NIRS

HIMAC

Status of ECR Ion Sources for Carbon Ion Radiotherapy in Japan

Contents:

1. Approaches for the promotion in Japan
2. Development of ion sources
3. Present status of ion sources

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National Institute of Radiological Sciences

1. Approaches for the promotion in Japan

NIRS HIMAC

Strategy by Japanese government

[Comprehensive 10-Year Strategy for Cancer Control, 1984-1993]

1984 HIMAC project at NIRS as the 1st medical dedicated heavy-ion accelerator in the world has been funded by Ministry of Education, Culture, Sports, Science and Technology (MEXT).

[2nd Comprehensive 10-Year Strategy for Cancer Control, 1994-2003]

1994 Start of clinical trials with carbon ions at NIRS under prescribed clinical protocols.

2001 The 2nd facility (Hyogo Ion Beam Medical Center) has been opened.

2003 Carbon ion therapy has approved as “advanced medical technology” by Ministry of Health, Labour, and Welfare (MHLW).

[3rd Comprehensive 10-Year Strategy for Cancer Control, 2004-2013]

2004 “Workshop for popularization of the charged-particle radiotherapy” was held by MEXT and the summary report has been distributed.

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2007- “Program for the Human Resources Development Relating to Charged Particle Radiotherapy” has been funded by MEXT.

2007- Approved the construction of “the next-generation irradiation systems” at NIRS.

2010 First treatment at Gunma University.

2011 Start of clinical trials with the respiratory gated 3D scanning at NIRS.

NIRS HIMAC

1st Decade: Construction of HIMAC

[Comprehensive 10-Year Strategy for Cancer Control, 1984-1993]

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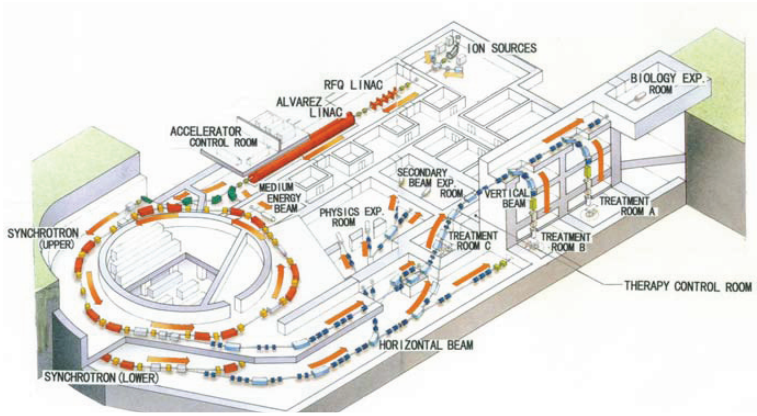
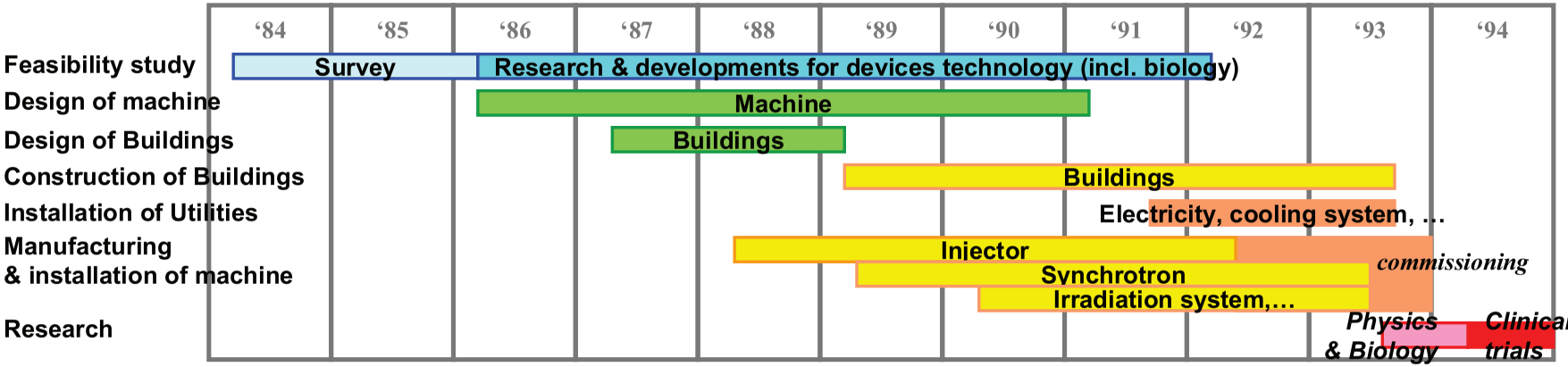


Size: 60 x 120 m
Construction cost: 32.6GJPY
(Building 14.6GJPY)
(machine 18.0GJPY)



"Summary at the 10th anniversary of the heavy ion radiotherapy", edited by MEXT, Monbu-Kagaku Jihou No.1541, August 2004, pp. 10-49.

