Consumer Applications of Superconducting Technology and Future Prospects

Company website
http://www.mhims.co.jp/en/index.html

Katsuya Sennyu

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Mitsubishi Heavy Industries Machinery Systems, LTD (MHI-MS)

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MITSUBISHI HEAVY INDUSTRIES MACHINERY SYSTEMS

1. Company profile
2. Consumer application of accelerator
3. Difference between NRF, SRF and SM
4. Problem of SRF
5. History of industrialization in SRF technology
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7. Summary

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1-1. Company organization

MITSUBISHI HEAVY INDUSTRIES MACHINERY SYSTEMS

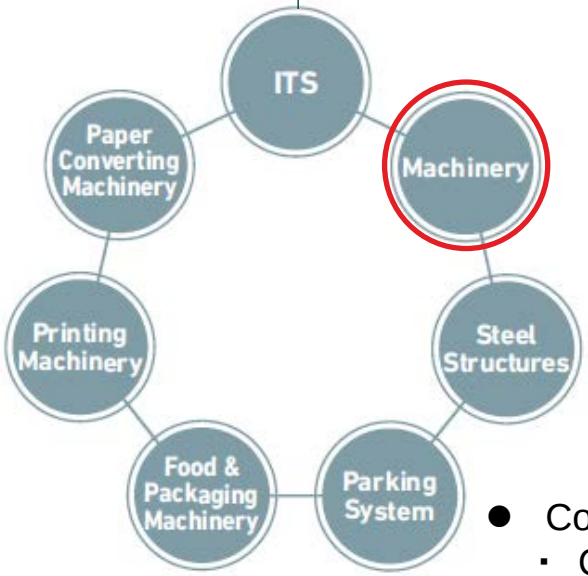
Mitsubishi Heavy Industries, ltd

Power systems

Industry & Infrastructure

MHI-MS

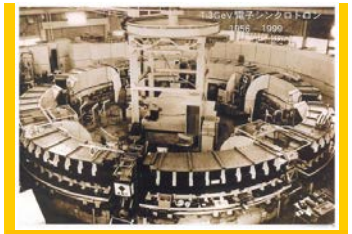
Aircraft, Defense & Space



- Cooperate overview
  - Capital 2 billion JPY
  - Employee 2,000

1-2. History of accelerator business

MITSUBISHI HEAVY INDUSTRIES MACHINERY SYSTEMS

1959-1961	1971-1973	1979-1982	1985-1986	1986-1991
				
Electron Linac for Tokyo Univ.	Proton Linac for KEK PS Injector	Electron Linac for KEK PF Injector	APS Cavity for KEK TRISTAN MR	SC Cavity for KEK TRISTAN MR

1996-1998	1998-2003	2002-2008	2002-2012	2004-2006
				
ARES Cavity for KEKB MR	DTL/SDTL Cavity for J-PARC Injector	Ceramic Chamber for J-PARC RCS	ACS Cavity for J-PARC Inj. Upgrade	SC Crab Cavity for KEKB MR

2006-2007	2006-2008	2009-2012	2010-2013	2011-(2015)
				
Copper Chamber for KEKB MR	C-band Accelerator for RIKEN XFEL “SACLA”	L-band SC Cavity for KEK STF (ILC R&D)	500MHz SC Cavity for NSRRC TPS	S-band Accelerator for PAL XFEL PJ

