Current Status of Neutron Science Research at HANARO and Possibilities for Joint Beam Utilization

December 5th 2025

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Neutron Science Division
Korea Atomic Energy Research Institute

KAERI Korea Atomic Energy Research Institute

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Korea Atomic Energy Research Institute

I. INTRODUCTION

Korea Atomic Energy Research Institute

KAERI Korea Atomic Energy Research Institute

History

1950~1970s

Feb. 3, 1959
Atomic Energy Research Institute (AERI) was established as an affiliate of the Office of Atomic Energy (OAE).

Feb. 17, 1973
Atomic Energy Research Institute (AERI), Radiological Research Institute (RRI), and Radiation Research Institute in Agriculture (RRIA) merged into one to become the present KAERI.

Dec. 1, 1976
Korea Nuclear Fuel Development Institute (KNFDI) was established.

1980s

Dec. 19, 1980
KAERI merged with KNFDI and changed the name to the Korea Advanced Energy Research Institute.

Dec. 30, 1989
The previous name of Korea Atomic Energy Research Institute was restored.

1990s

Feb. 15, 1990
Nuclear Safety Center under KAERI became an independent organization, the Korea Institute of Nuclear Safety(KINS).

Dec. 16, 1996
Activities on nuclear engineering, nuclear fuel design, and radioactive waste management were transferred from KAERI to domestic industries.

2000s~

Oct. 25, 2004
Technology Center for Nuclear Control under KAERI became an independent organization of the National Nuclear Management and Control Agency (Currently Korea Institute of Nuclear Nonproliferation and Control).

Sep. 29, 2006
Jeongeup Advanced Radiation Technology Institute was established.

Mar. 27, 2007
KAERI newly inaugurated with a change in its Korean name.
Korea Institute of Radiological & Medical Sciences (KIRAMS) was spun off from KAERI and became an independent entity.

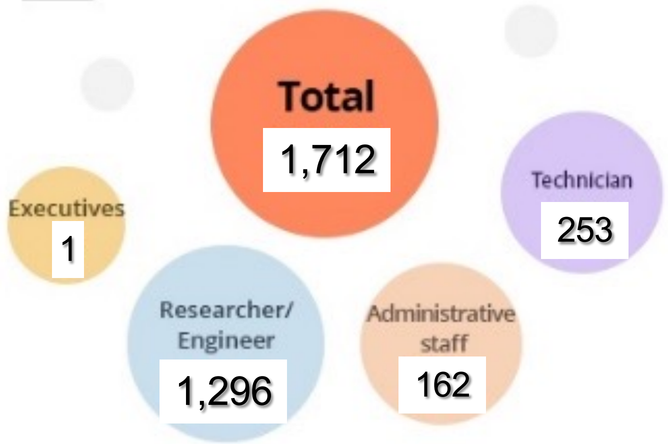
Jan. 1, 2013
Korea Multi-purpose Accelerator Complex (KOMAC), Gyeongju, was established.

BETTER & MORE

NUCLEAR R&D GLOBAL LEADER

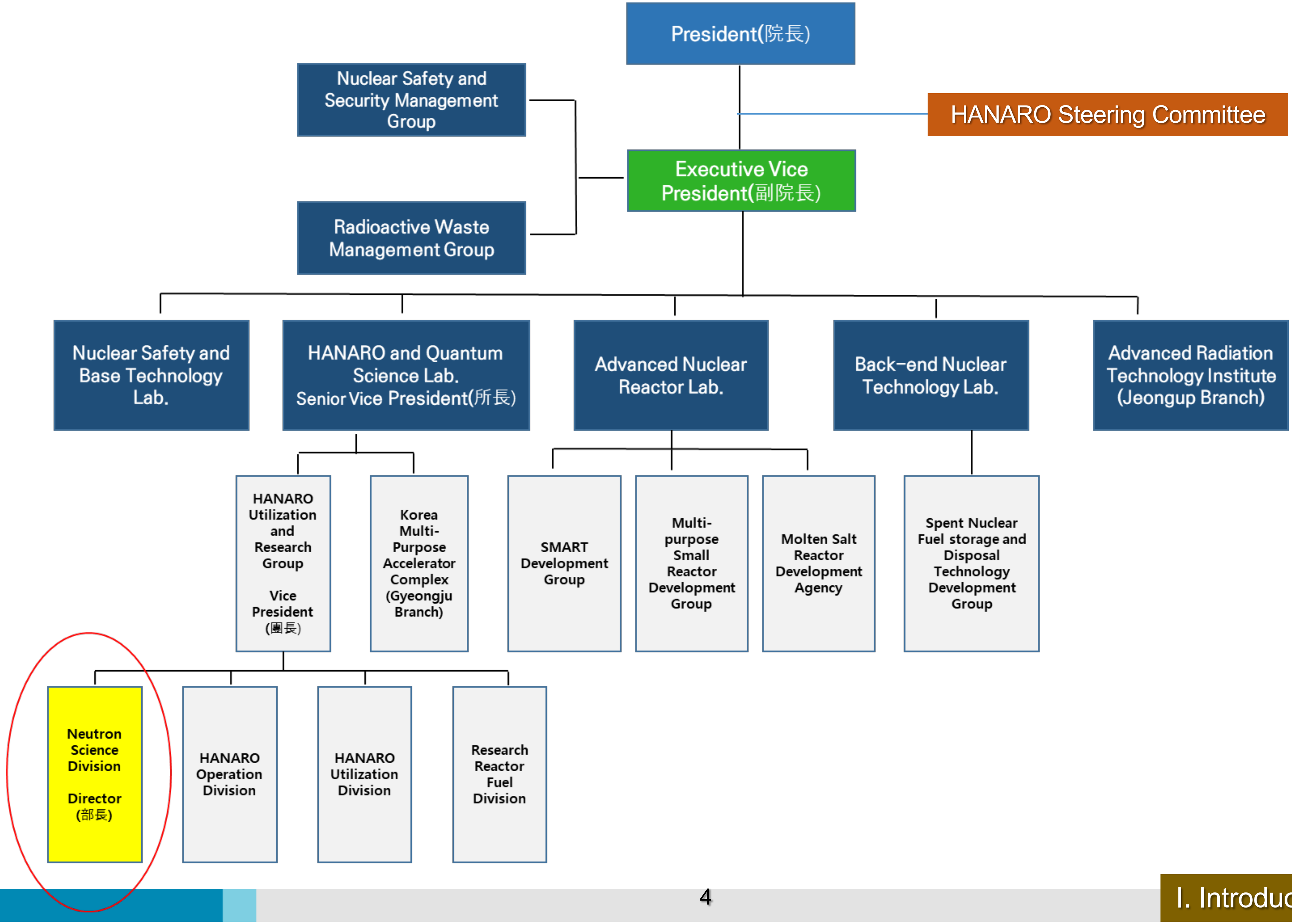
Number of Employees

Full-time employees as of Dec.2025

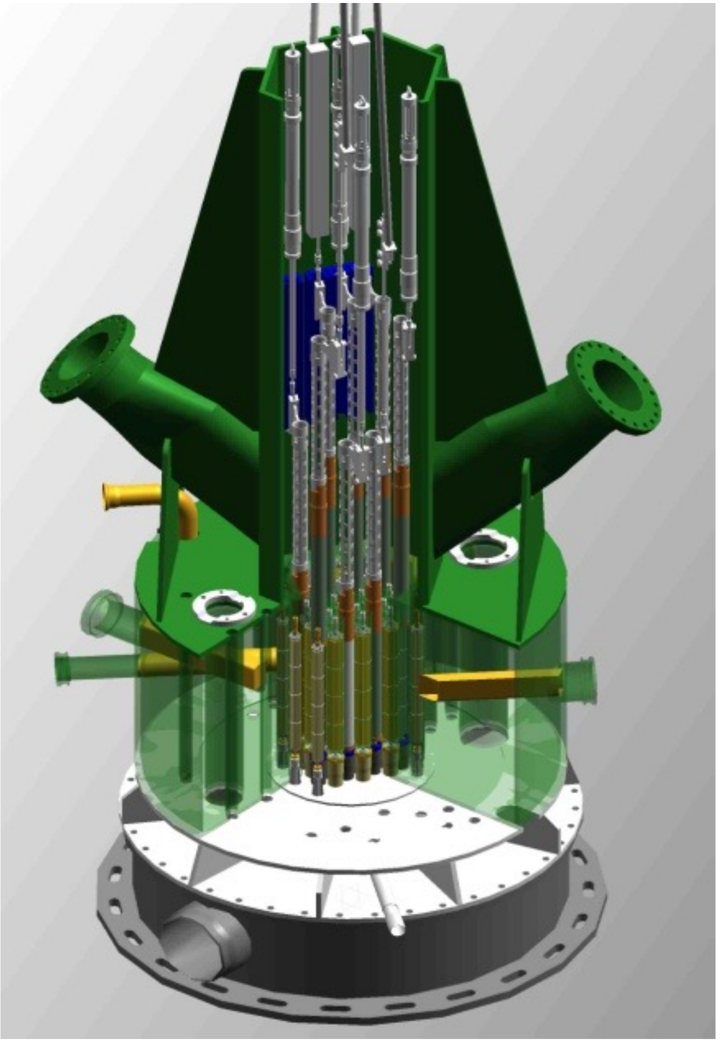


Location

Organization Chart of KAERI



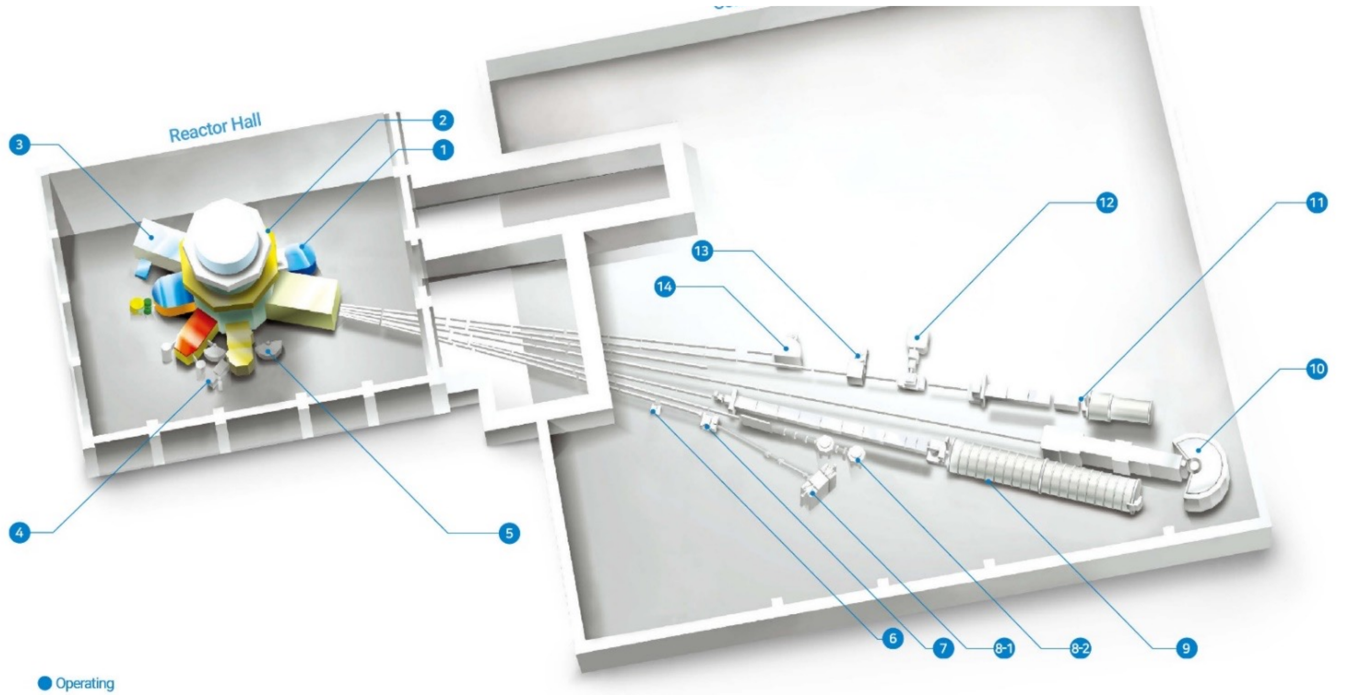
Utilization of HANARO



1. **Materials and Fuel Irradiation**
2. **Neutron Activation Analysis(NAA)**
3. **Neutron Transmutation Doping(NTD)**
4. **Radioisotope Production**
5. **Neutron Beam Research**

