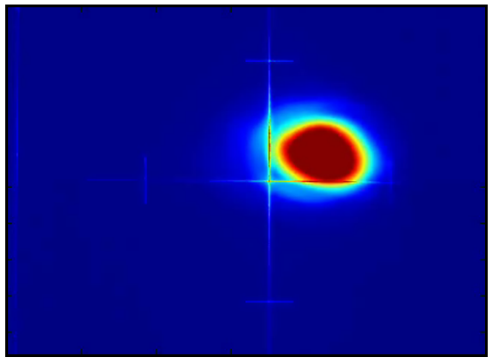
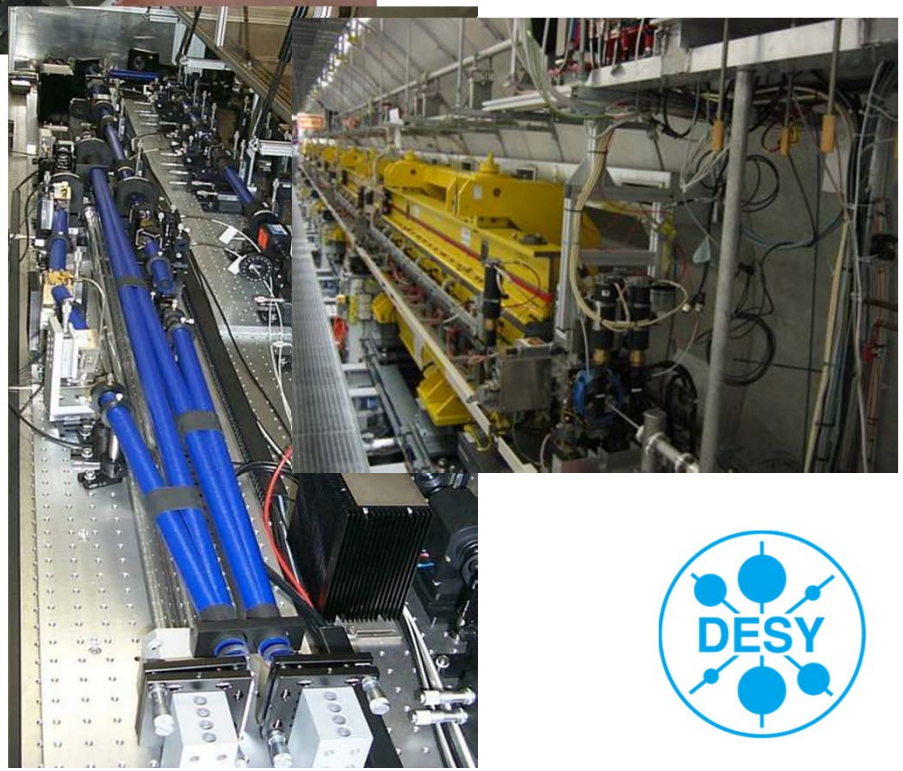
Notes on Requirements for cathodes from a SC Linac driven FEL

Siegfried Schreiber
DESY





EUROFEL Workshop on Photocathodes for RF guns

WG2

March 2, 2010
Lecce, Italy

HELMHOLTZ GEMEINSCHAFT

DESY

Light Sources

We talk about new generation light sources:

> X-ray single pass FELs → hundreds of pulses per second

> X-ray single pass FELs operated in burst mode
→ thousands of pulses per second

> X-ray ERLs → quasi cw operation with many thousands of pulses per second

Parameters:

> Aim for high peak and average brilliance of X-ray radiation

- High peak brilliance → beam quality
- High average brilliance → high beam current or many bunches/second

All light sources need electron sources

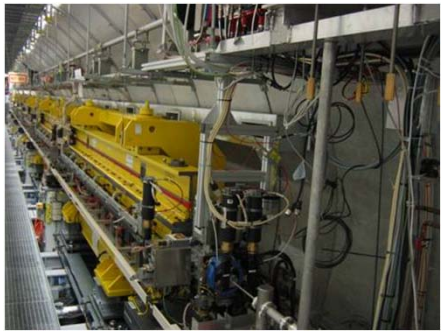
→ high quality and/or high average power systems