1-3. History of SRF development in MHI-MS

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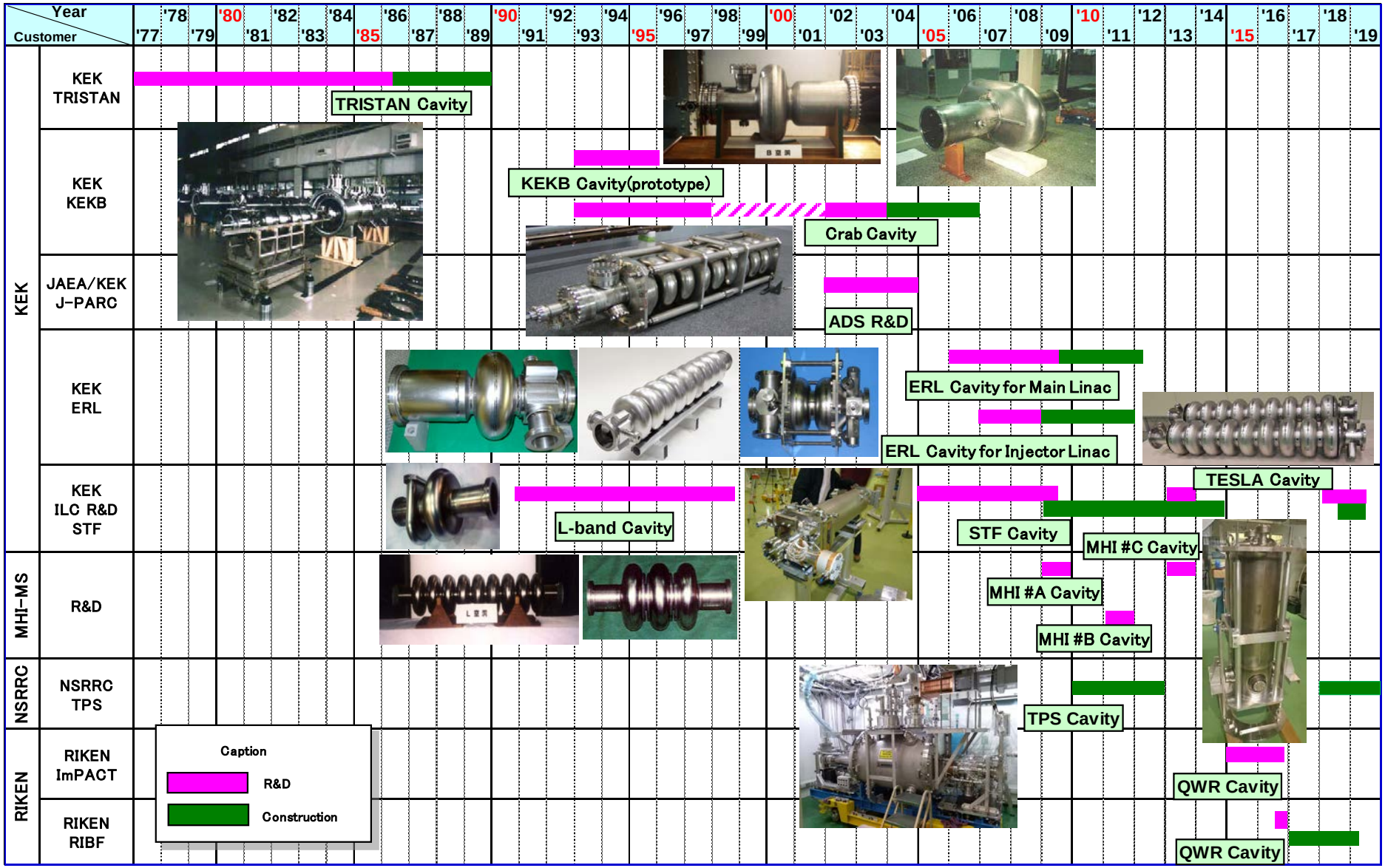

