Characteristic features and society-accountability of a new plan for the Tohoku Synchrotron Radiation Facility

(Tohoku Ring: SLiT-J)
Synchrotron Light in Tohoku, Japan

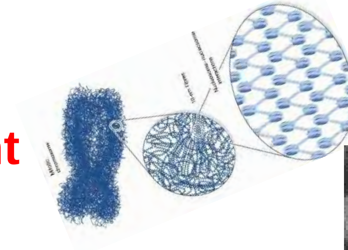
January, 2014

Tohoku synchrotron radiation facility committee (tentative)

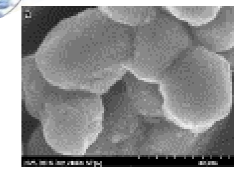
SR science pioneers materials / life sciences

- **SR science center to manage coherent light**
- **nm-size imaging and understanding of material structure using the coherent light**
- **Atomic-level imaging using high-brilliance, high-energy X rays**

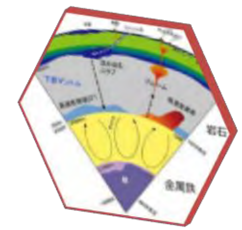
***New paradigms*:** origin of the solar system, evolution and structure of the giant planets, observation of living substances using DNA imaging, spatial structure of mesoscopic materials, etc.



Visualization of protein functions using DNA imaging



Space/time-resolved imaging for mesoscopic systems



Project on diffraction-limited LS (ERL, SPring-8 Ⅱ)

Advanced SR science aims at science/technology innovations

Project on mid-scale high-brilliance SR (SLiT-J)

Sustainable society

Scientific contribution

- **Strategic base for light-element materials using high-brilliance soft X-rays**
- **Strategic breakthroughs in reaction mechanism and energy saving using high-brilliance SR**

***New materials*:** carbon materials/devices of novel functions, rare-metal-free ferromagnetic materials including O and N, cathode materials for Li-ion battery, rare-earth-free oxynitride phosphors, power devices based on the interface of SiO_2/SiC, spintronics, magnetic devices, etc.

Cellular function and hierarchy : molecular imaging for living cells

Research on new functional materials : thermoelectric, battery, magnetic materials

Problems of the existing SR facilities

Problems regarding hardware

- **Absence of high-brilliance Soft X-ray (SX) sources in Japan**

  Significant delay in improvement of usage environment for SX nm-sized beam applications

  Mid-scale high-brilliance source (SLiT-J) is indispensable !

- **Absence of multi-purpose beamlines for SX nm-sized beam applications**

  Hesitation due to ultra-high vacuum systems and analyses which need expert knowledge

  Improvement of multi-purpose measurement BLs based on know-how from the advanced SPring-8 is indispensable !

Problems regarding the software

- **Unavailable for the increasing needs of industry for SX applications**

  Restricted opportunity of usage due to the chronic shortage of beam time

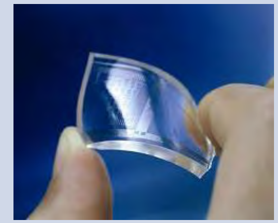
  Dedicated facility to create industrial innovation is indispensable rather than parasitic usage in a basic science facility !

- **Incompatible with the speed required in industry for new materials development**

  To provide opportunities in accordance with the speed of industrial development is essential !

Key technologies of the 21 century – light element strategy

Paradigm shift from mass consumption/emission of carbon toward conservation and near total recycling of material elements

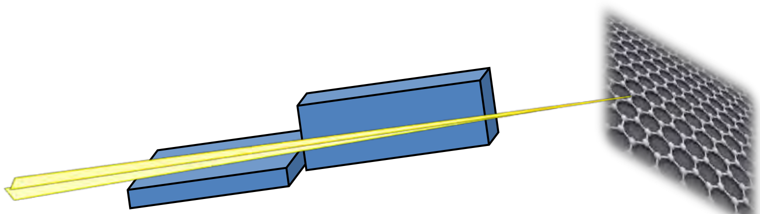
Diamond	Graphite	Carbon fiber	Graphene	C nanotube
				
The highest hardness and high thermal conductivity	High heat resistance (3000°C) and thermal conductivity	Light and high strength	The highest mobility	High current density and tensile strength

SX nm-sized beam application is essential!

