Single bunch x-ray pulses on demand from a multi-bunch synchrotron radiation source

Resonant pulse picking and MHz Chopper

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Workshop at MAX-IV March 2015

Flexible x–ray pulse lengths from BESSY II

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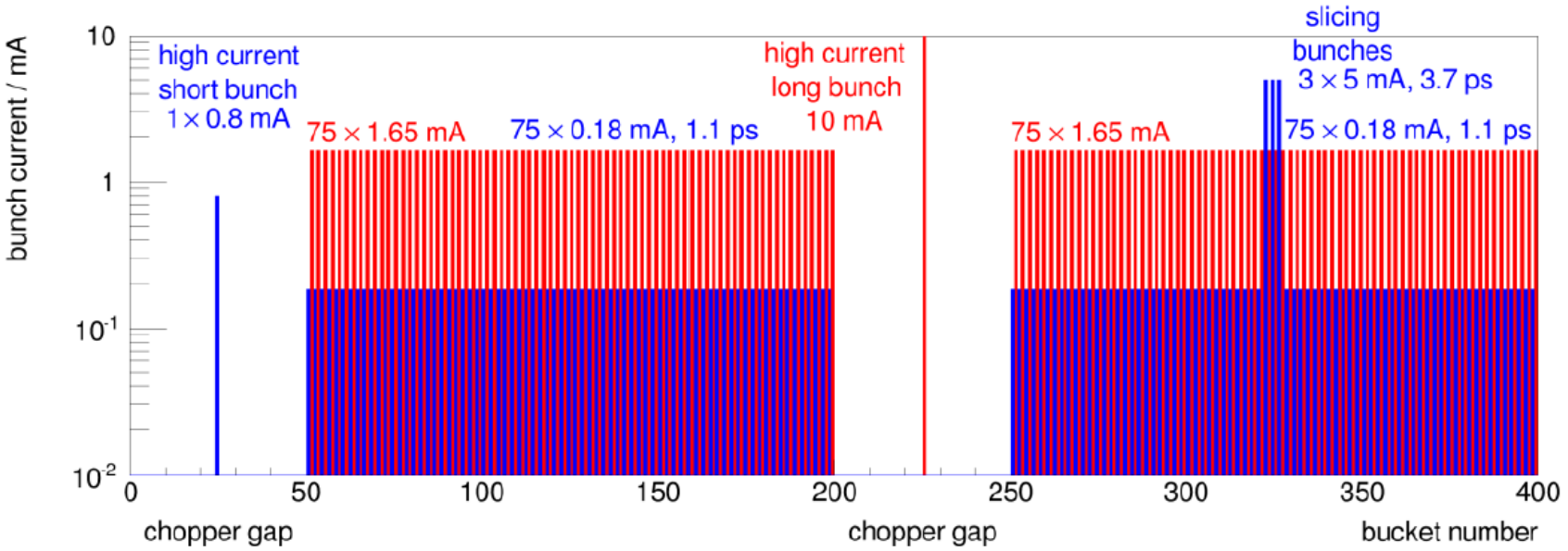
- we are already providing flexible x-ray pulse lengths:
  normal mode / low alpha / slicing
  rms: 15 ps / 3 ps / 42 fs (100fs FWHM)

- agreed filling pattern at BESSY-VSR :



If one pulse is selected - > how to get rid of all the others ?
(gating ignores that sample is still illuminated by average power)

Bunch separation schemes planned at BESSY II

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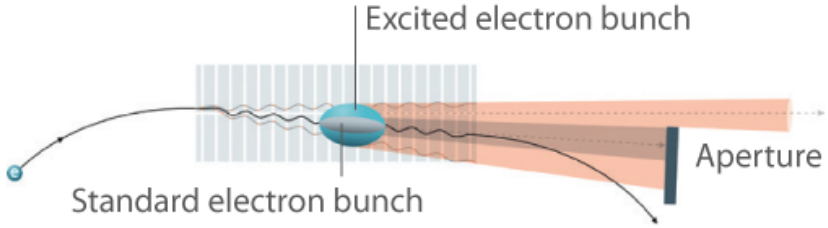
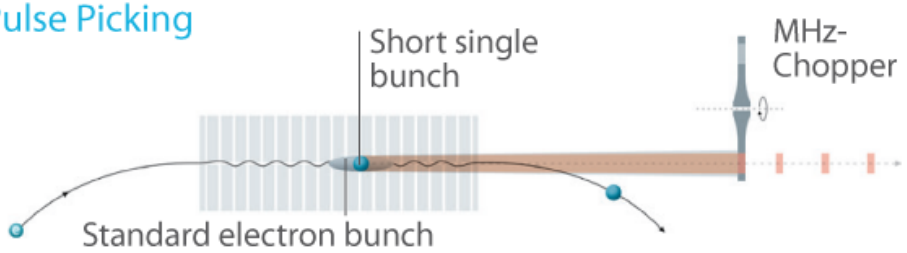
Resonant excitation



