Time-resolved X-ray diffraction at the Photon Factory Advanced Ring (PF-AR) to Probe Photo-Induced Phase Transition in Organic CT Crystals

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Outline

1: Characteristics of Photo-Induced Cooperative Phenomena (Photo-Induced Phase Transition :PIPT)

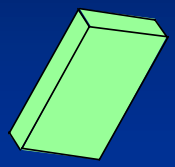
2: Ultra-fast (THz), highly sensitive Non-equilibrium Melting of Charge Order in Organic Super Conductor Candidate (EDO) even at 260 K (Metal-Insulator Transition)

3 : 100-ps resolved X-ray diffraction at the Photon Factory Advanced Ring (PF-AR)

4: Summary

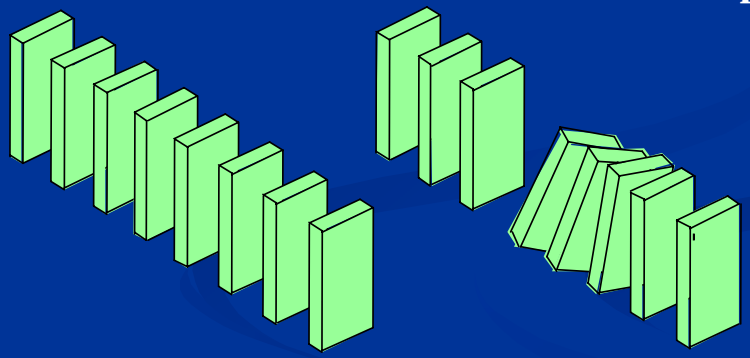
What is photo-domino ?

- **Cooperative response due to cooperative interaction**
- **Control of electron-lattice-spin (multi-)coupling by internal correlation effect (instability)**
- **Various Application**



Localized

Domino effect due to cooperativity



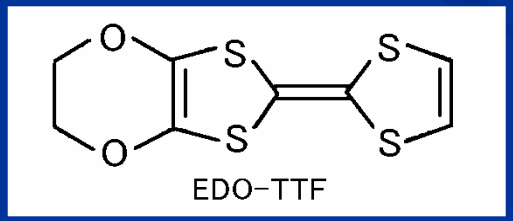
Cooperative response

¼ filled A_2B salts occupy quite important position due to Charge, Spin and Lattice coupled multi-instability.

Targets for picosecond-resolved X-ray diffraction

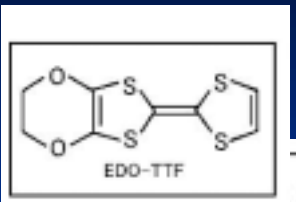
- Organic or inorganic materials where electronic and structural changes are strongly coupled
- Photoactive proteins
- etc …

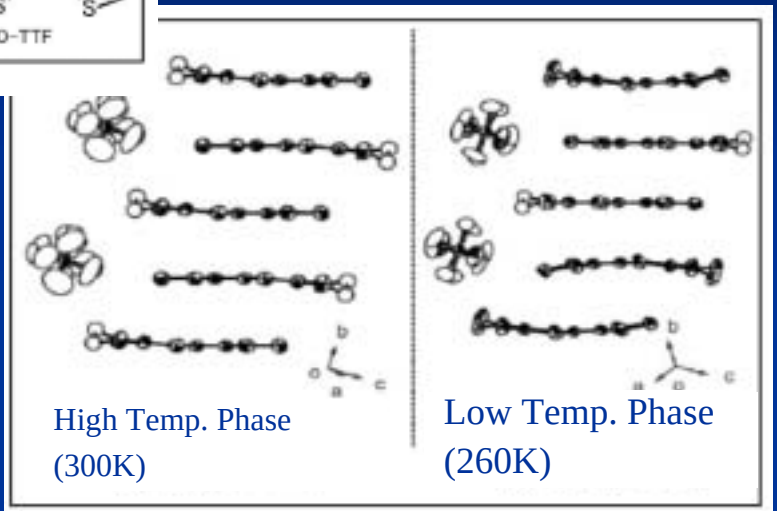
Metal-to-insulator transition in $(EDO\text{-}TTF)_2PF_6$



