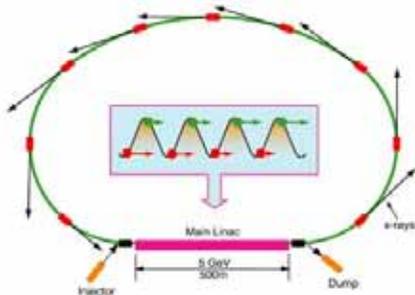
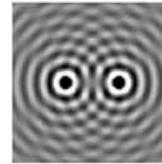


PF-BT部を利用した ショートパルス利用実験の検討

放射光二系
足立伸一

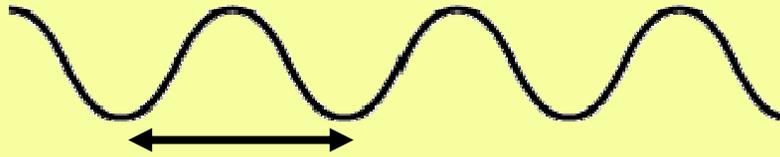
カオス光源から空間・時間コヒーレント光源へ



<http://erl.chess.cornell.edu/>

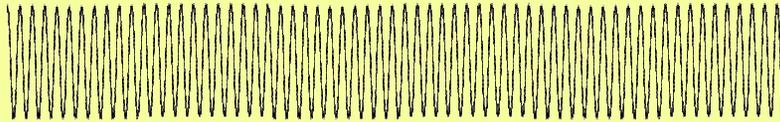
	Emittance	Bunch length	Spatial coherence	Temporal coherence
Storage ring	~ 1 nmrاد	~ 50 ps	×	×
Energy recovery linac	~ 1 pmrad	~ 100 fs		×
Future X-ray Laser	?	?		

光の波長と周期



近赤外光

$$\lambda = 1 \mu\text{m} \quad (E = 1.24 \text{ eV}), \quad T = 3.3 \text{ fs}$$



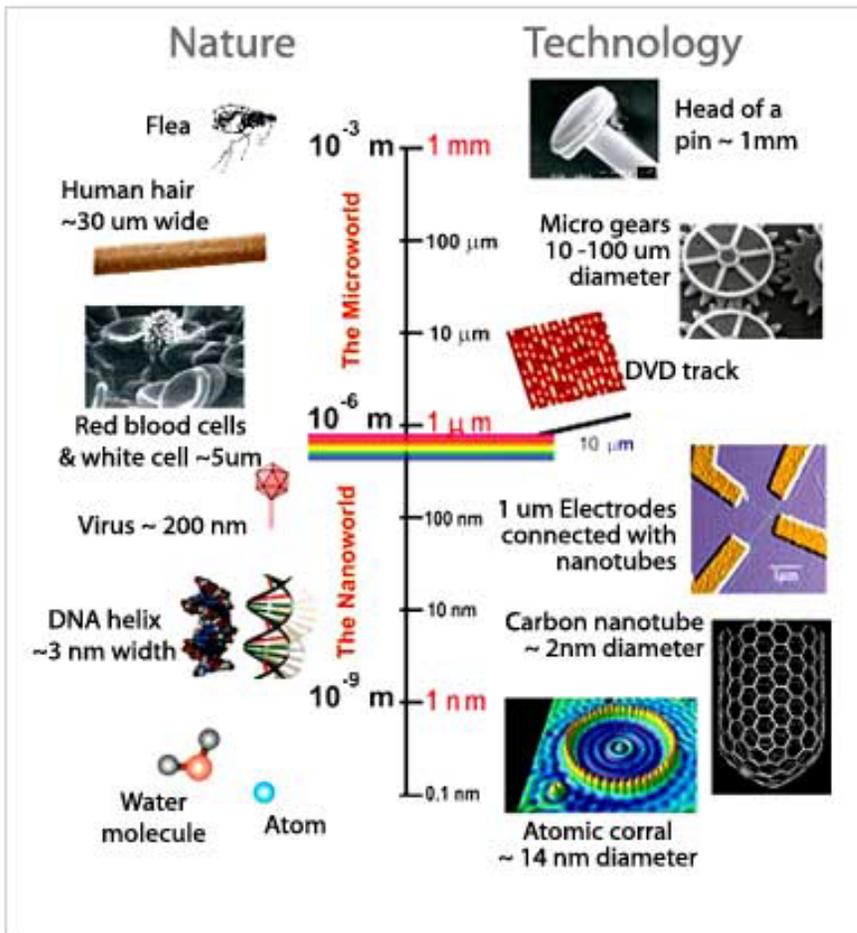
X線

$$\lambda = 0.1 \text{ nm} \quad (E = 12.4 \text{ keV}), \quad T = 0.33 \text{ as}$$

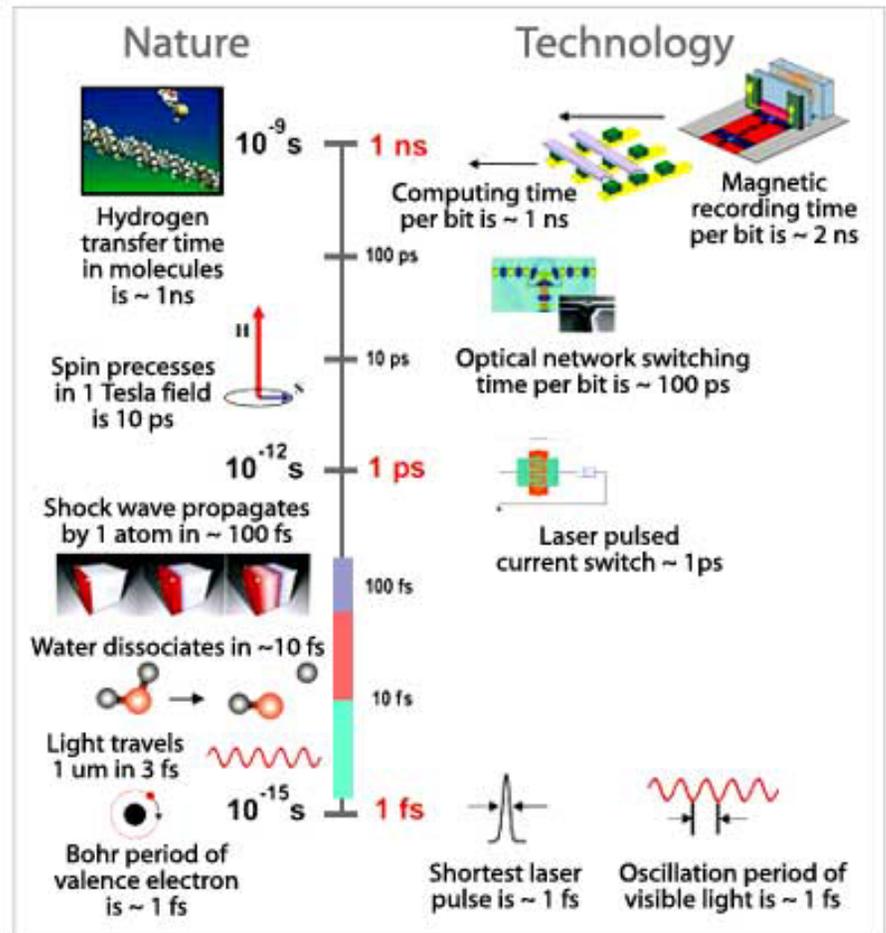
Ultra-Small and Ultra-Fast

<http://www-ssrl.slac.stanford.edu/lcls/>

Ultra-Small



Ultra-Fast



空間コヒーレンス利用実験例

単一の細胞の干渉像から実像を再現

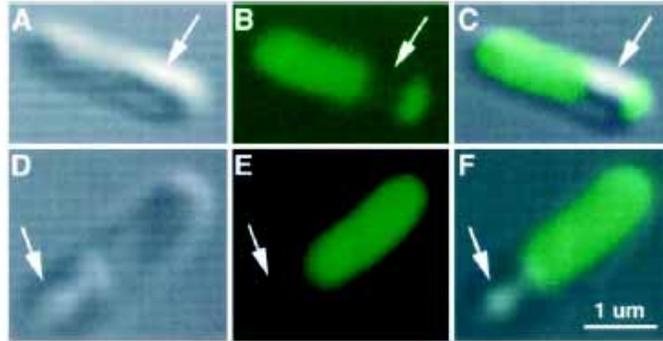


Fig. 3. *E. coli* expressing the indicator protein. Individual bacteria are seen using transmitted light (A and D) and fluorescence (B and E), where the yellow fluorescent protein (green) is seen throughout most of the bacteria except for one small region in each bacterium that is free of fluorescence (arrows), consistent with Fig. 2. C and F show the fluorescent image superimposed on the transmitted light image.

