Hierarchical Dynamics of Soft Matters & Prospects of Japanese Future Light Sources

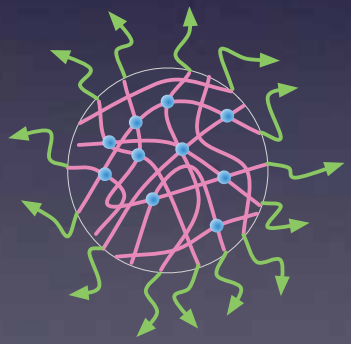
Yuya Shinohara

Department of Advanced Materials Science, Graduate School of Frontier Sciences, The University of Tokyo

yuya@k.u-tokyo.ac.jp

Soft Matter

Soft Matter



Soft Matter

Complexity & Flexibility

Soft Matter

Complexity & Flexibility

Hierarchical Structure

and

Heterogeneity

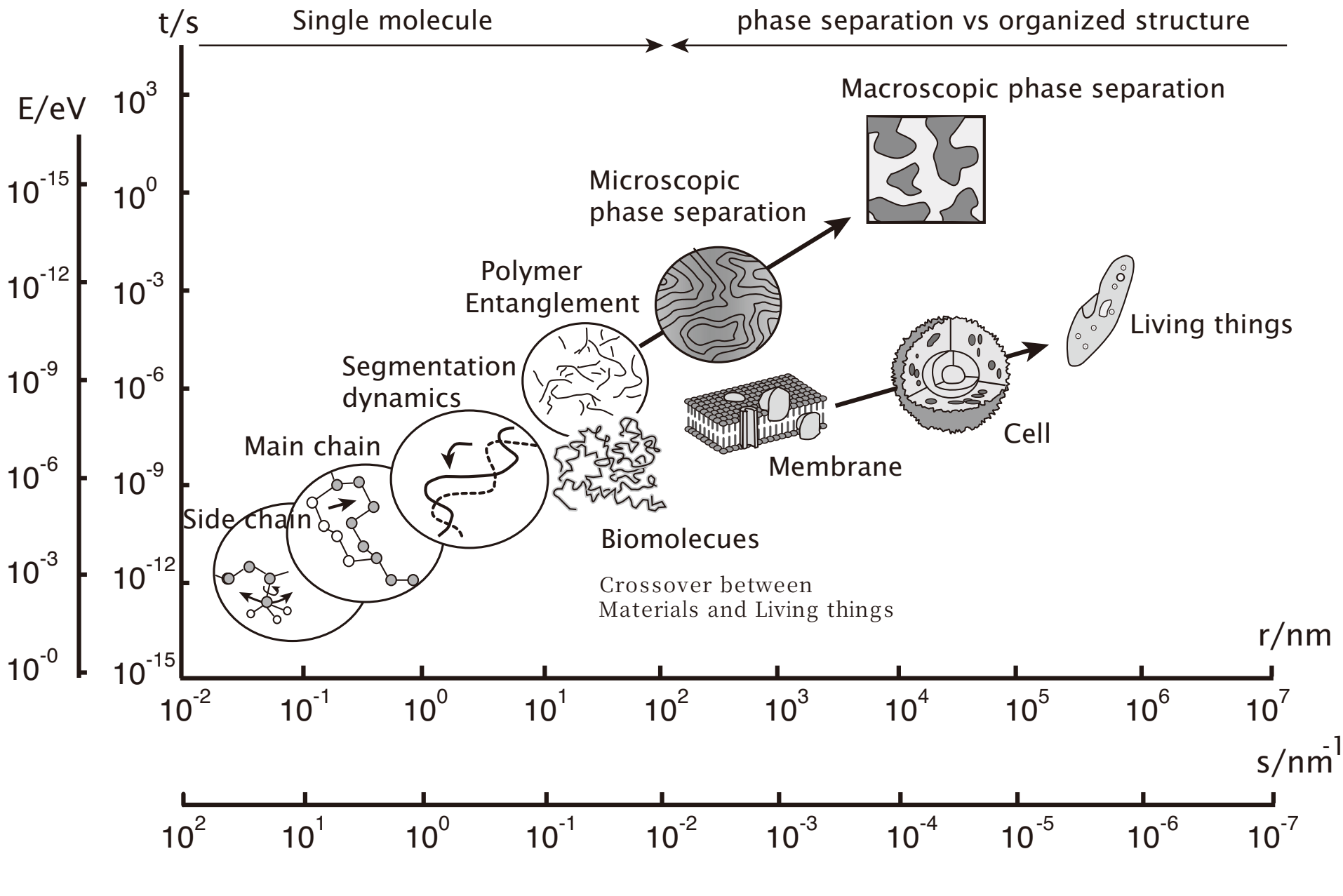
Soft Matter

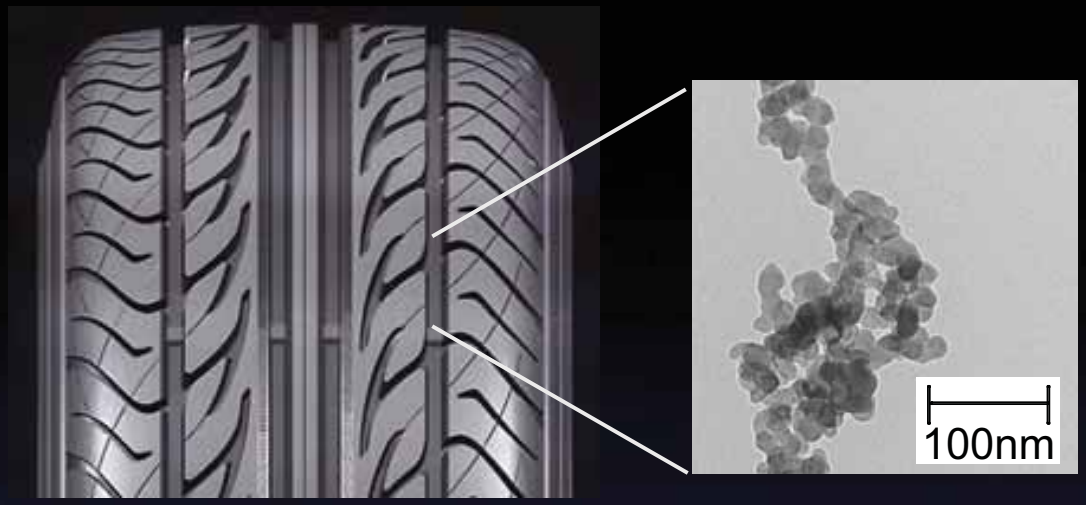