1-4. Development for ILC in MHI-MS

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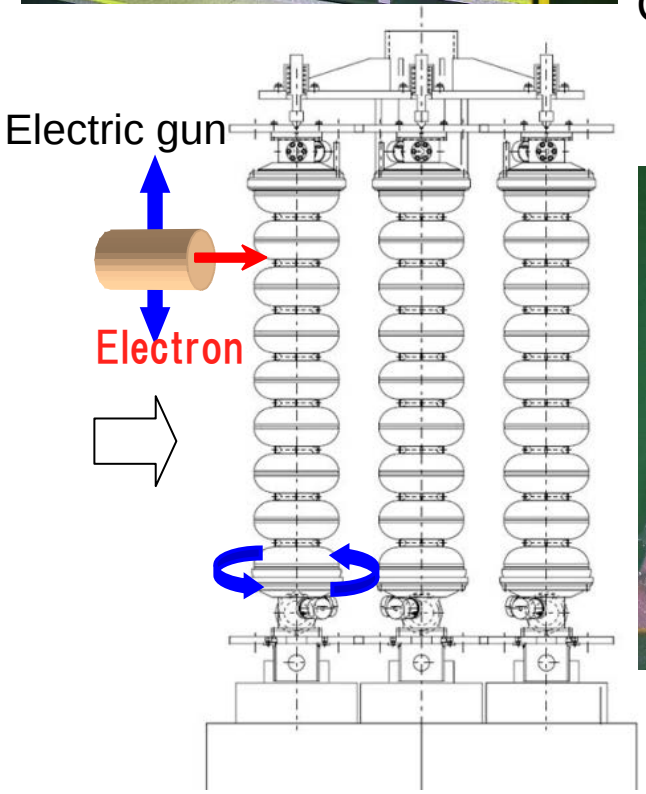
Electron Beam Welding （EBW）: Key technology of cavity fabrication

- EBW is processed in the vacuum atmosphere
- EBW melt the base metal by electron beam power without welding rod

Clean welding procedure lead to good cavity performance



All parts are welded by one batch

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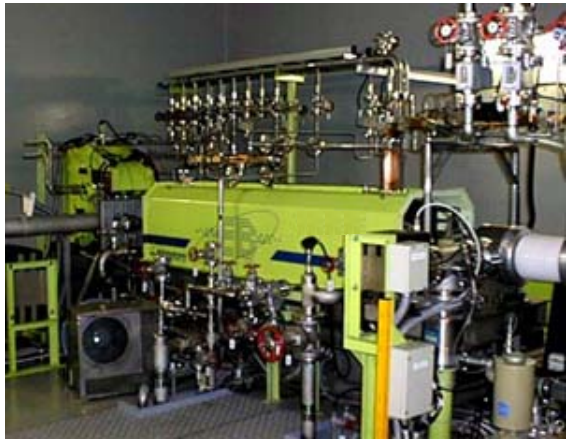
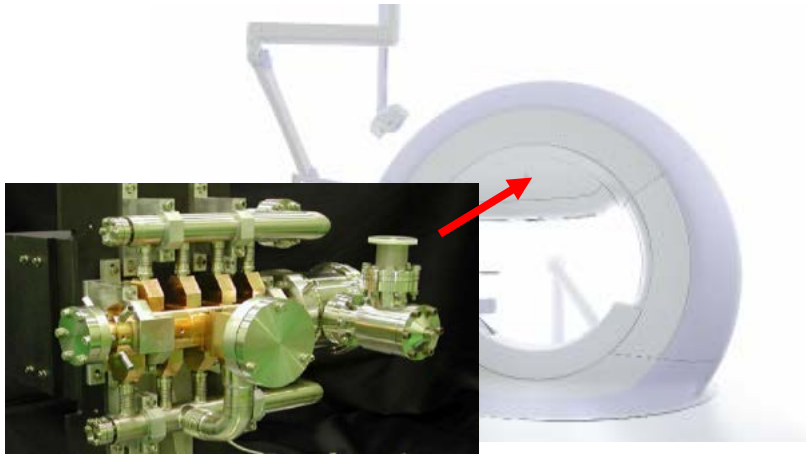
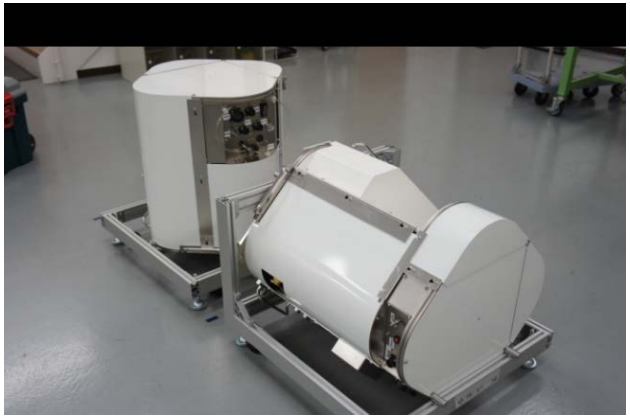
2. Consumer application of accelerator