J. Miao et al.: PNAS **100** (2003) 110.

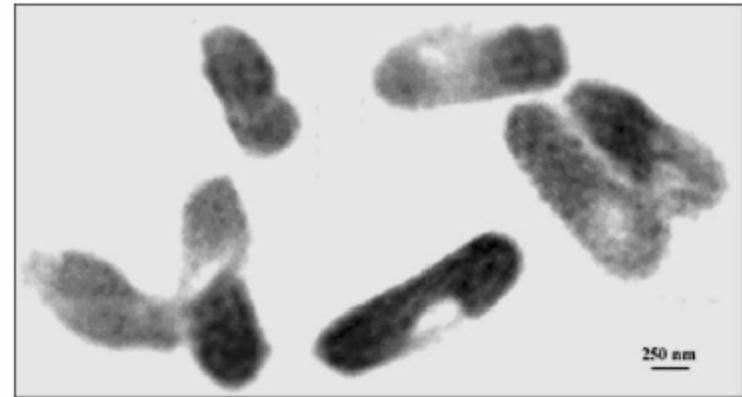
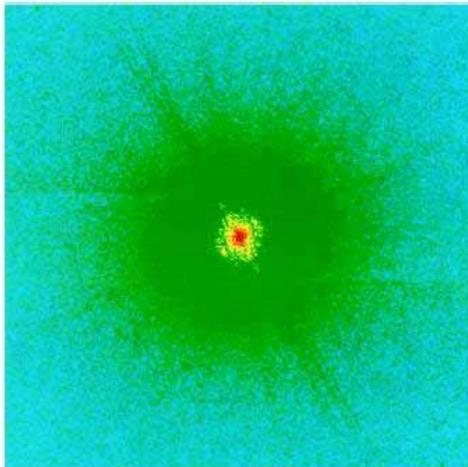
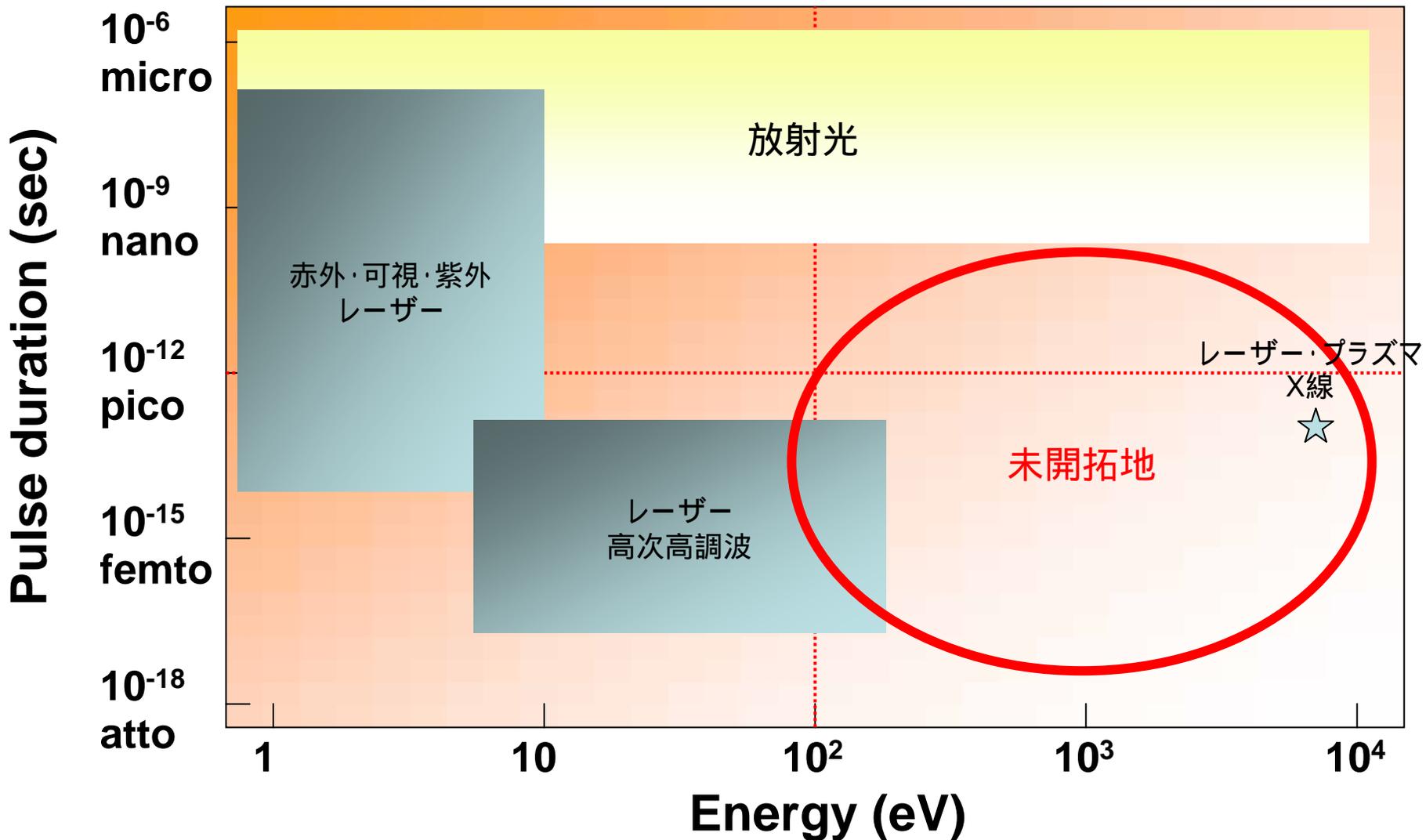


Fig. 2. An image reconstructed from Fig. 1. The dense regions inside the bacteria are likely the distribution of proteins labeled with KMnO_4 . The semitransparent regions are devoid of yellow fluorescent proteins.

光源のエネルギーとパルス幅



サブピコ秒X線光源へ

Source	Pulse length (fs)	Repetition rate (Hz)	Photon flux	Energy range
Sub-Picosecond Pulse Source (SLAC)	80	10	2×10^7 photons/pulse/1.5%b.w.	8-10 keV
Laser Bunch Slicing (Advanced Light Source)	200	40000	5×10^7 photons/sec/0.1%b.w.	0.2-10 keV
Laser-produced plasma X-ray	~100	10	6×10^{10} photons/pulse/ 4π sr	8 keV (Cu-K α)
Laser / high harmonic generation	100 - 0.1	10 - 10000	$\sim 10^8$ photons/sec/0.1%b.w.	10 eV-1 keV
KEK PF-BT line	500	20	$\sim 10^7$ photons/pulse/1%b.w.	0.2-10 keV
Linac Coherent Light Source (SLAC)	230	120	2×10^{12} photons/pulse/0.2%b.w.	1-10 keV

Sub-Picosecond Pulse Source (SLAC)

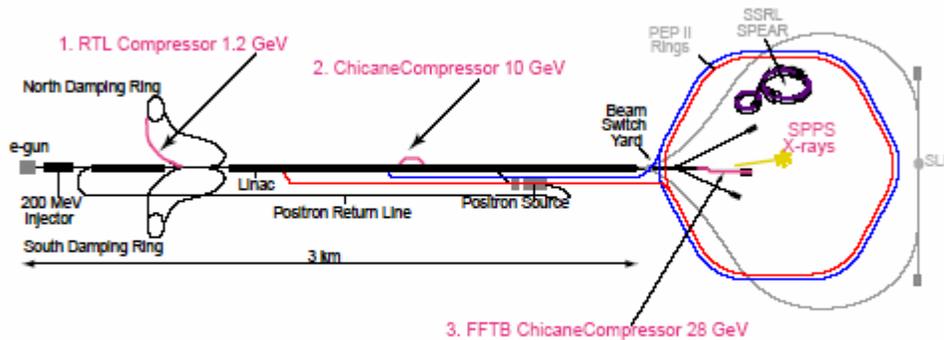


Figure 2. Layout of the SLAC accelerators showing the 3-stage bunch compression for the SPPS.

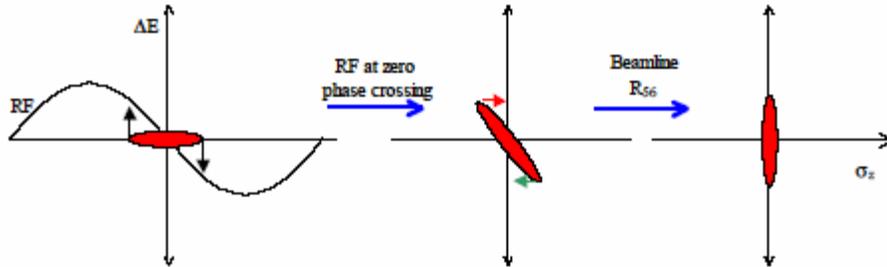


Figure 3. Schematic of ideal bunch compression where the bunch is given a correlated energy spread from head to tail followed by transport through a dispersive section whose path length varies with energy (as in Figure 4).

