PF Single-bunch Workshop
November 7-8, 2008

watching photo-induced dynamics with picosecond x-ray

Photon Factory, KEK
ERATO Non-Equilibrium Dynamics Project, JST

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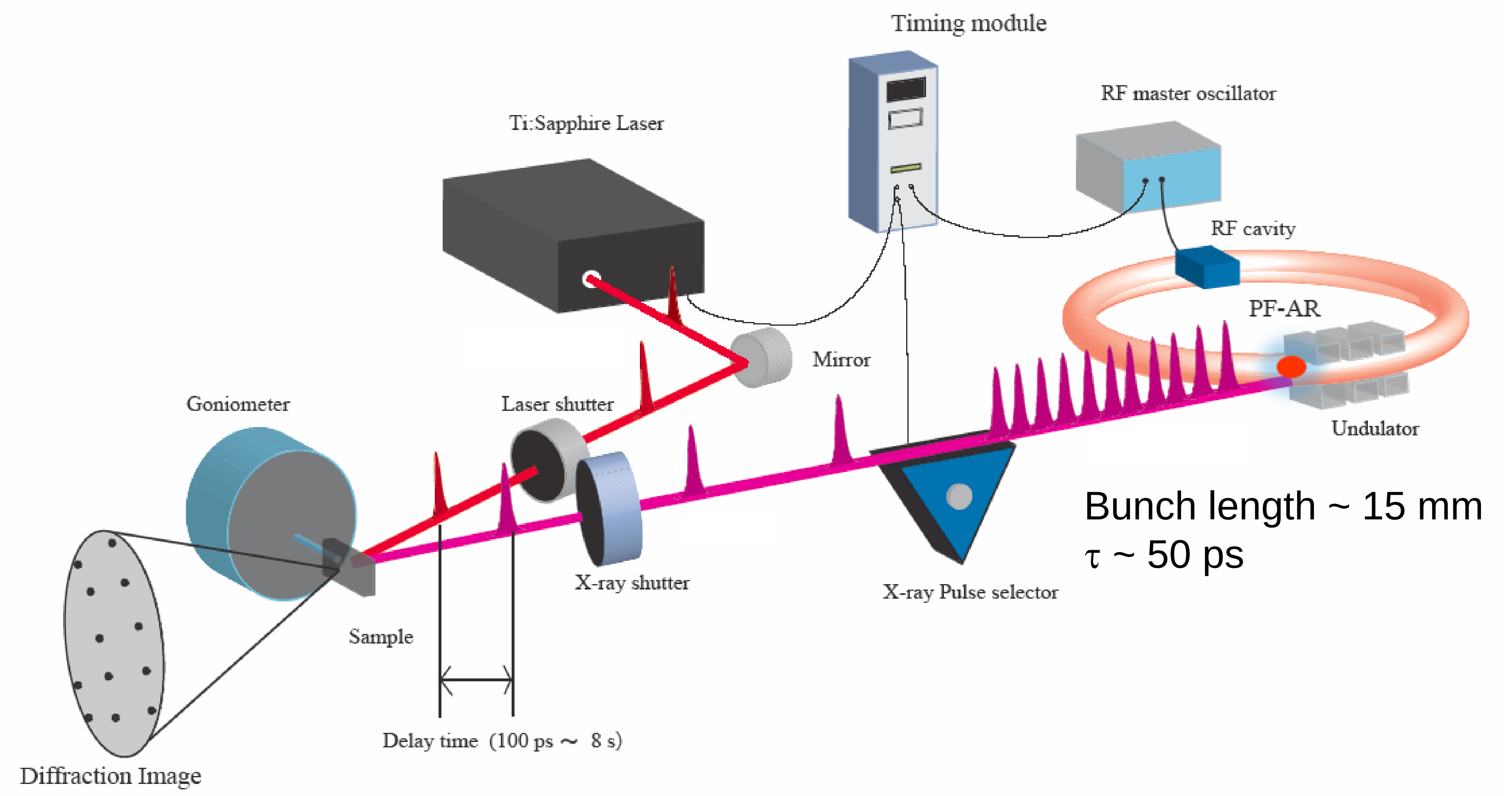
JST Non-Equilibrium Dynamics Project ERATO

utilizing pulsed nature of the synchrotron radiation for structural dynamics studies



