17TH ADVANCED BEAM DYNAMICS WORKSHOP ON

FUTURE LIGHT SOURCES

Practical Side of In-Vacuum Undulators

H. Kitamura, RIKEN

APRIL 6-9, 1999
ARGONNE NATIONAL LABORATORY, ARGONNE, IL U.S.A.

Practical side of in-vacuum undulators

Hideo Kitamura
Harima RIKEN, SPring-8

1. **How to realize UHV for in-vacuum undulators without any accident**

2. **Field correction**

3. **Image current heating**

4. ~~**Independent tuning**~~

5. **In-vacuum revolver undulator**

Insertion Devices at SPring-8

λ_u mm	N	G_{min} mm	B_{max} tesla	K_{max}	type	Pol	installed	scheduled 2000
24	187	5.0	1.0	2.2	INV-XU	hor	1	
26	172	7.0	0.83	2.0	INV-XU	hor		1
26 52	172	5.0	1.02	2.6	INV-F8	hor/ver	1	
28	160	6.5	1.0	2.4	INV-XU	hor		1
32	140	8.0	0.83	2.3	INV-XU	hor	8	1
32	781	12	0.56	1.67	INV-XU	hor		1
36	125	7.0	0.33	1.1	INV-HU	circ		1
37	2x37	8.0	0.5	1.7	INV-VU	ver	1	
40	112	15	0.59	2.2	INV-XU	hor	1	
44 92	102 48	20 20	0.5 0.36	2.1 3.1	Rev	hor circ		1
100 200	44	30	0.74	6.9	F8	hor/ver	1	
120	16	36			HU	circ	1	
120	2x12	30		3.0	HU	circ	1	
120	37	30 (20)	0.8 (1.1)		EW	circ	1	
						Total	16	6

How to realize UHV for in-vacuum undulators

without any accident

1. Coating

developed by Sumitomo Special Metal (SMC)

Cu electroplating	**: NG!**
Ni electroplating	**: good → KEK device**
TiN ion-plating	**: good**
Ti + TiN ion-plating	**: very good →SPring-8 devices**

2. Baking temperature to get UHV

Higher temperature = better vacuum
irreversible demagnetization

↓

special PM having high coercivity
+ 24hr aging ($T_{aging} = T_{baking} + 10℃$)

1990 KEK device
NEOMAX-30SH (SMC) iHc =21kOe
T_{baking}=115℃, T_{aging}=125℃

1995 SPring-8 devices (old)
NEOMAX-33UH (SMC) 25kOe
T_{baking}=125℃, T_{aging}=145℃

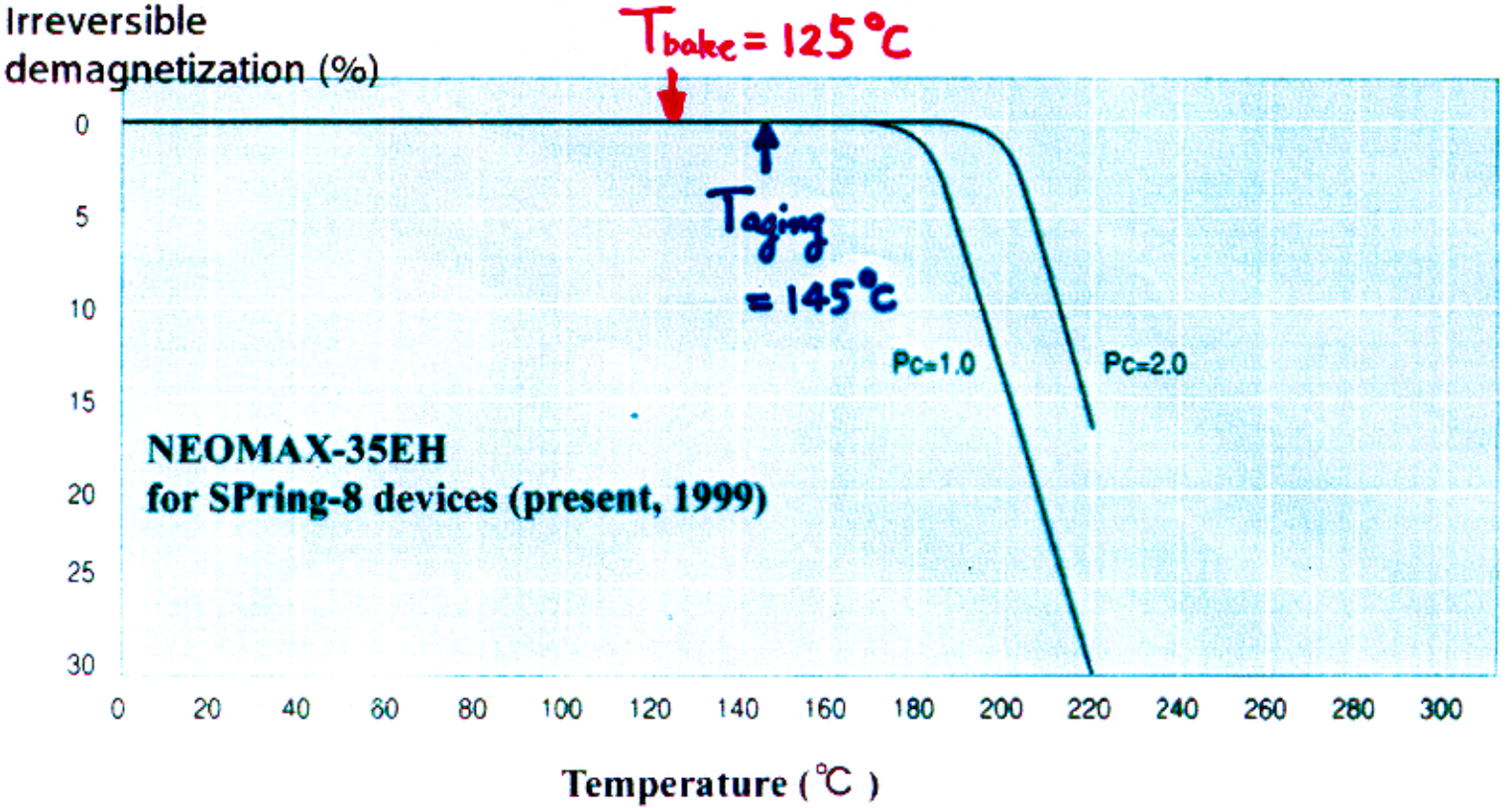
1999 SPring-8 devices (present)
NEOMAX-35EH (SMC) 25kOe
T_{baking}=125℃, T_{aging}=145℃