Krejcik et al.
 21st ICFA Beam Dynamics Workshop on
 Laser-Beam Interactions, June 11-15, 2001
 at Stony Brook USA

Atomic-Scale Visualization of Inertial Dynamics

A. M. Lindenberg,¹ J. Larsson,² K. Sokolowski-Tinten,³
 K. J. Gaffney,¹ C. Blome,⁴ O. Synnergren,² J. Sheppard,⁵
 C. Caleman,⁶ A. G. MacPhee,⁷ D. Weinstein,⁷ D. P. Lowney,⁷
 T. K. Allison,⁷ T. Matthews,⁷ R. W. Falcone,⁷ A. L. Cavalieri,⁸
 D. M. Fritz,⁸ S. H. Lee,⁸ P. H. Bucksbaum,⁸ D. A. Reis,⁸ J. Rudati,⁹
 P. H. Fuoss,¹⁰ C. C. Kao,¹¹ D. P. Siddons,¹¹ R. Pahl,¹²
 J. Als-Nielsen,¹³ S. Duesterer,⁴ R. Ischebeck,⁴ H. Schlarb,⁴
 H. Schulte-Schrepping,⁴ Th. Tschentscher,⁴ J. Schneider,⁴
 D. von der Linde,¹⁴ O. Hignette,¹⁵ F. Sette,¹⁵ H. N. Chapman,¹⁶
 R. W. Lee,¹⁶ T. N. Hansen,² S. Teichert,¹⁷ J. S. Wark,⁵ M. Bergh,⁶
 G. Huldt,⁶ D. van der Spoel,⁶ N. Timneanu,⁶ J. Hajdu,⁶
 R. A. Akre,¹⁸ E. Bong,¹⁸ P. Krejcik,¹⁸ J. Arthur,¹ S. Brennan,¹
 K. Luening,¹ J. B. Hastings¹

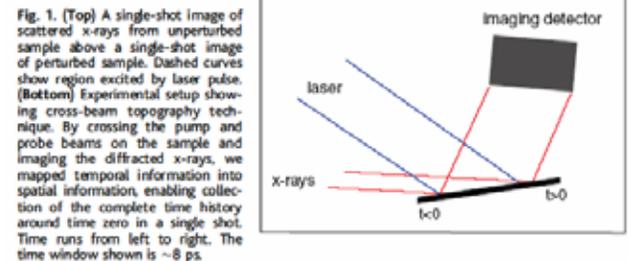
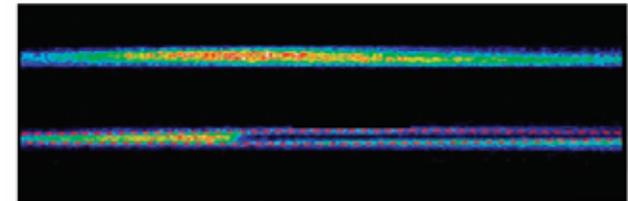
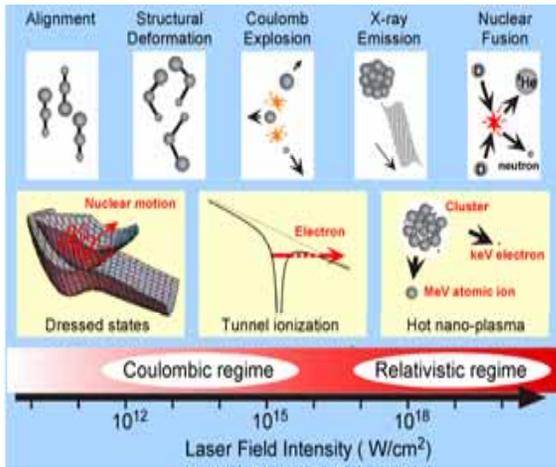


Fig. 1. (Top) A single-shot image of scattered x-rays from unperturbed sample above a single-shot image of perturbed sample. Dashed curves show region excited by laser pulse. (Bottom) Experimental setup showing cross-beam topography technique. By crossing the pump and probe beams on the sample and imaging the diffracted x-rays, we mapped temporal information into spatial information, enabling collection of the complete time history around time zero in a single shot. Time runs from left to right. The time window shown is ~ 8 ps.

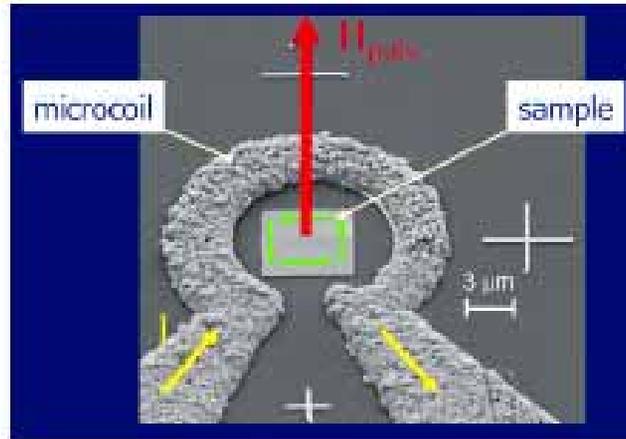
Lindenberg et al.
 Science (2005) 308, 392.

原子·分子

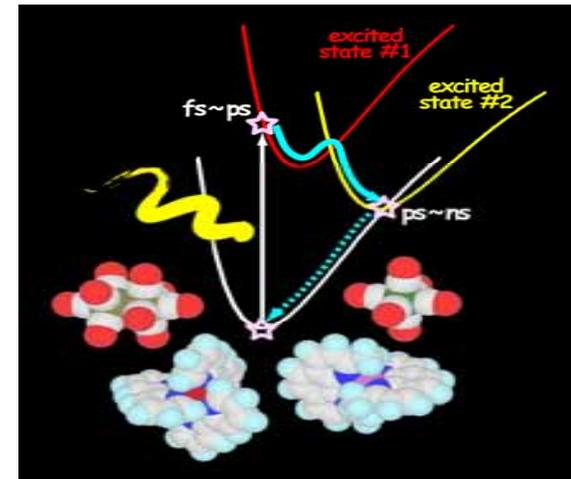


K. Yamanouchi, Science **295**, 1659 (2002).

XMCD, PEEM

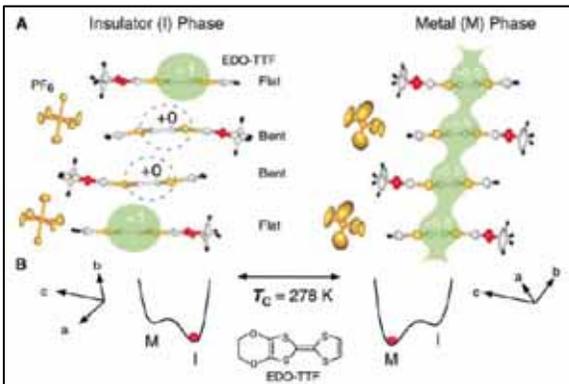


XAFS



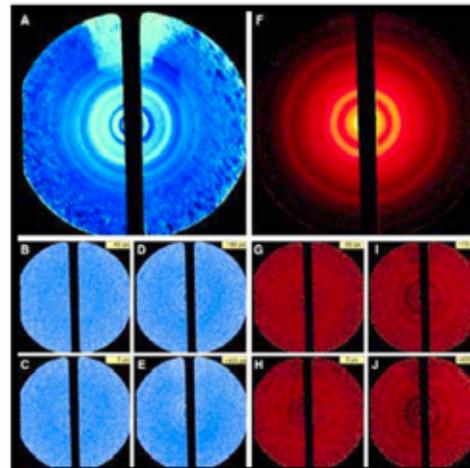
Time Domain Science with SR

構造物性



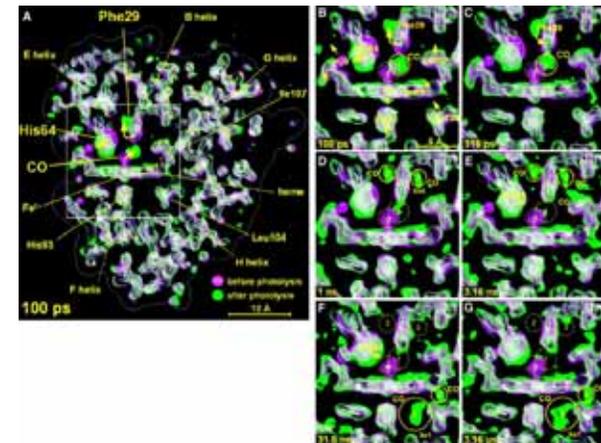
Chollet et al. (2005) Science **307**, 86

小角散乱



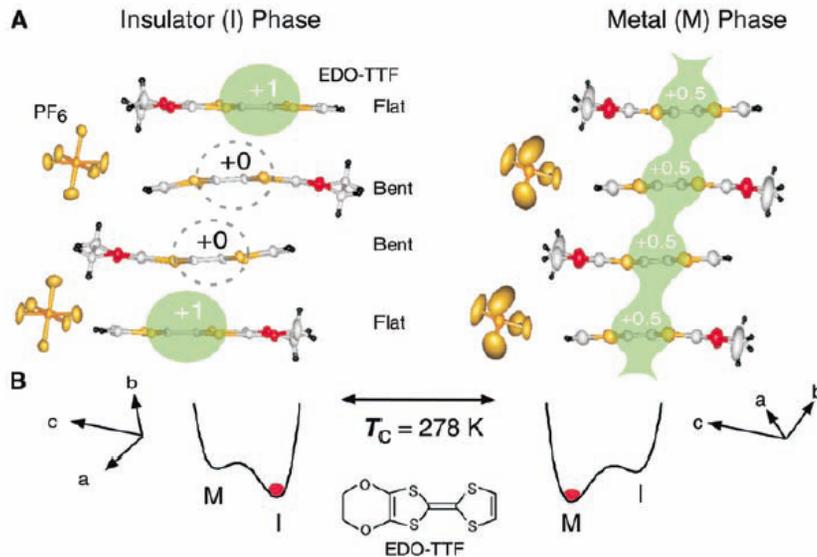
Ihee, et al., (2001) Science **291**, 458.

