T. Kageyama Jan. 23, 1997

Development of ARES Cavity

Overview

- Prototype cavities
  and their high-power and beam experiments
- HOM absorbers
- Coaxial antenna damper for coupling cavity
- Input Coupler

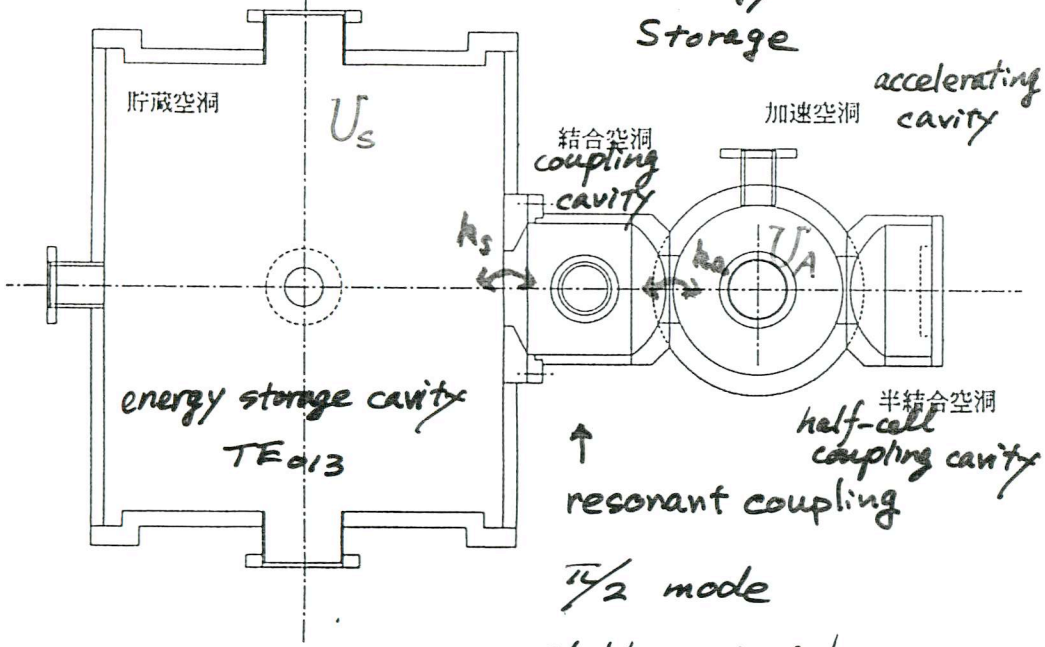
The ARES (Accelerator Resonantly coupled with Energy Storage) cavity is a three-cavity system operated in the $\pi/2$ mode.

A HOM-damped accelerating cavity is coupled with a high-Q energy storage cavity (TE013) via a coupling cavity.

The coupling cavity is equipped with a coaxial antenna damper to reduce the impedances of the parasitic 0 and π modes.

ARES structure

Accelerator
Resonantly coupled
with
Energy
Storage

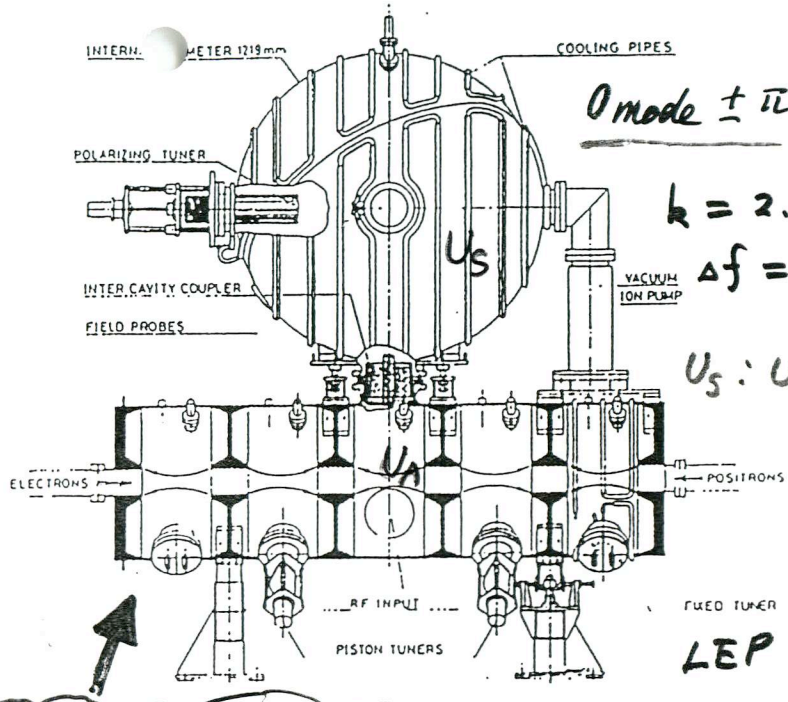


↑ resonant coupling

$\pi/2$ mode

stable against heavy beam loading

$$\frac{U_S}{U_A} = \frac{k_a^2}{k_s^2}$$



0 mode ± π mode

$k = 2.5 \times 10^{-4}$

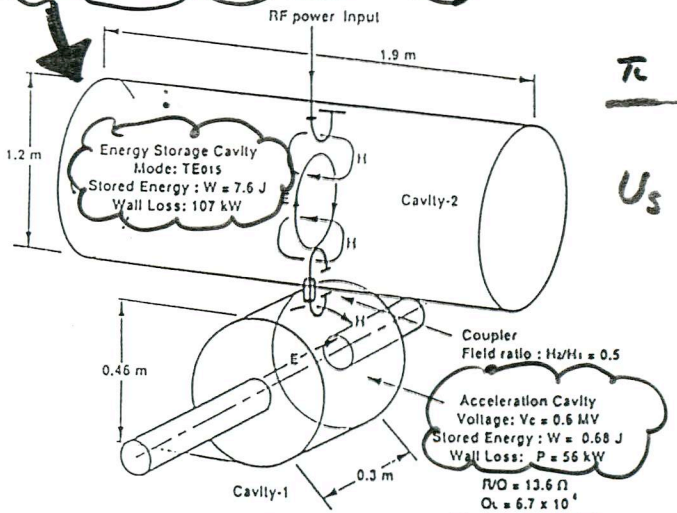
$\Delta f = 89$ kHz

$U_S : U_A = 1 : 1$

LEP

Fig. 34 One unit of the LEP coupled-cavity accelerating structure

non ARES structures



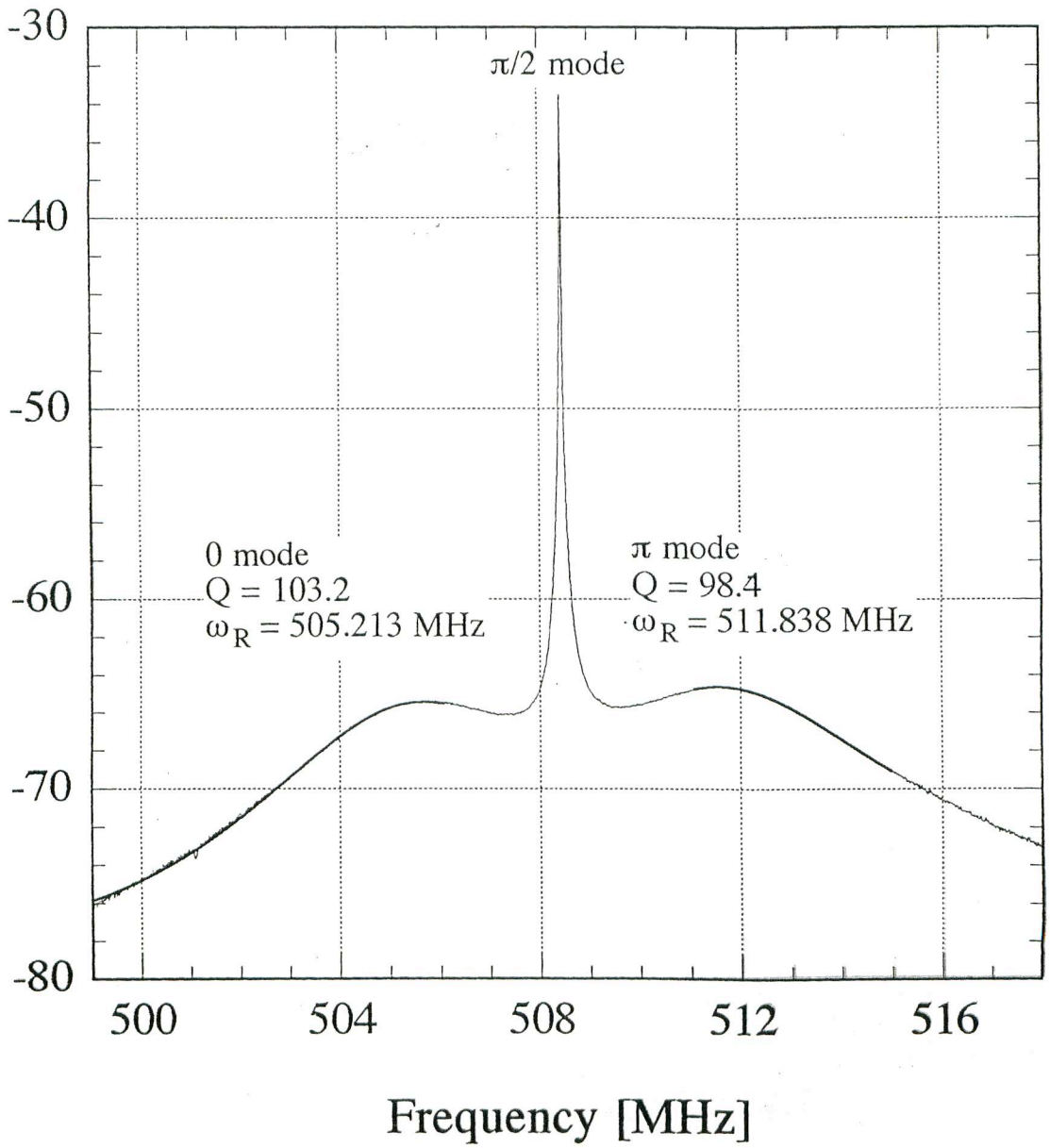
π mode

$U_S : U_A = 1 : 1$

T. Shintake

π モードでは $U_S : U_A$ は 1:1 で
任意のエネルギー分配比をとることは不可!

ARES96#1 0, π モード
測定 10月 '96



ARES96

The ARES scheme has the following advantages over a non-ARES one without a coupling cavity like the LEP normal conducting cavity operated in the π (0) mode:

The π/2 mode has excellent field stability against heavy beam loading.

The stored energy ratio Us:Ua can be easily adjusted by changing the coupling factor ratio ks:ka.

The parasitic 0 and π modes can be selectively damped by installing a coaxial antenna coupler into the coupling cavity.

The impedance contributions from the damped 0 and π modes cancel out each other.

It should be noted that the coupling cavity is the keystone of the ARES structure.

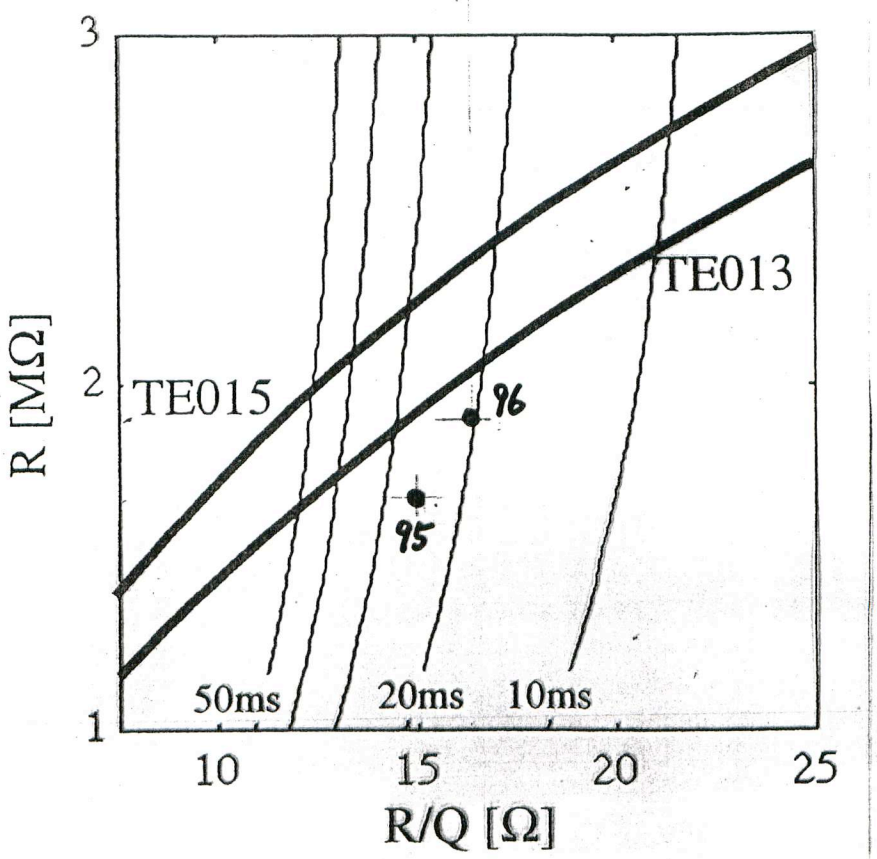
Two prototypes with different HOM-damping schemes were developed:

ARES95 with Quadrupole Counter-Mixing (QCM) choke.

ARES96 with Grooved Beam Pipes (GBP's) and rectangular waveguides.