Complexity & Flexibility

Hierarchical Structure
and
Heterogeneity

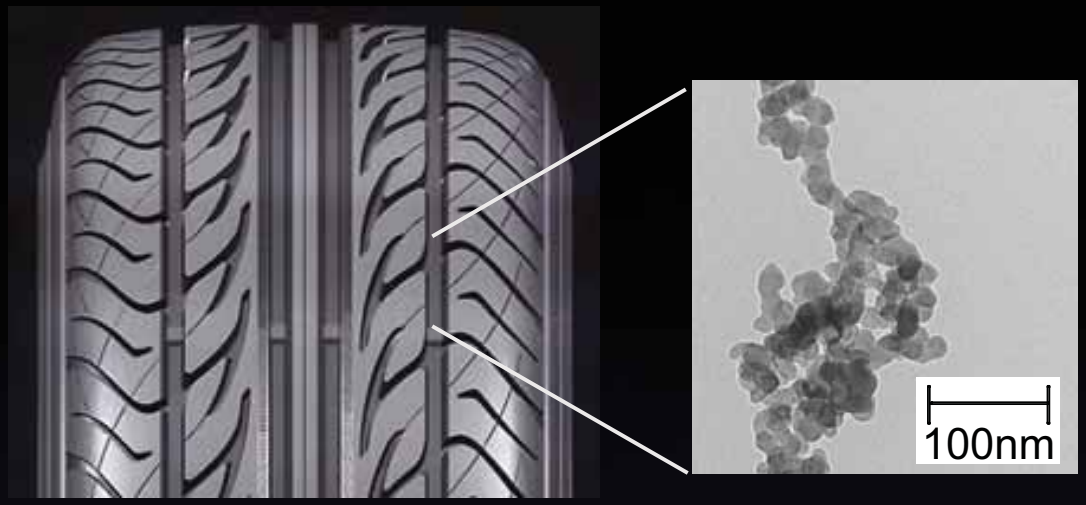
XPCS using
Future Sources

Hierarchical Structure of Soft Matter

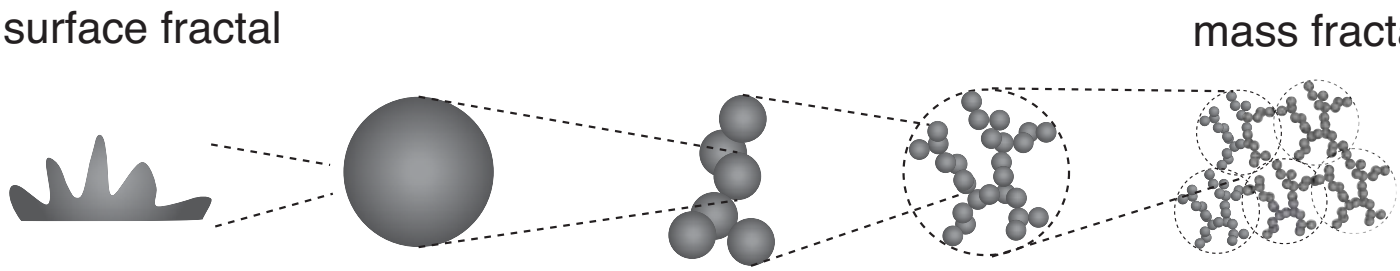


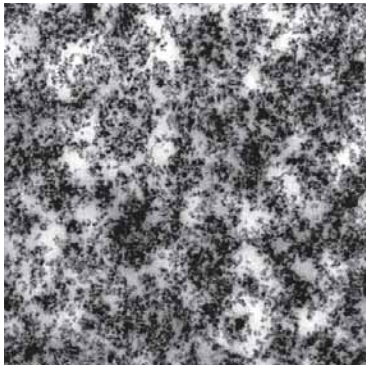


Reinforcement Effect

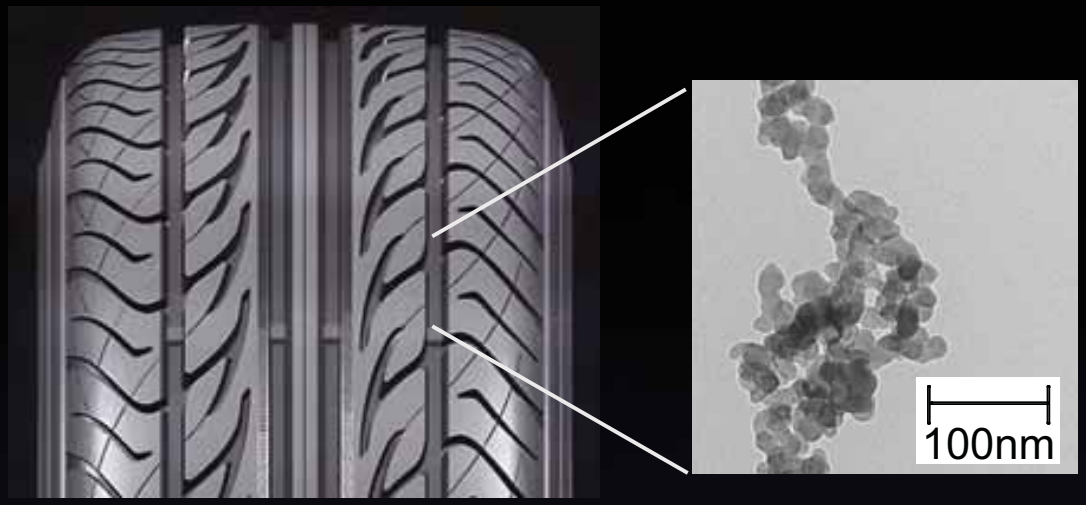


Reinforcement Effect



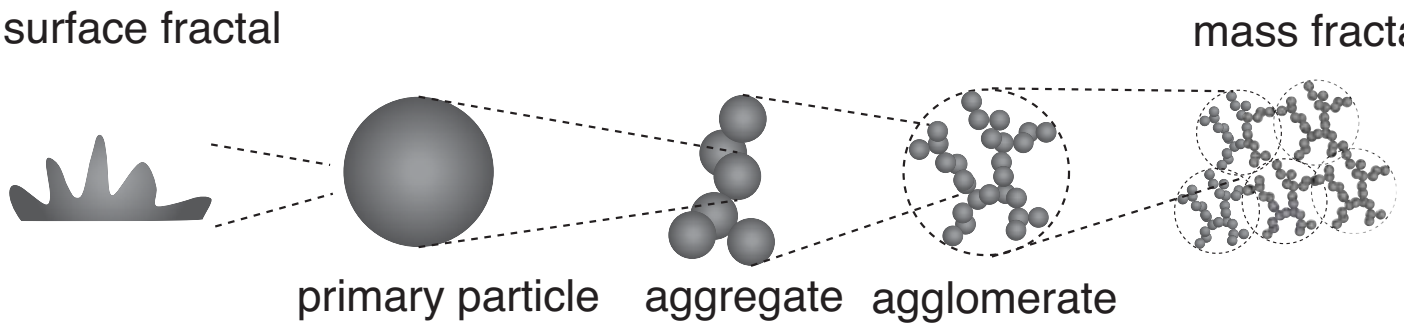


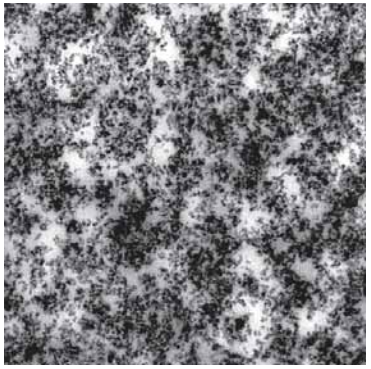
TEM Image



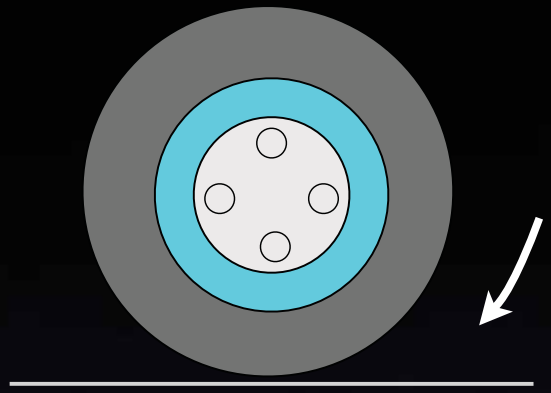
Reinforcement Effect

Time scale ?