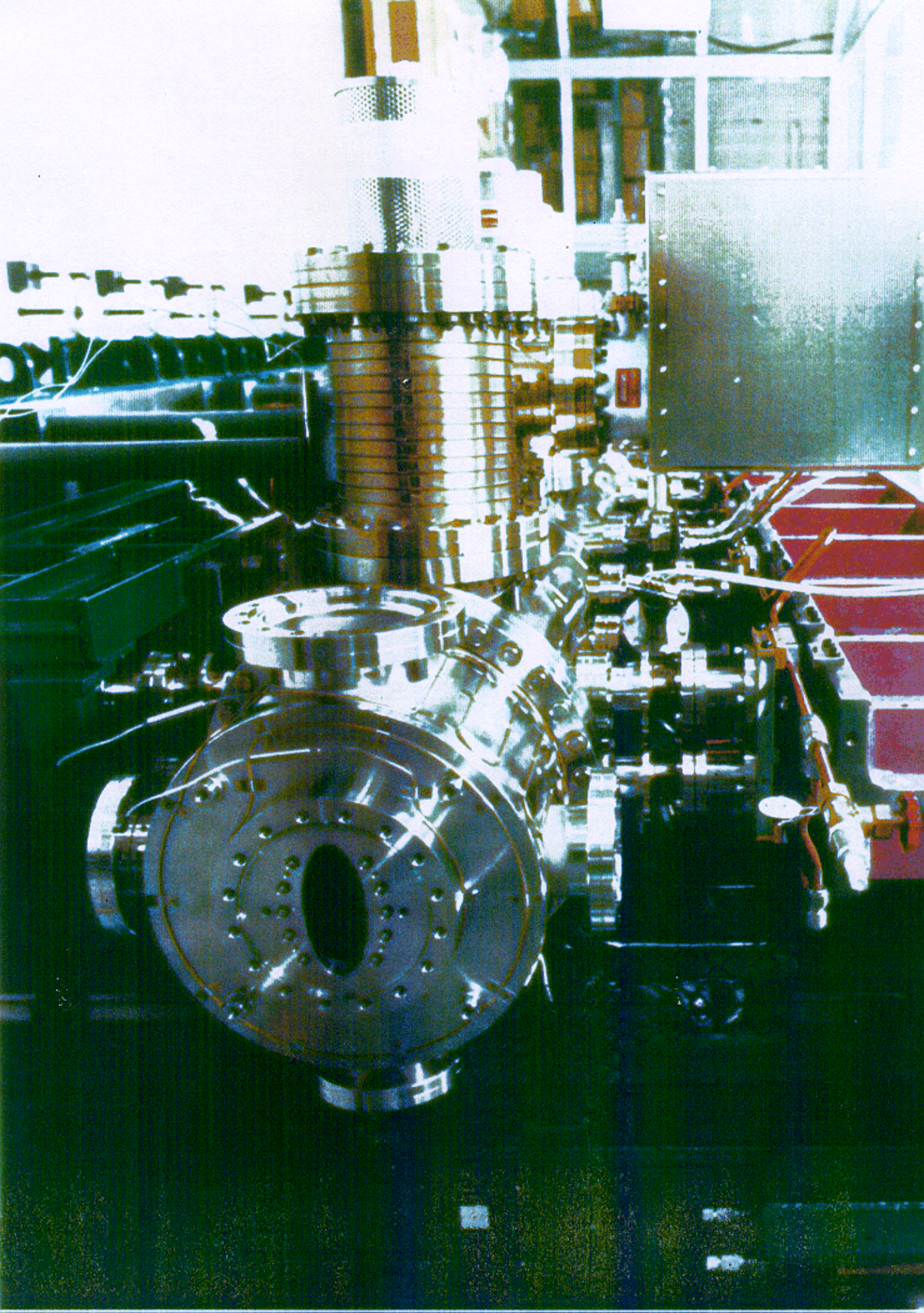
3. Pumping speed

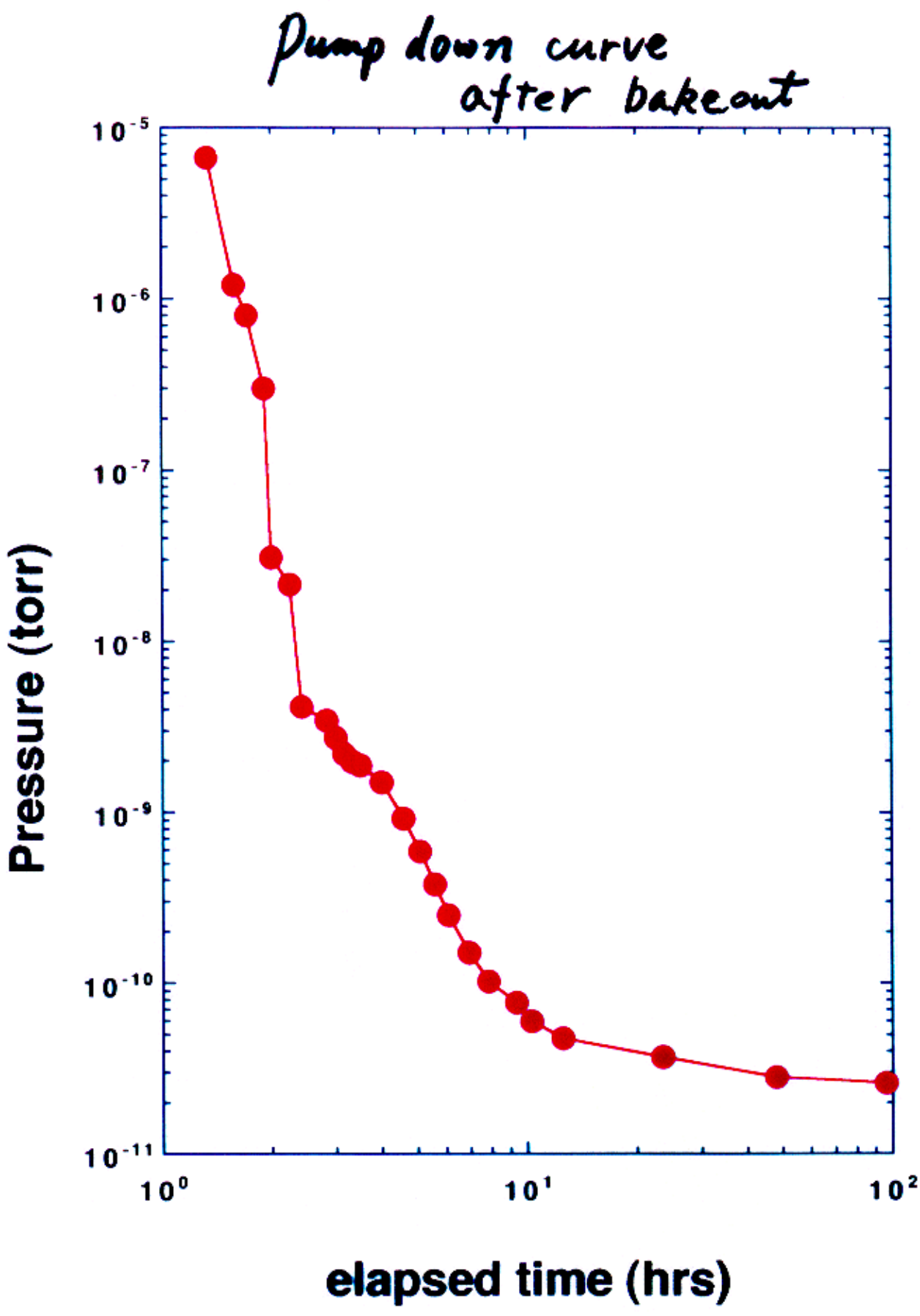
As high as possible ! Don't be stingy!

4. Thermal expansion at UHV bakeout

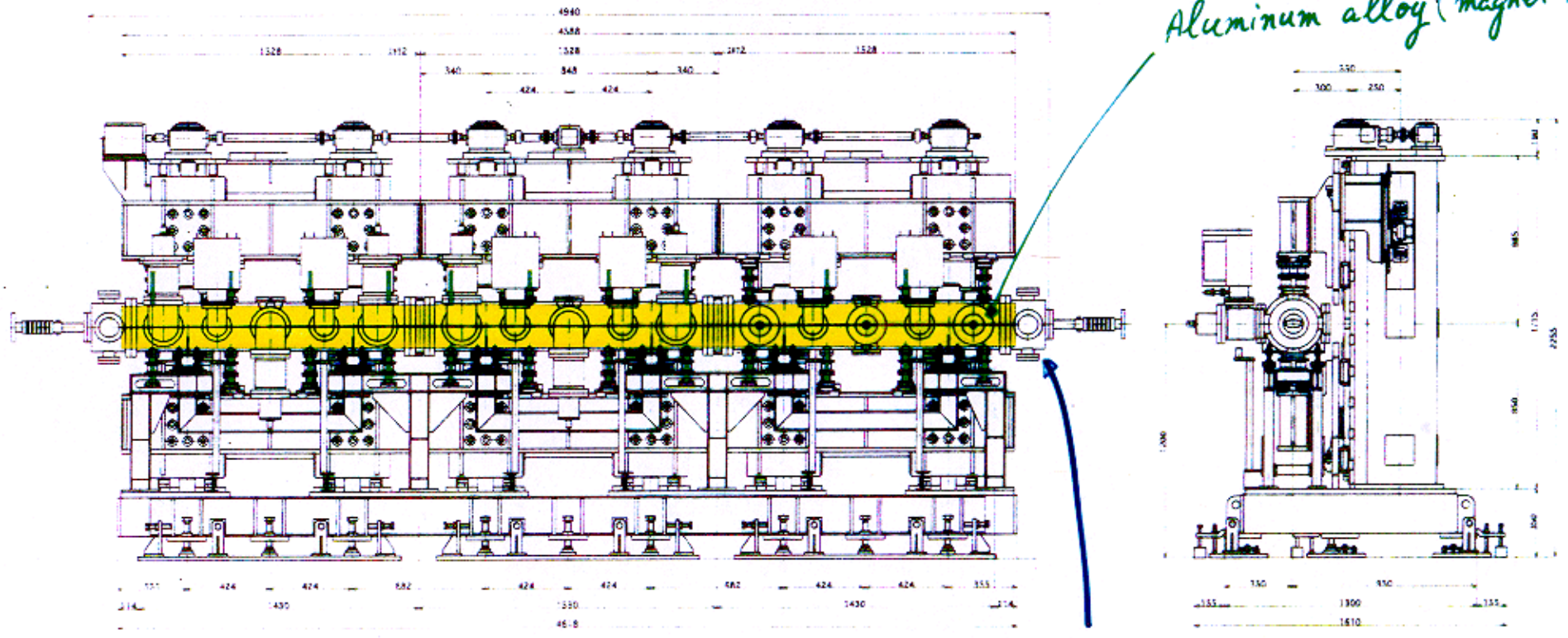
Very long undulator


Irreversible
demagnetization (%)
T_{bake} = 125 °C
T_{aging}
= 145 °C
Pc=1.0
Pc=2.0
NEOMAX-35EH
for SPring-8 devices (present, 1999)
0
5
10
15
20
25
30
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
Temperature (℃)




Pump down curve
after bakeout
Pressure (torr)
10^-5
10^-6
10^-7
10^-8
10^-9
10^-10
10^-11
10^0
10^1
10^2
elapsed time (hrs)

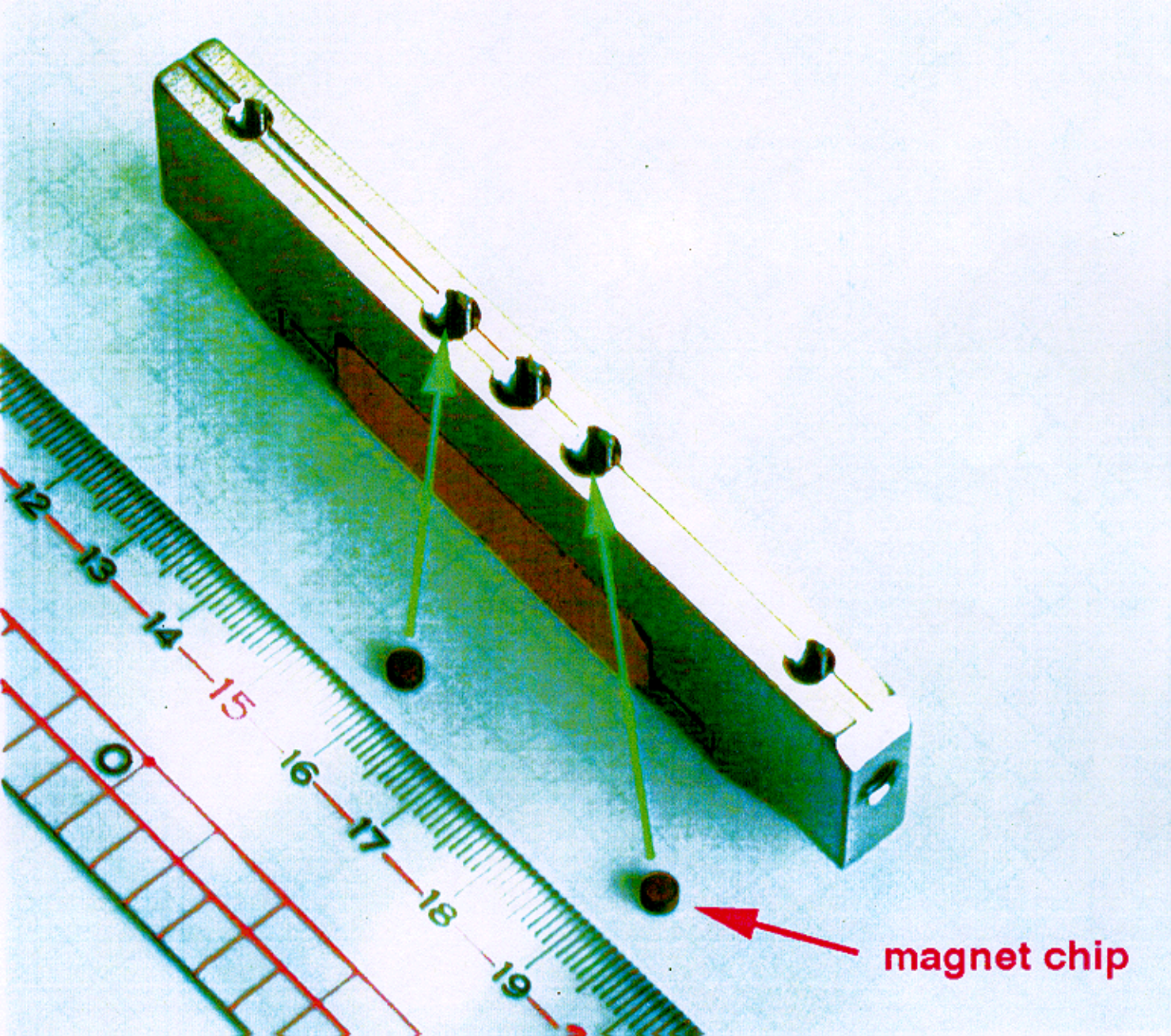
Standard In-Vacuum X-ray Undulator
λ_u=3.2cm, N=140, K_{max}=2.4