II. INSTRUMENTS

Instrument Layout

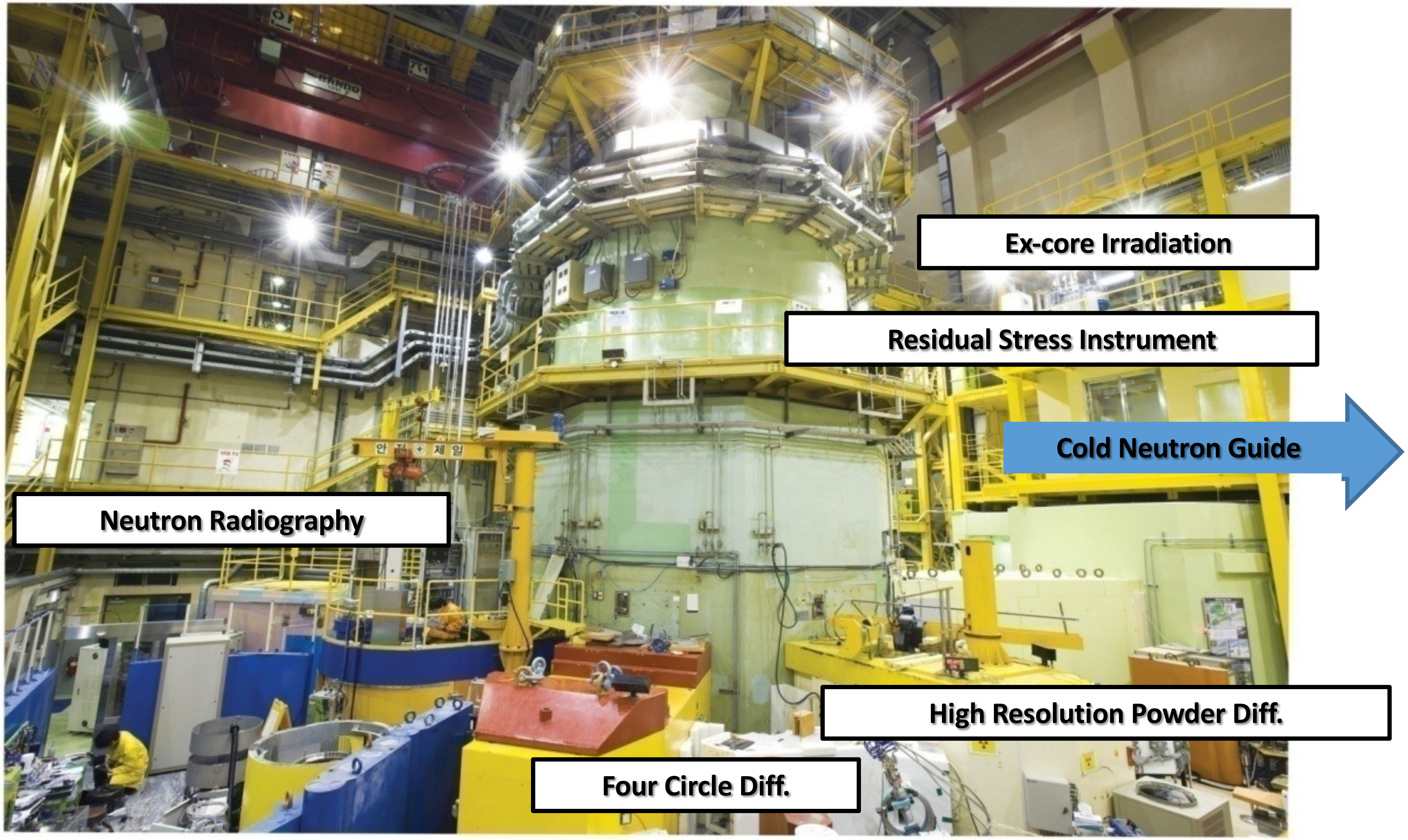


*** : Belongs to other Institute**
+ : Belongs to other division at KAERI

01 Residual Stress Instrument	06 Guide Test Station
02 Ex-core Neutron irradiation Facility	07 Vertical type REFlectometer
03 Neutron Radiography Facility	+08 Cold Neutron Activation Station
04 Four Circle neutron Diffractometer	9 40m Small Angle Neutron Scattering instrument
05 High Resolution Powder Diffractometer	10 Disk-Chopper Time-of-Flight spectrometer
	11 18m Small Angle Neutron Scattering instrument
	*12 KIST Ultra-Small Angle Neutron Scattering instrument
	13 Bio-REFlectometer
	14 Cold neutron Triple-Axis Spectrometer

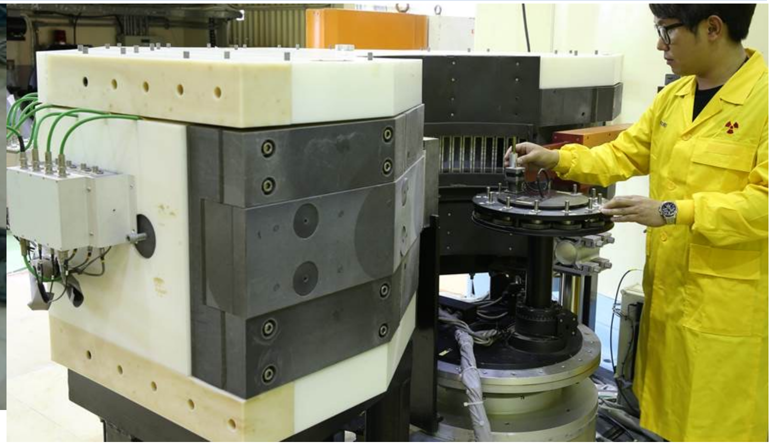
Strategy : Among 12 KAERI instruments, we are operating intensively underlined 10 instruments

Instruments in the Reactor Hall



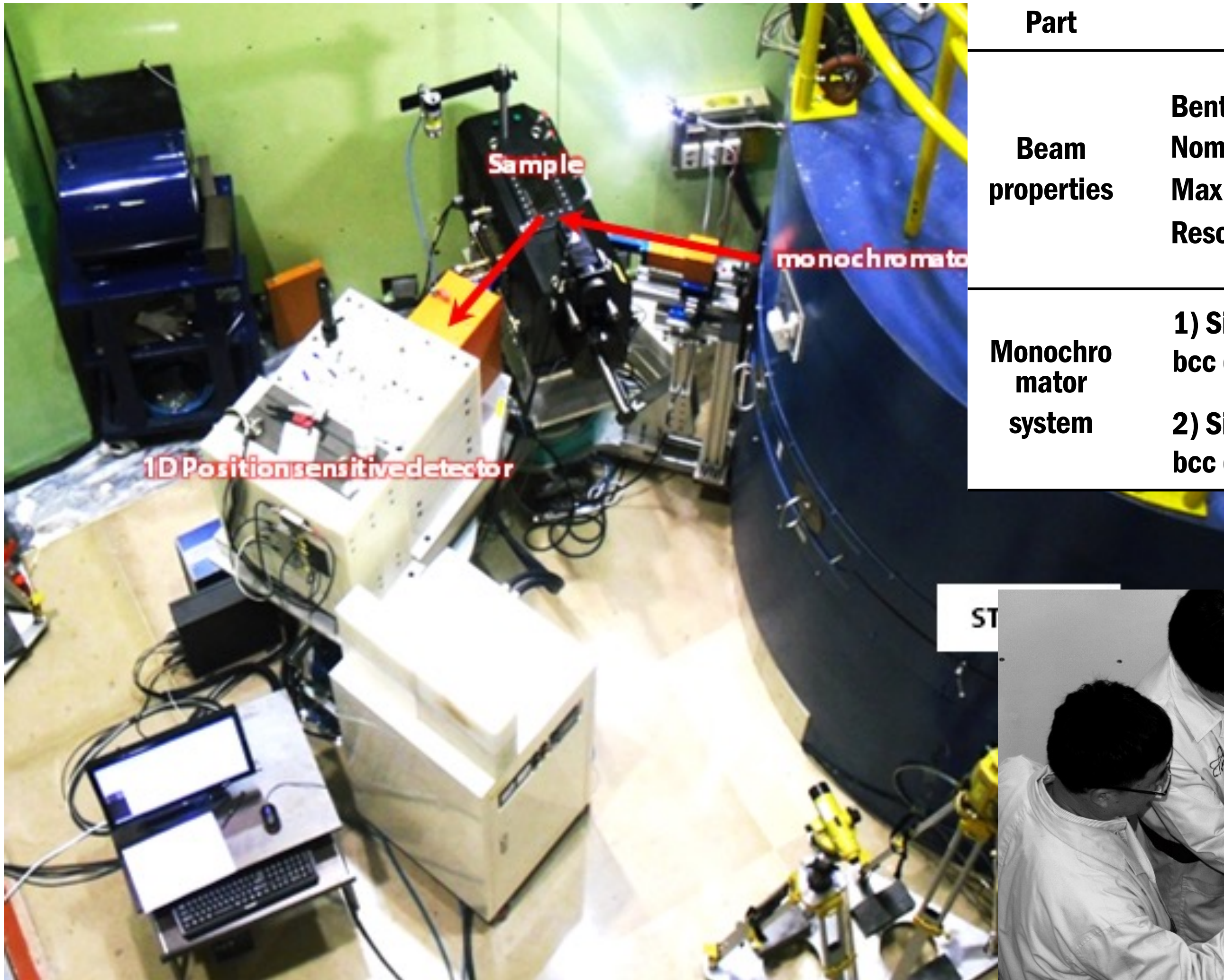
HRPD High Resolution Powder Diffractometer

HRPD specification	
Monochromator	
number of slabs	9 slabs (vertically focused)
reflection plane	Cu(220), Ge(331), Ge(335),PG(002)
Collimators	
first collimator unit(FCU)	6', 10', 20', open(~50')
Second collimator	30' , open
Third collimator	10'(fixed)
Detectors	
Multi-detectors : 32 He-3 proportional counters	