Sterilization system



X-ray therapy system



Non-Destructive Inspection system
(From AET Inc HP)

X-ray CT scanning system
(From TESCO Corp HP)

Content

3. Difference between NRF, SRF and SM

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	Normal Conducting Radio Frequency	Super Conducting Radio Frequency	Super Conducting Magnet
Material	Cu, Al, Fe, etc.	Nb	NbTi, Nb3Sn,YBCO, etc.
Cooling medium	Water	Liquid Helium	Direct cooling, Liquid Helium, Liquid Nitrogen
Cooling system	Chiller	Large refrigerator	Compact refrigerator
Operating temperature	Around 20℃	Around −270℃	Around −270℃, −196℃
Electrical resistance	−	−	0
RF loss on the surface	R_N	～$R_N \times 10^{-6}$(≠0)	−
Operating duty	Low	High	Direct current
Consumer Application	Low duty and high power X-ray source	−	MRI, Linear Motor Car

Only SRF is **not** used for consumer application by now.

Content

4.Problem of SRF

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SRF is a good accelerator for high current beam and high power.

Problem

(1) It was difficult to fabricate SRF cavity and the cavity performance had a big gap from ideal one

➡ The improvement of fabrication technology including surface treatment was proceeded step by step.

(2)There are a lot of factors that affect the performance of SRF cavity Cavity performance can't be evaluated until cooling test by LHe

➡ Process management and inspection camera made the cavity performance stable

(3) RF loss of SRF can not be neglected and SRF cavity need large refrigerator

➡ Large hurdle for consumer application

Content

5.History of industrialization in SRF technology

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SRF community has proceeded industrialization
by a lot of development of technology

Era	Major project	Developed technology
1980's	TRISTAN (KEK)	・High purity Nb ・Forming technology ・Electron Beam Welding technology ・Annealing technology ・Electro Polishing technology
1990's	LEP2 （CERN）	・Nb sputtering technology ・Mass production technology
2000's	EXFEL （DESY)	・Inside inspection technology ・High Pressure Rinsing technology ・Ultra Pure Water technology ・Clean pumping technology ・Automatic technology
2010's	LCLS2 （SLAC)	・Nitrogen doping technology ・Magnetic shielding technology
2020's	ILC/EUV-FEL	

Note: These technology have developed at various laboratory and company in the world

5.History of industrialization in SRF technology

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Innovation has created by a 4 times change from original

4 times Eacc gradient

Key technology

TRISTAN → EXFEL

High Pressure Rinsing

4 times speed

(Engine)

4 times Q value

EXFEL → LCLS2

Nitrogen doping

We are here now

4 times speed

(Motor)

Pictures from HP of JR Tokai, Porsche, Goo-net

5.History of industrialization in SRF technology

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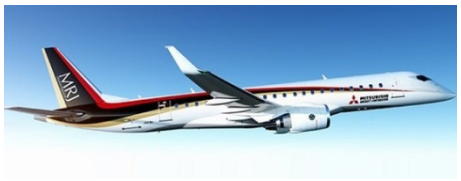
4 times speed



New technology

(Jet Engine)

Innovation

e.g. 4 more times Q value

LCLS2 → Future Project

MgB2 or Multilayer?