構造生物



Schotte et al.(2003) Science **300**, 1944

構造物性分野：光誘起結晶ダイナミクス



Chollet et al. (2005) Science 307, 86

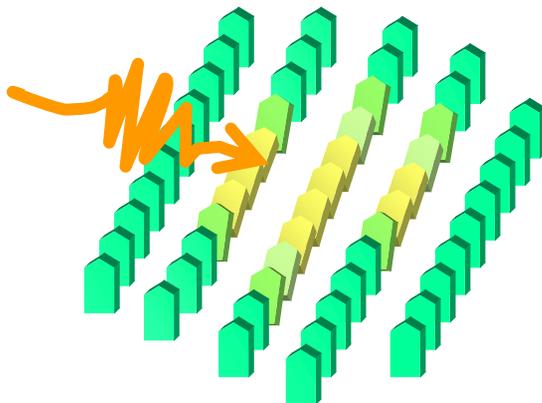
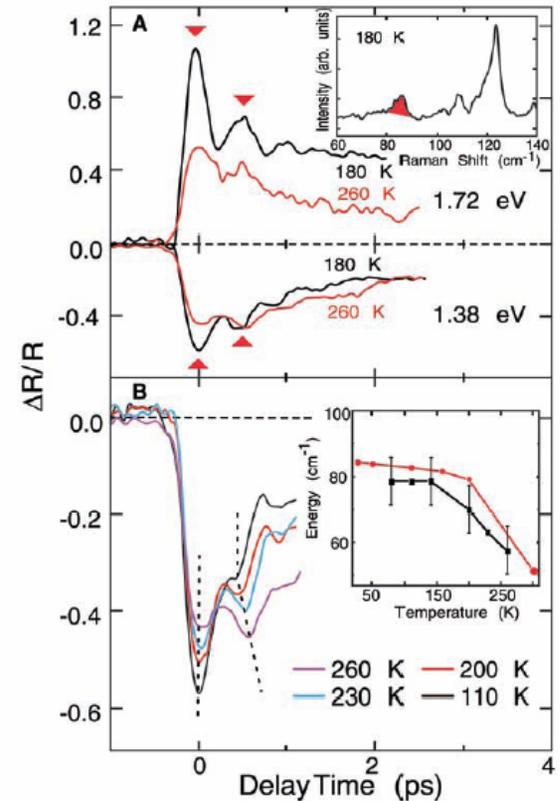


Fig. 3. (A) Probe photon energy dependence of the time profile for the $\Delta R/R$ observed at 180 K (black lines) and 260 K (red lines). The probe photon energy was 1.72 and 1.38 eV for the upper and lower panels, respectively. Triangles indicate the peak positions due to the vibratile structure observed at 180 K. (Inset) Raman spectrum in the low-energy region for the I phase observed at 180 K. Temperature dependence of the Raman shift energy for the red-colored mode is plotted in the inset of (B). (B) Temperature dependence of the time profile for the $\Delta R/R$ observed at 1.38 eV. (Inset) Temperature dependence of the Raman shift for the red-colored mode in the inset of (A) and that for the vibratile frequency estimated from the time profile of $\Delta R/R$ (black squares). Error bars (mean \pm SE) show the observed data fluctuations changing the sample crystal. The red and black lines serve as an eye guide.



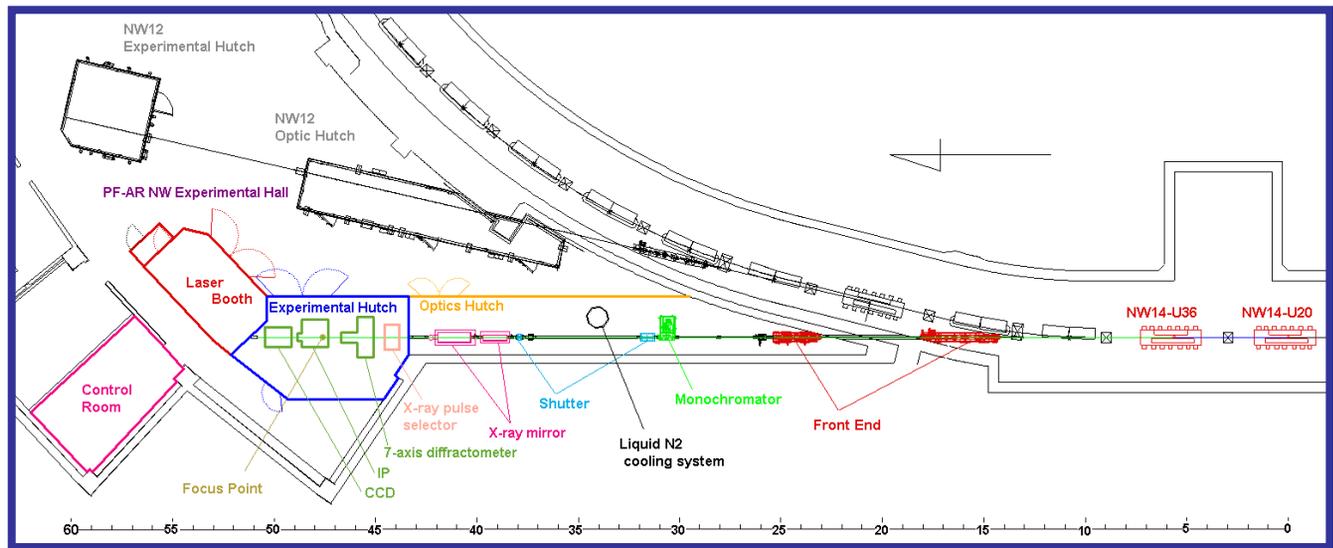
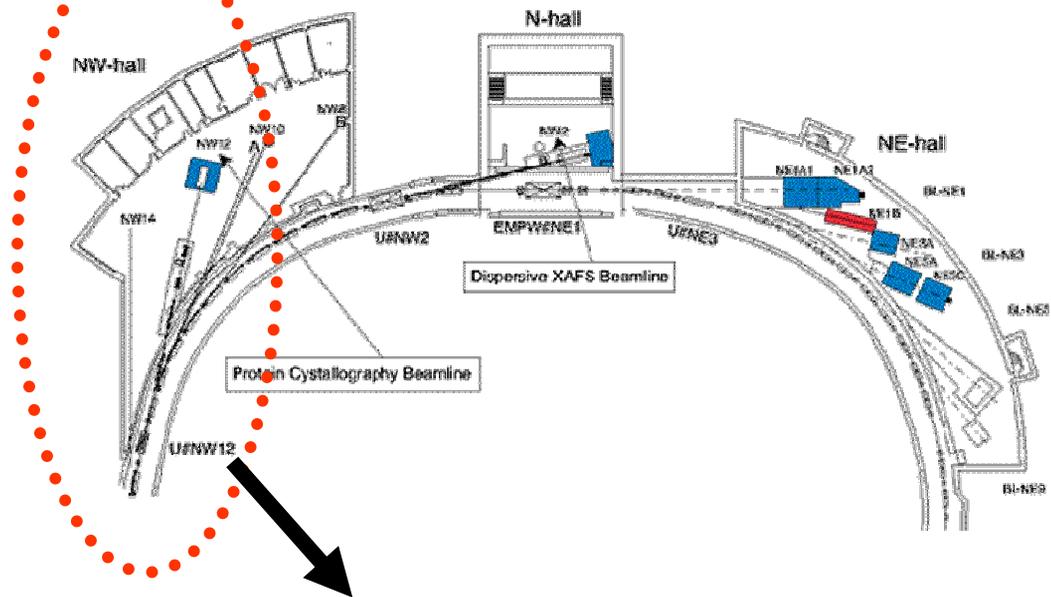
放射光要求仕様：

エネルギー： 5 keV – 20 keV

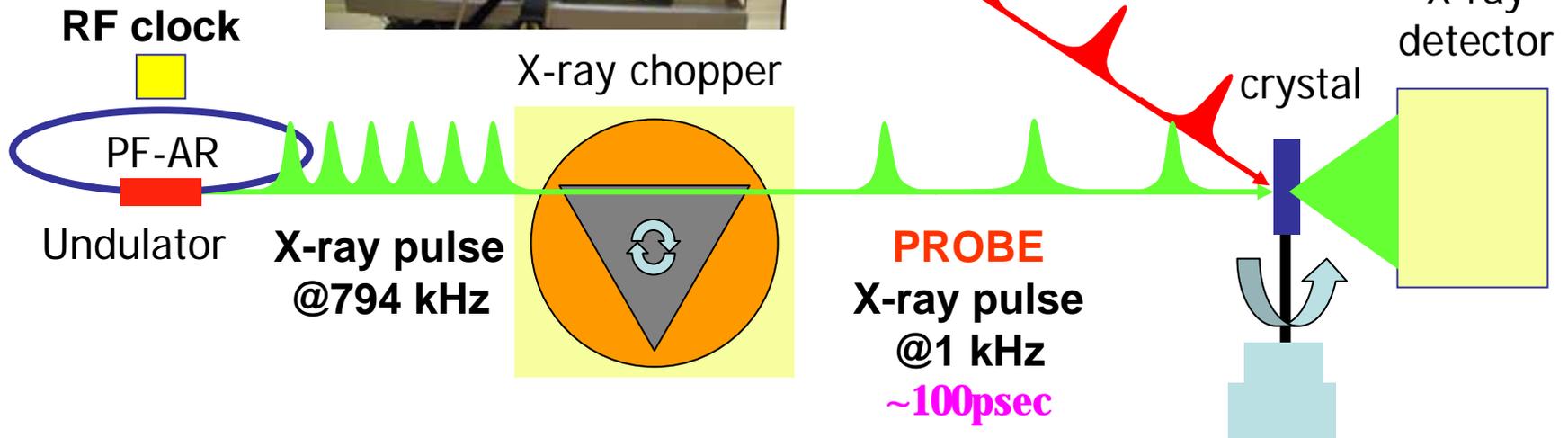
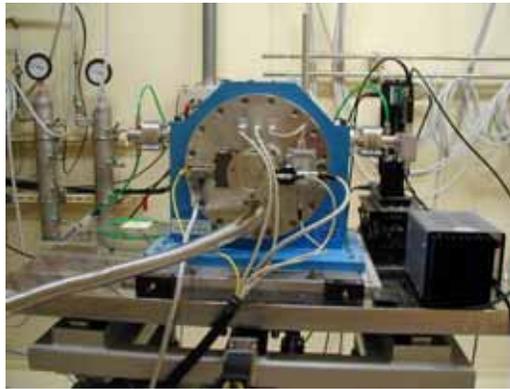
パルス幅： 1 ps – 100 fs