Pol-controlled nm-size XAS: for oriented structures

nm-size PES: for bonding states of C-C

***In-situ* nm-size XES:** for synthetic processes



KB condenser mirrors

Innovations brought by C materials

Electronic devices

High-speed wide-band data transmission

Structural materials

Energy saving from light weight , high strength and low friction

Heat transfer materials

Energy saving by temperature and heat transfer control

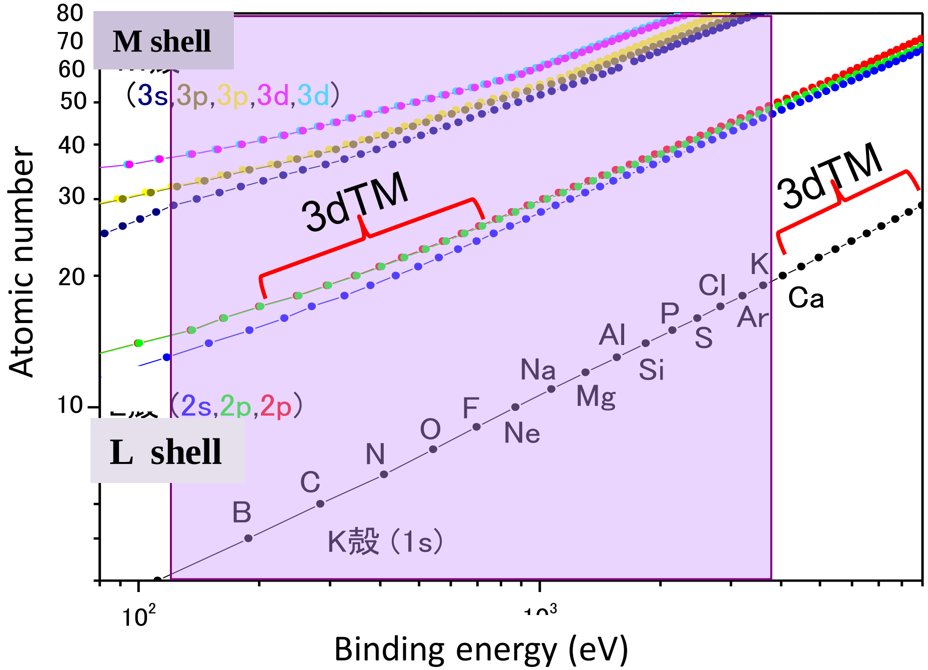
Establish precise synthesis conditions for novel nanoscale carbon materials based on analyses using SX nm-sized beam applications

Development of light-element materials promoted by Soft X-rays nm-sized beam application

Light-element strategy: to realize specific functions by controlling the structure of light-element materials without rare metals

Light elements：B, C, N, O, Mg, Al, Si, P, S, etc.

- Rich on the earth and stable supply
- Contributable to energy saving because of light weight
- Creation of novel high-functional materials by controlling structures



Absorption edges of the light elements appear in the SX region.

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Elucidate the relations between the electronic states and functions of light-element materials using SX nm-sized beam applications.

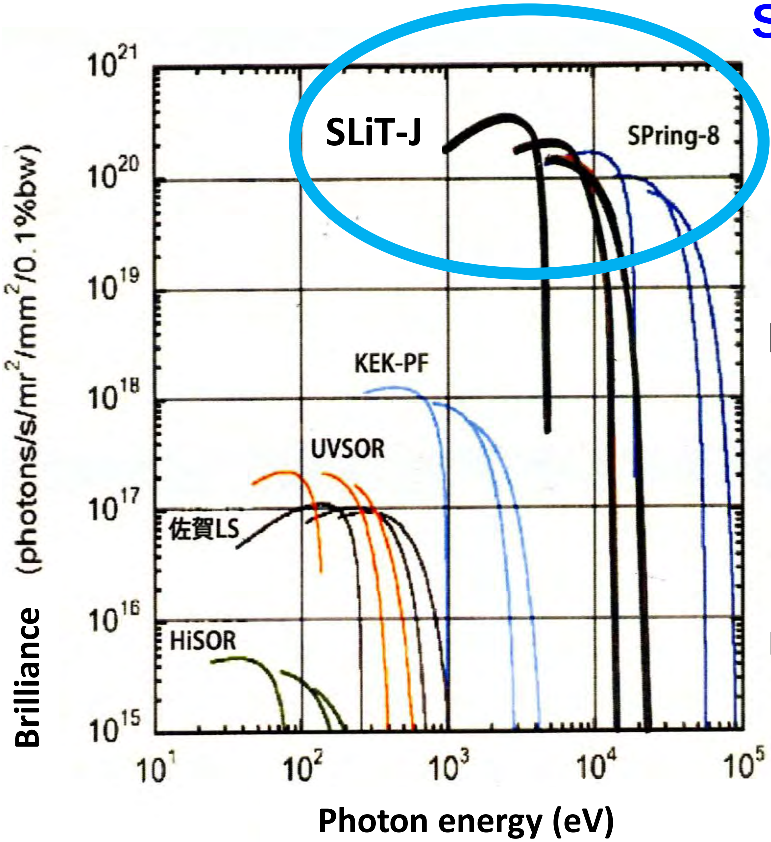
Materials innovations based on the light-element strategy using nm-sized Soft X-rays（SX）spectroscopy