A. Ota, H. Yamochi, and G. Saito
J. Mater. Chem. **12** 2600 (2002).

Crystal structures of $(EDO\text{-}TTF)_2PF_6$





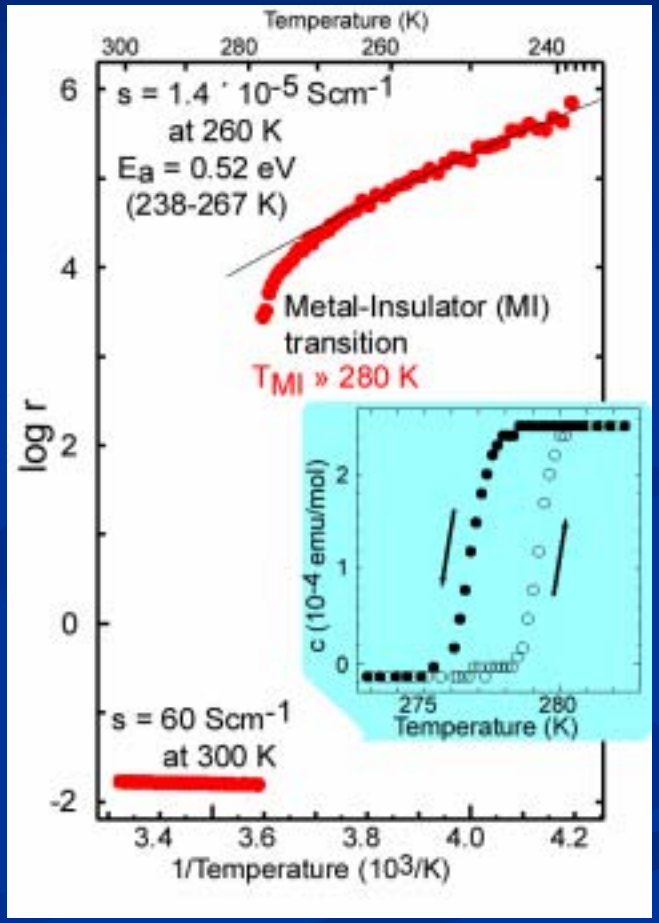
***J. Mater. Chem.*, (2002) 12, 2600**

Peierls transition

Charge Ordering

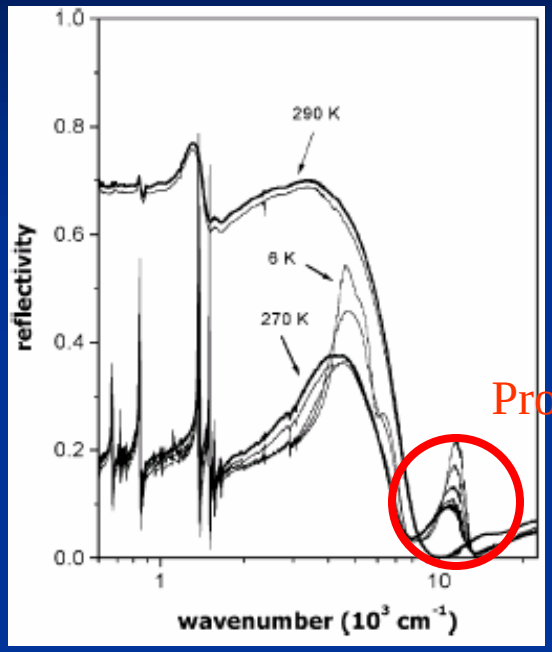
Anion Ordering

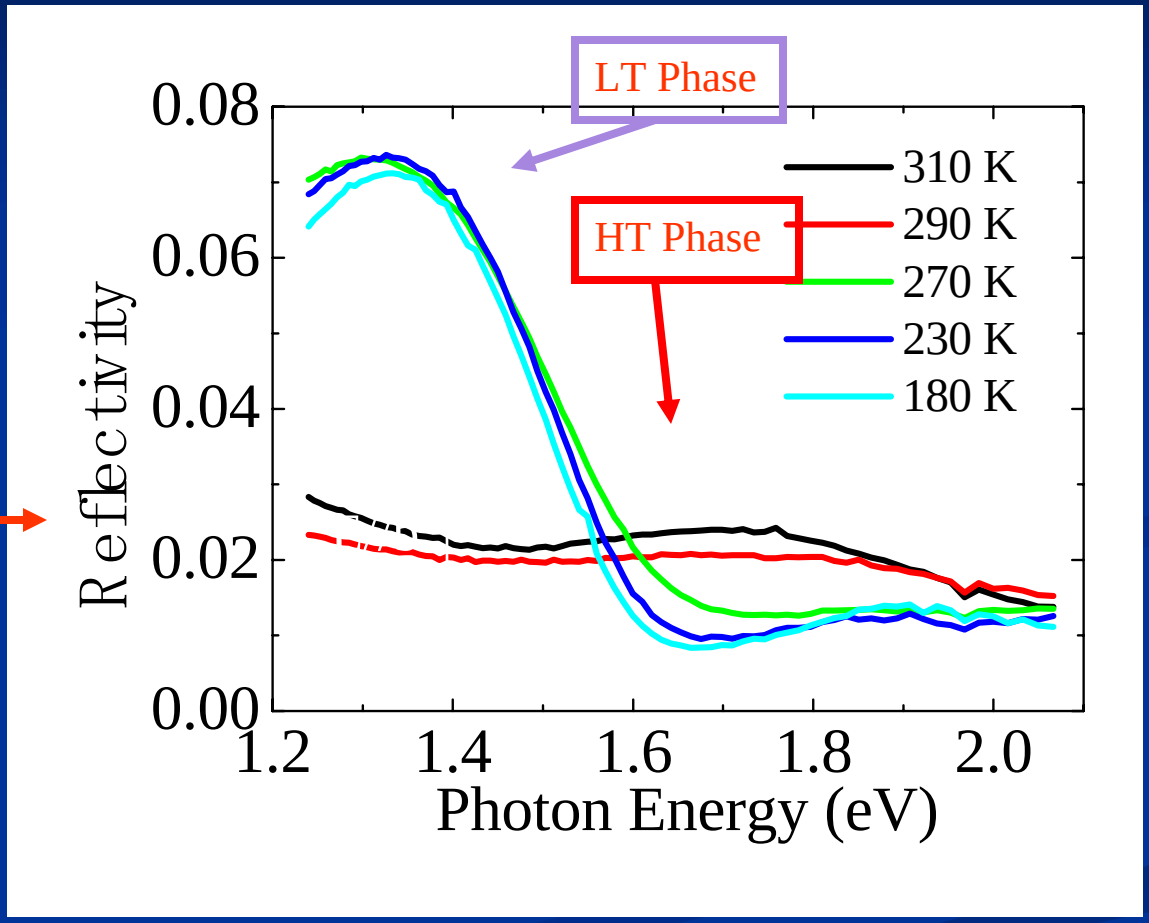
A novel M-I transition



Important target for photo-induced phase transition

Temperature Dependence of Reflectance Spectra





O.Drozdova, K.Yakushi, A.Ota, H.Yamochi,and G.Saito

Synthetic Metals, 133, 277-279 (2003)

How the transition can be probed?

Large Change in 0.8 – 1.8 eV Region

(Important for application)

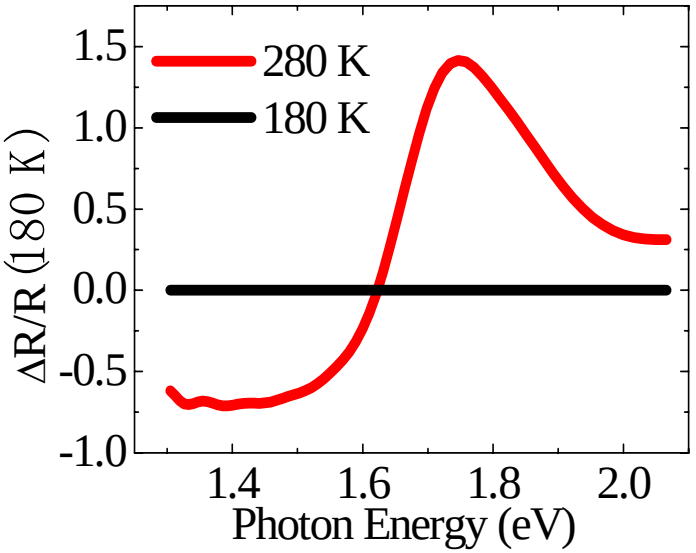
Spectral change by photo-excitation

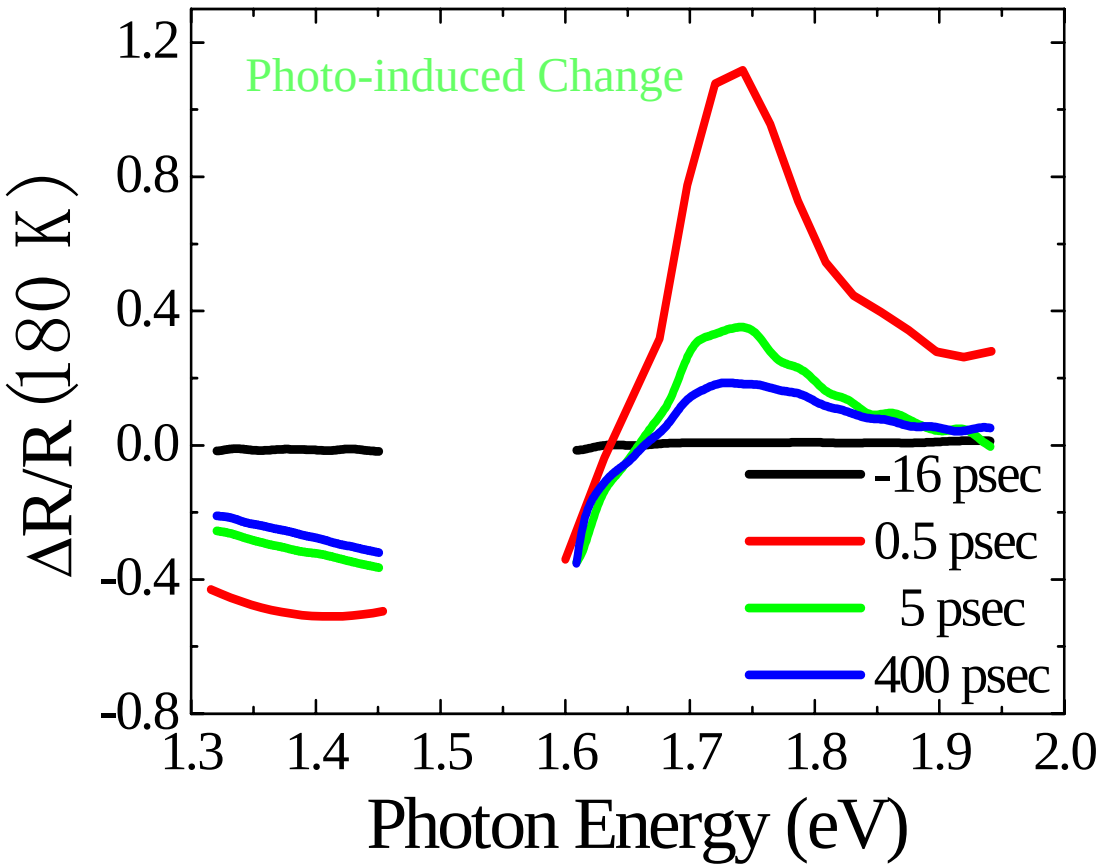
1:Quite similar to thermally induced I-to-M transition (Disappearance of CO band)

2:Highly efficient and fast conversion with 800nm excitation

(a few tens- a few μJ/cm^2 pulse:1 photon for every 1-3 thousands molecules)