Bunch length ~ 15 mm
$\tau \sim 50$ ps

picosecond time-resolved x-ray techniques - basic concept

synchrotron radiation x-rays:

structural studies at atomic resolution

diffraction, XAFS, scattering, etc

×

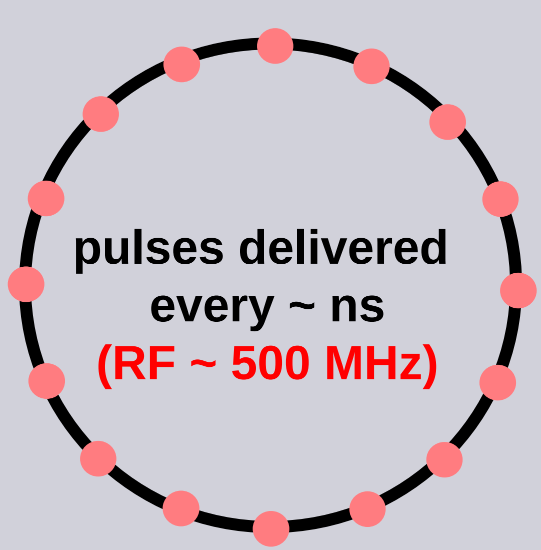
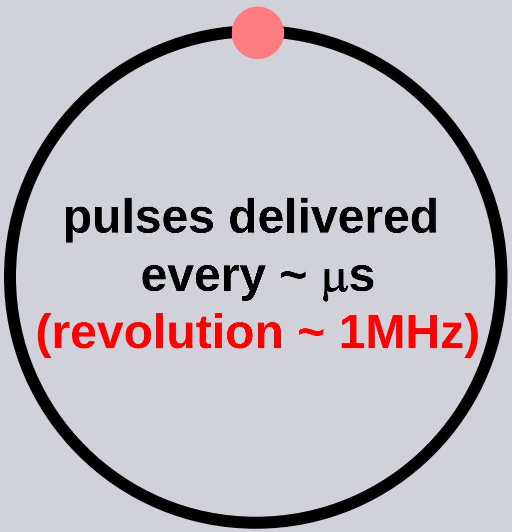
pulsed nature of SR:

time resolution ~100ps

=

structural dynamics at atomic and~100ps resolution

pump-probe x-ray diffraction
multi- *vs.* few-bunch mode

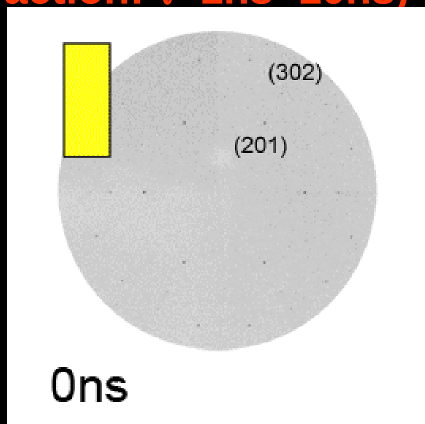
	Multi-bunch	Few-bunch
bunch filling example		
merit	High ring current Long life time	Time-resolve available
demerit	Not easy to use for TR applications	Low ring current Short life time

few-bunch modes for pump-probe experiments at SR facilities

	PF-AR (Tsukuba)	ESRF (Grenoble)	APS (Chicago)	SPring-8 (Hyogo)
Ring energy	6.5 GeV	6.0 GeV	7.0 GeV	8.0 GeV
Pump-probe mode/year	~4000 hours (100% single bunch)	~1700 hours (~30% 4-, 16-bunch, hybrid mode)	~800 hours (hybrid mode)	~1000 hours (~20%, D-mode)
Max. current/bunch charge/bunch	60 mA 76 nC	16 mA 40 nC	60 / 16 nC	3 mA 14 nC
Bunch duration (RMS)	62 ps	73 ps	65 / 40 ps	20 ps
Beam life time	20 h	6 h (s.b.)	∞ (top-up)	∞ (top-up)
Horizontal emittance	290 nmrad	4 nmrad	3 nmrad	3 nmrad