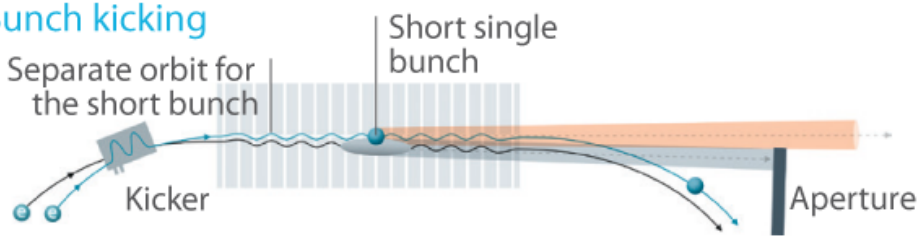
Demonstrated at BESSY II ✔

Pulse Picking



First Test Phase / BES.9 ✔

Bunch kicking



Development during POF III

BESSY-VSR

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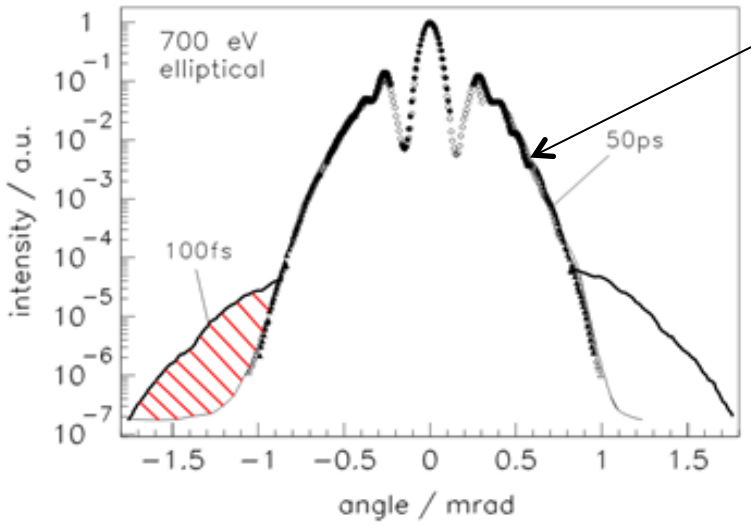
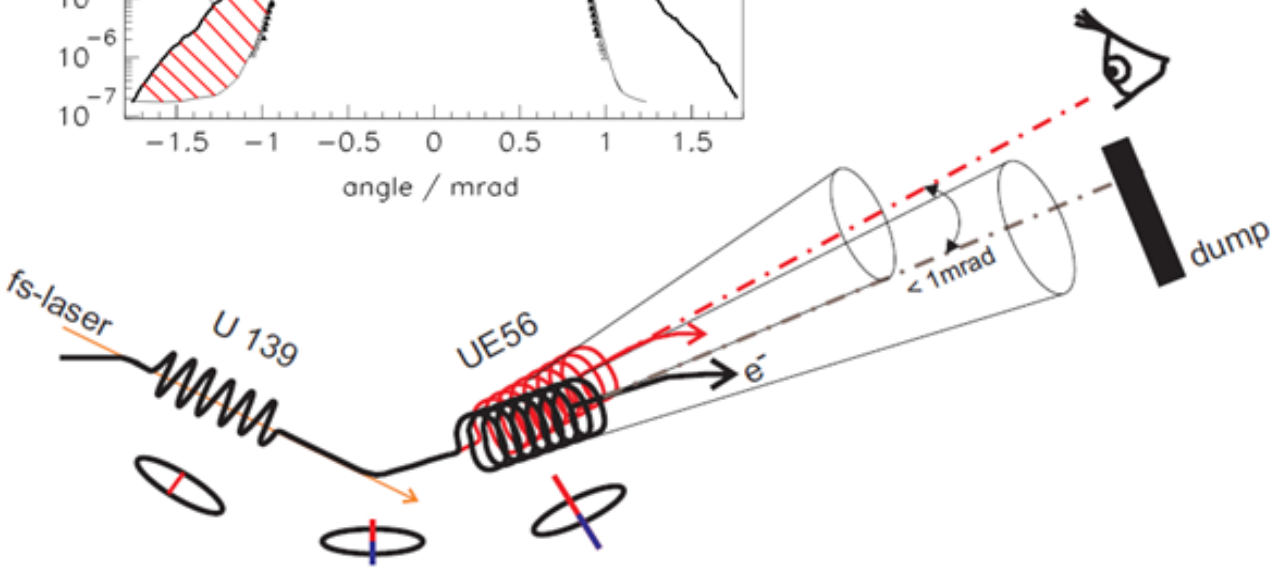
How to separate off-axis undulator radiation example: Slicing at BESSY II

2003 initial experiment at UE56/1PGM:

- very steep off-axis decay !
- hor. separation could work !





- „sliced“ electrons travel with different energy ⇨ dispersion – angular separation

Resonant X-ray Pulse Picking (PPRE) - basic ideas

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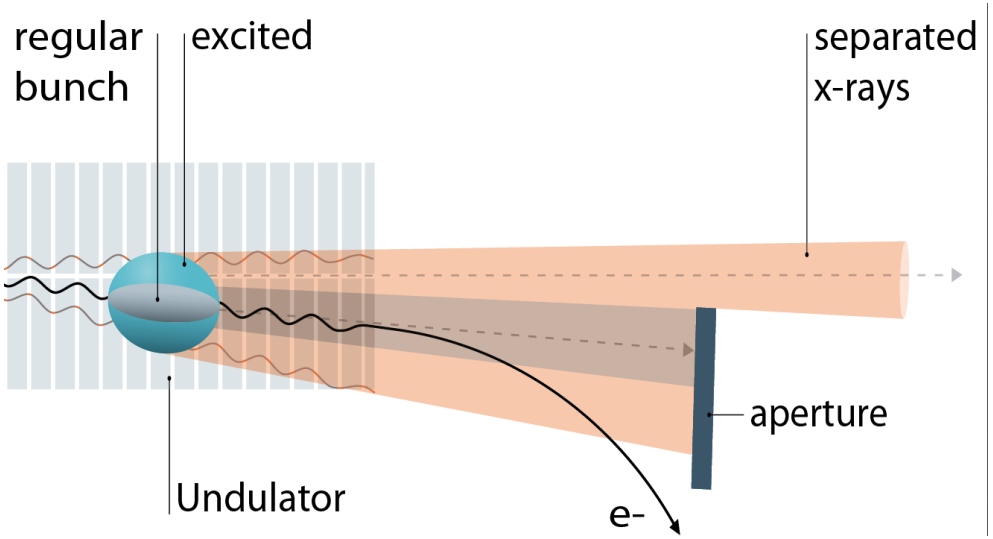
- **If we separate regular off-axis undulator radiation - does weak bunch excitation + „orbit bump“ work as well?**



- Only one bunch is weakly excited horizontally at 190 kHz (side band of the synchrotron tune -> stationary incoherent betatron oscillations
- regular photons are kicked away by local orbit bump (typ. 0.5 mrad)
- **SB - photons in beamline at 1.25 MHz** - by resonant but incoherent transverse horizontal excitation of electrons and stationary turn by turn „blurring“ of exited bunch‘s emittance

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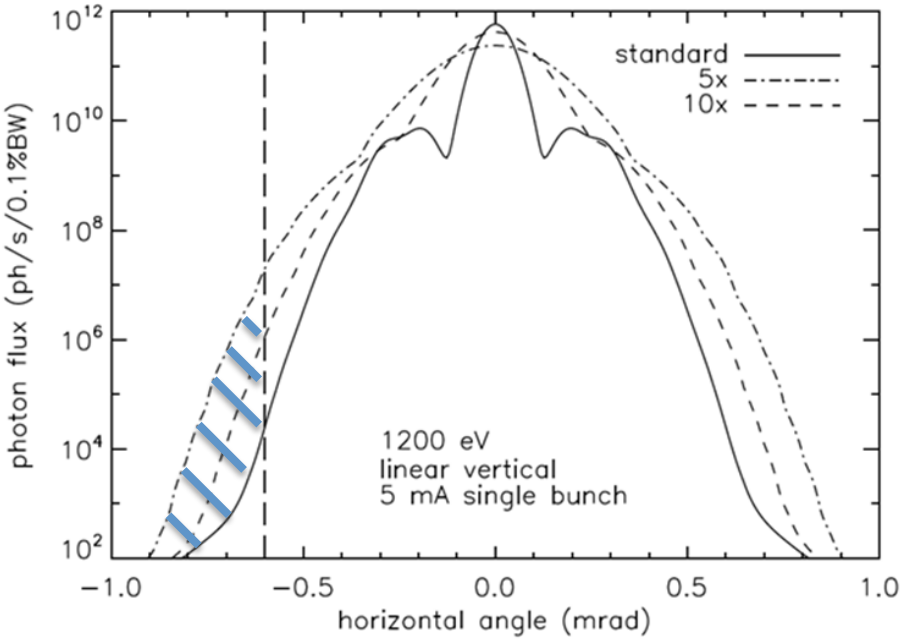
How to separate off-axis undulator radiation ?
Will weak bunch excitation + local orbit bump work?