NIRS HIMAC

2nd Decade: Clinical trials

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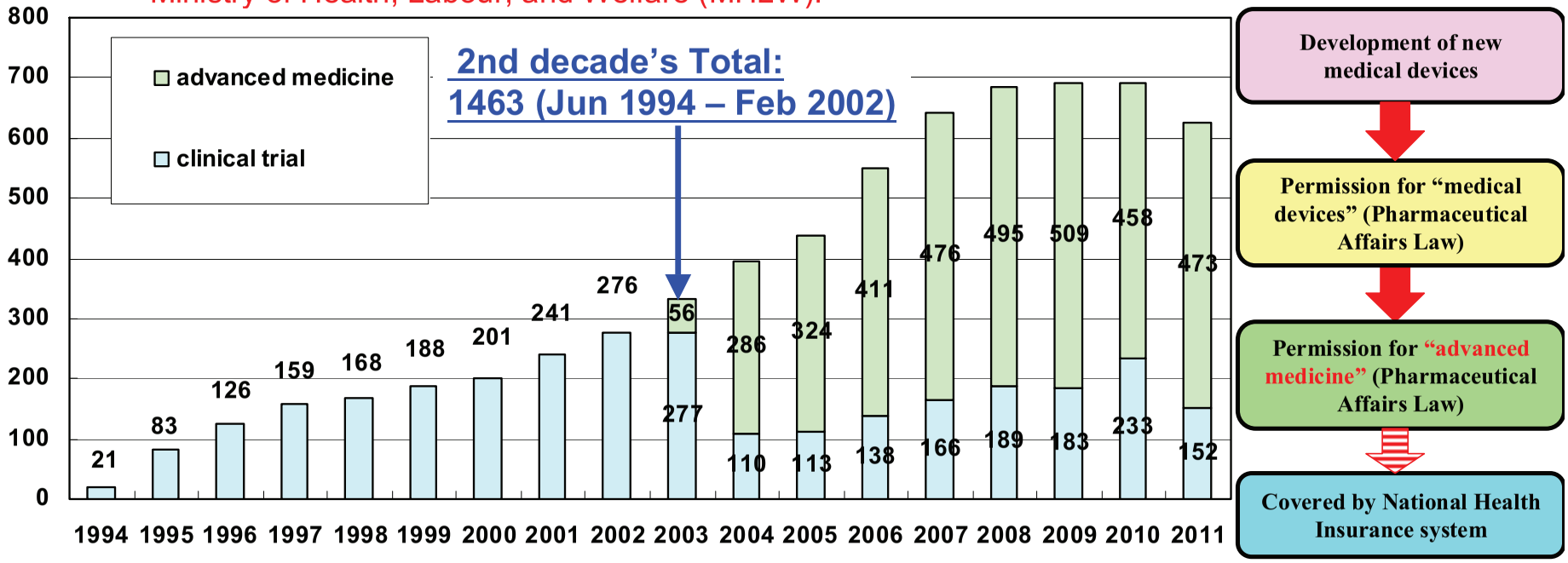

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3rd Decade: Down-sizing

[Comprehensive 10-Year Strategy for Cancer Control, 1984-1993]

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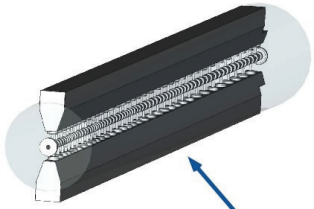
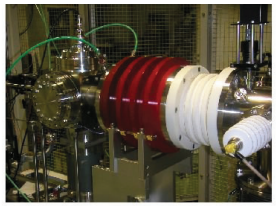
NIRS HIMAC

Prototypes for hospital-specified facility

Linac

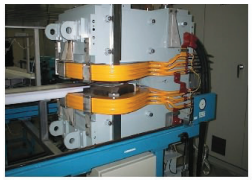


Ion source

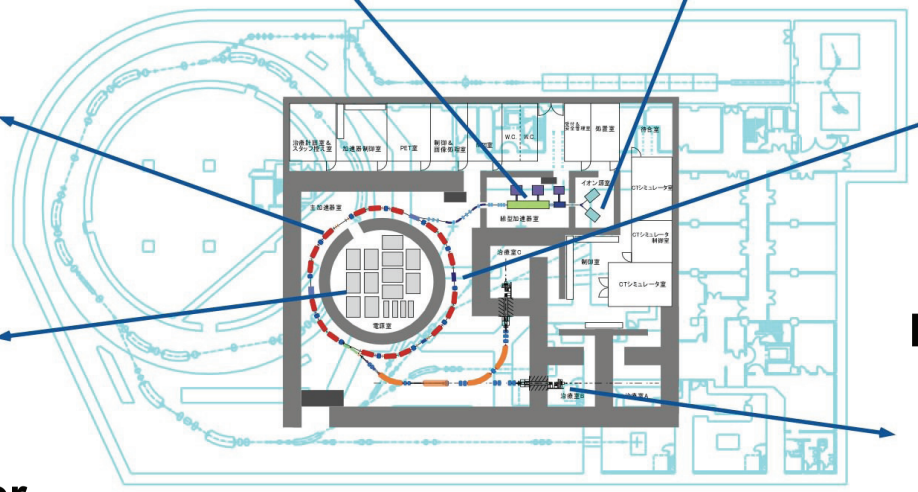


Design concept:
Optimization for carbon beam only!!

Synchrotron Magnet

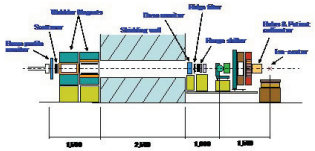


Acc. cavity



Magnet power supply

Irradiation system



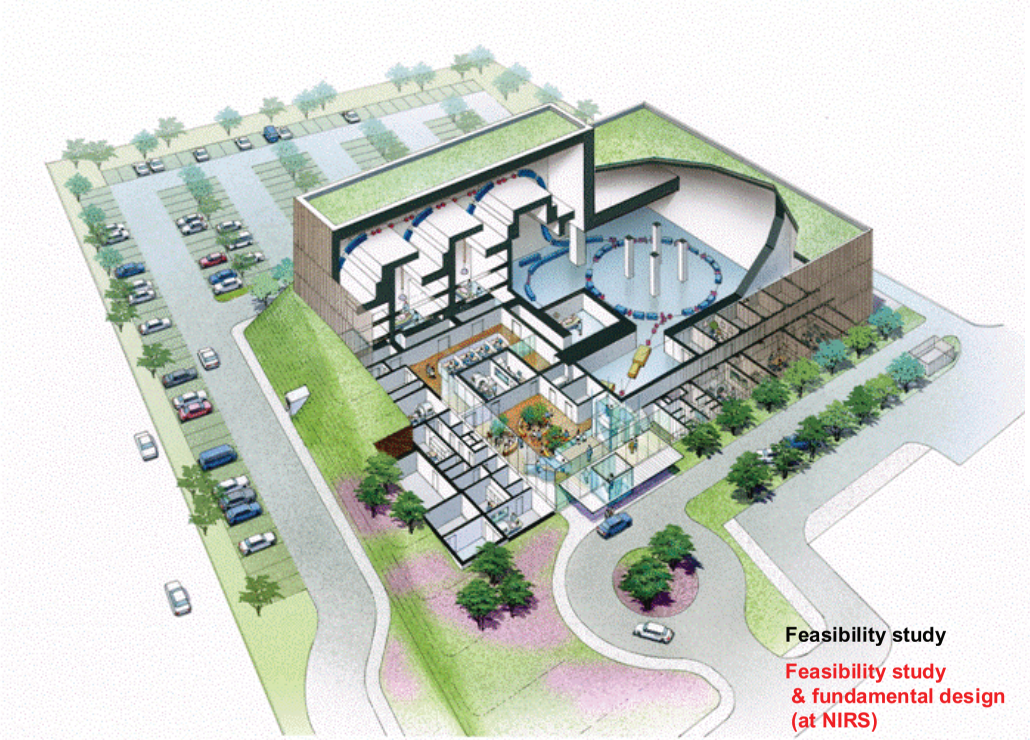
20 m

Size and Cost → 1/3 of HIMAC

K. Noda *et al.*, J. Radiat. Res. **48**:Suppl.A A43 (2007).

NIRS HIMAC

Gunma University Project



Gunma University Heavy ion Medical Center

GHMC Gunma university heavy ion medical center 群馬大学 重粒子線医学研究センター

Feasibility study

Feasibility study & fundamental design (at NIRS)