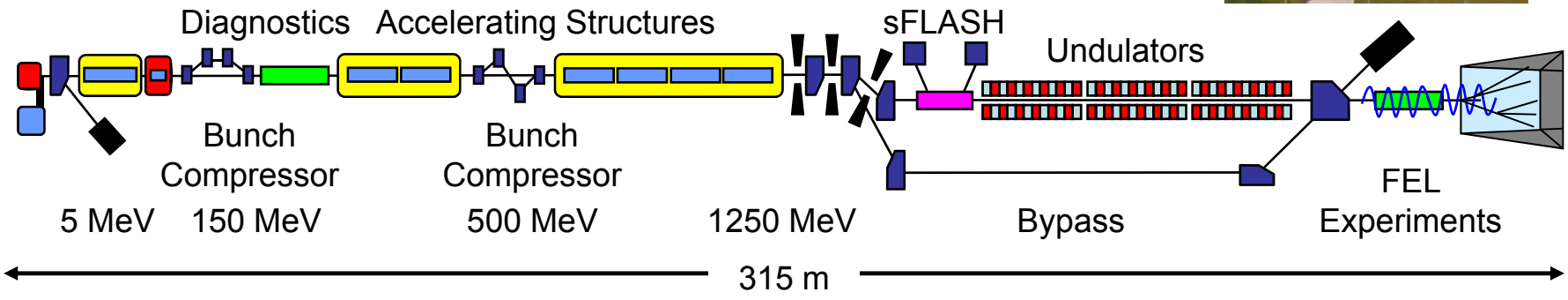
Parameter Spaces

- Low repetition rate machines
  - LCLS
  - Spring8 XFEL
  - Fermi@Elettra
  - SparcX
  - SwissFEL
- Burst mode machines
  - European XFEL
  - FLASH
- High repetition rate machines
  - NLS
  - WiFEL
  - BerlinPro ERL
  - Cornell ERL

FLASH – operates in burst mode





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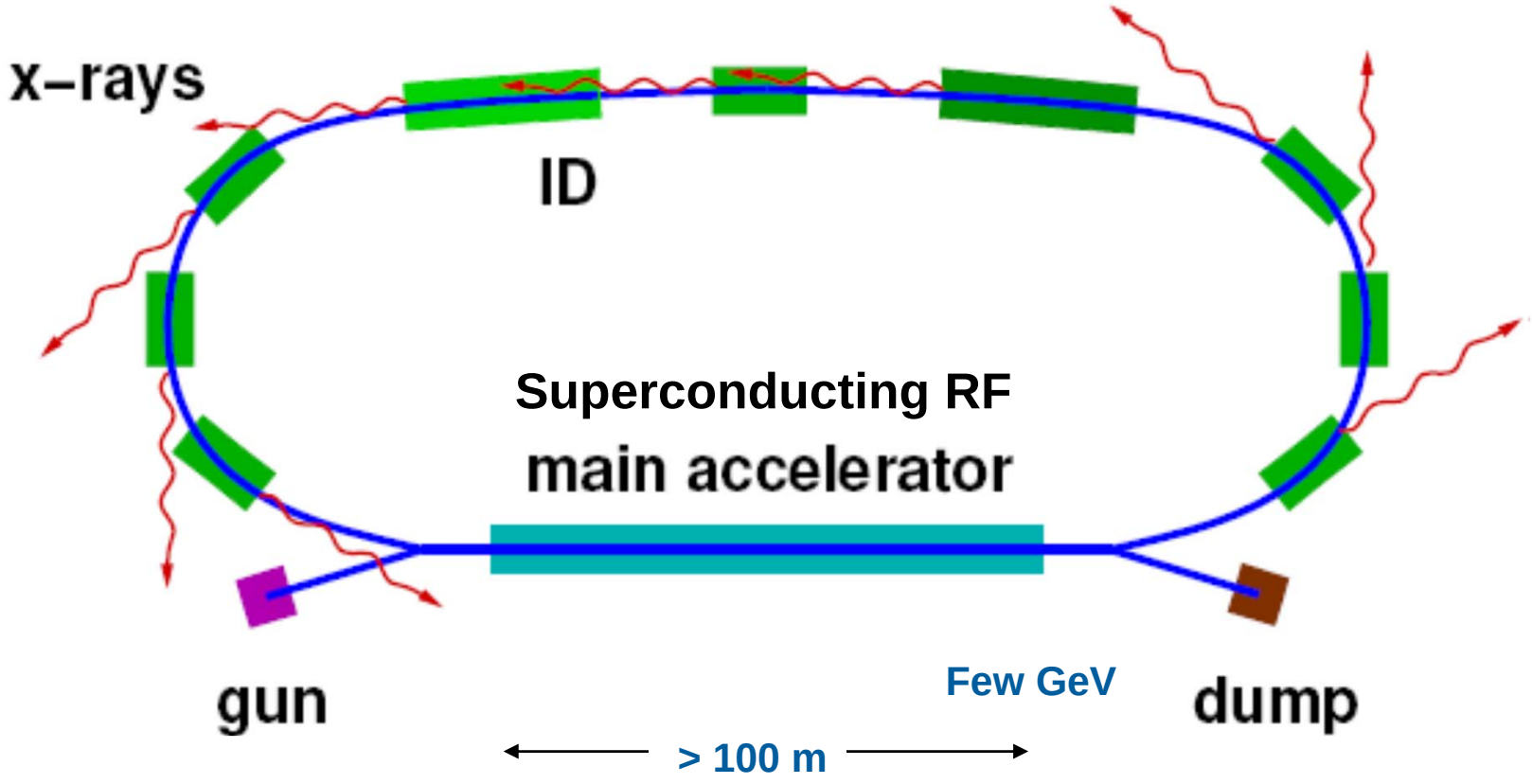
ERL – Energy recover linac