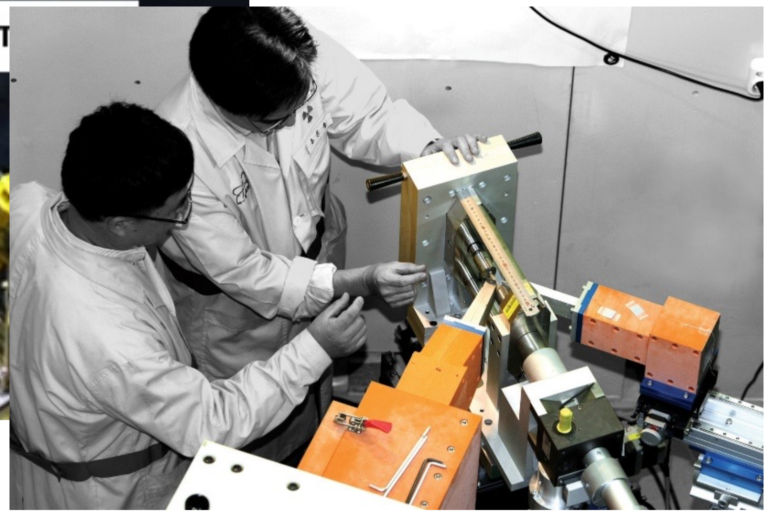


Responsibles : Seongsu Lee & Hyungsub Kim available since 1999

RSI Residual Stress Instrument

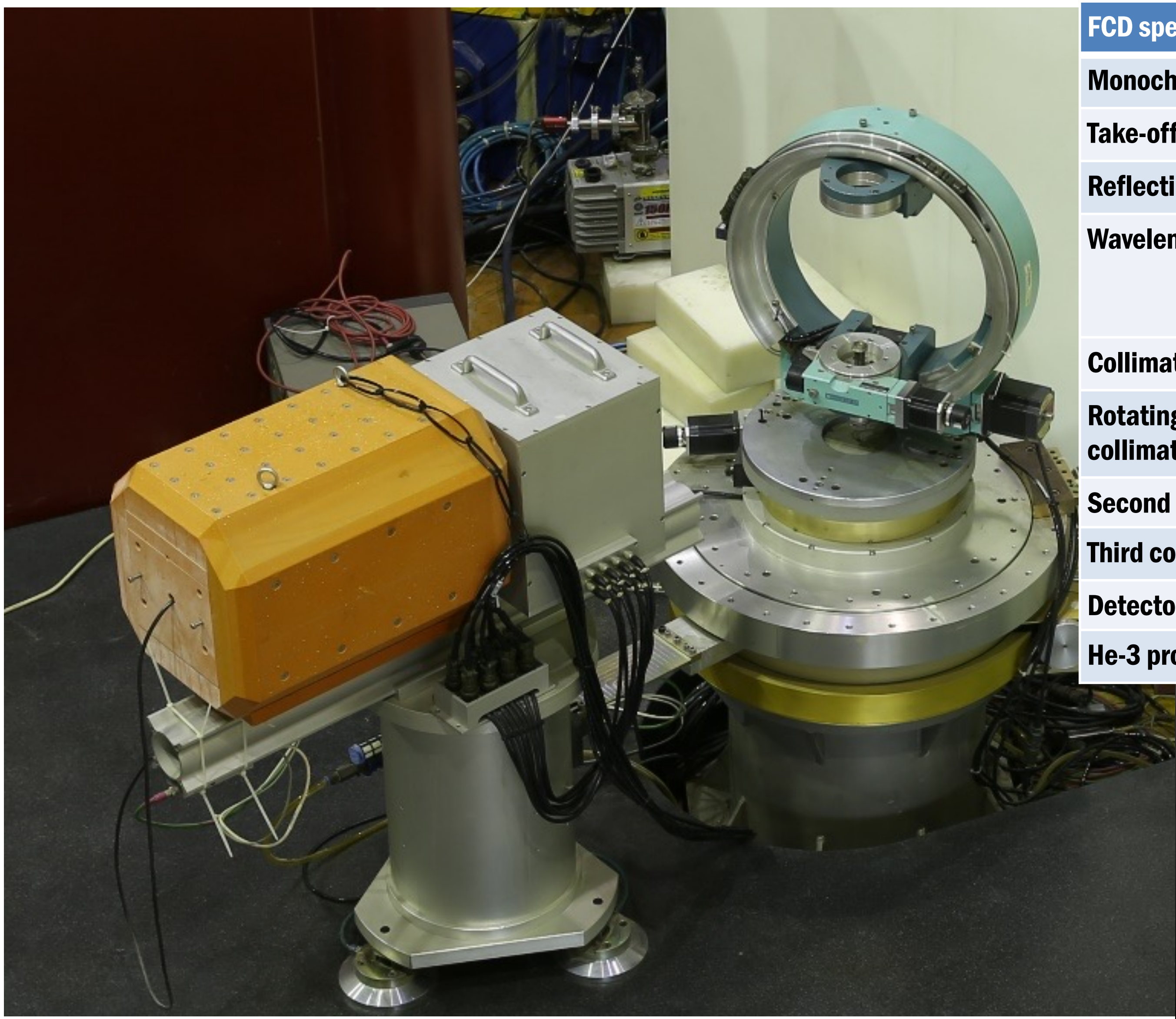


Part	Characteristic
Beam properties	Bent perfect crystal monochromator Nominal gage volume: 1 ~ 120 mm^3 Max flux: 2.6 x 10^6 n/cm^2s Resolution ($\Delta d/d$) = 4 x 10^{-3} (0.4%)
Monochro mator system	1) Si (220), λ=1.47Å bcc (211),(220), fcc (220),(311),(222) 2) Si (111), λ=2.40Å bcc (110), fcc (111)

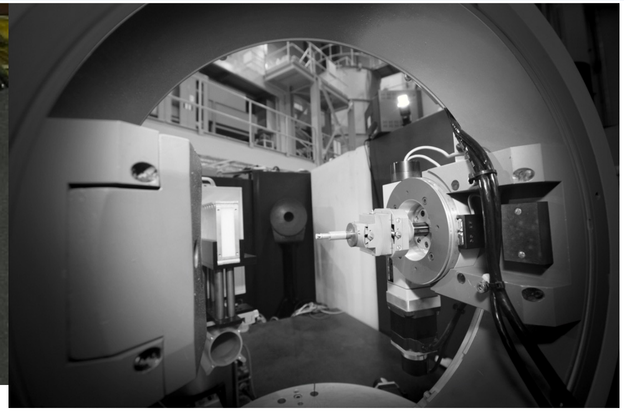


Responsibles Wanchuck Woo and Hobyung Chae, Available since March 2009

FCD Four Circle Neutron Diffractometer

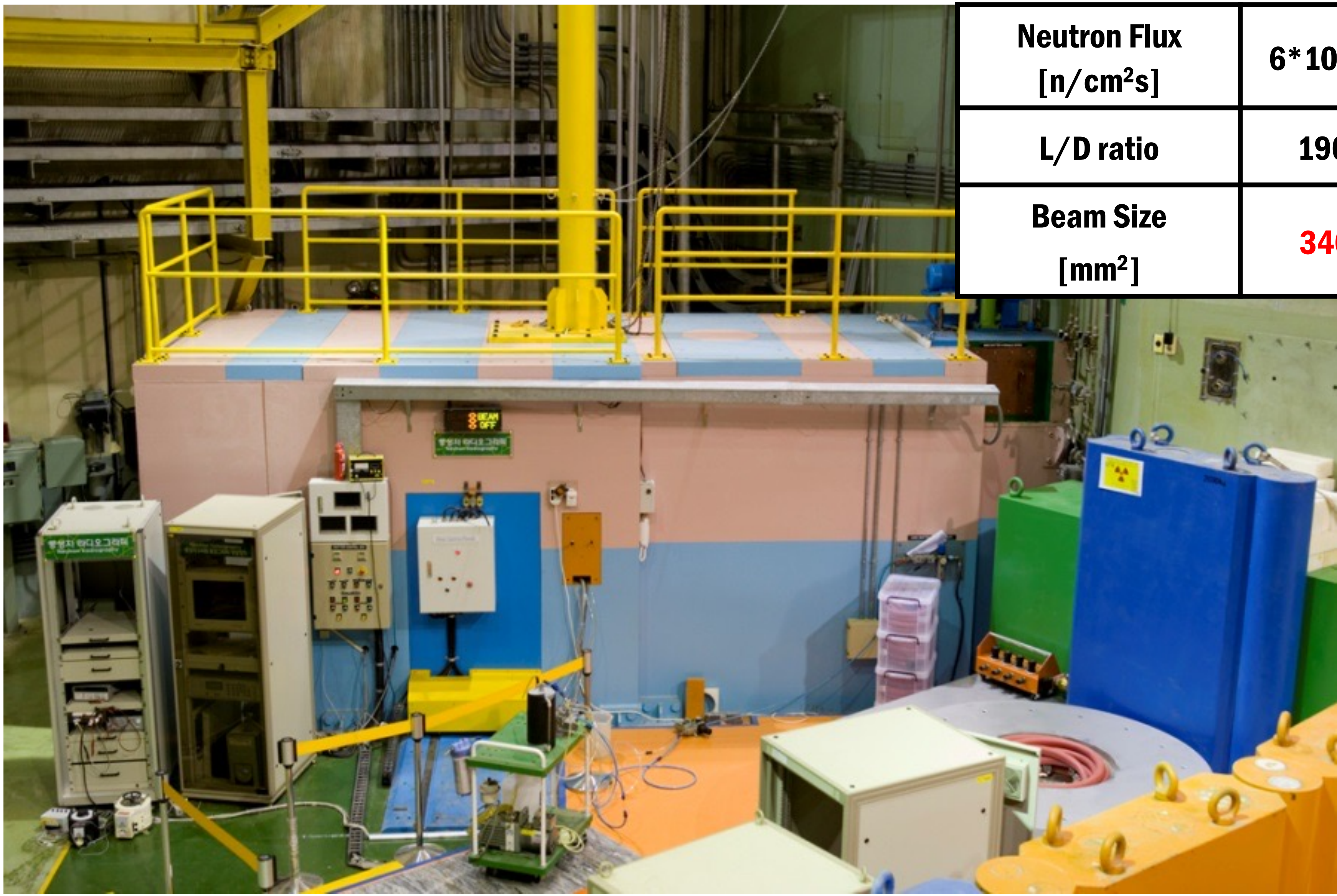


FCD specification	
Monochromator	
Take-off angle	-45°
Reflection plane	Ge(311), Ge(422), Ge(111)
Wavelength	$\lambda_{(311)}$=1.3155, $\lambda_{(422)}$=0.8892, $\lambda_{(111)}$=2.5151 Å
Collimators	
Rotating shutter collimator (α1)	20' , 30' , open(˜50')
Second collimator (α2)	Open(˜55')
Third collimator (α3)	Free setting with slits
Detector	
He-3 proportional counter (tube: dia. 50mm)	



Responsible: In-Hwan Oh, available since 1999 with major upgrade 2005-2009

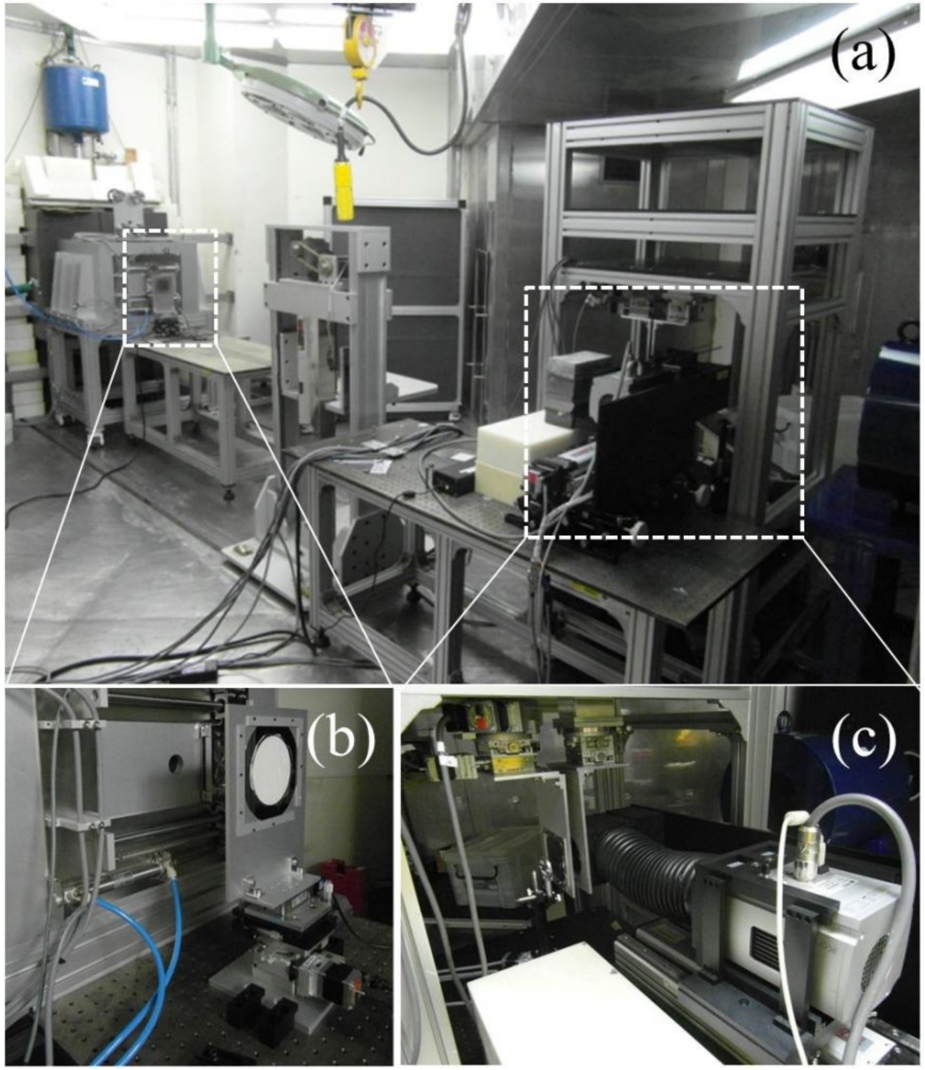
NRF Neutron Radiography Facility



Neutron Flux [n/cm²s]	$6*10^6$ ~ $2*10^7$
L/D ratio	190 ~ 290
Beam Size [mm²]	340 * 450