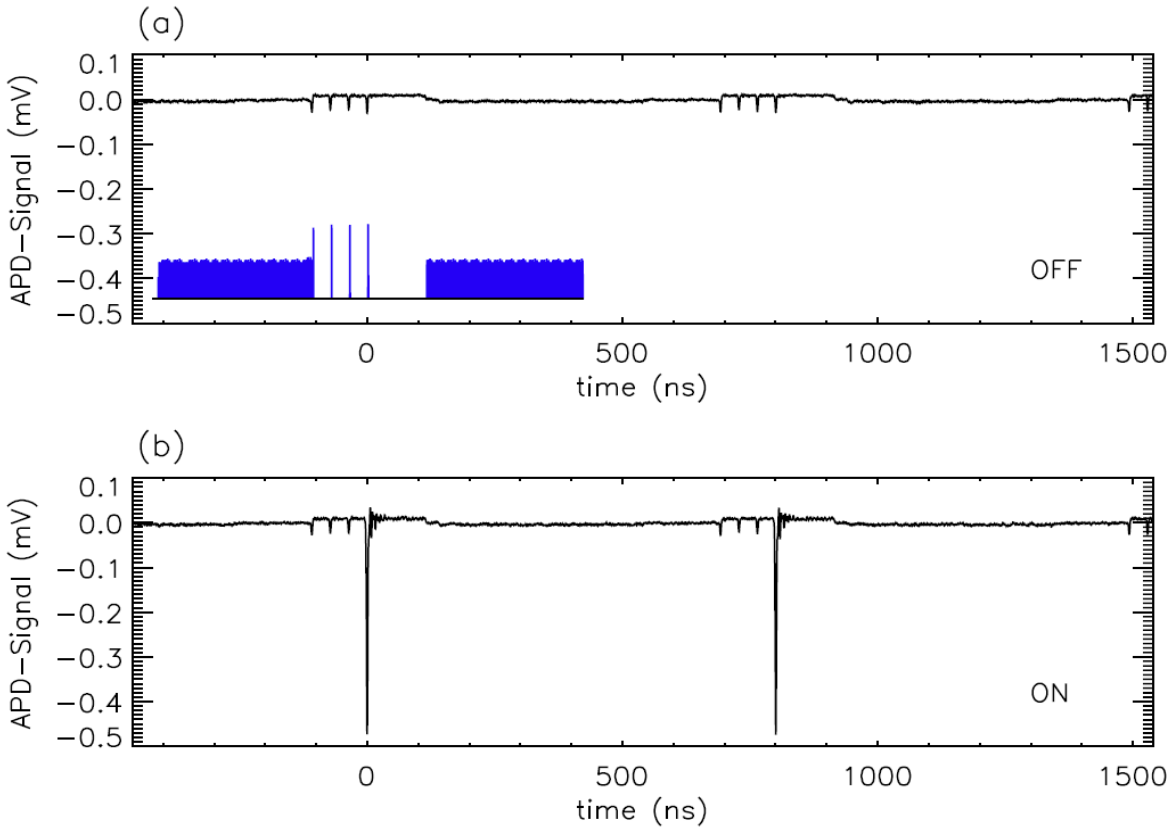


- blow up in (SB's) emittance leads to **blurred angular distribution** of the ID- radiation

- simulations say: potentially many orders (4) of magnitude separation possible at expense of flux

Resonant X-ray Pulse Picking (PPRE) - experiments

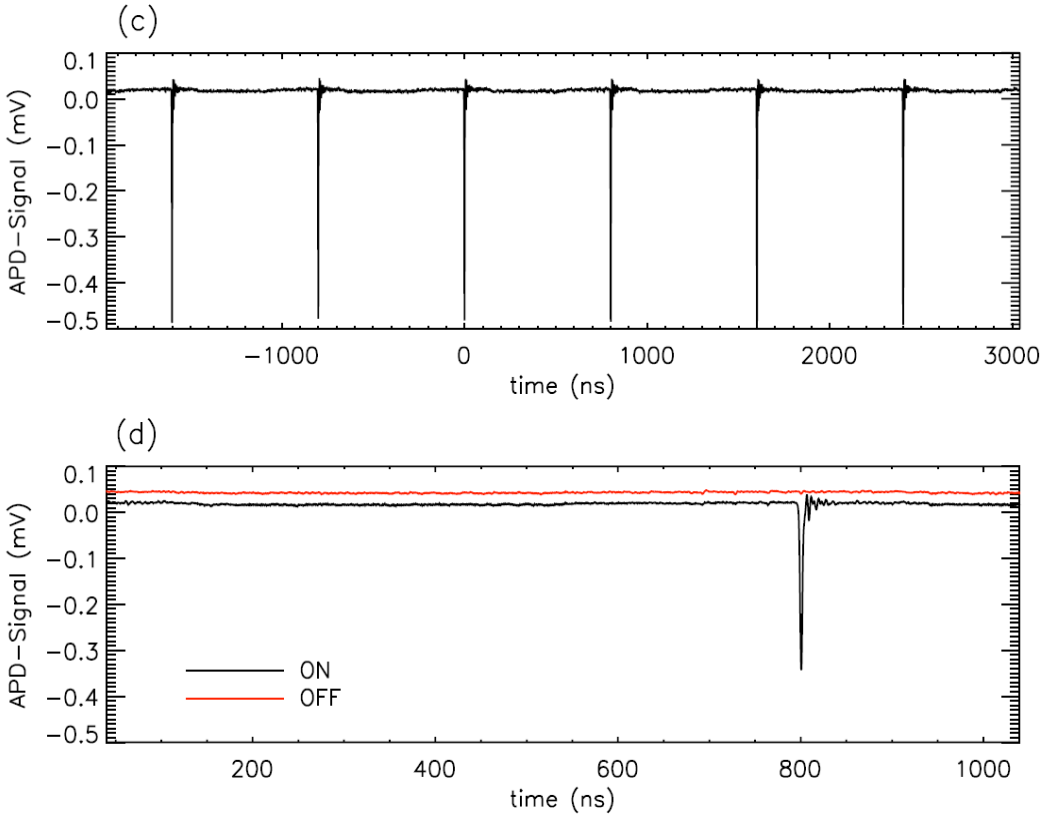
- **„femtobump“ situation UE56/1 PGM, 1200 eV , - 0.6 mrad**
- **aperture set to accept a very little MB signal**
- **we are far off-axis now !**



- with excitation ON in (b) the signal from excited bunch grows rapidly !