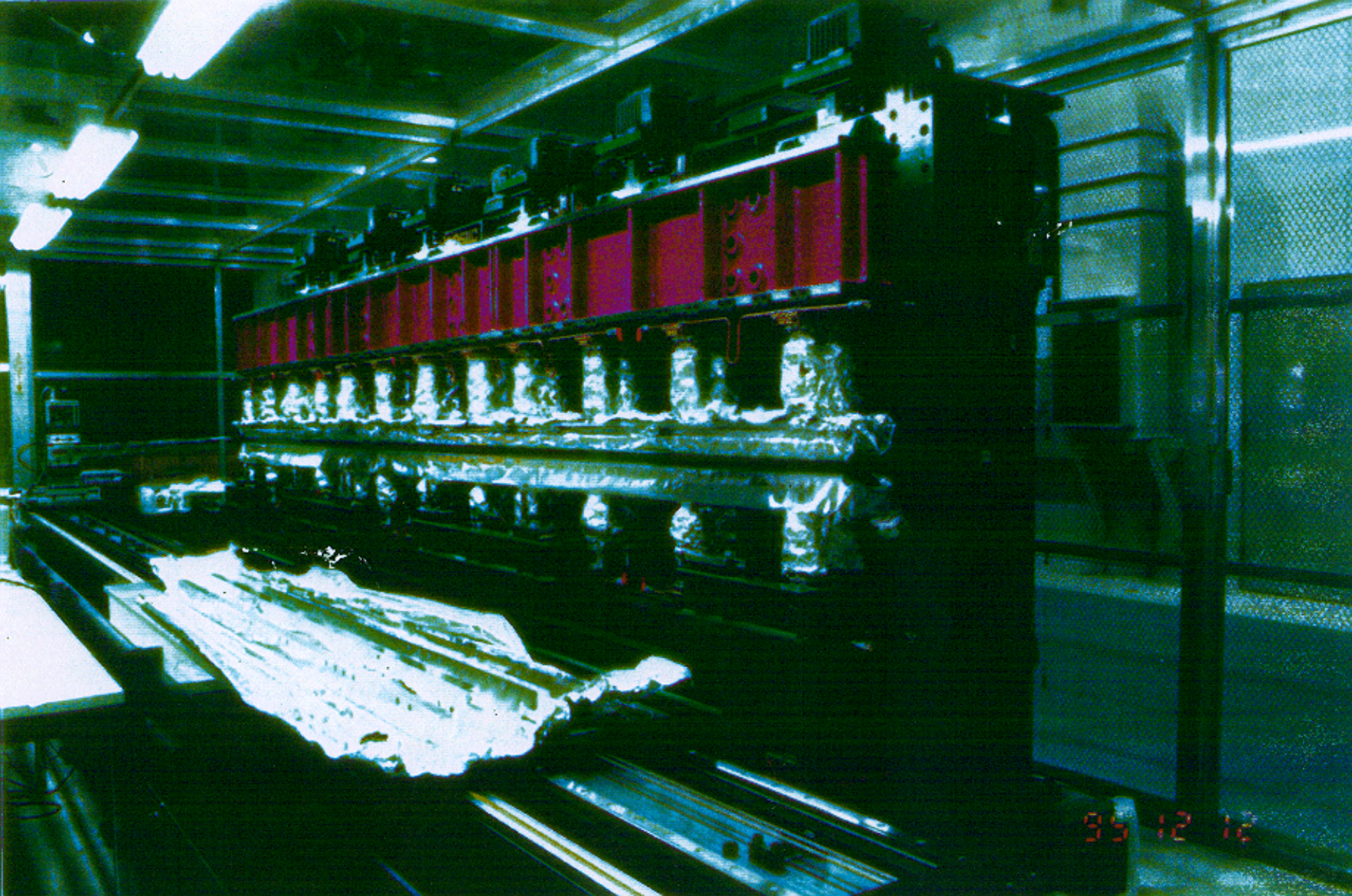


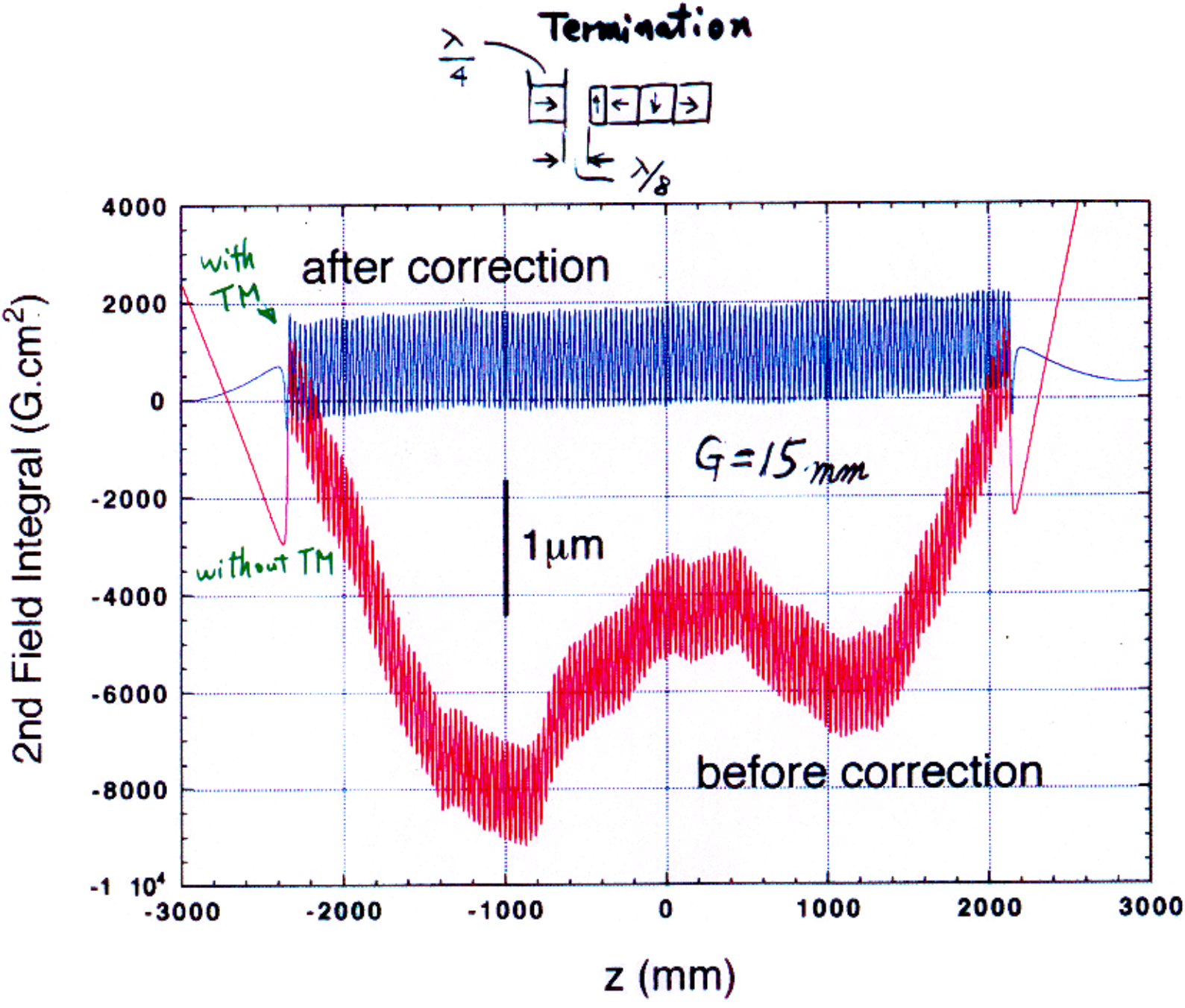
$T_{mag} \sim 125°C$

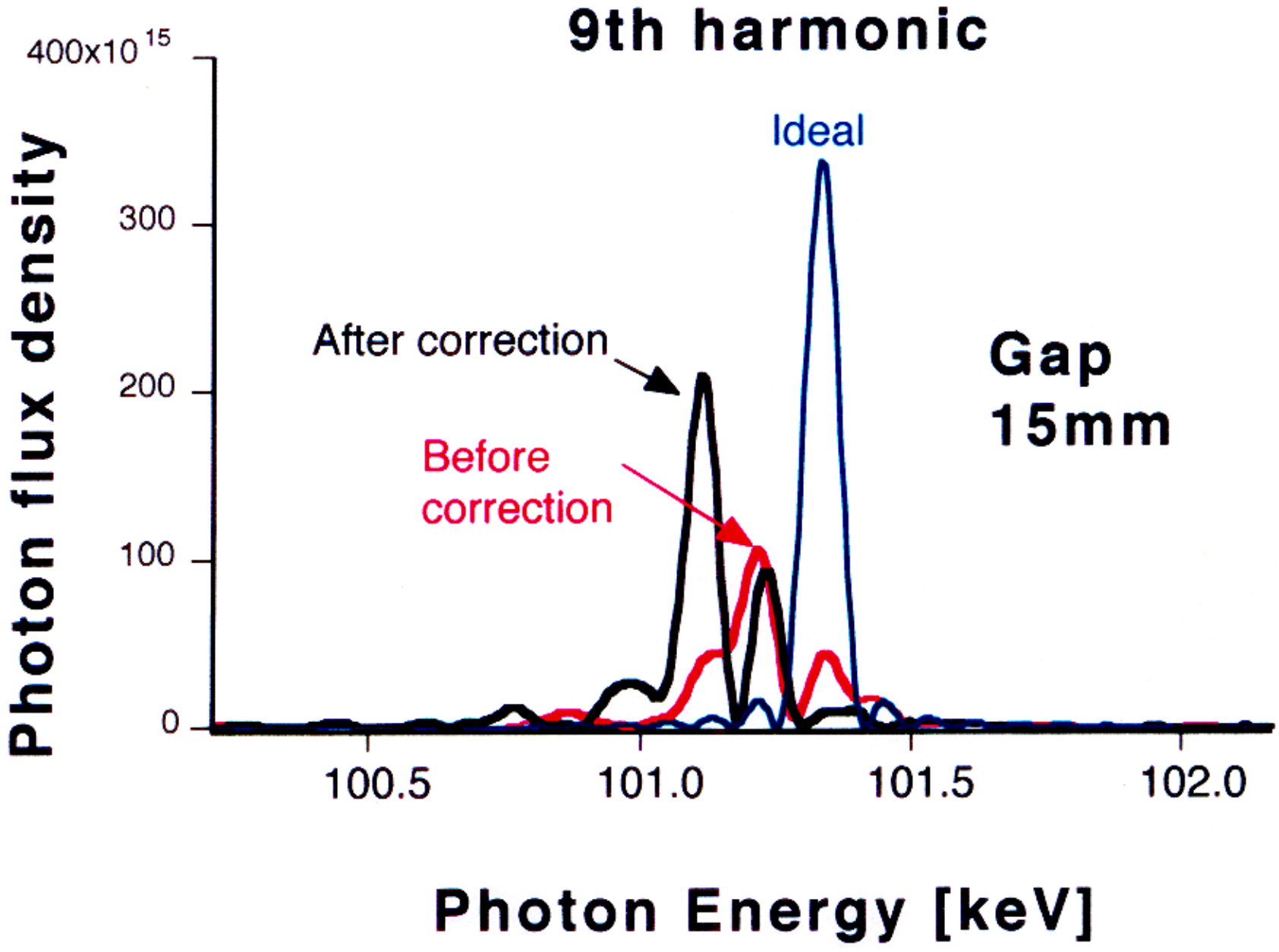
$T_{chamber} \sim 200°C$

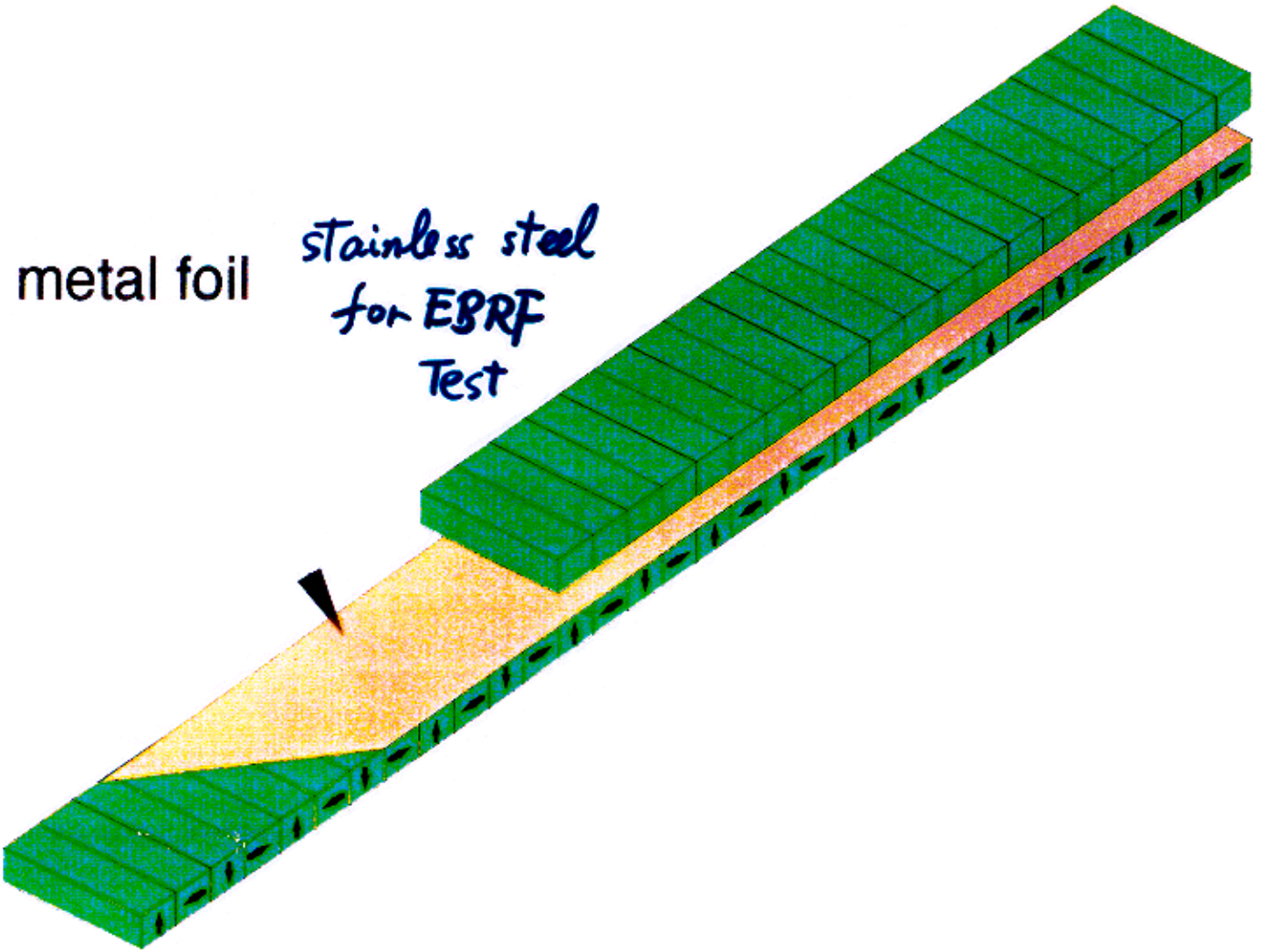
標準型真空封止X線アンジュレータ(BL09XU)


12
13
14
15
16
17
18
19
0
magnet chip

