



The ORS as a routine diagnostic device for FLASH and the XFEL.

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ORS: Optical Replica Synthesizer

FLASH, XFEL: SASE

SASE is very sensitive to the properties of the electron bunch

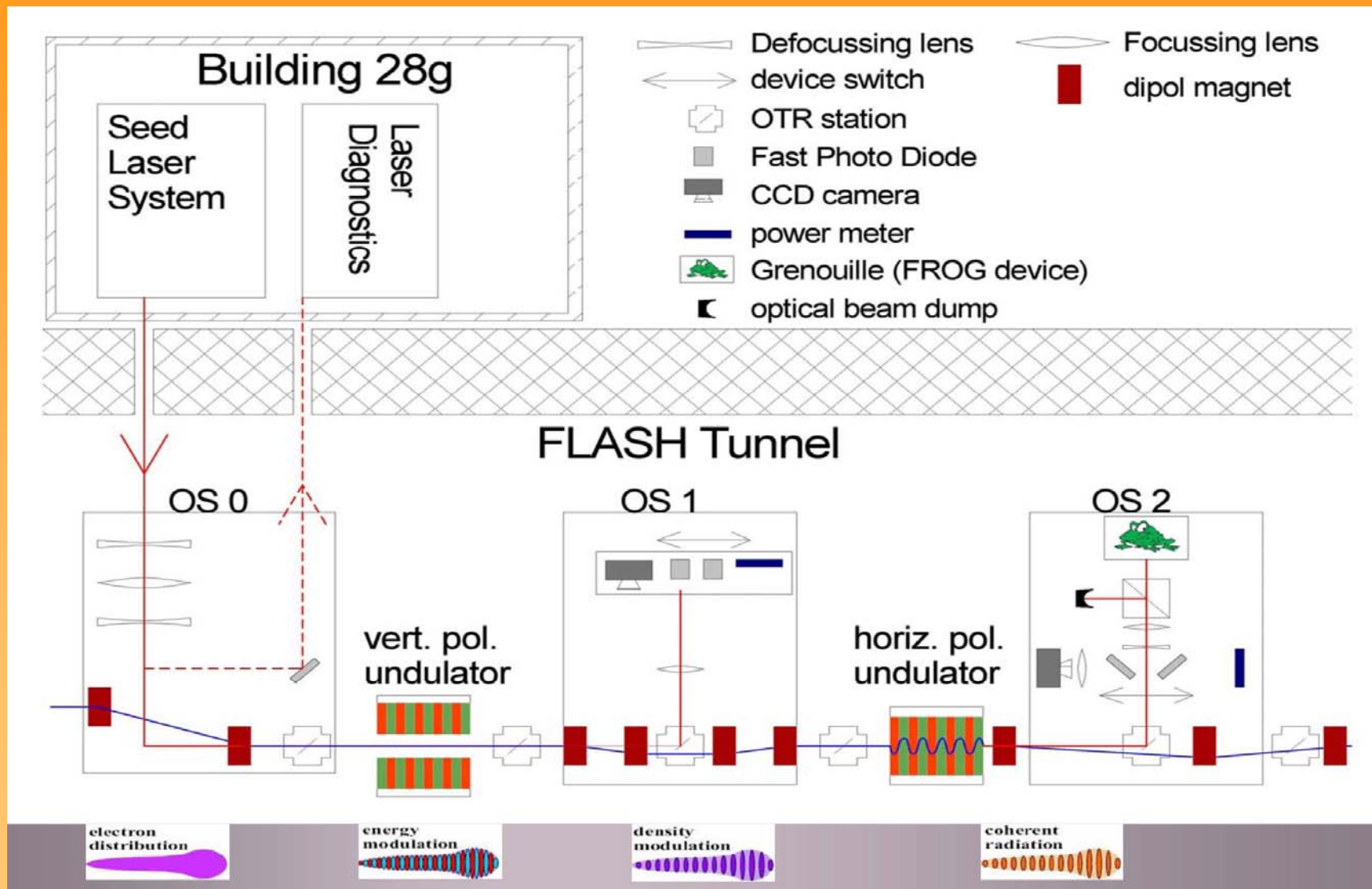
electron bunch properties: longitudinal density profile
slice emittance
slice energy spread

need to control and measure these properties!

