Achieve the Time-resolved Experiments Using Pulsed X-ray Source Based on Synchrotron Radiation

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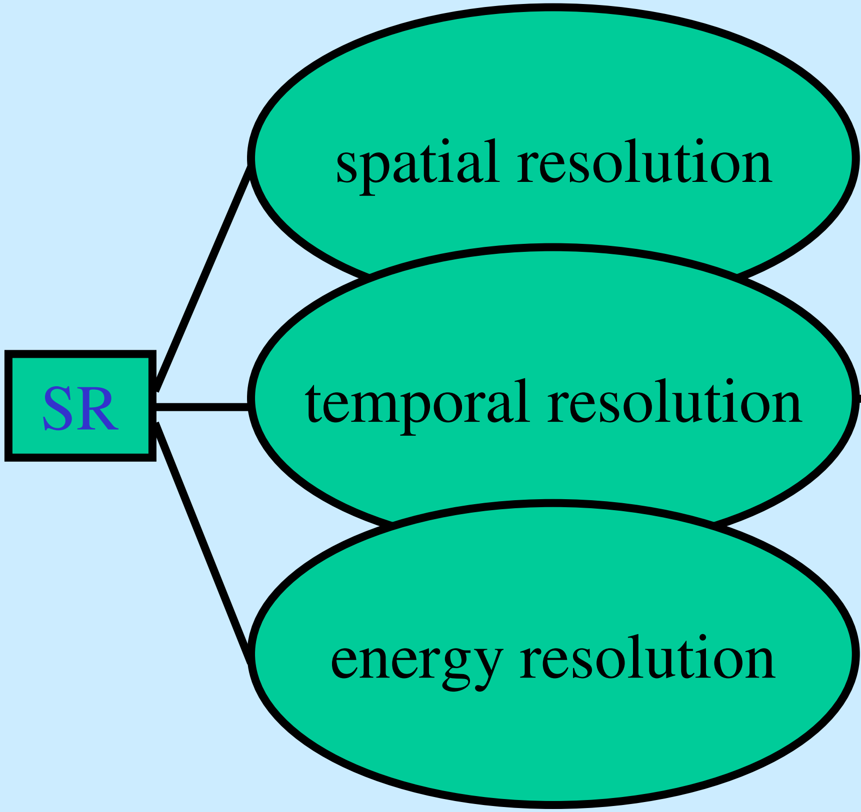
Outline

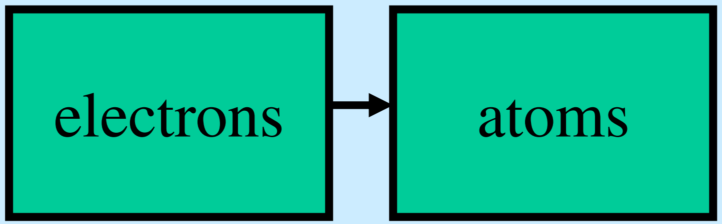
- Timing system for synchrotron radiation
- Generation of pulsed X-rays
- Time-resolved VUV spectroscopy at BSRF
- Laser pump-X-ray probe XAFS experiment
- Some concerns for pump probe experiments

Why time-resolved experiment



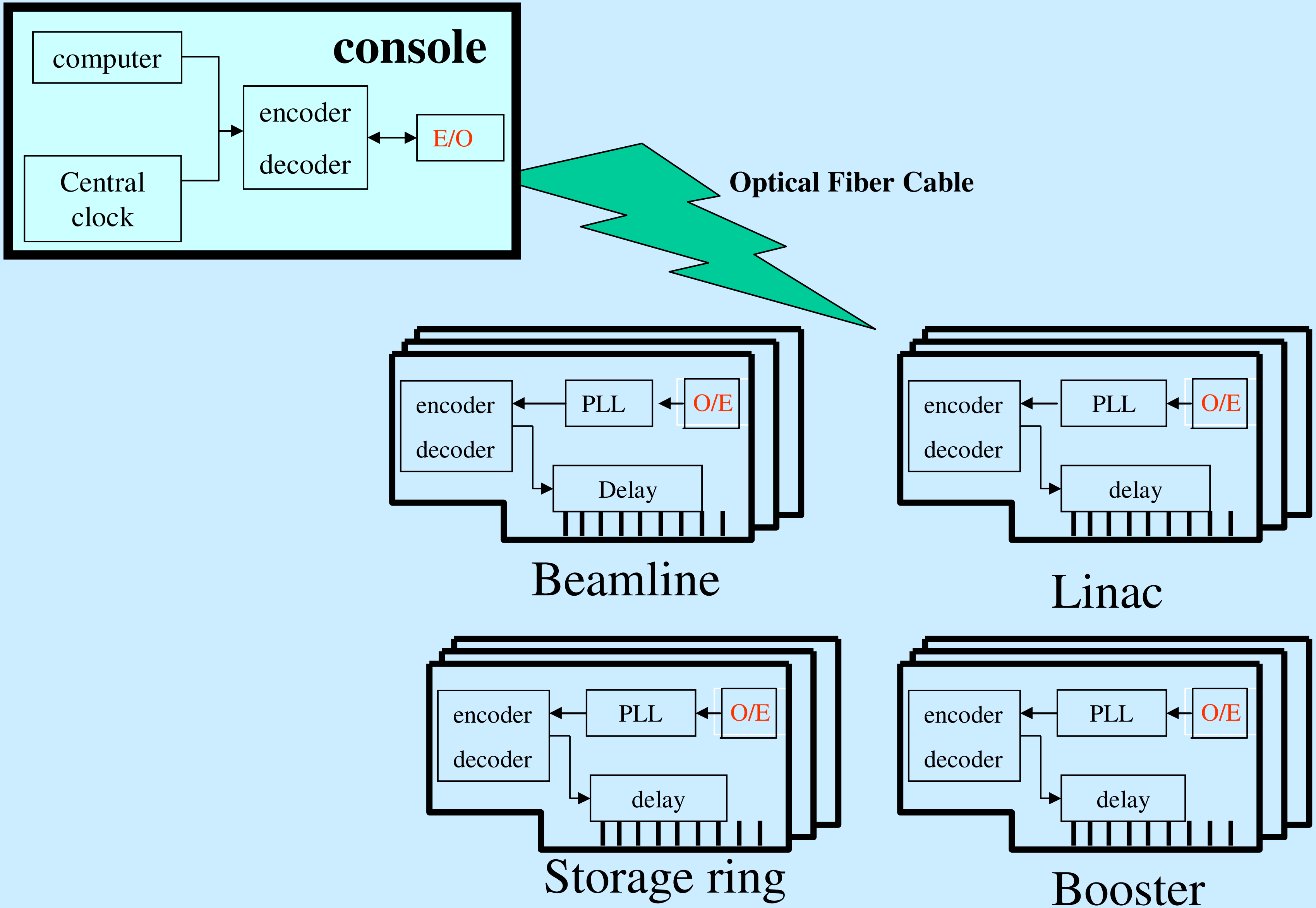
fast scan, fast data acquisition, pump-probe technique

- electronic lifetime spectra of excited states, metastable state
- ultrafast chemical reactions
- ultrafast phase transitions
- surface dynamics
- ultrafast biological processes



