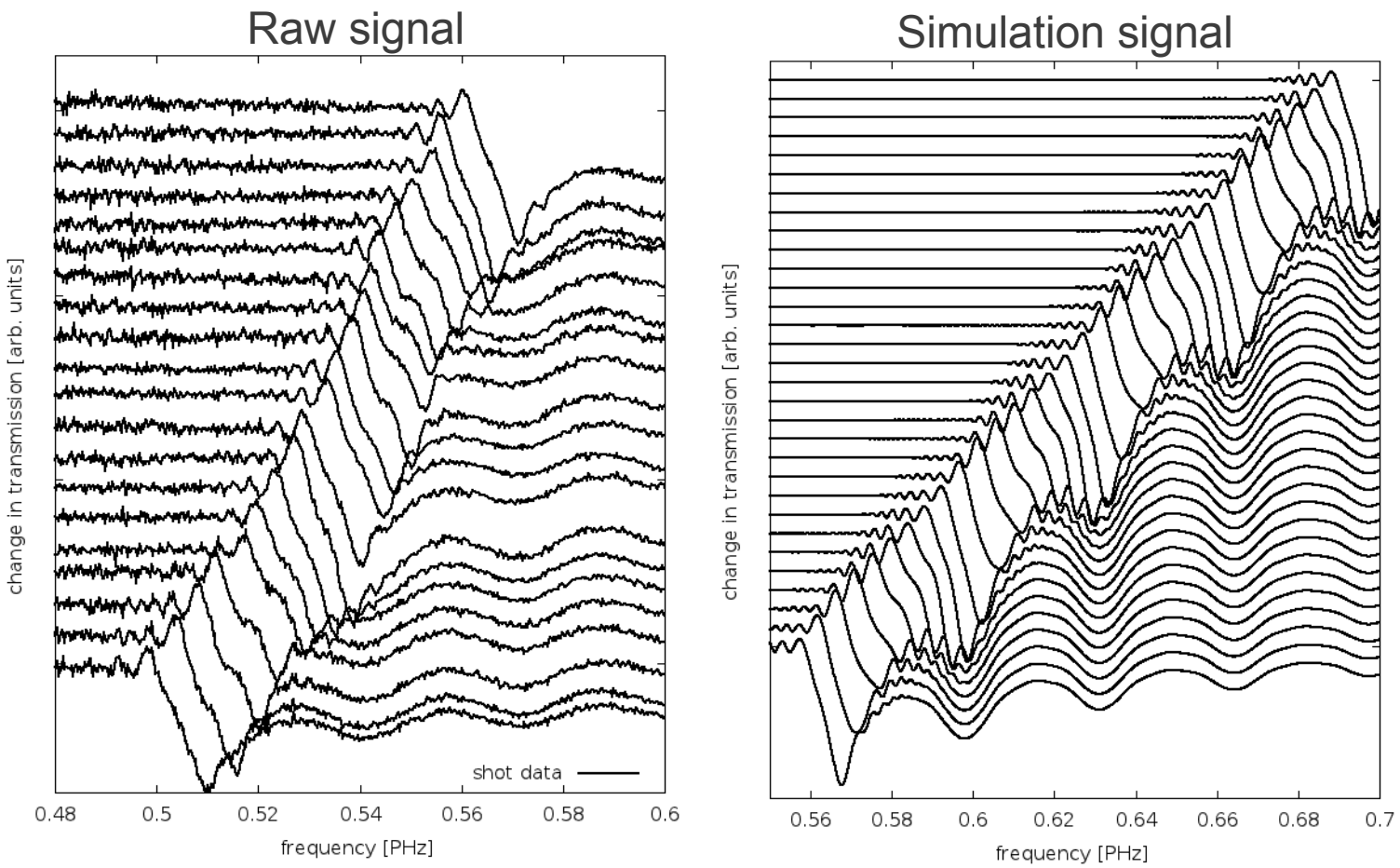
Timing – almost there now



Harmand *et al.*, submitted



Improving timing



Hartmann *et al.*, in preparation