Responsibles: Tae-Joo Kim and Young-Ju Kim, Available since 1997

ENF Ex-core Neutron Irradiation Facility



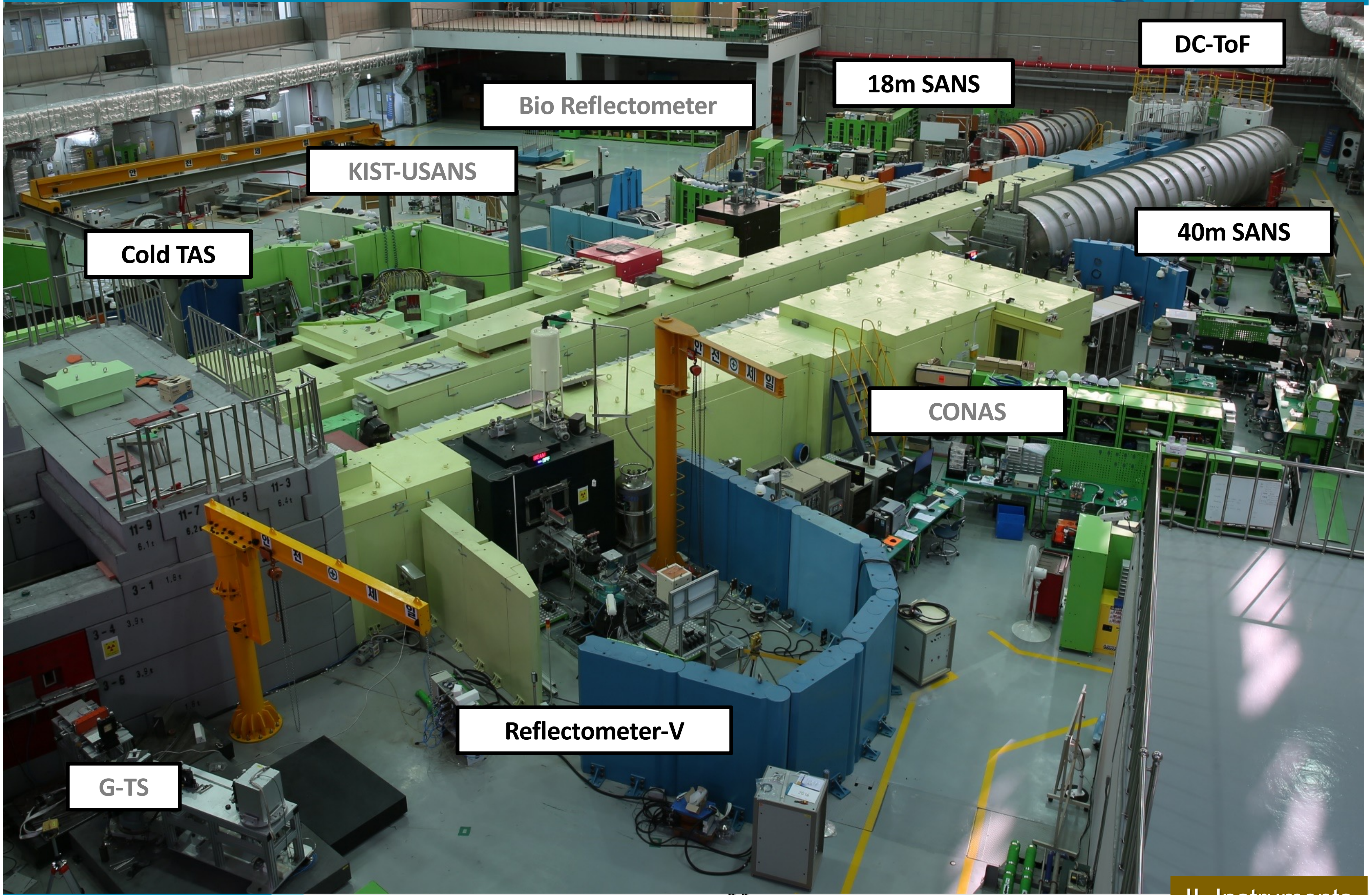
	Specification
Beam filter	Silicon(Diameter 20cm, Length 40cm) Bismuth(Diameter 10cm, Length 15cm)
Thermal neutron flux (max)	1.49 x 10^9n/cm^2, s
Space	5.5m(length)x3.5m(height)x4 m(width)

Applications

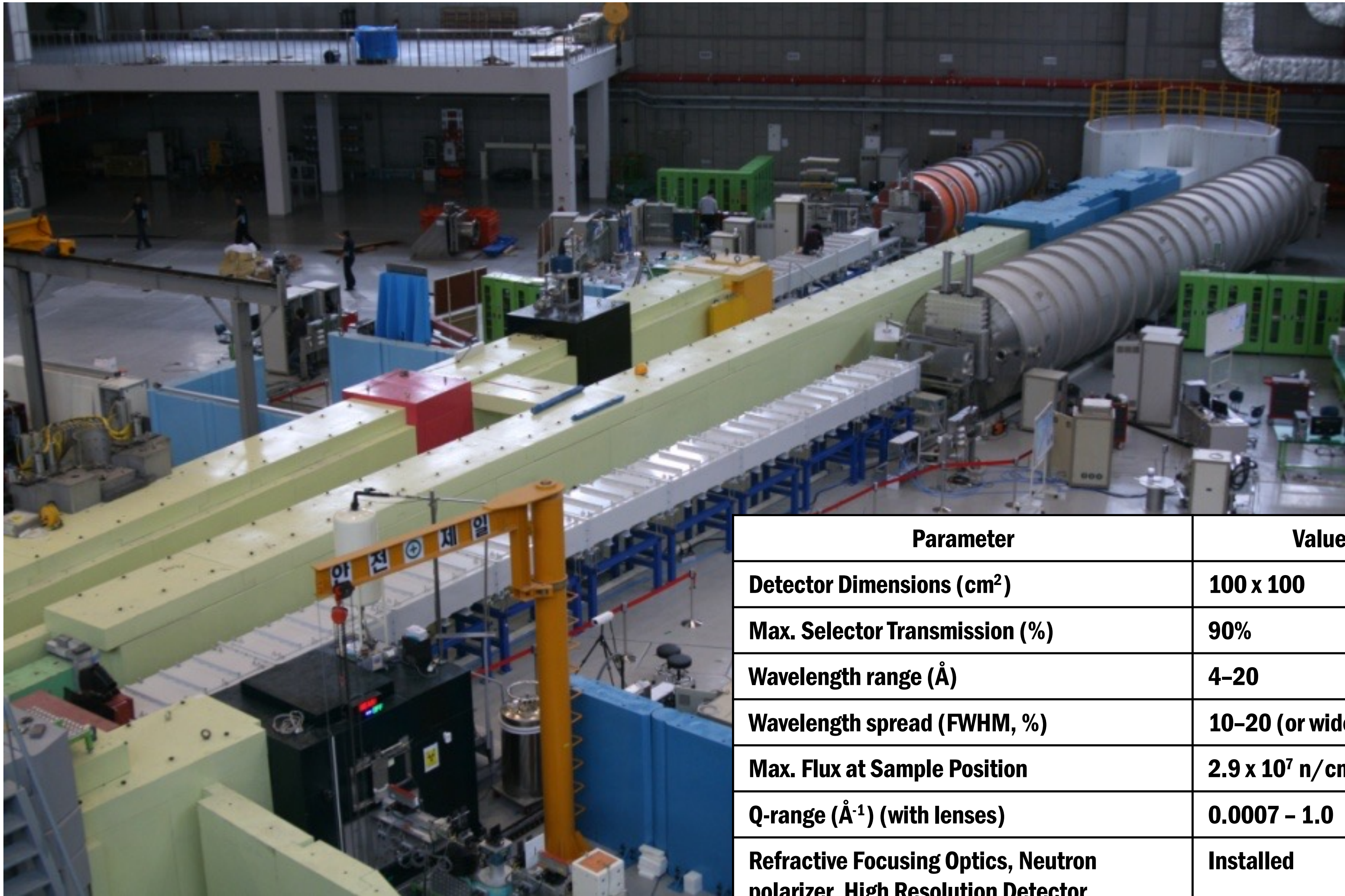
- ✓ Neutron Irradiation Test
- ✓ Autoradiography for Boron Distribution
- ✓ Phase Contrast Imaging
- ✓ Dark Field Imaging (Neutron Decoherence Imaging)
- ✓ High Resolution Neutron Imaging
- ✓ Neutron Detector Development Test Station
- ✓ Energy Selective Imaging (Future)
- ✓ Polarized Neutron Imaging (Future)

Responsibles: Jong-Yeol Kim, Available since 2004

Instruments in the Guide Hall



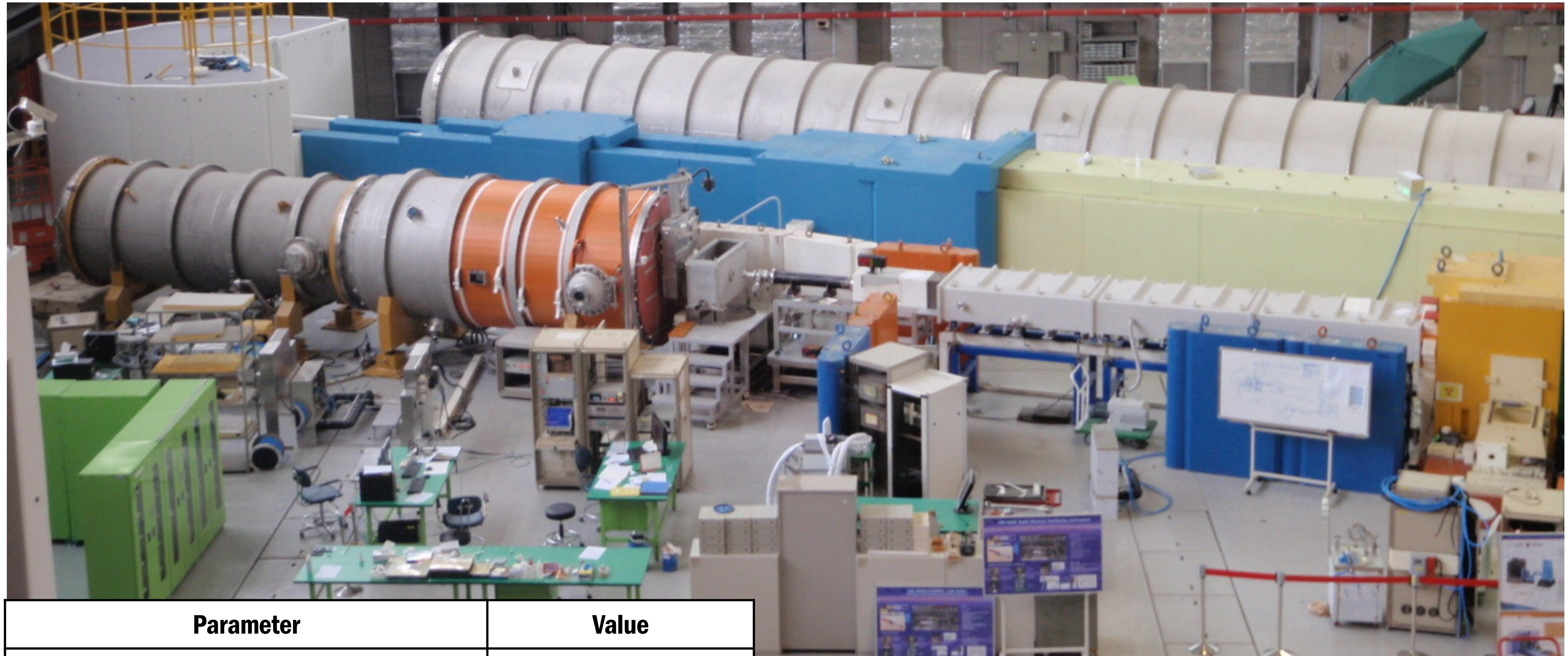
40M-SANS 40 m Small Angle Neutron Scattering Instrument



Parameter	Value
Detector Dimensions (cm^2)	100 x 100
Max. Selector Transmission (%)	90%
Wavelength range (Å)	4–20
Wavelength spread (FWHM, %)	10–20 (or wider)
Max. Flux at Sample Position	2.9×10^7 n/cm^2.sec
Q-range ($Å^{-1}$) (with lenses)	0.0007 – 1.0
Refractive Focusing Optics, Neutron polarizer, High Resolution Detector	Installed

Responsible : Jong-Dae Jang and Young-Soo Han, Available since November 2010

18M-SANS 18 m Small Angle Neutron Scattering Instrument



Parameter	Value
Detector Dimensions (cm^2)	64 x 64
Max. Selector Transmission (%)	90%
Wavelength range (Å)	4–20
Wavelength spread (FWHM, %)	10–20 (or wider)
Max. Flux at Sample Position	2.5×10^7 n/cm^2.sec
Q-range ($Å^{-1}$) (with lenses)	0.003 – 0.5