Resonant X-ray Pulse Picking (PPRE) - experiments

- **aperture set to block regular photons + „strong PPRE“**
- **pure SB-signal remains**



- up to **4 orders** separation possible – hey, it works !!!
- we see a stationary **1.25 MHz** SB – signal although excitation is only at **190 kHz !**

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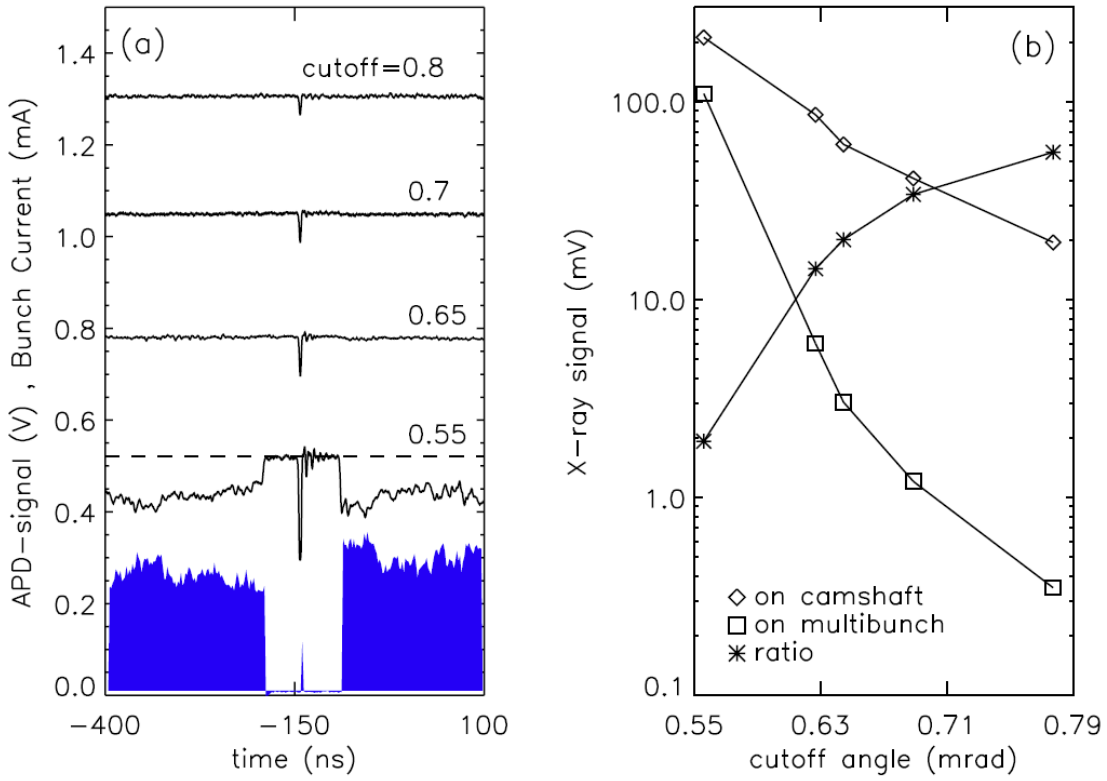
Femtobump situation UE56/1 PGM, low alpha mode, very small bunch charge in camshaft bunch



- works as well !!!
- stationary **1.25 MHz** SB – signal from ultrashort bunch !!!
- real signal-to-background hard to detect but ~3 orders Purity possible !

Resonant X-ray Pulse Picking (PPRE) - experiments

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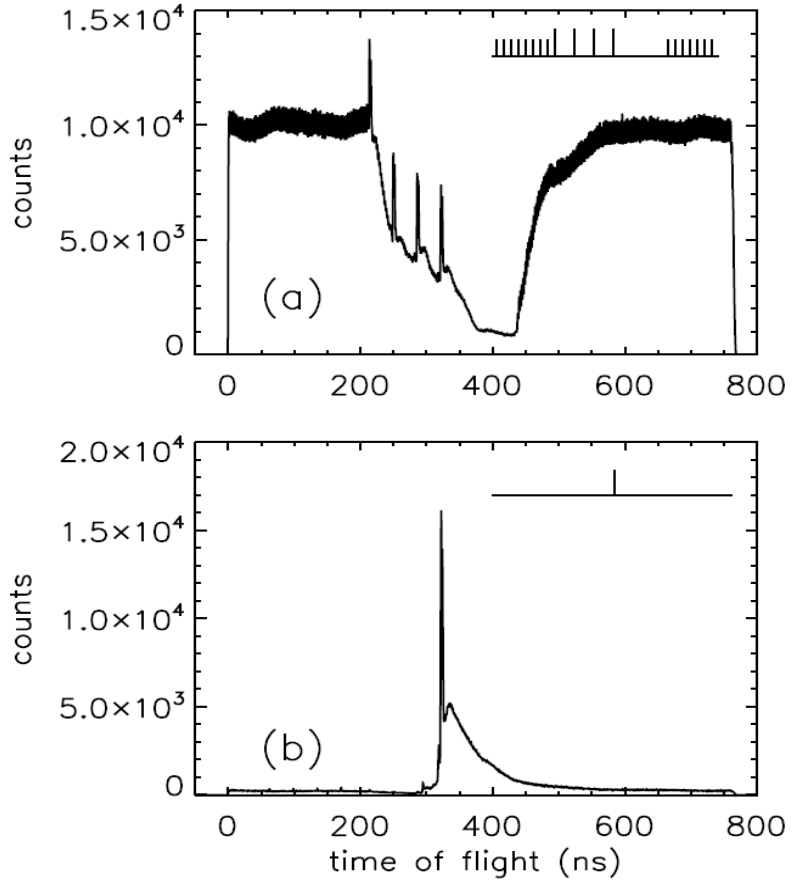
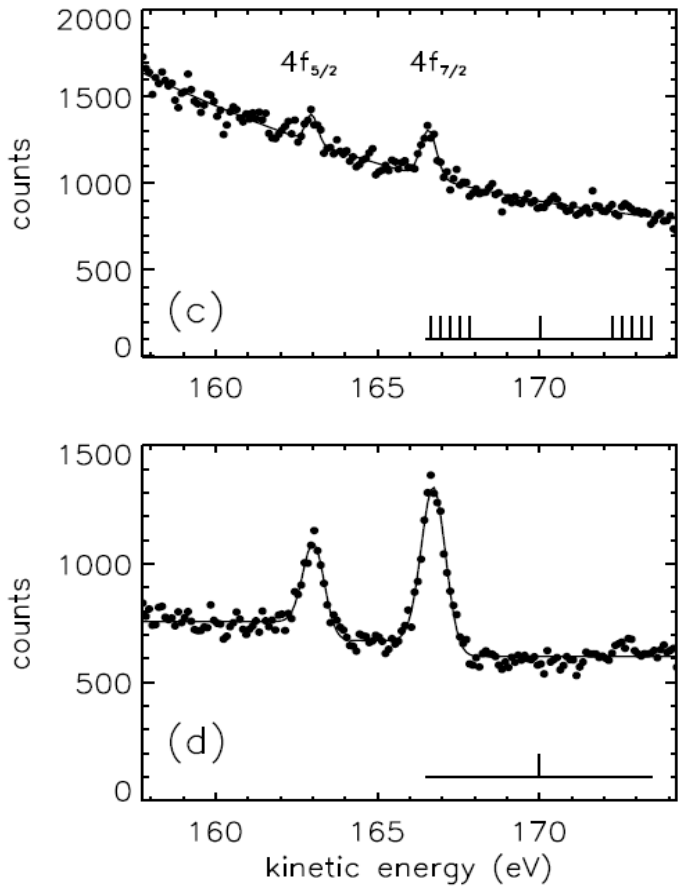
Can we really do a SB experiment with ARTOF using PPRE ?