visible-ultraviolet-X-ray

Timing system in synchrotron radiation



Control of timing system

Timing system

linac accelerator:
Injection sequence
gun trigger
Klystron
Kicker

Beamline:
data collection
triggering

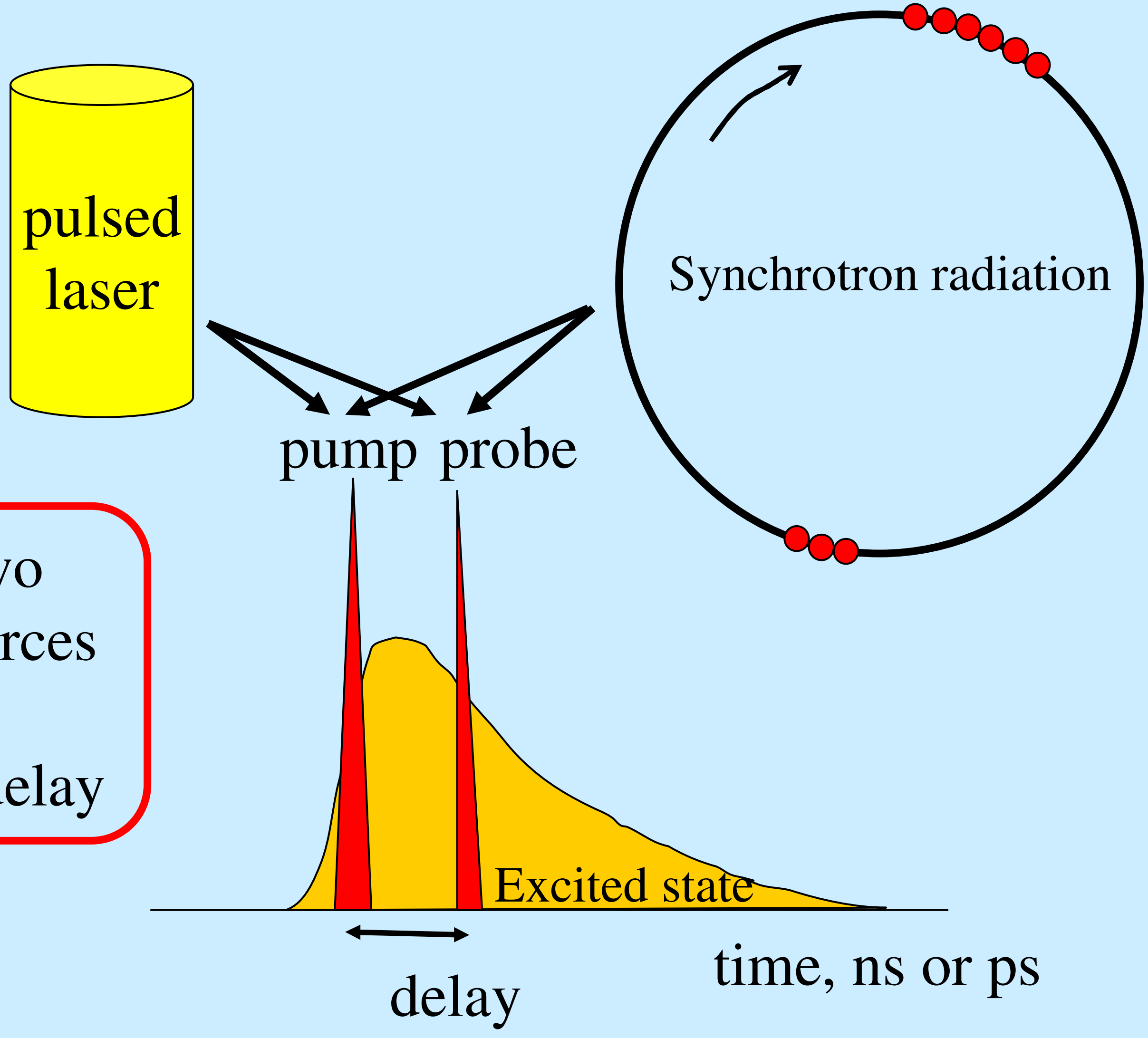
Booster:
injection sequence

storage ring:
injection sequence
pluse Magnet

beam diagnostics：
triggering

- **high precision**
- **low noise**
- **tune capability of delay**

Pulsed light source in time-resolved experiment



synchronize two independent sources

control of time delay

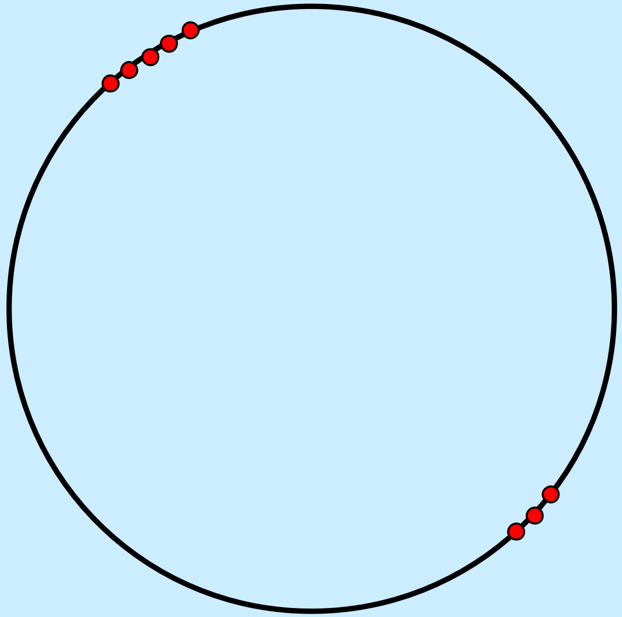
Fill mode at storage ring

BSRF

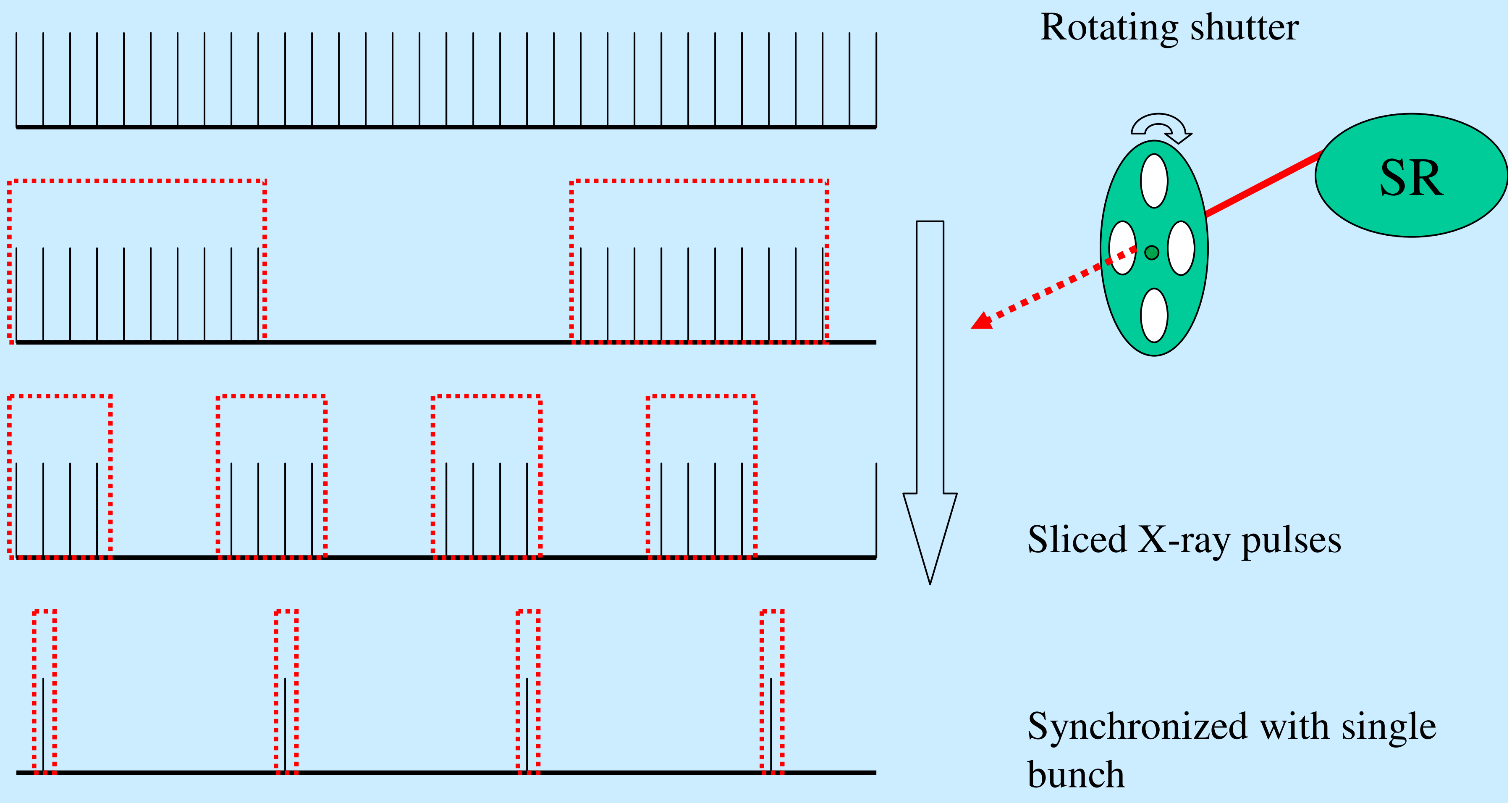
- RF 200MHz (500MHz for BEPCII)
- Multi-bunch fill : 100 bunches, 160-260ps in width (50ps for BEPCII)
- Single-bunch fill: period 800ns, 160ps in width

APS

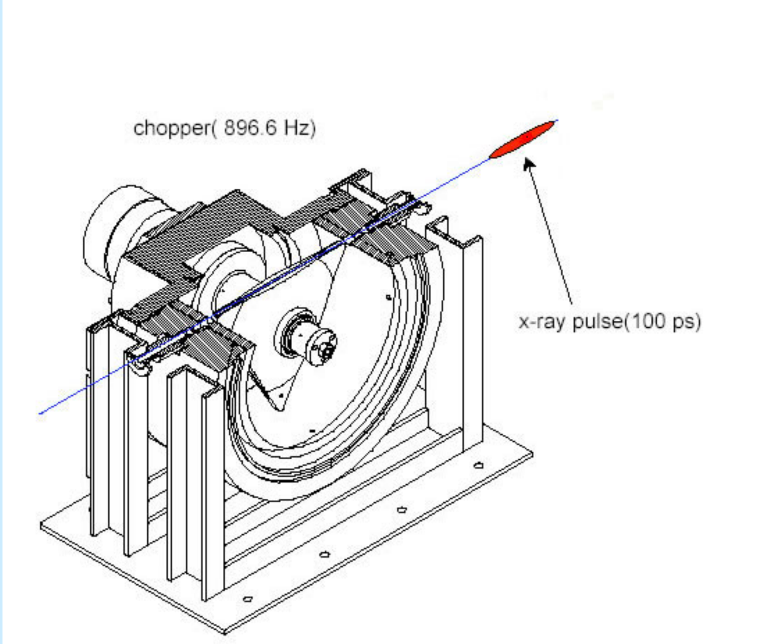
- RF 352MHz
- Rountine: non-Top up operation 23 singlets
- Rountine: Top up operation 23 singlets, continuous top-up with refill
- Special operating mode (SOM)
  - hybrid fill 1+8×7
  - hybrid fill 3+8×7