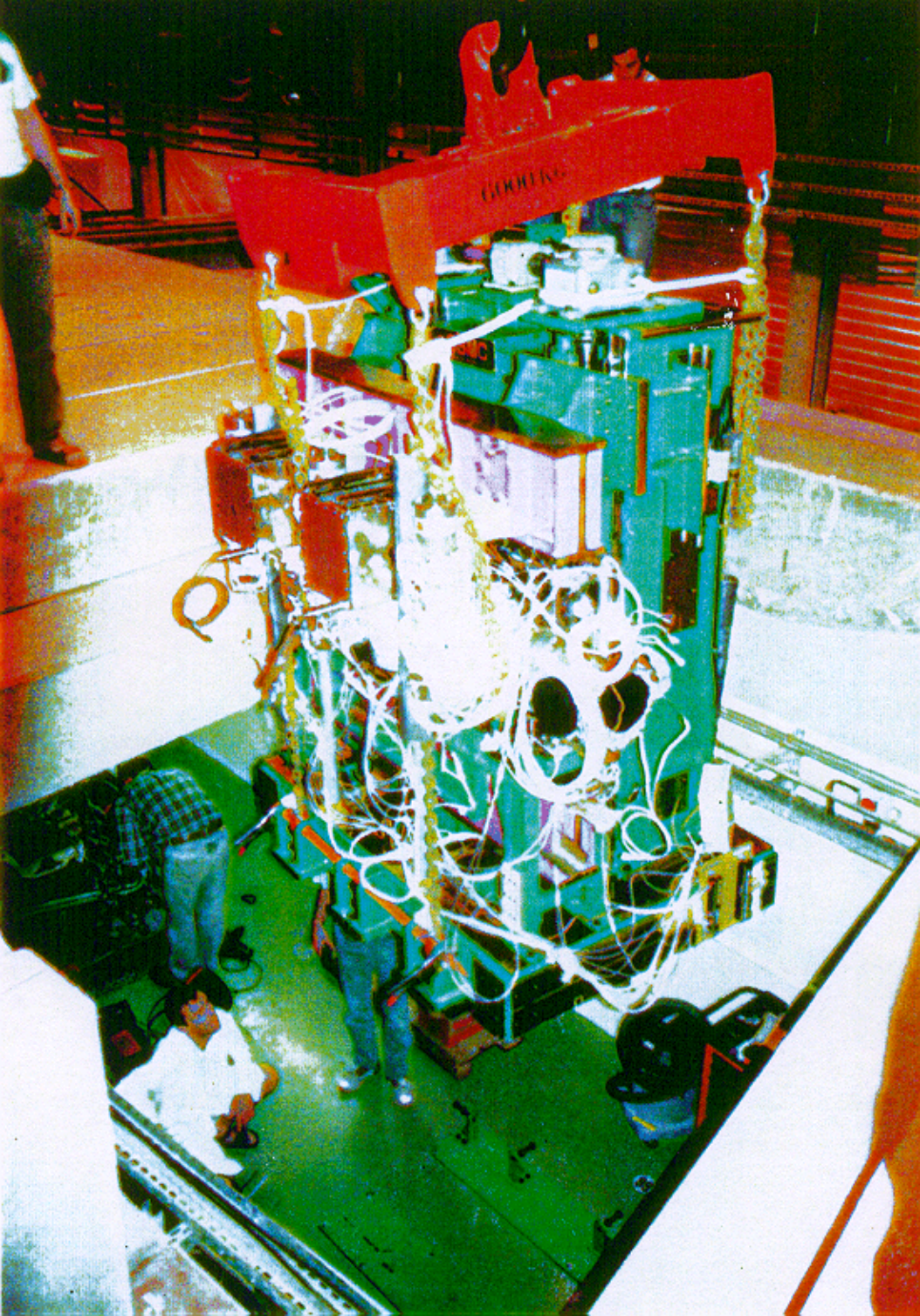

95 12 12

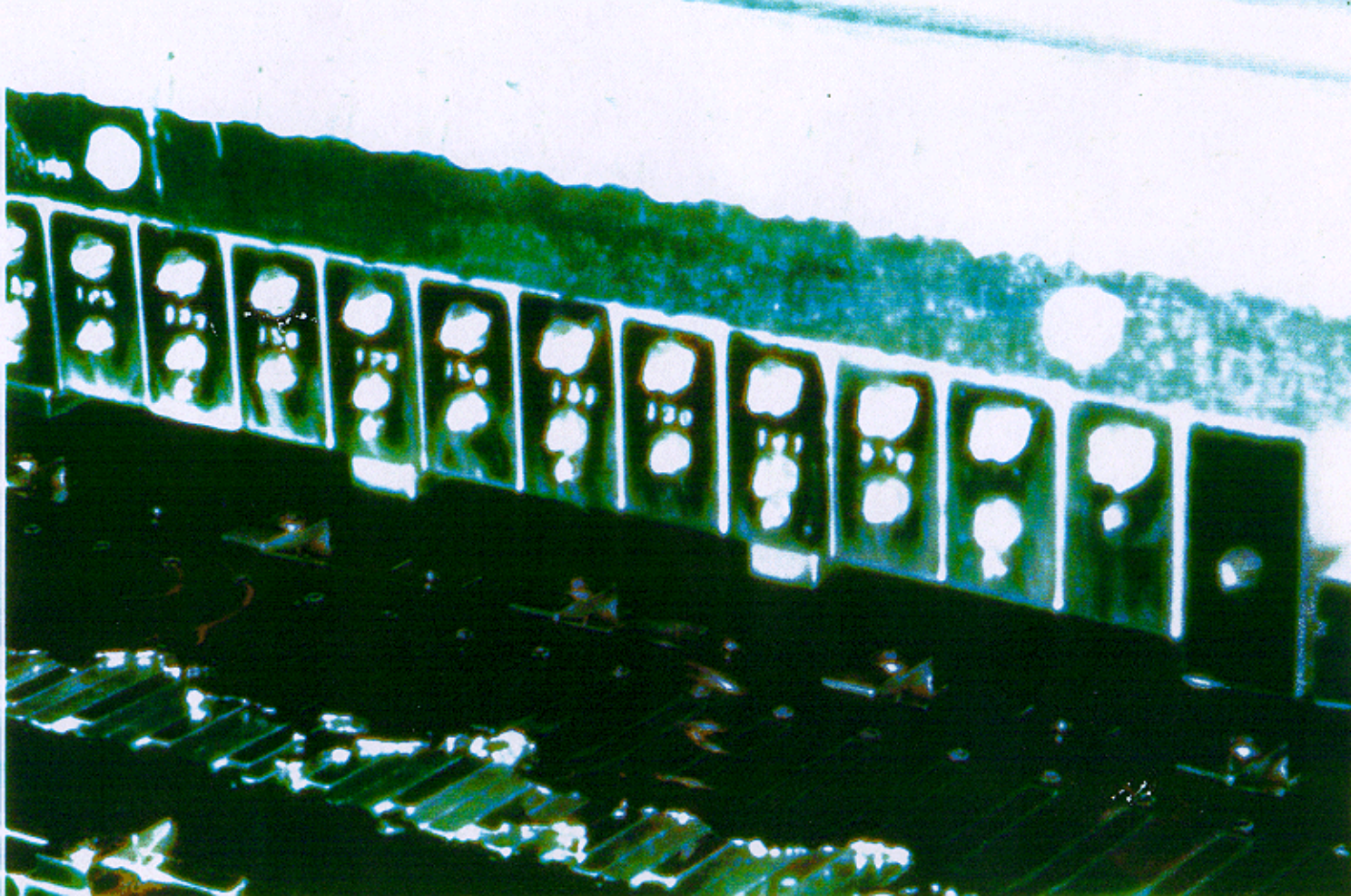

Termination
λ/4
λ/8
after correction
with TM
without TM
G=15 mm
1μm
before correction
2nd Field Integral (G.cm²)
z (mm)
4000
2000
0
-2000
-4000
-6000
-8000
-1 10⁴
-3000
-2000
-1000
0
1000
2000
3000