Through ILC/EUV-FEL

↓

New Application for consumer

High efficiency refrigerator

Pictures from HP of JR Tokai, MRJ

Content

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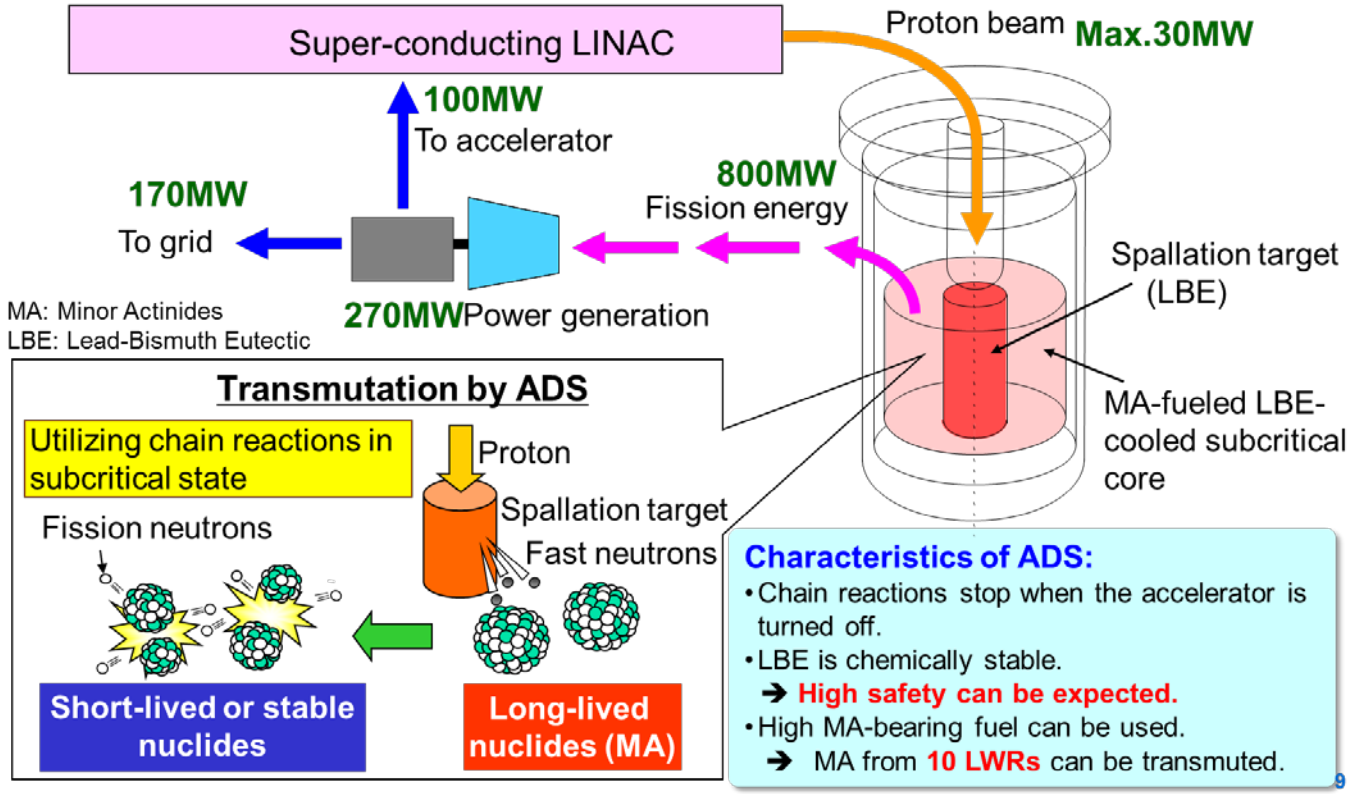
Transmutation of Nuclear Waste (Accelerator Driven Systems)

- High intensity protons are accelerated by SRF and irradiated to target
- Generated Neutrons are irradiated to long-lived nuclides

  ⇒ Contribution to reduction of environment impact

Q value of SRF effect to the operation and construction cost of refrigerator

ADS project in China has already launched!