Manufacturing Design of machine and Buildings

Construction of Buildings

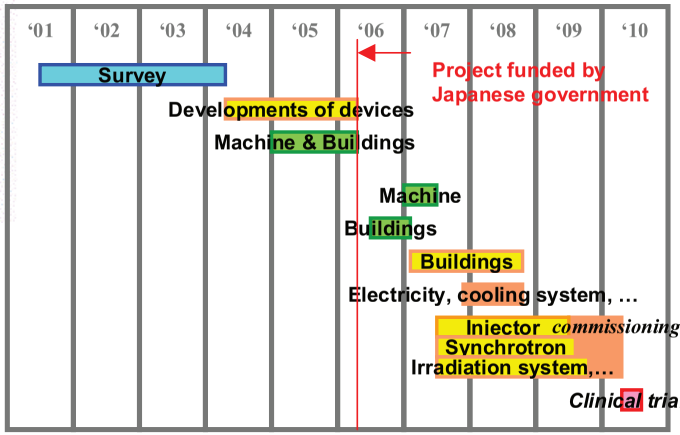
Installation of Utilities

Manufacturing & installation of machine

Clinical trials

Demonstration of the new downsized carbon-RT facility in Japan.

- Dedicated carbon beam only
- Wobbler & layer-stacking irradiation systems



S. Yamada et al., NIRS-M-218, p.170 (2009).

NIRS HIMAC

Saga HIMAT Project

Public and private partnership
- Foundation established by the local government and private companies.
- Medical supports from several core hospitals in this region.
- no own hospital is held.

2. Development of ion sources

‘The Pioneer’ NIRS-ECR at HIMAC

Launched to the linac in 1993

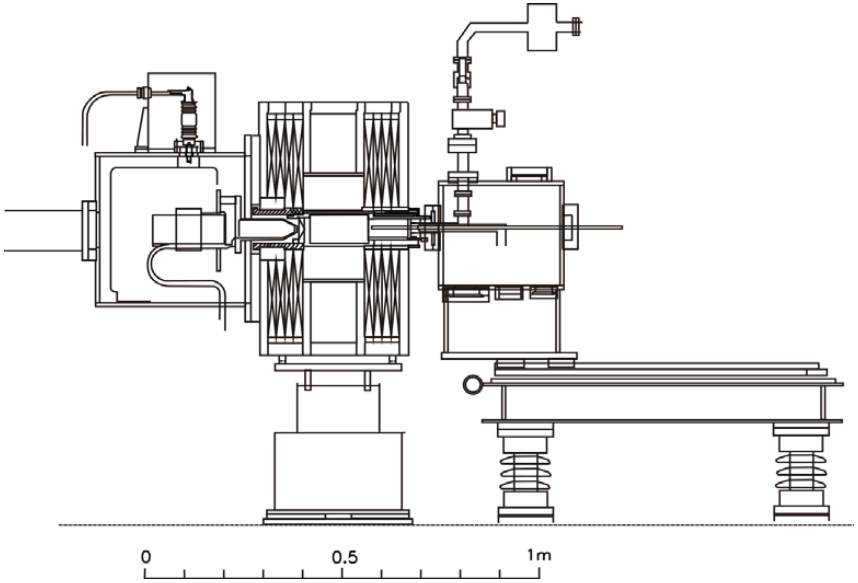
10 GHz microwave(ECR at 3.6 kG)

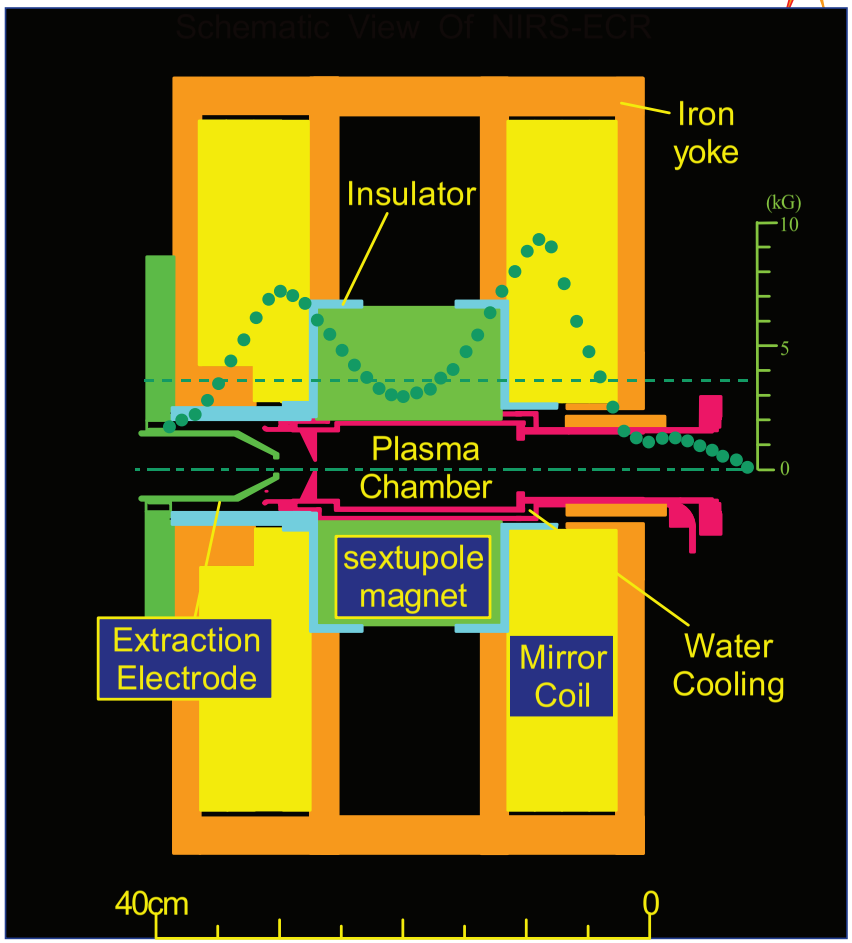
Simple minimum B structure

- Mirror field: 9.3 kG / 7.6 kG
- Axial field: 8.0 kG

Extraction voltage: 25kV max.