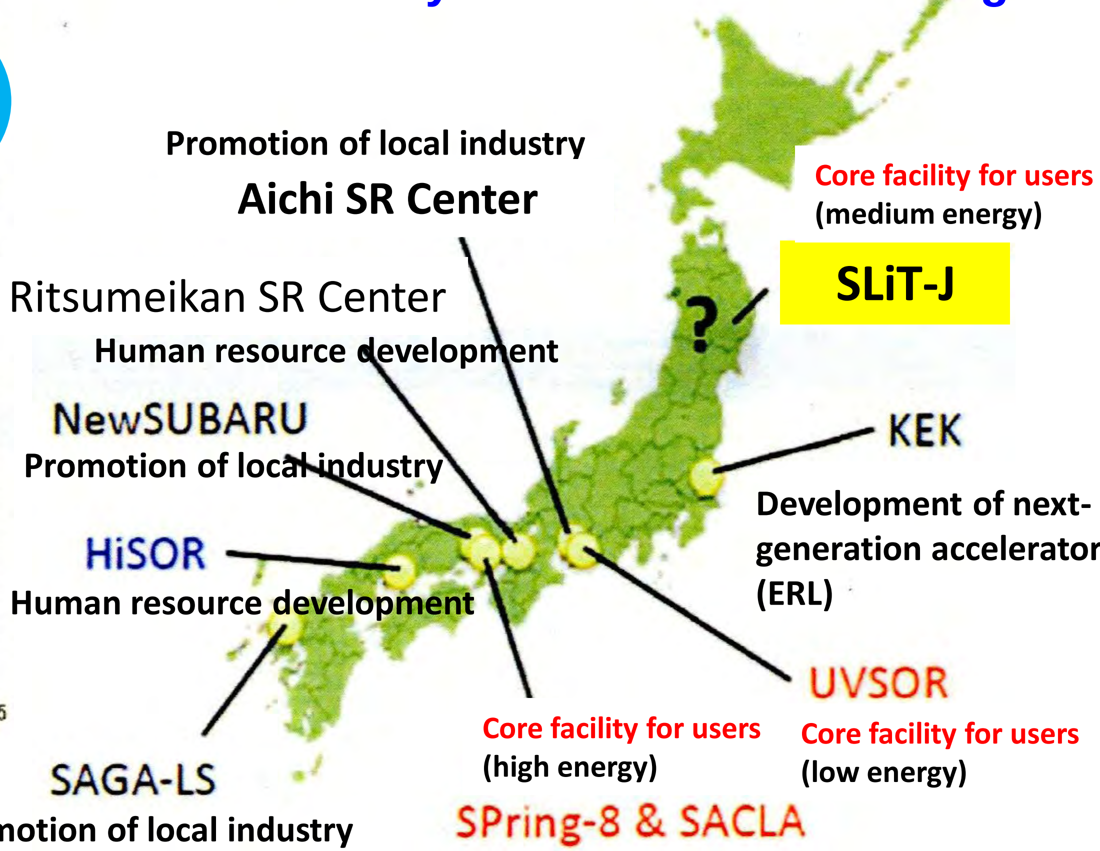
Concerted effects of the domestic SR facilities brought by SLiT-J

Synergistic effect between SLiT-J and SPring-8 is expected.

nm-sized hard/soft X rays available at suitable ring according to the analysis.

SLiT-J will cost only a fifth amount of SPring-8 !





- **Appearance of SLiT-J makes clear the role of each facility and promotes distinctive and specialized usage**
- **Reduces possible risks of the predicted Tonankai earthquake.**

Synchrotron Light in Tohoku, Japan (SLiT-J) : the most advanced facility for high-brilliance Soft X-rays

Main objectives :

Materials with the light elements such as C, N, O, Al, Si, etc.