> Energy recovery to reach high average power



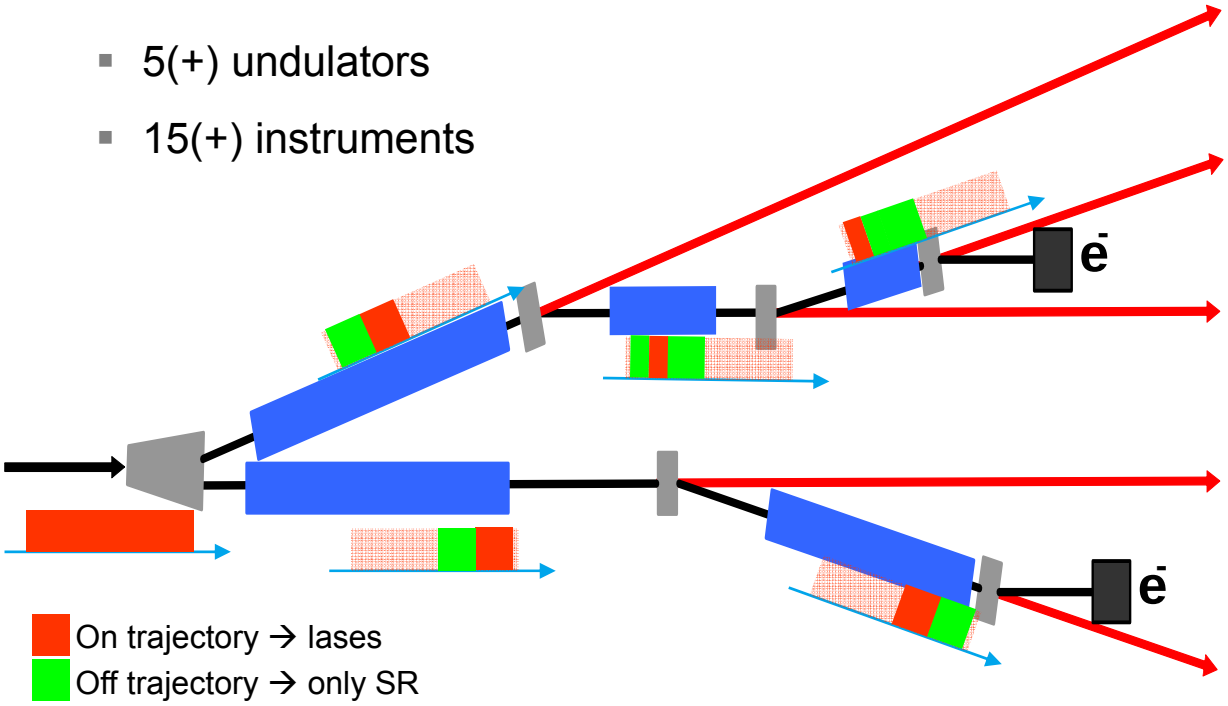
Bunch Pattern – typical examples

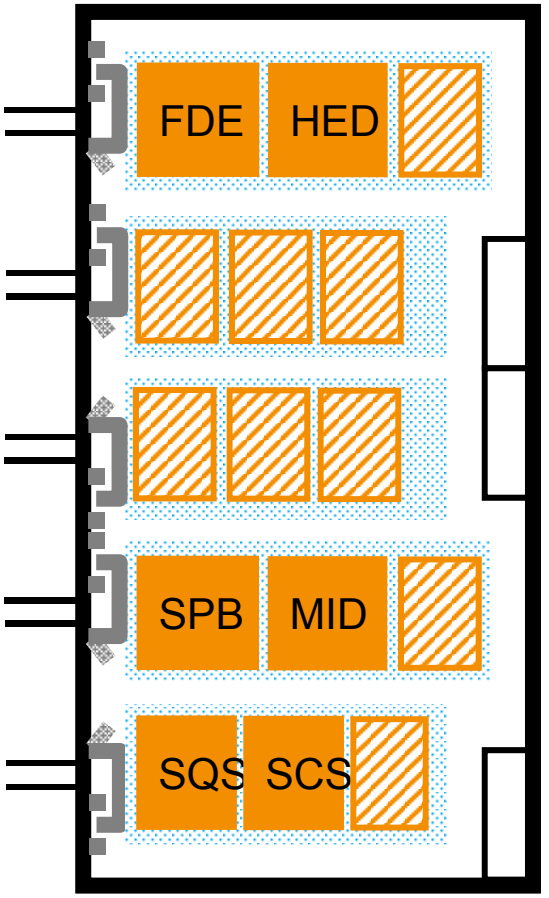
	Macro-pulse repetition rate	Macro-pulse length	Bunches per macro-pulse	Beam current during macro-pulse	Max bunches per second
LCLS	120 Hz	--	1	--	120
Spring8 XFEL	60 Hz		50		3000
Fermi@Elettra	10 Hz 50 Hz		1 1		10 50
super Fermi@Elettra	100 Hz		100		10000
European XFEL	10 Hz	650 µs	2900 @ 4.5 MHz	4.5 mA	29000
FLASH	10 Hz	800 µs	800 @ 1 MHz	1 mA	8000
BerlinPro ERL	1.3 GHz	cw	--	100 mA	$1.3\ 10^9$
Cornell ERL	1 MHz 1.3 GHz	cw	--	1 mA 25/100 mA	$1.3\ 10^6$ $1.3\ 10^9$
ILC (RDR)	5 Hz	970 µs	1000 - 5400	9 mA	5000 – 27000

EuXFEL: Simultaneous operation of many instruments

> Within the bunch train

- 2 e$^-$-beamlines
- 5(+) undulators
- 15(+) instruments