9th harmonic
400x10 15
300
200
100
0
Photon flux density
Ideal
After correction
Before
correction
Gap
15mm
100.5
101.0
101.5
102.0
Photon Energy [keV]

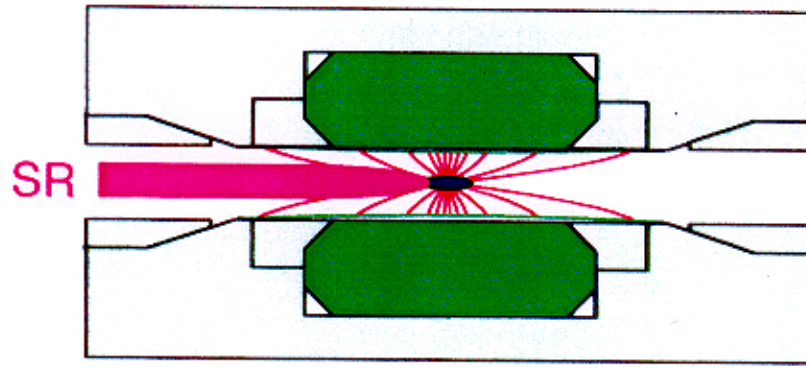


Magnet Cover

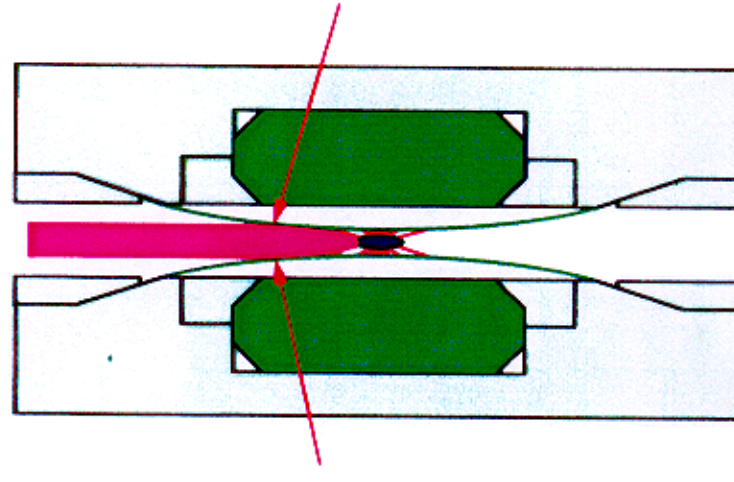




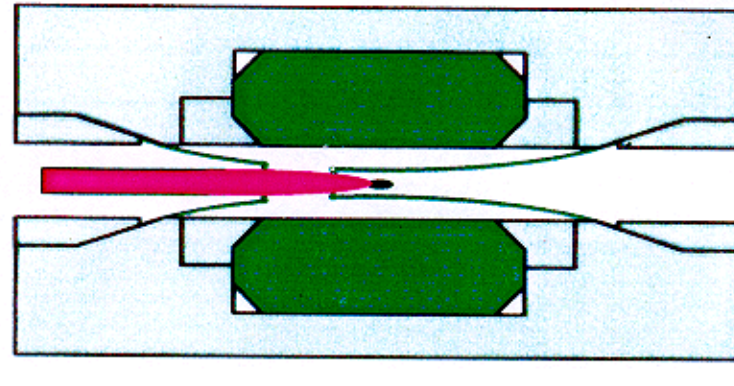
STEP 1



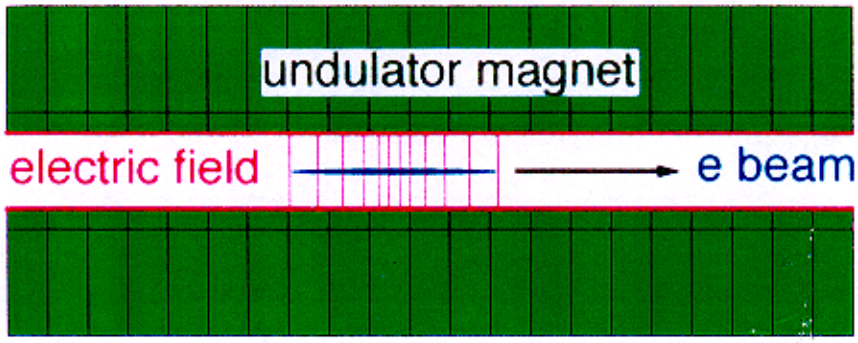
STEP 2



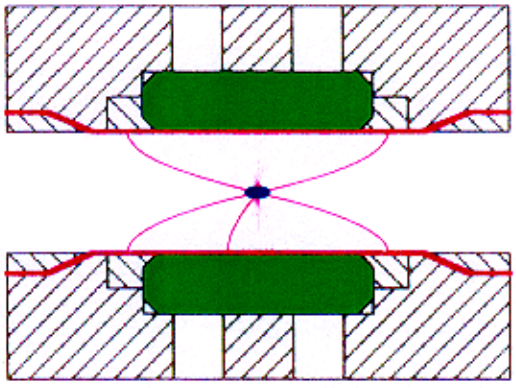
STEP 3



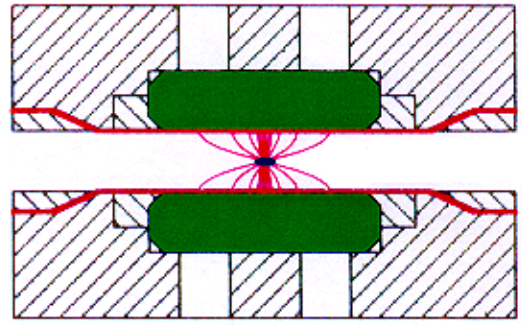
Power generated by image current



low current density



high current density



$$P = MI_b^2\left(\frac{L_u}{\pi G}\right)\frac{\Gamma(3/4)}{\omega_o \sigma_t^{3/2}}\sqrt{\frac{\mu_o \rho}{2}}$$

Bane and Krinsky

M : number of bunches
I_b : beam current per bunch
ρ : resistivity
L_u : length of undulator
G : gap
σ_t : bunch length

Metal foil

Cu : low resistivity

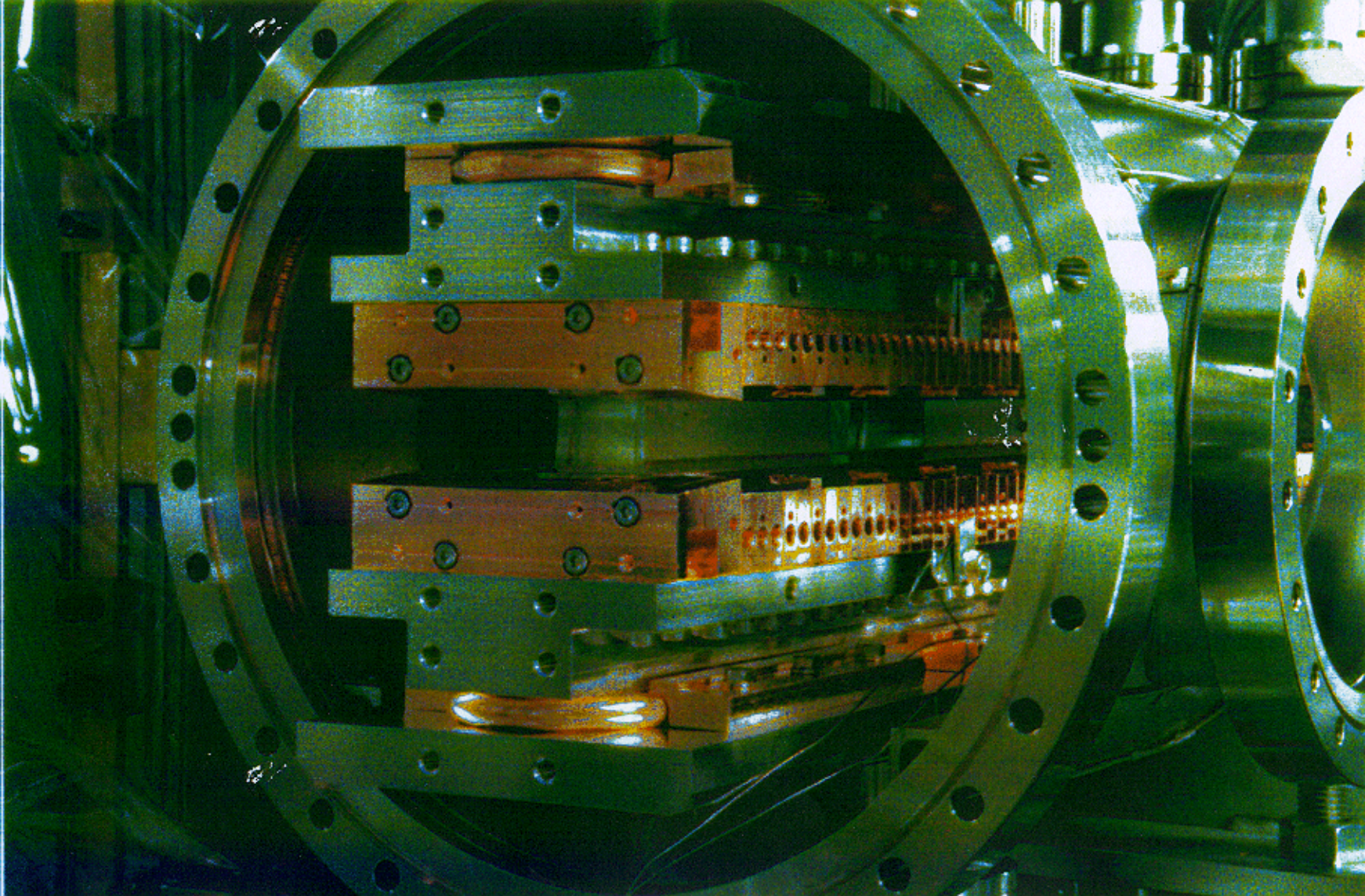
Ni : magnetic force→good thermal contact