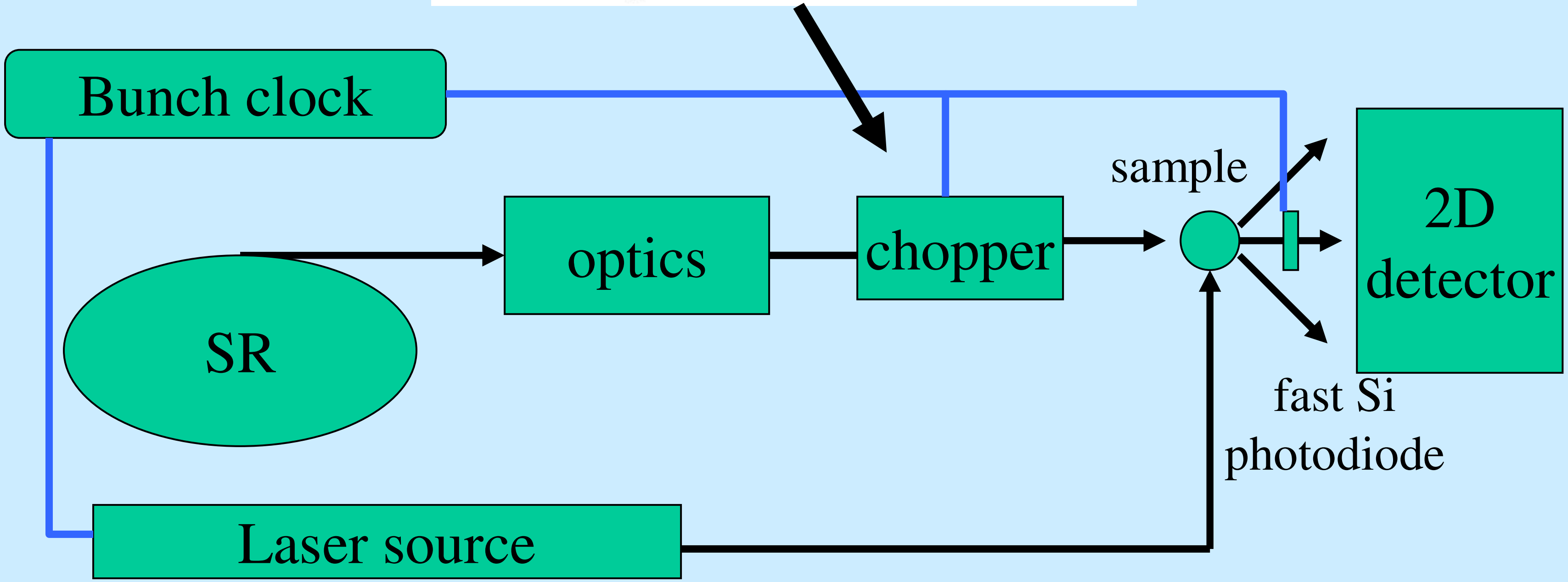


Synchrotron radiation : pulsed X-ray source



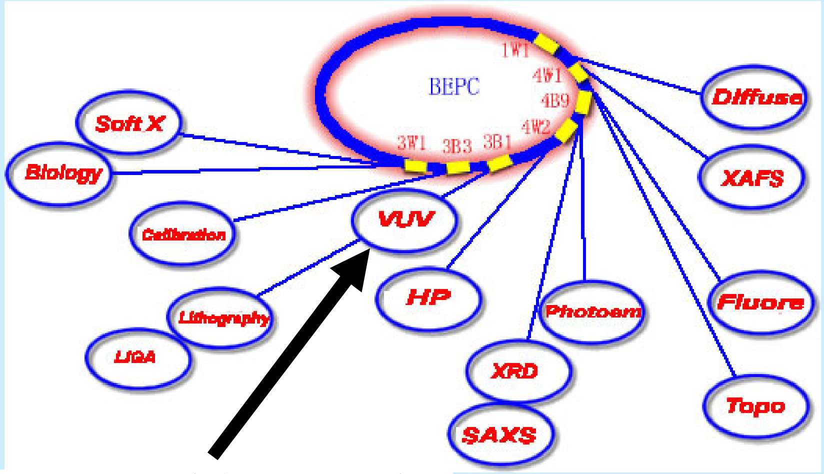
Mechanic shutter

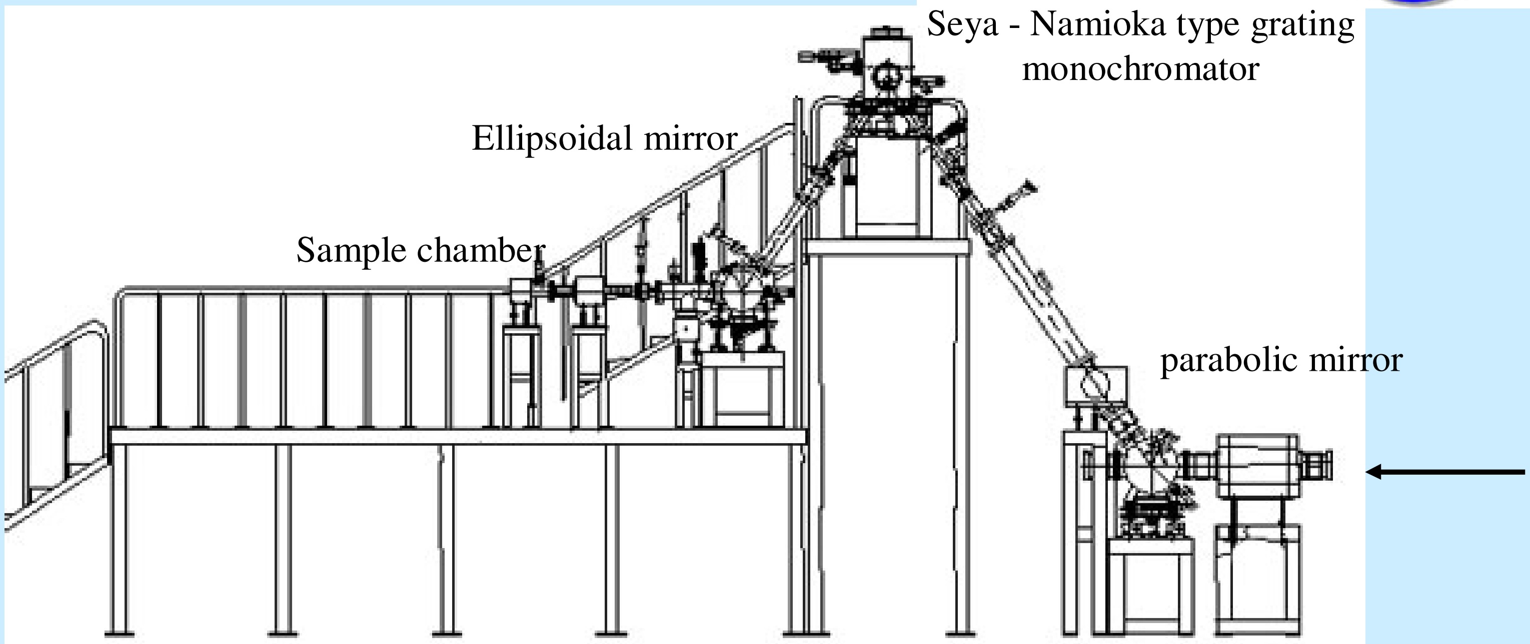




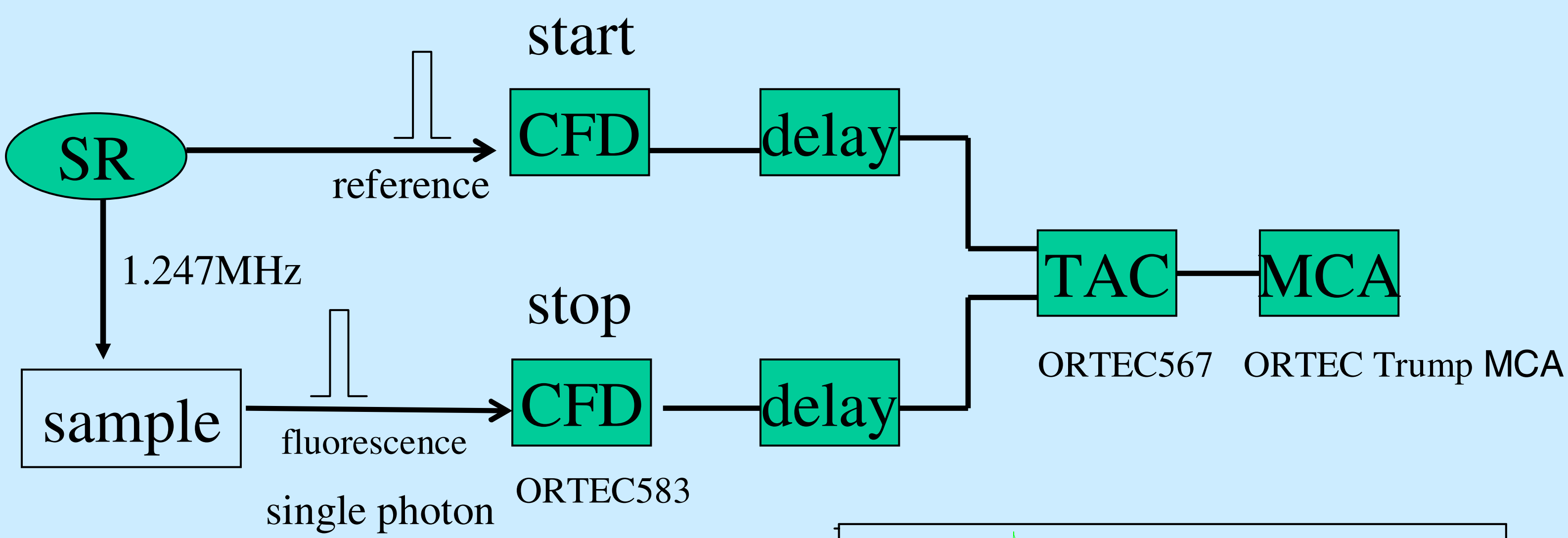
Single photon timed-resolved spectroscopy at beamline 3B1B, BSRF

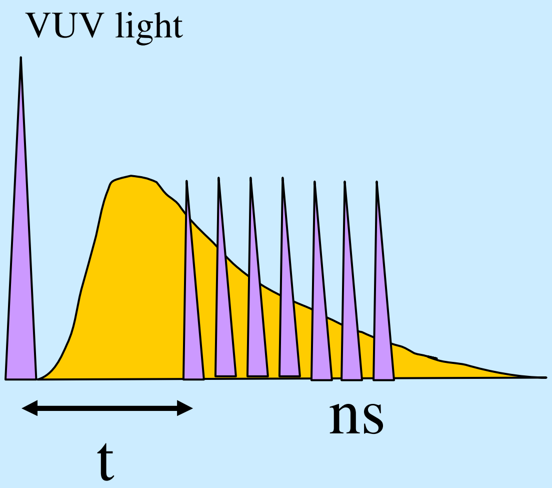
Wavelength Range:	100 nm - 550 nm
Resolution:	10^{-3}
Photon flux:	10^{9} photons/sec
Beam size:	3 mm (H)*1 mm (V)