Boxes only placeholders !

Sophisticated electron bunch distribution

- 27.000 bunches/sec to 5 beamlines
- in average 10-20 Hz and ~500 pulses/train
- using kicking methods to make bunches lase only in dedicated undulator

Cathodes for Electron sources

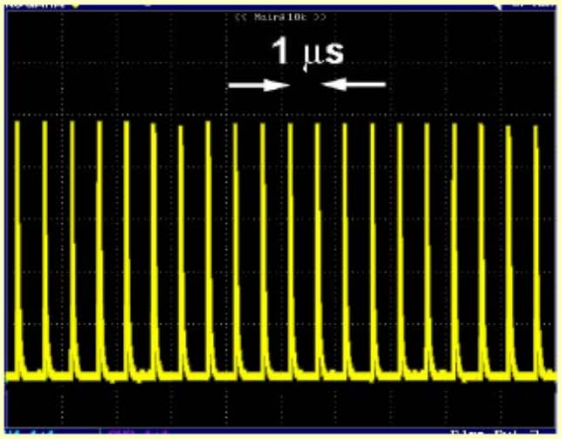
	Macro-pulse repetition rate	Macro-pulse length	Max bunches per macro-pulse	single pulse energy	Wave-length	Cathode Type	Charge per second	QE
FLASH	10 Hz	800 µs	800 @ 1 MHz	100 µJ IR 10 µJ UV	1047→ 262 nm	Cs_2Te	8 µC	10 %
European XFEL	10 Hz	650 µs	2900 @ 4.5 MHz	100 µJ IR 10 µJ UV	1047→ 262 nm	Cs_2Te	450 W	10 %
LCLS	120 Hz	--	--	20 mJ	800 → 255 nm	Cu	--	<0.01 %
Fermi@ Elettra	10 Hz 50 Hz	--	--	20 mJ	800 → 255 nm	Cu	--	< 0.01 %
BerlinPro ERL	1.3 GHz	--	--	1 µJ	550 nm	CsK_2Sb	--	10 %
Cornell ERL	1 MHz 1.3 GHz	--	--	10 µJ 1 µJ	800 nm	GaAs (?)	--	>10 %