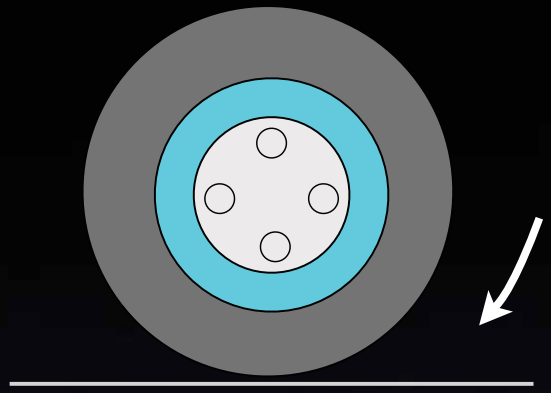
TEM Image



Rolling Resistance

(Fuel Efficiency)

60 km/h → ~ 10 Hz



Rolling Resistance

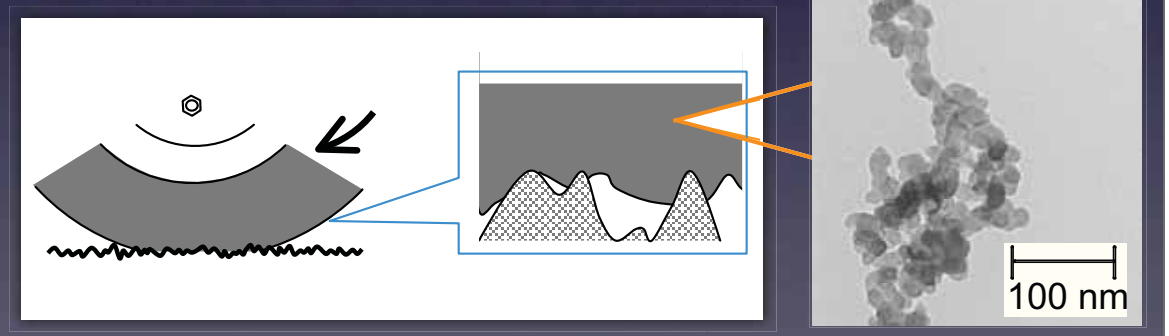
(Fuel Efficiency)

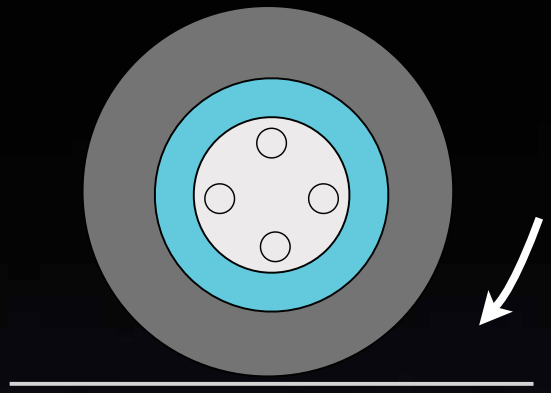
60 km/h → ~ 10 Hz

Traction Performance

@ brake, wet road surface

~ 10^4 - 10^6 Hz





Rolling Resistance

(Fuel Efficiency)

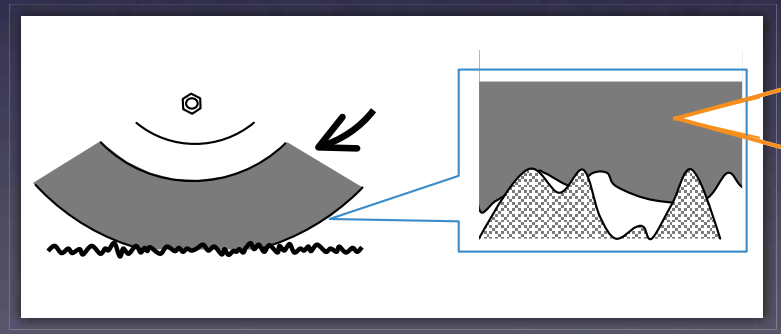
60 km/h → ~ 10 Hz

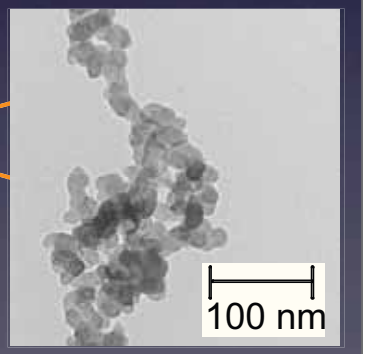
Dynamics of Particles in Different Time Scales ??