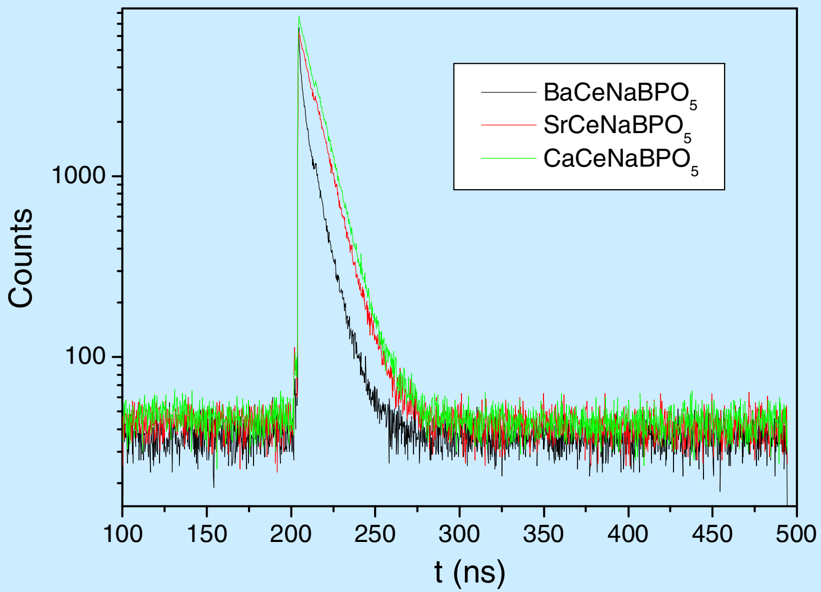




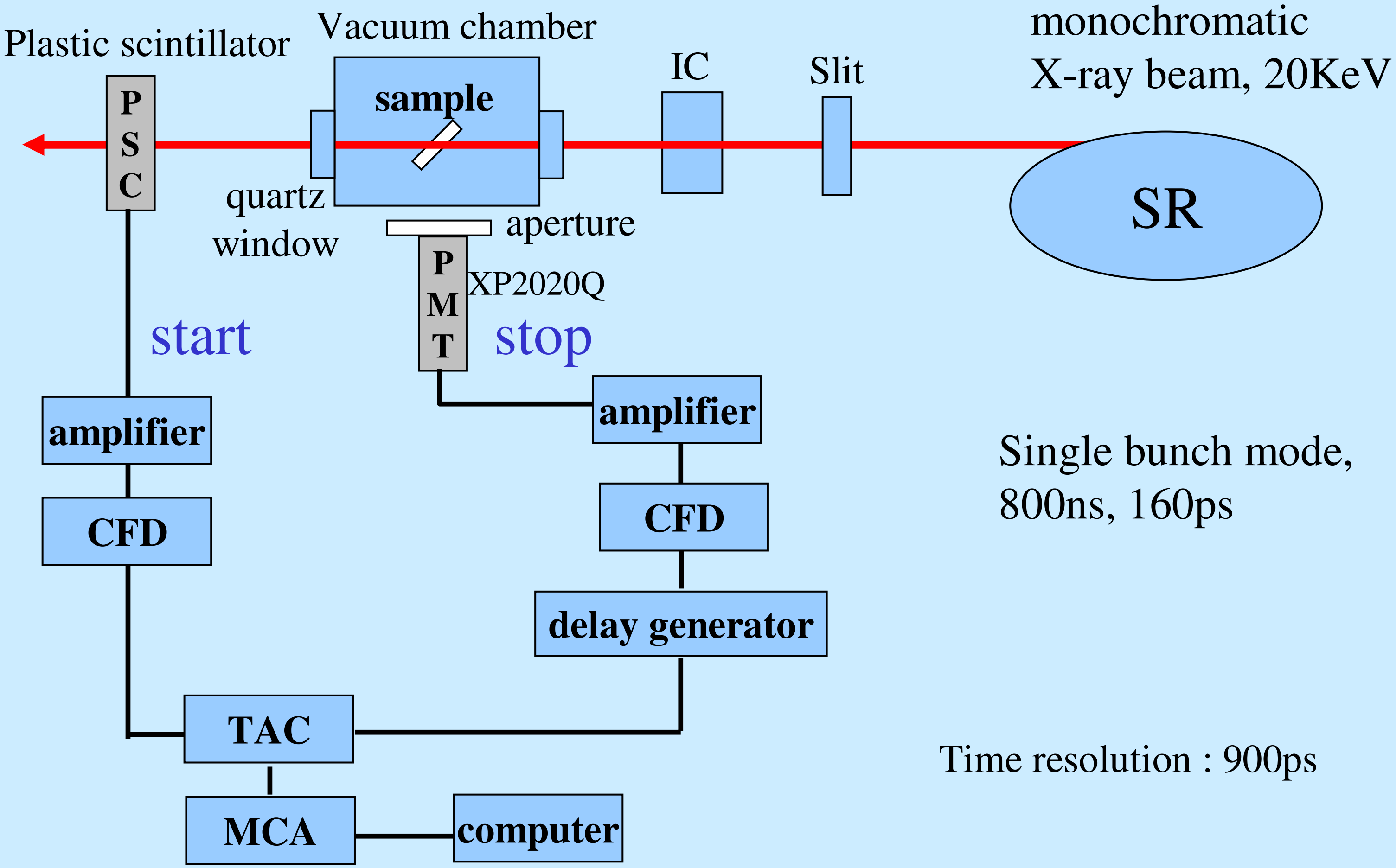
Time correlated single photon counting







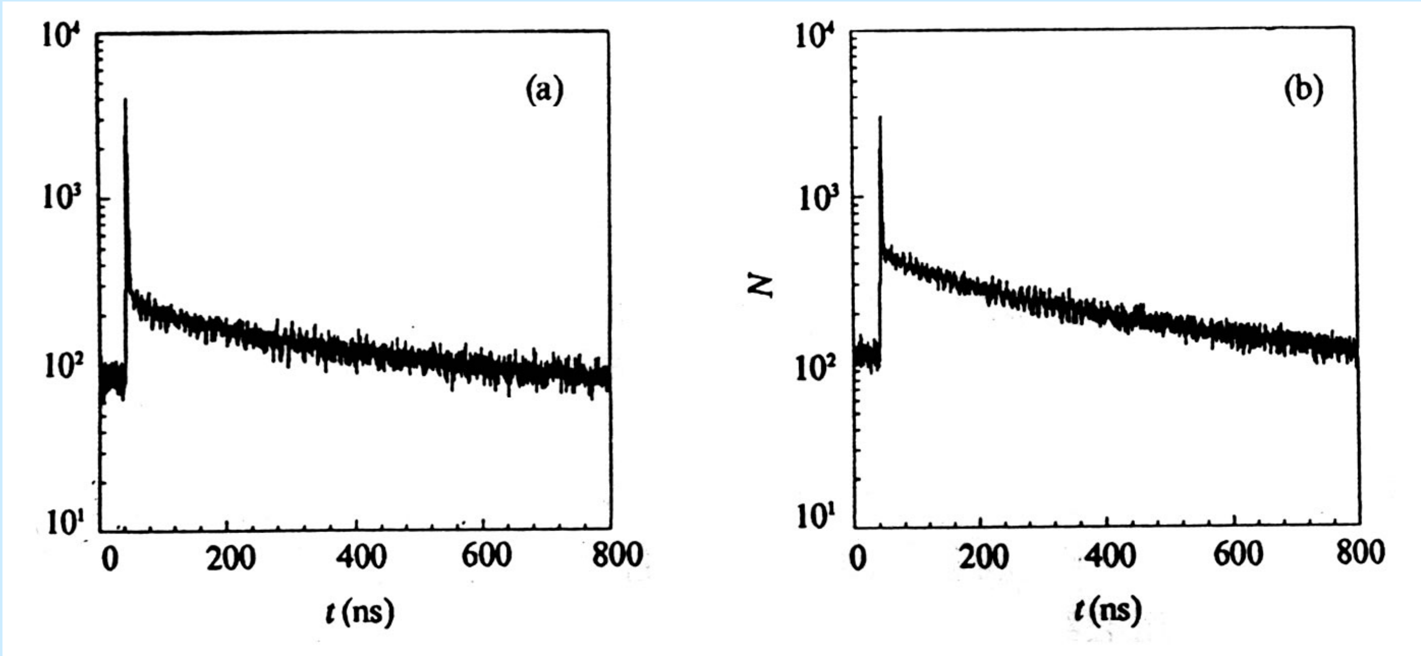
A time-resolved experiment performed at beamline, 4W1B