Thermally-induced Change



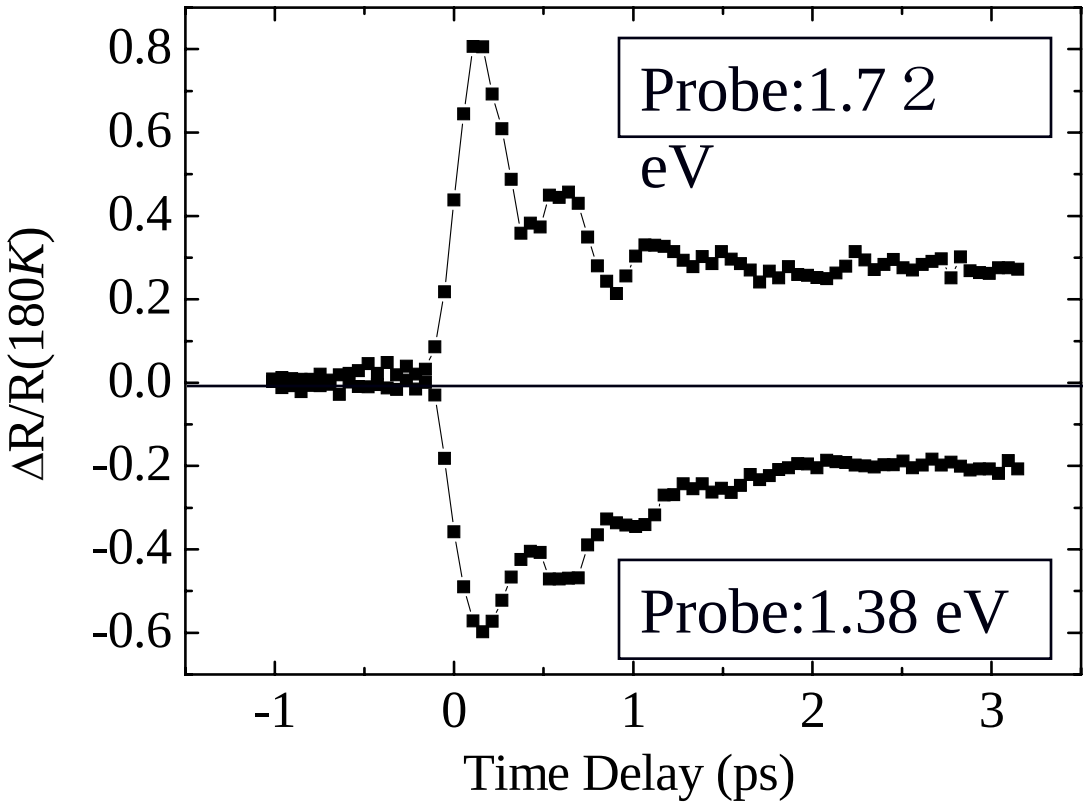


Fast Time-dependence in reflectivity change

Vibrational structure scarcely depends on probe wavelength

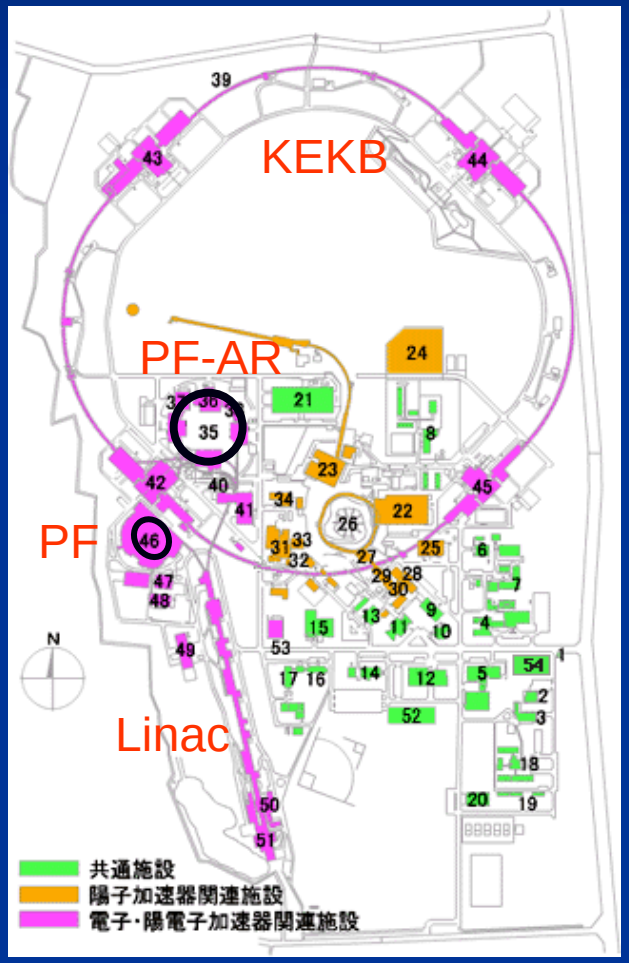
Some vibration in electronic structure

Similar signal has been also observed for $(EDO)_2AsF_6$



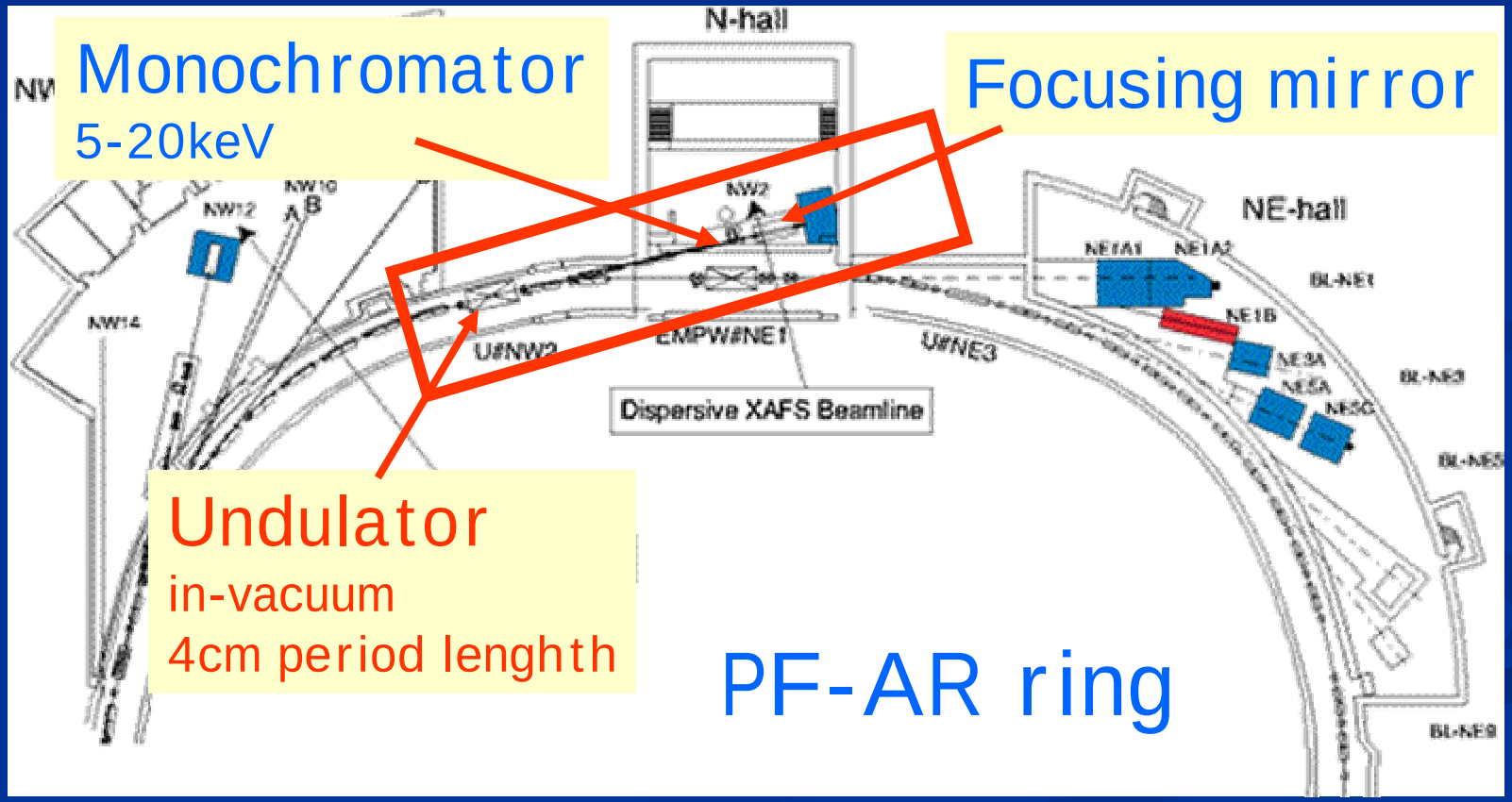
Coherent Phonon ? E-L coupling plays key role ?