skin depth: < 1μm

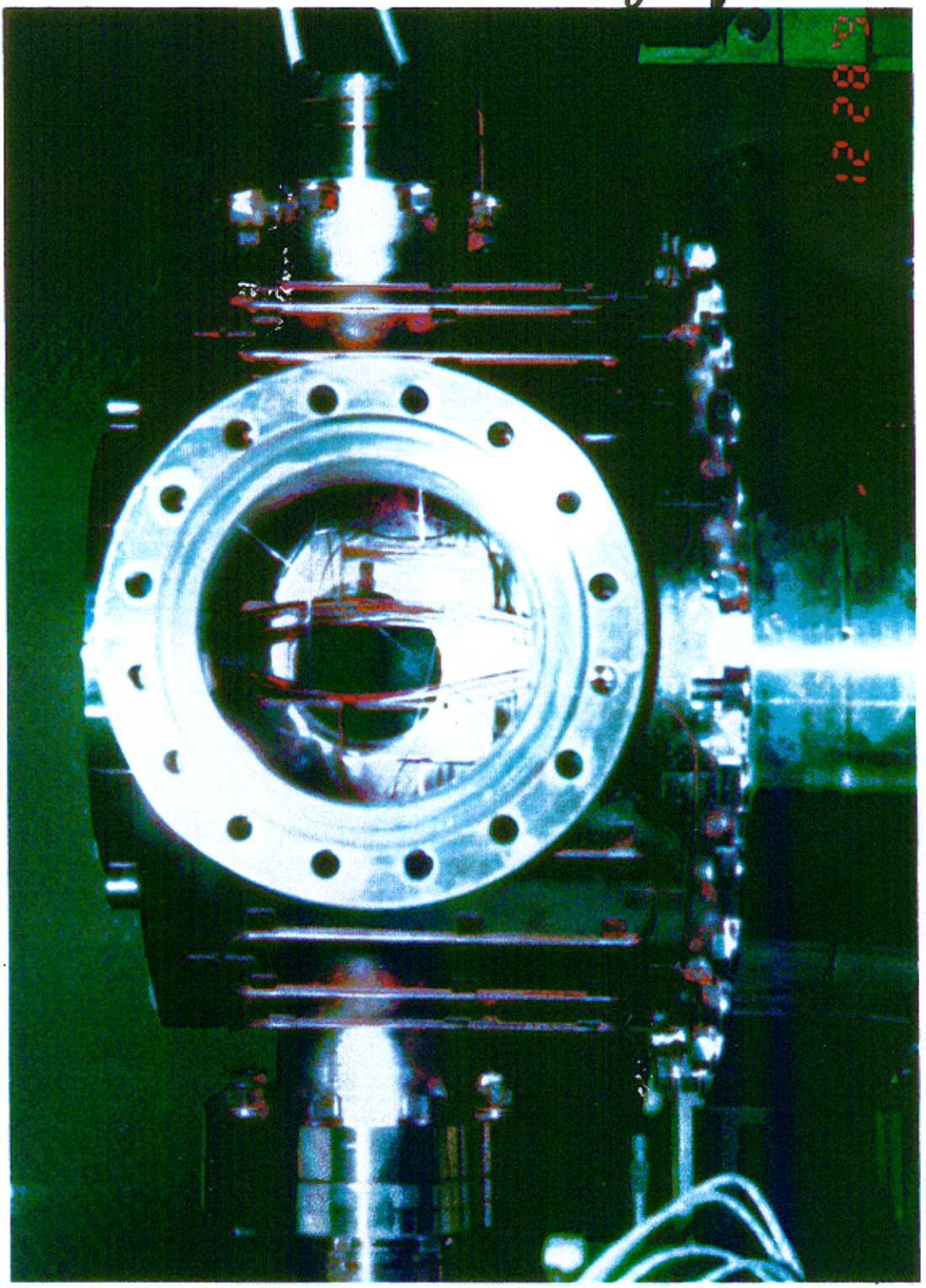
Ni (50μm) + Cu (10μm)

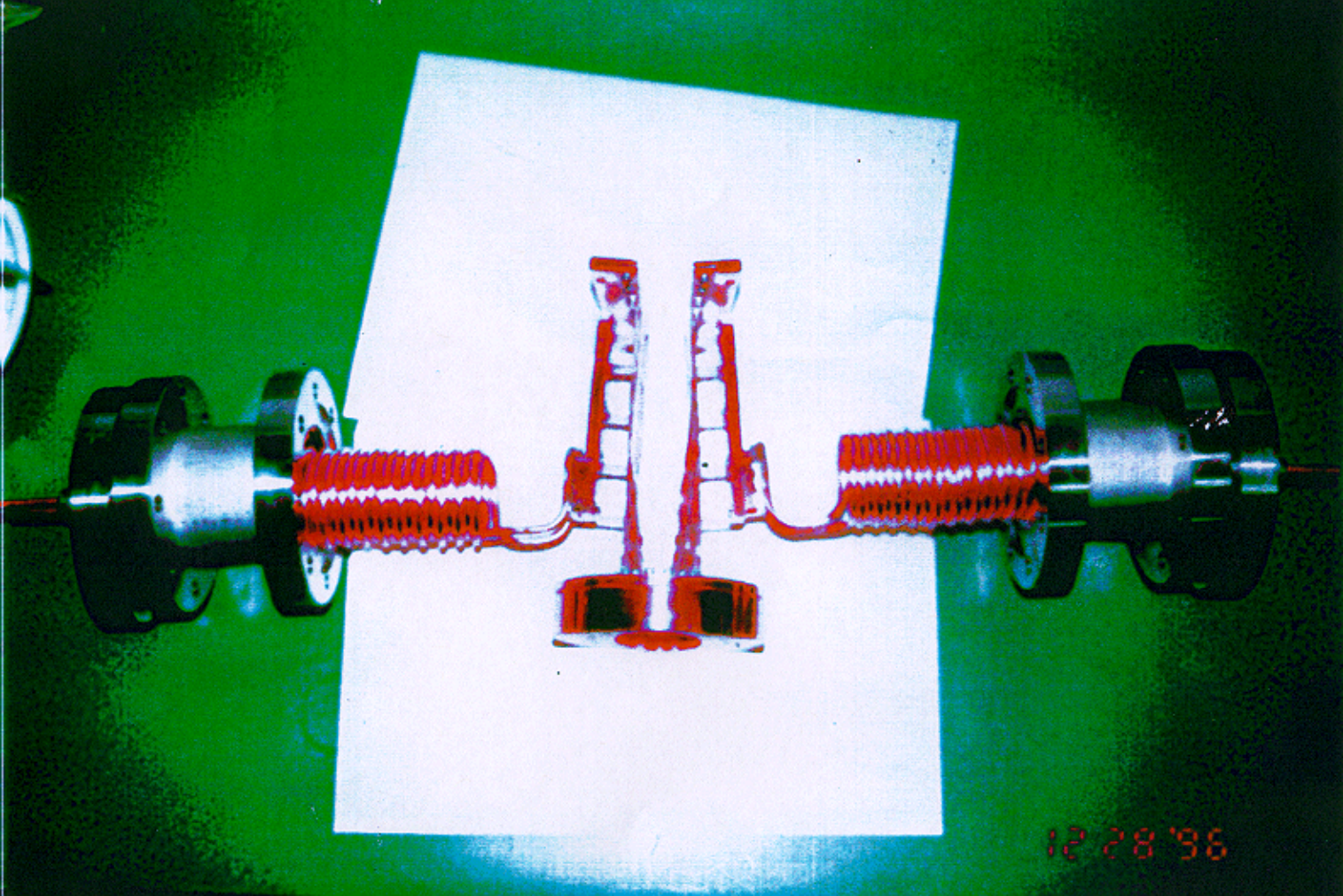
↓

magnetic flux loss : < 0.1% (λu = 32mm)