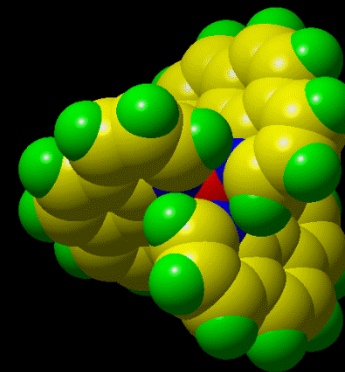
picosecond time-resolved x-ray applications

Laser shock-induced lattice deformation of CdS single crystal (TR single-shot Laue diffraction: τ~1ns~10ns)



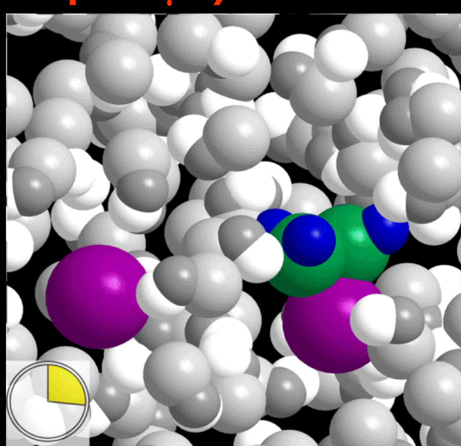
Ichiyanagi et al. (2007) APL, 91, 231918.

Photo-induced spin-crossover transition of metal complex in solution (TR-XAFS: τ ~700ps)

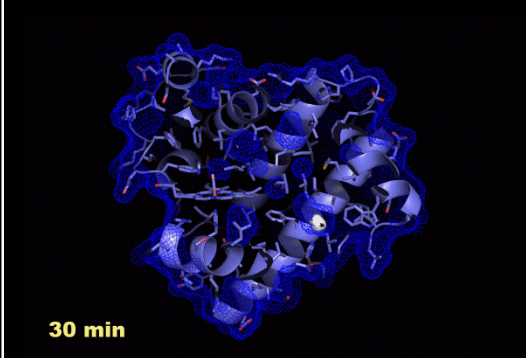


Sato et al. (2008) JSR, in press

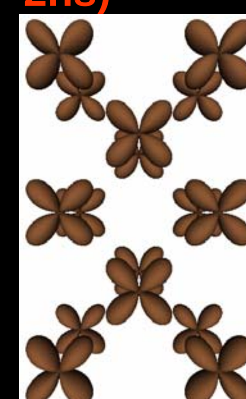
Photochemical reaction in liquid (TR-liquid scattering: τ~100ps~1μs)