繰り返し周波数： 1 kHz – 1 MHz

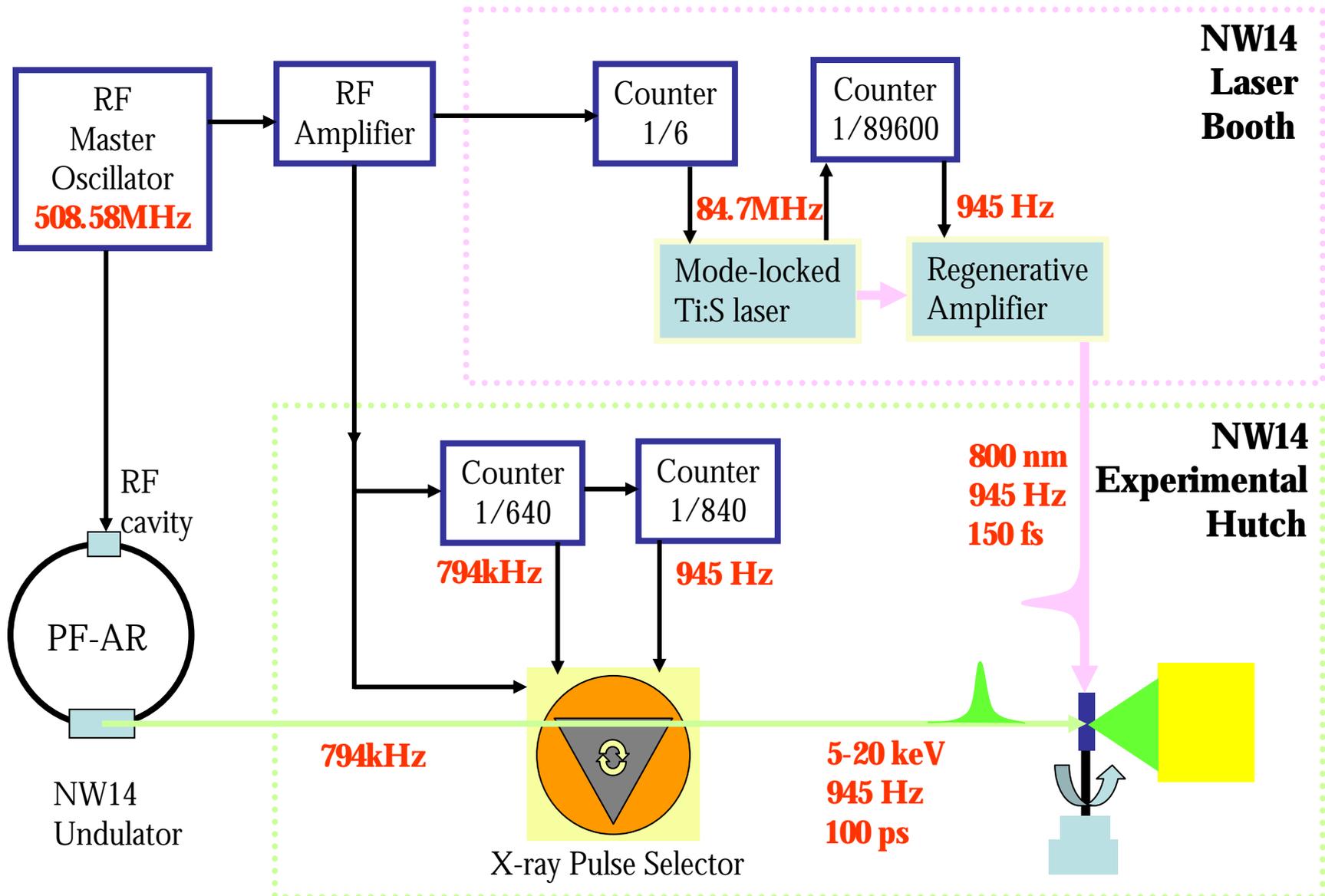
100ピコ秒時間分解X線回折実験 ビームラインNW14



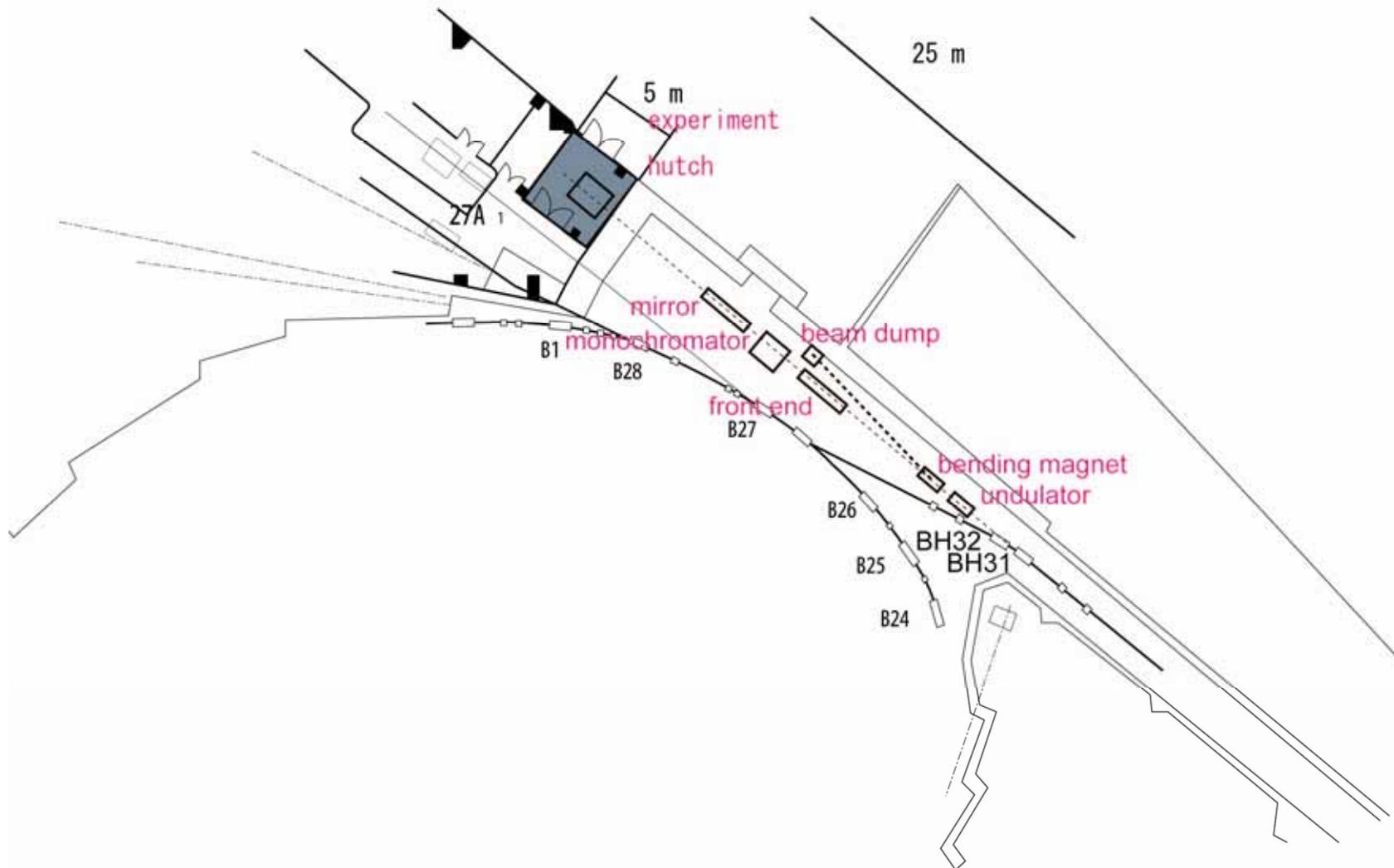
Pump-probe X-ray diffraction at PF-AR NW14A