electron bunch: moving at $v \approx c$
ca. 20 μm long
ca. 100 μm wide

hard to measure directly
 \Rightarrow measure an optical copy instead

ORS: Optical Replica Synthesizer





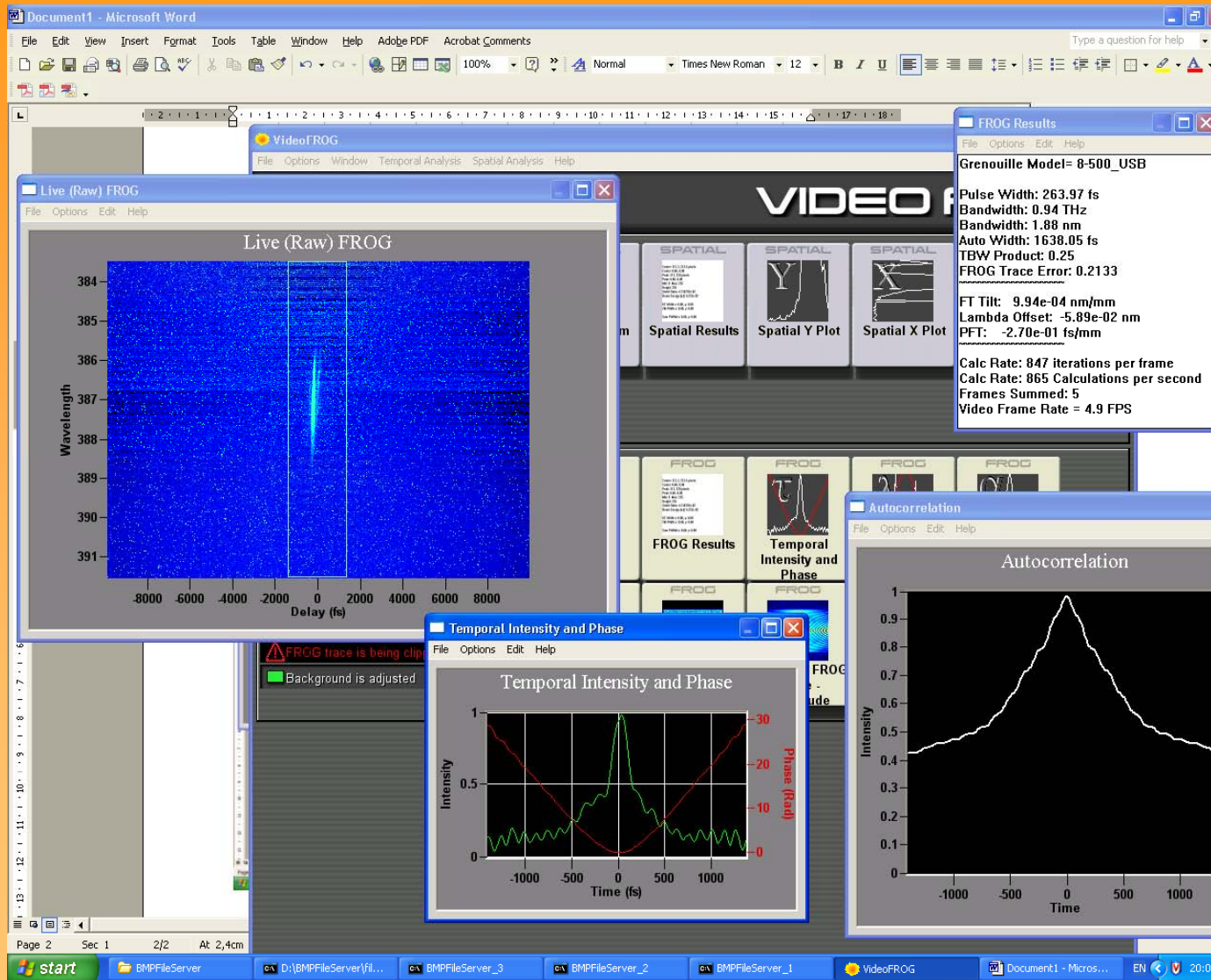
ORS: Optical Replica Synthesizer



achievements so far:

- locked modified CPA2001 laser to FLASH RF system.
- overlap in time and space of laser pulses and electron bunches @ 5 Hz.
- density modulation of electron bunch.
- coherent OTR: increase by a factor of ca. 10^4 .
- coherent radiation from modulated electron bunch: ca. 5 μJ /pulse.
- FROG trace using Grenouille long-pulse model 8-500.

ORS: First FROG trace





ORS: what's next?

This on-going shift we will try to:

- FROG trace using Grenouille short-pulse model 8-50
- ORS and SASE?
- ORS and FIR?