Specifications of single-bunch mode at PF-AR and ESRF



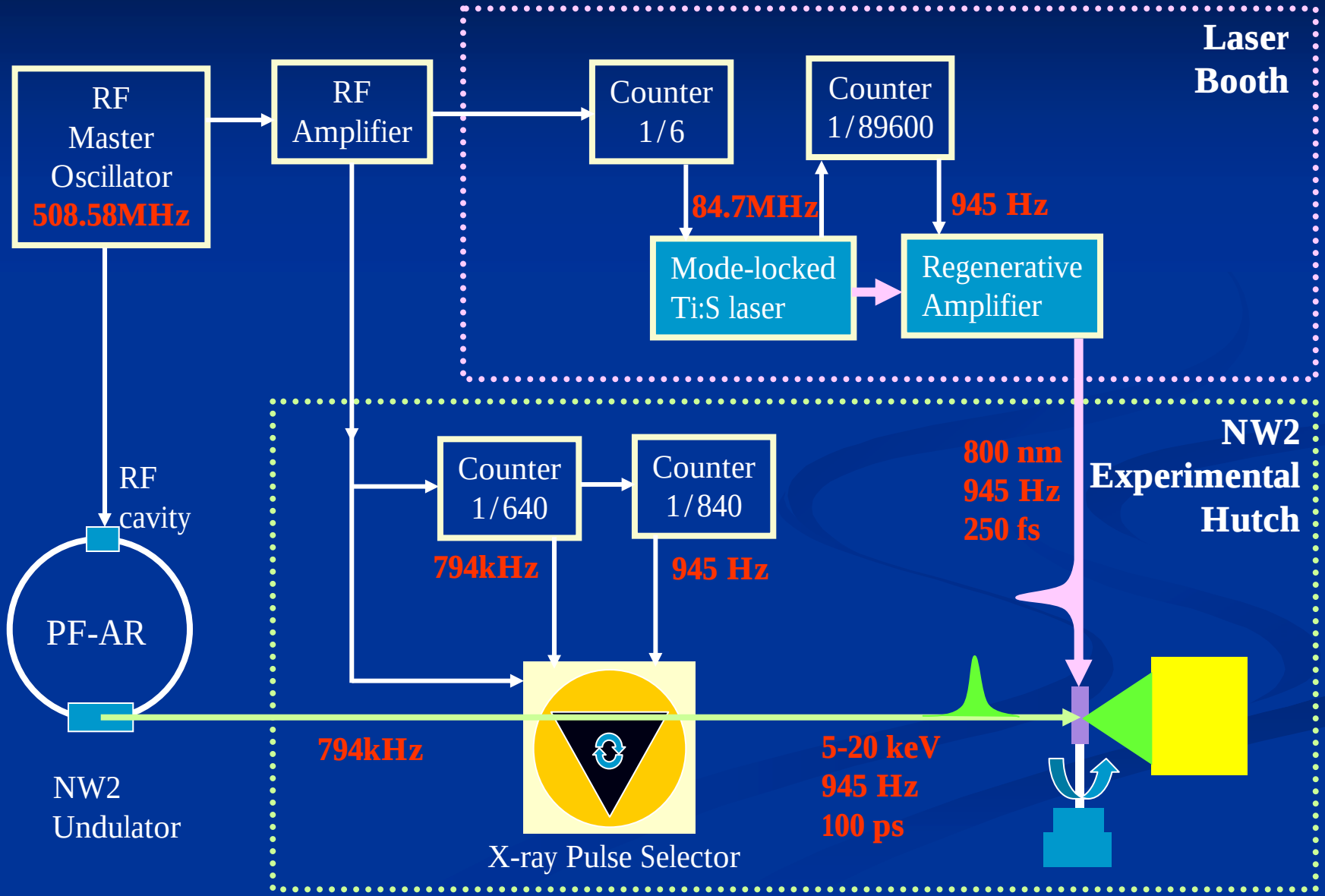
	KEK PF-AR	ESRF
Ring energy	6.5 GeV	6.0 GeV
Time resolved mode/year	~5000 hours (100% single bunch)	~1700 hours (~30% s.b., 16-bunch, hybrid)
Ring current / bunch	60 mA	16 mA max.
Bunch duration	~ 100psec	~ 150psec
Beam life	15-20 h	6-8 h
Beam size at the sample	0.26 mm (v) x 0.6 mm (h)	0.10 mm (v) x 0.06 mm (h)
Emittance	**290 nmrad**	**3 nmrad**

PF-AR NW2 beamline
(for time-sharing use of time-resolved XAFS and diffraction)