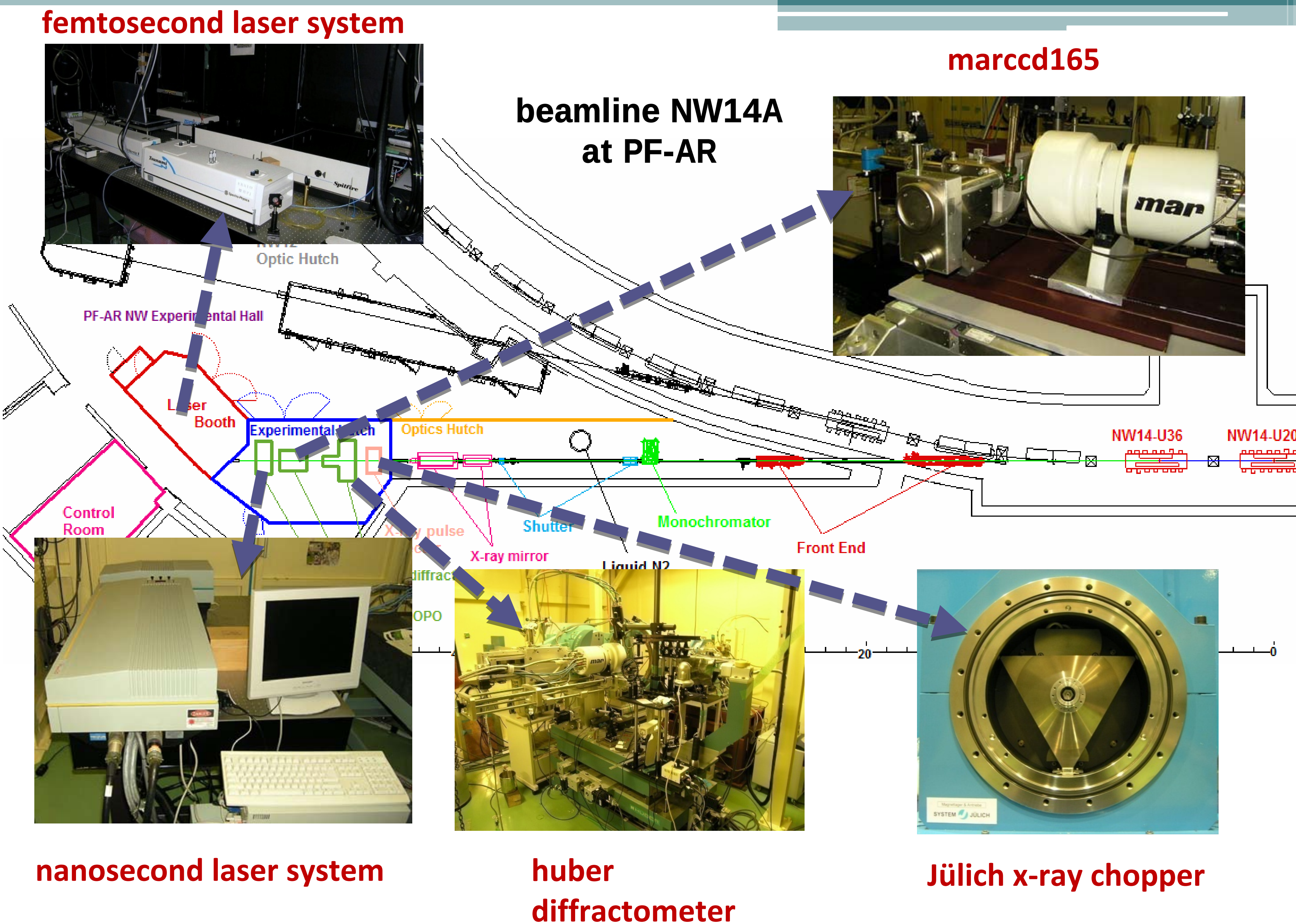


Ligand migration dynamics in protein crystal (τ~800 min)

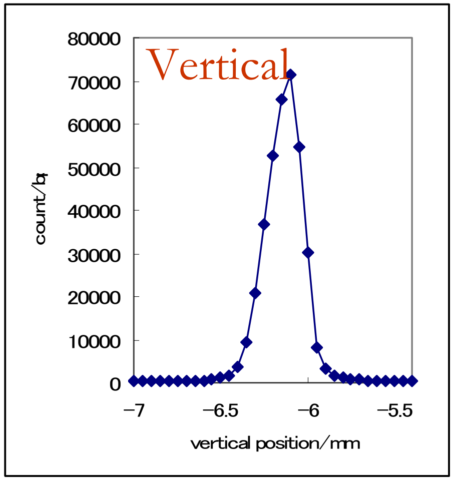


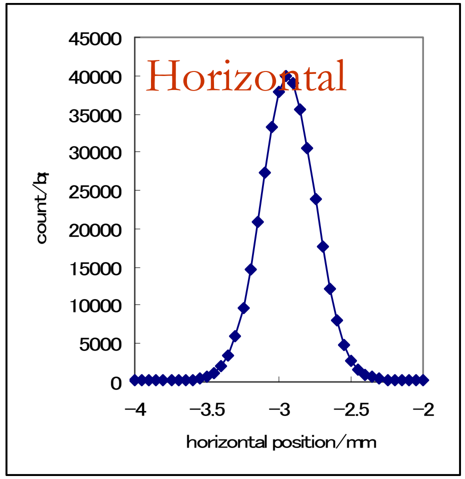
Insulator-to-metal phase transition in perovskite manganite thin film (τ~ 50ps ~ 2ns)