Timing diagram



PF-BT部配置図

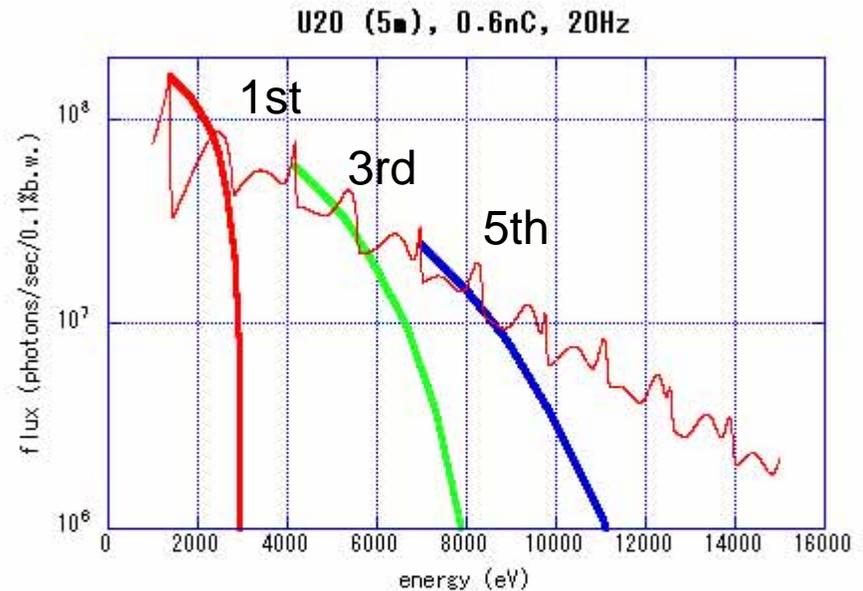


PF-ARシングルバンチとピコ秒運転モードの パラメータ比較

Parameters	PF-AR SB	PF-BT PS
Electron energy (GeV)	6.5	2.5
Average current (mA)	60 (75nC, 794kHz)	1.2×10^{-5} (0.6nC, 20Hz)
Natural emittance (nmrad)	293	160
Coupling	0.01	1
Bunch	1	1
σ_t (psec)	50	1

アンジュレータ(周期長20mm)の パラメータとスペクトル 2.5GeV、0.6nC、20Hz運転時

Parameters	
Periodic length (mm)	20
Number of Periods	75
Total Length (m)	5.0
Kmax	1.5
Minimum gap (mm)	5



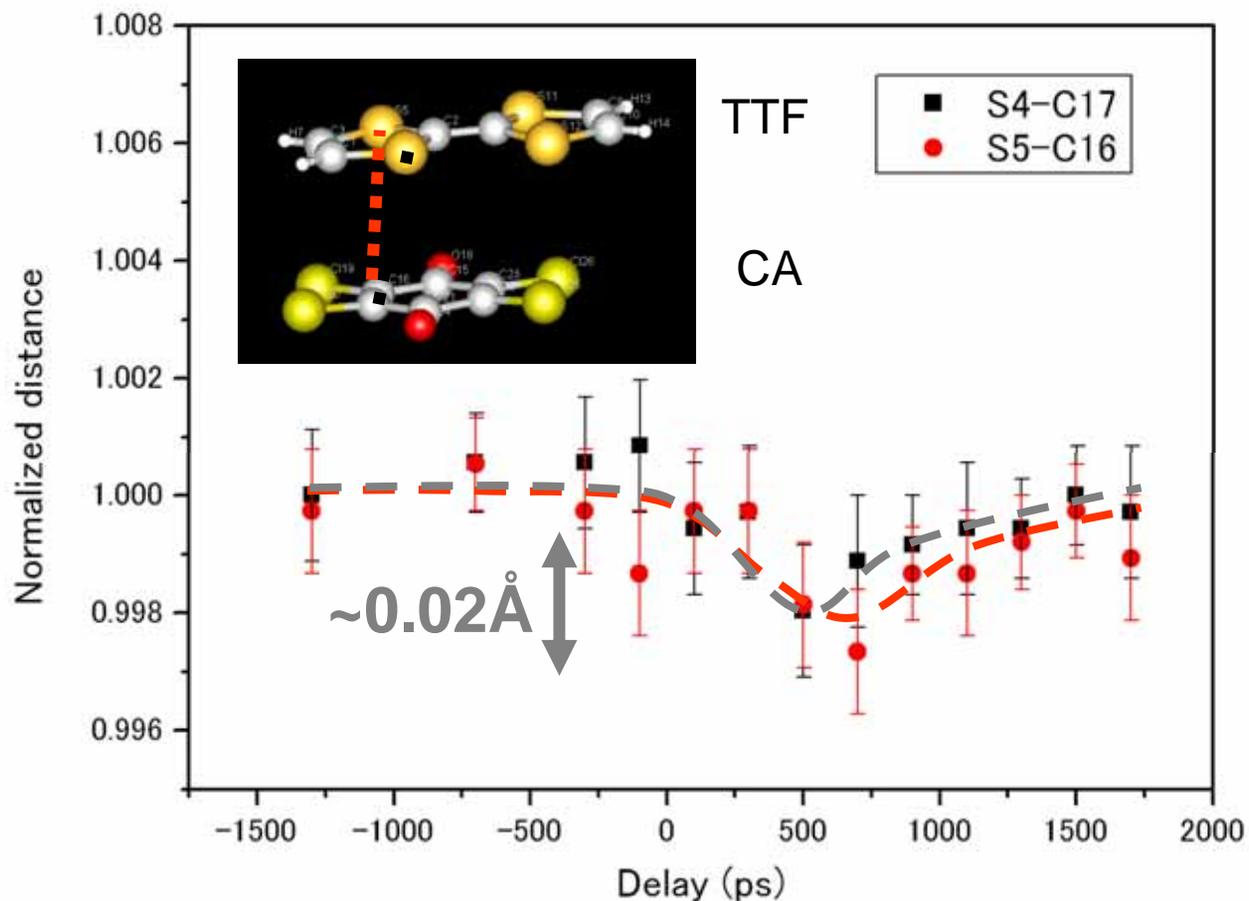
各測定モードで利用可能な光子数と 実現可能な測定

PF-AR	パルス 繰り返し	間引き	試料上でのフラックス (1-10keV)	測定
単色	794kHz	なし	$\sim 10^{12}$ phs/sec/0.01%b.w.	定常状態構造解析(パルス性を使わない実験)
白色	794kHz	なし	$\sim 10^{15}$ phs/sec/10%b.w.	大強度白色実験 エネルギー分散型XAFS
単色	1kHz	あり	$\sim 10^9$phs/sec/0.01%b.w.	1kHzのフェムト秒レーザーと組み合わせた時間分解単色実験。1kHzで可逆的に変化する試料に限られる。(現在NW14で行っている測定の大部分を占める。)
白色	1kHz	あり	$\sim 10^{12}$ phs/sec/10%b.w.	1kHz時間分解白色実験 1kHzの繰り返し可能な試料
PF-BT				
単色	25Hz	なし	$\sim 10^6$ phs/sec/0.01%b.w. $\sim 10^5$ phs/pulse/0.01%b.w.	25Hz時間分解白色実験。1kHz以下25Hzまでの繰り返し可能な試料。光子数が不足?
白色	25Hz	なし	$\sim 10^9$phs/sec/10%b.w. $\sim 10^8$phs/pulse/10%b.w.	25Hz時間分解白色実験 1kHz以下25Hzまでの繰り返し可能な試料

まとめ

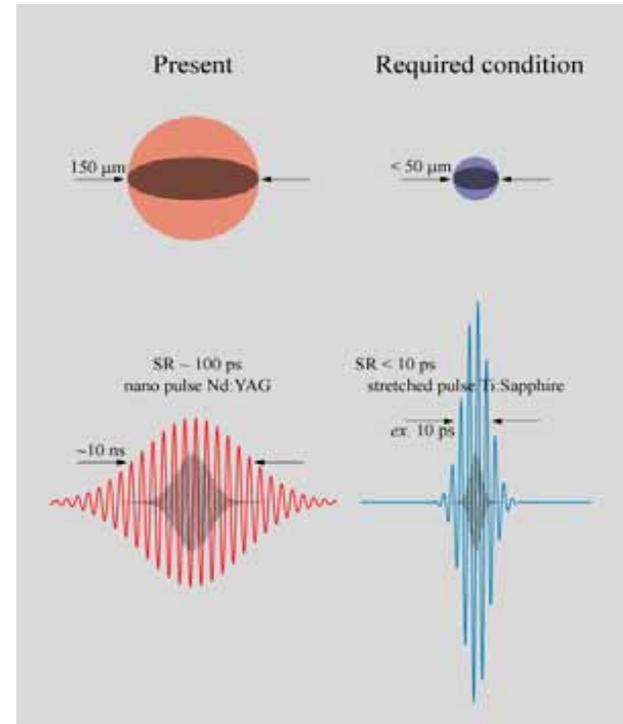
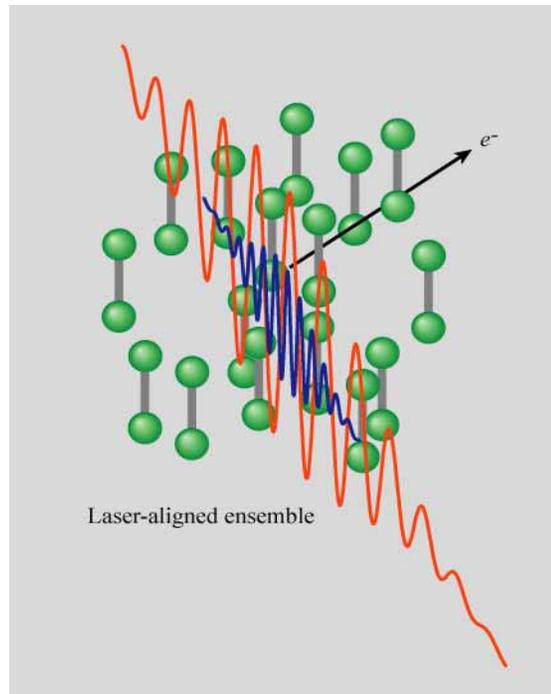
- PF-BT部は、現有の施設を利用して実現可能なピコ秒短パルス放射光光源として魅力あり。
- ただし、繰り返し、平均輝度が低く、AR等で我々が通常行っているような短バンチ時間分解実験には向かない。
- SLACのSPPSと同等な実験はできるだろう。
- エネルギーバンド幅を広げてできる実験(白色回折・エネルギー分散XAFS)がまずは有望か。