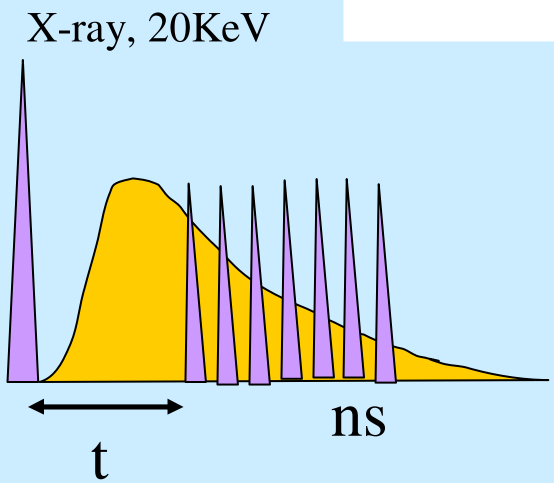


Single bunch mode,
800ns, 160ps

Time resolution : 900ps

Fluorescence lifetime spectra of BaF_2 crystal dopped with Ce^{3+}

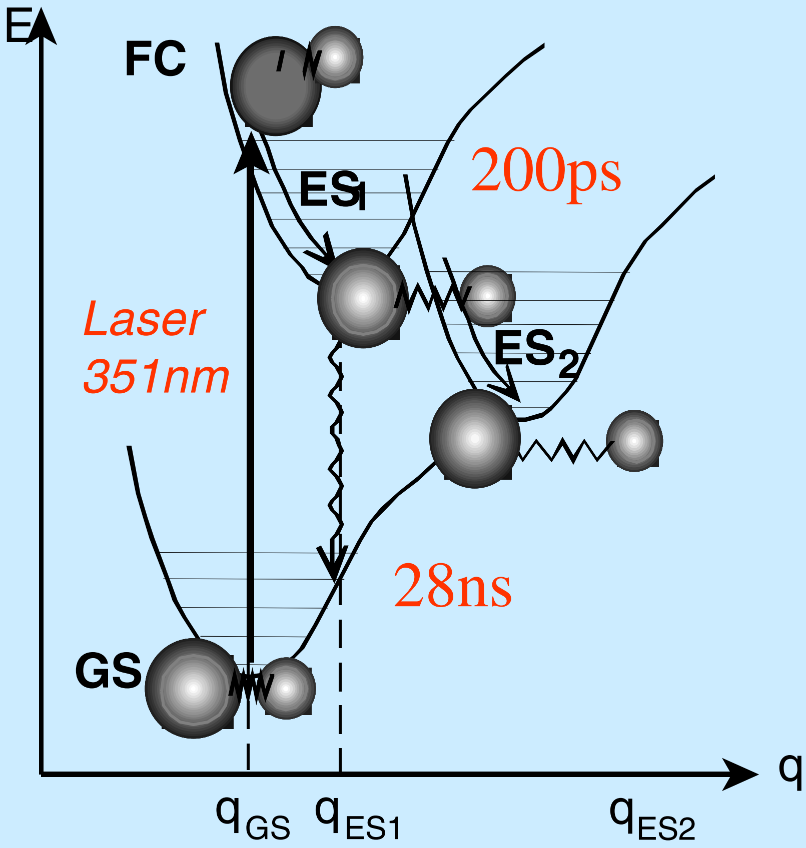


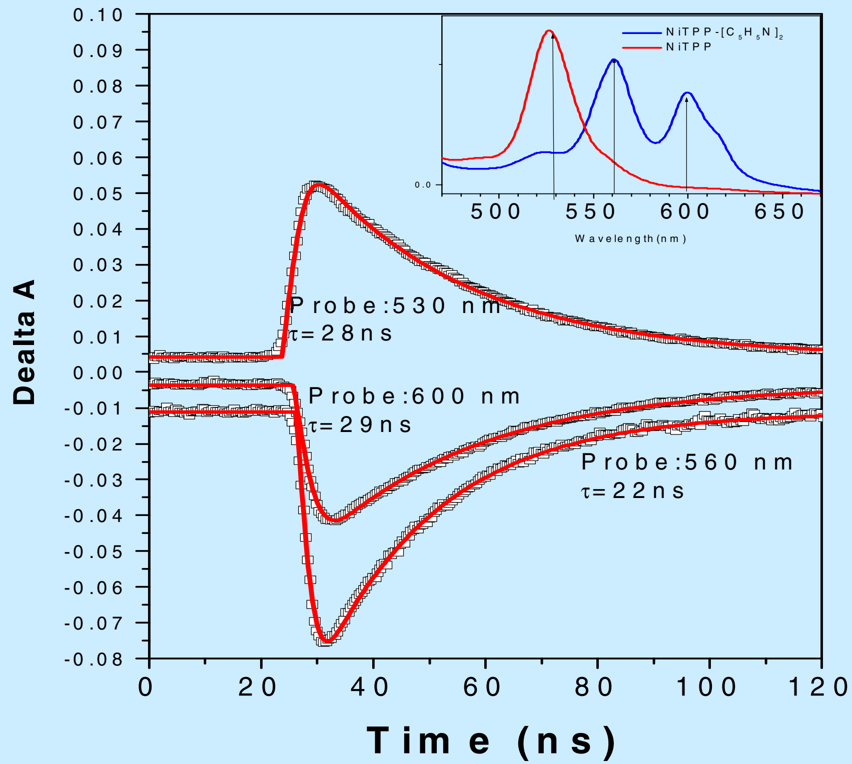


(a) 0.56mol%, (b) 1.64mol%

Jiang Haiyin, et al. High Energy Physics and Nuclear Physics, 20, 1996, 1103

Probe the excited state induced by light in molecules

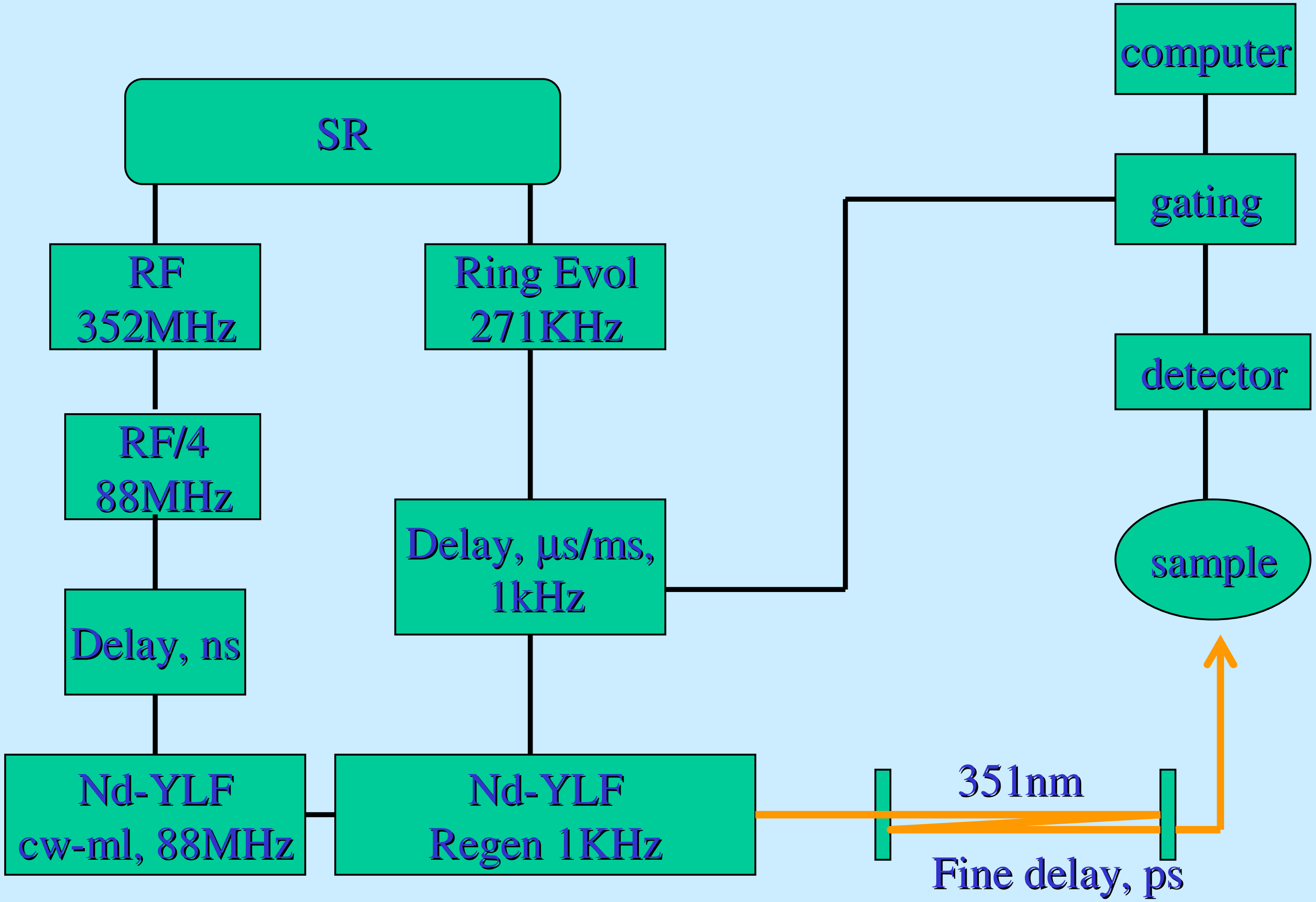




Time evolution of optical absorption change monitored at characteristic wavelengths for unchelated (530nm) and bi-axial chelated (560 and 600 nm) NiTPP in piperdine solution using 351 nm pulse as the pump and a xenon lamp as the probe.

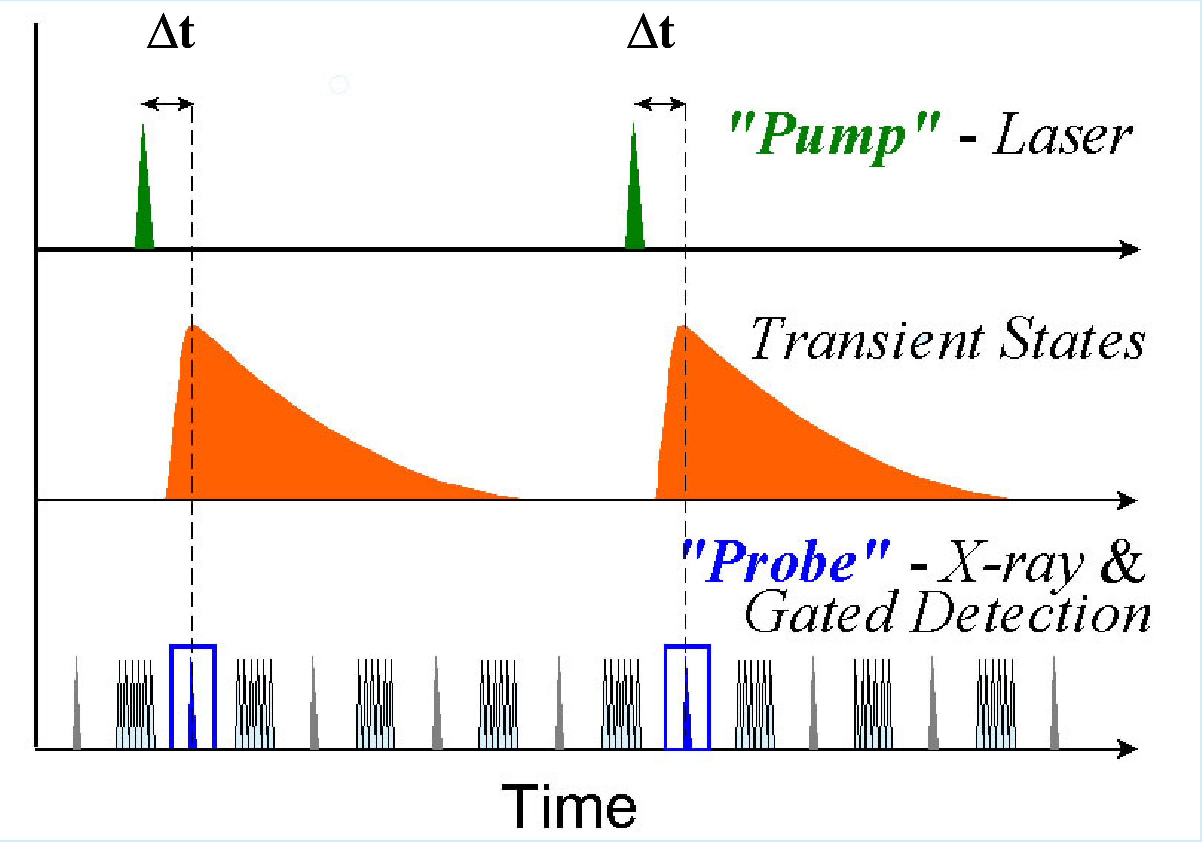
Timing-system for laser pump and X-ray probe XAFS at APS

