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

Peter van der Meulen
Stockholm University
Div. Molecular Physics

ORS: Optical Replica Synthesizer

FLASH, XFEL: SASE

SASE is very sensitive to the properties of the electron bunch

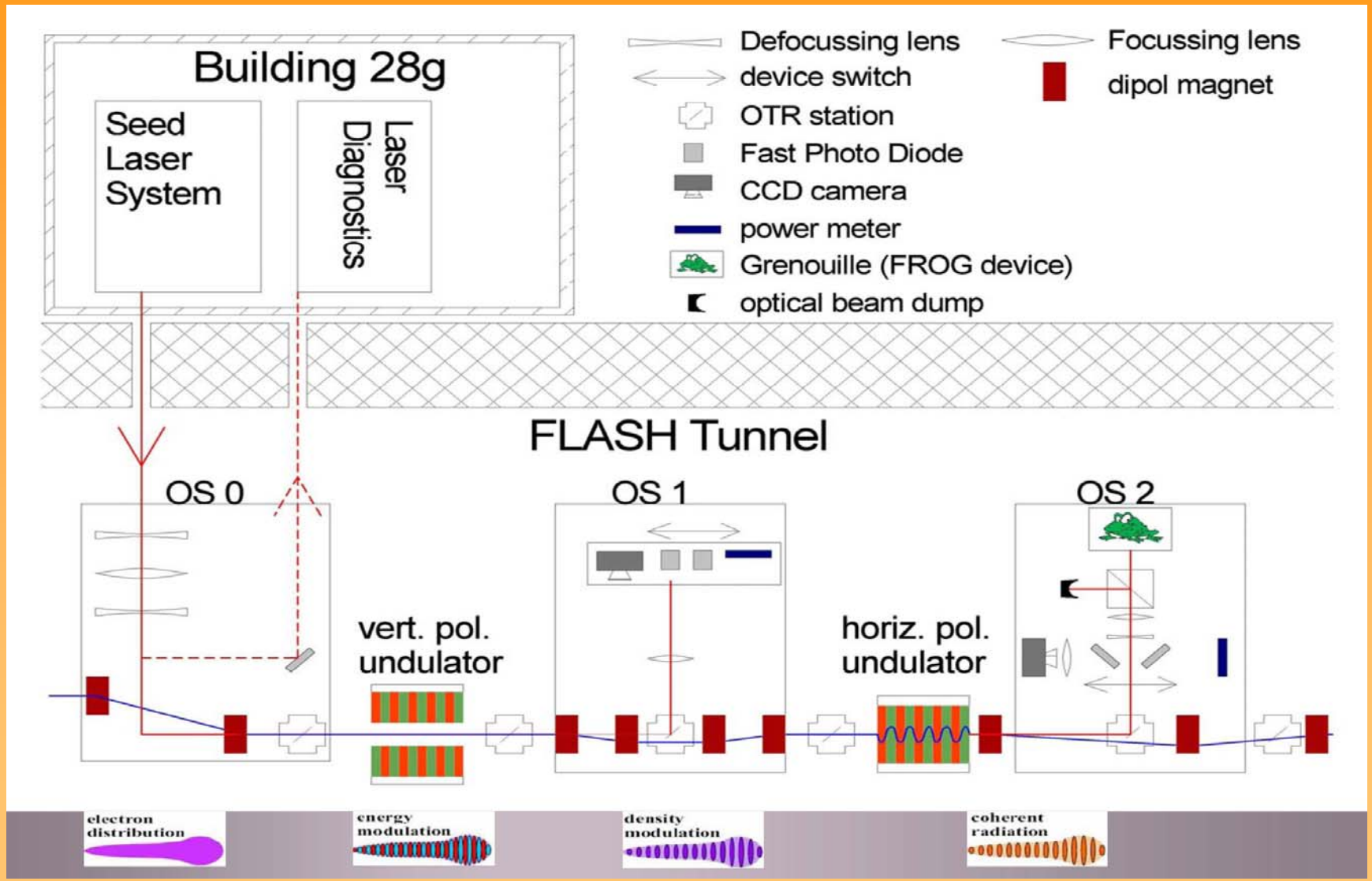
electron bunch properties: longitudinal density profile
slice emittance
slice energy spread

need to <u>control</u> and <u>measure</u> these properties!