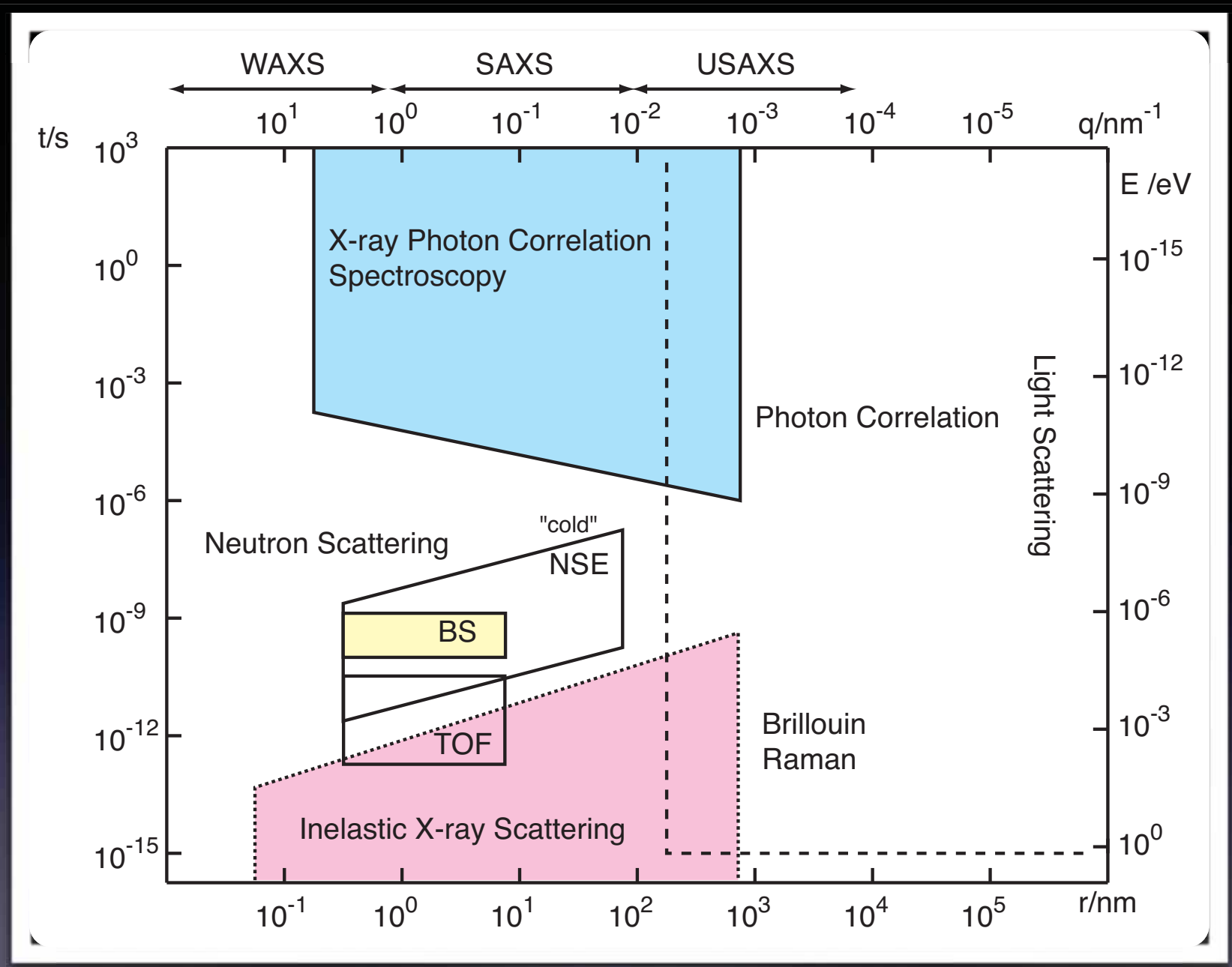
Traction Performance

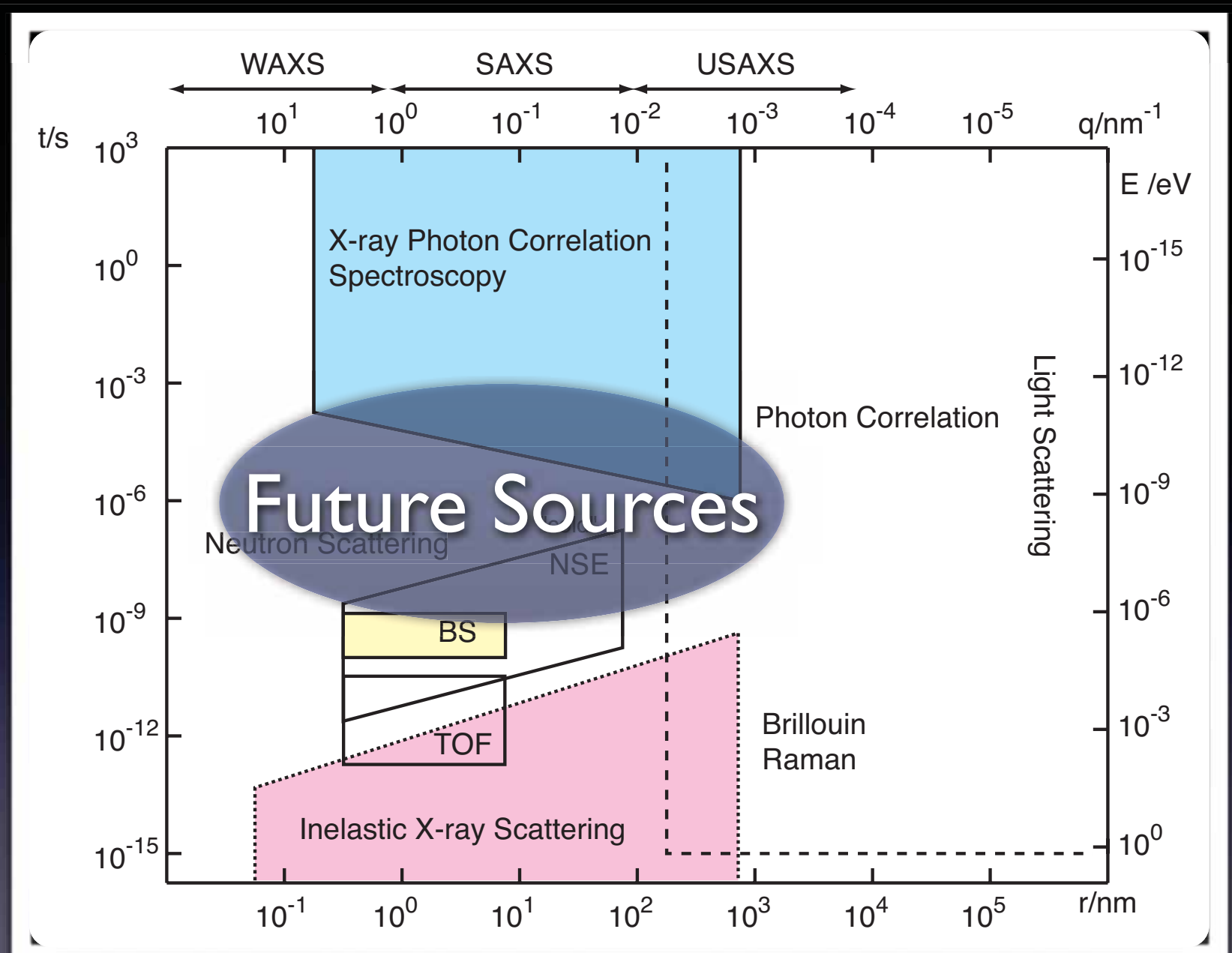
@ brake, wet road surface

~ 10^4 - 10^6 Hz

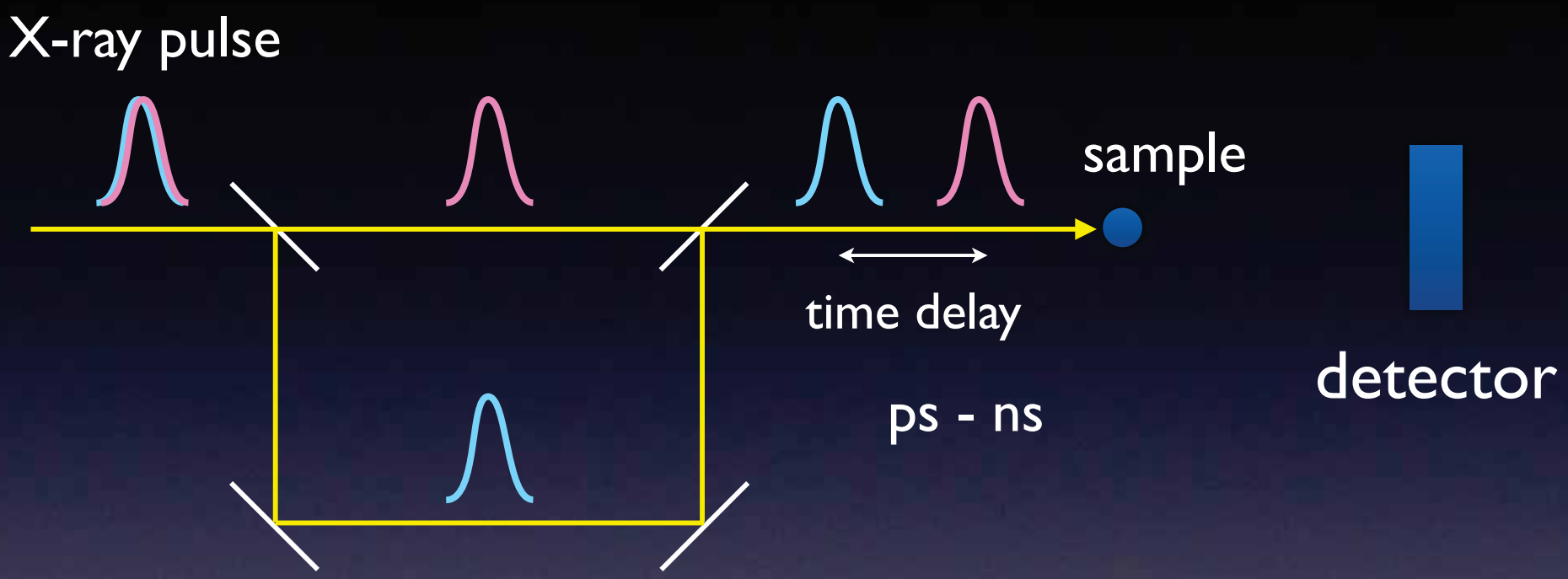




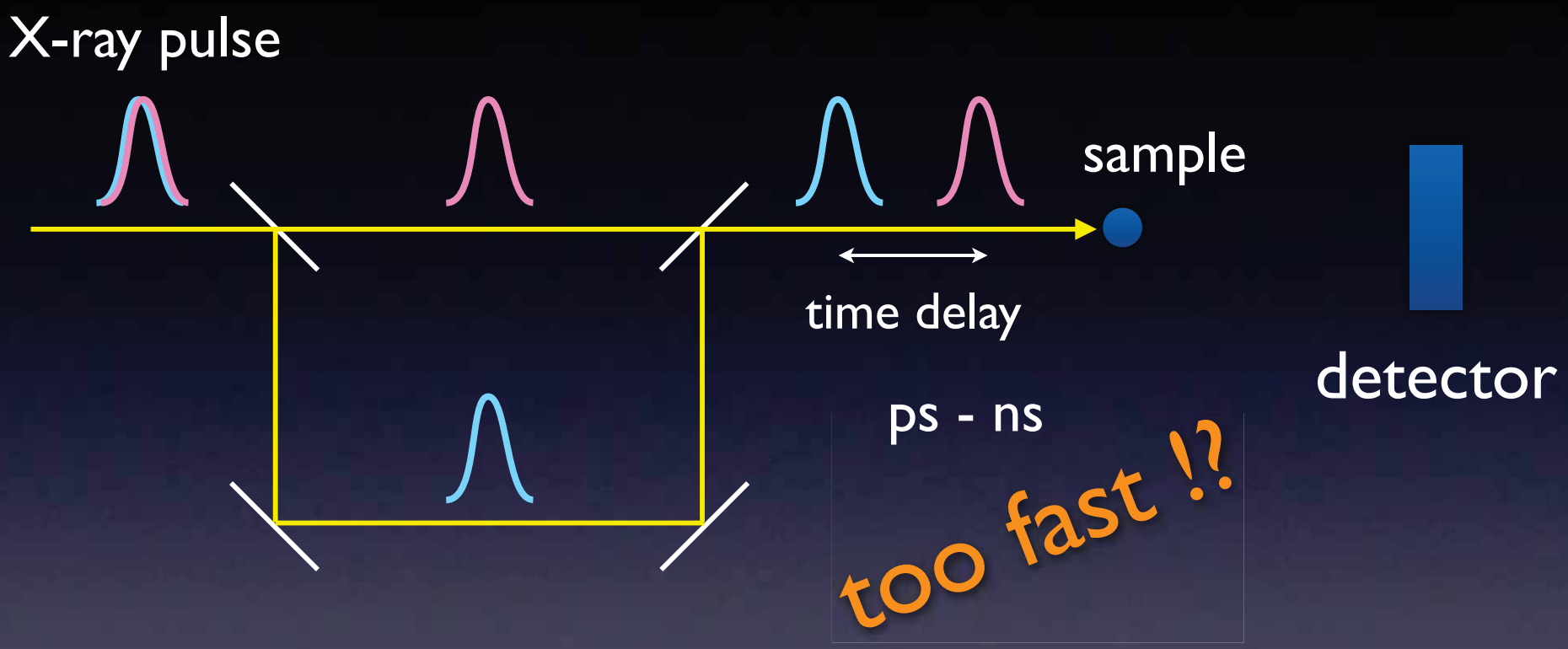

WAXS
SAXS
USAXS
t/s
q/nm^{-1}
10^{3}
10^{0}
10^{-3}
10^{-6}
10^{-9}
10^{-12}
10^{-15}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
E /eV
10^{-15}
10^{-12}
10^{-9}
10^{-6}
10^{-3}
10^{0}
X-ray Photon Correlation Spectroscopy
Photon Correlation
Light Scattering
Neutron Scattering
"cold"
NSE
BS
TOF
Brillouin
Raman
Inelastic X-ray Scattering
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
r/nm


WAXS
SAXS
USAXS
t/s
q/nm^{-1}
E /eV
r/nm
X-ray Photon Correlation Spectroscopy
Photon Correlation
Light Scattering
Future Sources
Neutron Scattering
NSE
BS
TOF
Brillouin
Raman
Inelastic X-ray Scattering