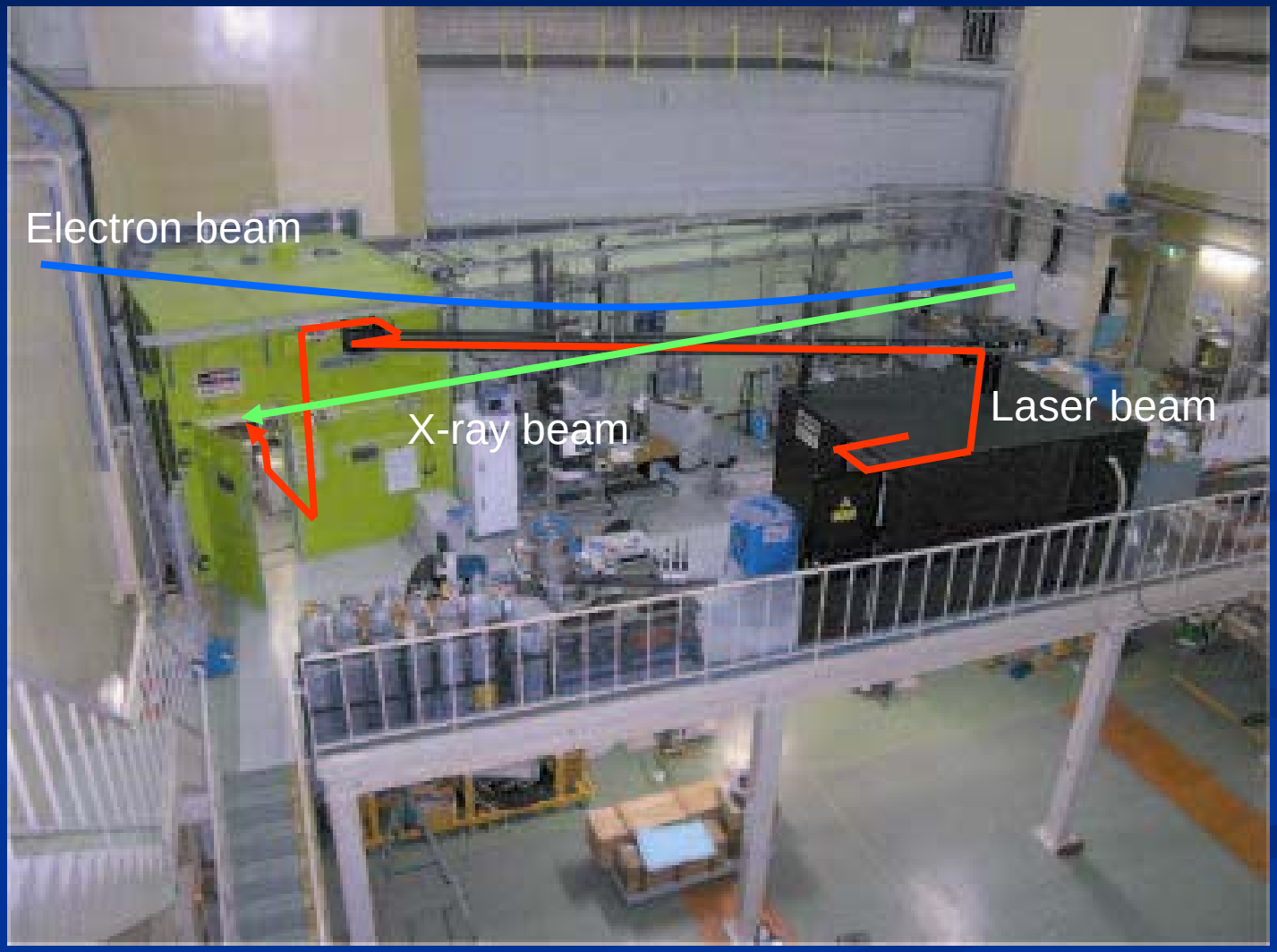


Pump-probe X-ray diffraction at PF-AR NW2

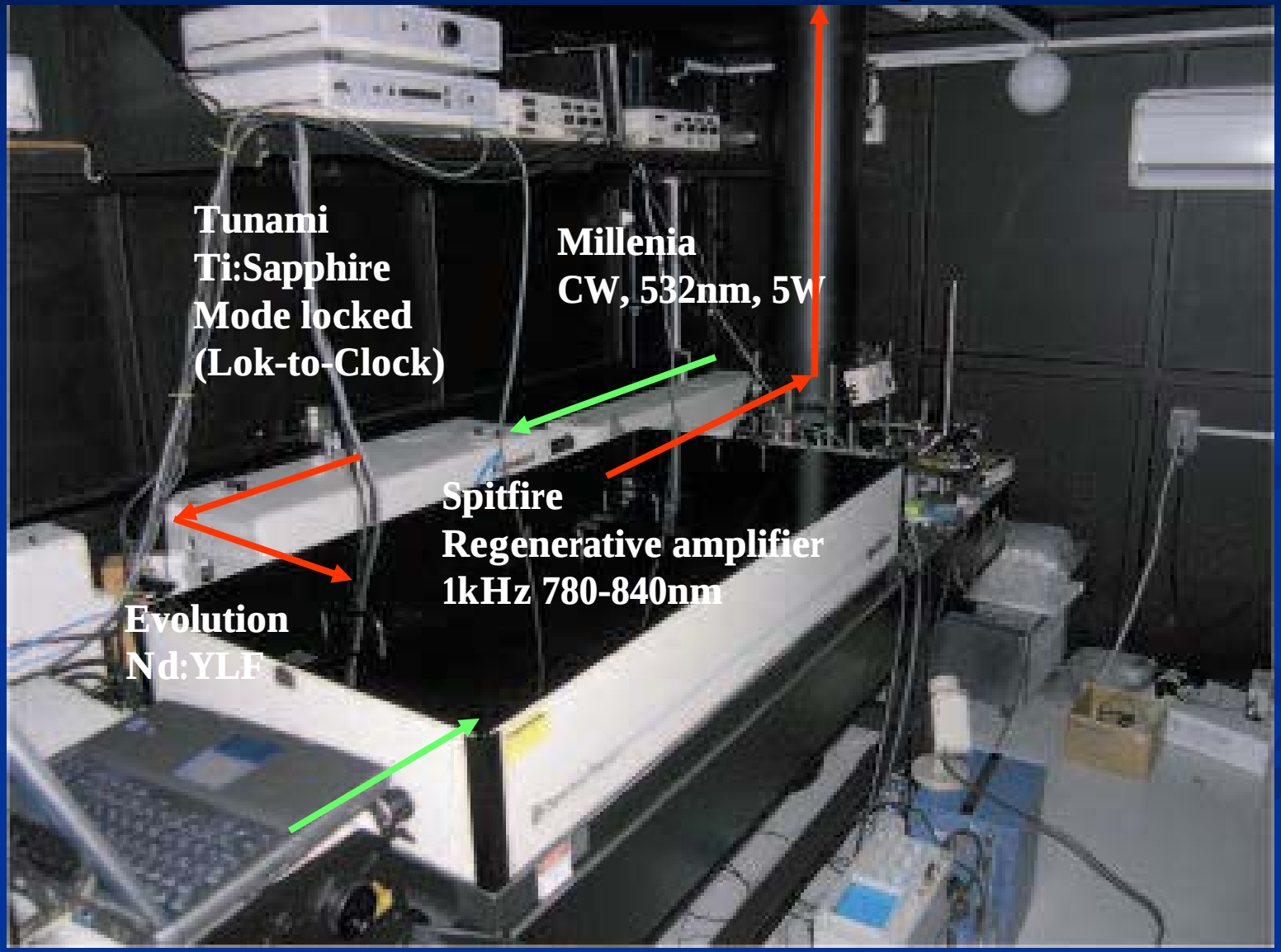
Timing diagram



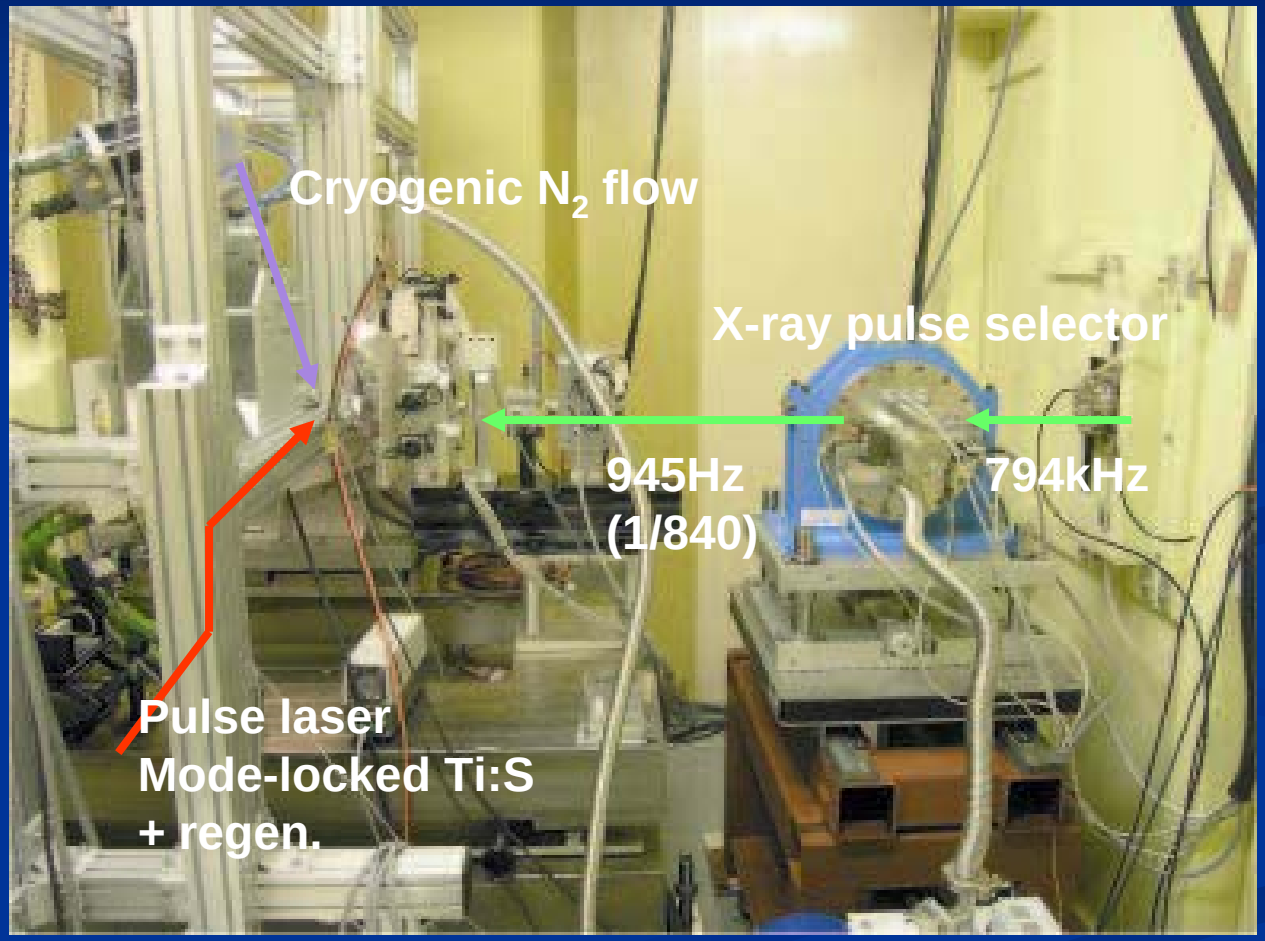
Beamline NW2