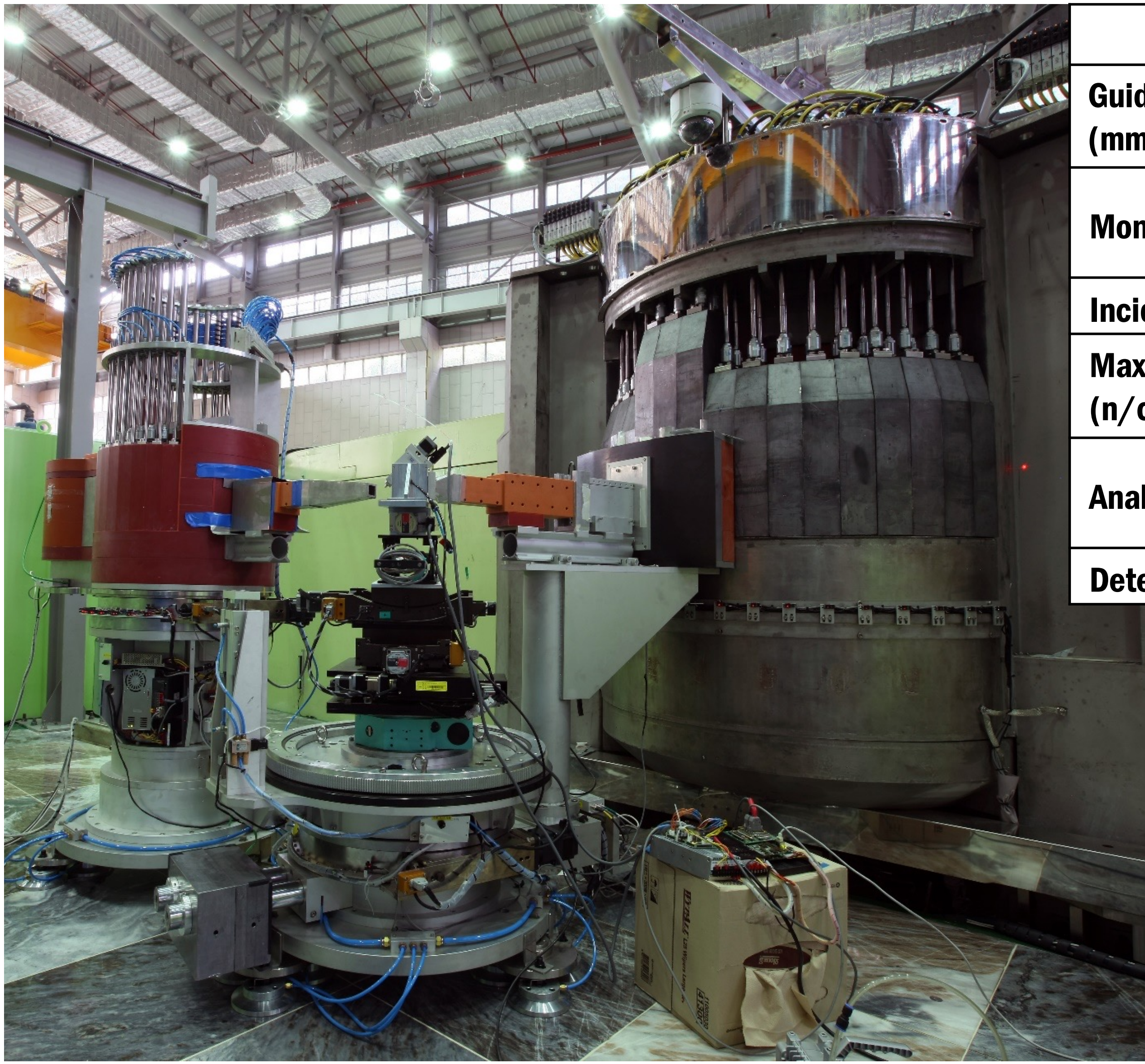
Responsible: Eunjoo Shin, Available since November 2010

REF-V Vertical Neutron Reflectometer

Parameter	Characteristics
Reflection plane	Vertical
Monochromator	Focused, PG(002) , β=0.4°
Wavelength, $\Delta\lambda/\lambda$	4.7535 Å, ~2.0%
Filter	Be, liquid nitrogen cooled
Q range, $\Delta Q/Q$	0.003 ~ 0.3 $Å^{-1}$, > 2.0%
Flux at sample	6.0×10^5 $n/cm^2/sec$
Detector	He3 Single
Polarizer, Analyzer Spin Flipper	Fe/Si SM(m=3) Mezei type, FR>95%,P=94%

Responsible : June-Hyuk Lee available since 2007 at Reactor hall and 2012 at Guide hall

Cold-TAS Cold Neutron Triple-Axis Spectrometer

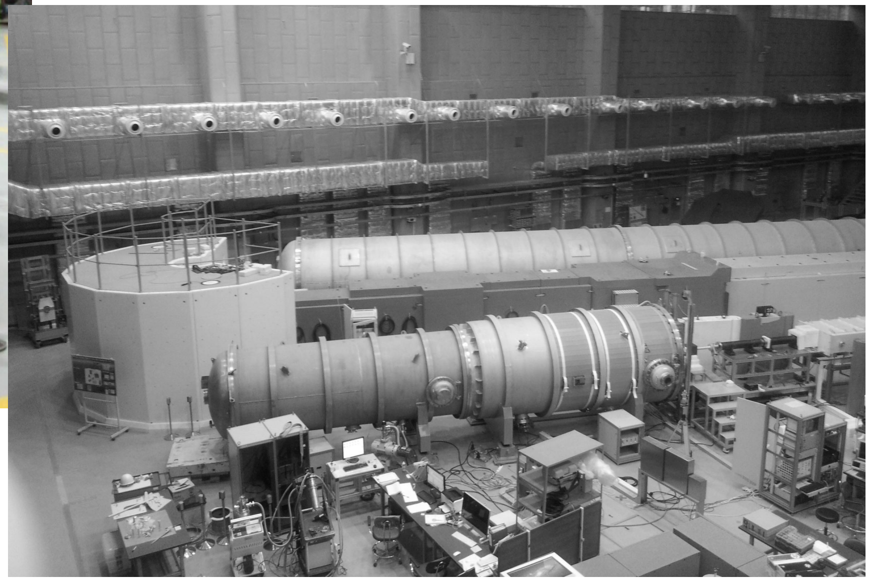


Parameter	Value
Guide Dimension (mm × mm)	50 × 150
Monochromator	Vertically Focusing PG(002)
Incident neutron energy (meV)	2 ~ 20
Max. flux at sample (n/cm^2s @ 4 Å, open-open)	9.2×10^6
Analyzer	Horizontally Focusing PG(002)
Detector	Single ^3He

Responsible: SungDae Ji available since 2021

DC-ToF Disk Chopper Time-of-Flight Spectrometer

- Sample-Detector distance : 2.5m
- Maximum rotation Speed: 20,000rpm
- Chopper Configuration : 6 Disks(2 double choppers + 2 single chopper)
- Position Sensitive detector
  - ϕ25, 2m long
  - 57 PSDs are installed



Responsible : Ji-Yong So, available since 2018

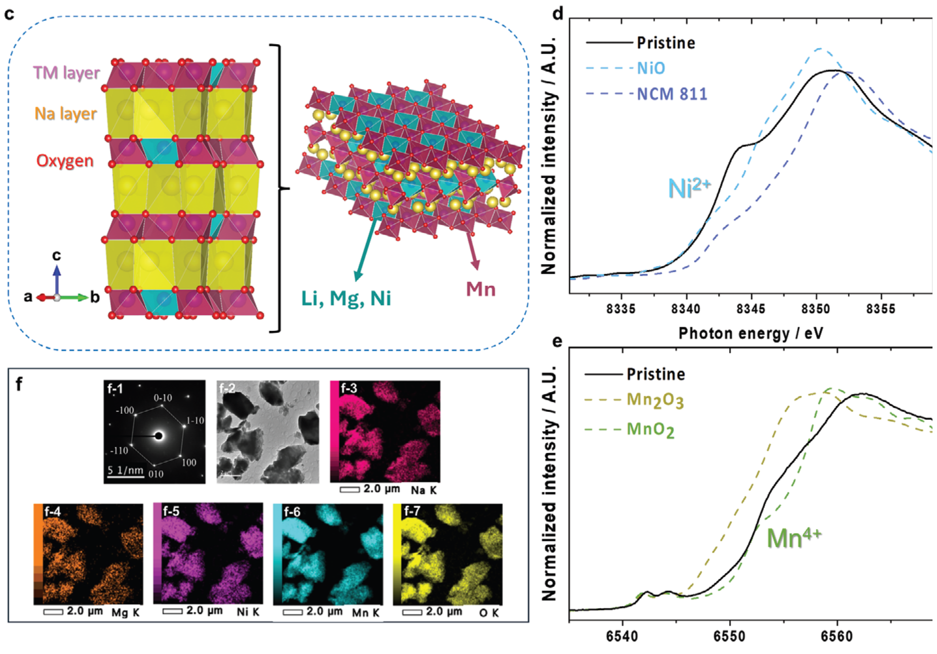
III. OUTCOMES

Study on Sodium-Ion Battery

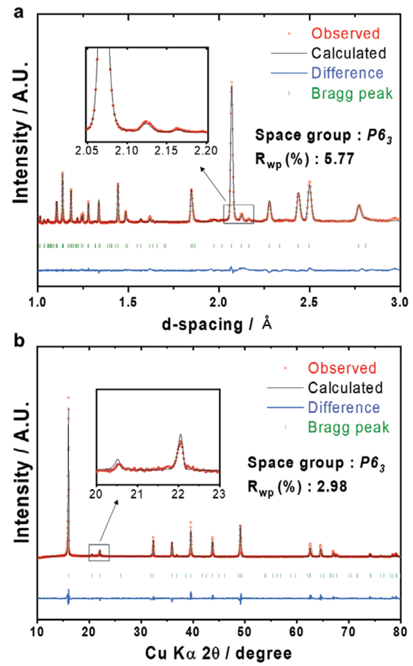
✓ Understanding the oxygen-redox reactions within Mn-rich layered cathode materials is an important strategy to improve the capacity of sodium-ion batteries while satisfying the demand for low cost and the use of abundant resources.

- Neutron diffraction elucidate the Li migration phenomena within the transition metals and sodium layers.

❖ Schematic illustration & surface analysis



❖ ND & XRD data



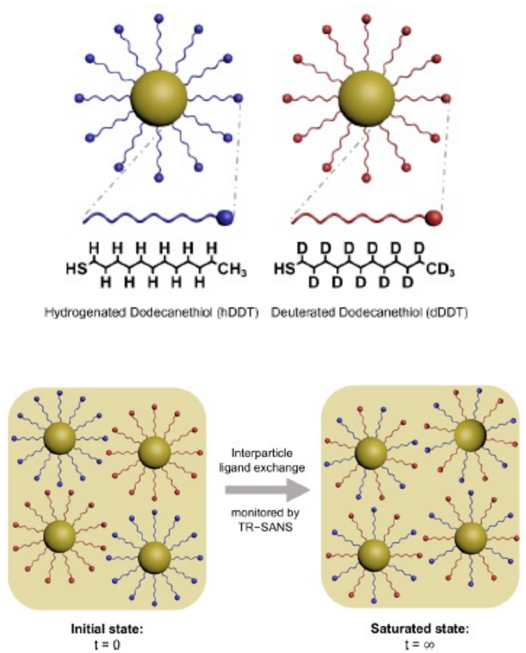
S.-J. Lee *et al.*, Theoretical and Experimental Optimization of P2-Type Sodium-Ion Battery Cathodes via Li, Mg, and Ni Co-Doping: A Path to Enhanced Capacity and Stability, Adv. Energy Mater. ***15***, 2405111 (2025).

Colloidal dispersions: H-D Ligand Exchange Phenomenon

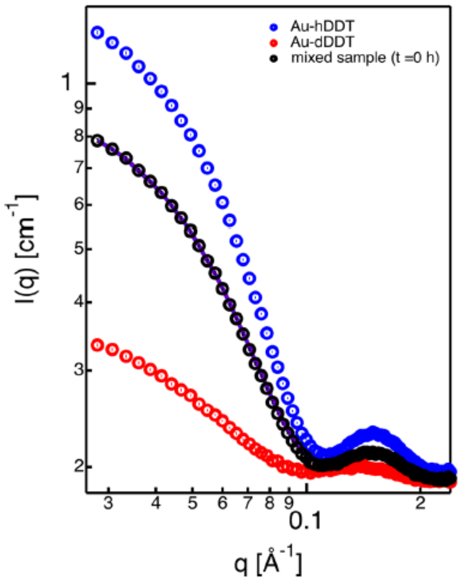
✓ This study quantitatively revealed the temperature dependent kinetics of interparticle ligand exchange between gold nanoparticles (AuNPs) using time-resolved small angle scattering measurements (TR-SANS).

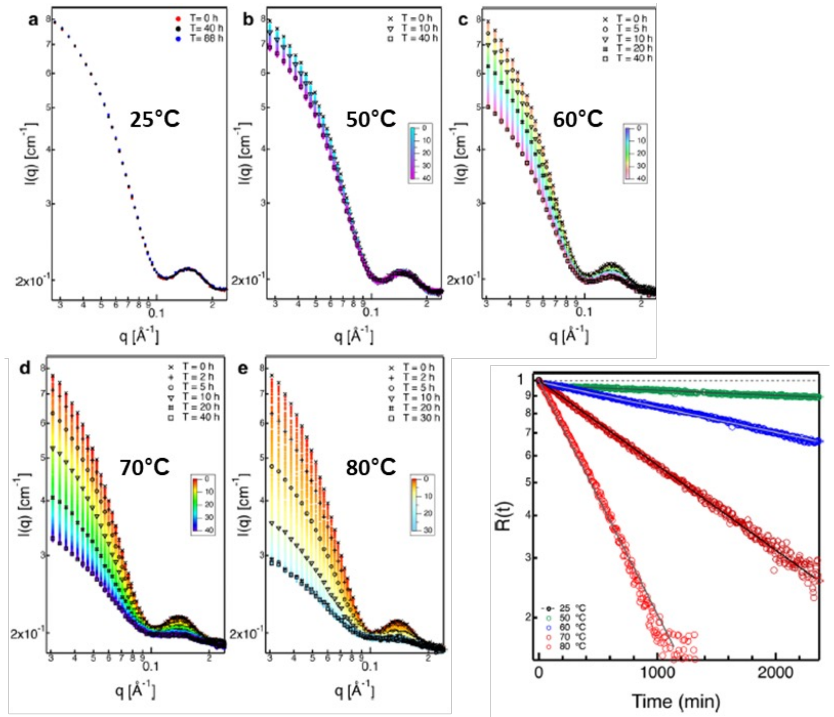
- To understand temperature-dependent ligand exchange process, gold nanoparticles coated with H-ligand (Au-hDDT) and D-ligand (Au-dDDT) were mixed in a 1:1 ratio, and the ligand exchange rate was identified through TR-SANS.