RF parameters of the accelerating mode
加速モード基本特性

	ARES95	ARES96
Ua／Us	1／8．9	1／8．3
R／Q　(Ω)	14．8	16．3
Q	112000	117000



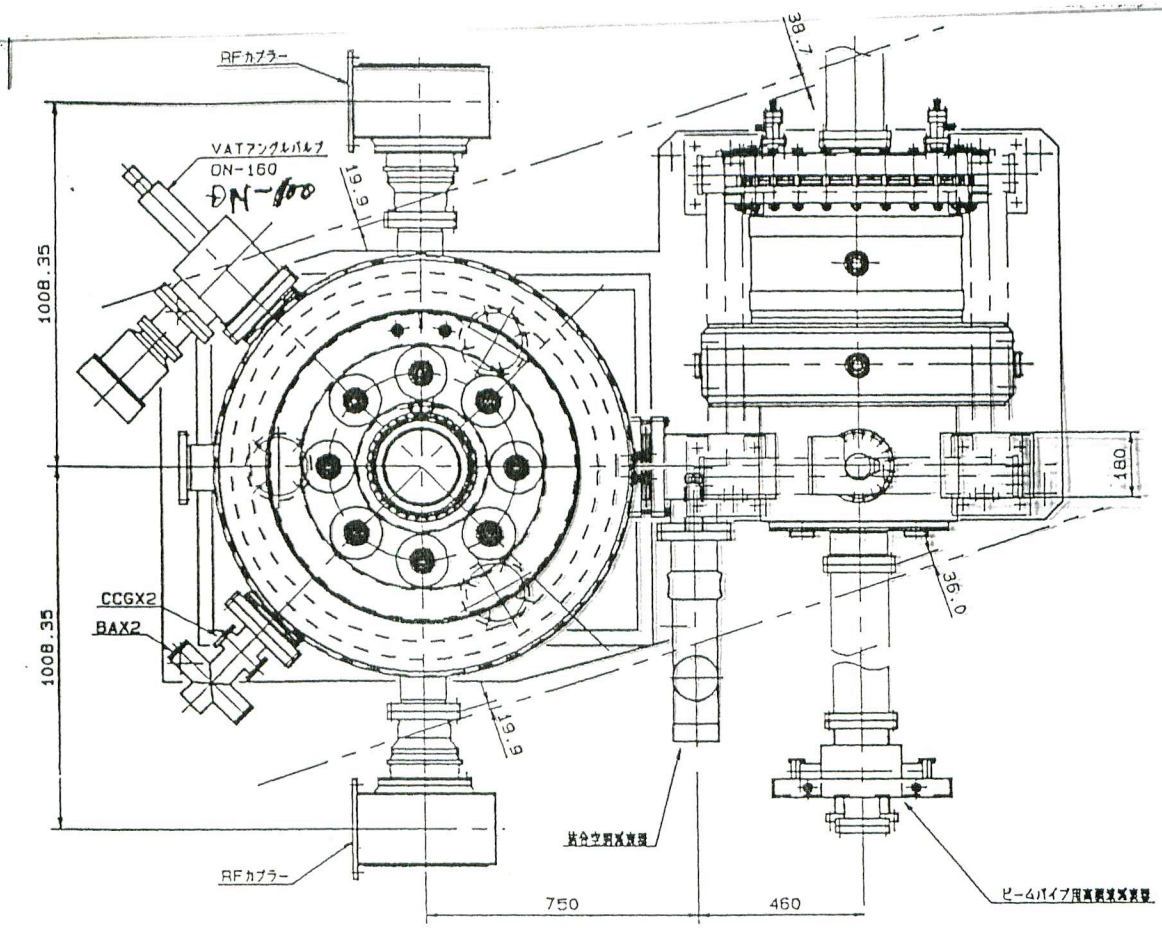
ARES95

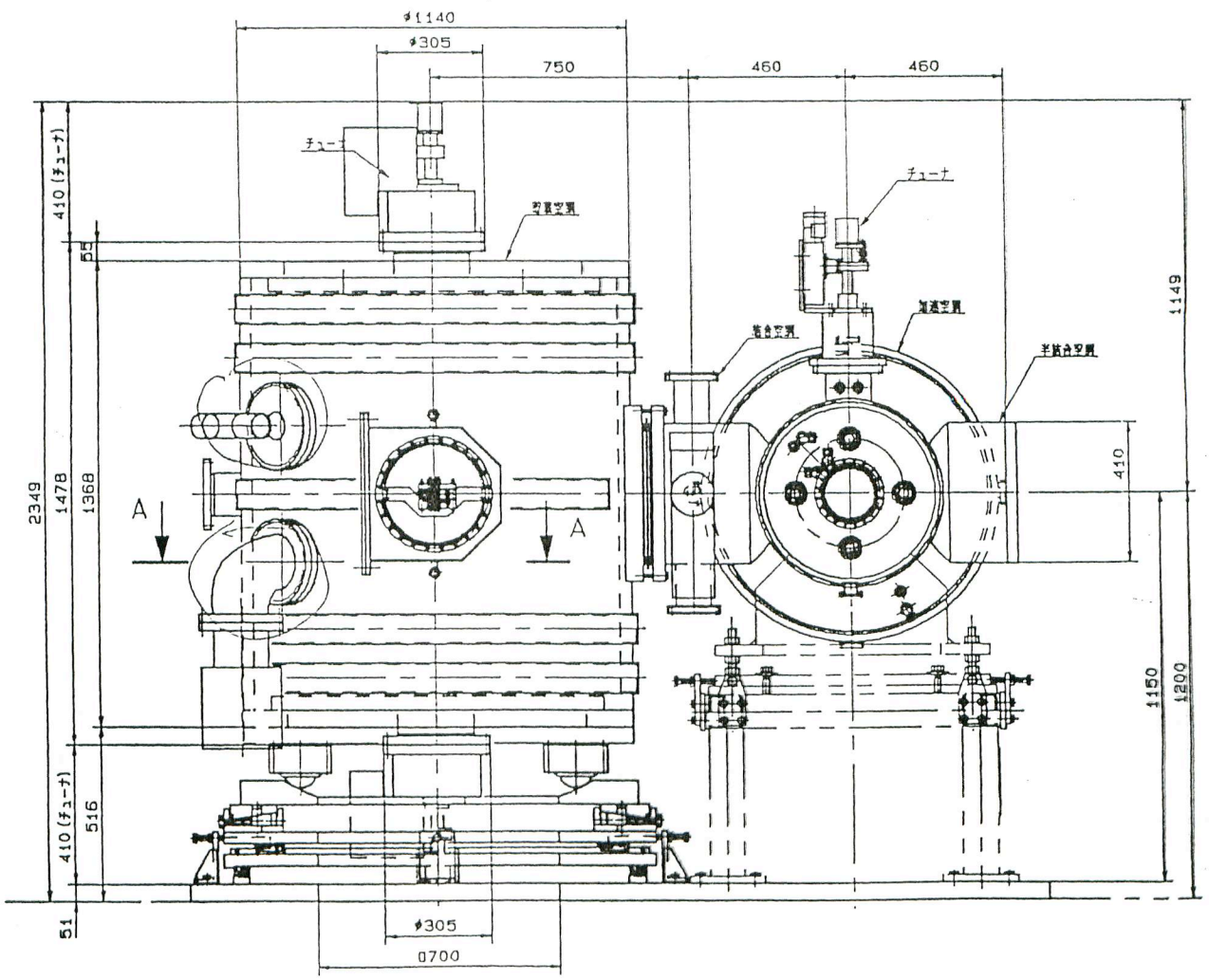
Why QCM choke?

The two apertures to the coupling cavities at both sides of the accelerating cavity mixes the accelerating mode with a quadrupole component.

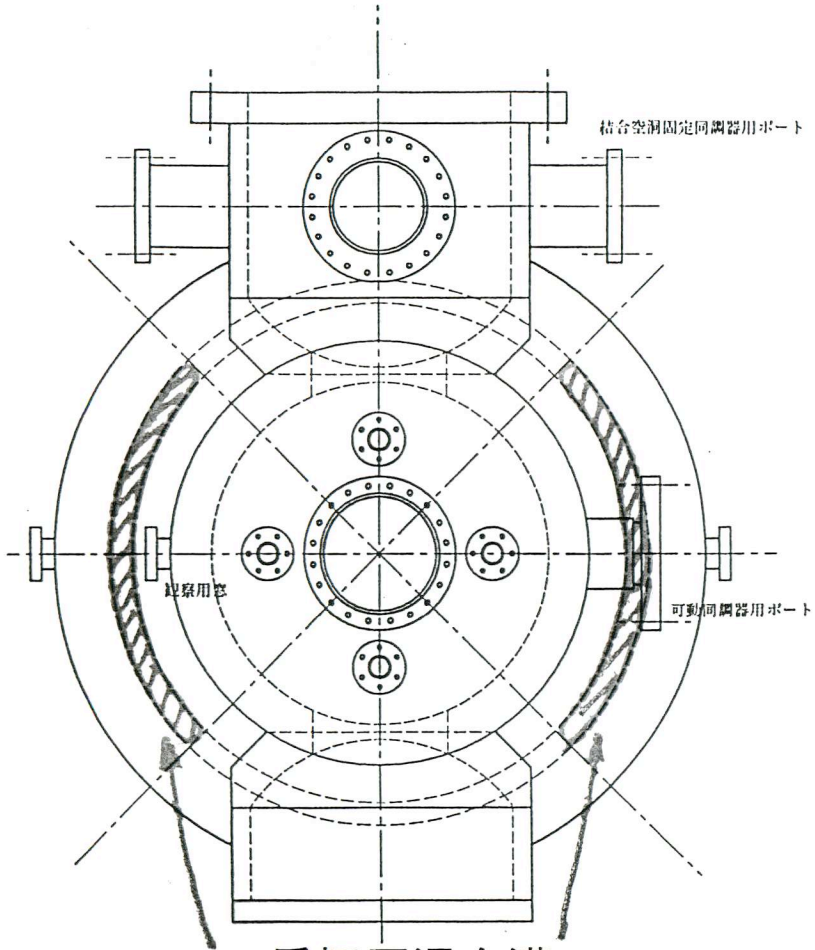
The quadrupole (TE21) component cannot be blocked by an axially symmetric choke. The Q value of the accelerating mode reduces about ~50%.

The solution with Quadrupole Counter-Mixing scheme: Generating another quadrupole component at the choke structure with quadrupole symmetry and blocking the TE21 wave toward the HOM absorbers.


RFカプラー
VATアングルバルブ
DN-160
DN-100
1008.35
1008.35
CCGX2
BAX2
38.7
19.9
180
36.0
19.9
750
460
RFカプラー

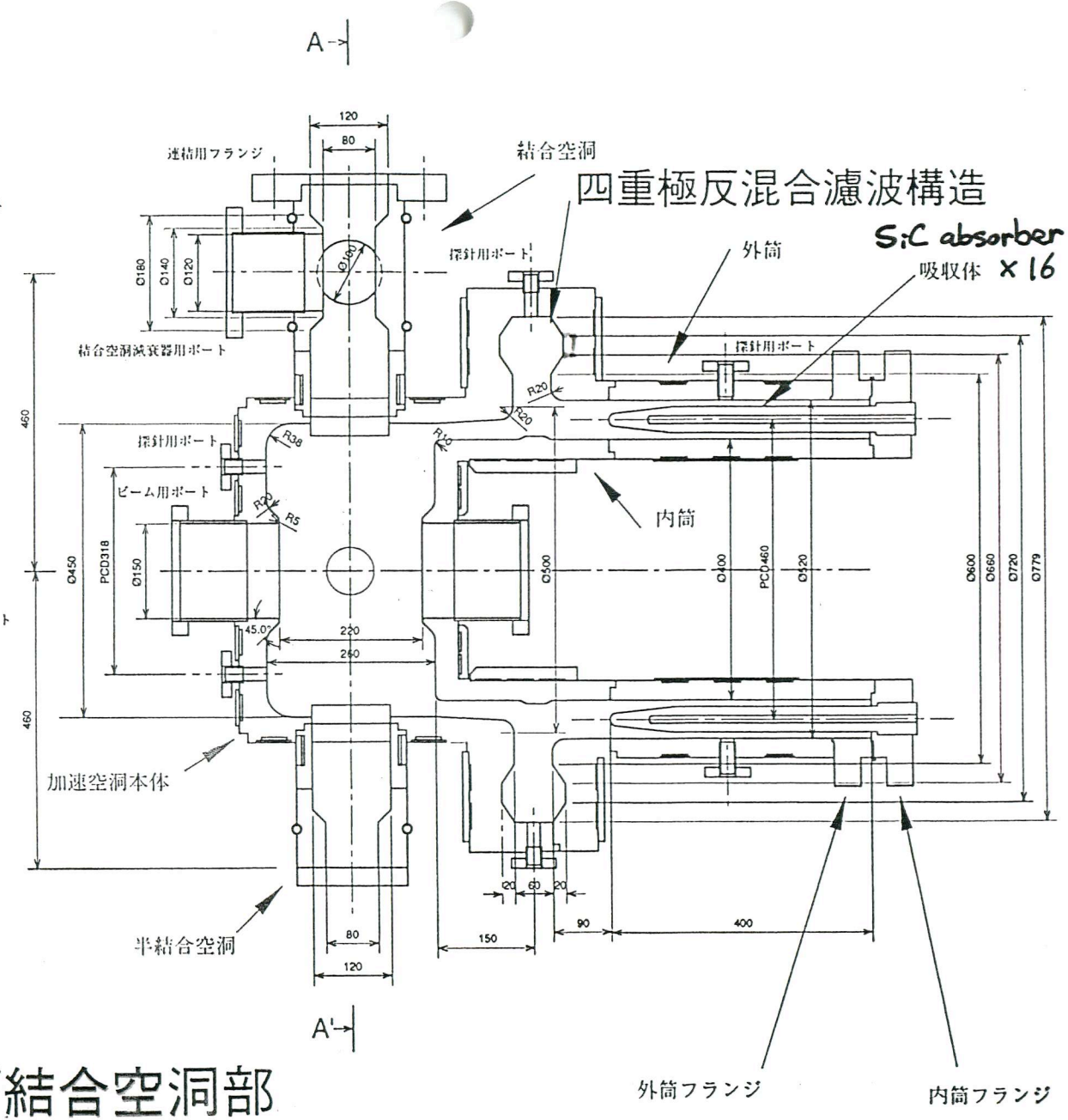

φ1140
φ305
750
460
460
410(チューナ)
55
1478
1368
516
410(チューナ)
51
2349
A
A
1149
410
1150
1200
φ305
□700