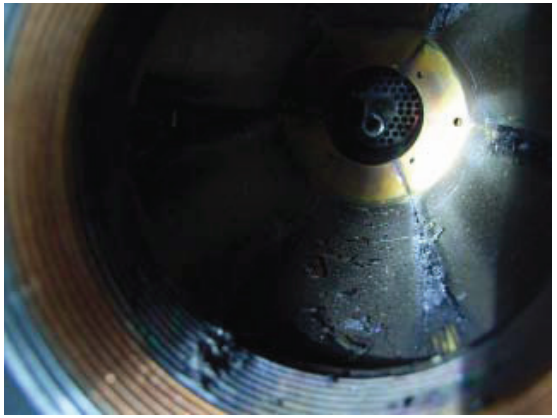
C2+ Intensity: 300 emA (C4+: 430 emA)

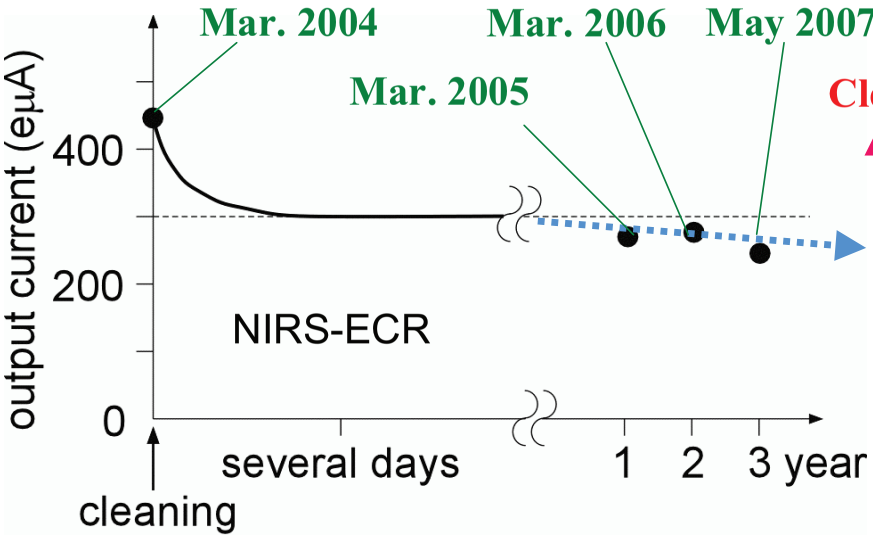




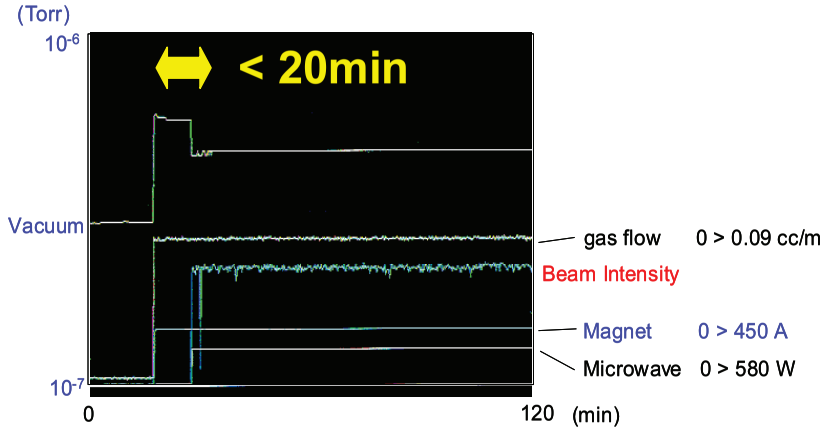
A. Kitagawa *et al.*, Rev. Sci. Instrum. **79**, 02C303 (2008).

Maintenance-free ion source





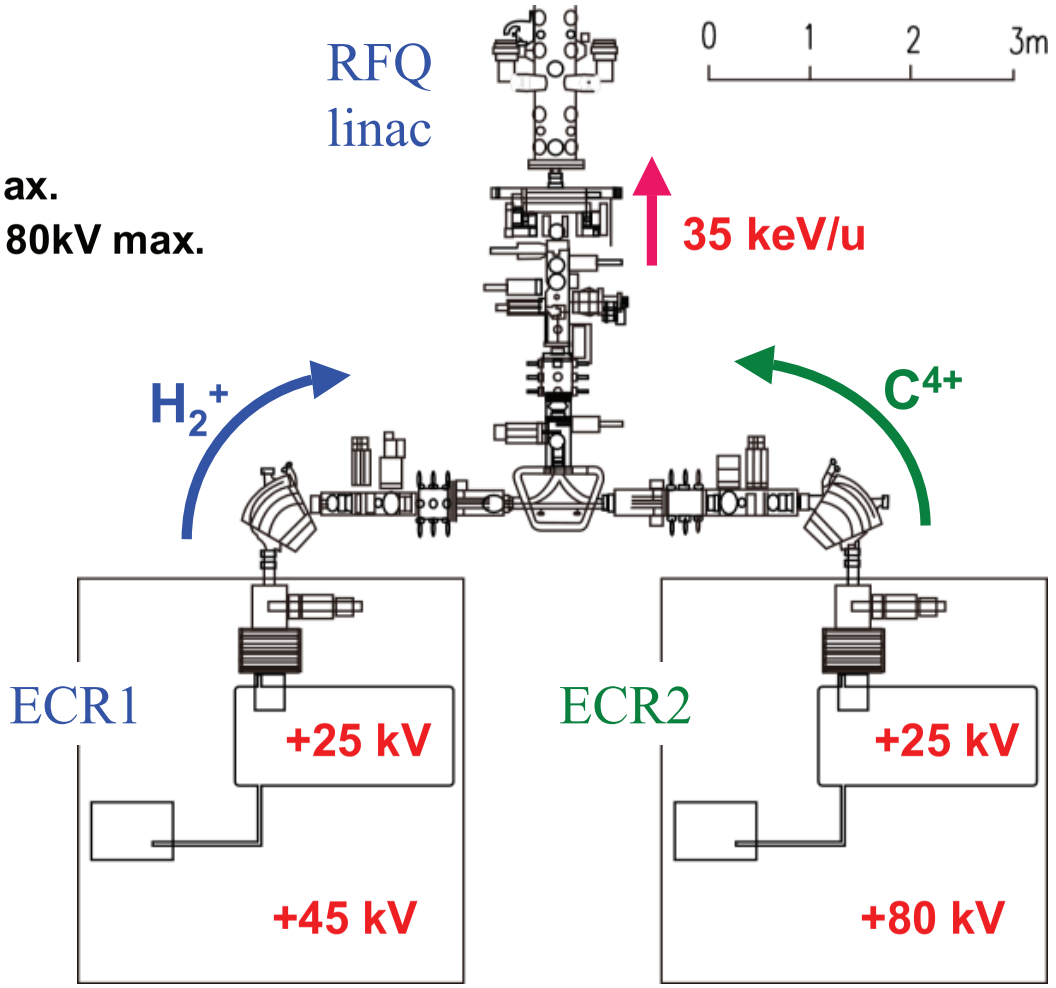
Variation in the beam intensity after starting the ECRIS