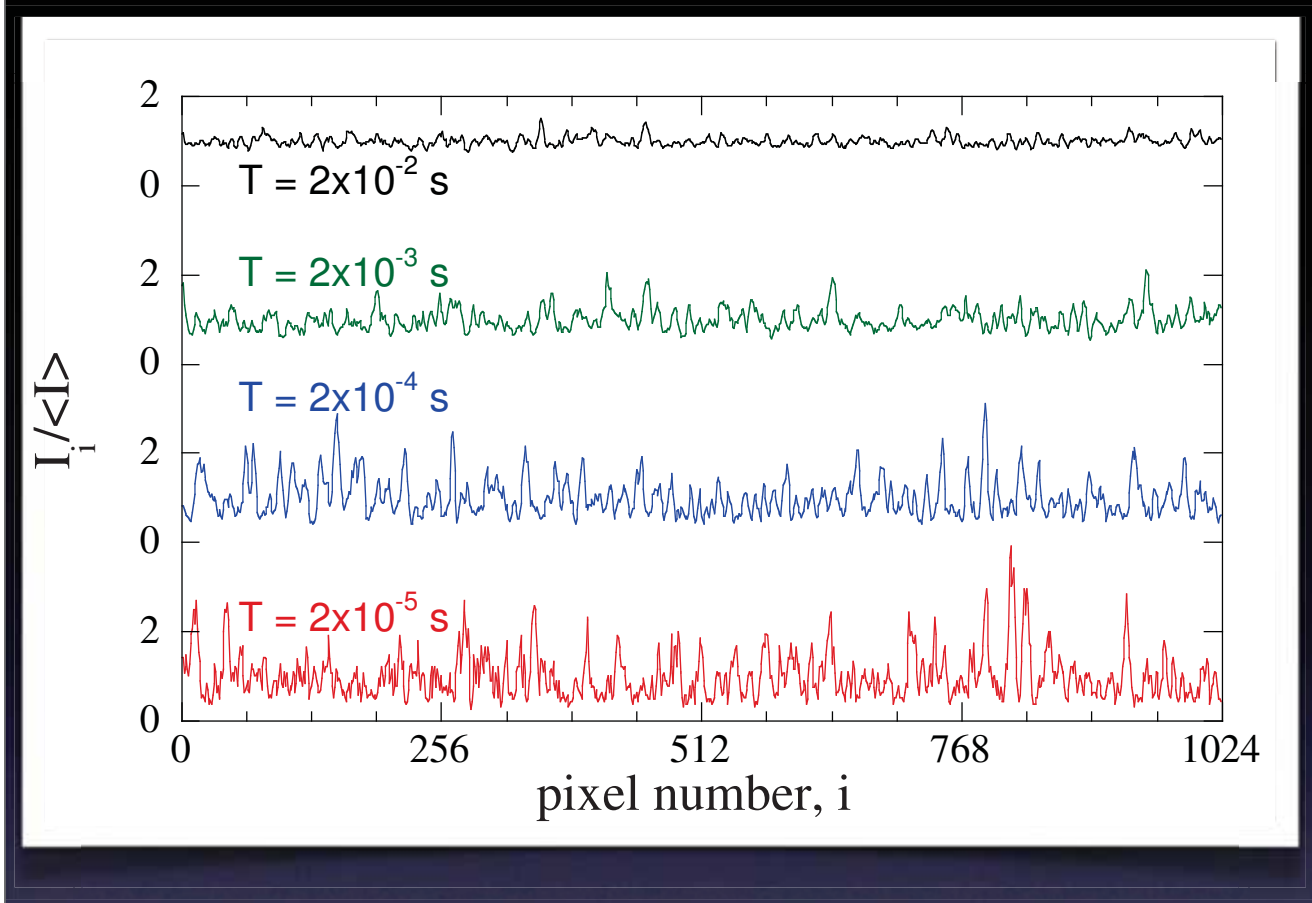
Speckle Visibility Spectroscopy with FEL



Speckle Visibility Spectroscopy with FEL



SVS with ERL



D. J. Durian et al.,

Phys. Rev. Lett. **90**, 184302 (2003).
Rev. Sci. Instrum. **76**, 093110 (2005)

Changing Exposure Time --> Change in Visibility of Speckle Patterns

Continuous Source --> XPCS in milli-, micro- & nano-seconds !!

important for Soft Matter Science

XPCS in milli-, micro- & nano-seconds

XPCS in milli-, micro- & nano-seconds

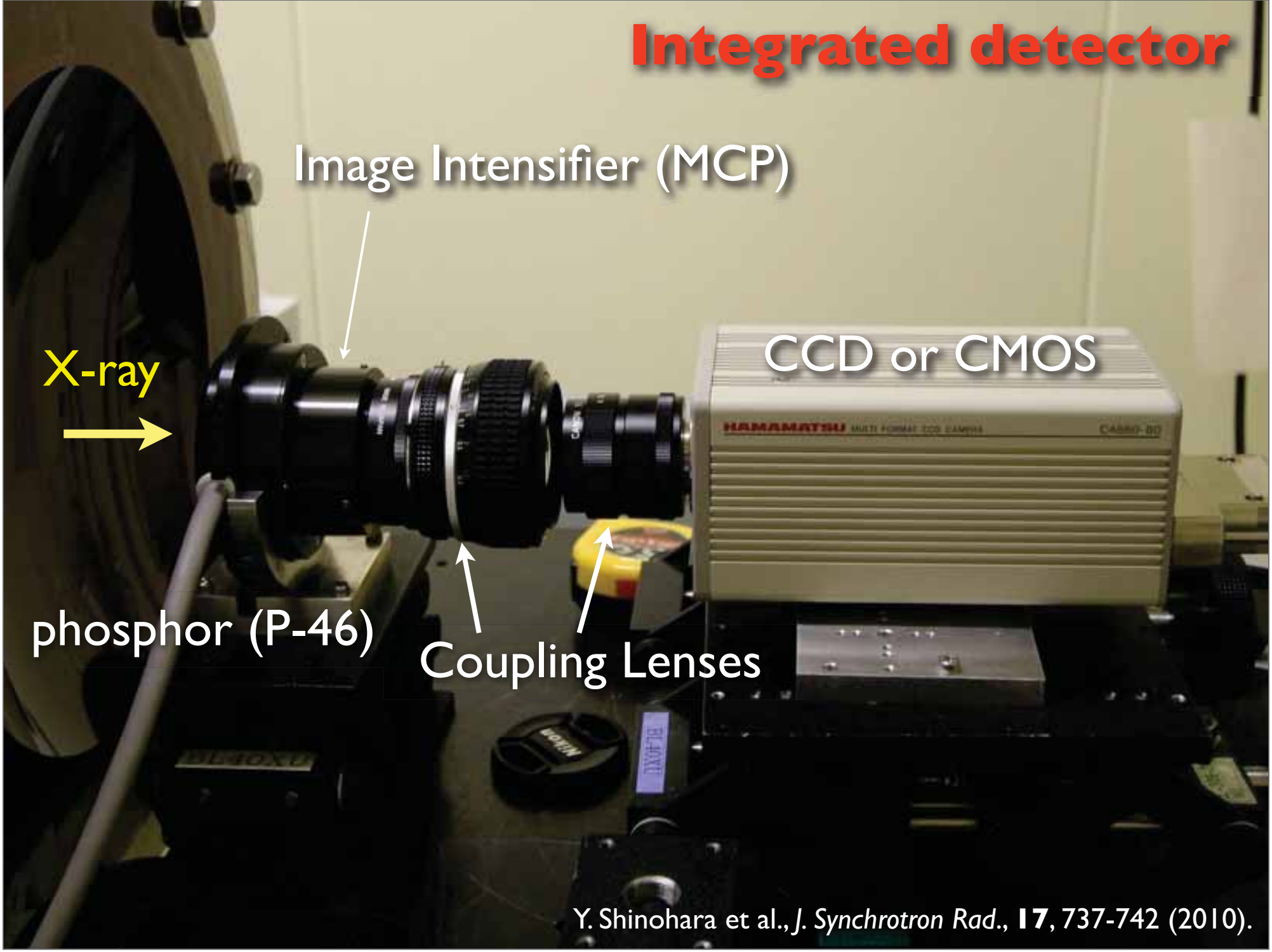
How ??

XPCS in milli-, micro- & nano-seconds

How ??

Let me introduce..... our detector for XPCS

Integrated detector



Y. Shinohara et al., *J. Synchrotron Rad.*, **17**, 737-742 (2010).

Advantage

Exp. time: easily adjustable (Electronic-shutter)

Image sensor: wide selection

high count rate (integrated detector)

(relatively) low-cost !

high compatibility with ERL (??)