ARES95



四重極反混合溝

QCM grooves



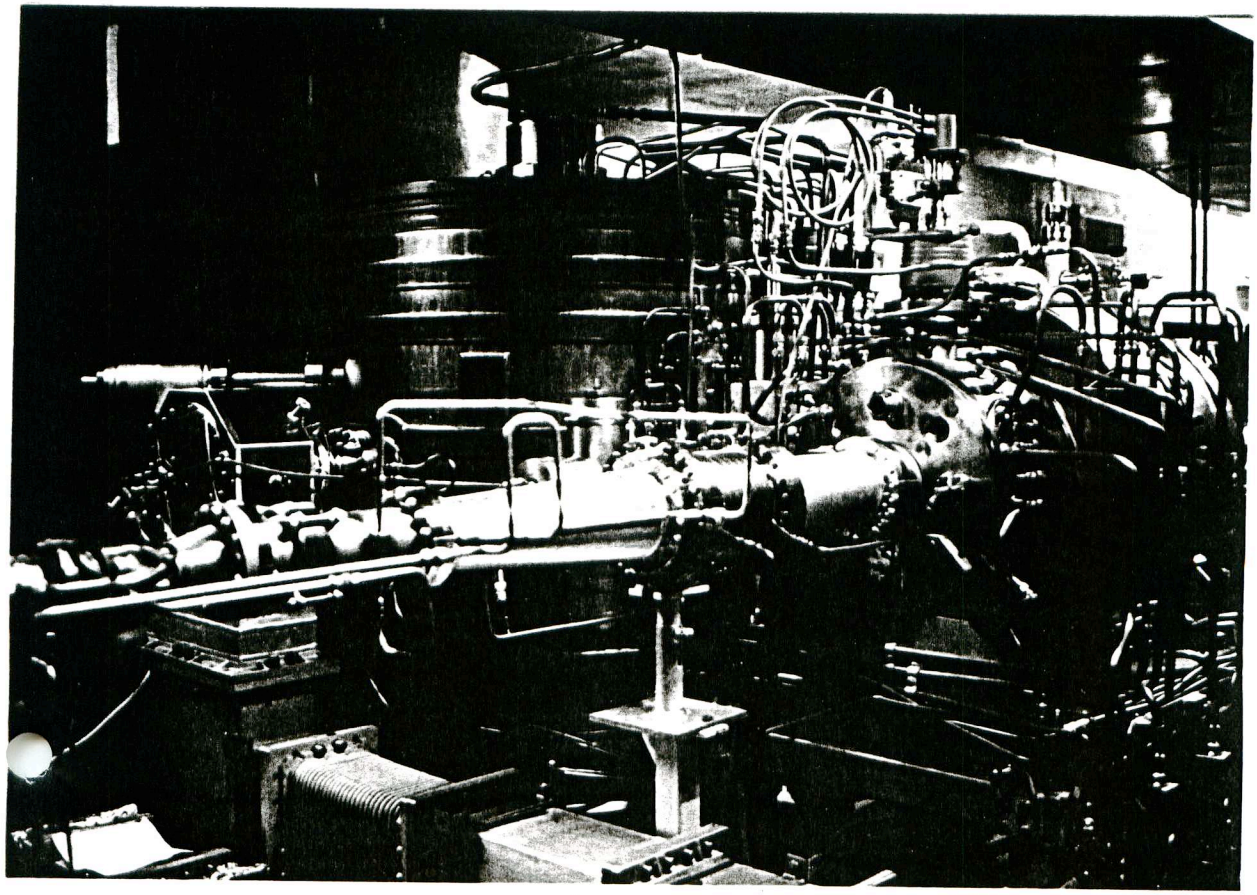
９５試　ＡＲＥＳ加速及び結合空洞部

QCM (Quadrupole Counter-Mixing)　Choke Structure

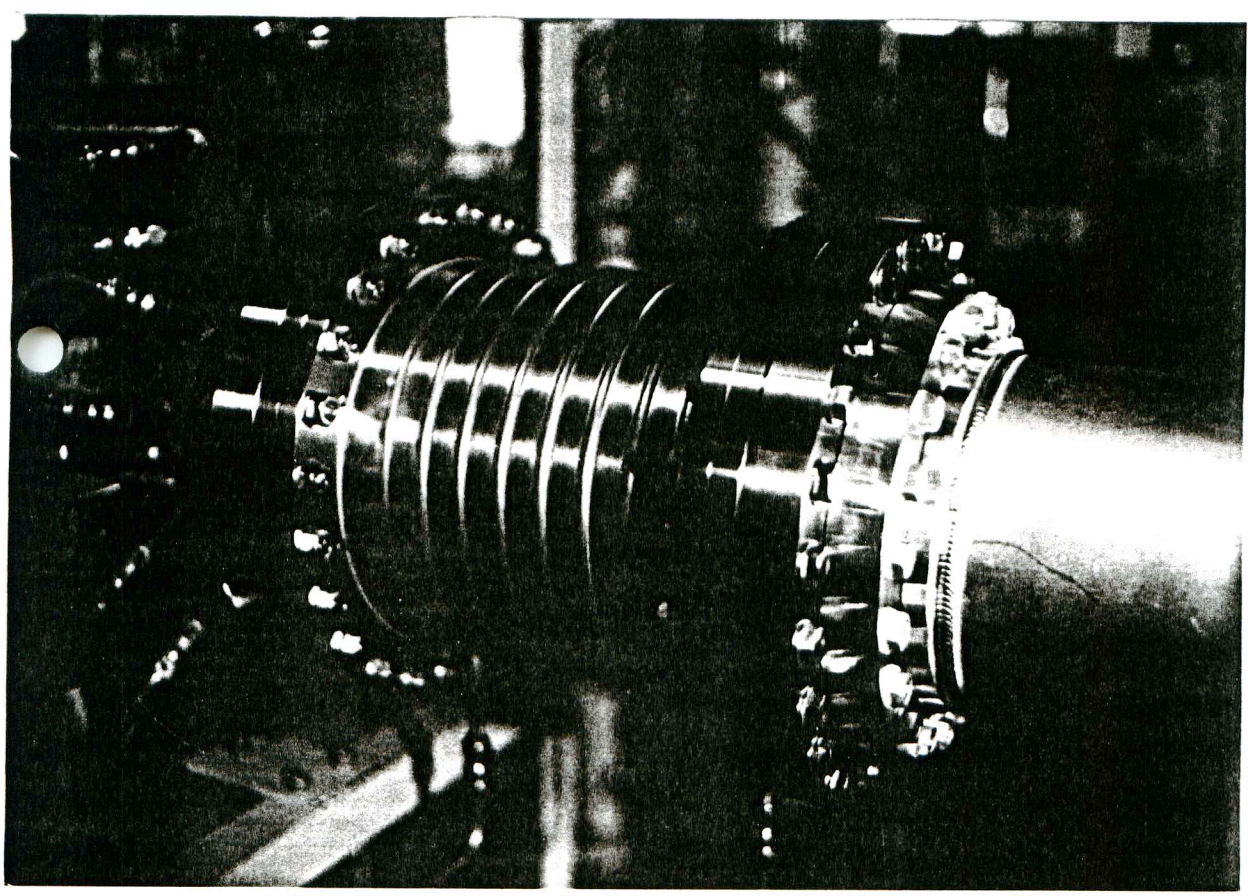
Quadrupole CounterMeasure

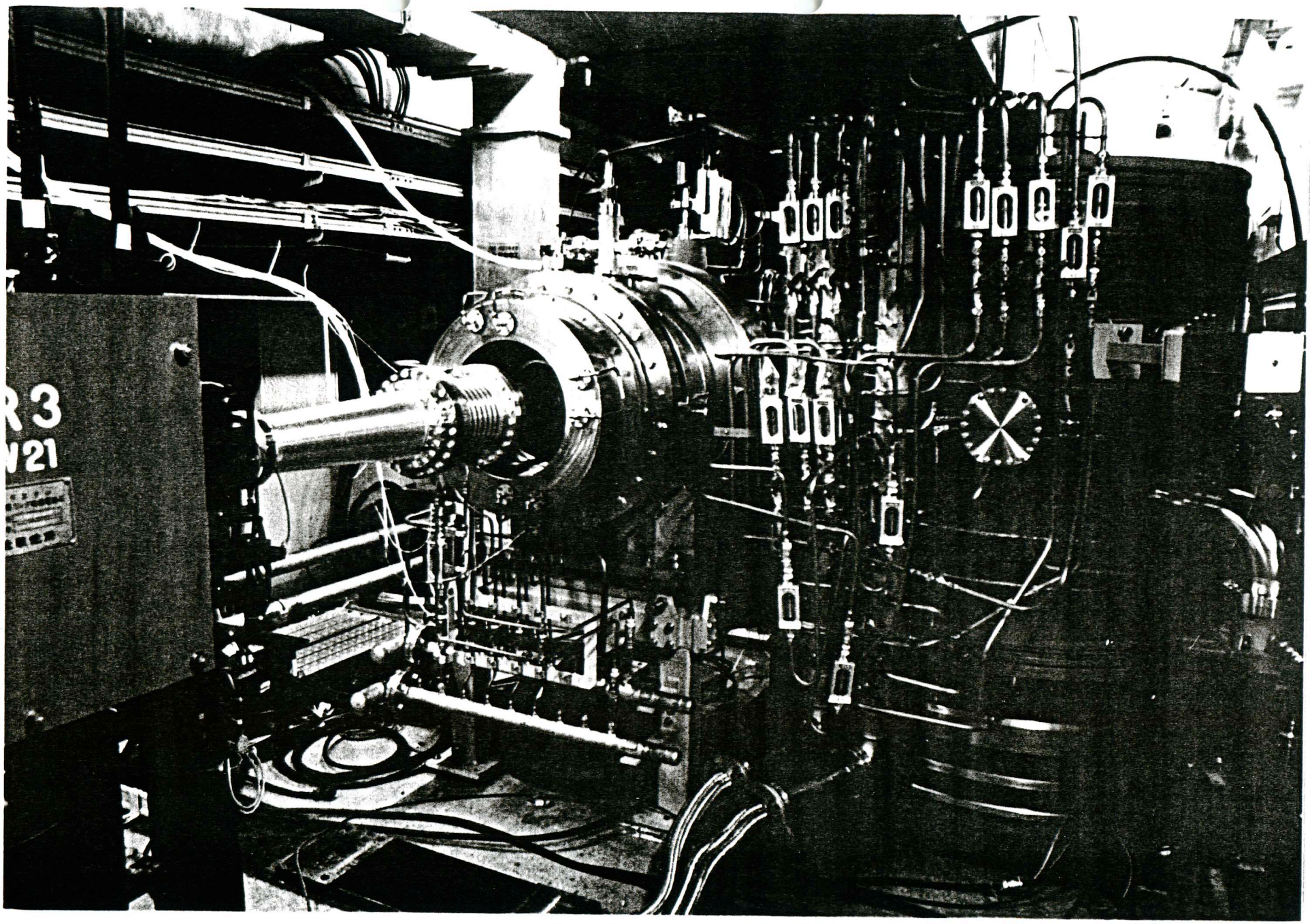
備考

加速空洞の姿勢について、そのピッチ、ロール、及びヨー角はビーム軸方向を基準として定義する。



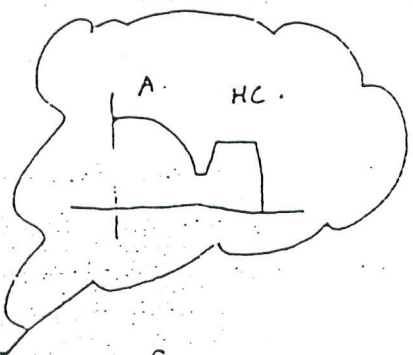
ARES 95



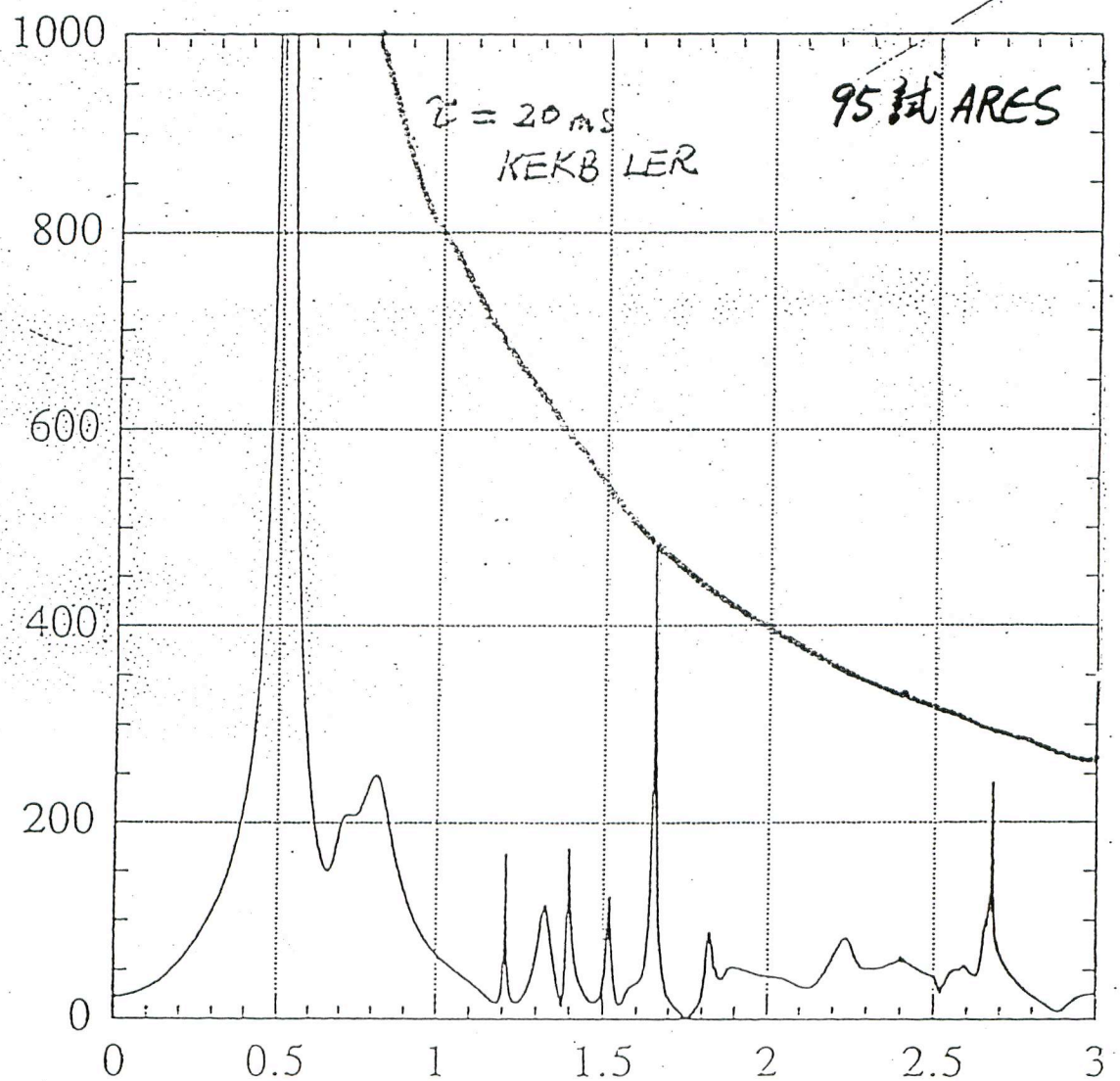


ARES95 in TRISTAN AR

96.03.04



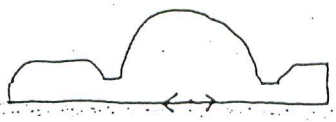
Longitudinal Impedance of
A-cav and Two Counter balances
(MAFIA T3, $0 < s < 66m$, $\sigma_z = 2cm$)



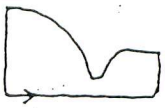
$Z_{//}$

ARES 95

水平方向

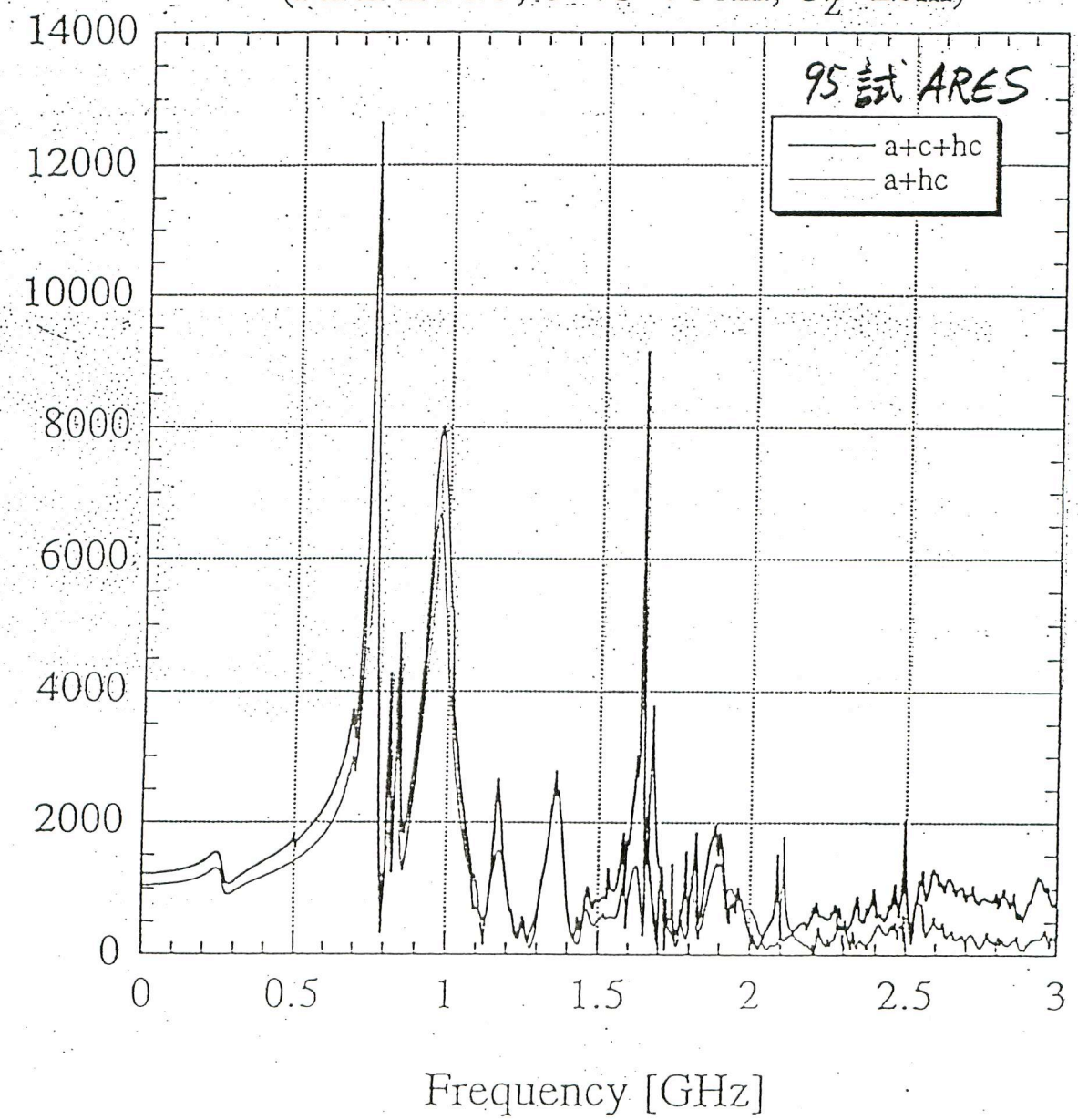


a+c+hc
offset ±12mm



a+hc
offset 12mm.

Transverse Impedance of
A-cav and Counter balance
(MAFIA T3, 0 < s < 66m, σ_z=2cm)



Z_x

ARES95

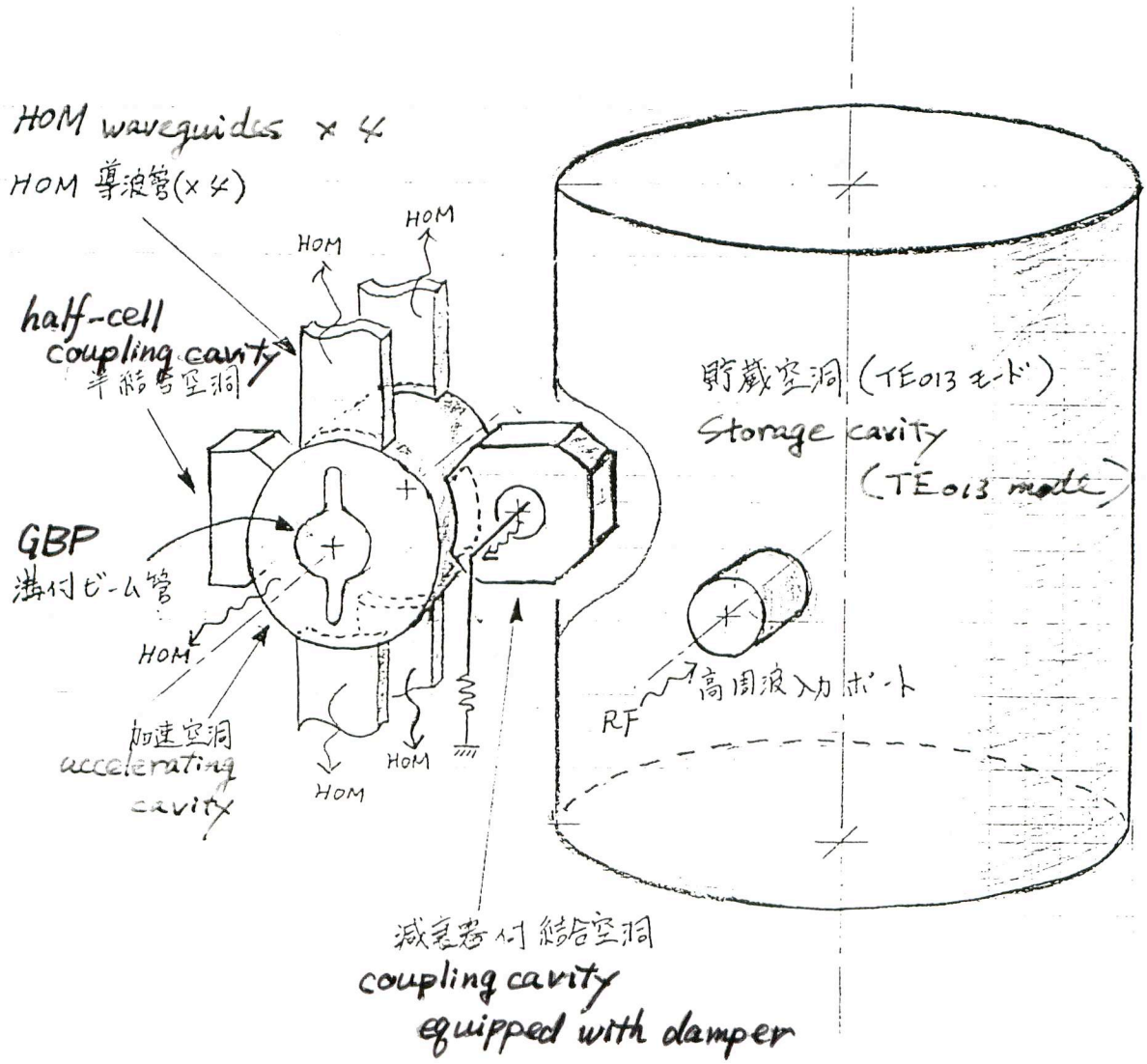
ARES96

with a HOM-damped accelerating cavity more suitable to the ARES scheme and with better cost performance.