NIRS
HIMAC

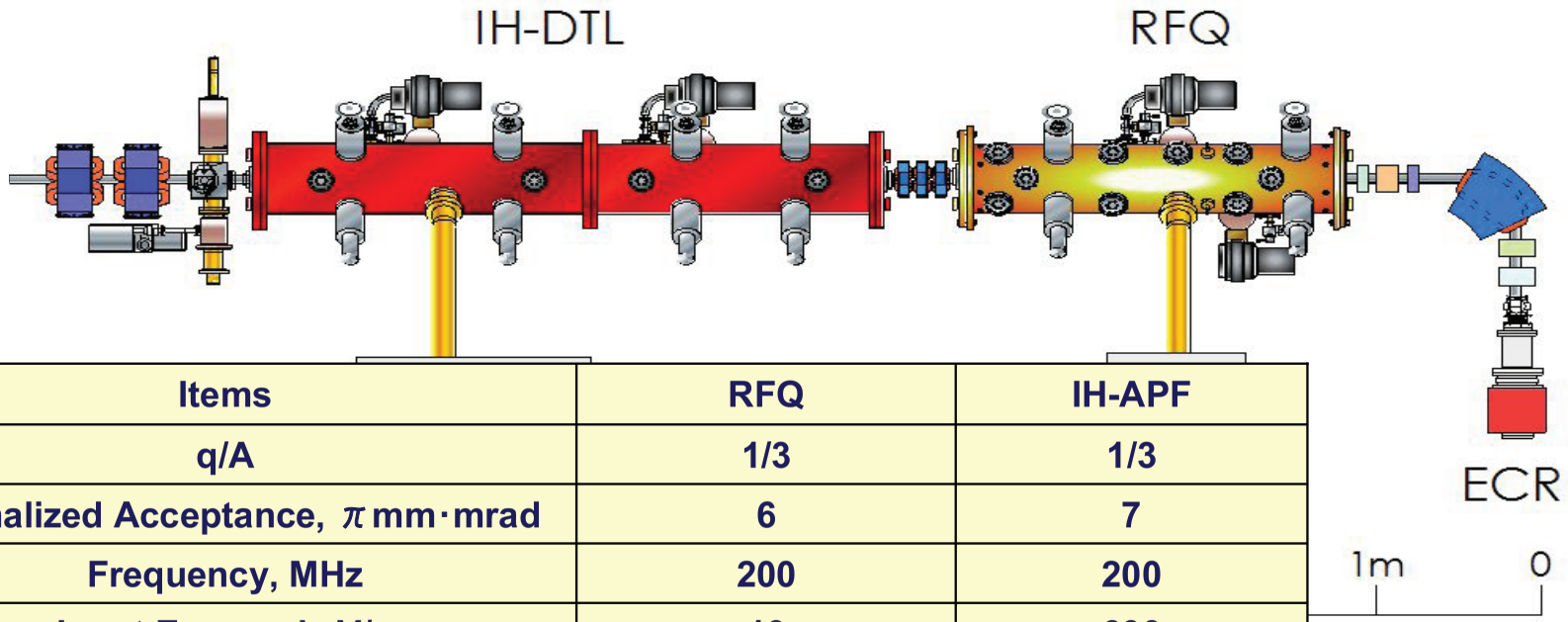
‘1st Commercial Medical Device’ at HIBMC

Constructed in 1999
Almost copy of NIRS-ECR
Lifetime: over one year
Extraction voltage: 25kV max.
High voltage platform with 80kV max.
C^{4+} Intensity: 400 eμA
H_2^+ Intensity: 1.3 emA



NIRS HIMAC

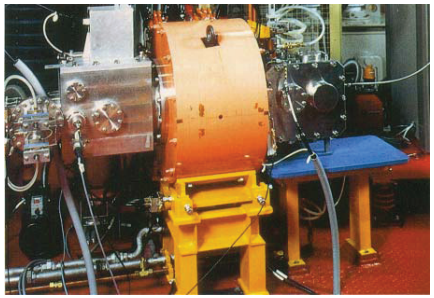
Requirement for the hospital specified facility

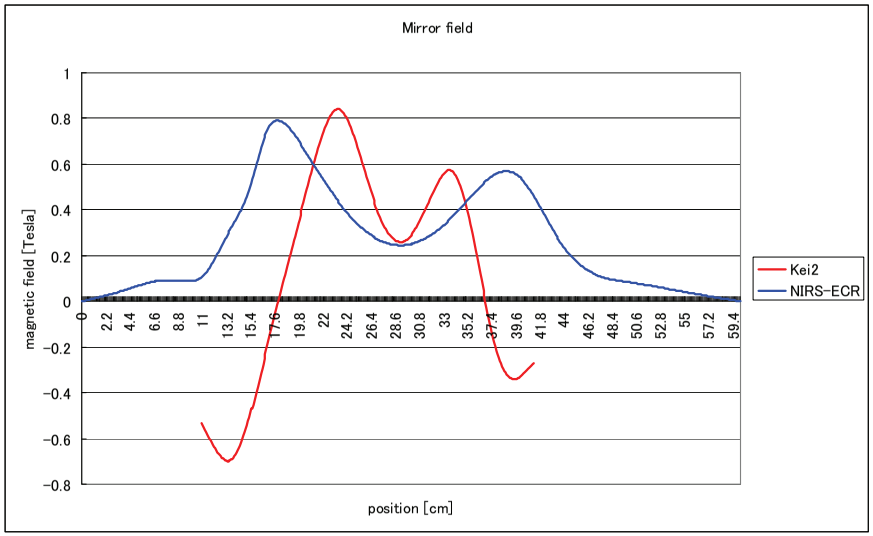


Items	RFQ	IH-APF
q/A	1/3	1/3
Normalized Acceptance, π mm·mrad	6	7
Frequency, MHz	200	200
Input Energy, keV/u	10	600
Output Energy, keV/u	600	4,000
Inside diameter of tank, m	~ 0.35	~ 0.35
Tank length, m	2.5	3.5
Max. surface field, MV/m	23.6 (1.6 Kilp.)	23.6 (1.6 Kilp.)
Peak RF power, kW	~ 100	~ 500