ID11D, BESSRC-CAT



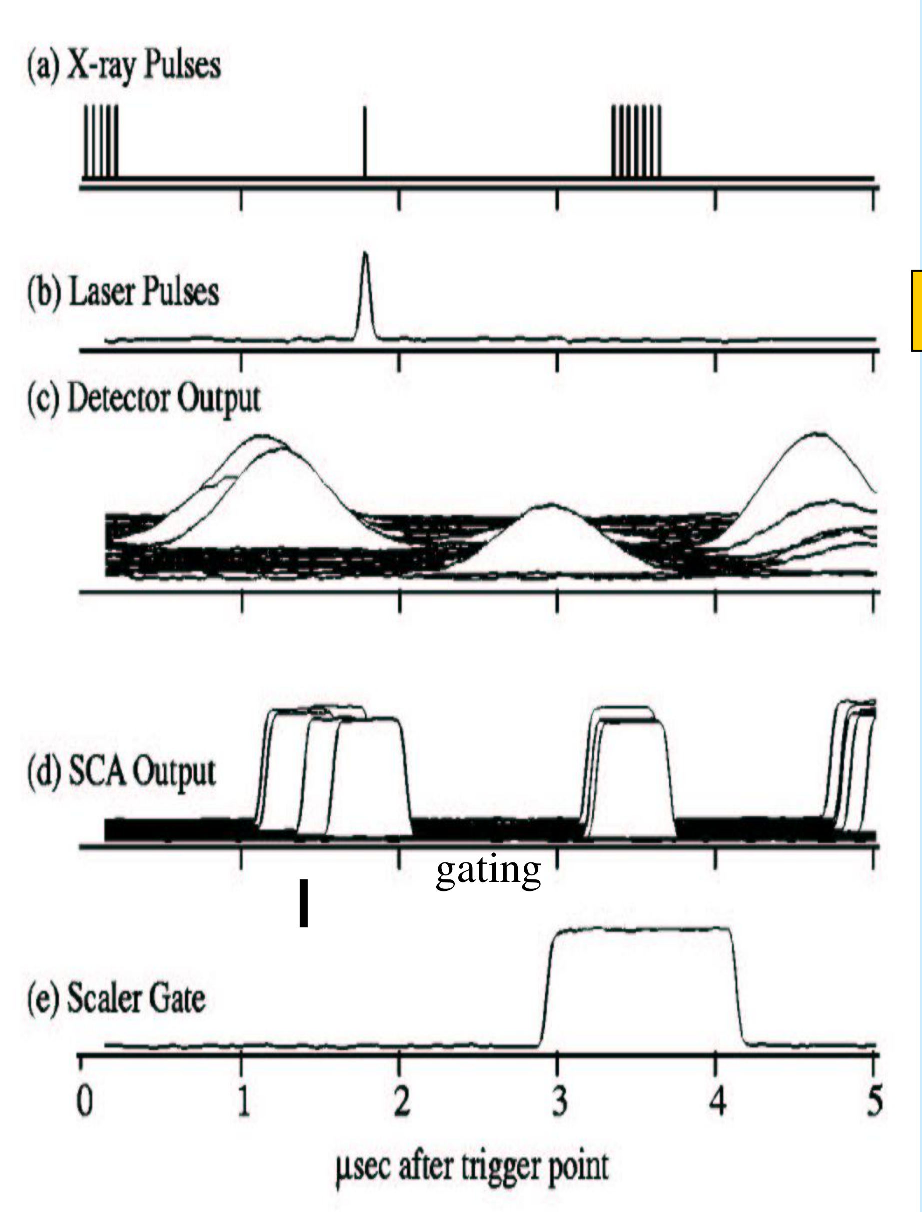
Guy Jennings, et al. Rev. Sci. Inst. 73, 2002, 362

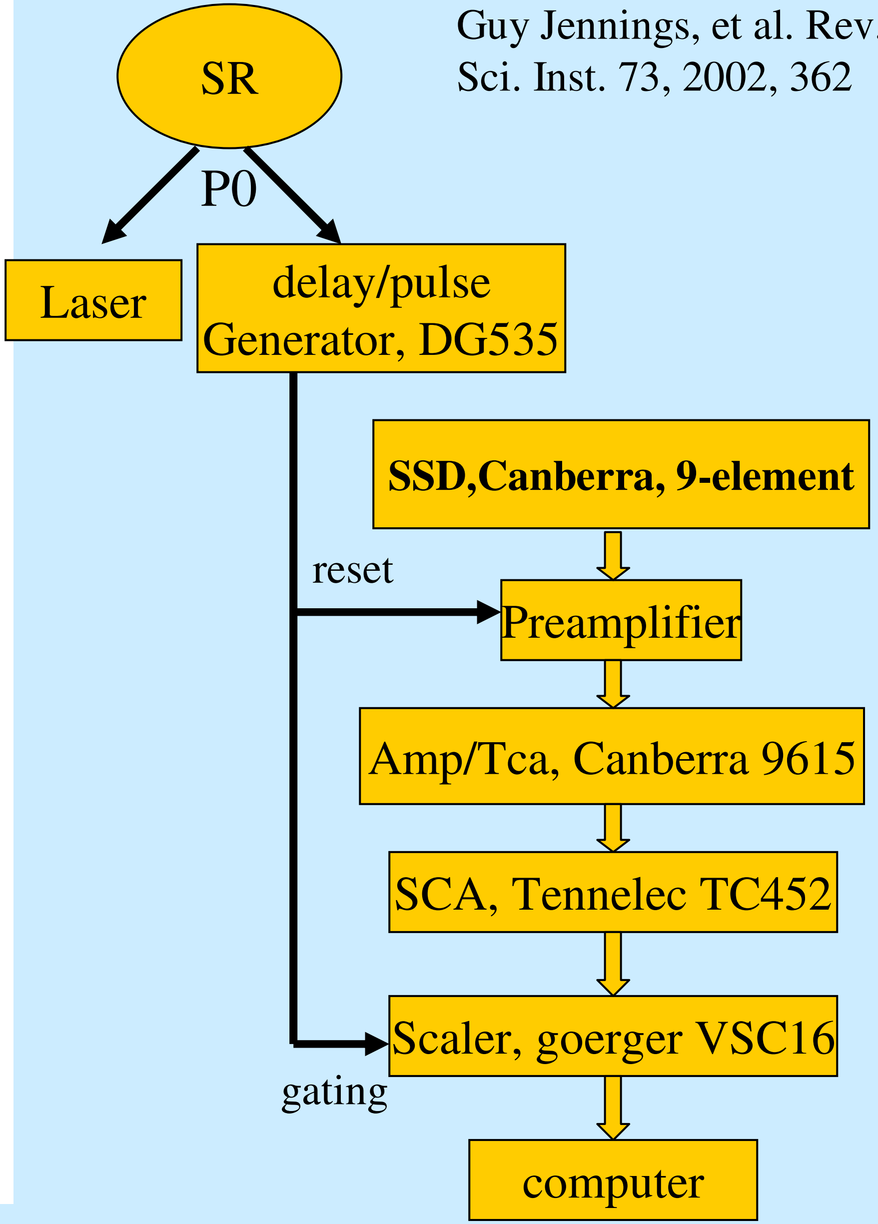
Time-resolved laser pump-X-ray probe techniques



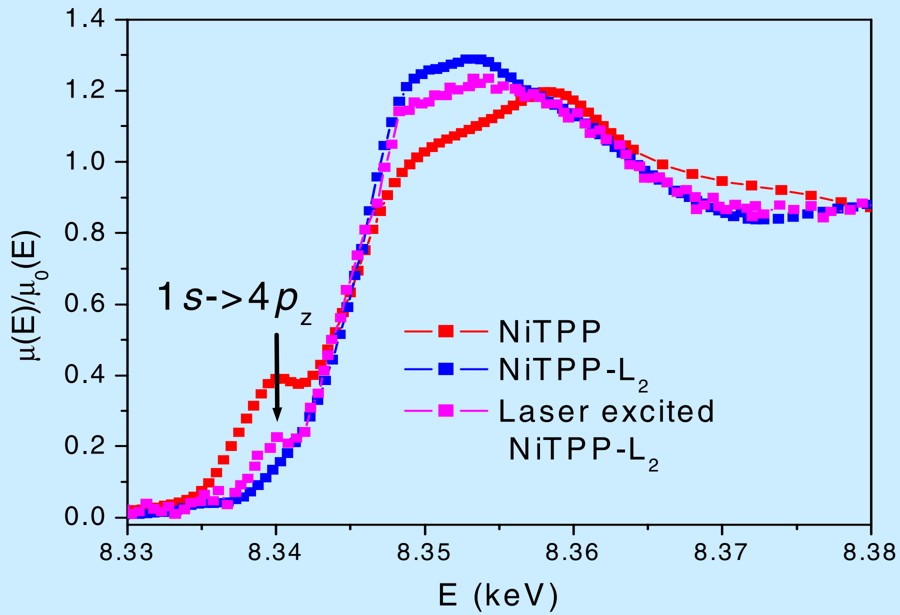
Time sequence of the laser pump/X-ray probe experiment, which requires synchronization of laser pulse, X-ray pulses and gated detection, Δt.