The accelerating cavity has

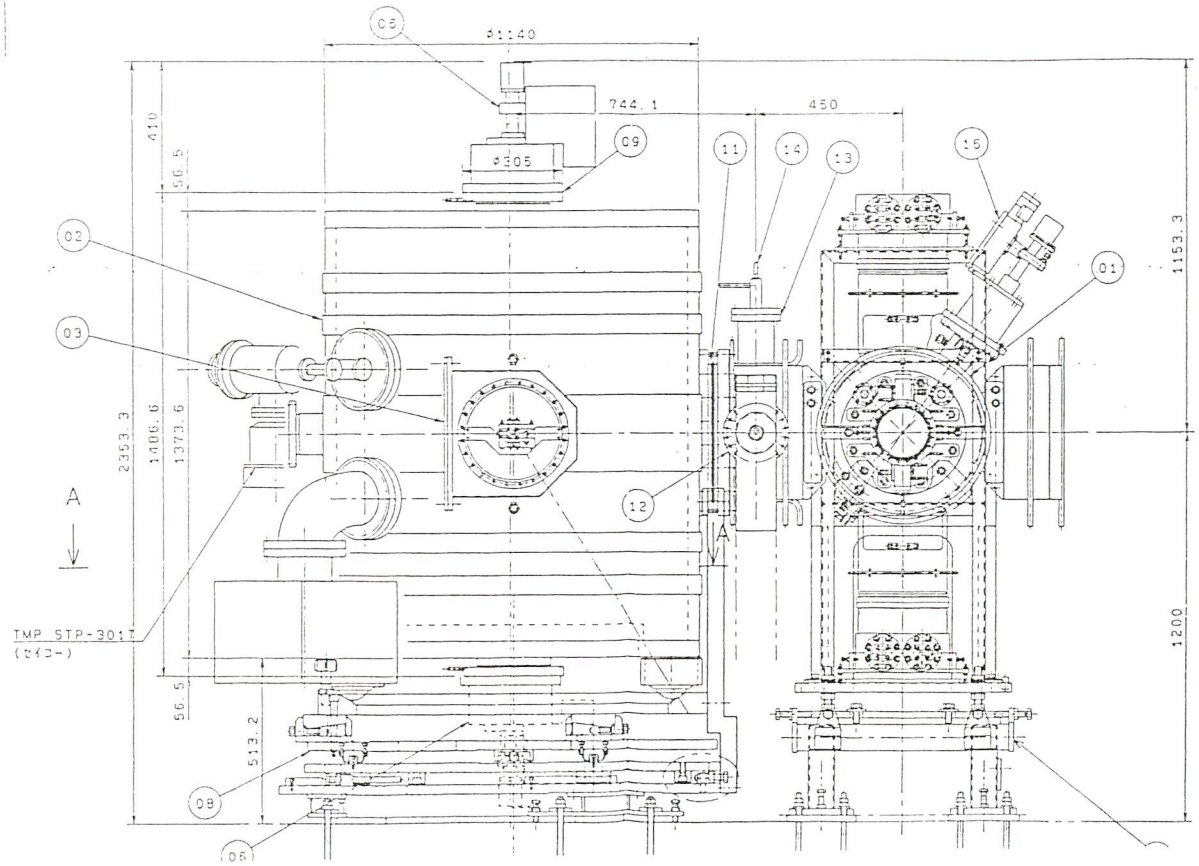
four rectangular waveguides damping monopole and dipole(V) modes,

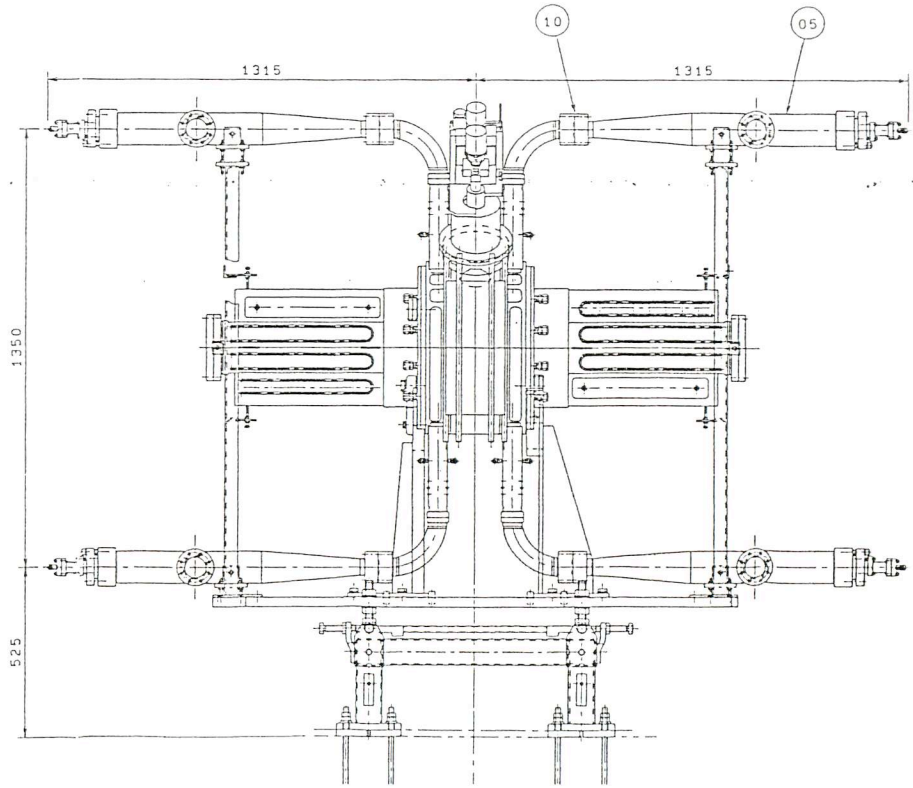
and Grooved Beam Pipes (GBP's) damping dipole(H) modes.



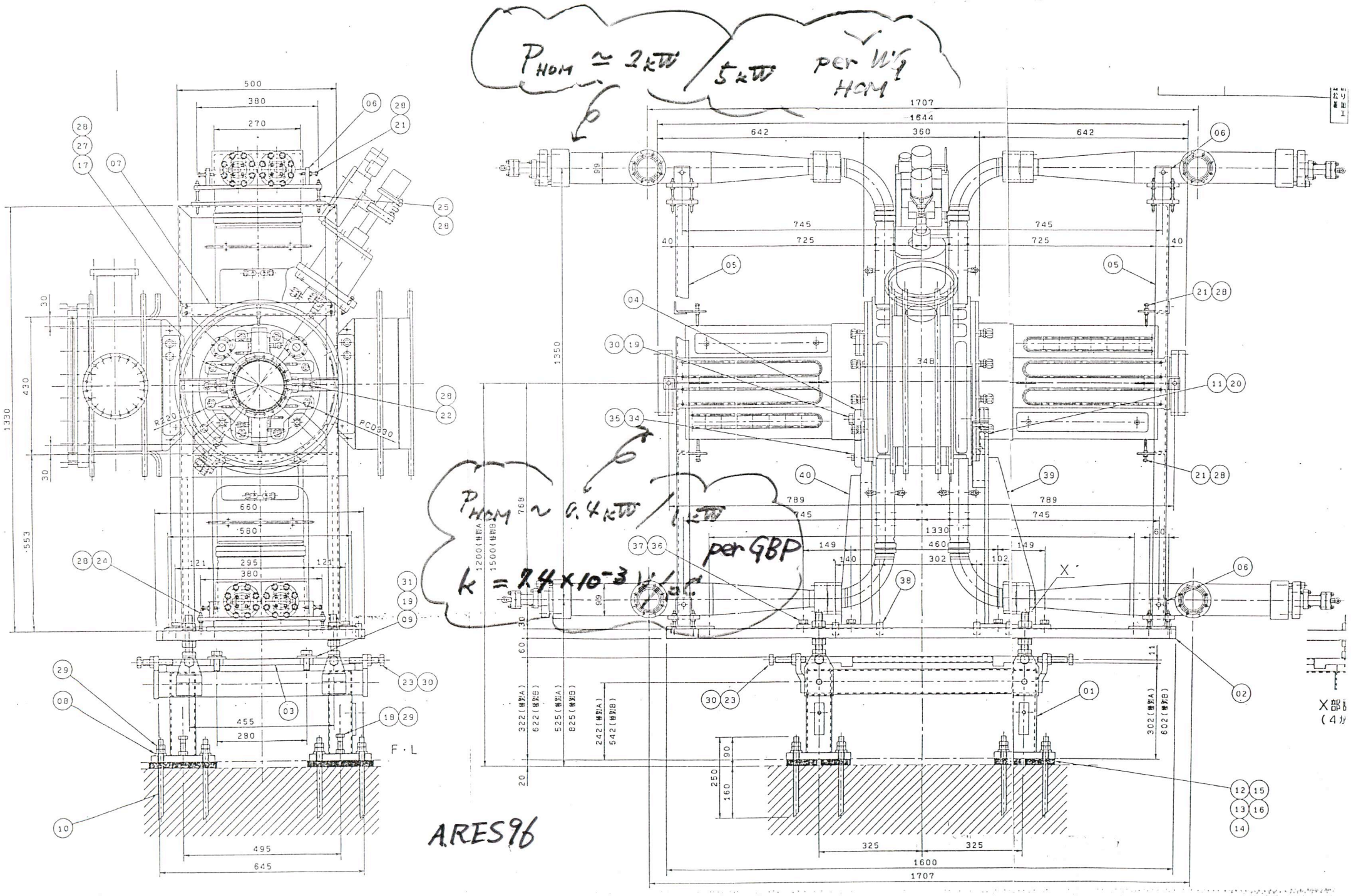
ARES 96

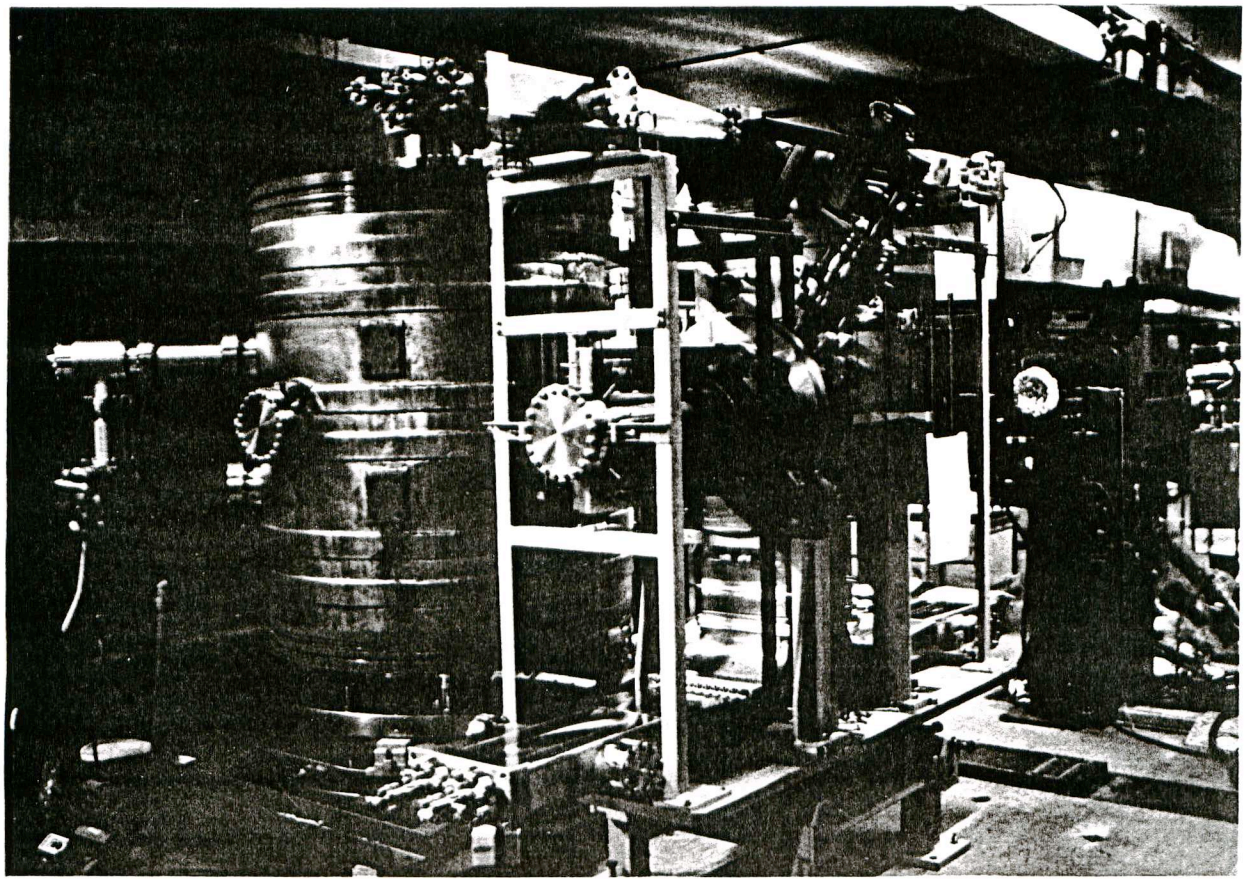
96試 ARES 空洞

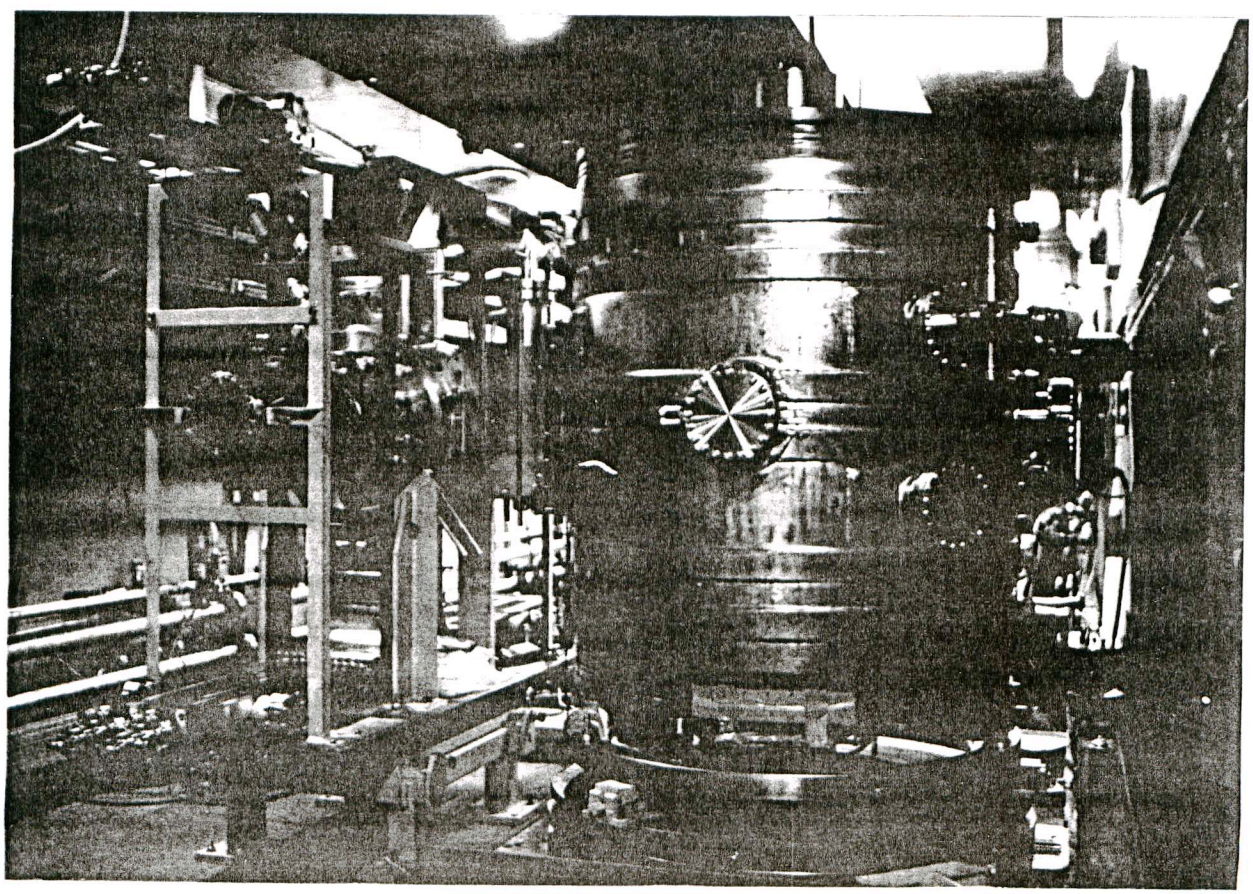

08
φ1140
744.1
450
410
56.5
φ305
09
11
14
13
15
02
03
01
1153.3
2353.3
1406.6
1373.6
A
12
A
TMP STP-301T
(ターボ)
1200
56.5
513.2
08
05