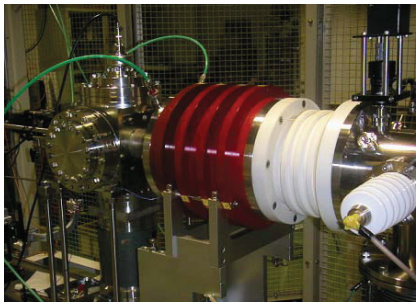
Design concept of Kei series

NIRS-ECR





Kei, Kei2



1. Replace coils by permanent magnets.
2. But it's mirror ratio is adjusted to good experiences at NIRS-ECR.
3. Microwave coupling, chamber cooling, and vacuum structures follow many practices at NIRS-ECR.
4. High voltage insulation structure learns experiences at NIRS-HEC.

<u>Goal</u>

Keep the similar performance

- C^{4+} intensity
- Lifetime
- Easy maintenance & operation

‘The prototype’ Kei2 at the test bench

Developed in 2002

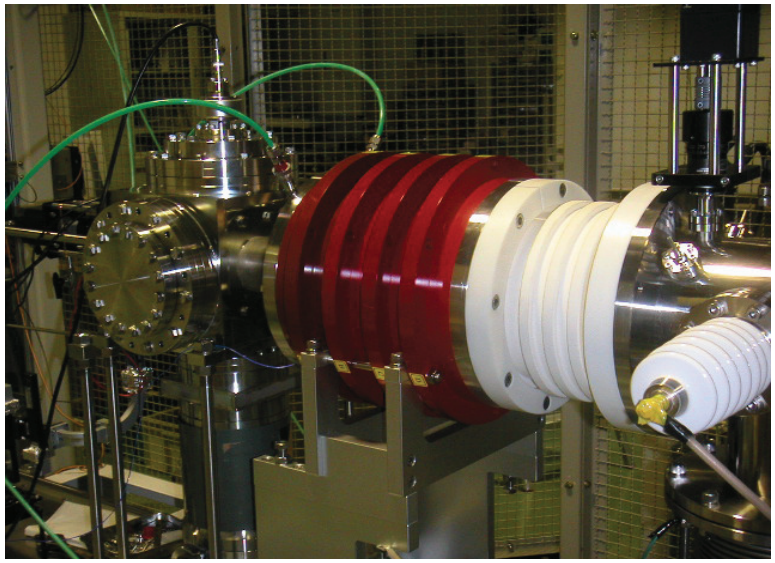
All permanent magnets realized the similar ratio of magnetic fields at NIRS-ECR

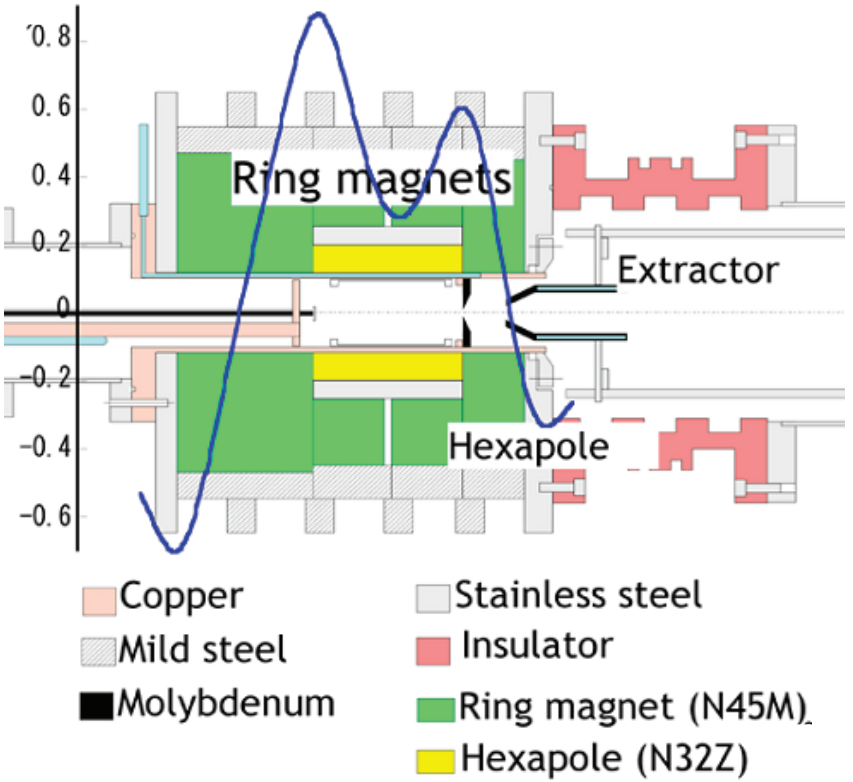
10±0.25GHz 650W TWT amplifier

High extraction voltage: 30kV (40kV max.)