femtosecond laser system
beamline NW14A
at PF-AR
marccd165
Optic Hutch
Control
Room
Optics Hutch
X-ray mirror
Shutter
Monochromator
Front End
NW14-U36
NW14-U20
OPO
20
0
nanosecond laser system
huber
diffractometer
Jülich x-ray chopper

x-ray features – two undulators





Focused beam size at the sample position

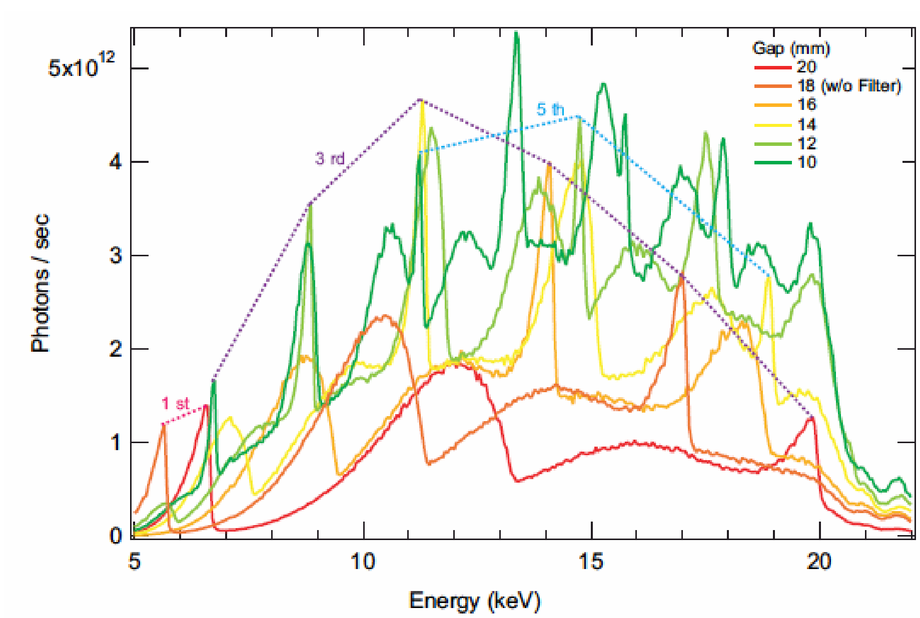
Vertical: 241 μm (FWHM)

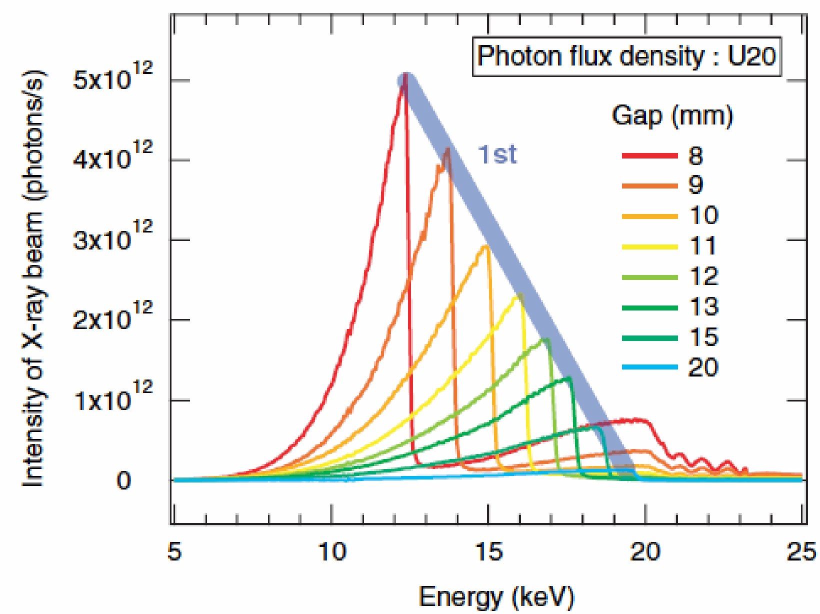
Horizontal: 437 μm (FWHM)