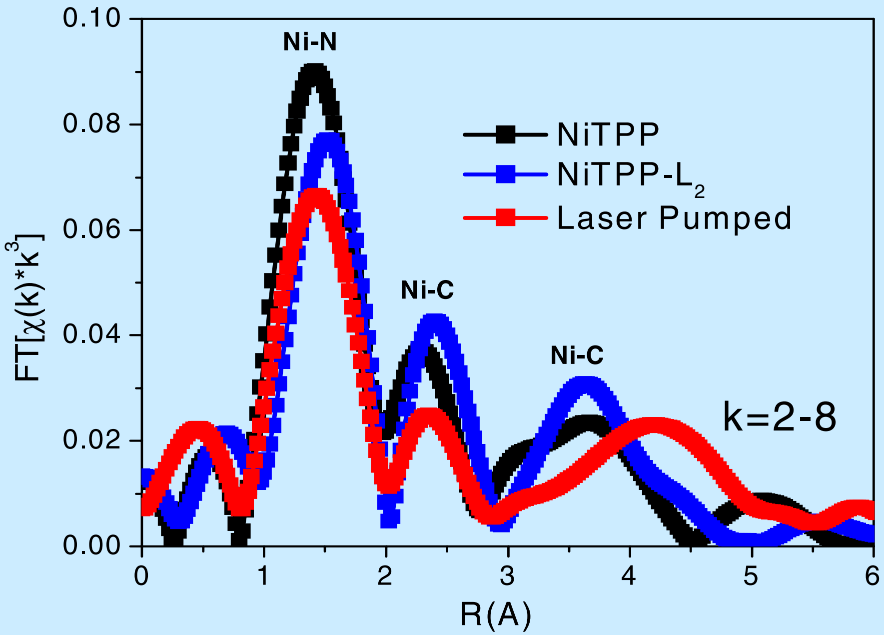
Readout electronics

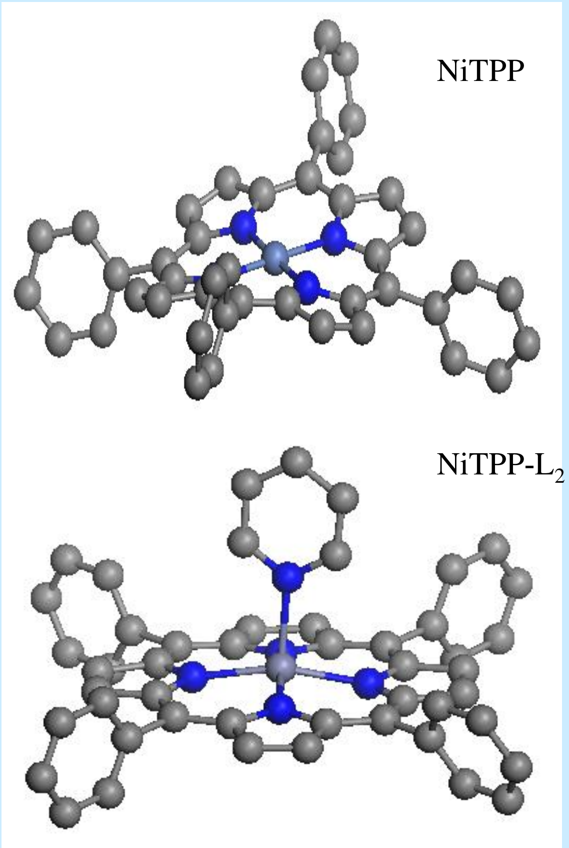




Guy Jennings, et al. Rev. Sci. Inst. 73, 2002, 362

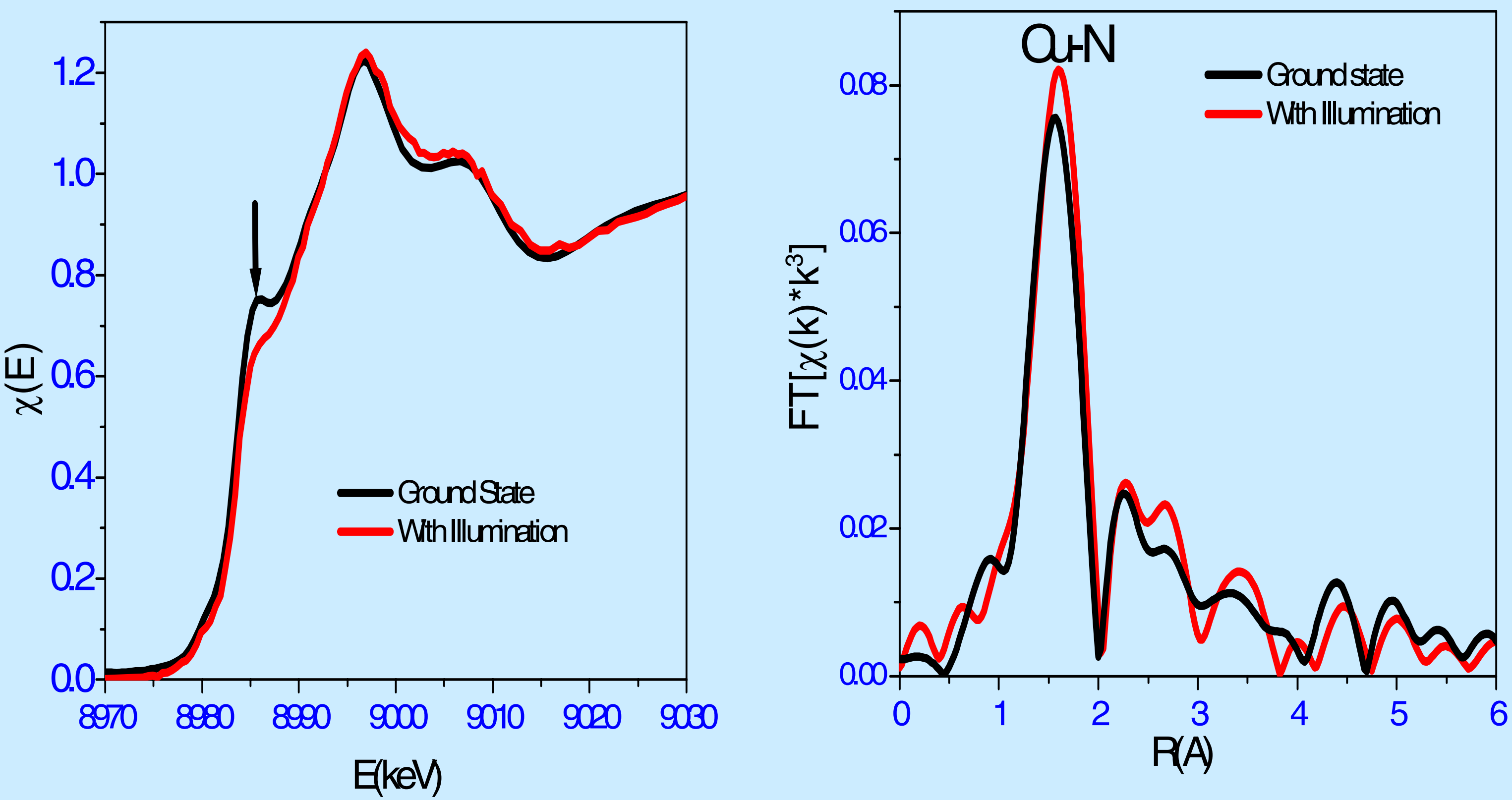






L.X.Chen, et al. Science, 2001, 292, 262

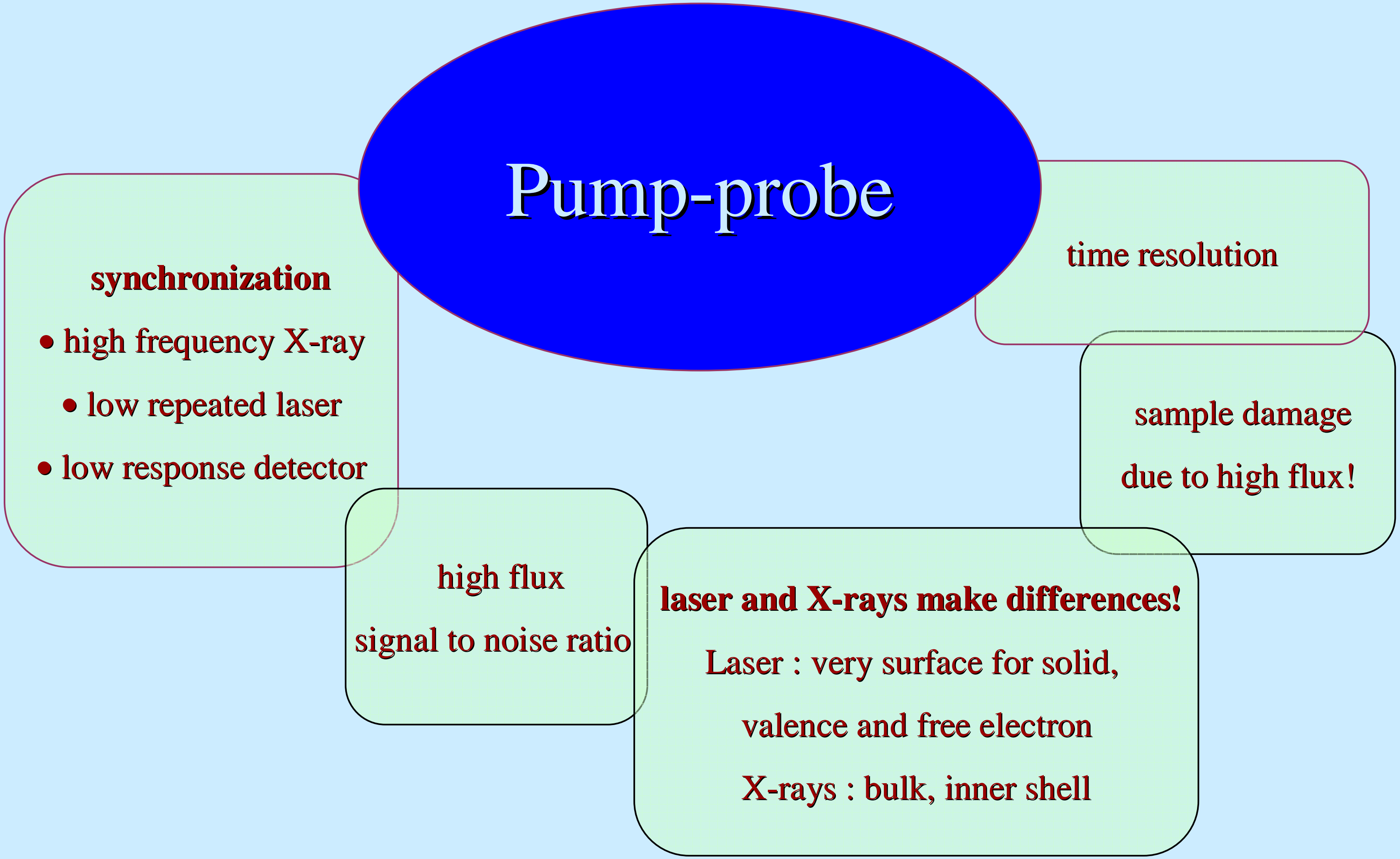
$[Cu(dmp)_2](BArF)$ in toluene with and without light excitation



XANES spectra and Fourier transformed spectra of $[Cu^{I}(dmp)_2](BArF)$ in toluene with and without light excitation.