Lifetime: one year

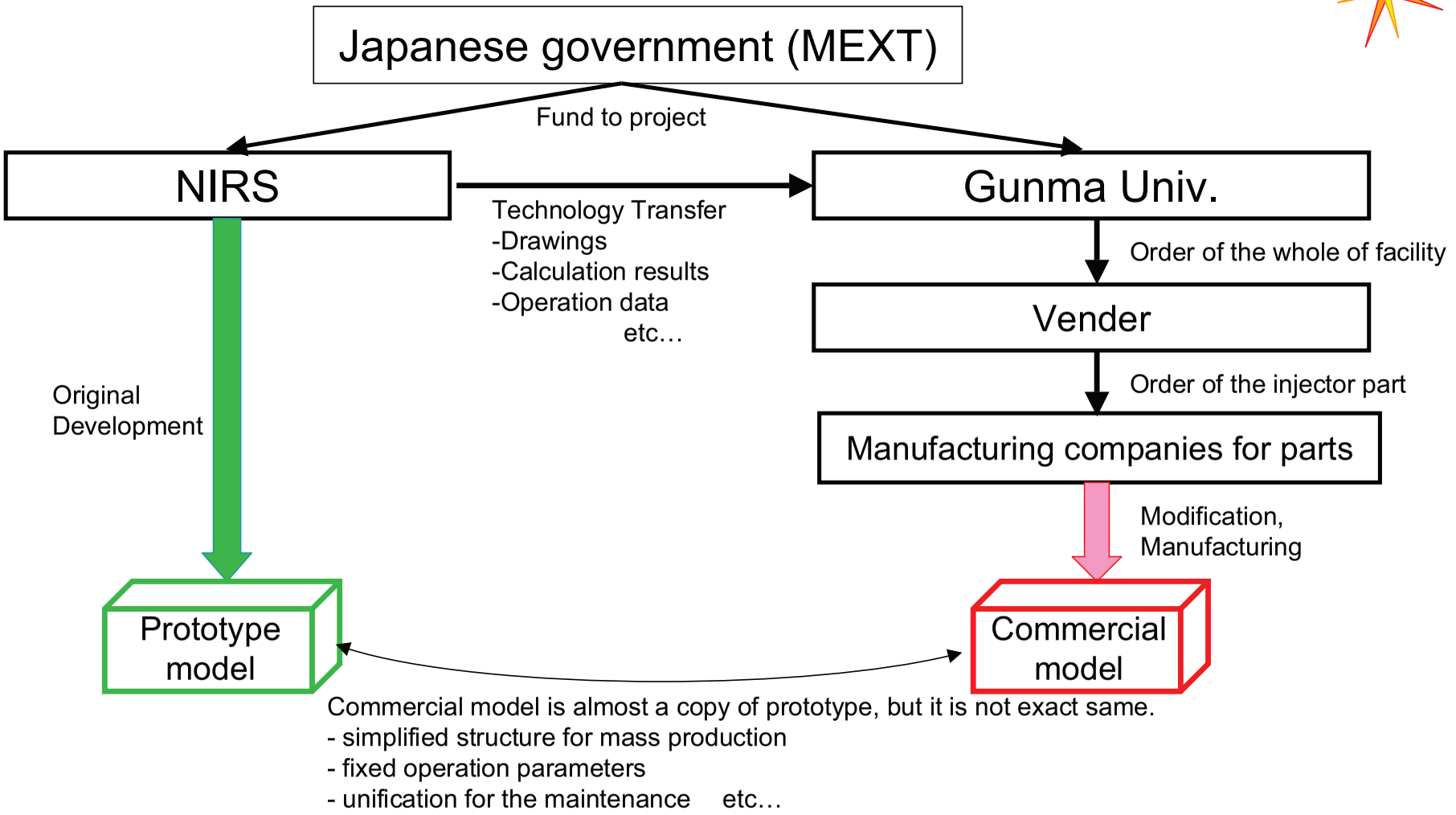
C^{4+} Intensity: 600 eμA (1 emA max.)





M. Muramatsu *et al.*, Rev. Sci. Instrum. 76, 113304 (2005).

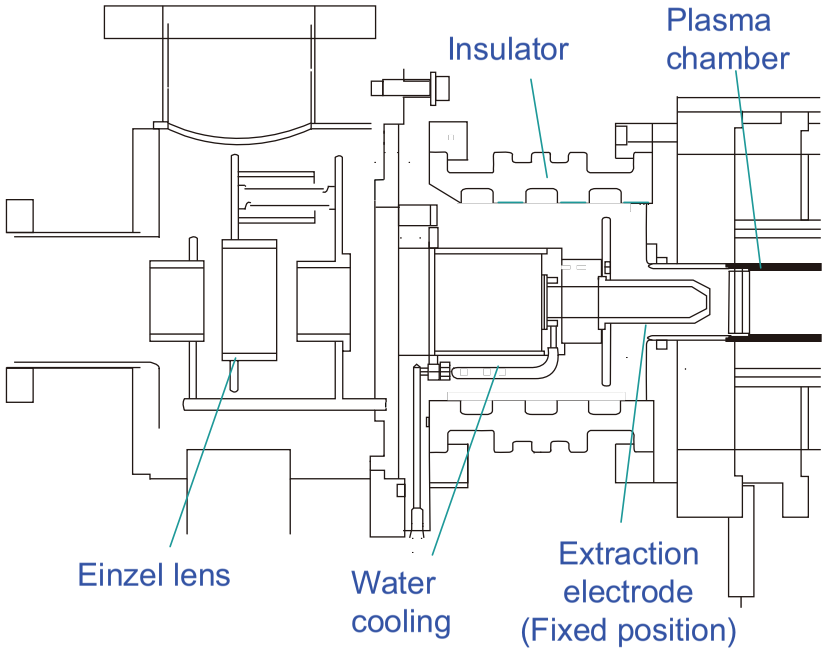
Technology transfer



KeiGM at Gunma Univ.

Launched to the linac in 2009
Almost copy of Kei2
10±0.25GHz 650W TWT amplifier
High extraction voltage: 30kV
Lifetime: one year
C^{4+} requirement: 200 eμA