TTF分子とCA分子間の 原子間距離の時間依存性



原子分子分野：強光子場中の分子ダイナミクス

- 強光子場科学の展開における高輝度短パルスX線・軟X線源の役割



(資料提供：足立純一氏)

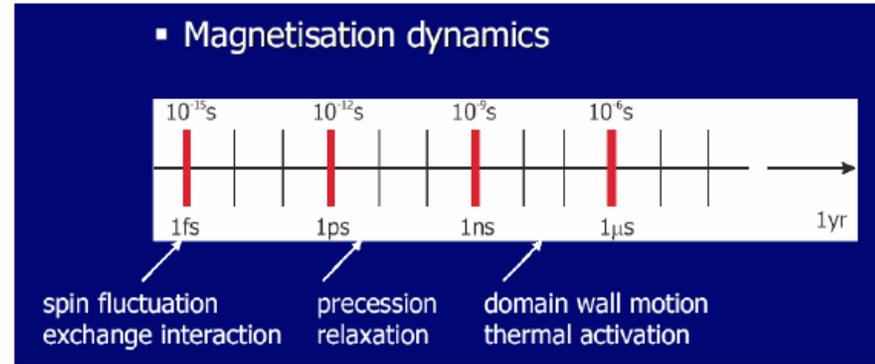
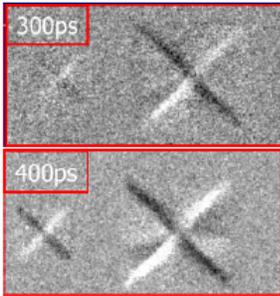
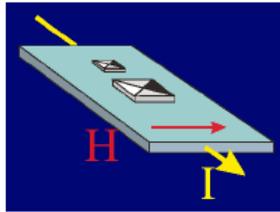
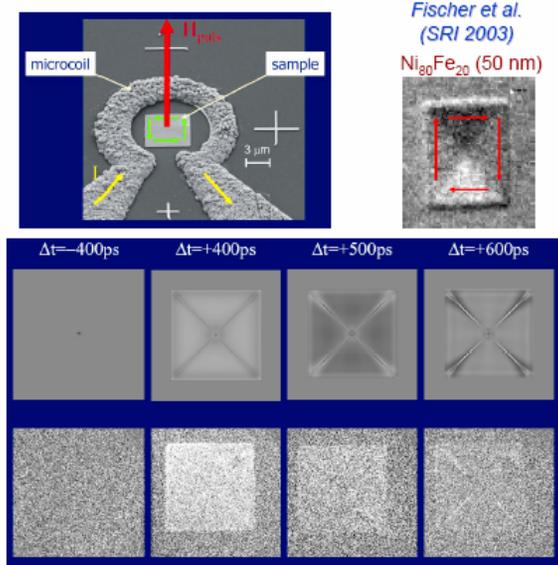
放射光要求仕様：

エネルギー： 50 eV – 1000 eV

パルス幅： 10 ps – 100 fs

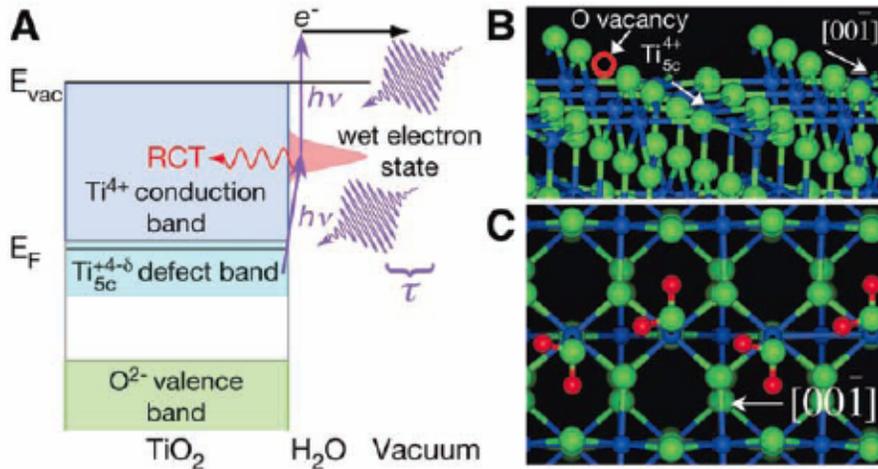
繰り返し周波数： 1 kHz – 1 MHz

XMCD, PEEM分野: 磁化・固体表面ダイナミクス



- **Present:** sub-ns magnetic pump-probe, coherent scattering (Goedkoop et al., SRI 2003) XMCD imaging (Fischer et al., SRI 2003)
- **Future:** spin dynamics in fs regime?

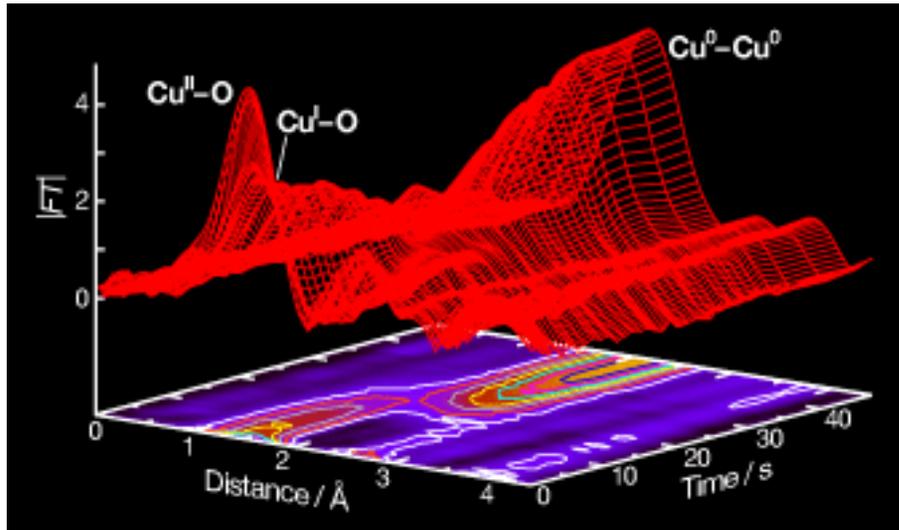
Fischer et al. (SRI2003)



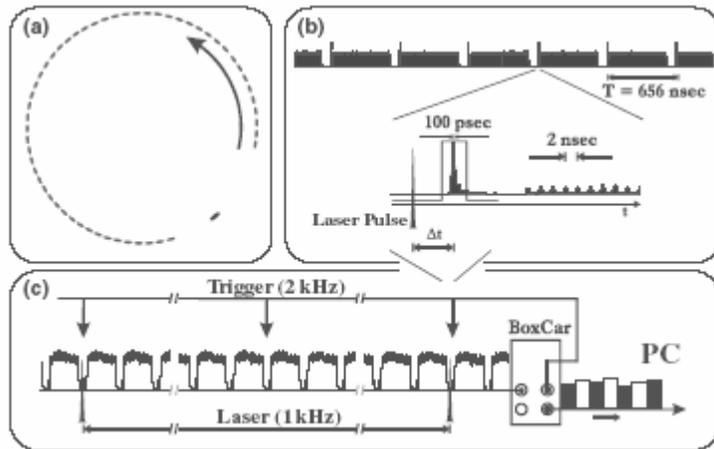
Onda et al. Science 308 (2005) 1154

放射光要求仕様:
エネルギー: 100 eV – 10 keV
パルス幅: 100 ps – 100 fs
繰り返し周波数: 1 kHz – 1 MHz

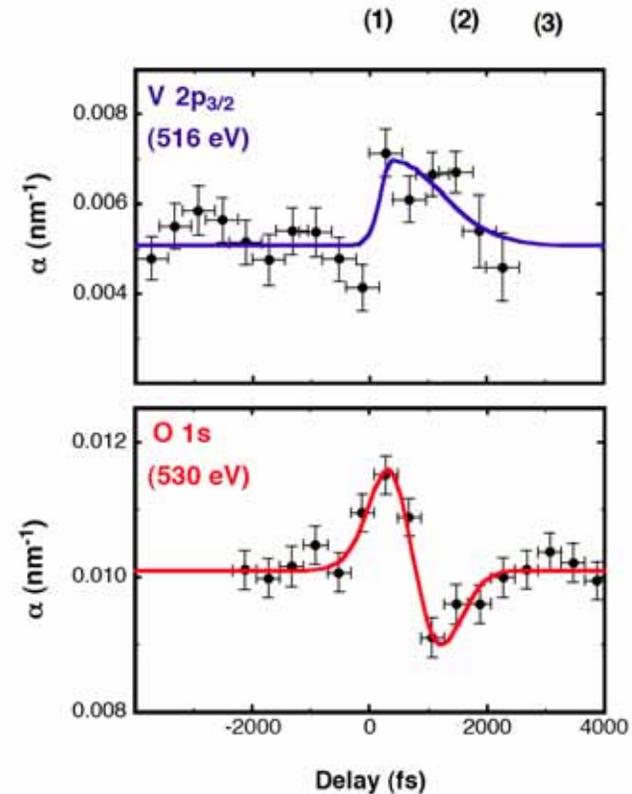
XAFS分野：高速反応ダイナミクスへの適用



(資料提供：稲田康宏氏)



Saes et al. (2003) PRL 90, 04743-1



A.Cavalleri et.al., Phys.Rev.Lett. in press.