❖ Concept of experimental



❖ TR-SANS profile





S.-J. Lee *et al.*, Interparticle Ligand Exchange Kinetics Revealed by Time-Resolved SANS. *Nano Letters* ***25***, 981-986 (2024).

Polymers: Structural Transformations of Doped Conjugated Polymers

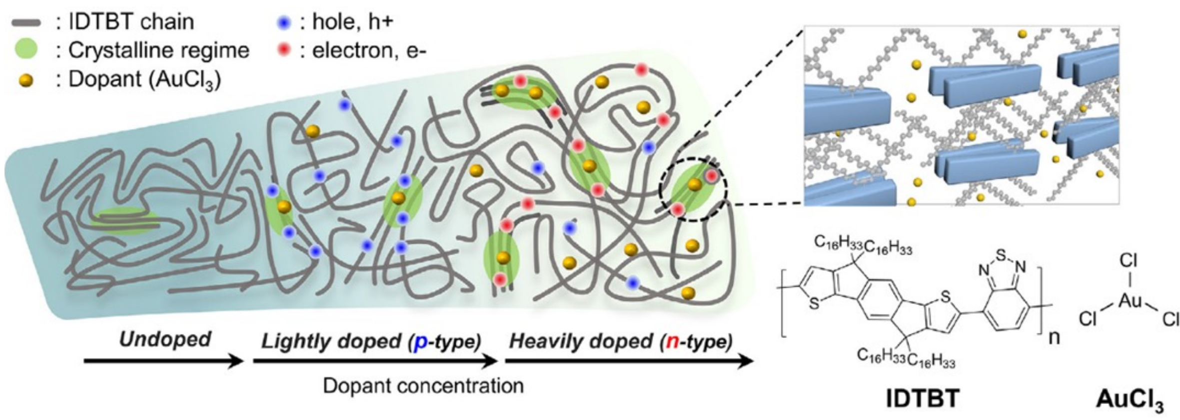
✓ SANS study of heavily doped conjugated polymers

- Stiffness of polymer chains were characterized by Kuhn length.

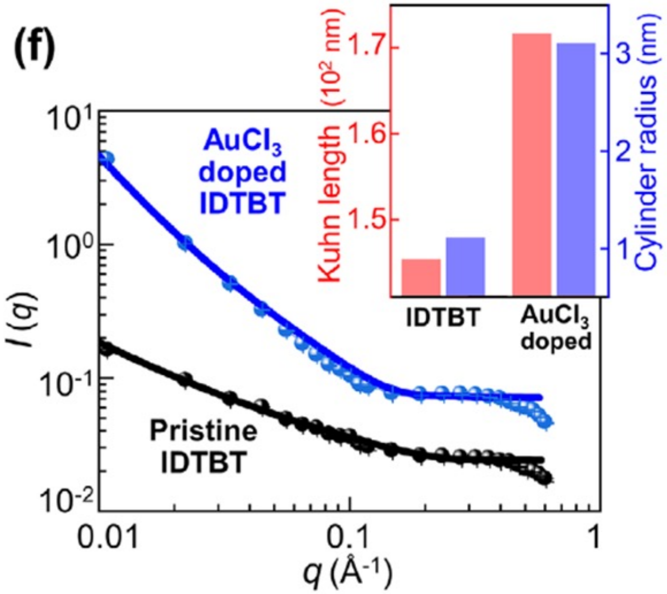
  Undoped = 145.3nm → Doped = 171.6 nm

- Doped polymers induced a conformational transition of the polymer chains toward a more extended configuration with reduced bending.

❖ **Schematic drawing**



❖ **SANS profile**



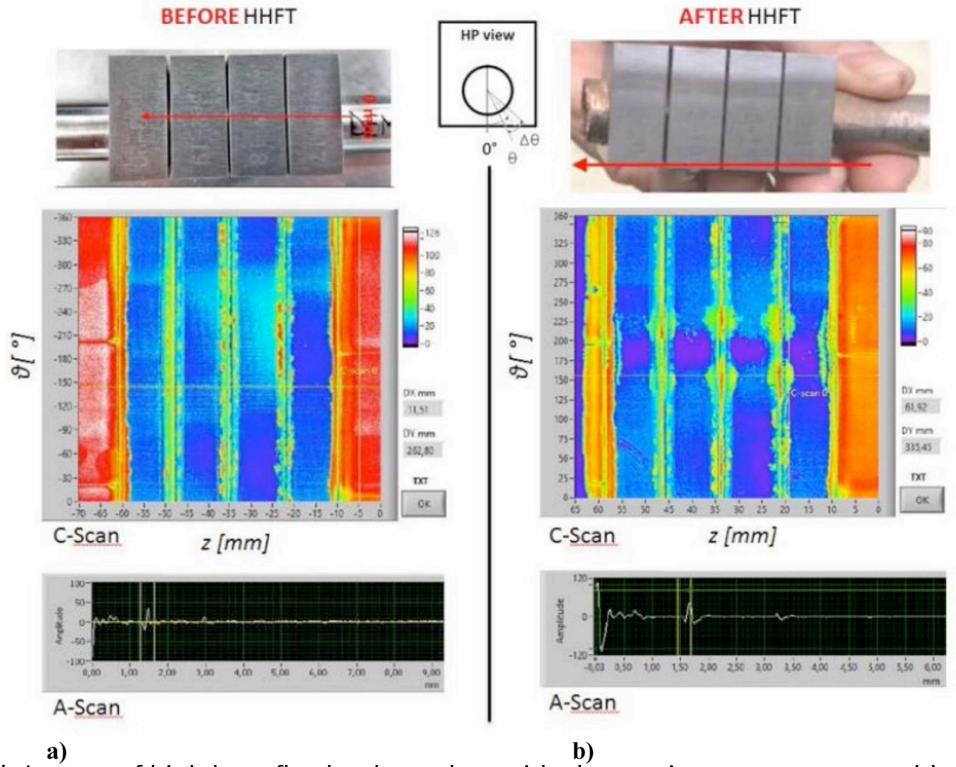
Eunsol Ok *et al.*, Accompanying Structural Transformations in Polarity Switching of Heavily Doped Conjugated Polymers. *Advanced Materials* **2505945**, (2025).

Residual Stress Measurement: Fusion Reactor Components

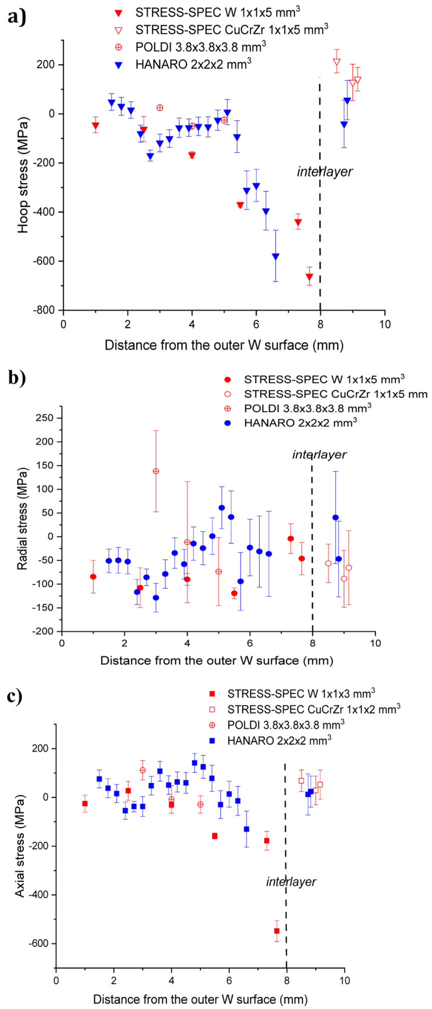
✓ Plasma-facing component (PFC) under high heat-flux (HHF) loads is the most important factor to determine the lifetime of the component in future fusion reactor

- Sample : 4 Tungsten blocks + CuCrZr pipe
- Stress contributions were determined non-destructively by means of neutron diffraction technique. (HANARO, FRM II, SINQ)

❖ **Samples**



❖ **Residual stress data**

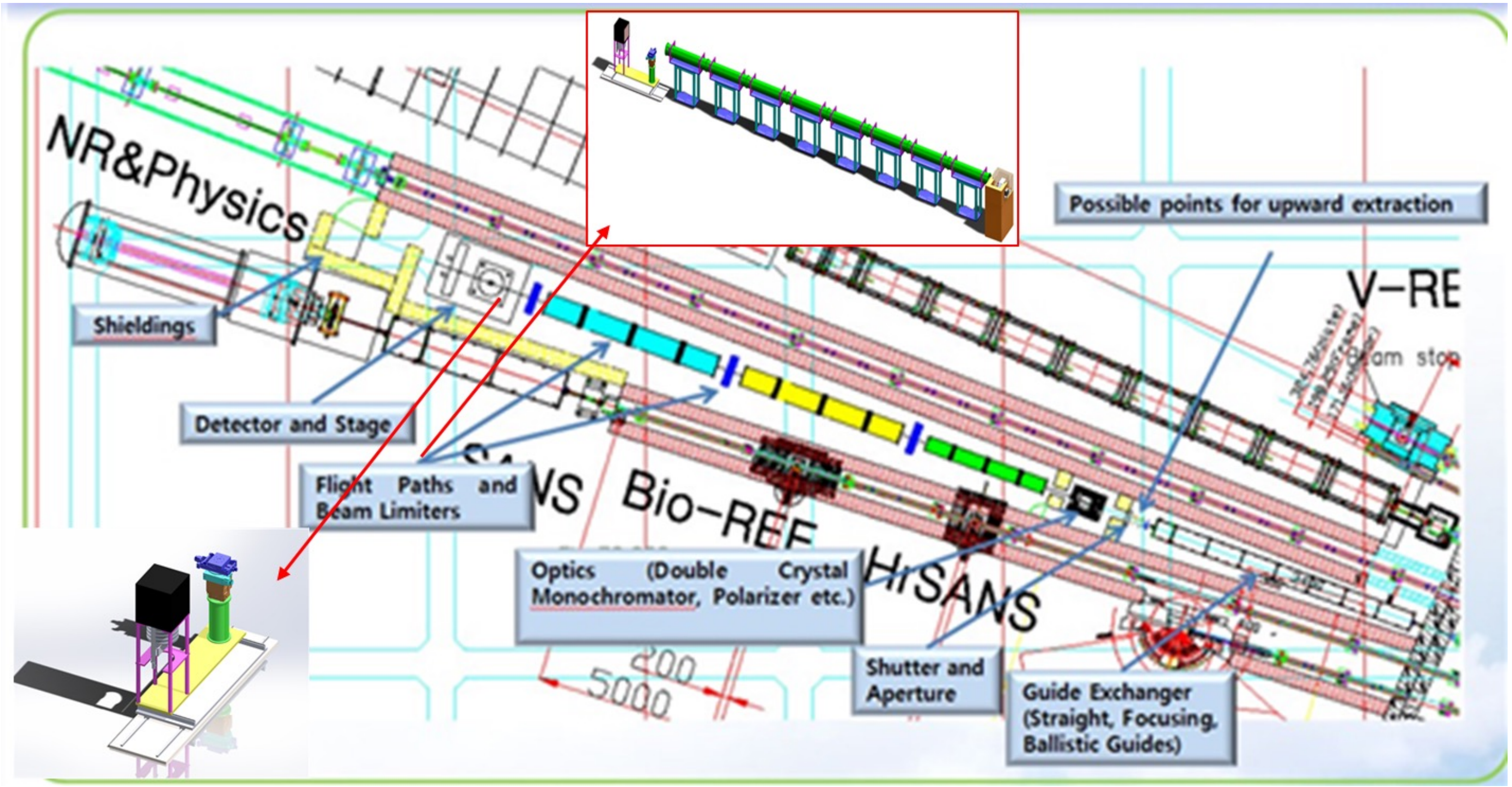


J.-H. You *et al.*, Impact of high heat flux loads on the residual stress in a tungsten-monoblock plasma-facing component. Fusion Eng. & Design, 114804, (2025).