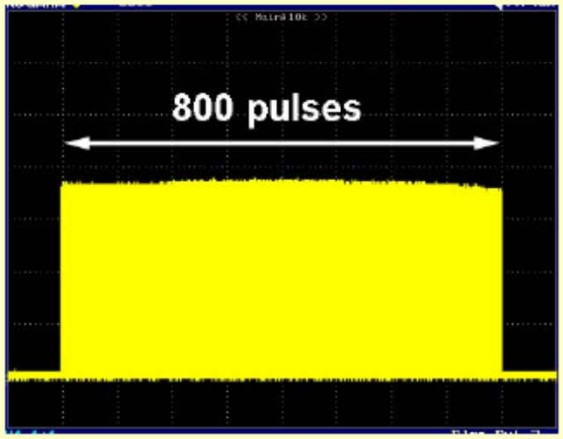
Lasers for Electron sources

	Macro-pulse repetition rate	Macro-pulse length	Max bunches per macro-pulse	single pulse energy	Wave-length	Laser Pulse length	Power in burst	Average power
FLASH	10 Hz	800 µs	800 @ 1 MHz	100 µJ IR 10 µJ UV	1047→ 262 nm	10 ps rms	100 W	0.8 W
European XFEL	10 Hz	650 µs	2900 @ 4.5 MHz	100 µJ IR 10 µJ UV	1047→ 262 nm	20 ps flat hat	450 W	3 W
LCLS	120 Hz	--	--	20 mJ	800 → 255 nm	10 ps flat hat	--	2.4 W
Fermi@ Elettra	10 Hz 50 Hz	--	--	20 mJ	800 → 255 nm	10 ps flat hat	--	1 W
BerlinPro ERL	1.3 GHz	--	--	1 µJ	550 nm	10 ps	--	1.3 kW
Cornell ERL	1 MHz 1.3 GHz	--	--	10 µJ 1 µJ	800 nm	?	--	10 W 1.3 kW

Example: FLASH/PITZ burst mode laser

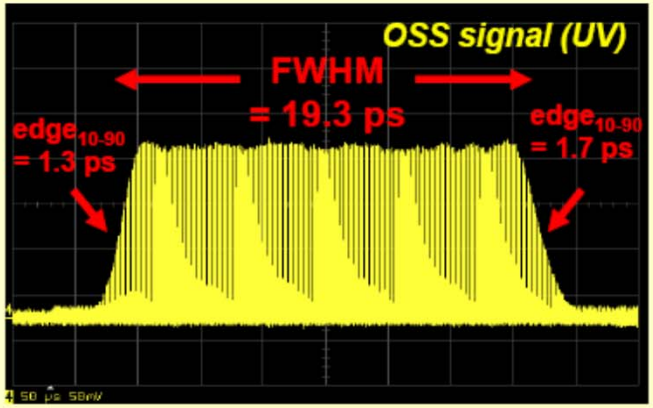
- State-of-the-art laser system for longitudinally flat hat pulses in burst mode
- Challenge: upgrade from 1 MHz to 5 MHz bursts for the Eurpean XFEL





UV pulse trains containing up to 800 micropulses

I. Will, G. Klemz et al, MBI/DESY



Shape of the micropulses measured with the optical sampling system

Summary

- Electron sources:
- For high average power, we need cathodes with
  - high QE – to keep laser power reasonable
  - Operable in superconducting environment
- For high QE cathodes, state-of-the-art lasers exists or are close to be finished for most sources
  - issue here is the requirements on shaping (transverse and longitudinal) in combination with high average power
  - Best would be a high QE for the lasers fundamental wavelength
  - For instance Ti:Saphire / GaAs
  - Is GaAs operable in SC guns? What's about cesiation?
- Low QE cathodes or high QE for non-fundamental laser wavelength are disfavored