M. Muramatsu *et al.*, Rev. Sci. Instrum. 76, 113304 (2005).

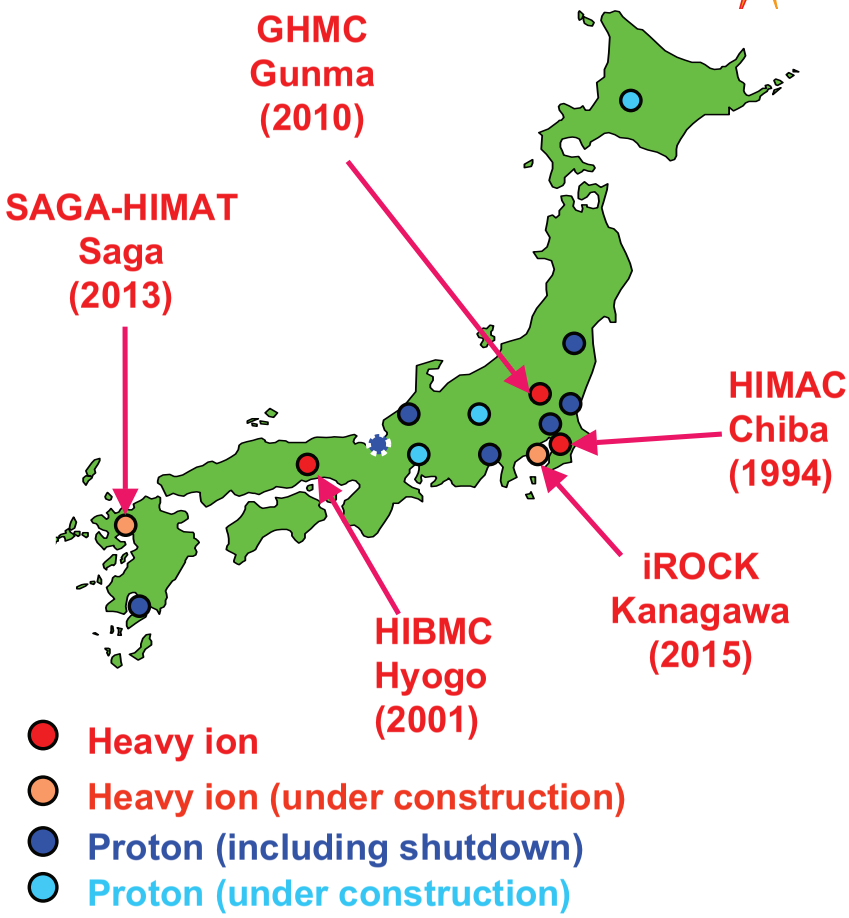


3. Present status of ion sources

Present facilities

Name	Type	Facility	Launch
NIRS-ECR	N	HIMAC	1993
NIRS-HEC	H	HIMAC	1997
ECR1	N	HIBMC	1999
ECR2	N	HIBMC	1999
KeiGM	K	GHMC	2009
Kei2	K	HIMAC	2010
KeiSA	K	SAGA-HIMAT	2012(plan)
?	K	iROCK	2014(plan)

N: NIRS-ECR type
K: Kei series
H: NIRS-HEC



Operation of NIRS-ECR type

NIRS-ECR

Status in 2011

Operation time: approximately 6000 hours / year*

Serious failure: none

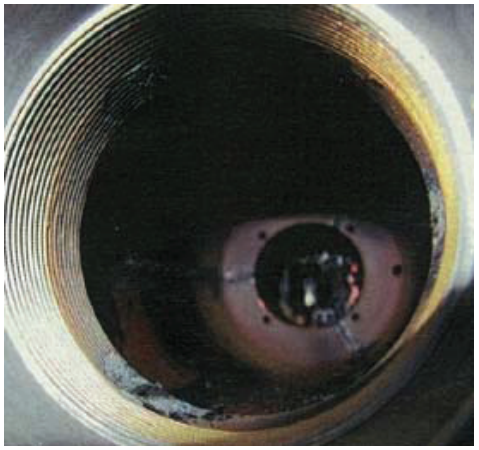
Items of routinely maintenance:

- **Inside of the plasma chamber**
  = no polish, only collect dusts (1 year)
- **Insulator**
  = clean up (1 y), replace (several years)
- **Water supply**
  = replace (several years)
- **TWT tube**
  = replace (over 15,000 h)
- **Small electronics parts**
  = replace (several years)
- **Control system**
  = replace (irregular)

* Recent yearly operation time
  2005: 5900
  2006: 5948
  2007: 5887
  2008: 6091
  2009: 5691
  2010: 5924
  2011: 6305

NIRS HIMAC

Deterioration by carbon deposition

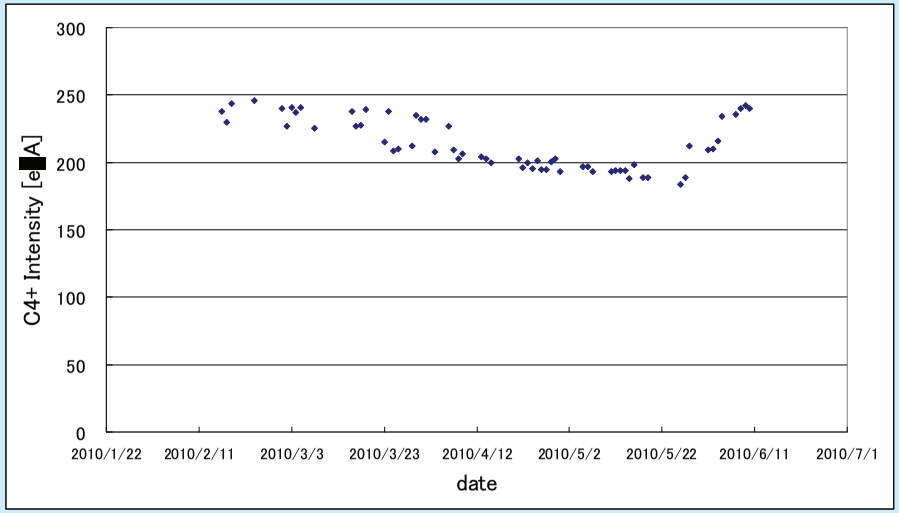


Clean up

Operation of Kei2 type

KeiGM

Operation time: 4000 hours (2010~)
Serious failure: 1
at the microwave amplifier
Maintenance items:
•Cleaning of chamber (a half y)
= polish



KeiSA

The basic performance had been tested at the factory and has been installed in the facility.
It will be launched in December.

Ion source for iROCK

Kei2 type has selected.

Summary

1. **Approaches for the promotion in Japan**

   Carbon ion radiotherapy (C-RT) has been promoted in Japan;

   - The yield of HIMAC project has awakened interests of local regions. There are five facilities under operation or construction
   - The approaches for the promotion are almost based on 10-year Strategy by the government.

2. **Developments of ion sources**

   There are two types of ECR ion sources for C-RT;

   - NIRS-ECR successfully realized the daily clinical use.
   - Kei series had been optimized for a C-RT dedicated facility.

3. **Present status of ion sources**

   Each ion sources satisfied the requirements.

The 15th International Conference on Ion Sources

9 - 13 September 2013

Makuhari Messe, Chiba, Japan

Organized by National Institute of Radiological Sciences

For further information will be delivered on http://www.nirs.go.jp/conf/icis13/