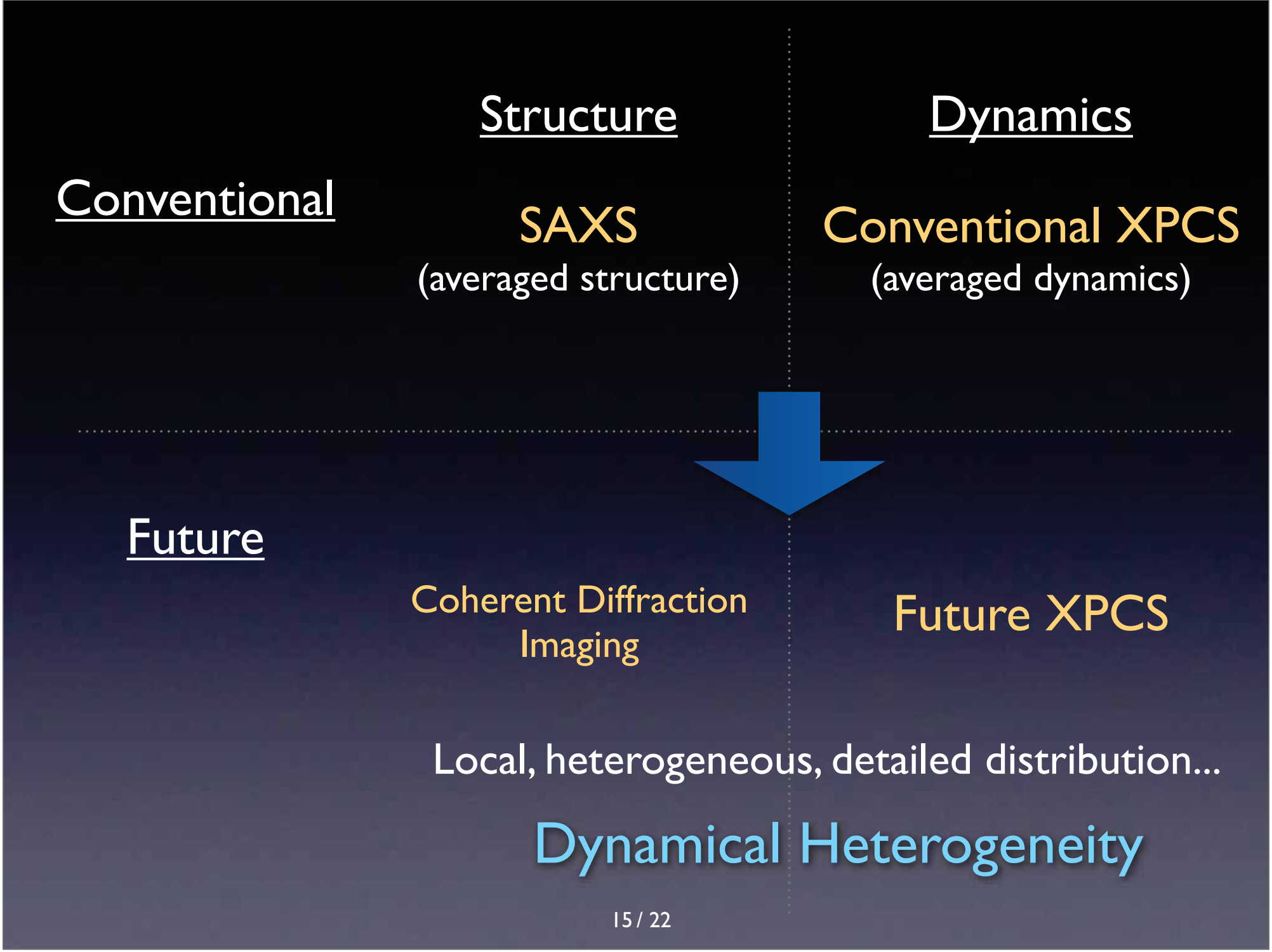
Scattering Study of Soft Matter...

Averaged Structure & Dynamics

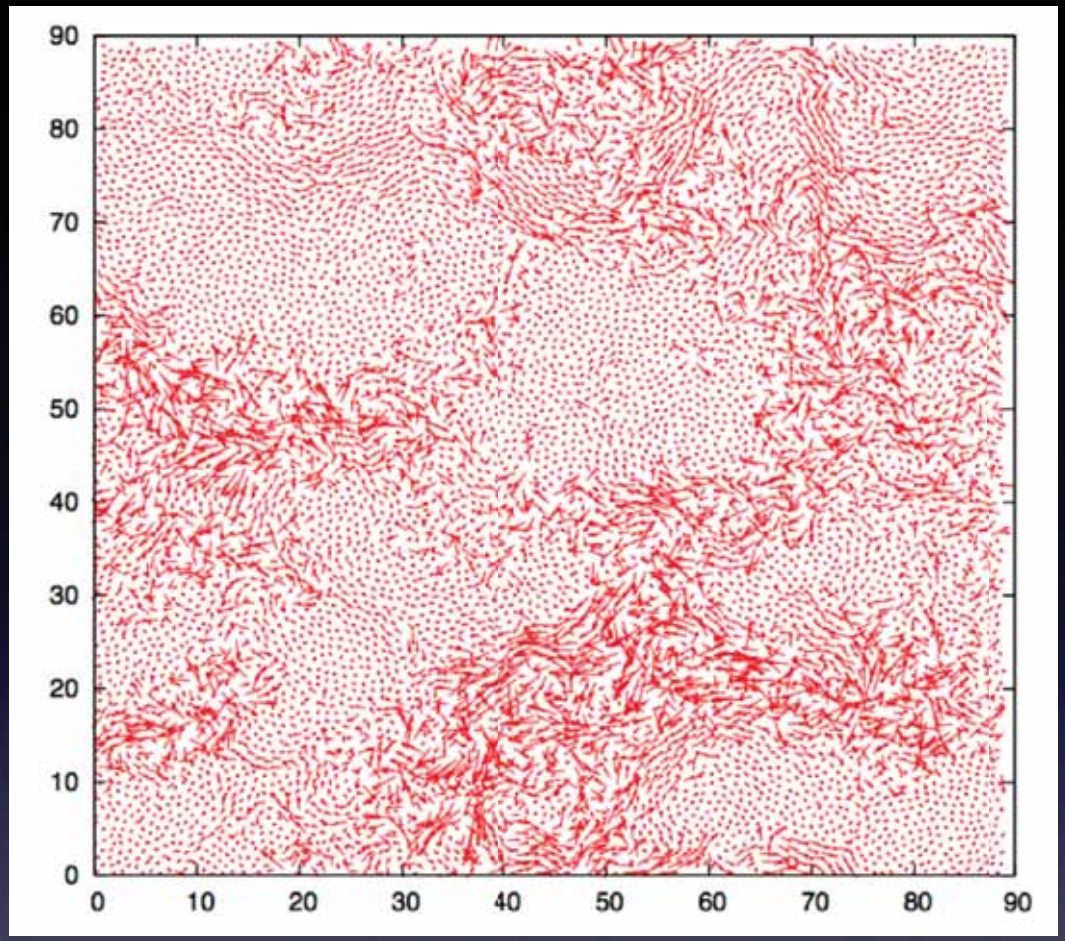
SAXS, (conventional) XPCS....