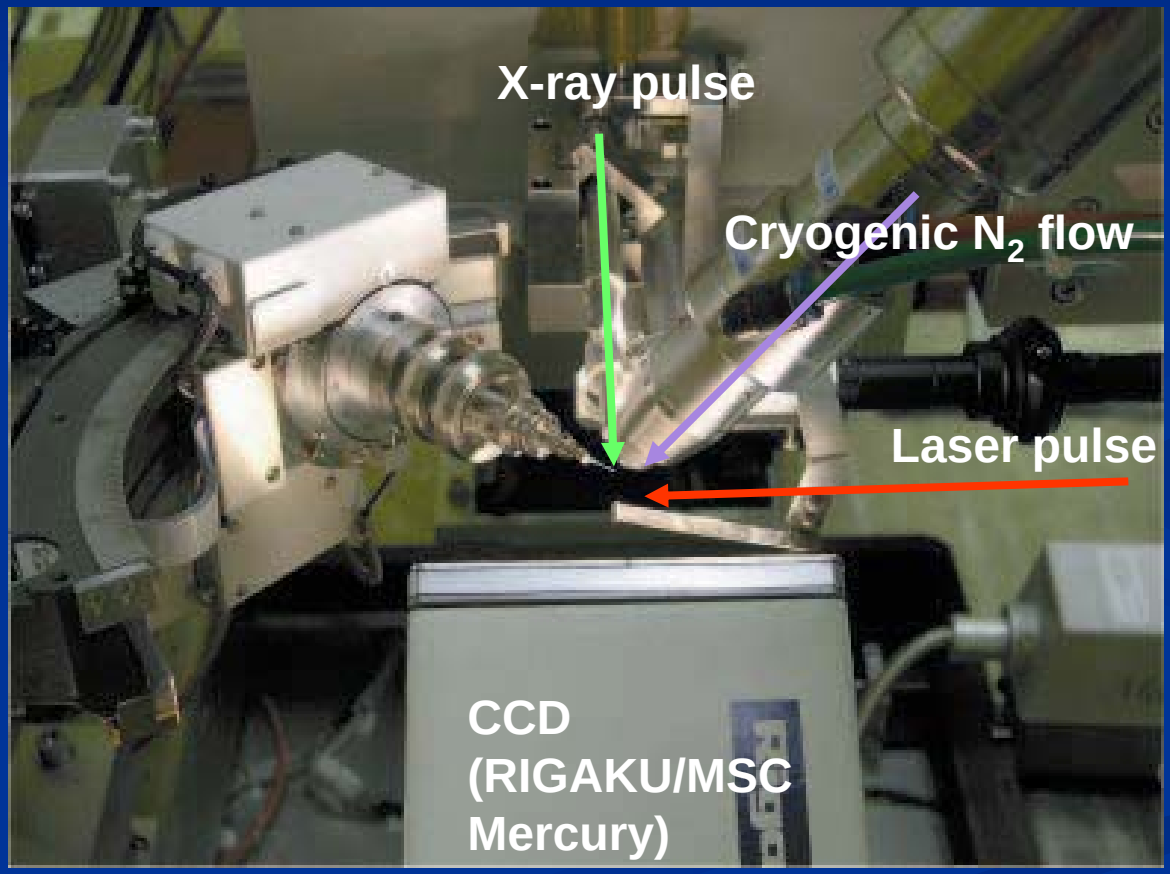
Femtosocond laser system



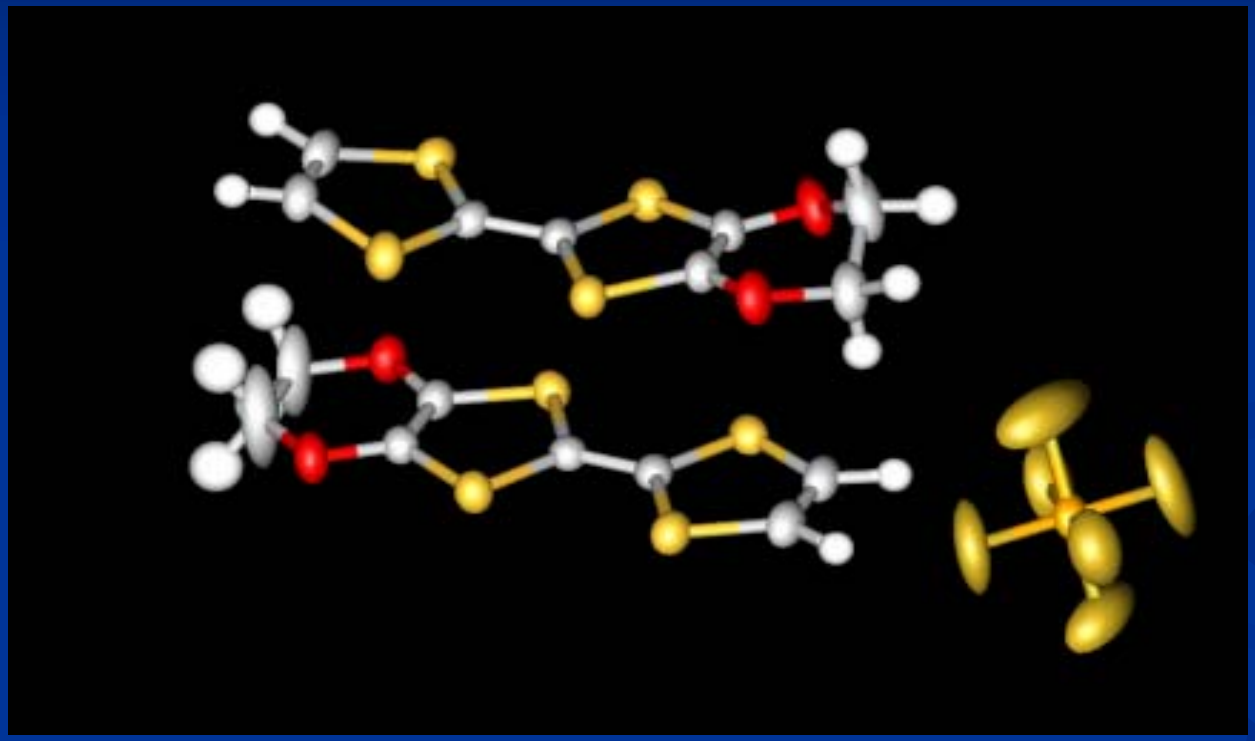
PF-AR NW2 experimental hutch



PF-AR NW2 diffractomator



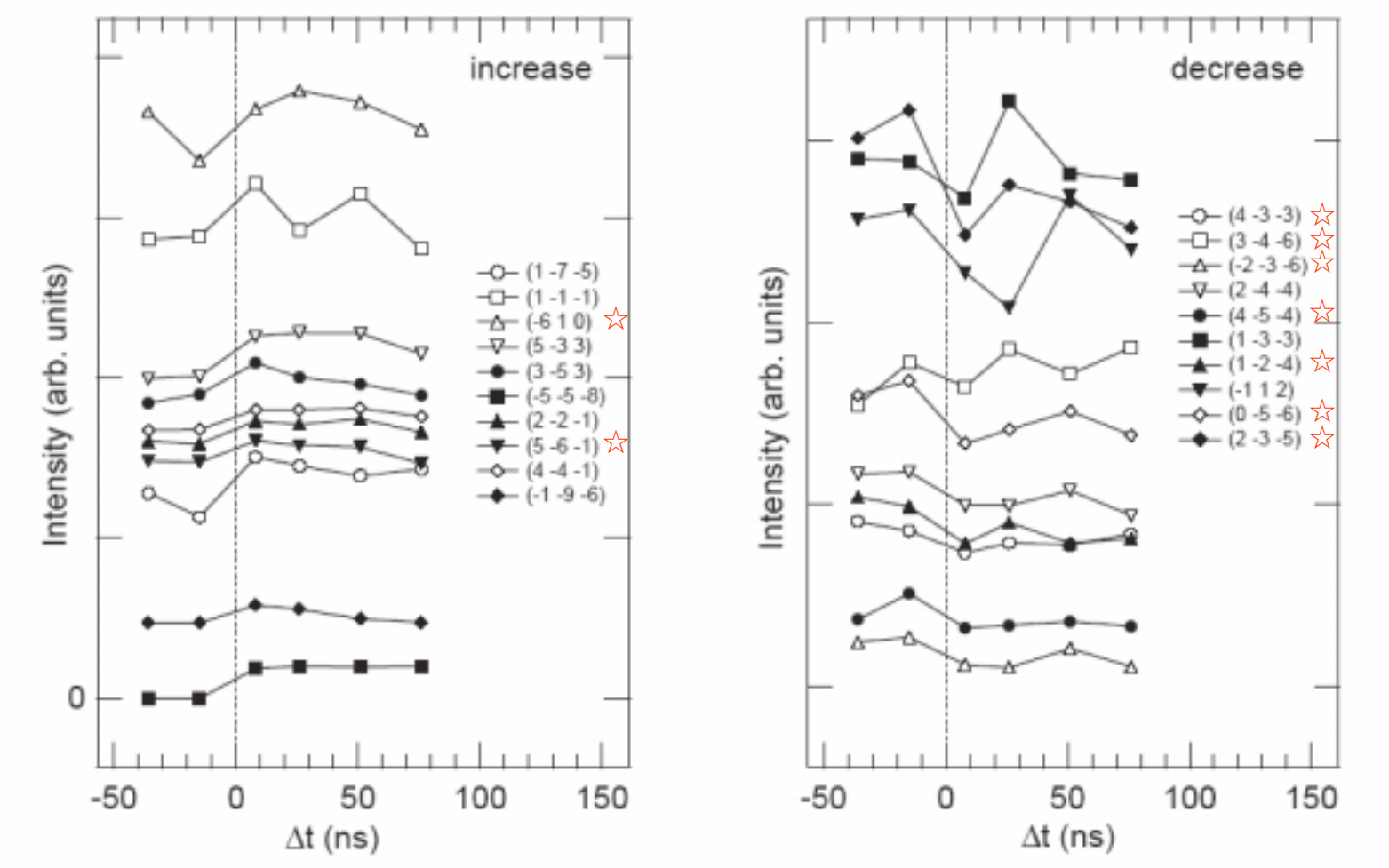