normal mode | **low alpha mode**





PPRE OFF

PPRE ON

- **yes we can, even in low alpha mode !**
  with Ruslan and the ARTOF team at UE56/1

Resonant X-ray Pulse Picking (PPRE) - Conclusions

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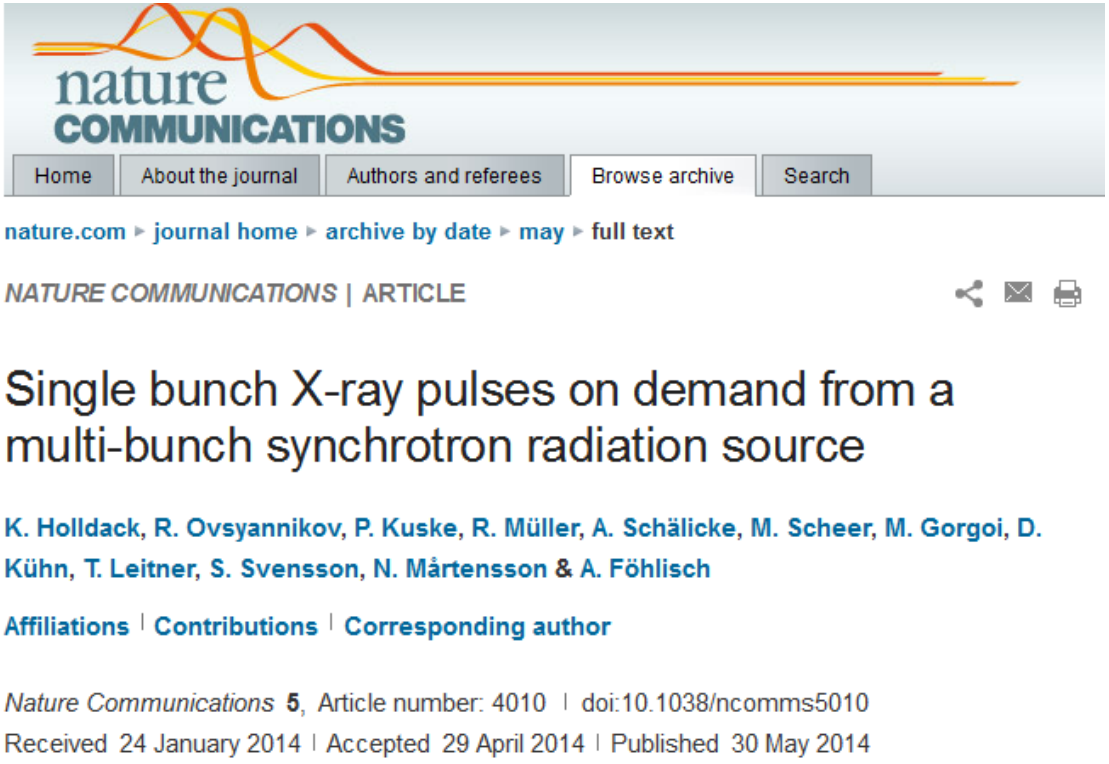
- separation and ARTOF spectra successfully repeated at UE52, UE56/2
- PPRE does not disturb other users (compatible with normal mode)
- less photons than in SB but up to 1e9 ph/s at purity up to 1e4

- fits well to ARTOF as a high acceptance instrument and time-resolved PES
- no big investments on machine side needed but :
  signal loss of ~ 3 orders -> but fits well to charge limit of PES



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Single bunch X-ray pulses on demand from a multi-bunch synchrotron radiation source

K. Holldack, R. Ovsyannikov, P. Kuske, R. Müller, A. Schälicke, M. Scheer, M. Gorgoi, D. Kühn, T. Leitner, S. Svensson, N. Mårtensson & A. Föhlisch

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Bunch separation schemes at BESSY II

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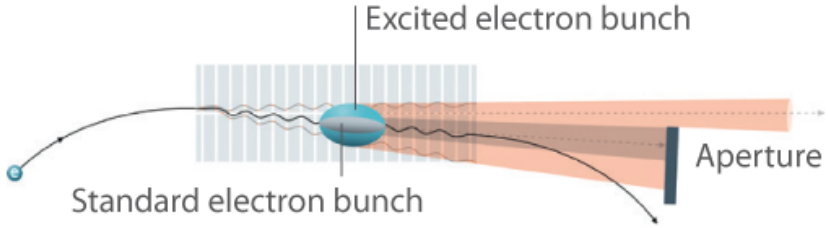
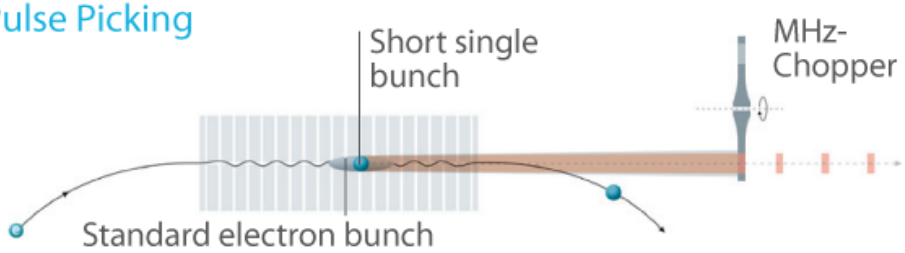
Resonant excitation