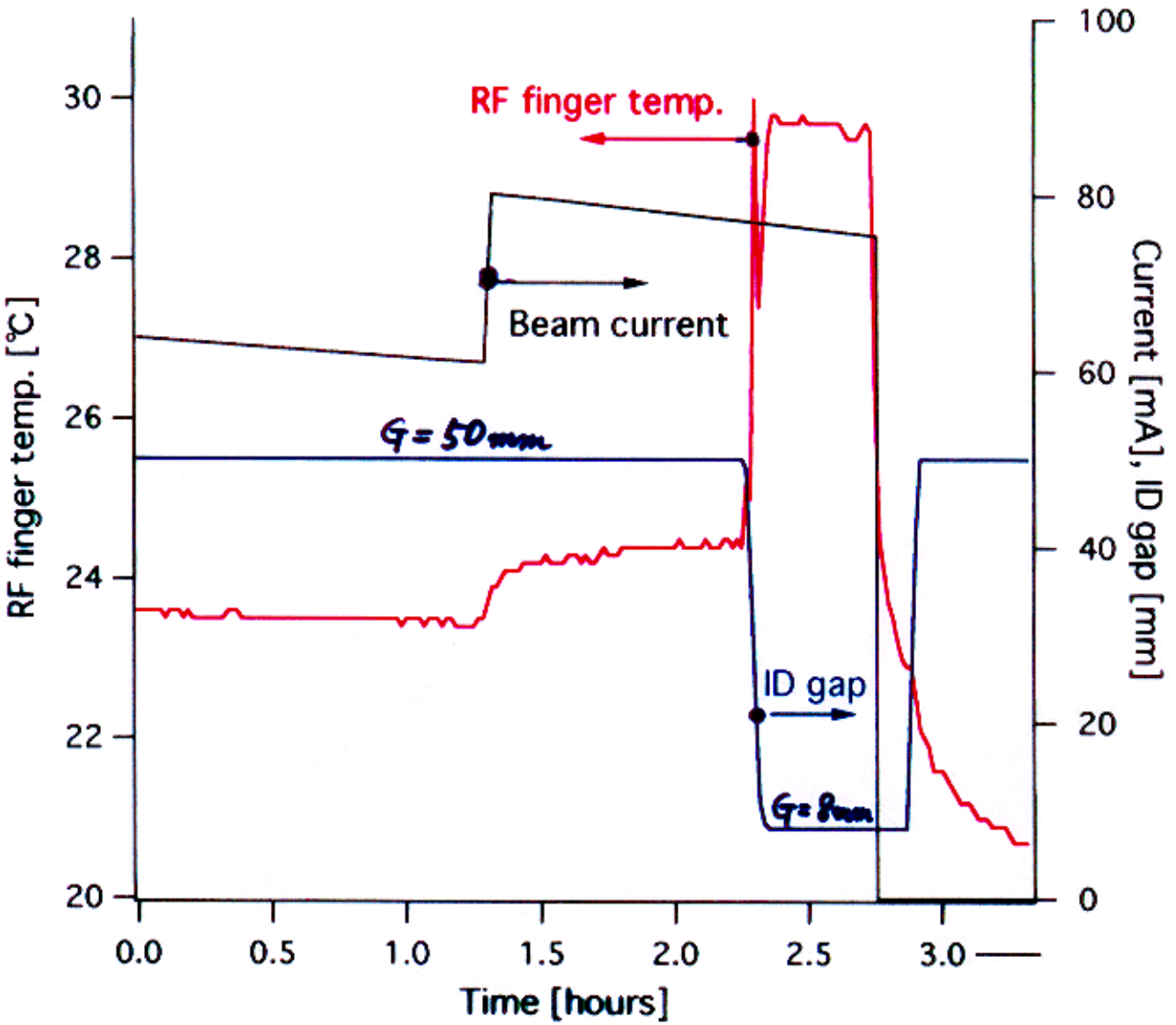


rf-finger (old type)
without water cooling system




12 28 96

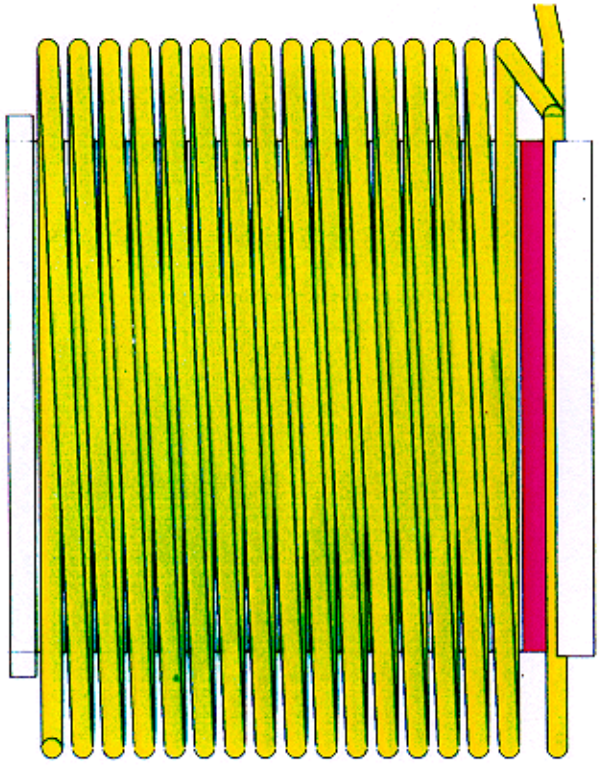
at SPring-8



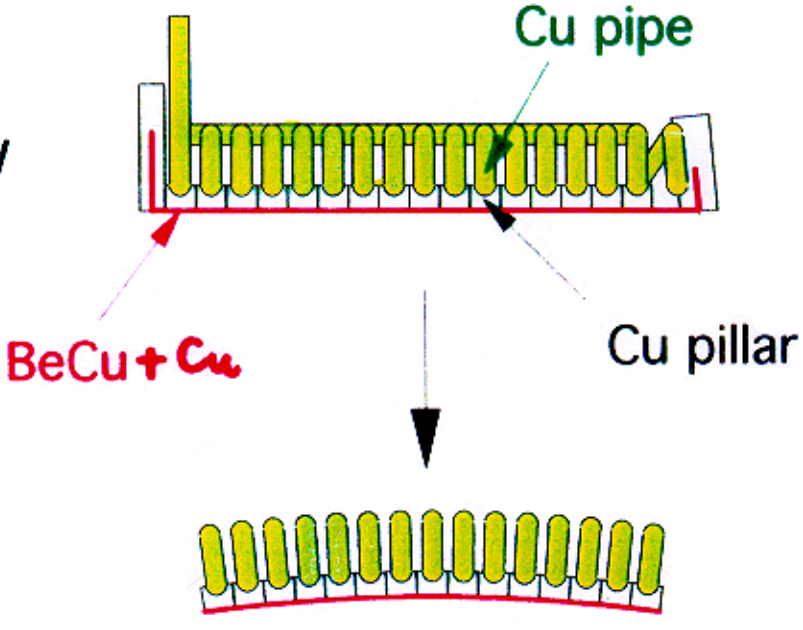
SPring-8 ID39 transition temperature
Undulator entrance, upside
(1/6 filling, 98/06/11)

Water cooling system for flexible rf-finger

top view



side view



In-vacuum Revolver Undulators (mini gap)

R&D study at SPring-8

Characteristics

1. **Four different period lengths**

   $\lambda u = 6, 10, 15, 20$ mm

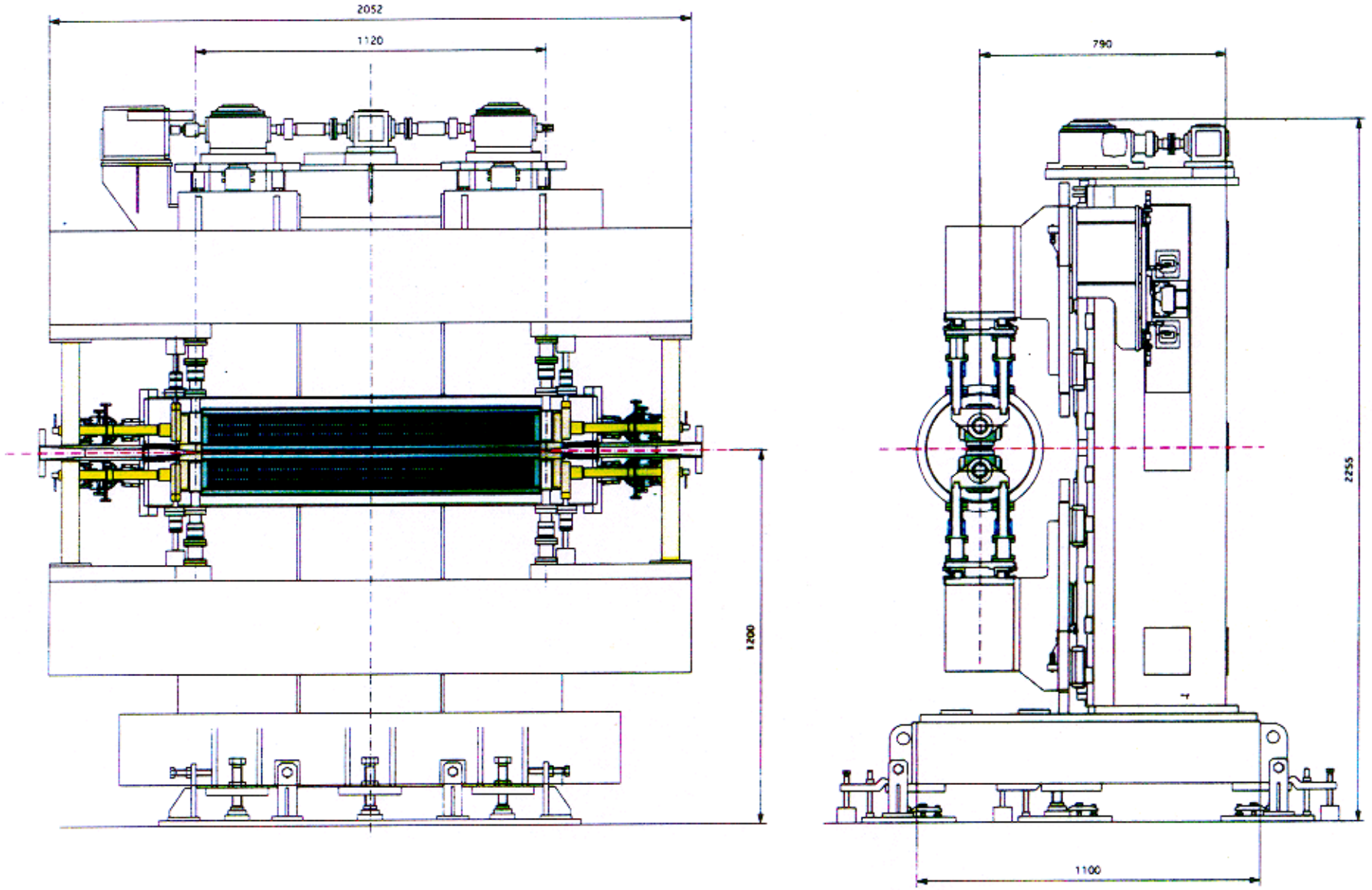
2. **L = 1 m**

3. **Gmin = 2 mm**

4. **Detachable/attachable flexible rf finger**

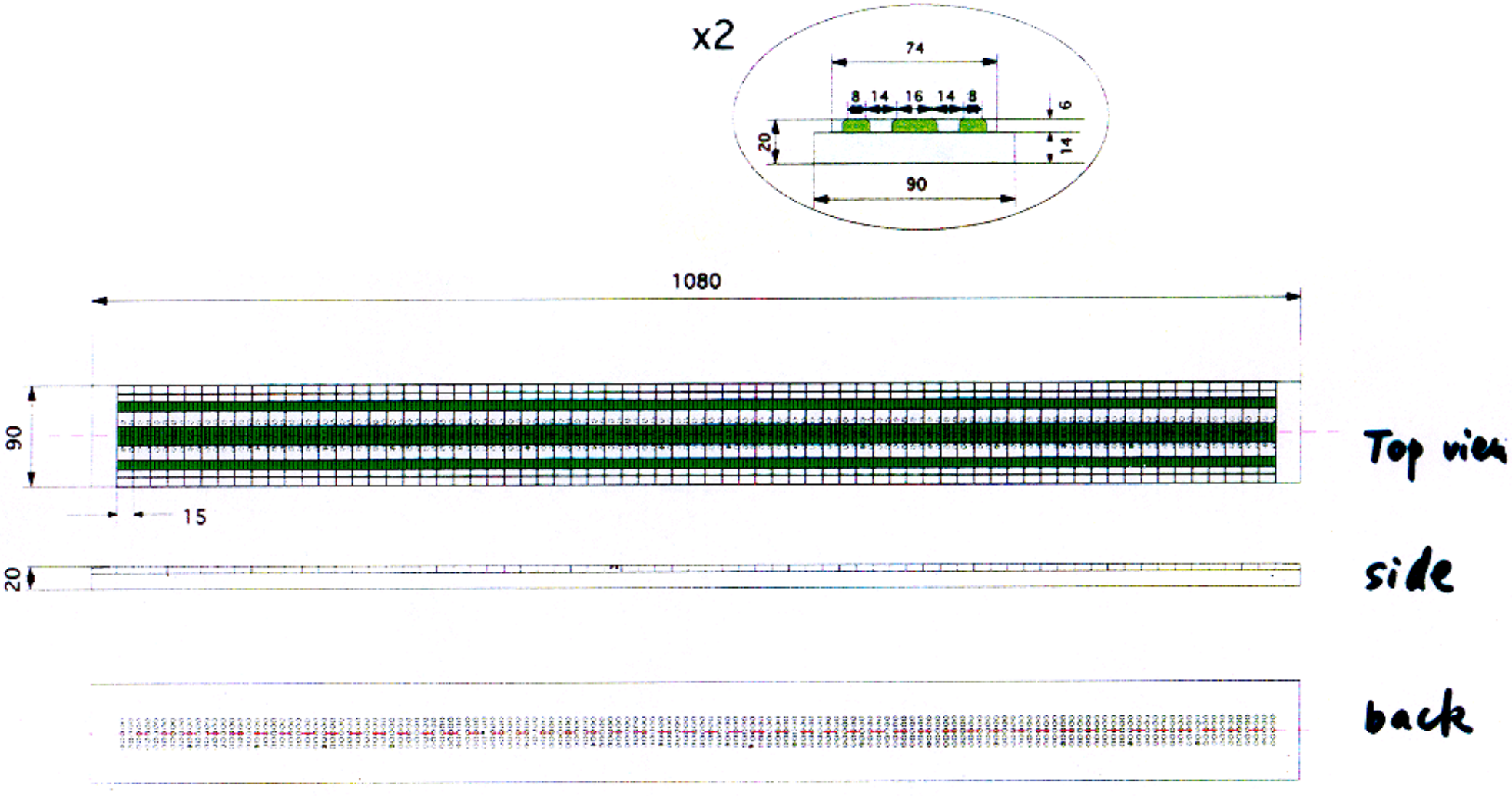
5. **Net load minimized by additional magnetic arrays to obtain repulsive force**