Routine diagnostics?

requirements:

- non-destructive
- every shot, 10 Hz/1 MHz macro/microbunch structure
- every other shot (compare LOLA)?
- ‘easy’ from user and/or operator perspective
- no interference with user’s measurement

what to measure (electron bunch):

- bunch position
- total bunch charge
- longitudinal bunch profile
- slice emittance
- slice energy spread



Routine diagnostics?

what to measure (VUV beam):

- beam position
- spatial mode
- energy/pulse
- pulse frequency spectrum
- longitudinal pulse profile

the electron bunch is an elusive commodity: never routine!

often the VUV beam characterization can be performed after the user's experiment

The ORS as a routine diagnostic?

- longitudinal bunch profile according to Saldin et al. (NIM A **539**, 499, 2005): single-shot measurement
- longitudinal bunch profile: multi-shot measurement

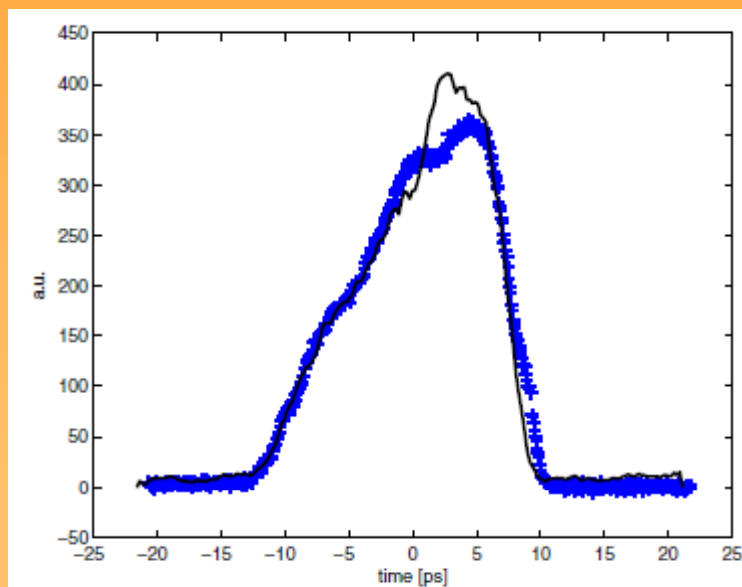


FIG. 5. (Color) Comparison of the longitudinal profile of the electron bunch measured with the transversely deflecting cavity LOLA (blue crosses) and the optical-replica synthesizer (black).

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The ORS as a routine diagnostic?

- imaging using coherent OTR/ODR
 - high k – small wavelength compared to THz measurements
 - high intensity

$$I(\mathbf{r}) \propto N \int d^2\mathbf{r}' dz \rho(\mathbf{r}',z) \left| \mathbf{E}_{\text{one-electr}}(\mathbf{r}-\mathbf{r}') \right|^2 + N^2 \left| \int d^2\mathbf{r}' dz \exp(-ikz) \rho(\mathbf{r}',z) \mathbf{E}_{\text{one-electr}}(\mathbf{r}-\mathbf{r}') \right|^2$$

$$I_{\text{coh}}(\mathbf{r}) \propto N^2 \left| \int d^2\boldsymbol{\kappa} \rho(\boldsymbol{\kappa},k) (\boldsymbol{\kappa} \exp(i\boldsymbol{\kappa}\mathbf{r})) / (\boldsymbol{\kappa}^2 + \alpha^2) \right|^2 \quad \alpha = k/\gamma$$