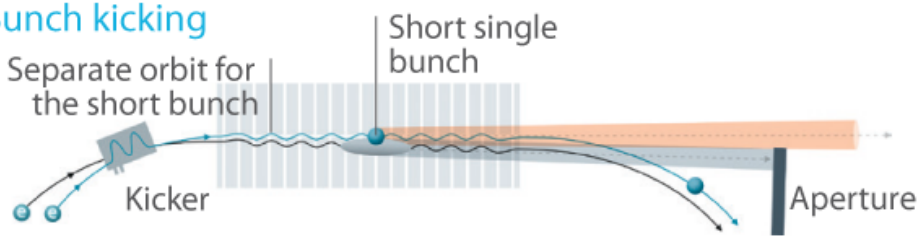
Demonstrated at BESSY II ✔

Pulse Picking



First Test Phase / BES.9 ✔ →

Bunch kicking

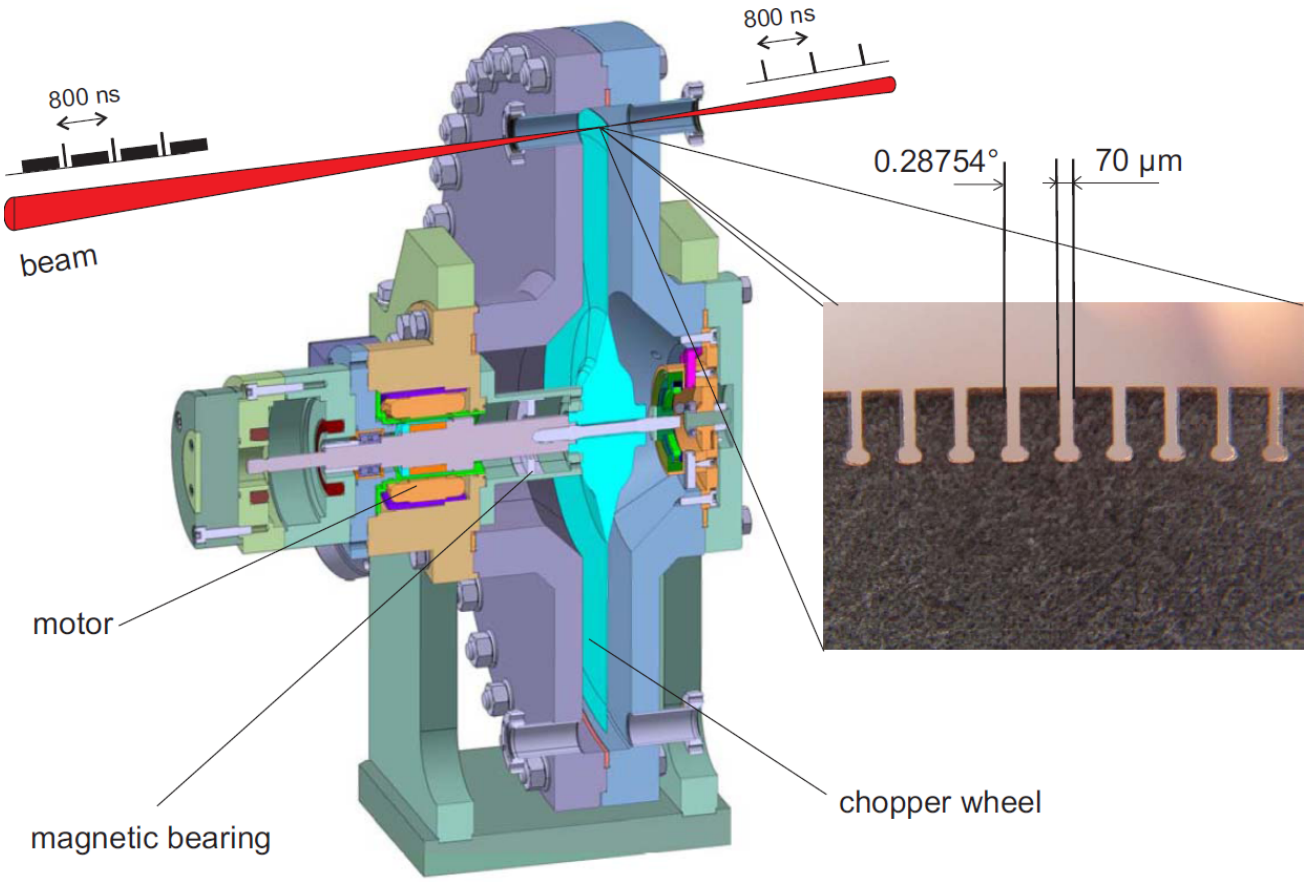


Development during POF III

BESSY-VSR

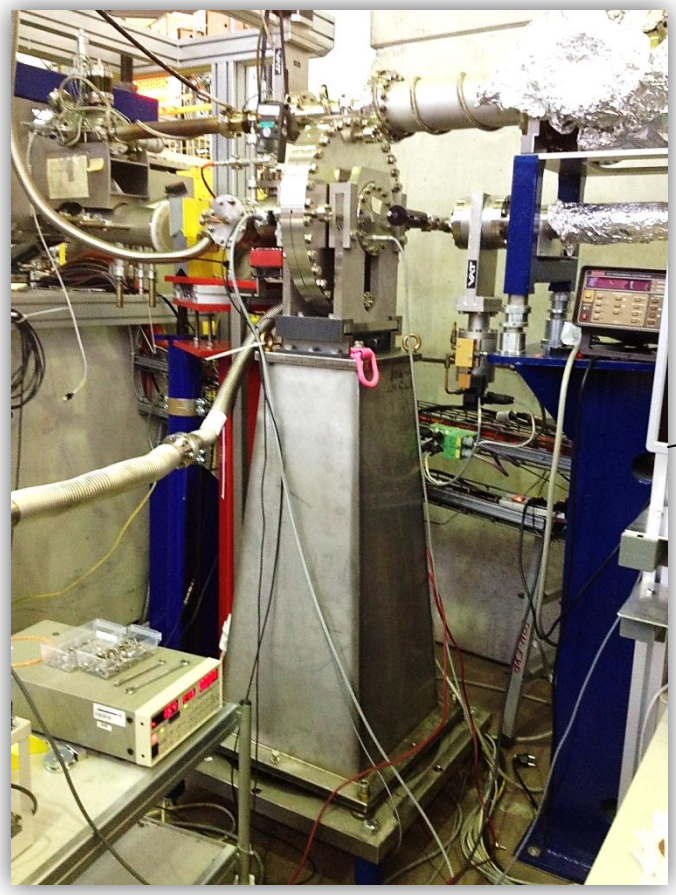
Phase locked MHz-chopper at BESSY II

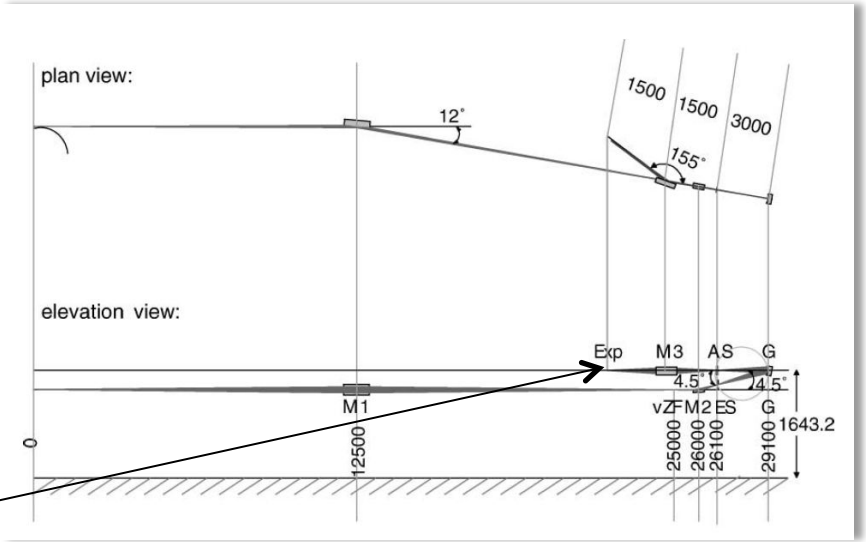
- **initiated by Prof. Kirschner (MPI) in mid 2000 years**
- **protoype built by FZJülich Abt. ZEA**
- **further developed FZJ/HZB since 2012**
- **a high-tech device !**



D. Förster, B.Lindenau, M. Leyendecker, C. Winkler, F.O. Schumann, J. Kirschner, A. Föhlisch, K.Holldack
A phase locked MHz pulse selector for X-rays (submitted)