From H. Oigawa, 2015

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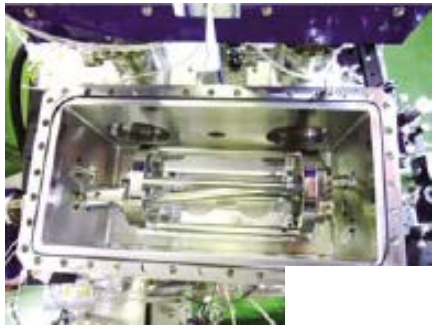
Compact high brightness photon beam generator by SRF

【Motivation】

- High luminance X-ray source in company or collage
- Application for Genome analysis, nanomaterial analysis, high resolution X-ray imaging

【Technology】

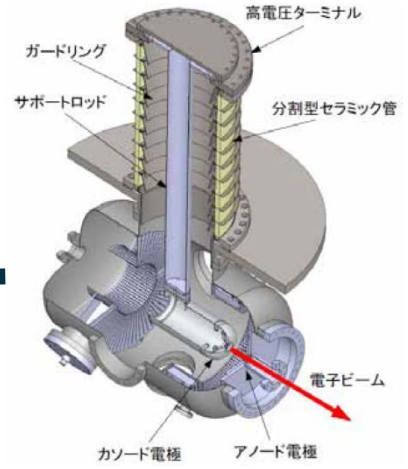
- Inverse Compton scattering by collision with laser and electron beam
- High luminance and high power of X-ray source



Laser pulse accumulator

SRF

Bird view



Electron gun

From J. Urakawa et al, 2012

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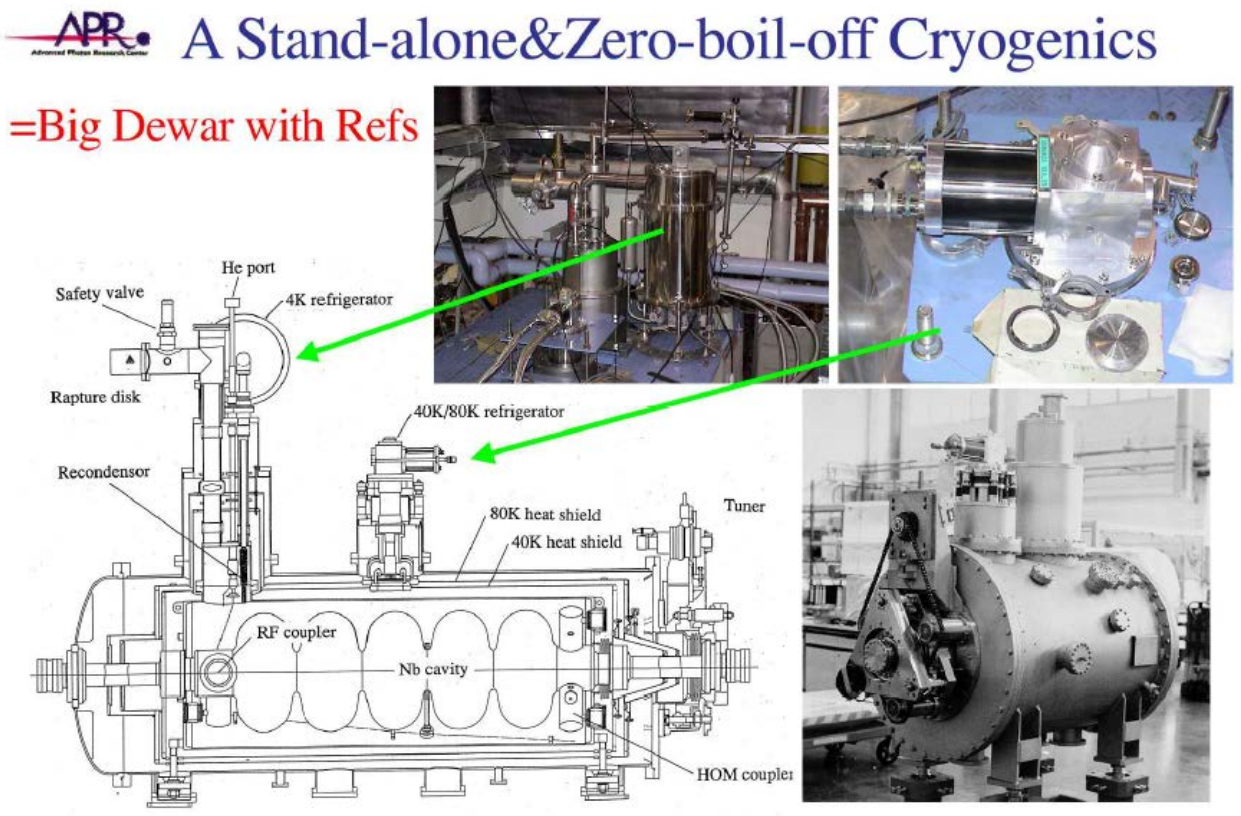
4 times Q value and more leads to innovation of compact SRF system by closed cycle compact refrigerator