Crystal structure of EDO-TTF 3.5nsec after laser excitation (250K)



Triclinic P1

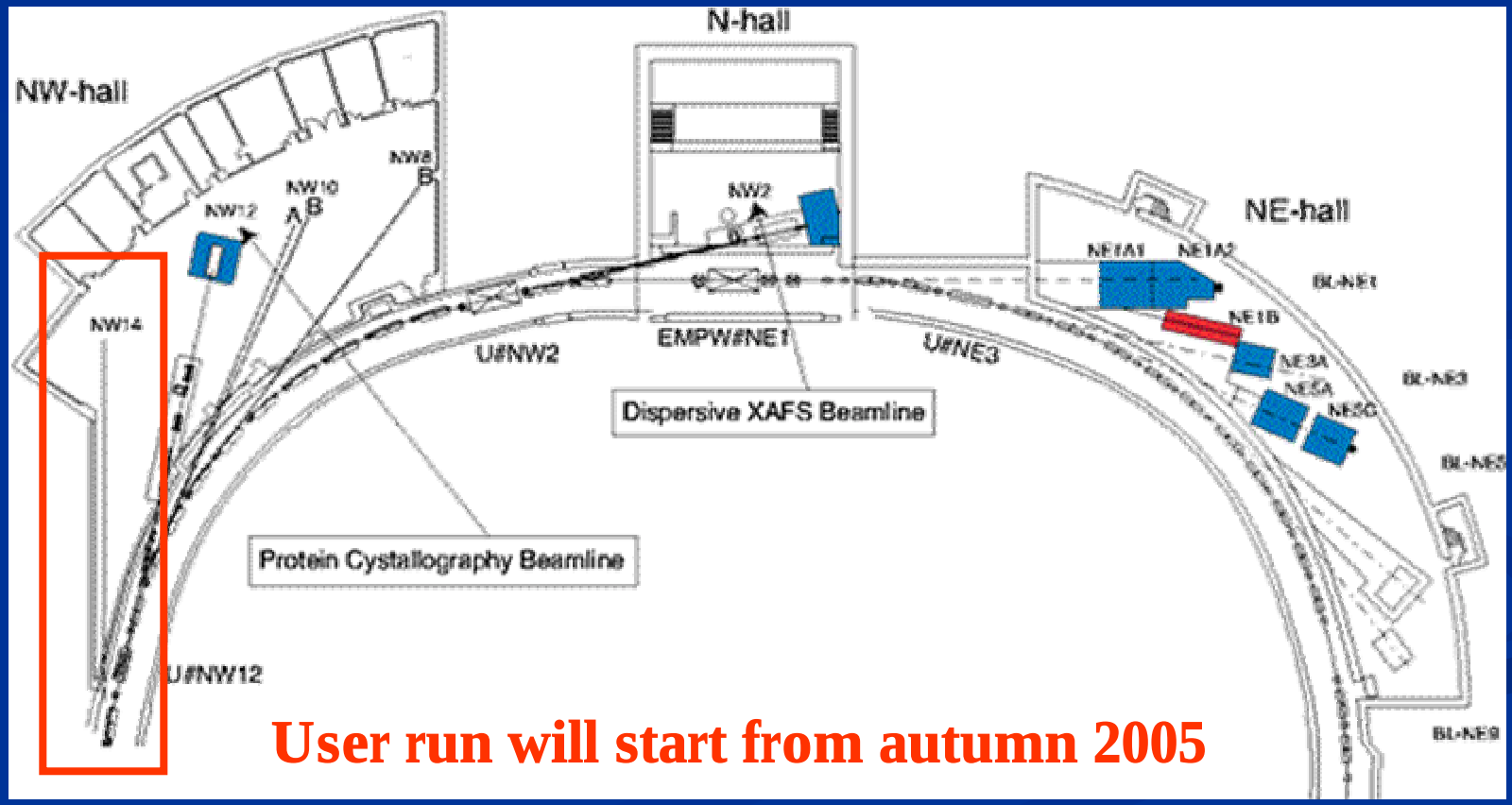
a=9.74(2), b=11.07(2), c=11.15(3)
α=101.6(1), β=100.2(1), γ=88.5(1)
V=1159(4)