X-ray Pulse characterization – Measuring double pulses

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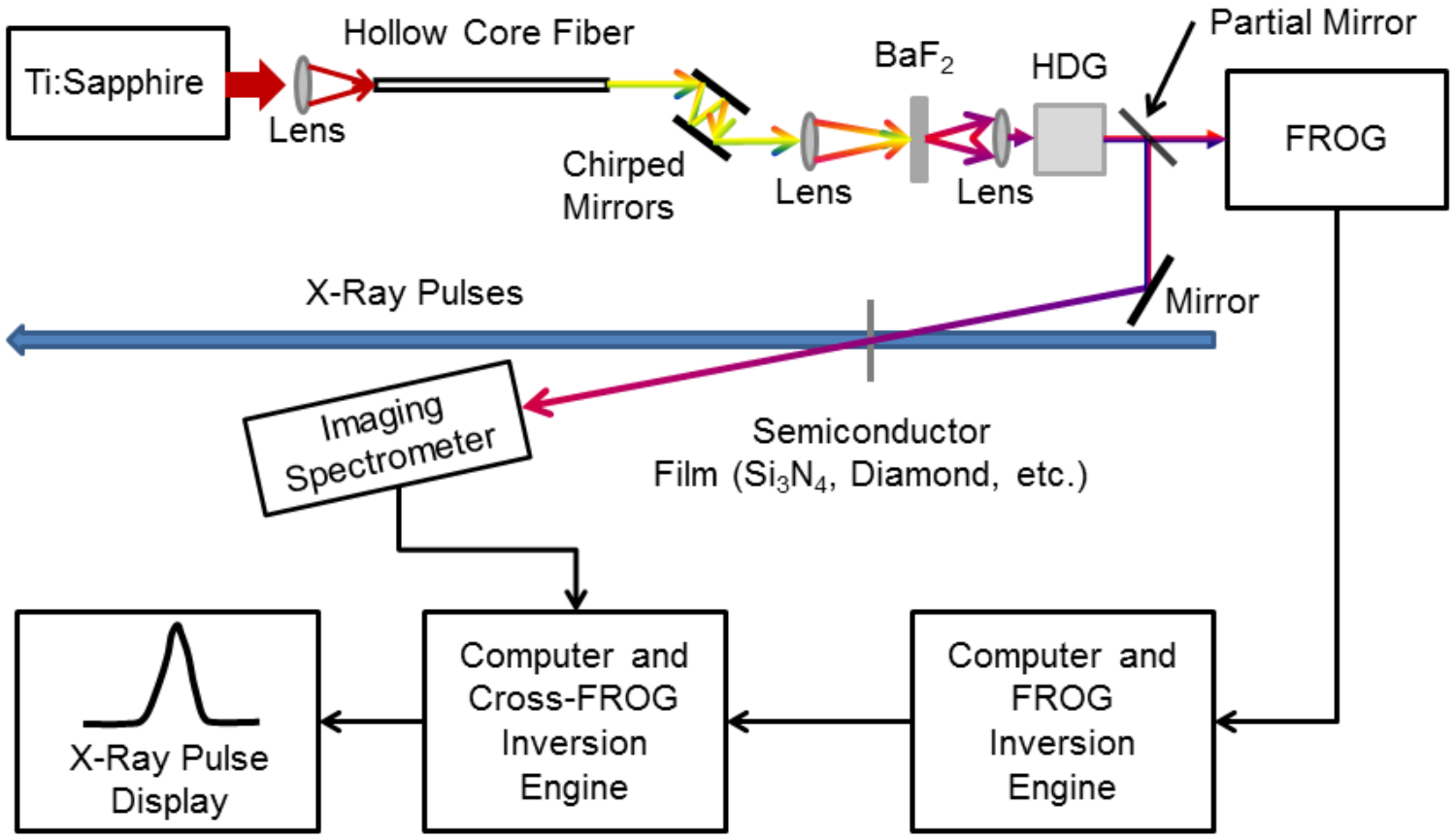