New Instrument : Cold Neutron Radiography Facility

❖Cold NR at CG4B Beam Line

- High resolution and energy selective neutron imaging
- Budget for the construction will be ready next year(most probable)



IV. USER PROGRAM

Korea Atomic Energy Research Institute

Recent Activities

- Proposal review committees for HRPD & 40M SANS is operational
- HANARO has usually hosted two summer school every year

  - Cold Neutron Summer School(SANS, REF, DC-TOF)
  - Neutron Diffraction Summer School(HRPD, FCD, RSI)

Cold Neutron Summer School
(Aug. 4-5)

Neutron Diffraction Summer School
(Aug. 6-8)

For International Users

- HANARO neutron beam instruments are available not only to Korean users but also to international users

- Call for proposal and allocation of the beamtime is proceeded by email written in Korean. Only registered persons can receive the e-mail

  -> Very difficult access to international users

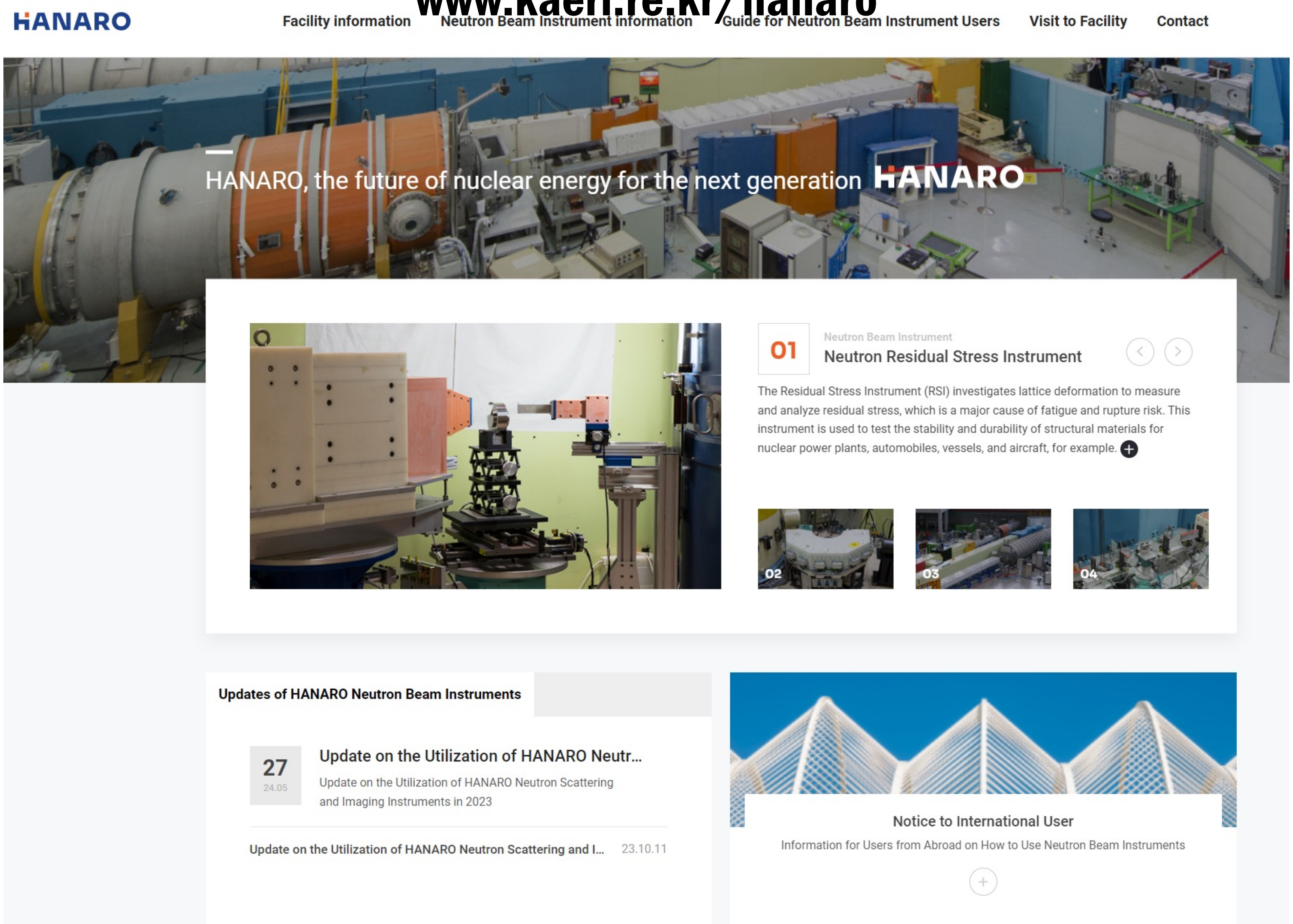
- English e-mail registration system in the English website will be available next month

- Next call for proposal e-mail will be sent in Korean and English

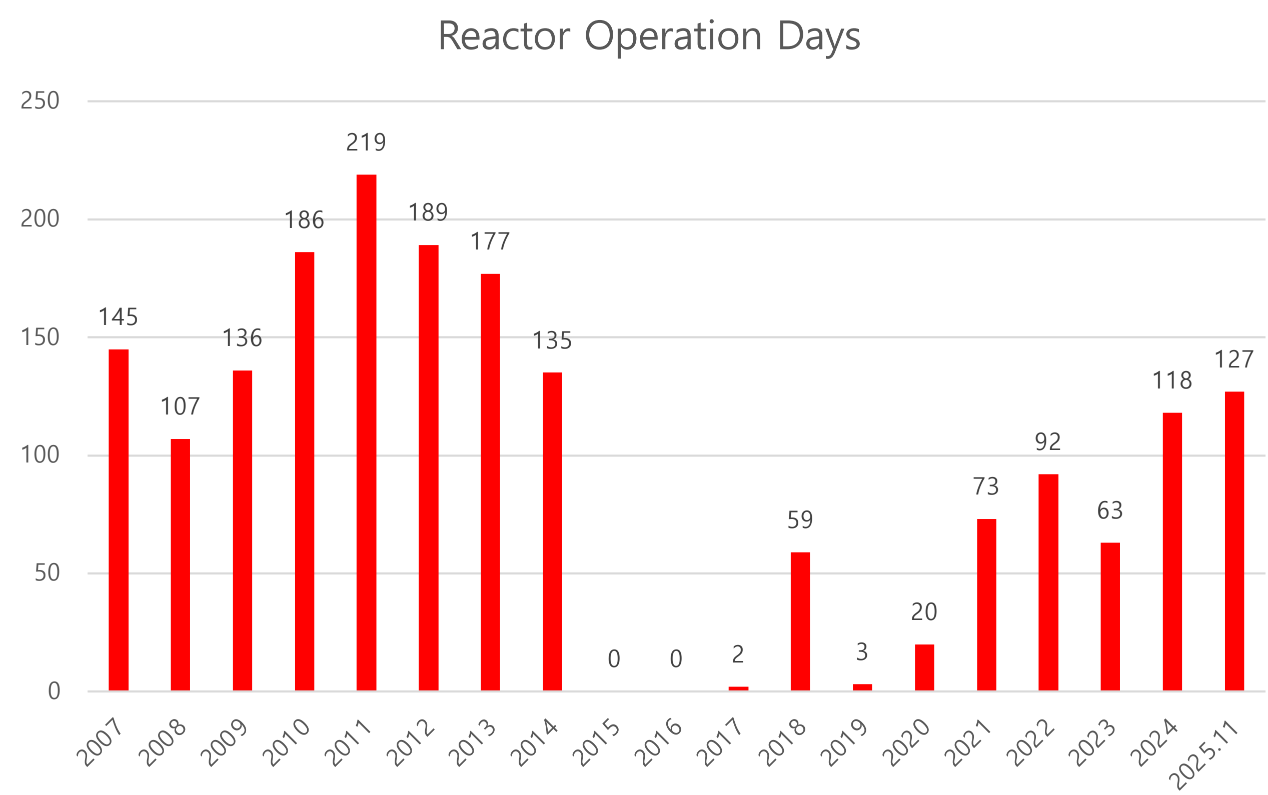
- Foreign users interested in using HANARO neutron beam instruments may email their inquiries to useroffice@kaeri.re.kr and receive a reply from HANARO staff in charge of the instrument in question.

English Homepage of HANARO Neutron Facility

www.kaeri.re.kr/hanaro



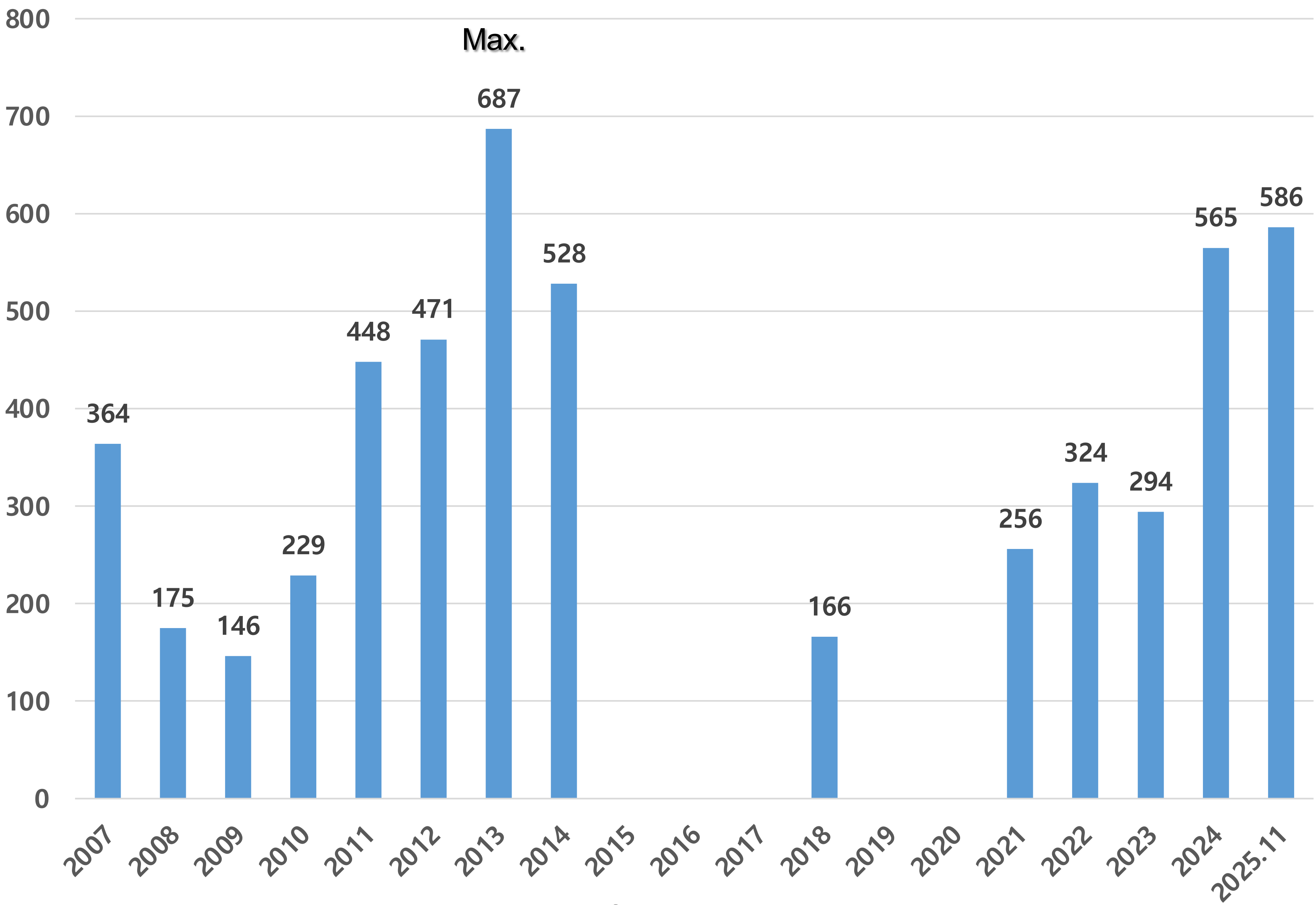
Operation History of HANARO



- **HANARO have operated for 127 days this year**
- **About 180 days of operation is expected in 2026**