Highly Coherent X-ray

~~Averaged~~ Structure & Dynamics


Structure
Dynamics
Conventional
SAXS
(averaged structure)
Conventional XPCS
(averaged dynamics)
Future
Coherent Diffraction Imaging
Future XPCS
Local, heterogeneous, detailed distribution...
Dynamical Heterogeneity

Visualization of Dynamical Heterogeneity



L. Berthier, *Physics*, **4**, 42 (2011)

Highly Brilliant
Continuous source

+

ex.)
Near-Field Scattering

R. Cerbino & A. Vailati, *Curr. Opin. Colloid In.*, **14**, 416 (2009)

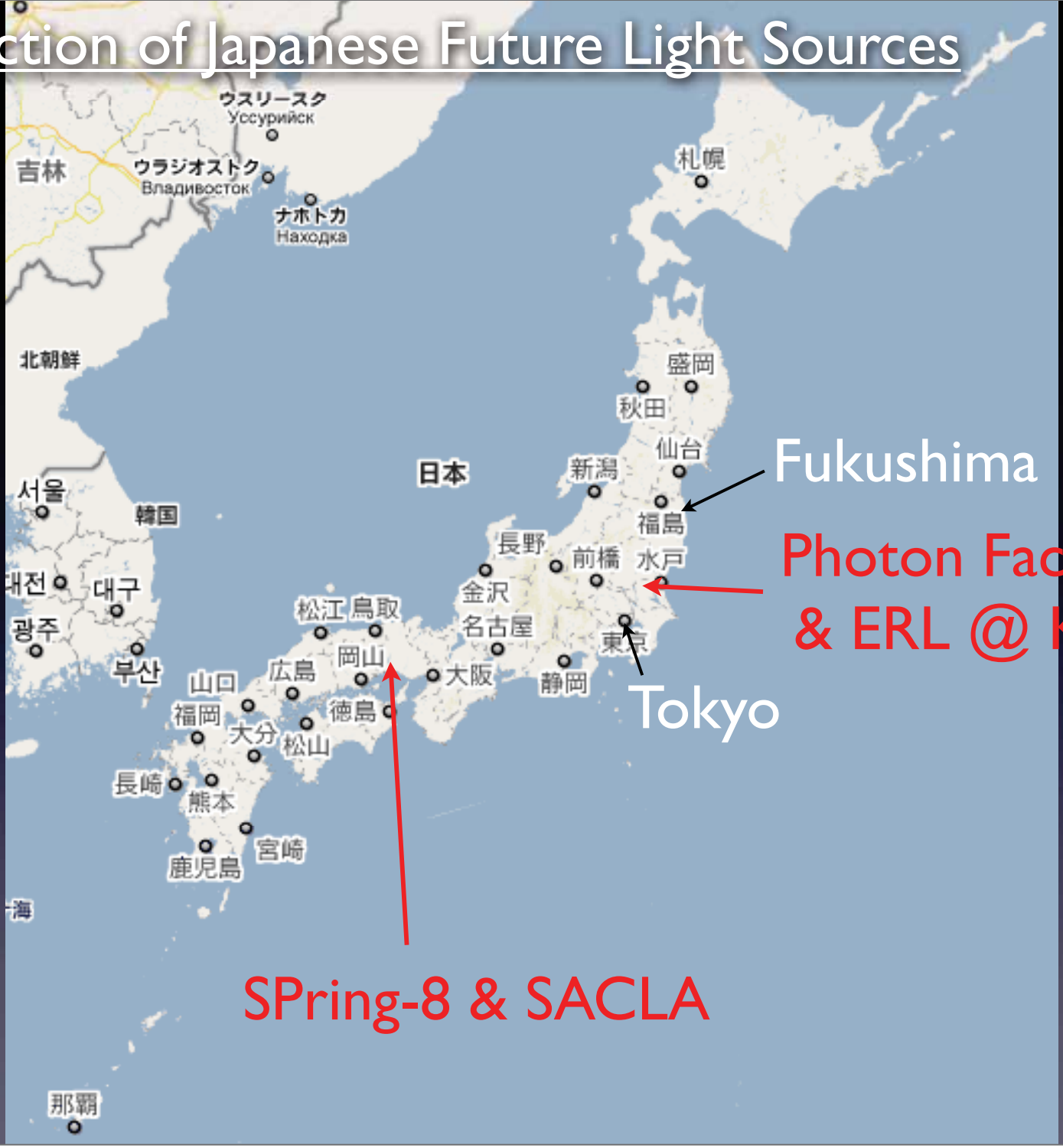
Mapping of Dynamics in nm - mm scale !!

Brief Summary

XPCS with Future Light Sources

- Dynamics in wider temporal scale
- Distribution of Dynamics

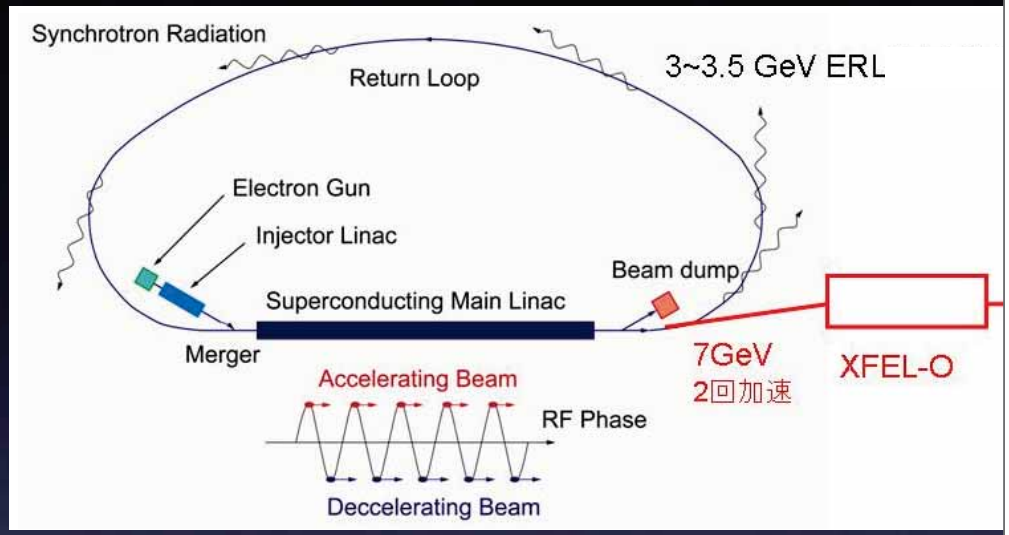
Introduction of Japanese Future Light Sources



SACLA & SPring-8


SACLA & SPring-8
X-ray laser
Upgrade to SPring-8 II ?
(Ultimate storage ring)
Combination of XFEL & USR !!

ERL Project @ KEK



Compact ERL
(35 MeV, 10 mA)

ERL & XFEL-O

Collaborators & Acknowledgement

Prof. Y. AMEMIYA (Univ. of Tokyo)

Dr. N. Yagi (JASRI/SPring-8)

Member of Amemiya lab & JASRI/SPring-8

Special thanks:

ERL Project office, Photon Factory, KEK