Hartmann *et al.*, upcoming beamtime

Double FEL pulses

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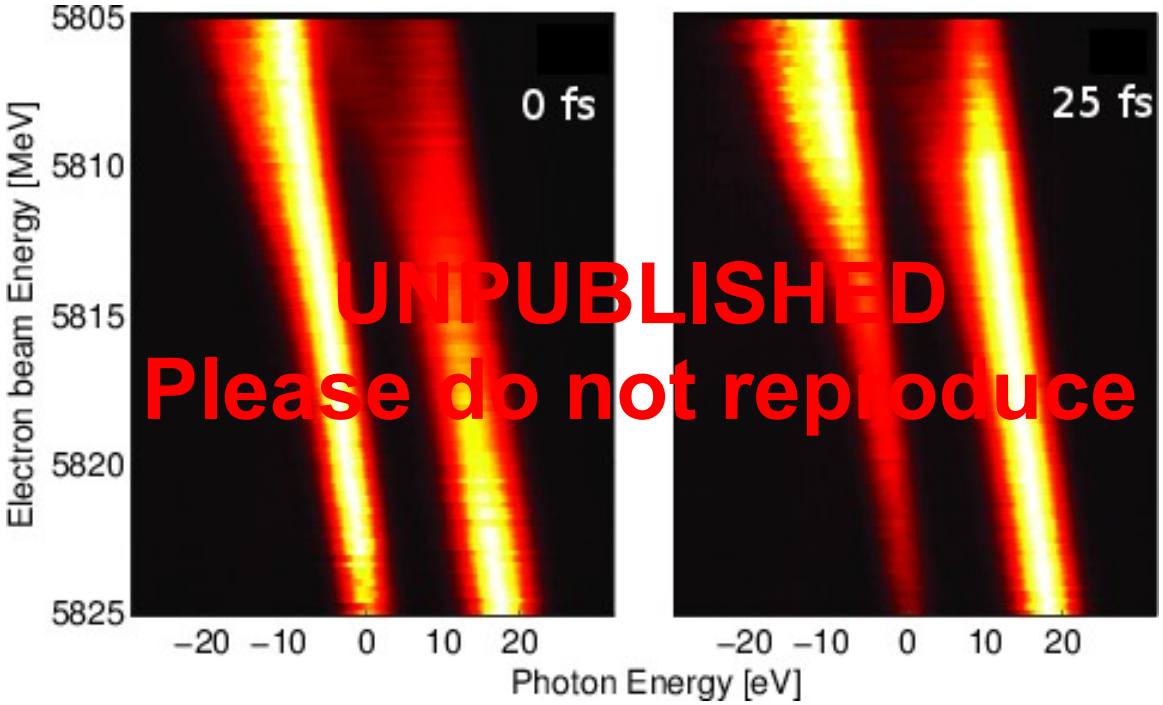