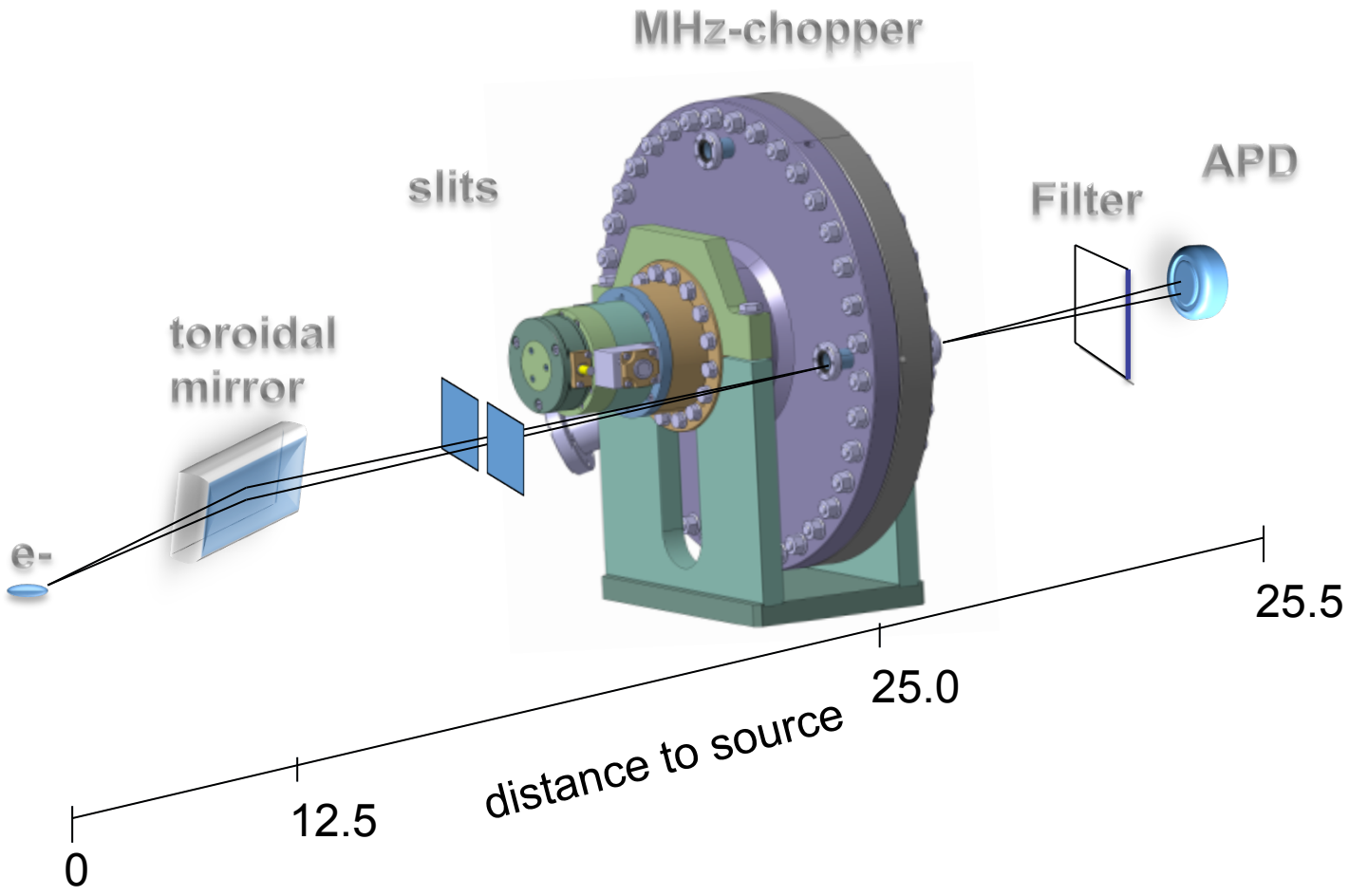
MHz-chopper at BESSY II



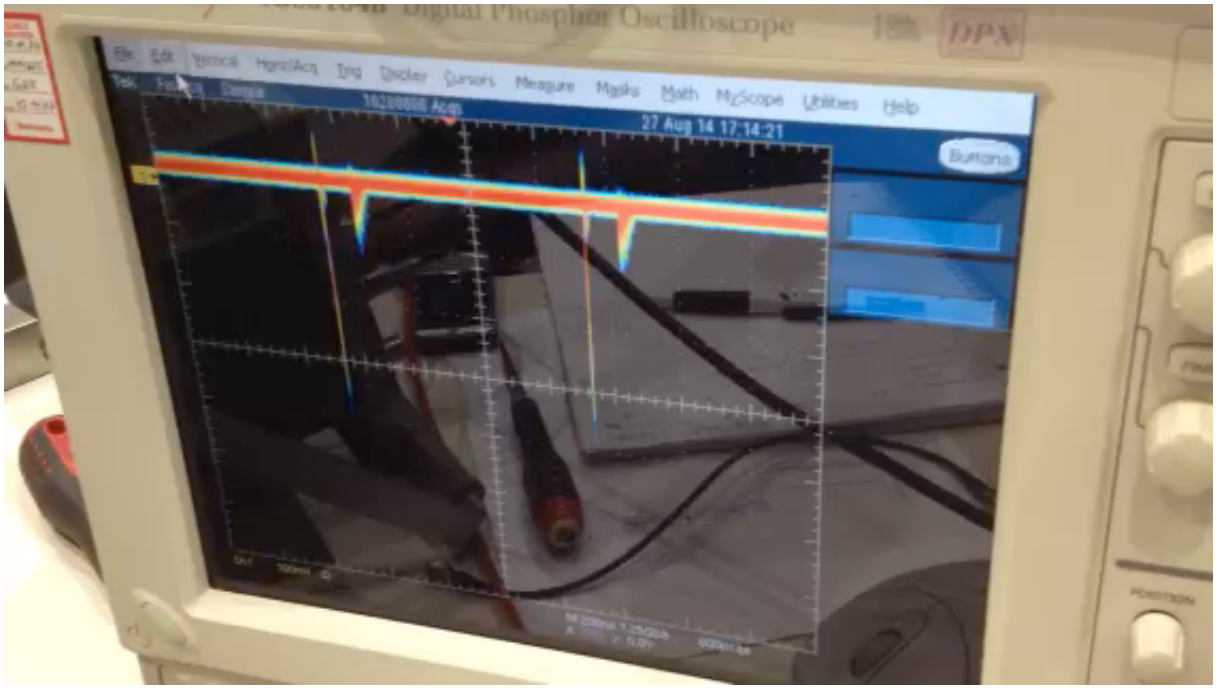


- needs small intermediate focus
- completely local
- no losses
- phase locked (with 2 ns)
- min. 70 ns time window
- 200 ns clearing gap easily supported (100 ns at smaller focus)