（source divergence: 0.32 x 0.05 mrad）

（focusing ratio: 4.53:1）

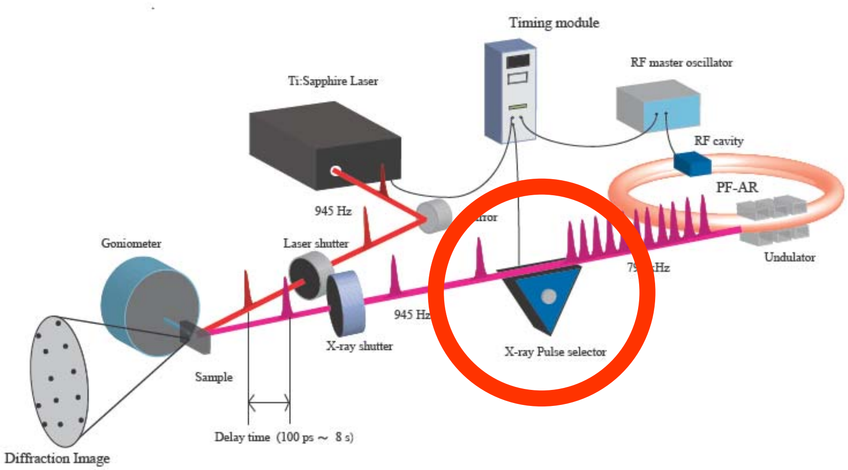
Photon Flux Spectra of U36 (left) and U20 (right)