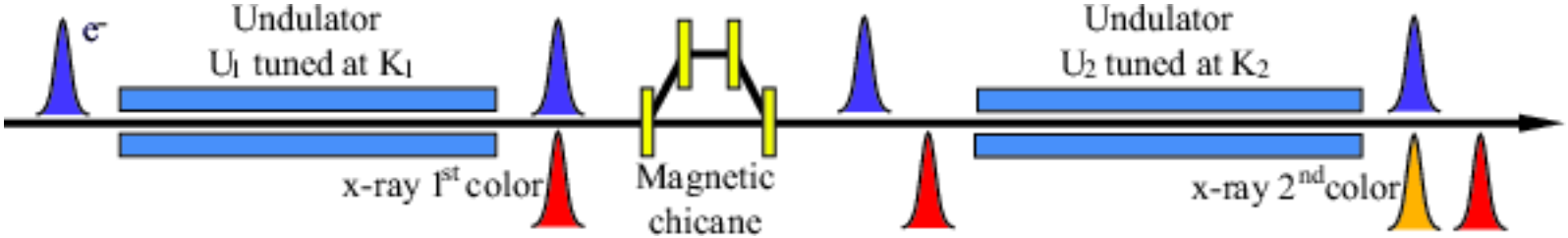

Lutman *et al.*, in preparation

Keeping good people

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- Scientists for the greater good
  - Wrap their heads around the whole experiment – narrow scientific focus yes, but the tools are the same
  - Direct technicians – techs usually don't grasp the subtle interactions, e.g. using ATI or NSDI for focus intensity calibrations.
  - Can't have them connecting cables so others can do their own science
- Super-techs who make it work
  - Doug French – ego free student
  - Steve Edstrom – master tweaker
- Look in unique places for unique solutions
  - Oliver Hickman – Renaissance man thinking outside the box (outside the plane)
  - Matt Weaver and Sebastian Carron – High Energy Physicists know about signal processing and event-based analysis... a new style of “lock-in”

Conclusions

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- Under-spec tomorrow is over-spec today
- Think inside the box
- Stretching improves flexibility
- Science begets science
- FELs are not synchrotrons

Thanks so much!

What does flexibility imply... a mess

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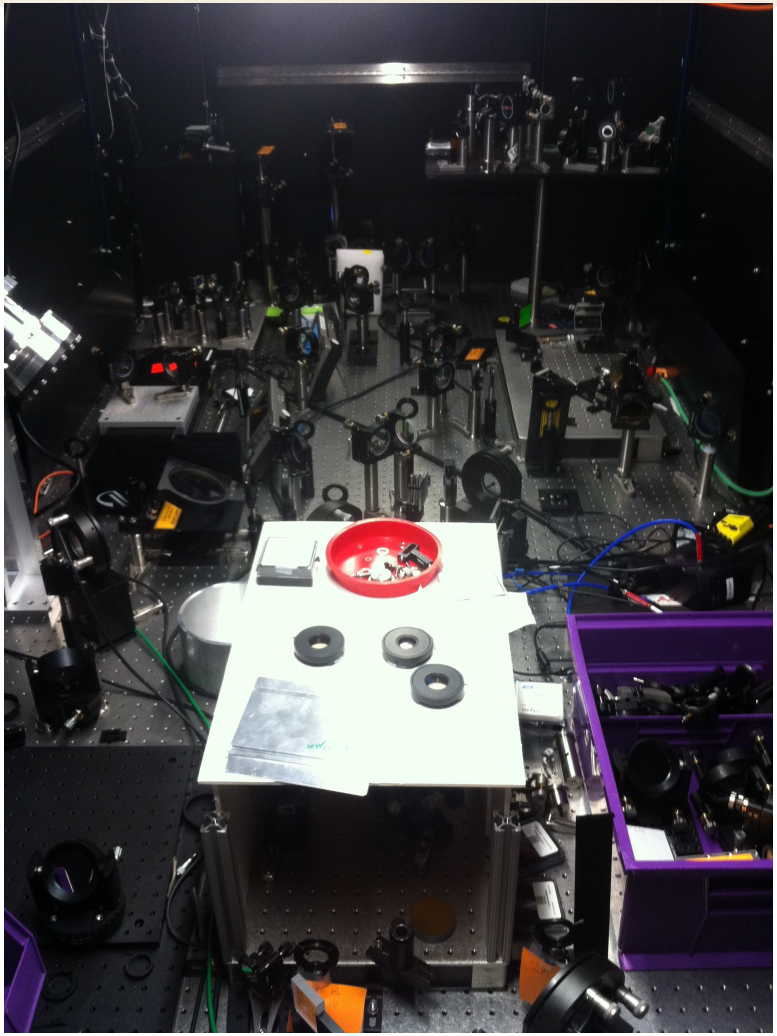
R&D machine studies are rarely granted beamtime

"I want delays all the way to a millisecond!" – Henrik Lemke

Constantly changing laser layout, even during beamtimes



Users want bleeding edge, but it's hard to validate

Timing code changes/breaks routinely, need a local expert 24/7

Passive stabilization is compromised when non-OCD collegues and users "help"

What does flexibility imply... a mess

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Users supply chambers and detectors

Users need "ownership" of experiment

Delicate balance of user ego and local experience

Optics are stripped every week

They use microscope objectives as ladders

XPP vs AMO

Grating Killer vs Seb Weber and Per Johnsson