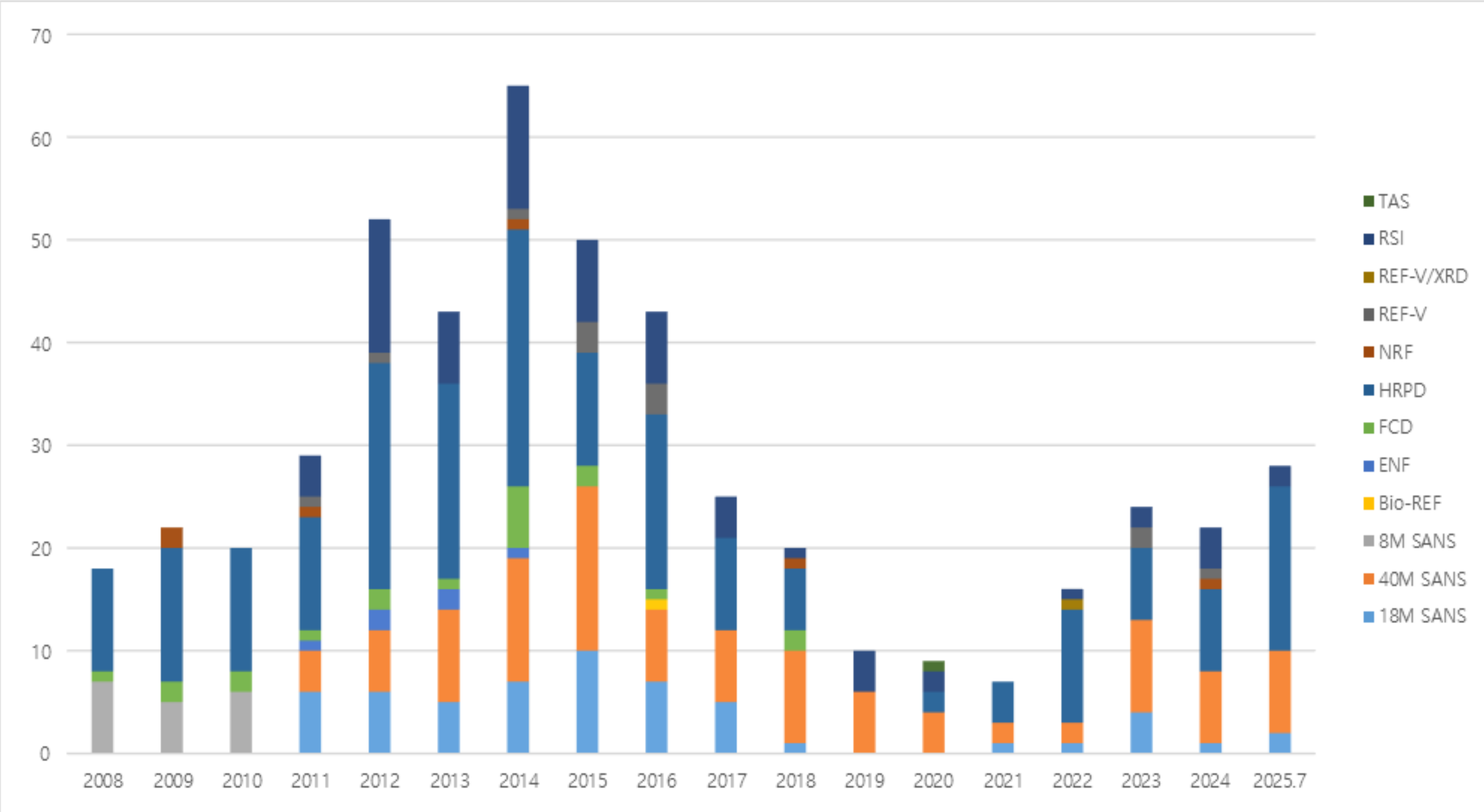
- **Seismic reinforcement work was carried out from 2015 to 2017**
- **Normal operation was possible since 2018, but we faced another problem.**
- **Strong regulation for research reactors has been introduced since July 2018**
- **When reactor trip occurs, we have get permission from the regulatory commission for restarting.**
- **Takes a lot of time to get permission to restart after a trip of the reactor**
- **Change the regulation was completed Sep. 19, 2024 : There is no obligation to report on trips which are not related to reactor safety**

Number of Users



Users = Principal Investigator of the accepted proposals + actual visitors

Annual Publication Trend



Statistics of 2024

Status of Use(Number means days)

Instrument	External users (A)			KAERI users (B)		Maintenance			Operation Ratio(%) (A+B+C)/ Total
	Industry	University	Institute	Neutron Sci. Division	Other Division	Un use	Repair	Beam test(C)	
RSI	-	52	7	34	7	8	-	4	92.9%
ENF	26	20	11	9	-	13	-	-	83.5%
NRF	21	10	16	5	1	22	-	4	72.1%
FCD	-	83	-	1	-	20	-	8	82.1%
HRPD	8	63	3	21	-	1	-	16	99.1%
REF-V	3	35	-	2	-	11	-	4	80.0%
40M-SANS	21	71	1	8	5	-	-	6	100.0%
18M-SANS	-	52	24	14	-	1	4	17	95.5%
Cold-TAS	-	-	-	29	-	72	-	11	35.7%
Sum	79	386	62	123	13	148	4	70	82.3%

Total days used by external users is 527 days
Among them over 15%(79 days) were used by industries

Statistics so far 2025

Status of Use(Number means days)

Instrument	External users (A)			KAERI users (B)		Maintenance			Operation Ratio(%) (A+B+C)/ Total
	Industry	University	Institute	Neutron Sci. Division	Other Division	Un use	Repair	Beam test(C)	
RSI	19	70	1	13	1	5	0	15	96.0%
ENF	5	43	6	14	3	16	0	0	81.6%
NRF	8	1	6	17	0	43	0	12	50.6%
FCD	-	49	1	37	0	0	0	37	100.0%
HRPD	7	69	11	21	0	0	0	16	100.0%
REF-V	11	41	-	18	0	27	0	27	78.2%
40M-SANS	22	69	8	8	10	0	0	7	100.0%
18M-SANS	1	63	9	0	0	0	14	37	88.7%
Cold-TAS	0	0	0	49	0	37	0	38	70.2%
Sum	73	405	42	177	14	128	14	189	85.0%

Total days used by external users is 520 days
Among them over 14%(73 days) were used by industries

Industry Use

❖ **From 2021 to 2025.11**

❑ **Total use days by outside users : 2018**

❑ **Use days by industry : 294 (about 15 %)**

❑ **Large companies (ranking in KRX, Nov.28)**

- **Samsung Electronics(1)**
- **LG Energy Solutions(3)**
- **Hyundai Motors(5)**
- **Doosan Enerbility(6)**
- **Hanwha Aerospace(10)**
- **Hyundai MOBIS(20)**
- **LG Chemicals(22)**
- **POSCO Holdings(25)**
- **Samsung SDI(26)**
- **SK on(31)**

Year	Use days by Korean Industries	Use days by All External Users	Use Ratio
2013	34	645	5%
2021	20	277	7%
2022	55	414	13%
2023	67	280	24%
2024	79	527	15%
2025.6	73	520	14%

V. COLLABORATION btw JAPAN AND KOREA ON NEUTRON SCIENCE

Collaboration btw Japanese Counterparts & KAERI

- **MOA btw Research and Education Center for Atomic Sciences, Ibaraki Univ. and HANARO AND Quantum Science Laboratory, KAERI has been renewed on Nov. 2024**

- **Professors at Kyoto University research reactor visited HANARO in June: Agree on the research cooperation in the future**

- **Collaboration between JAEA and KAERI**
  - **Annual meeting between JAEA and KAERI participating two presidents started last year**
  - **Report to the KAERI headquarter on activities participating both JAEA and KAERI(JK meeting and AONSA FDM)**

JK/KJ Meeting on Neutron Science

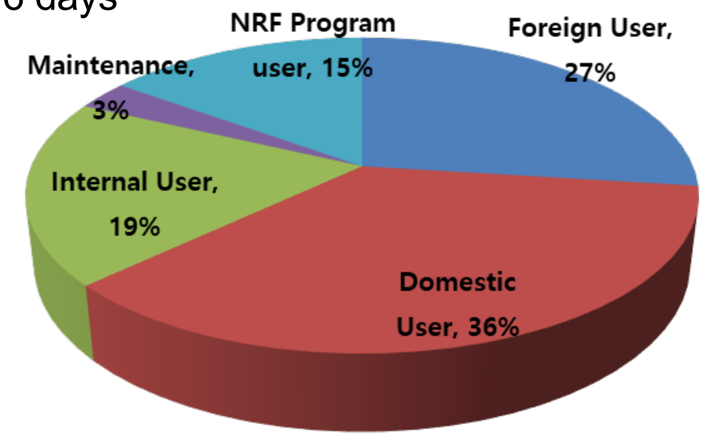
- **Started in 2000. Held alternately in Korea and Japan every year**
- **20th JK meeting was held in Daejeon on Sep. 12th as the satellite meeting of International HANARO Symposium 2025.**



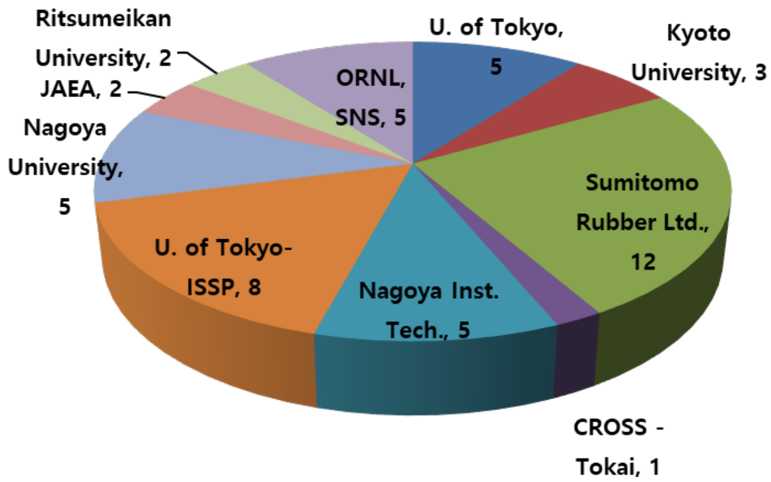

Not long time ago.... Year of 2013

About 10 Korean proposals submit to J-Parc every round

- User Statistics of 40M SANS Instrument



- Statistics of Foreign Users



NO	PI	Affiliation	Type of Affiliation	Instruments	Country	Use days
1	Kamiya	U. of Tokyo	University	40M SANS	Japan	5
2	Kanaya	Kyoto University	University	40M SANS	Japan	3
3	Masui	Sumitomo Rubber Ltd.	Industry	40M SANS	Japan	12
4	Matsuura	CROSS - Tokai	Natl. Institute	40M SANS	Japan	1
5	Okamoto	Nagoya Inst. Tech.	University	40M SANS	Japan	5
6	Shibayama	U. of Tokyo-ISSP	University	40M SANS	Japan	8
7	Takano	Nagoya University	University	40M SANS	Japan	5
8	Yue Zhao	JAEA	Natl. Institute	40M SANS	Japan	2
9	Sadakane	Ritsumeikan University	University	40M SANS	Japan	2
10	Wei Ren	ORNL, SNS	Natl. Institute	40M SANS	USA	5

Thank you!

Our income from industries 2024

No.	Company Name	Instrument Used	Use Days	Pay or Not	Comment
1	Hyundai Motor Company	NRF	21	Pay	Project(Half rate)
2	Samsung Electronics	ENF	25	Pay	Normal rate
3	Kumho Petrochemical	40M-SANS	1	Not	Trial Use
4	LG Display	REF-V	3	Not	Trial Use
5	Samsung Electro-Mechanics	ENF	1	Not	Trial Use
6	Samsung Electro-Mechanics	40M-SANS	1	Not	Trial Use
7	SCAI Therapeutics	40M-SANS	19	Not	Small company support program
8	POSCO Holdings	HRPD	1	Not	Local company support program
9	EcoPro BM	HRPD	1	Not	Local company support program
10	LG Energy Solution	HRPD	2	Not	Local company support program
11	Umicore	HRPD	4	Not	Local company support program

Our income from industries 2025

No.	Company Name	Instrument Used	Use Days	Pay or Not	Comment
1	Quantum Beam Solution	NRF	2	Not	Small company support program
2	SK on	NRF	2	Not	Trial Use
3	LG Energy Solution	NRF	2	Not	Trial Use
4	LG Energy Solution	ENF	2	Pay	Normal rate
5	Samsung Electro-Mechanics	ENF	1	Not	Trial Use
6	Samsung Electronics	ENF	4	Pay	Normal rate
7	HANA Materials	RSI	4	Not	Small company support program
8	POSCO	RSI	6	Pay	Project
9	Hyundai Motor Company	RSI	9	Not	Trial Use
10	POSCO Holdings	HRPD	1	Not	Local company support program
11	Umicore	HRPD	3	Not	Local company support program
12	LG Energy Solution	HRPD	1	Not	Local company support program
13	HANKOOK COATING	18M SANS	1	Not	Small company support program
14	SCAI Therapeutics	40M-SANS	17	Not	Small company support program
15	Natural Nature	40M-SANS	2	Not	Small company support program
16	Bojeong Food	40M-SANS	3	Not	Small company support program
17	iSAC Research	REF-V	11	Not	Local company support program