Time course of integrated intensities of diffraction spots

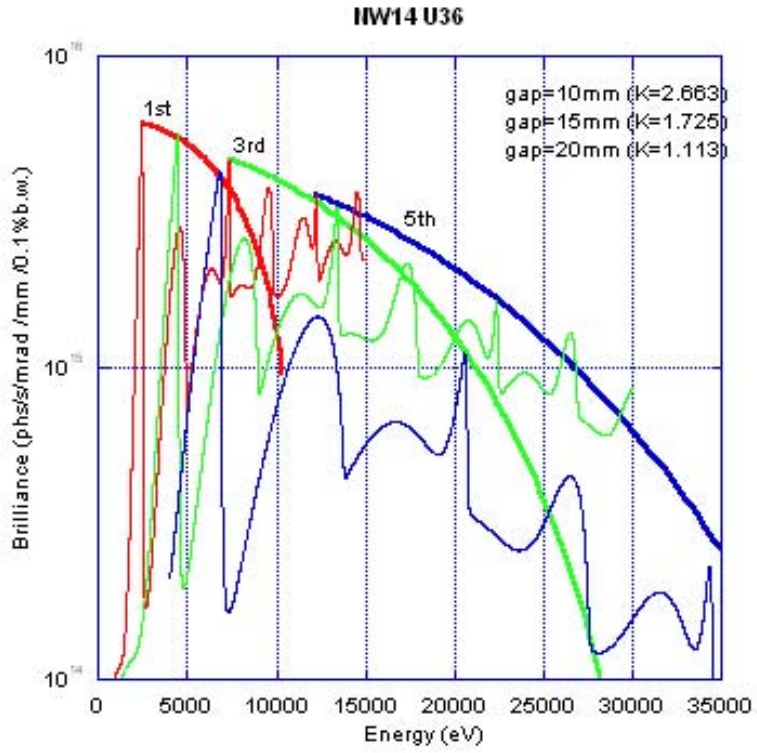


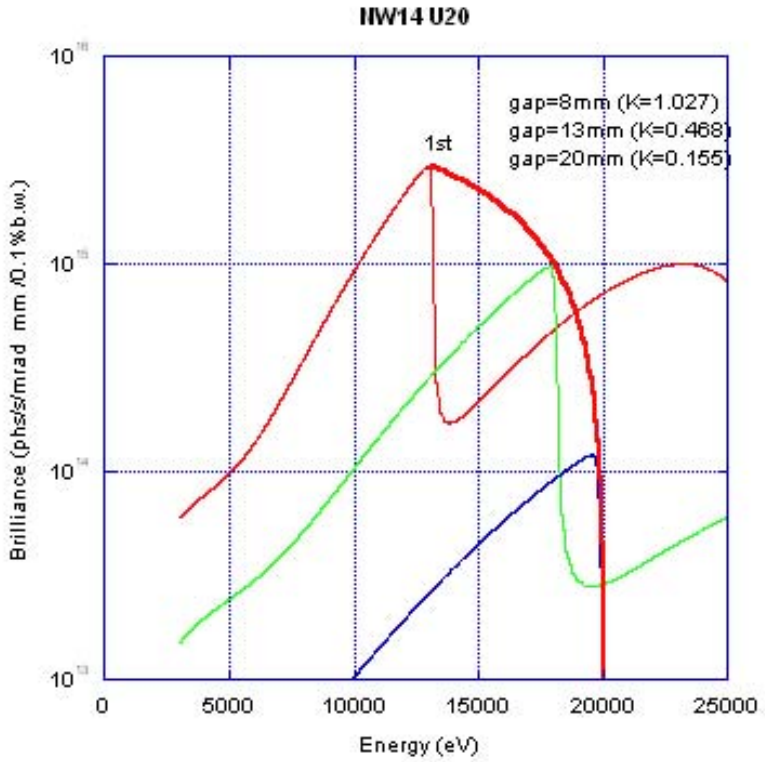
☆: h+k = odd, which are observed only in low-temp phase

A New Beamline, PF-AR NW14
fully dedicated to time-resolved diffraction (funded by ERATO, JST)



Two Undulators at NW14

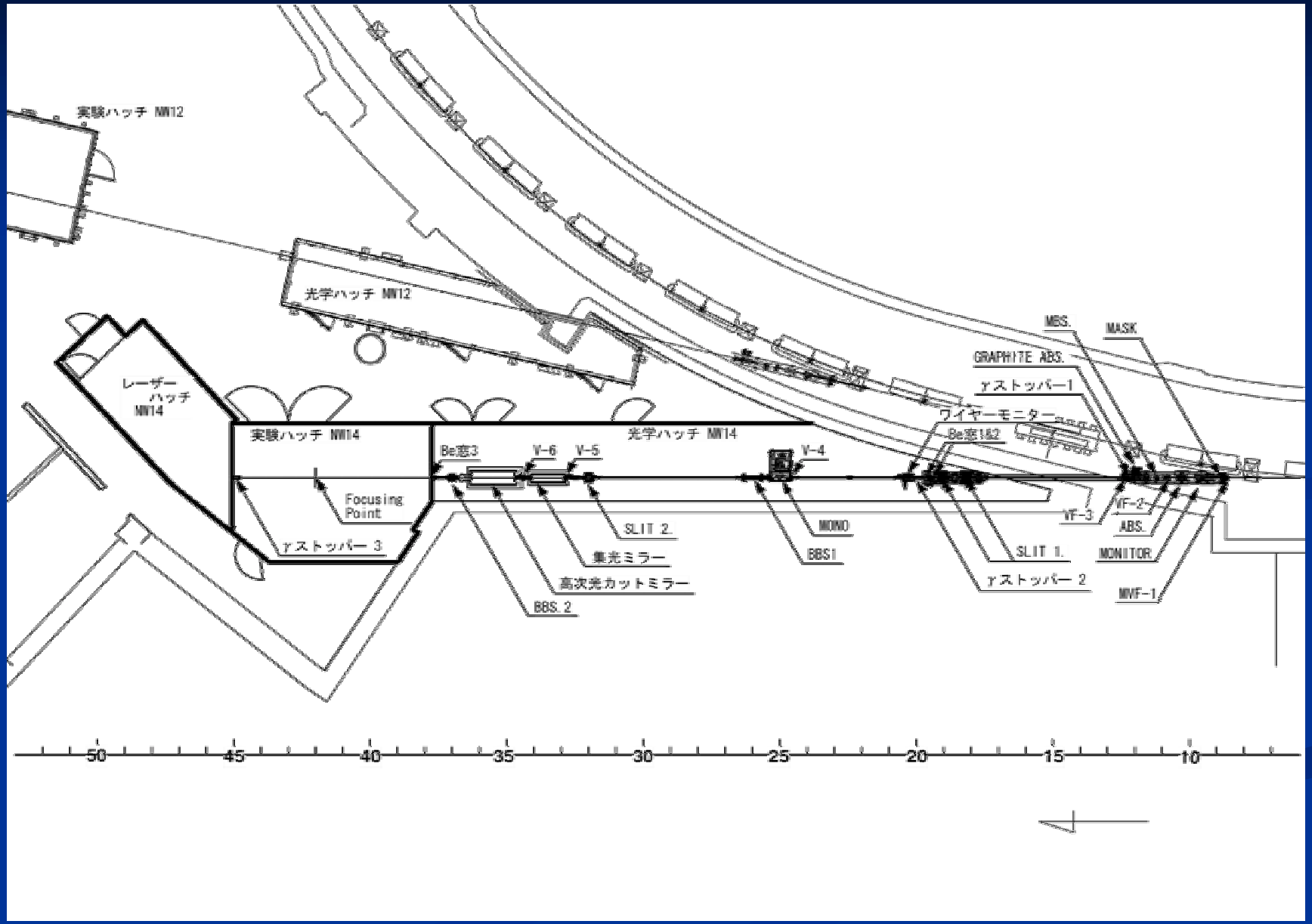




Period length: 36mm
Number of Magnets: 86
Total length: 3096mm
Minimum gap: 10mm

Period length: 20mm
Number of Magnets: 75
Total length: 1500mm
Minimum gap: 8mm

Layout of the NW14



Collaborators

- KEK-ERATO collaboration (Core members)
  - Ryoko Tazaki (ERATO, KEK, Chiba Univ.)
  - Shunsuke Nozawa (ERATO, JST)
  - Jun-ichi Takahashi (ERATO, JST)
  - Jiro Itatani (ERATO, JST)
  - Hiroshi Sawa (KEK PF)
  - Hiroshi Kawata (KEK PF)
  - Masahiro Daimon (ERATO, JST)
  - Shin-ya Koshihara (TITECH, ERATO JST)
- PF Light Source Division
- Tokyo Institute of Technology
  - Shin-ya Koshihara (TITECH, ERATO JST)
  - Matthieu Chollet (TITECH)
  - Laurent Guerin (TITECH)
  - Naoki Uchida (TITECH)
  - Souichi Fukaya (TITECH)
  - Tadahiko Ishikawa (TITECH)
- Univ. Rennes 1
  - Eric Collet
  - Herve Cailleau
- EDO-TTF crystal (Kyoto Univ.)
  - Akira Ota
  - Hideki Yamochi
  - Gunzi Saito
- And more …

end