6. **Two-stage differential pumping system for feedthrough rotatable axes.**



In-vacuum Revolver Undulator

図4-1-1 挿入光源開発装置



magnet array for λu = 15 mm

図4-1-3　永久磁石列B

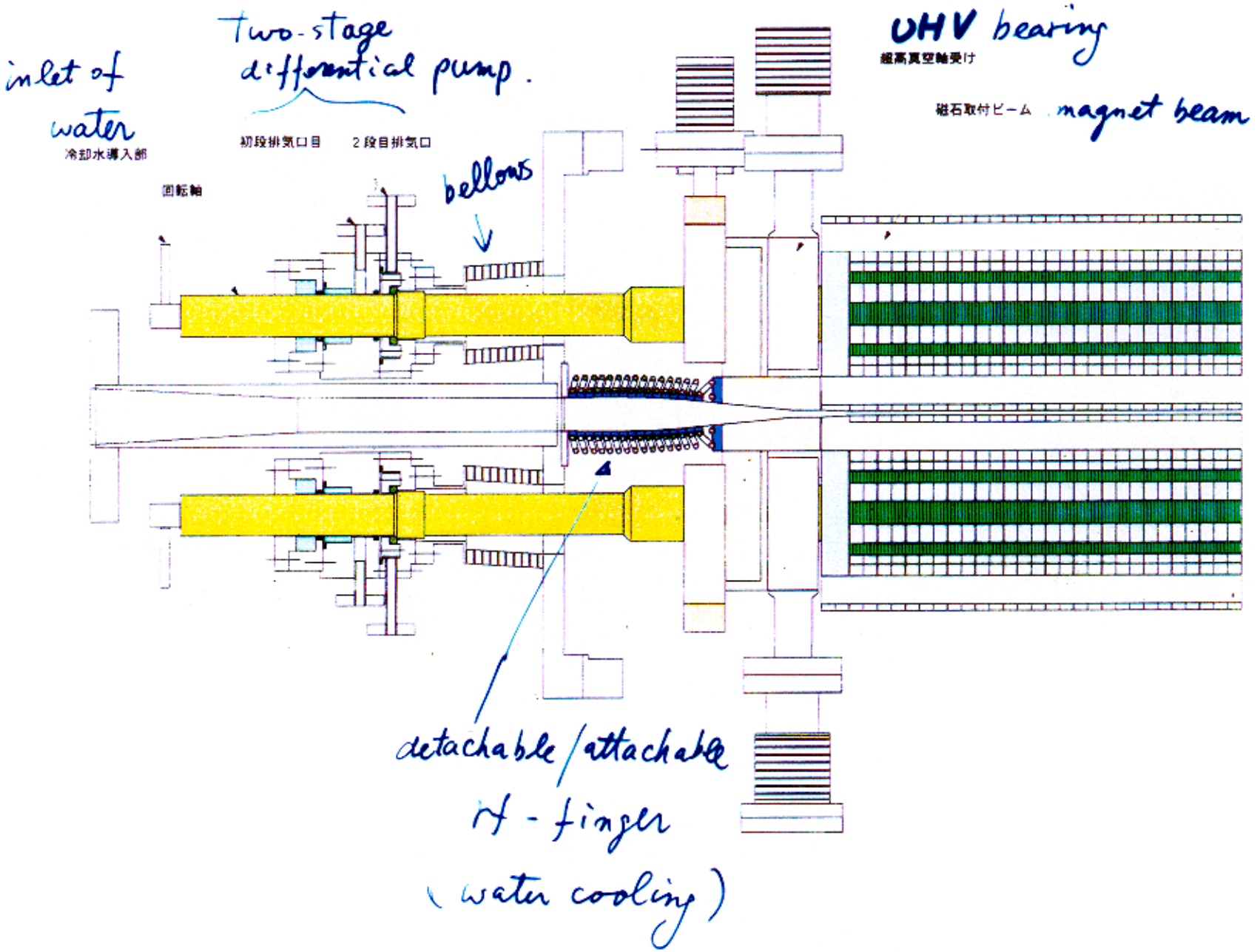
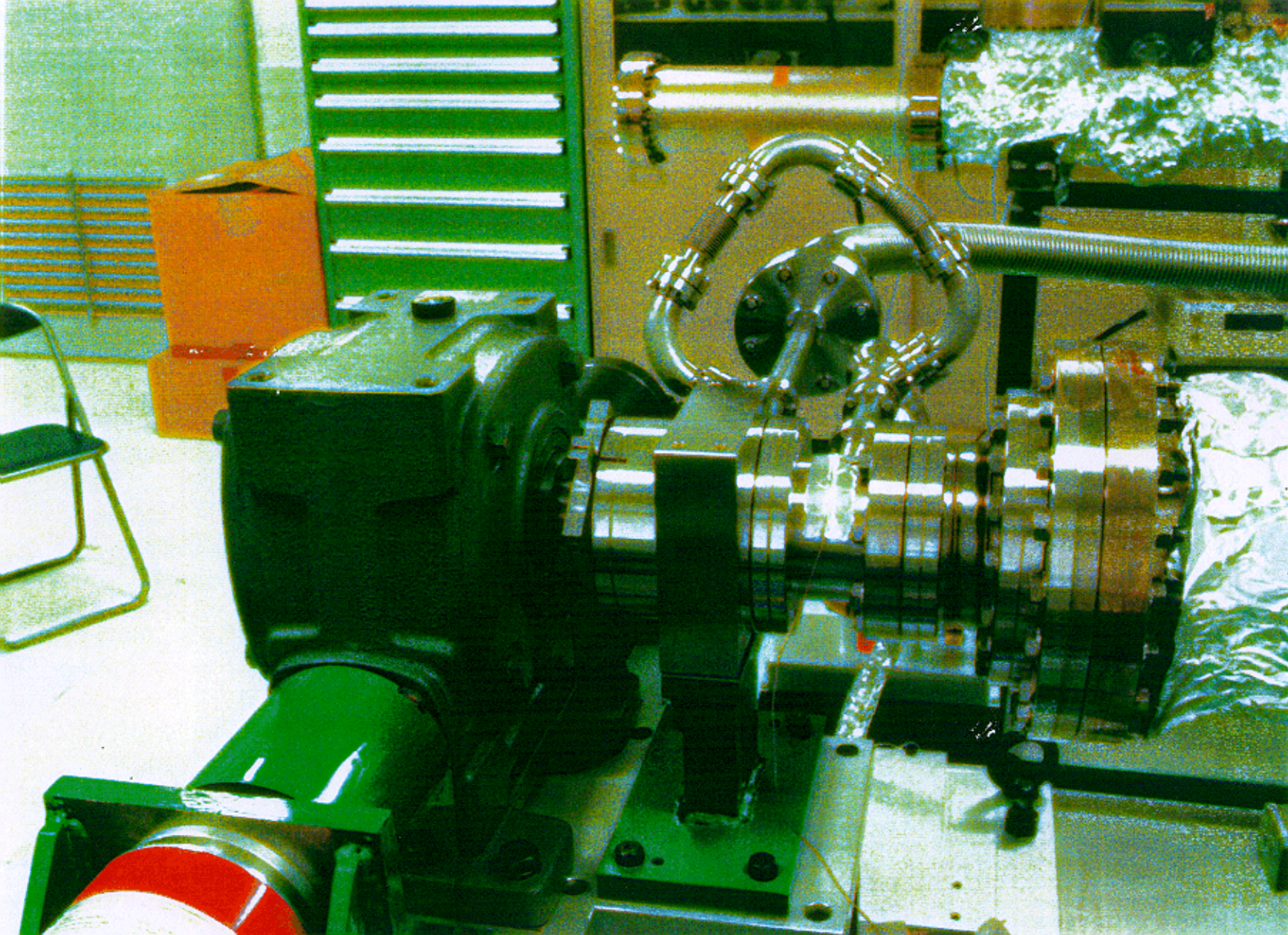
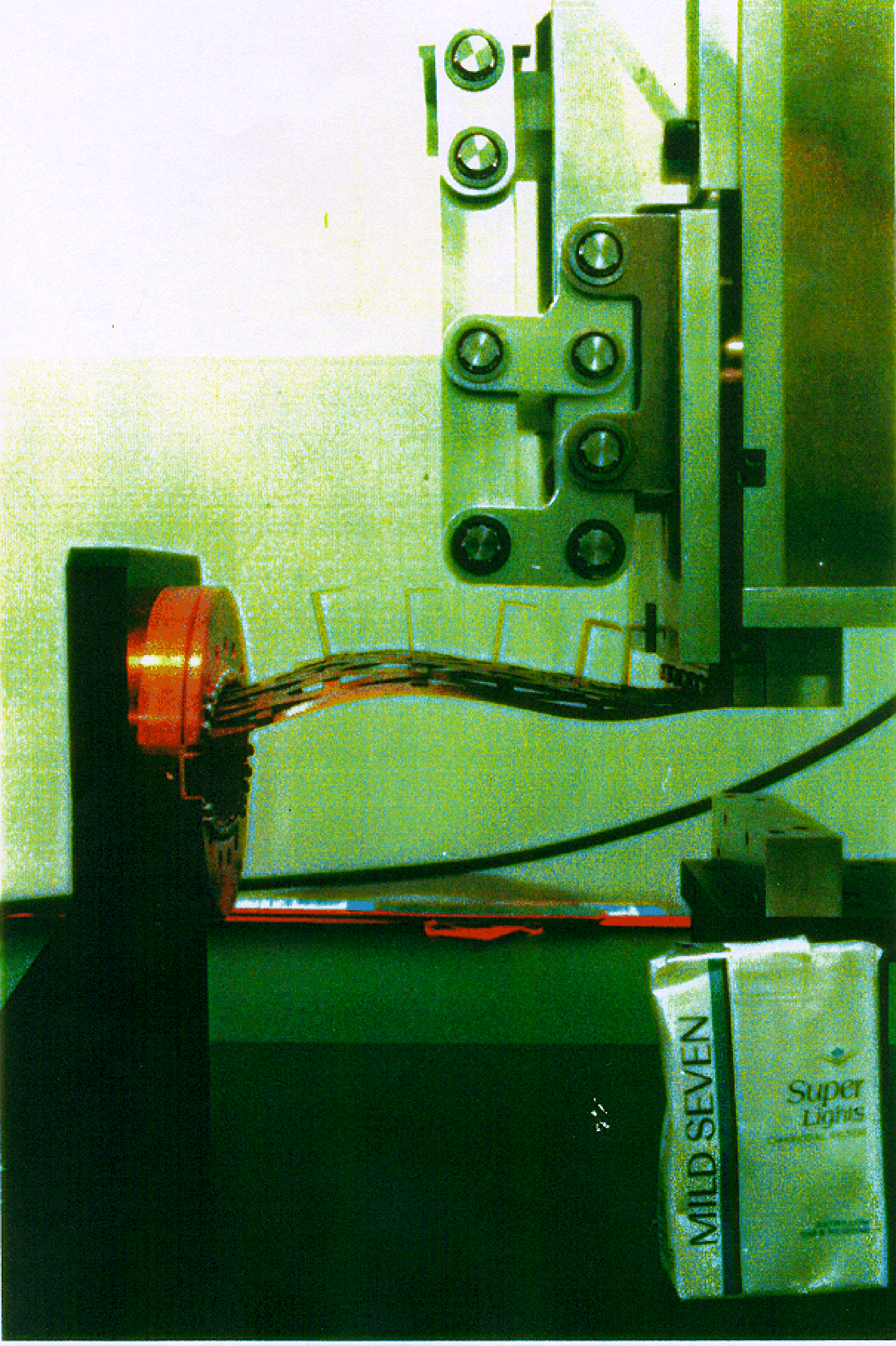

inlet of water
冷却水導入部
two-stage differential pump.
初段排気口目
2段目排気口
回転軸
bellows
UHV bearing
超高真空軸受け
磁石取付ビーム
magnet beam
detachable/attachable
rf-finger
(water cooling)

図4-1-7　回転導入部




MIDSEVEN


MILD SEVEN
Super
Lights