放射光要求仕様：

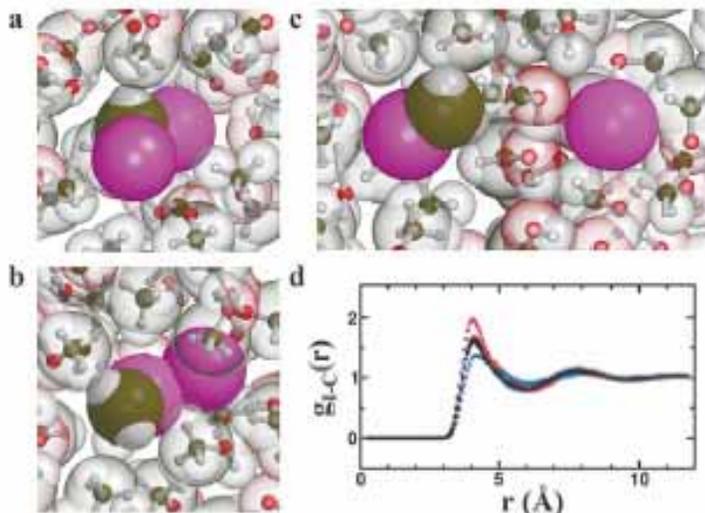
エネルギー：100 eV – 30 keV

パルス幅：100 ps – 100 fs

繰り返し周波数：1 kHz – 1 MHz

小角散乱分野：溶液反応ダイナミクス

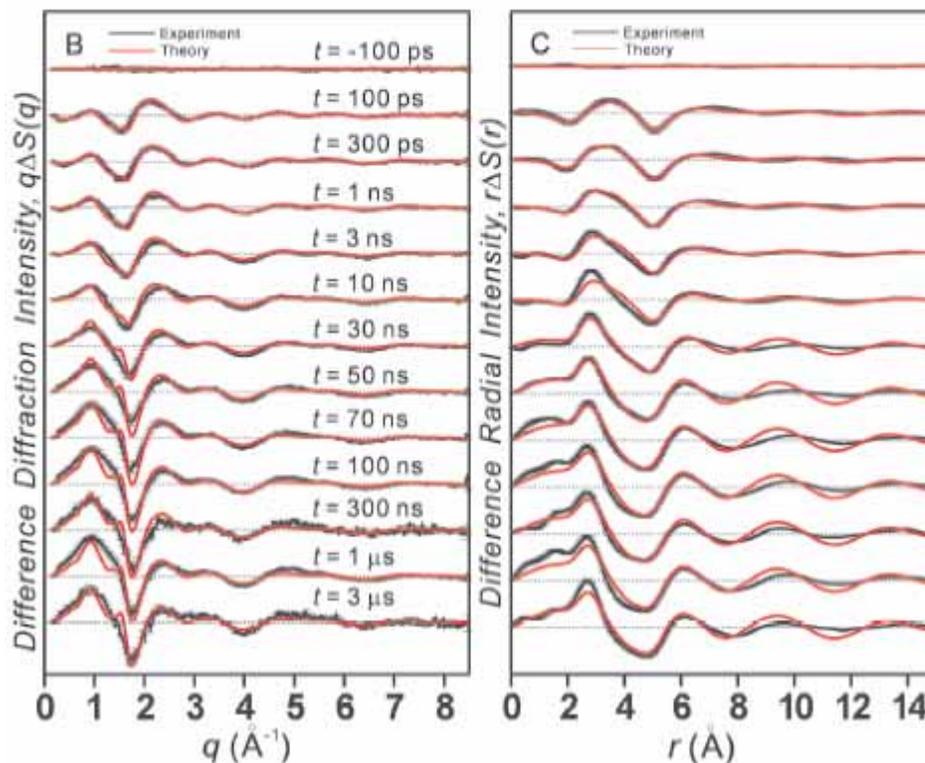
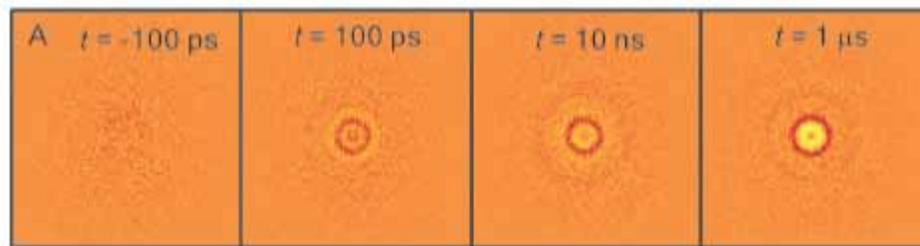
CH₂I₂ in methanol



Davidsson et al. (2005) PRL, **94**, 245503

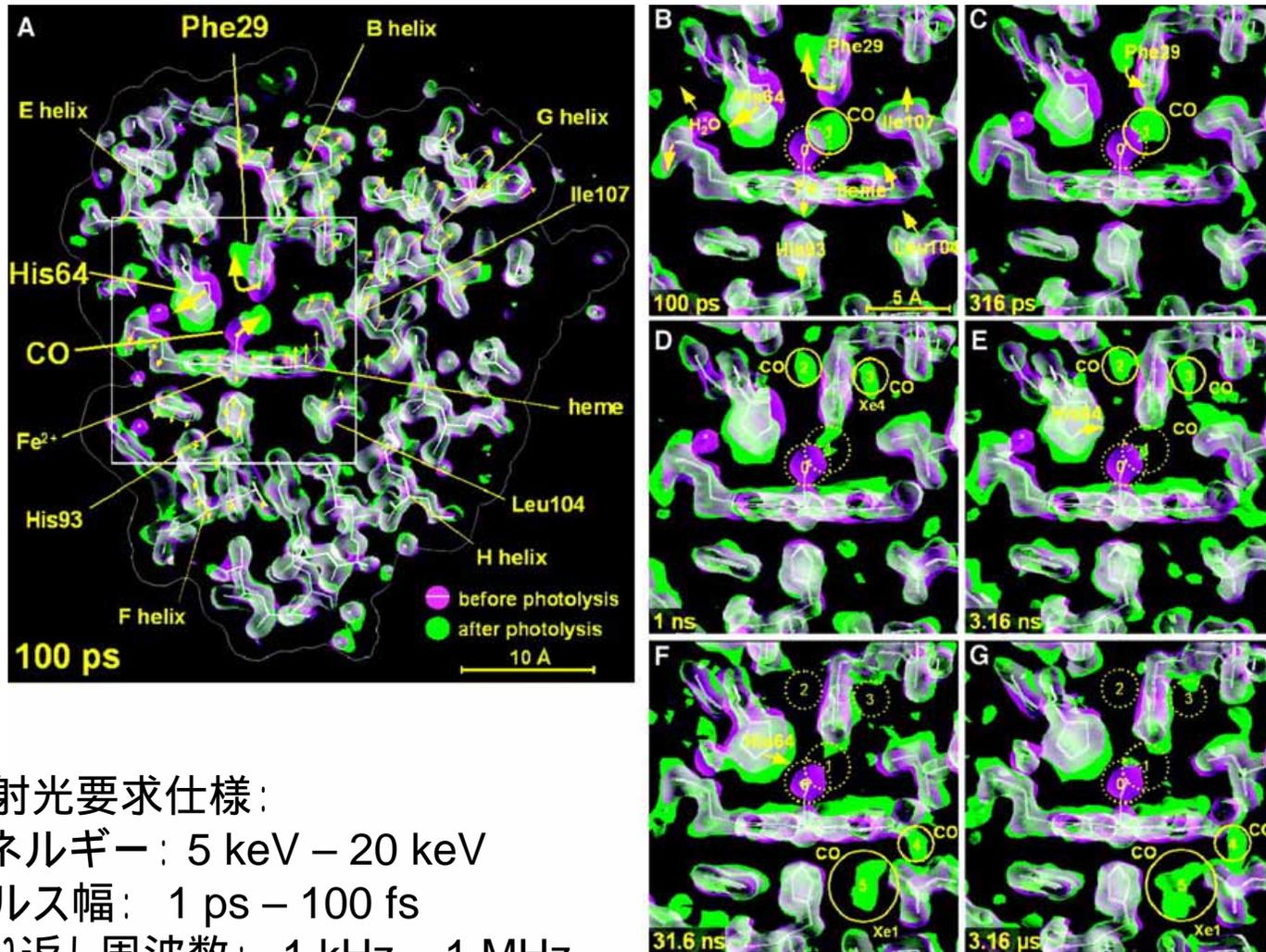
放射光要求仕様：
 エネルギー：10 keV - 20 keV
 パルス幅：1 ps - 100 fs
 繰り返し周波数：1 kHz - 1 MHz

C₂H₄I₂ in methanol



Ihee et al. Science (2005) in press

構造生物分野：光反応性タンパク質の 構造ダイナミクス



放射光要求仕様：
エネルギー： 5 keV – 20 keV
パルス幅： 1 ps – 100 fs
繰り返し周波数： 1 kHz – 1 MHz