Main methods :

Photoelectron/absorption/emission spectroscopy, MCD, PEEM, etc. using high-brilliance soft X-rays

Examples of research topics :

- Development of carbon materials/devices for novel functions
- Development of rare-metal-free ferromagnetic materials including O and N.
- 3D and time-resolved observation of the systems inside a cell
- Structure analysis of catalytic reactions by enzymes
- Analysis of domain structure for magnetic materials with O and N using PEEM
- Development of cathode material for Li-ion battery
- Exact analysis for the S atoms in polymers (rubber)
- Development of rare-earth-free oxynitride phosphors
- Development of power devices by analyzing the interface of SiO_2/SiC
- Resolving the mechanism of high-T_c oxide superconductors
- Precise estimation of trace elements in environmental substances
- High-resolution atomic and molecular spectroscopy of light elements
- Development of SX microscope and its application to nanoscale devices
- Development of spintronic magnetic devices

Note : These subjects are technically difficult to explore using SPring-8 and the planned SPring-8 II.

Characteristic concepts in the SLiT-J facility design

SPring-8：High brilliant hard X-ray facility to explore pioneering basic science and technology
SLiT-J: Low cost and energy saving soft X-ray facility for innovation in technology

Gathering and compiling advanced technologies developed in SPring-8, world–class high brilliant soft X-rays will be provided.

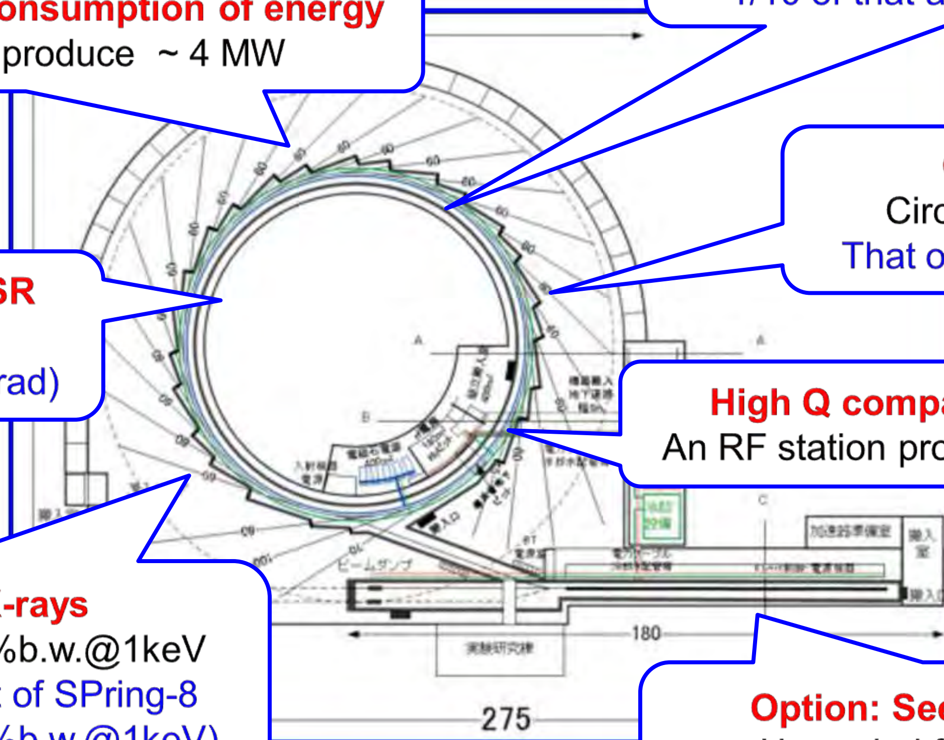
Energy saving
Power consumption ~ 3.7 MW
1/10 of that at SPring-8 (~30MW)

Local production for local consumption of energy
Mega-solar power plant produce ~ 4 MW

Compactness
Circumference 340 m
That of SPring-8 is 1436 m

World-class high brilliant SR
Emittance ~ 1.1 nmrad
1/3 of that of SPring-8 (3.4nmrad)

High Q compact RF cavityワーを
An RF station provides whole SR power



High brilliant soft X-rays
$>10^{21}$Phs/s/mrad^2/mm^2/0.1%b.w.@1keV
1000 times higher than that of SPring-8
($>10^{18}$Phs/s/mrad^2/mm^2/0.1%b.w.@1keV)

Option: Seeded soft XFEL
Upgraded from SASE-FEL
The use of perfectly coherent X-rays

The combination of SLiT-J and SPring-8 enables us to provide a high quality light source for studying various substances in a variety of states.

(specification of SPring-8 is denoted by blue letters)