10
05
1315
1315
1350
525

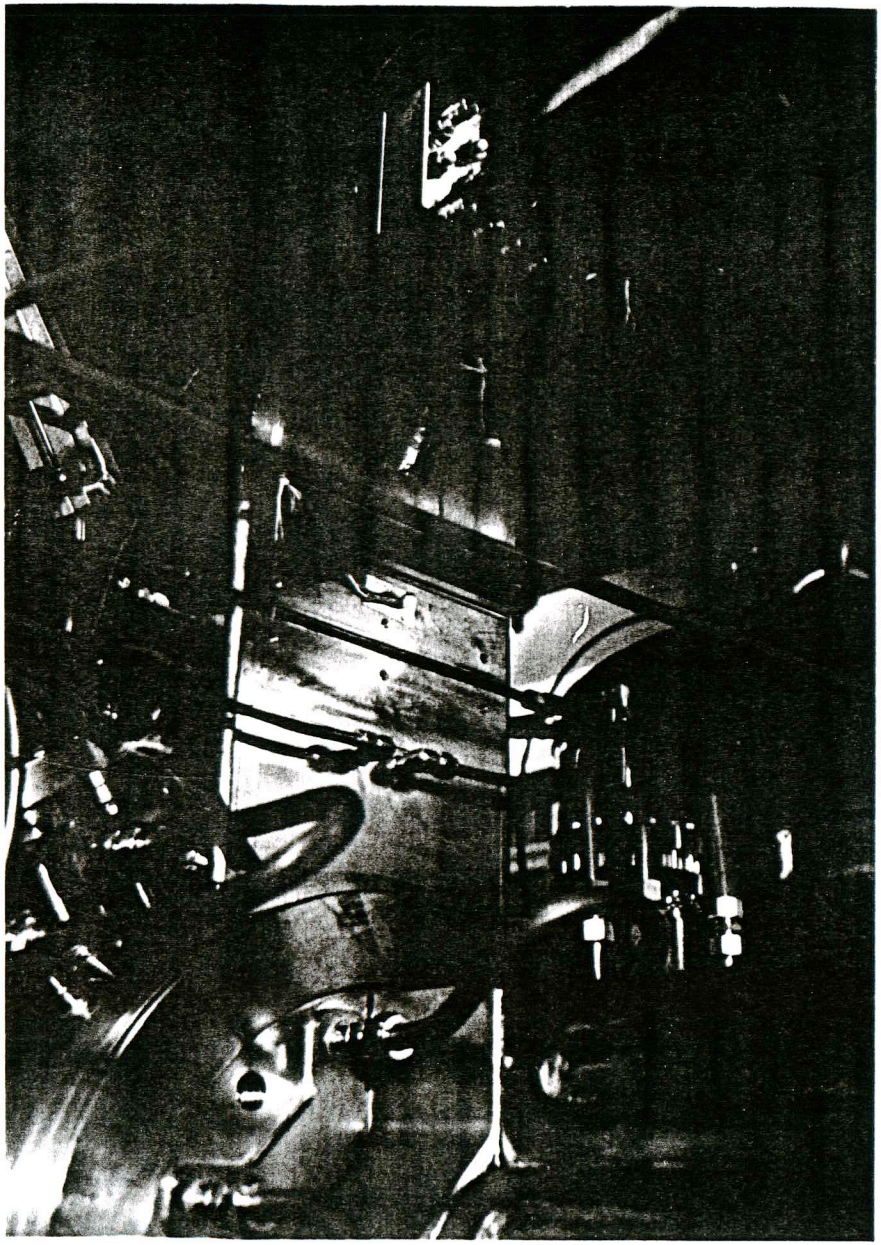
ARES 96

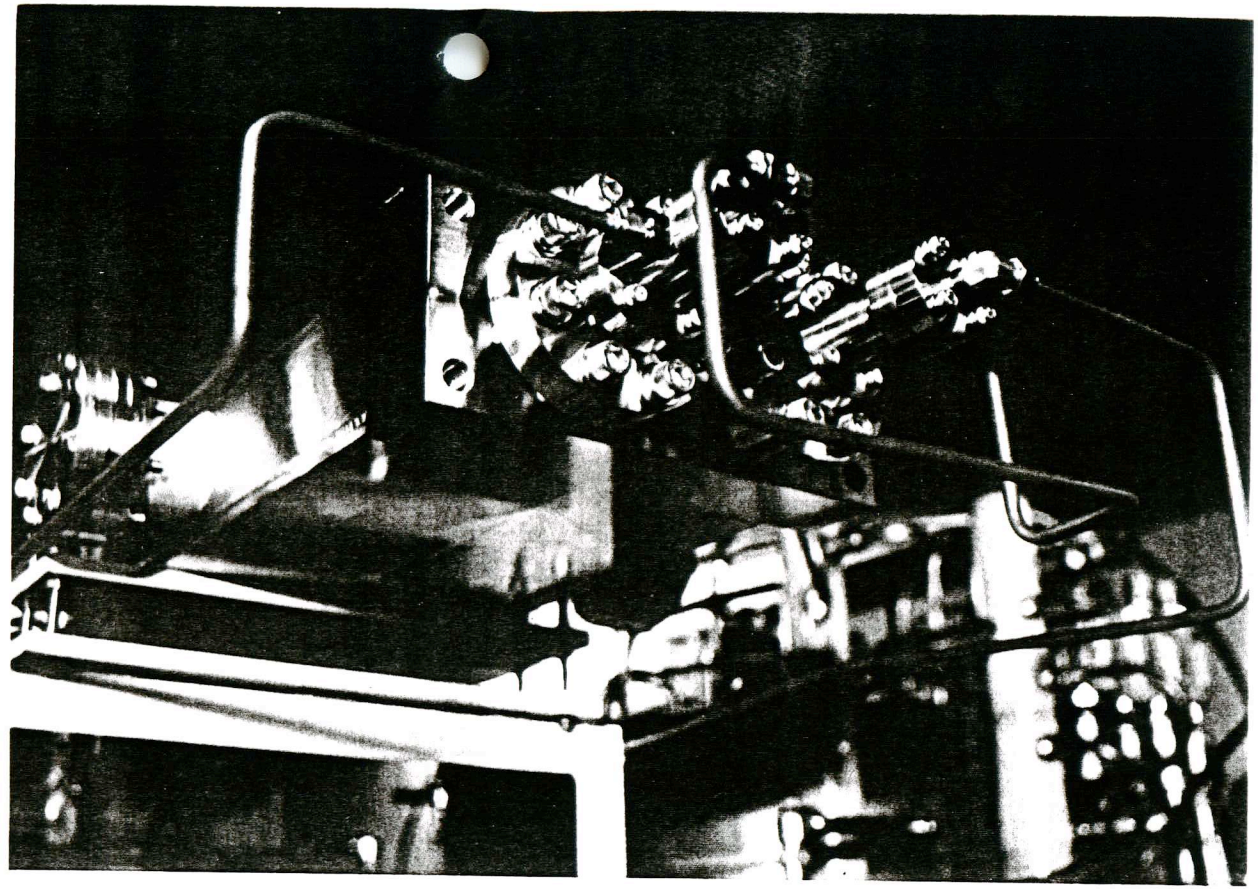

$P_{HOM} \simeq 2$ kW
5 kW per W/G HOM
$P_{HOM} \sim 0.4$ kW
per GBP
$k = 2.4 \times 10^{-3}$ V/pC
ARES96
F·L
X部詳
(4カ