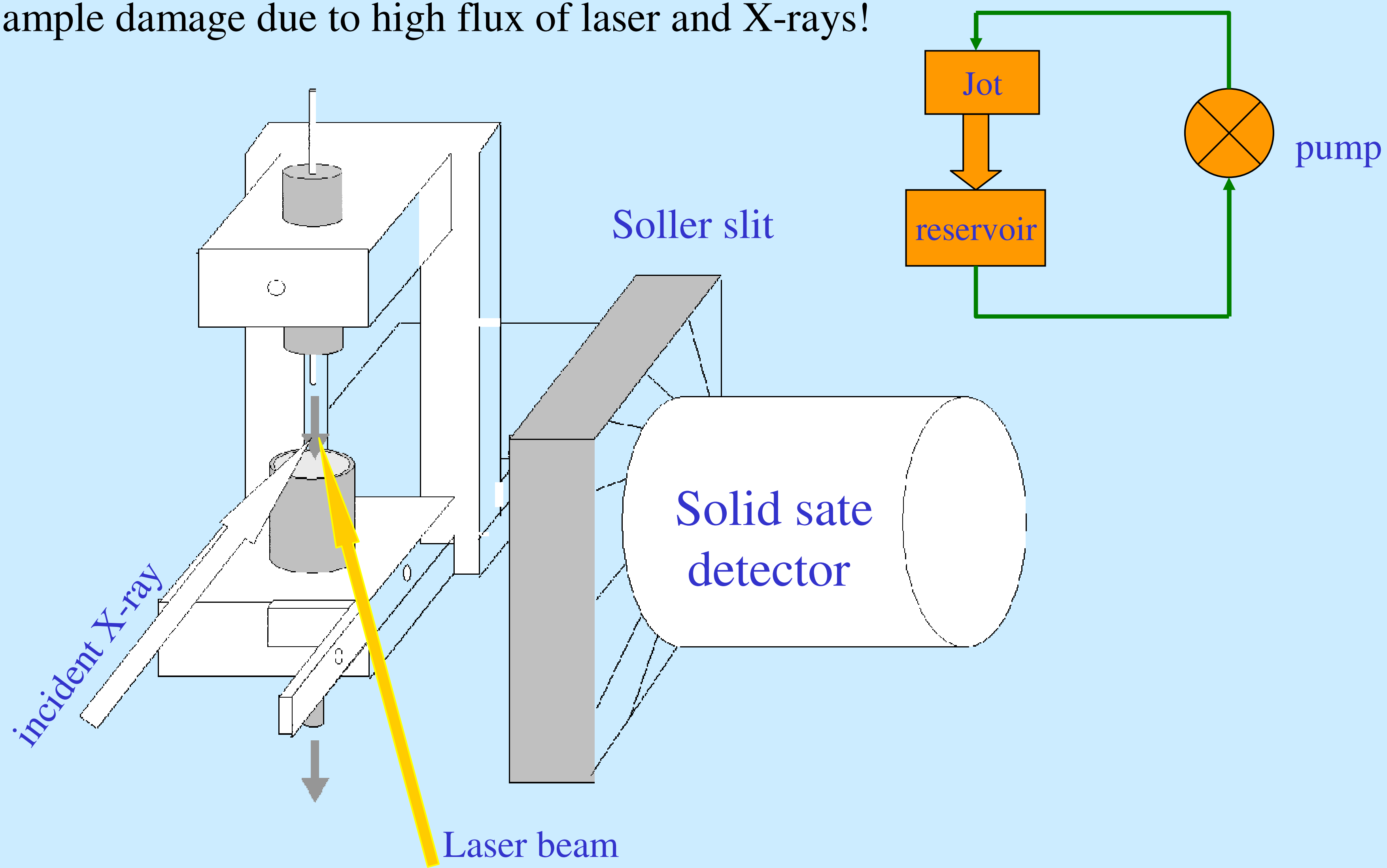
L.X.Chen,et al. J.Am.Chem.Soc.2002, 124, 10861

Some concerns in pump-probe experiments



Jot sample system for pump-probe experiment

Sample damage due to high flux of laser and X-rays!



Why 3d generation synchrotrons in pump-probe experiment

The fluorescence photons from a sample can be estimated by

$$I_f = I_a \times (\Omega/4\pi) \times \eta \times (\mu_k/\mu_T) \times \eta_{Det}$$

I_f: fluorescence signal, I_a : number of photon absorbed by the sample, Ω : solid angle covered by the detector, η : quantum yield of the fluorescence, μ_k, μ_T: the absorption cross sections of the atoms of interest and of the whole sample, η_{Det} : detector efficiency

For 1mMol Ni-containing sample(NiTPP), $1mm^2$ area and 0.5mm in thickness (15% absorbed), $I_a = 4.5\times10^7$ photons at 1KHz of pump-probe cycle, $\Omega/4\pi = 2.9\%$, $\eta = 40\%$ for Ni, the fraction of Ni in sample=0.6%, $\eta_{Det} = 1$

3rd-generation SR
($5.5*10^{11}$photons/s)

I_f =3100 photons/s, for a total count of 100000, 35s integration time is required for each point

1st or 2rd-generation SR
(10^9photons/s)

I_f =0.2 photons/s, 110h is needed!

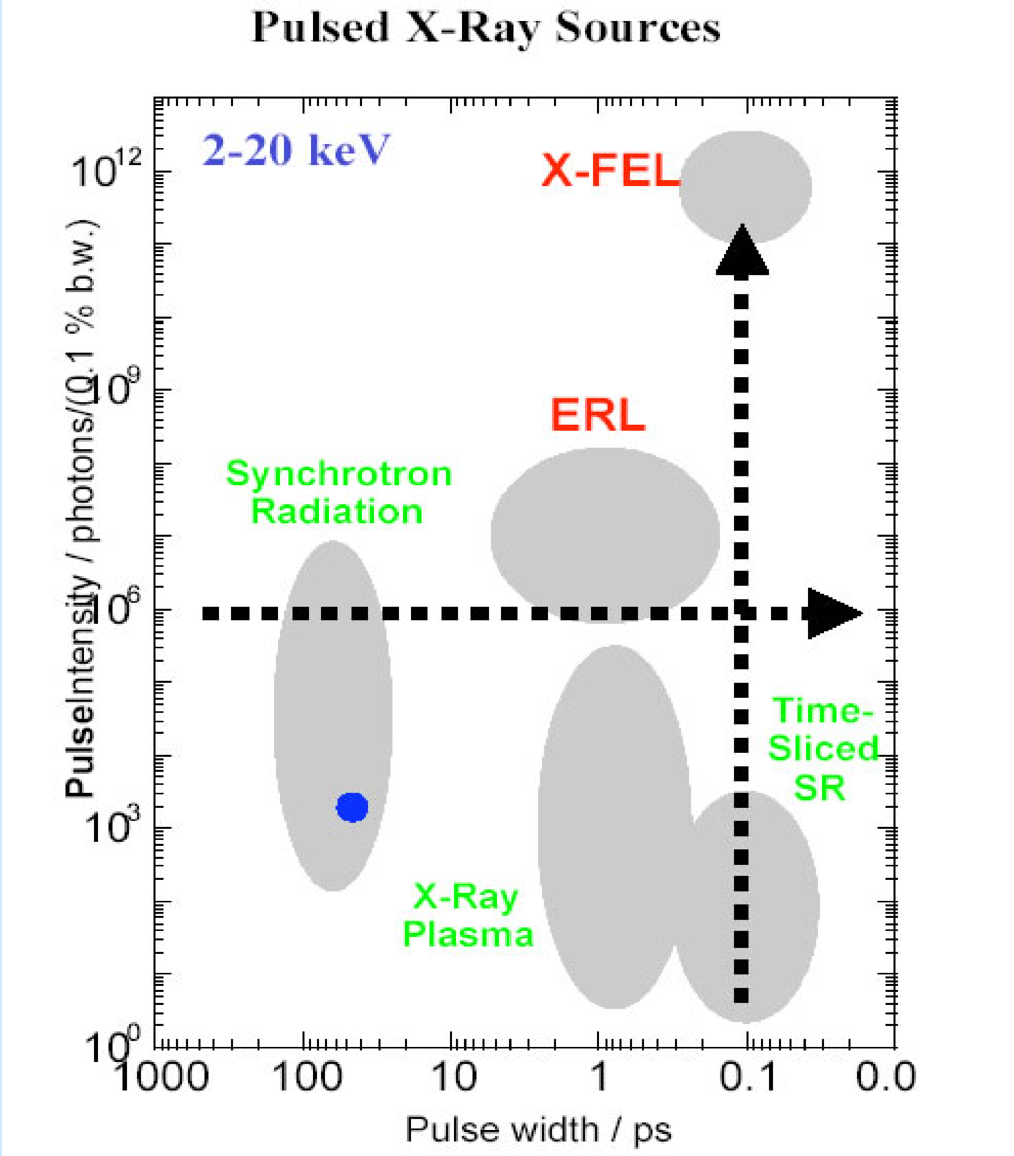
Time Resolution

Time resolution defined
by the width of X-ray pulse

Time scale for atomic
motion, vibrational period
~100fs

Synchrotron radiation
~ 100ps

X-FEL
~ 100fs



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