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

hard to measure directly
$\Rightarrow$ <u>measure an optical copy instead</u>

ORS: Optical Replica Synthesizer

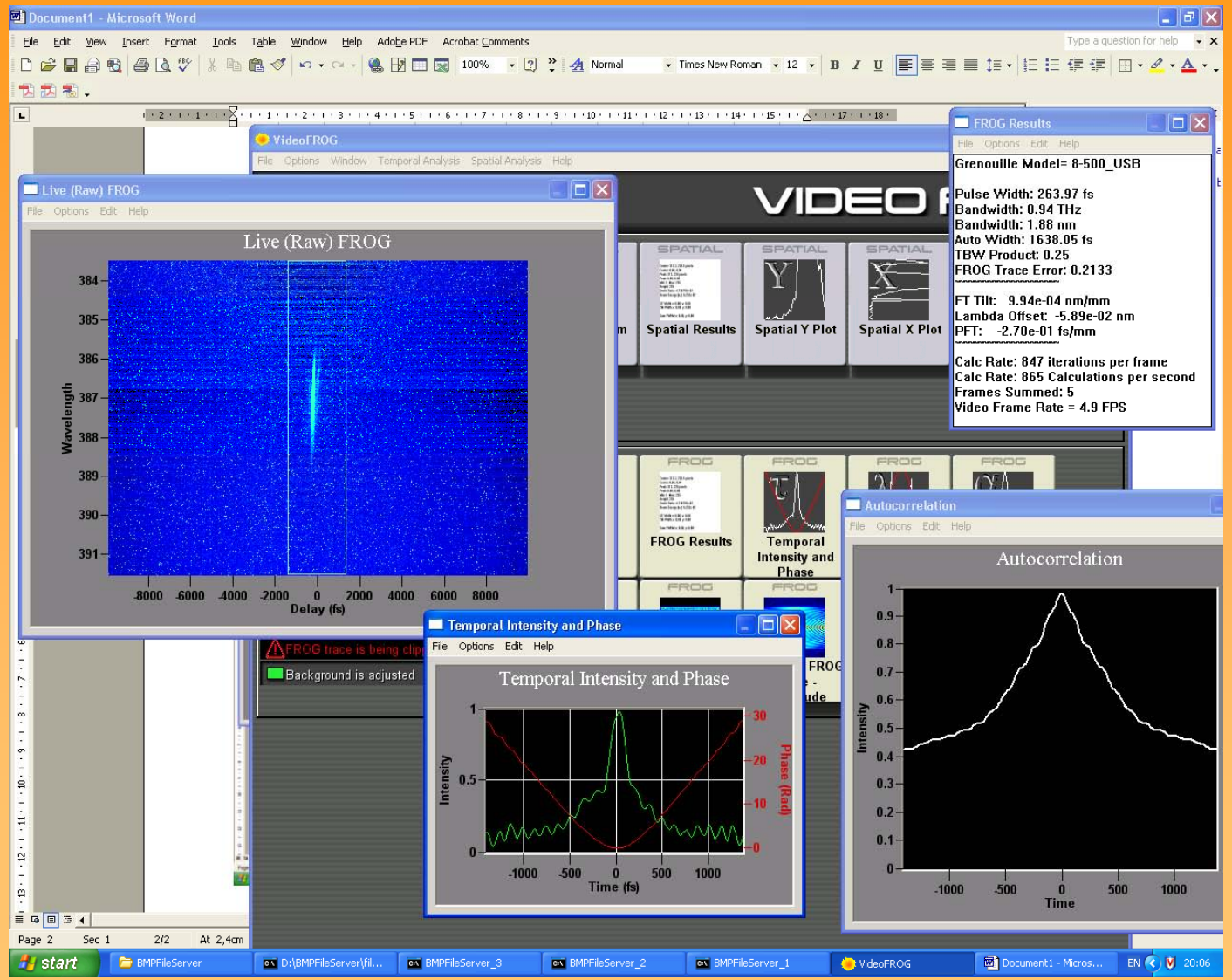


ORS: Optical Replica Synthesizer

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

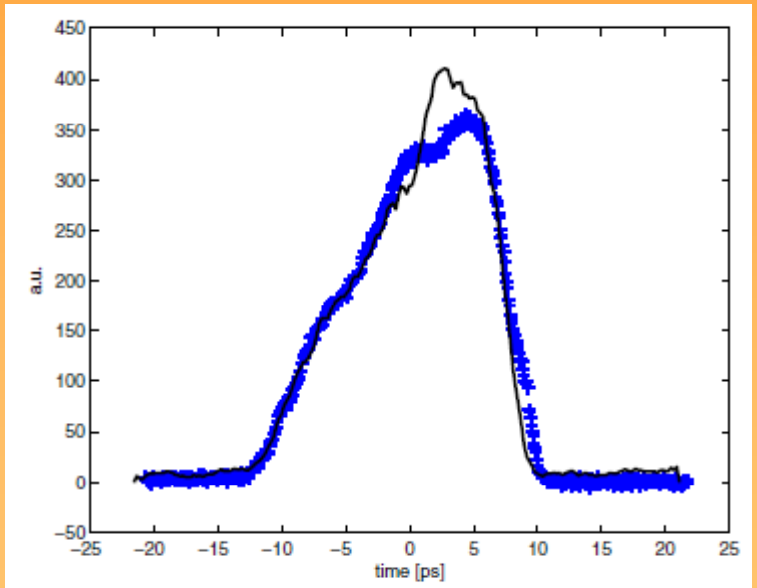


FIG. 5. (Color) Comparison of the longitudinal profile of the electron bunch measured with the transversely deflecting cavity LOLA (blue crosses) and the optical-replica synthesizer (black).

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The ORS as a routine diagnostic?

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

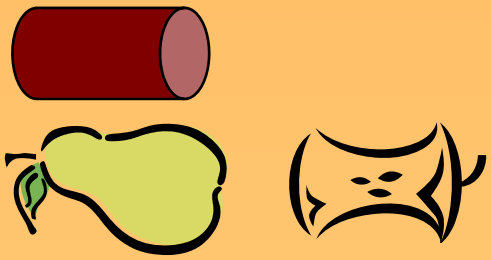
$$I(\mathbf{r}) \propto N \int d^2\mathbf{r}' \, dz \, \rho(\mathbf{r}',z) \left| \mathbf{E}_{\text{one-electr}}(\mathbf{r}-\mathbf{r}') \right|^2$$

$$+$$

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

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

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



but….

The ORS as a routine diagnostic?