MHz-chopper test setup



Video: MHz-chopper while locking to single bunch

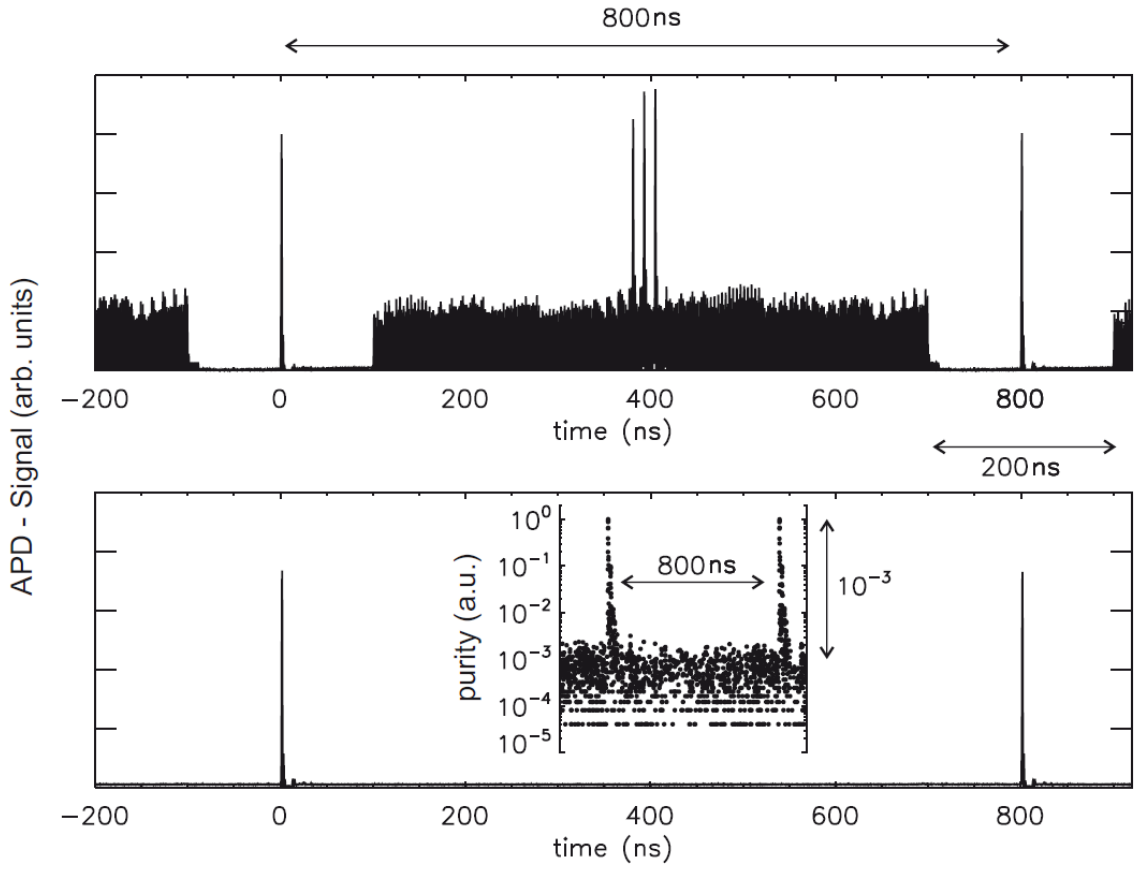


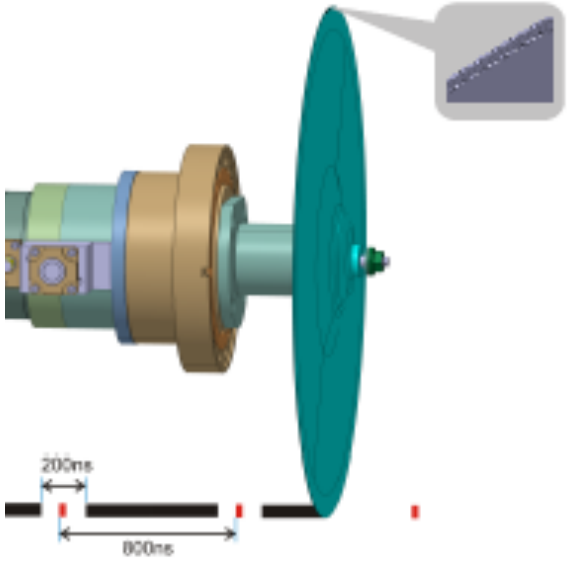
- synchronization between chopper wheel and bunches is only +/-2 ns !
- locks to the SB phase and stays there as long as required -> beamline „sees“ only SB

- Routine operation successfully started in Jan. 2015 in PM4 beamline (low dose PES)

MHz-chopper in Operation – July 2014

We confirmed a real single bunch signal from each turn with almost no losses at high purity - SB experiments now always possible in multibunch mode.





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A phase locked MHz pulse selector for X-rays (submitted)

MHz-chopper Conclusions

- new MHz-chopper performs as expected
- single bunch signal picked out from a 200 ns gap
- phase lock to (optical) revolution trigger with 2 ns stability
- new wheel installation successful -> 70 ns time window
  (together with 70 µm beamline slit: a ~150 ns opening window)
  but < 100 ns clearing gap supported if beamline slits ~20 µm
- chopper installed in user beamline (PM4), routine operation with ARTOF since Jan. 2015 started
- next choppers for other beamlines ordered in Jülich

General: We have demonstrated 2 out of 3 possible scenarios to pick out single x-ray pulses out of the SR-multi-bunch pulse train on a turn-by-turn basis

-> looking forward BESSY-VSR: very short pulses on demand

Resonant X-ray Pulse Picking (PPRE) - Data

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	Repetition rate	Pulse length (ps) FWHM	Bunch out of Multibunch train			Single bunch (SB / Hybrid / camshafts)		
			Current/ No. of e^-	Av. Flux [ph/s/ 0.1%BW]	Ph/ pulse	Current/ No. of e^-	Av. Flux [ph/s/ 0.1%BW]	Photons/ Pulse
Normal mode	1.25 MHz	30	0.5 mA/b /$2x10^9$	10^{12}	10^6	5mA/b /$2.5x10^{10}$	10^{12}	10^6
Single bunch Mode	1.25 MHz	90	0/0	0	0	20mA/b /$1x10^{11}$	$4x10^{12}$	$4x10^6$
Low Alpha Mode	1.25 MHz	7	40µA/b /$2x10^8$	$1x10^{10}$	10^4	40µA/b /$2x10^8$	$1x10^{10}$	10^4
Slicing mode	6 kHz	0.1	-	-	-	5µA/b/2.5e7	$5x10^6$	10-100
Pulse Picking Normal Mode	1.25 MHz	30	0.5mA/b /$2x10^9$	10^6-10^8	1-100	5mA/b / $2.5x10^{10}$	10^7-10^9	10-1000
Pulse Picking Low Alpha	1.25 MHz	7	40µA/b /$2x10^8$	10^5-10^7	1-10	40µA/b /$2x10^8$	10^5-10^7	1-10

Supplemental: MHZ chopper controls and synchronization