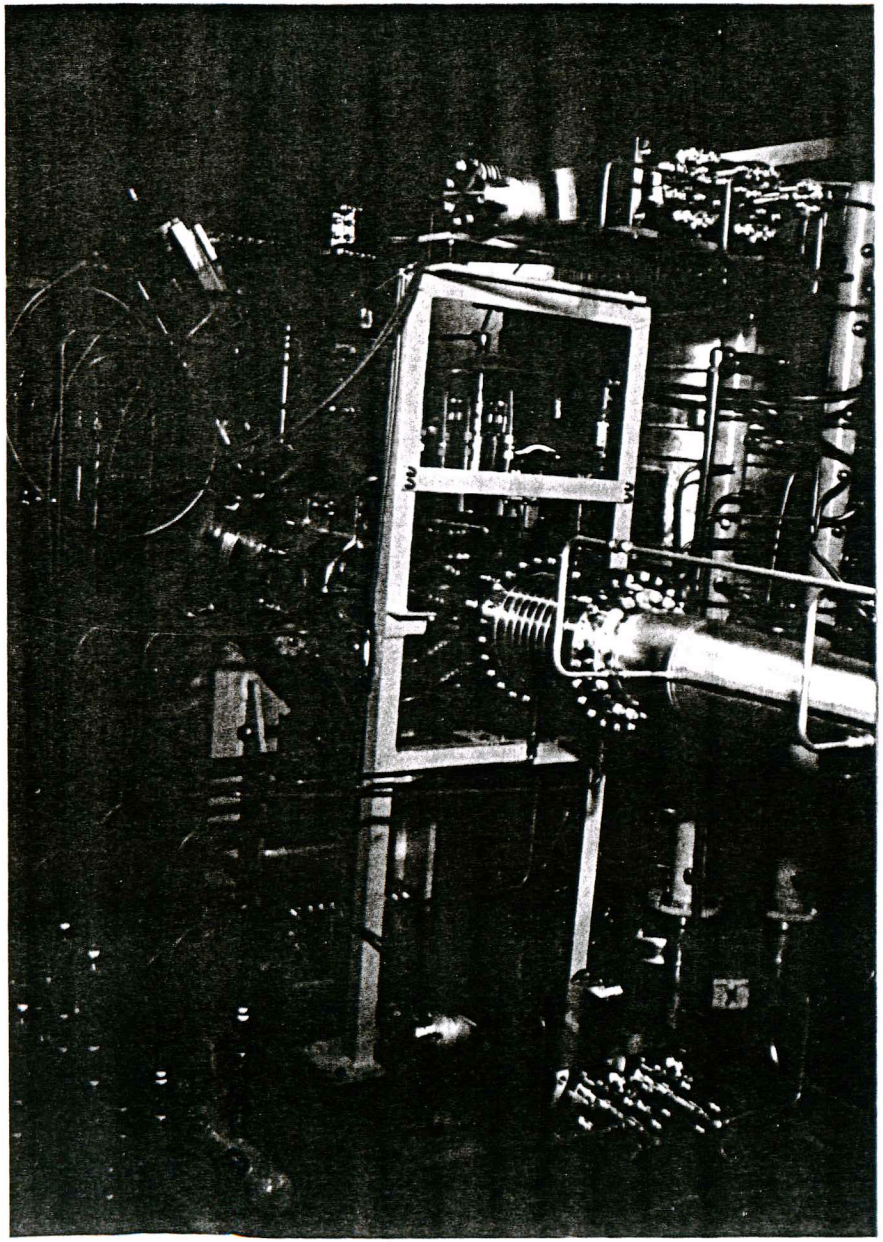
ARES 96





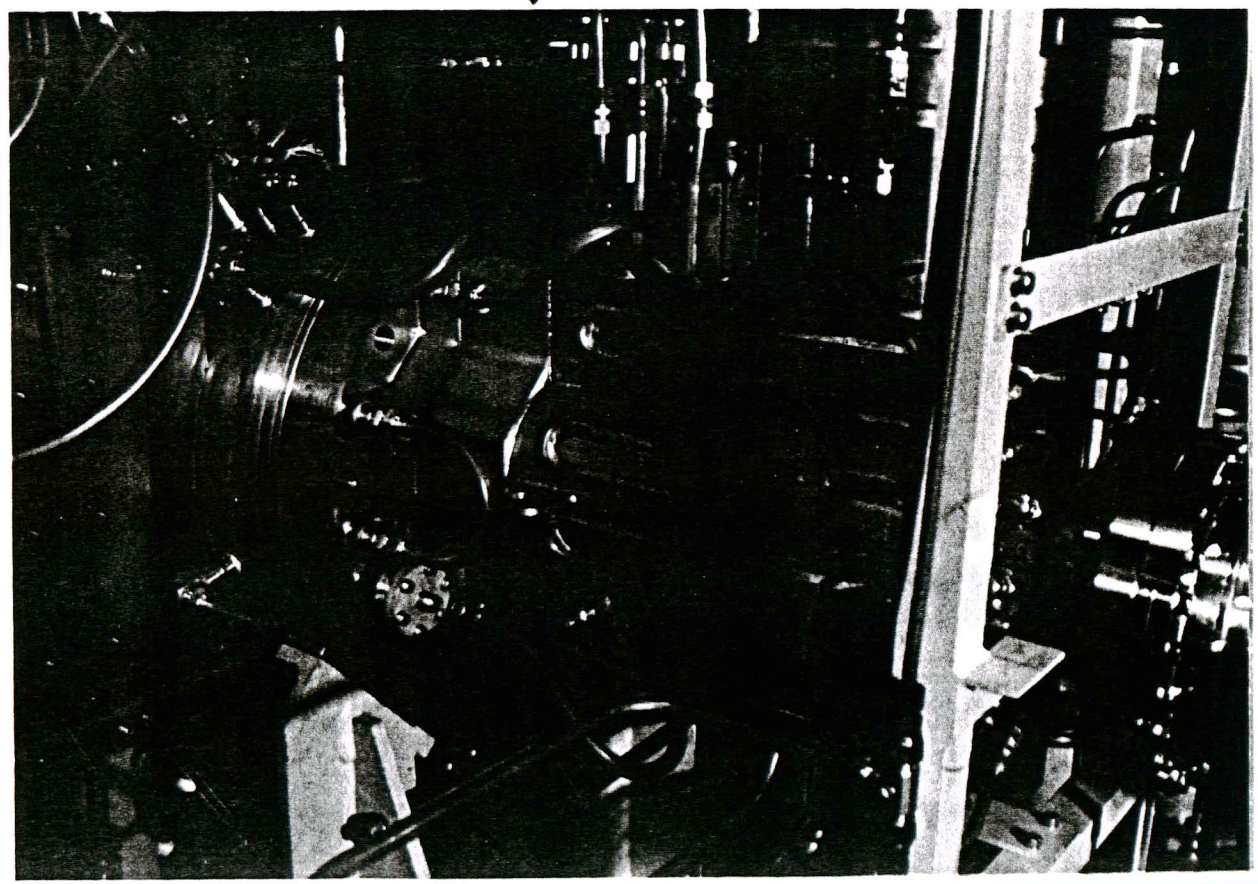
HOM WG

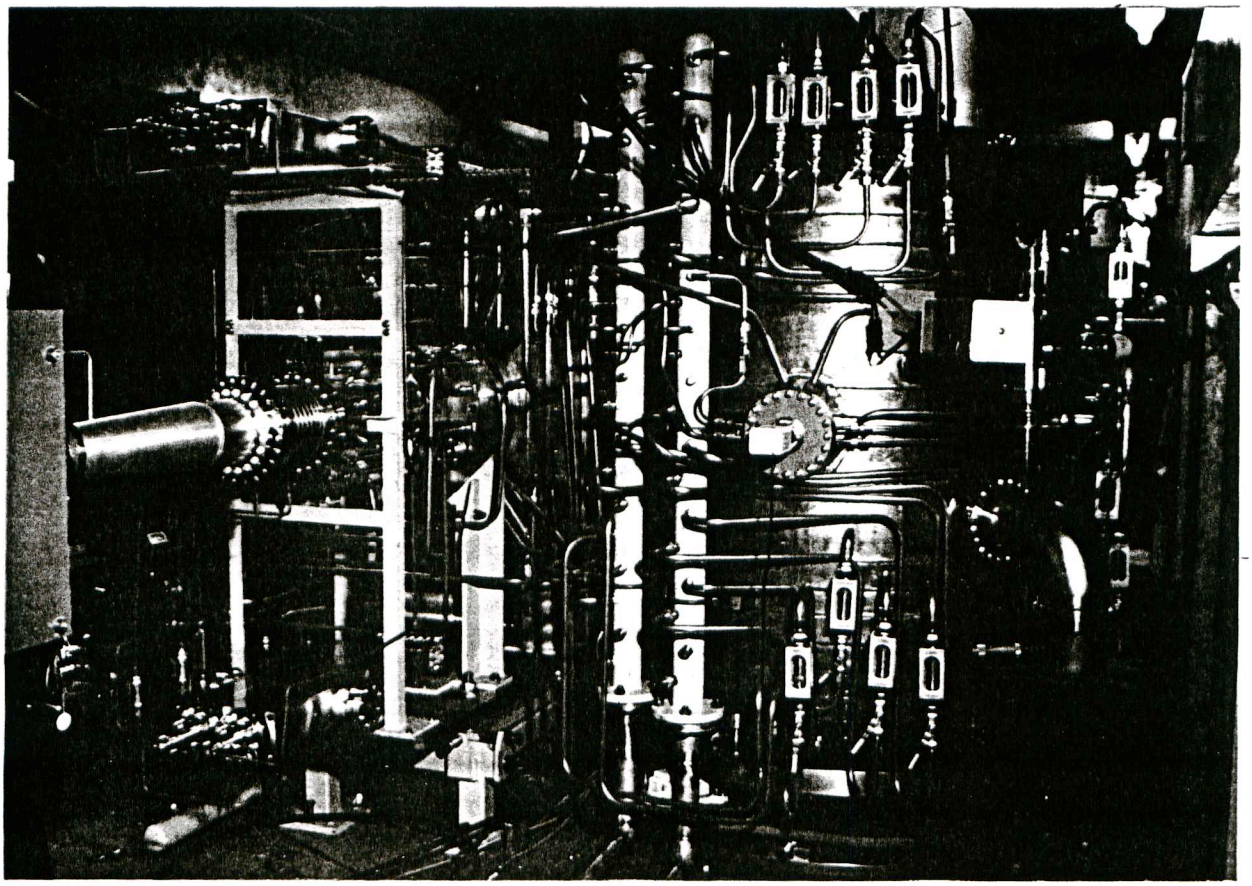
ARES96

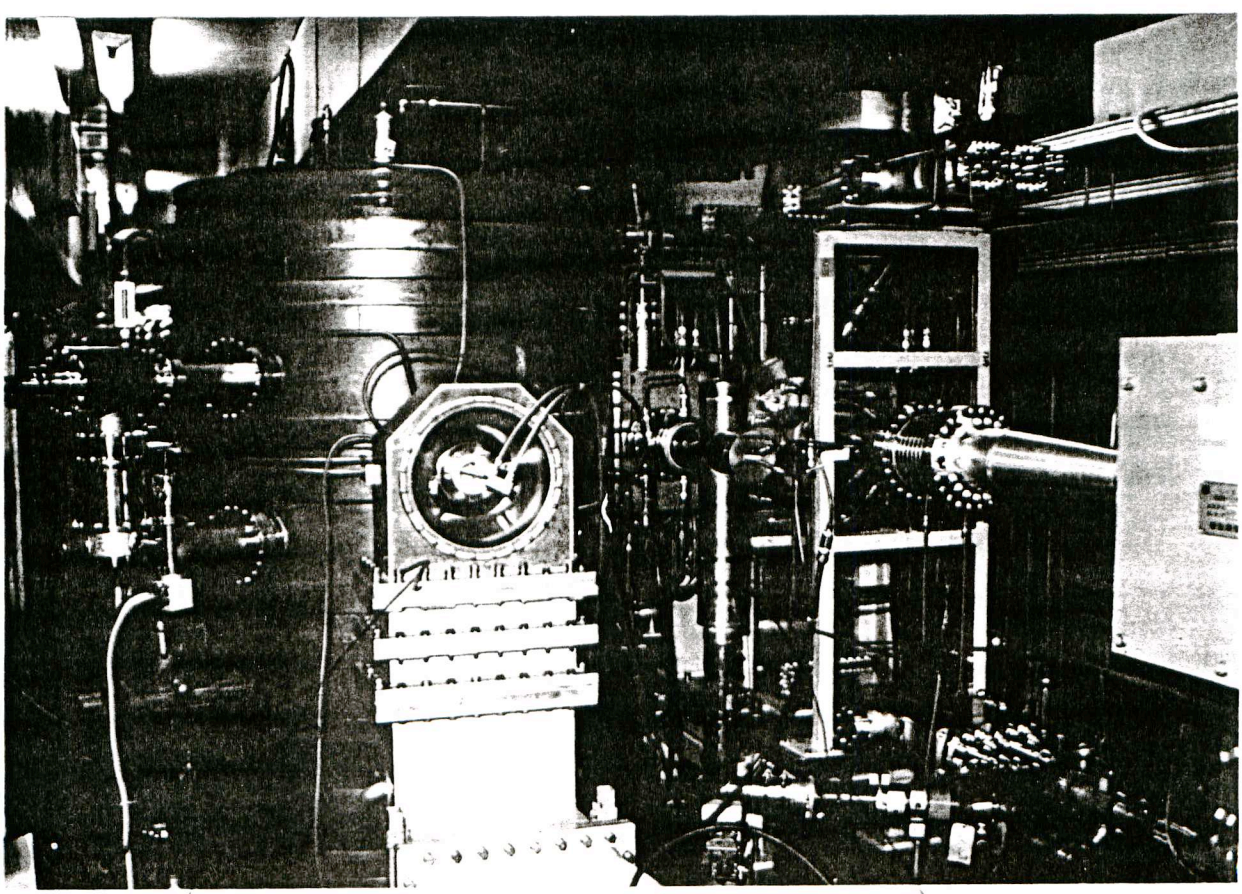


ARES96

Grooved Beam Pipe







Input coupler

Coupling Cavity Damper

ARES 96

MAFIA

FRAME: 4 09/05/96 - 13:35:02 VERSION[V321.0]

DC.DRC

H96A[D=440,O=256,IW=200,NH=8] WITH CBP

ARES 96

P--:3.20

#1DGRAPH

ORDINATE: IMPZAM
COMPONENT: -

FIXED COORDINATES:
DIM.....MESHLINE

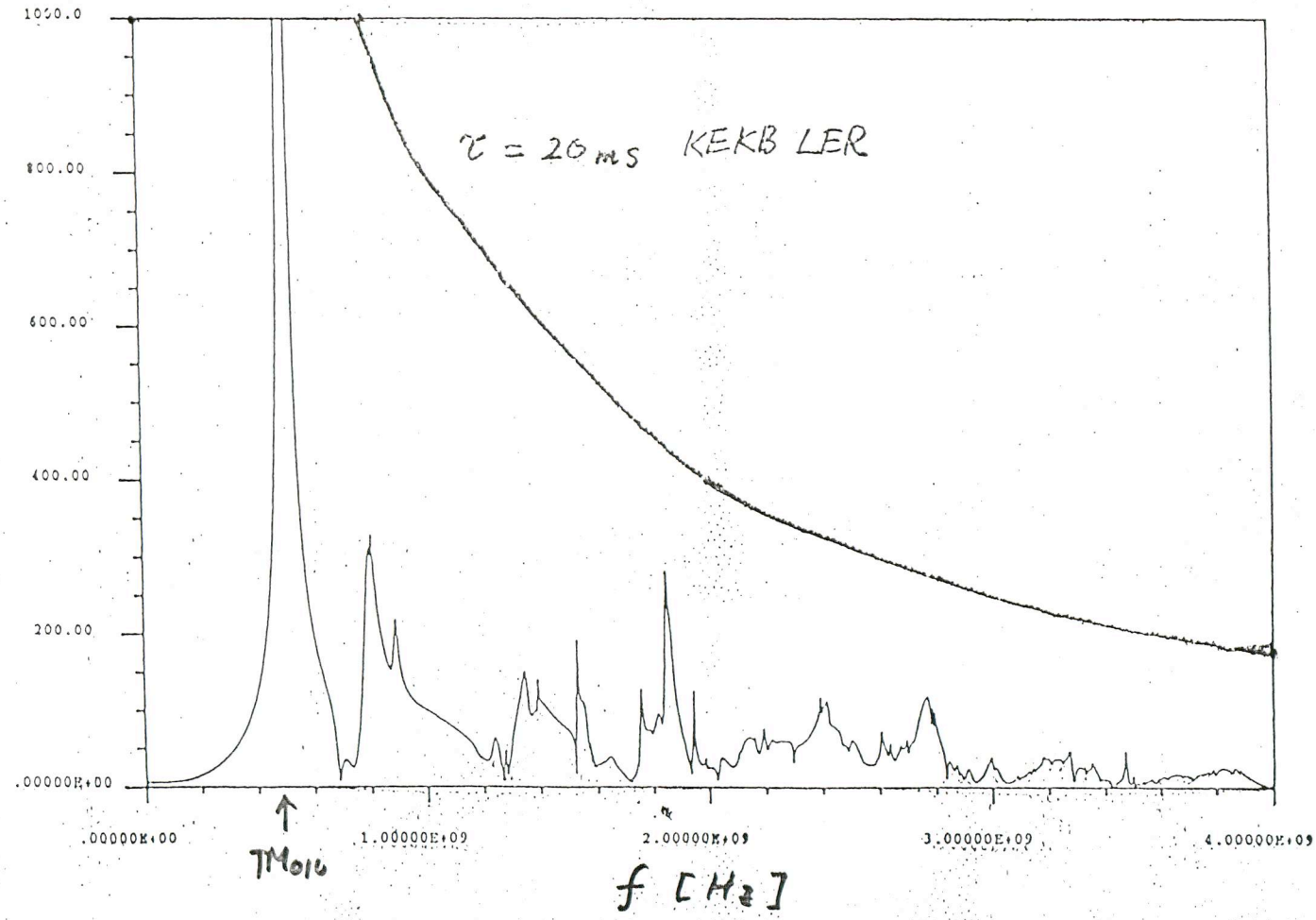
ABSCISSA: GEOMWAKE_F_14
[BASE OF IMPZAM]

REFERENCE COORDINATE: F
VARY.....MESHLINE
FROM 0
TO 16383

$\Sigma_{//}[\Omega]$ by MAFIA T3

1kΩ

96試ARES



MAFIA

FRAME: 9 15/05/96 - 13:00:37 VERSION[V321.0] DG.DRC

VERTICAL GRV ONLY

ARES 96

P--:3.20

#1DGRAPH

ORDINATE: IMPYAM
COMPONENT: -

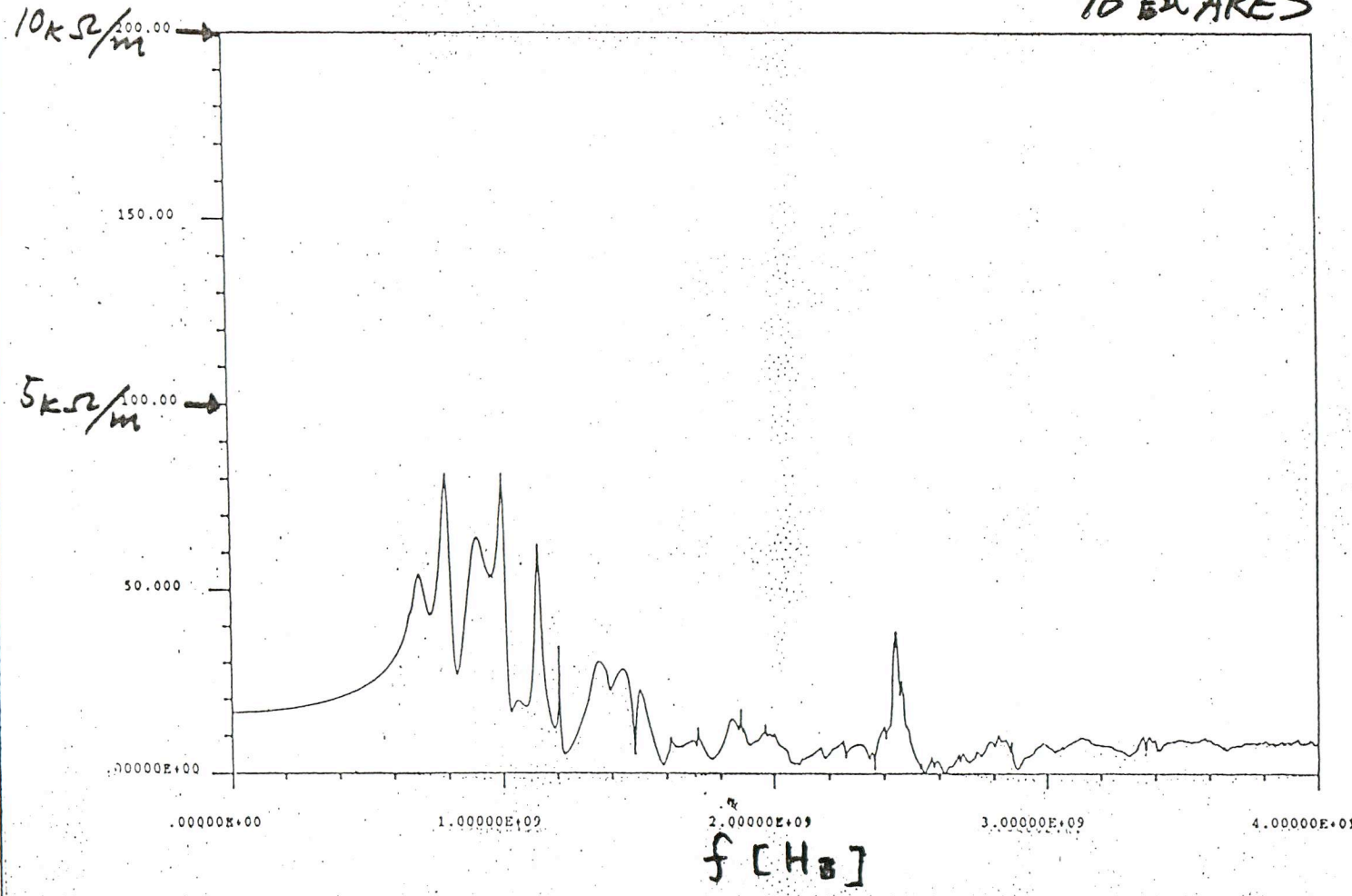
FIXED COORDINATES:
DIM.....MESHLINE

ABSCISSA: GEOMWAKE_F_14
[BASE OF IMPYAM]

REFERENCE COORDINATE: F
VARY.....MESHLINE
FROM 0
TO 16383

Z_y [Ω/m] by MAFIA T3

96試 ARES



MAFIA

FRAME: 7 16/05/96 - 18:03:25 VERSION[V321.0]