Closed cycle operation of SRF by compact refrigerator

From E. Minehara, et al, 2004

6.Future prospect by new technology

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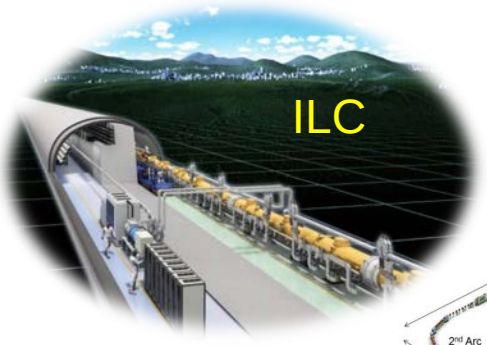


EUV-FEL

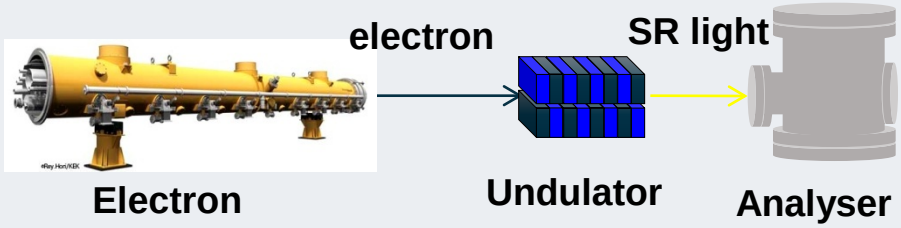
Continuing the development
- Extremely high Q cavity
- High capacity compact refrigerator

- Improvement of reliability
- Reduction of manufacturing cost

- High gradient/High Q-value
- Mass production

Generalization of SRF

Synchrotron Radiation facility in the company
- Application for innovative drug discovery
- Application for environment issue



- High resolution electronic microscope
- Cancer treatment
- Soil remediation
- Nuclear security system
- RI manufacturing facility for medical use

etc.

From H. Kawata, 2018

7. Summary

(1) MHI-MS have a lot of experience about SRF and MHI-MS is preparing for ILC / EUV-FEL.

(2) SRF fabrication technology have been established step by step in the world up to level of industrial product.

(3) High Q technology by nitrogen doping gave us the great potential of SRF for consumer application.

(4) Company expect to the next innovation like nitrogen doping technology for consumer application.
And ILC / EUV-FEL project enables this innovation.
We expect to realize ILC / EUV-FEL project.

Thank you for your attention!

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MITSUBISHI
HEAVY
INDUSTRIES
GROUP