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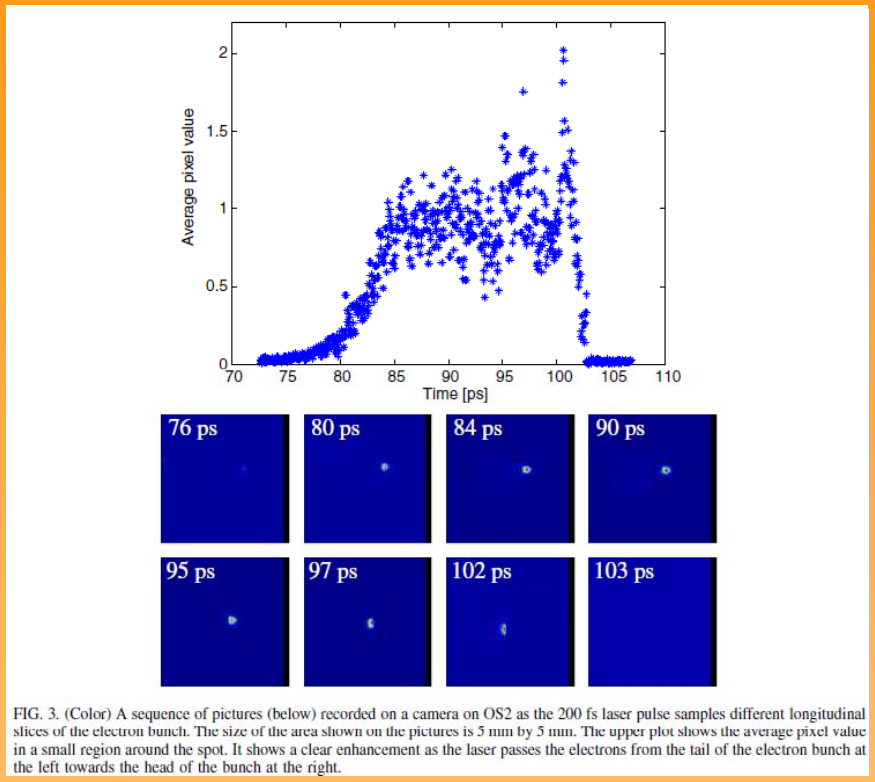
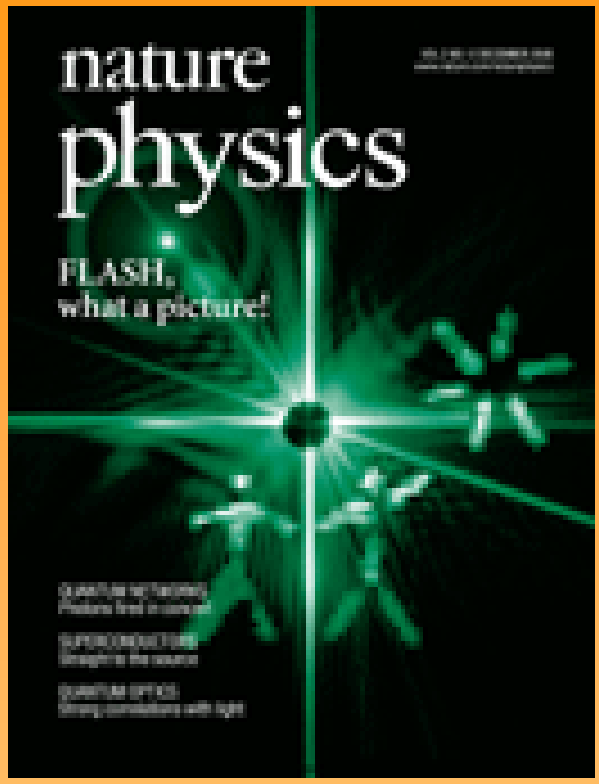


FIG. 3. (Color) A sequence of pictures (below) recorded on a camera on OS2 as the 200 fs laser pulse samples different longitudinal slices of the electron bunch. The size of the area shown on the pictures is 5 mm by 5 mm. The upper plot shows the average pixel value in a small region around the spot. It shows a clear enhancement as the laser passes the electrons from the tail of the electron bunch at the left towards the head of the bunch at the right.



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

Stockholm University:	Peter Salen
	Mathias Hamberg
	Mats Larsson
Uppsala University:	Volker Ziemann
	Gergana Angelova-Hamberg
DESY:	Holger Schlarb
	Florian Löhl
Hamburg University:	Joern Boedewadt
	Axel Winter
	Shaukat Khan
BESSY:	Atoosa Meseck

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

THANK YOU !