DC.DRC

PILLBOX WITH GBP 24BY90 LOADED WITH SIC

ARES 96

P--:3.20

#1DGRAPH

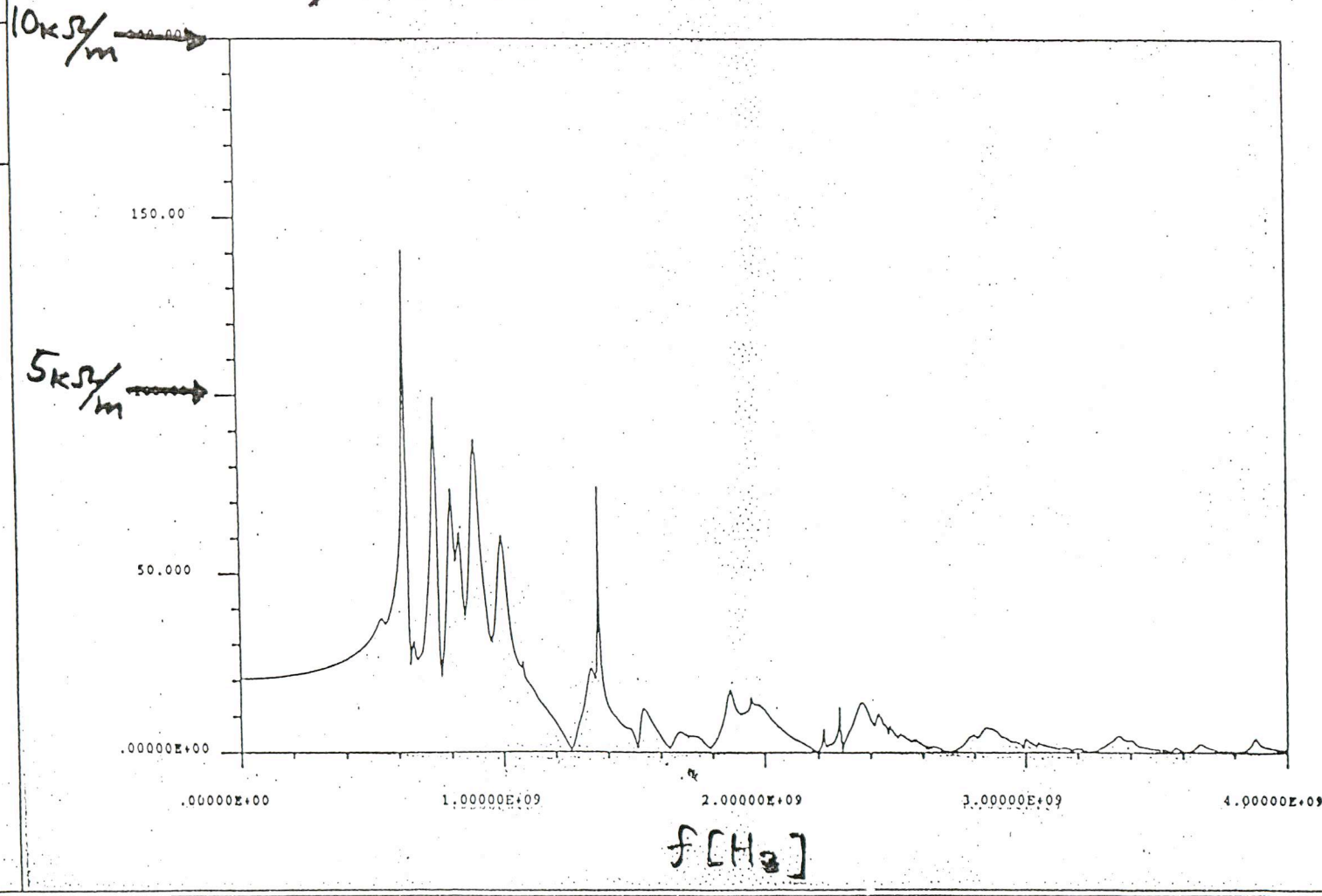
ORDINATE: IMPXAM
COMPONENT: -

FIXED COORDINATES:
DIM.....MESHLINE

ABSCISSA: GEOMWAKE_F_14
[BASE OF IMPXAM]

REFERENCE COORDINATE: F
VARY.....MESHLINE
FROM 0
TO 16383

Z_x [Ω/m] by MAFIA T3



High-power tests and experiments under high-current beam environment were carried out for ARES95 and ARES96:

- High-power test of ARES95 — Jul. 1996
  $P_c \leq$ 160kW (240kW) CW — $V_c \leq$ 0.5MV (0.6MV)

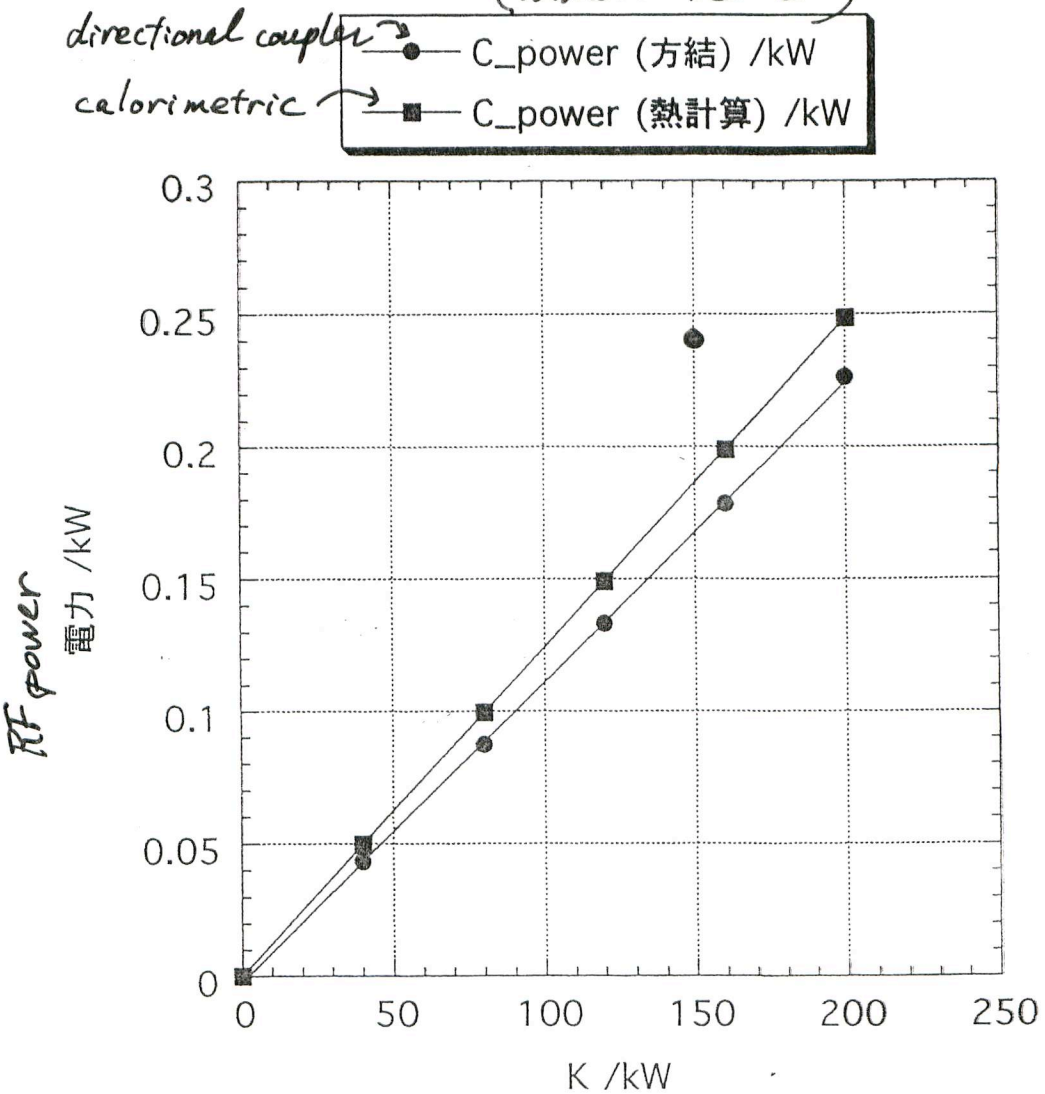
- High-power test of ARES96 — Oct. 1996
  $P_c \leq$ 240kW CW — $V_c \leq$ 0.6MV

- Beam experiments
  for both prototypes in TRISTAN AR — Oct. 17 ~Dec. 2, 1996

  V_c = 0.4~0.5 MV, $P_b \leq$ 80kW

Single bunch	≤100mA
Four bunches	≤200mA
Four four-bunch trains	≤500mA (570mA)

Output power from the coupling cavity damper
(without beam)



理論値 240 W ← (K出力 = 150 kW のとき)

calculation based on coupled-resonator model

($Q_c \simeq 55$
$f_\pi - f_0 = 6.6\ MHz$)

Beam experiments

studying the fundamental characteristics of ARES cavity under beam environment

observing HOM spectra excited by a single-bunch beam (100mA)

HOM survey by changing the tuner position of the accelerating cavity

calorimetric measurement of RF power absorbed by each HOM load

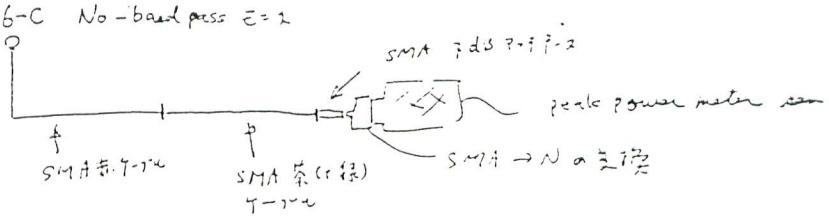
ARES 96

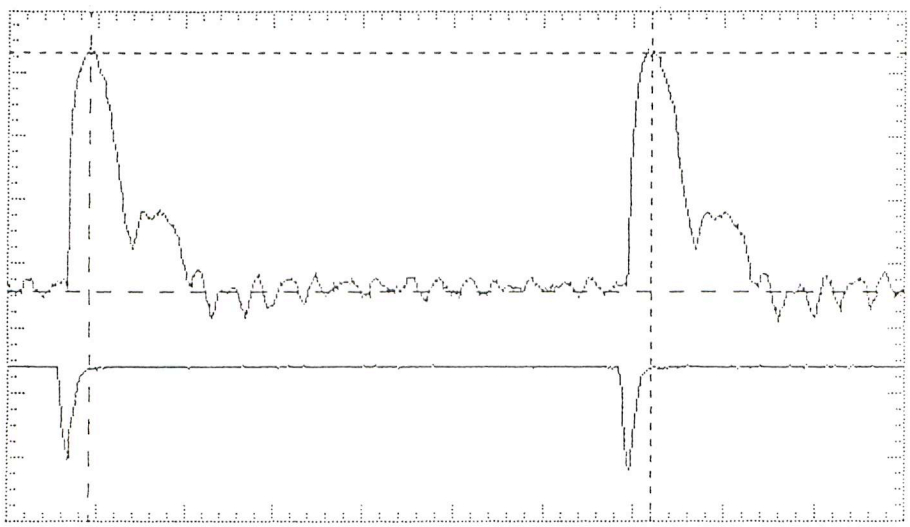
100mA Single bunch

100mA (1) 13:05 11/2

C-cavity output

hp awaiting trigger



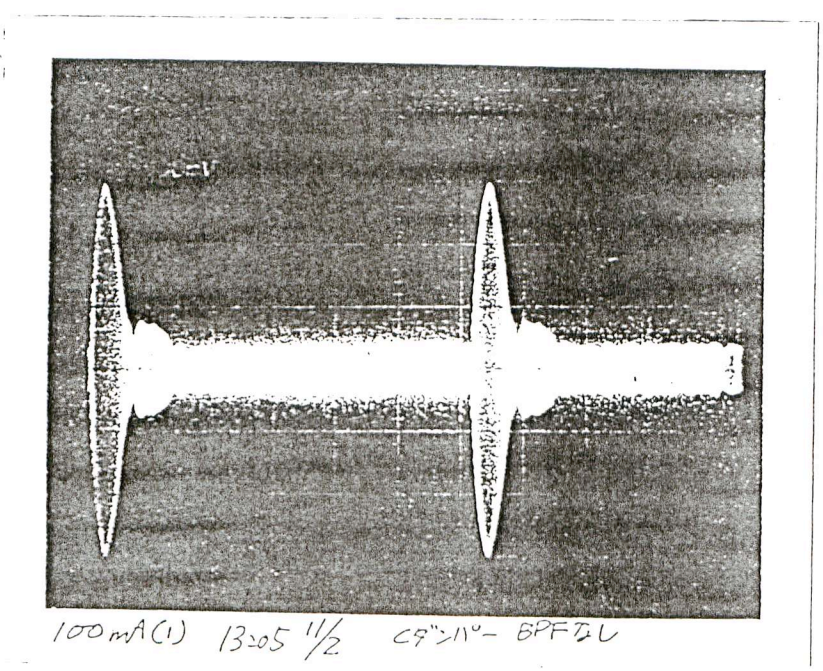


1 ref: 10.00 dBm
5.0 dB/div
ext loss: 0.00dB
BW: HIGH
2 500 mV/div
offs: 750.0 mV
1.000 : 1 dc

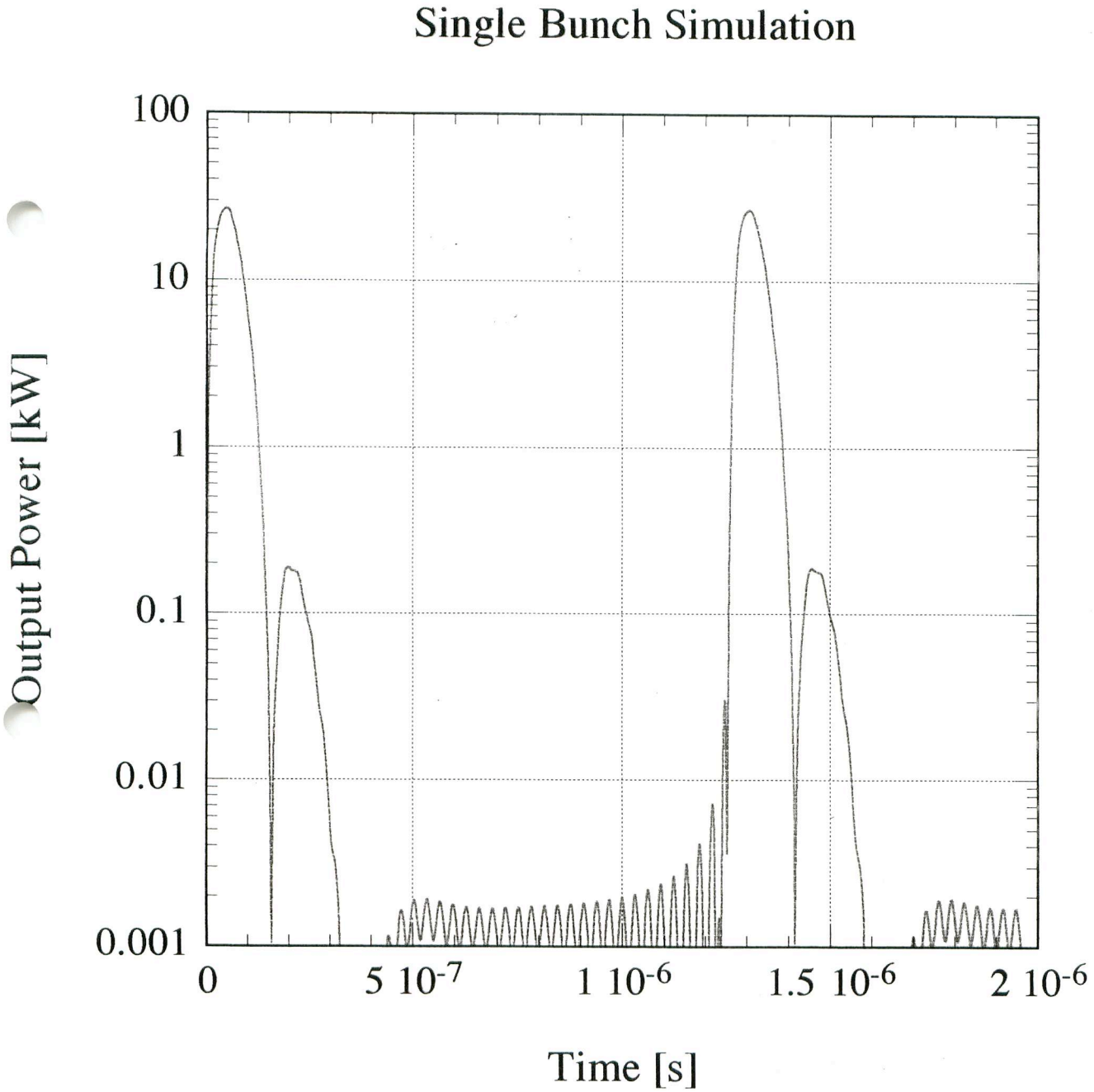
-120.000 ns 880.000 ns 1.88000 us
200 ns/div

marker2(1)	6.562 dBm	stop marker:	1.32000us
marker1(1)	-12.187 dBm	start marker:	64.000 ns
ampl ratio	18.750 dB	delta t:	1.25600us
		1/delta t:	796.178kHz