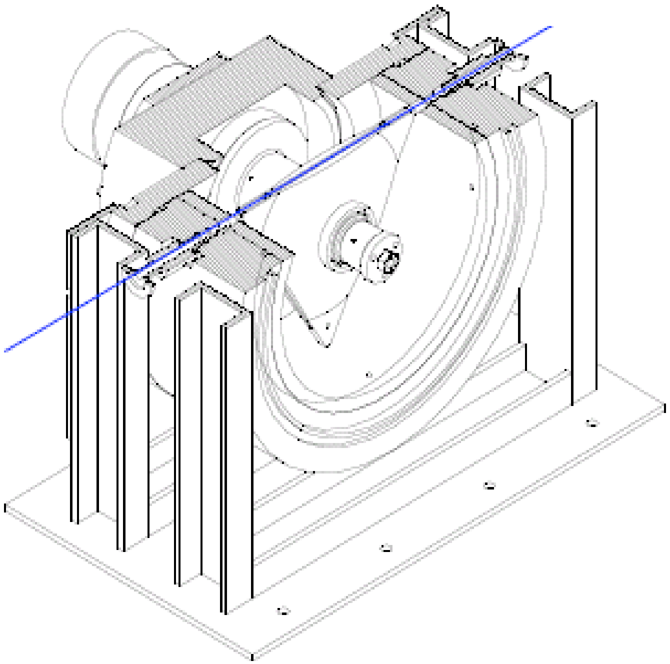


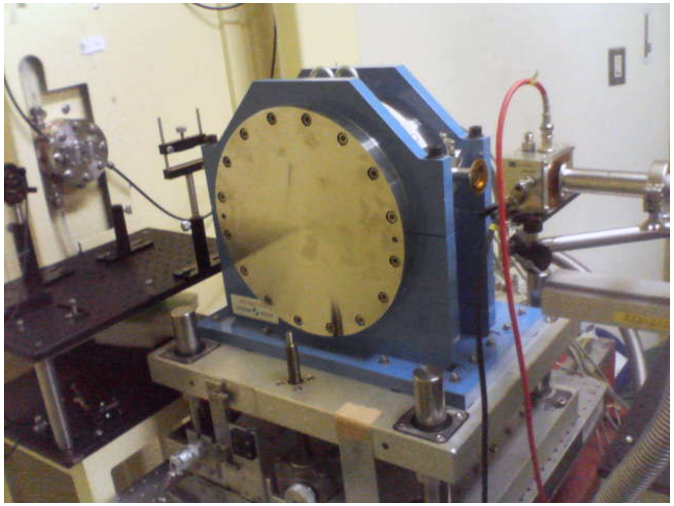


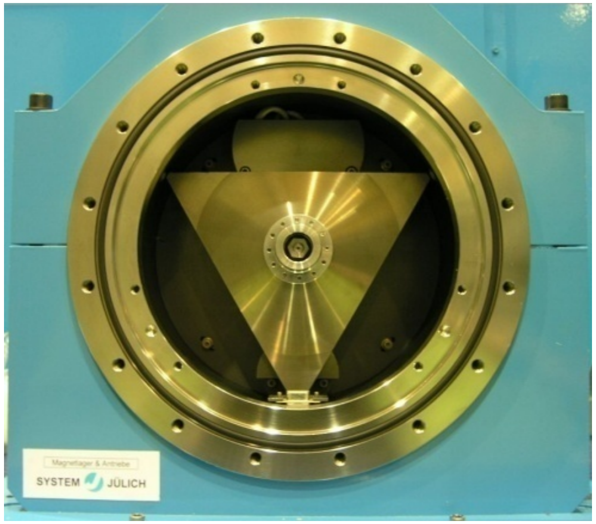
x-ray chopper

opens ~1μs every ~1ms



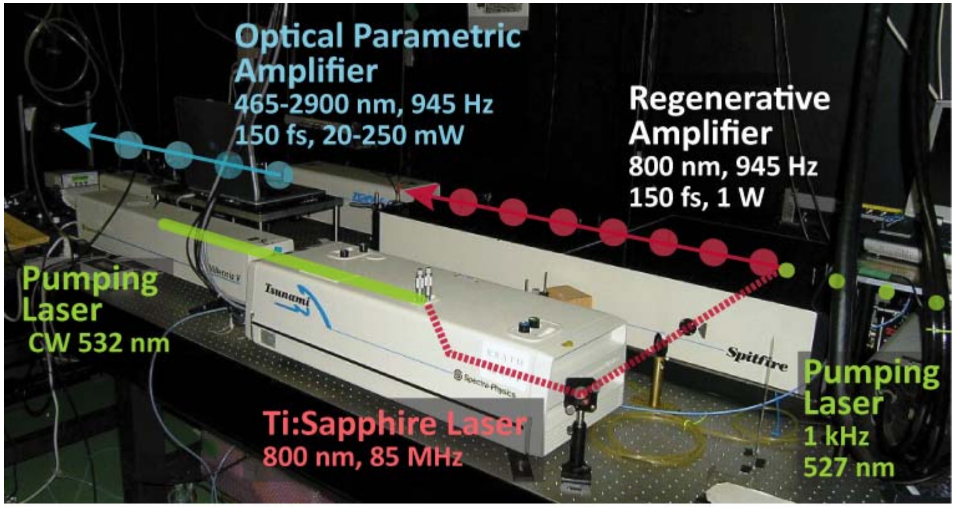






lasers

Femtosecond: Ti:Sapphire



<u>Femtosecond-laser system</u>

Millenia, Tsunami, Spitfire, Evolution
(Spectra Physics)
800nm, 1 kHz, 150fs, 1W

<u>OPA</u>

TOPAS-C
(Light Conversion)
465-2900nm, 945Hz, 150fs, 20-250mW

Nanosecond: Nd:YAG

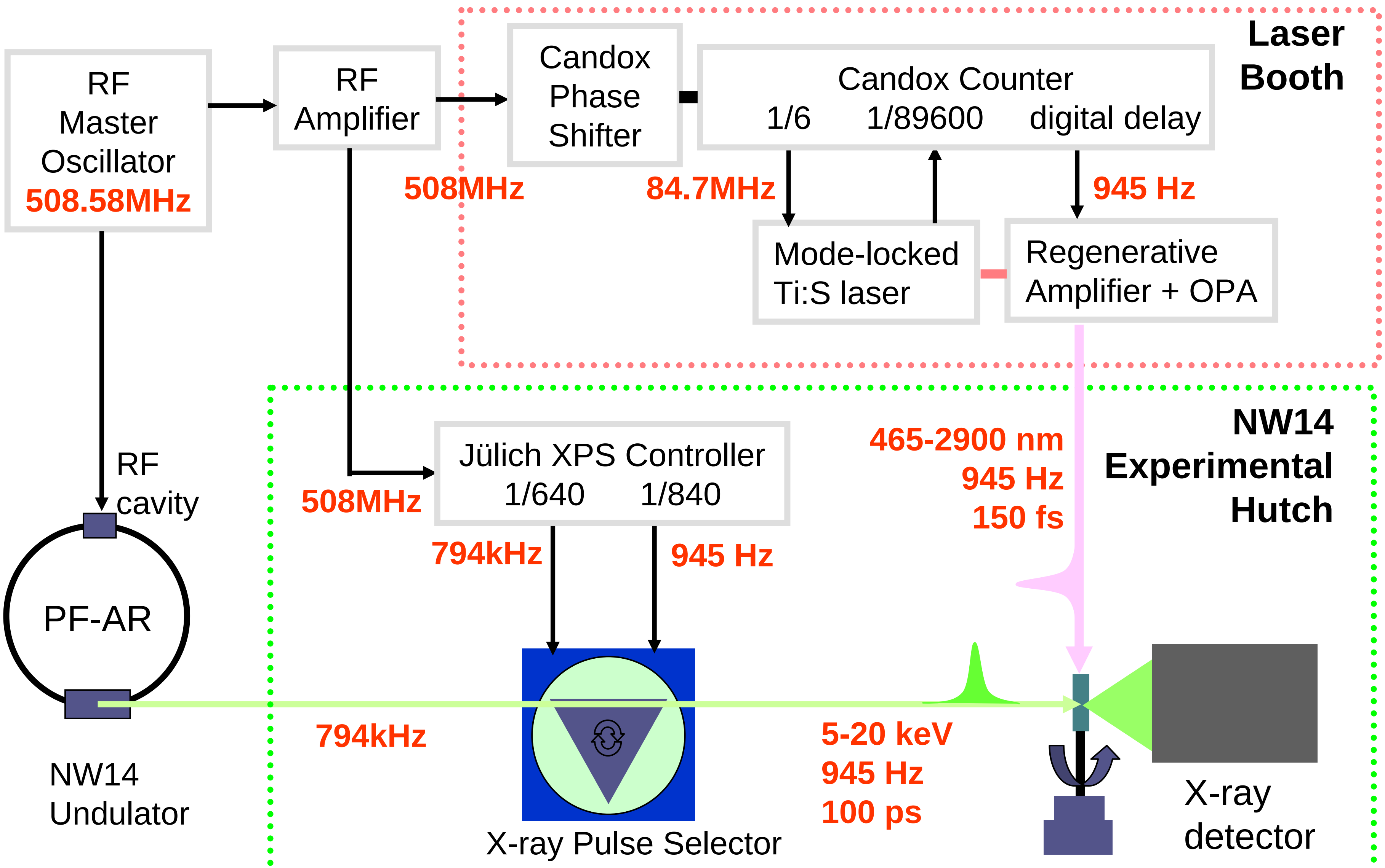
<u>Nanosecond-laser system</u>

Powerlite 8000 [Q-switched Nd:YAG]
(Continuum)
1064,532,355,266nm, 10Hz, 10ns, 10-1W

<u>OPO</u>

PANTHER OPO (Continuum)
220-2700nm, 10Hz, 10ns, 20-900mW

synchronizing scheme



conclusions & future prospects

- **Pump-probe method with synchrotron radiation enables us to explore dynamics of materials at atomic spatial resolution and picosecond time resolution.**
- **This technique adds another dimension (time) to most of SR applications like X-ray diffraction, scattering, absorption and imaging.**