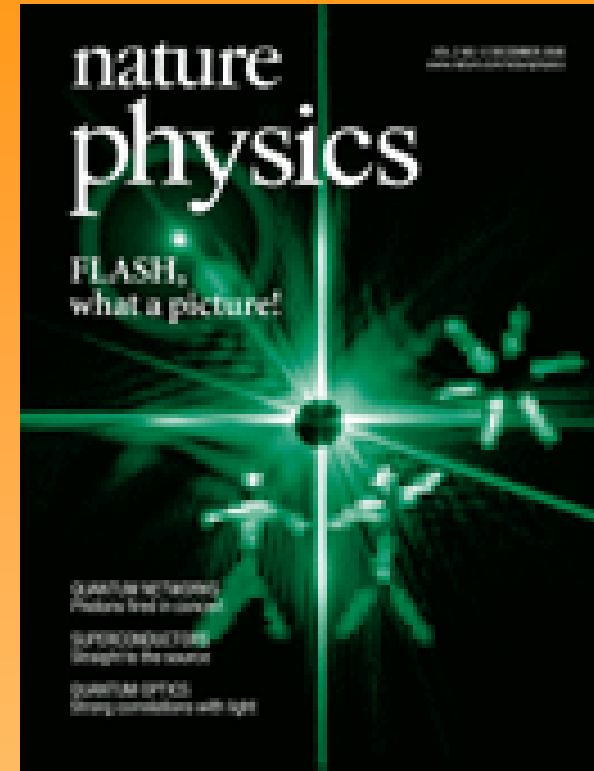
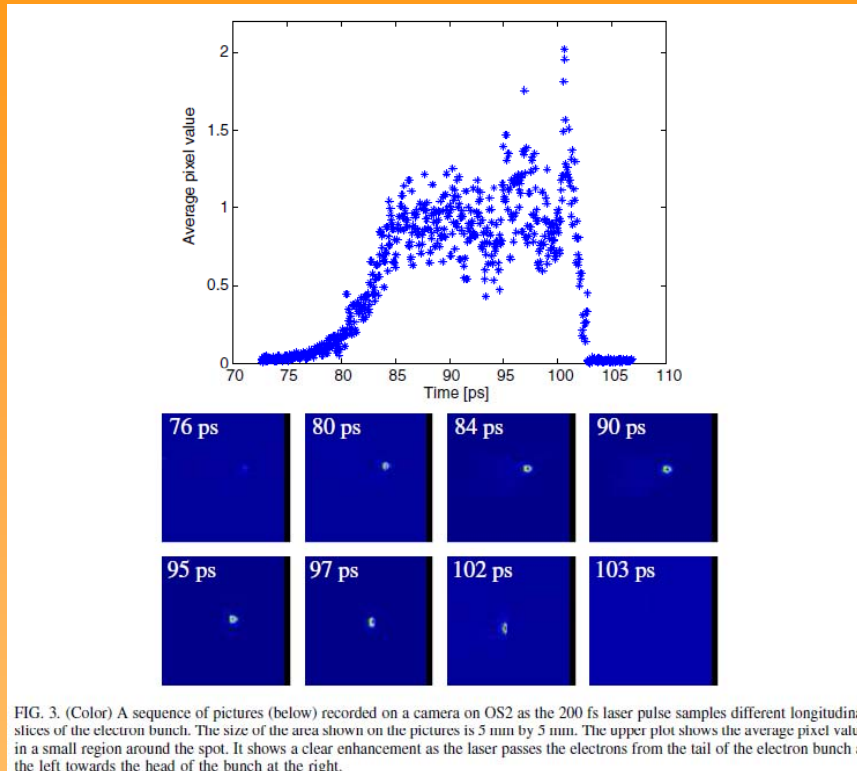
if $\rho(\boldsymbol{\kappa},k) = f(\boldsymbol{\kappa}) \cdot g(k) \Rightarrow X$



but....



The ORS as a routine diagnostic?



what about the possibility to do an image reconstruction using algorithms similar to those applied in single-particle X-ray diffraction?



multiple k 's and modulation using chirped seed pulses



The ORS as a routine diagnostic?

- compatible with SASE?
- destructive? every other shot?
- slice properties?
- stable RF-locked laser; minimum time jitter?
 - jitter: Holger Schlarb, Axel Winter and Florian Loehl
 - Clark-MXR CPA2001 from Stockholm University
 - Coherent HHG laser from sFLASH?
- spatial and temporal overlap?
 - better control of laser beam position
 - automation: Joern Boedewadt
- seed laser beam?
 - laser safety
 - interference with user experiments

The ORS as a routine diagnostic?

- alignment into Grenouille: ok
- magnets and undulators: ok
- optical quality of coherent beam?
 - OTR screens
- incorporation into sFLASH: ok (?)
 - (wo)manpower
 - 
- incorporation into XFEL?
 - 
 - modulation depth, $\sqrt{(\Delta E)^2} = 10^{-4} E_0$?



Conclusions

- no fundamental problems or show-stoppers to develop the ORS into a routine diagnostic
- hard work required – some issues are already addressed
- need more beam time – run in parasitic mode!



Collaborators

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DESY: Holger Schlarb

Florian Lühl

Hamburg University: Joern Boedewadt

Axel Winter

Shaukat Khan

BESSY: Atoosa Meseck

DESY: E. Saldin, E. Schneidmiller & M. Yurkov



THANK YOU !