2 ⏚ -125 mV



100mA(1) 13:05 11/2 ｷｬﾋﾞﾃｨ- BPFなし


Single Bunch Simulation
100
10
1
0.1
0.01
0.001
Output Power [kW]
0
5 10-7
1 10-6
1.5 10-6
2 10-6
Time [s]

ARES 96

110 20 mA 80 (66 mA). 64 bunch

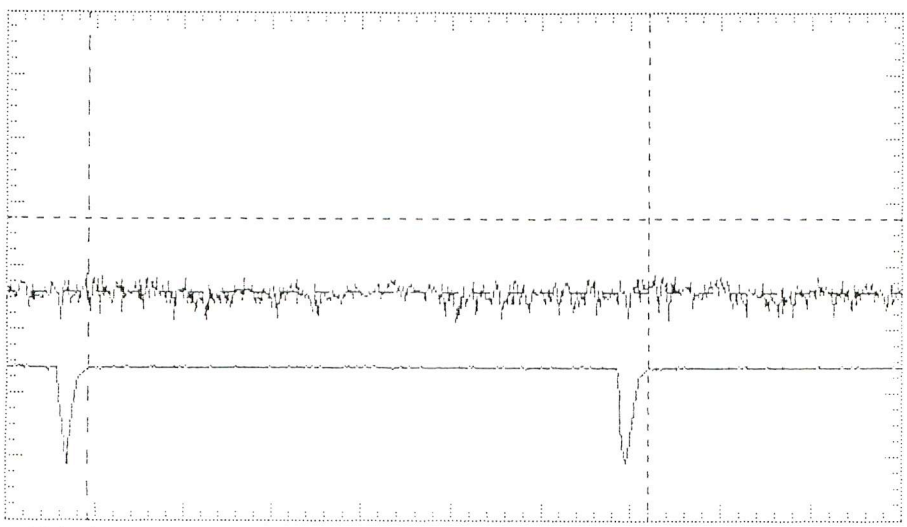
15:53

15:53

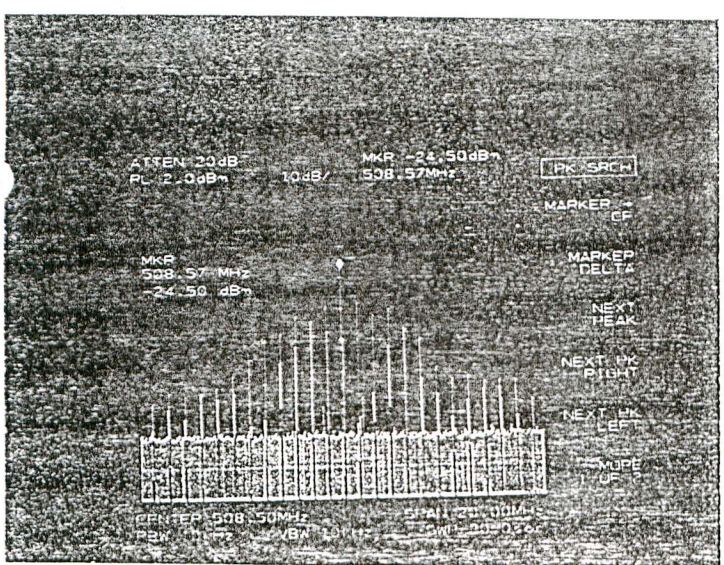
110 mA

C-cavity output

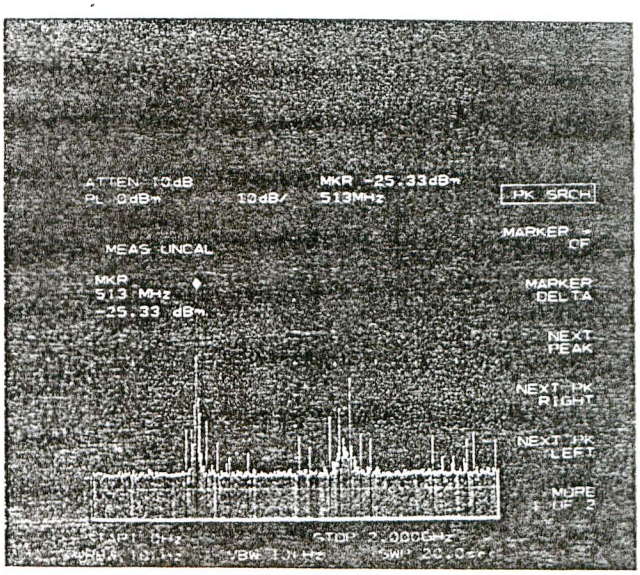
RF running



2 -125 mV



96年



1.07 mA.

↑ ?

西×射時の写真かと？

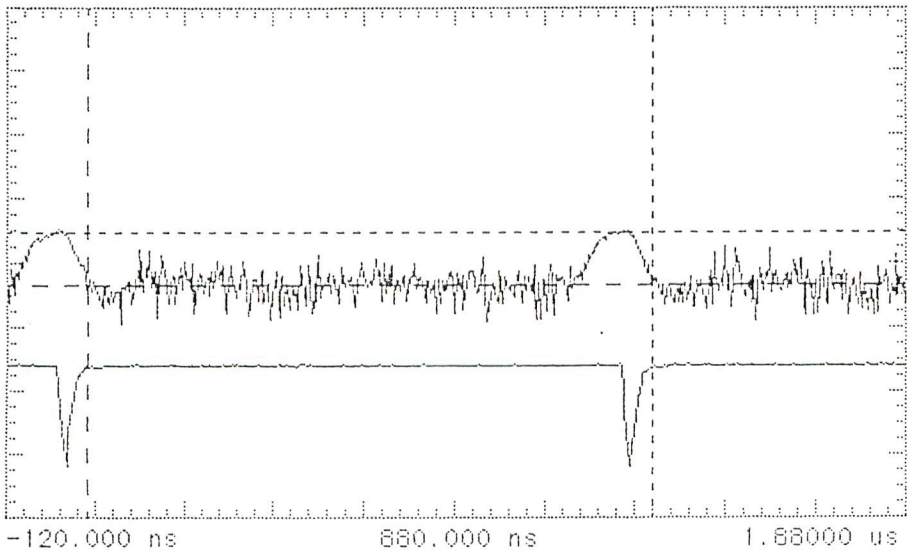
ARES 96

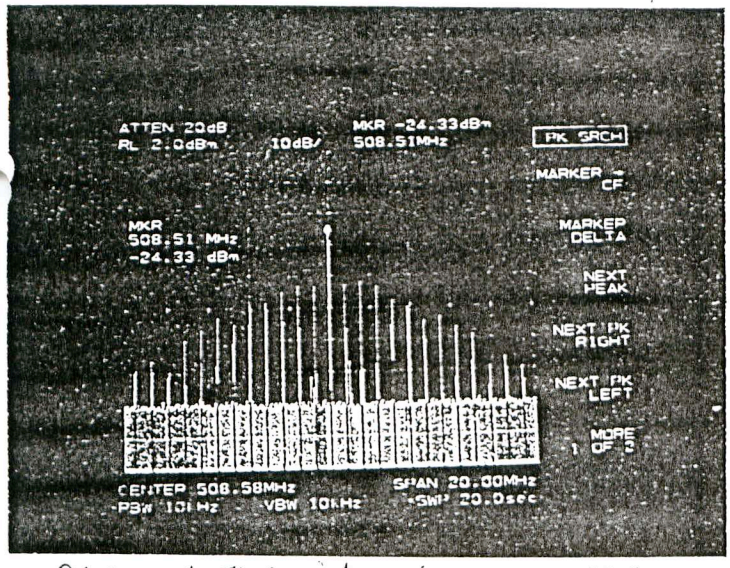
168.3 mA (59/64) 16:49 11/2

96 C.

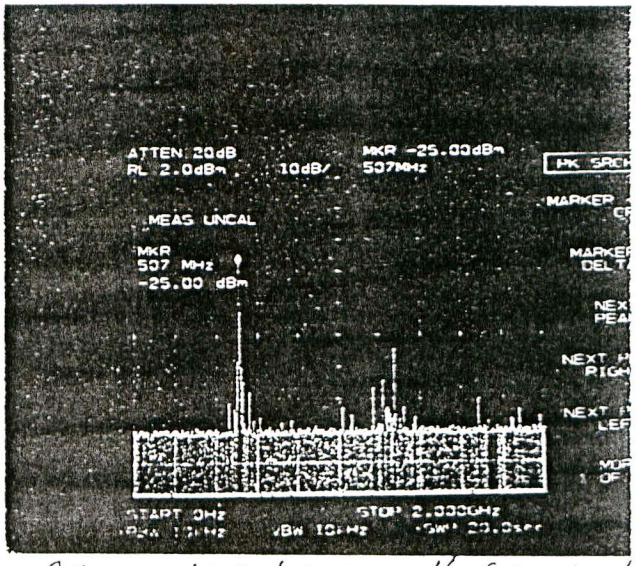
C-cavity output

hp running





96C 107.6 mA 16:53 11/2



96C 153.1 mA 16:52 11/

Beam : **Single Bunch 100mA**

ARES96 tuner scan

A-Cavity 400kHz/V

S-**3.0V**
A-**2.4** ~**5.4V** (0.2V step)

S-**5.4V**
A-**2.4** ~**3.8V** (0.4V step)

beam offset (H 5mm)
S-3.0
A-2.4 ~5.6 (0.4V step)

ARES95 tuner scan

A-Cavity 350kHz/V

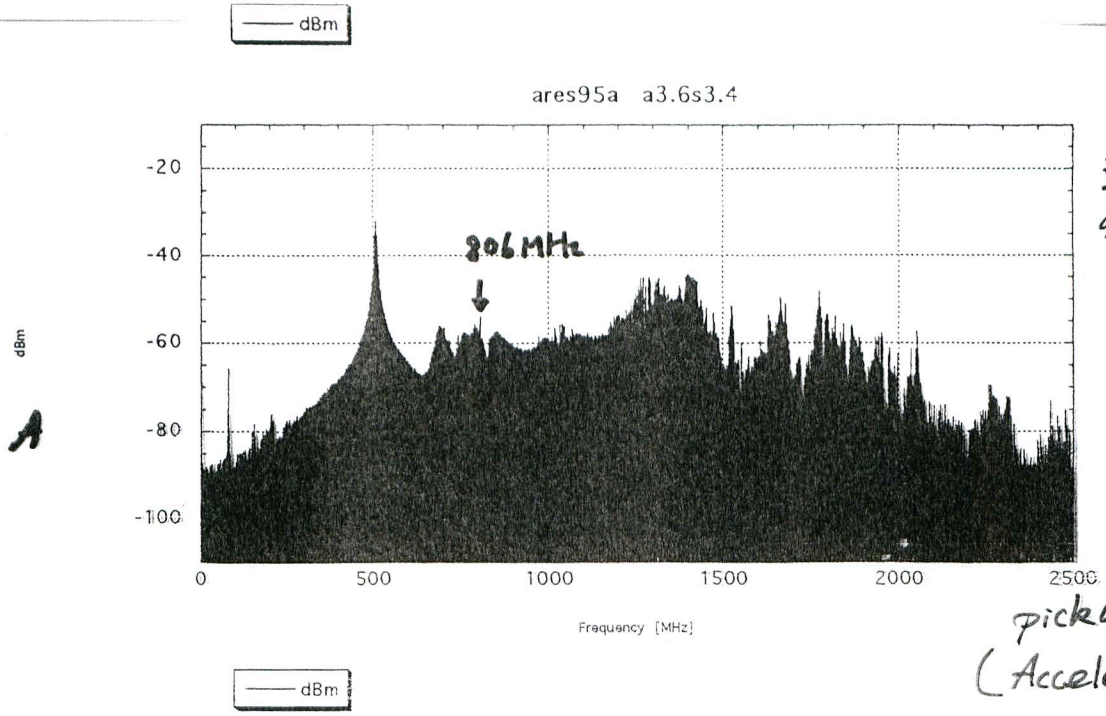
S-**3.4V**
A-**3.6** ~**6.8V** (0.2V step)

S-**6.4V**
A-**3.6** ~**4.8V** (0.4V step)

beam offset (H 5mm)
S-3.4V
A-3.6 ~6.8V (0.4V step)

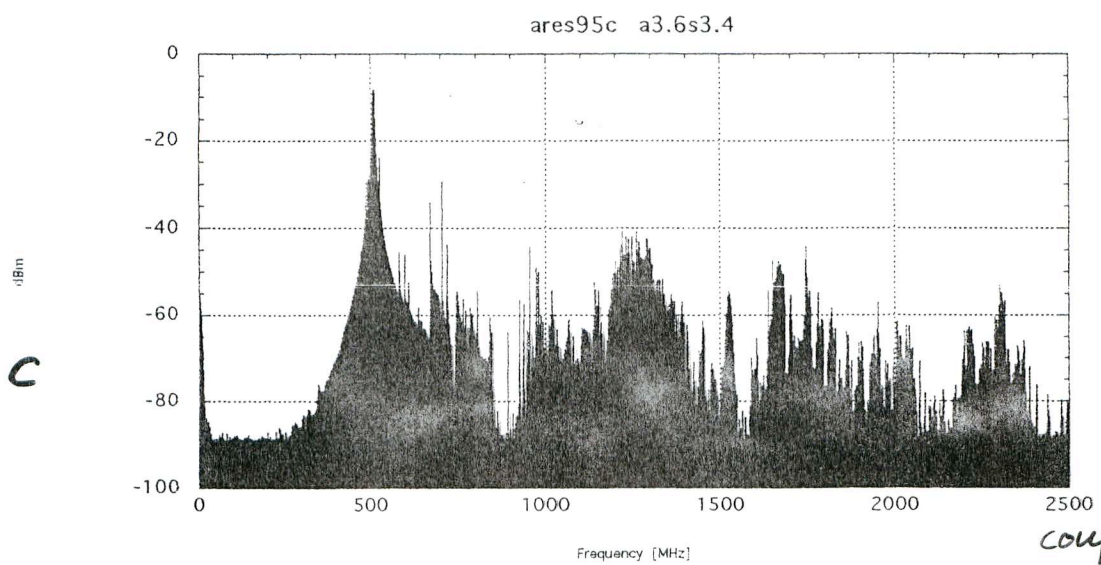
ARES95

単バンチ 100mA
Single bunch
100mA



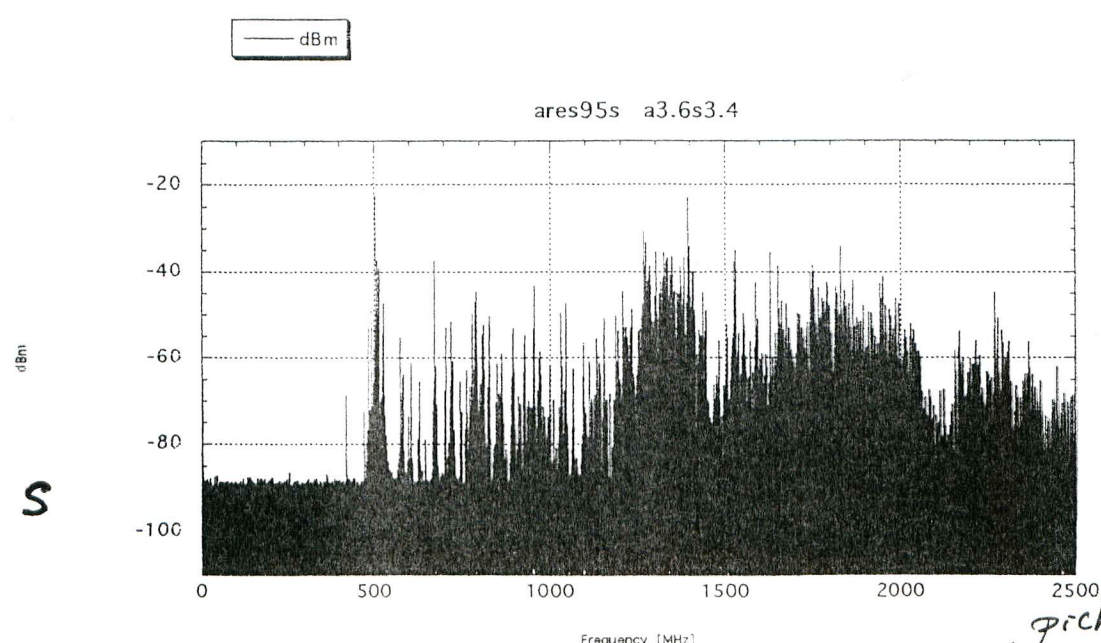
A

pickup
(Accelerating Cavity)



C

coupling cavity
damper



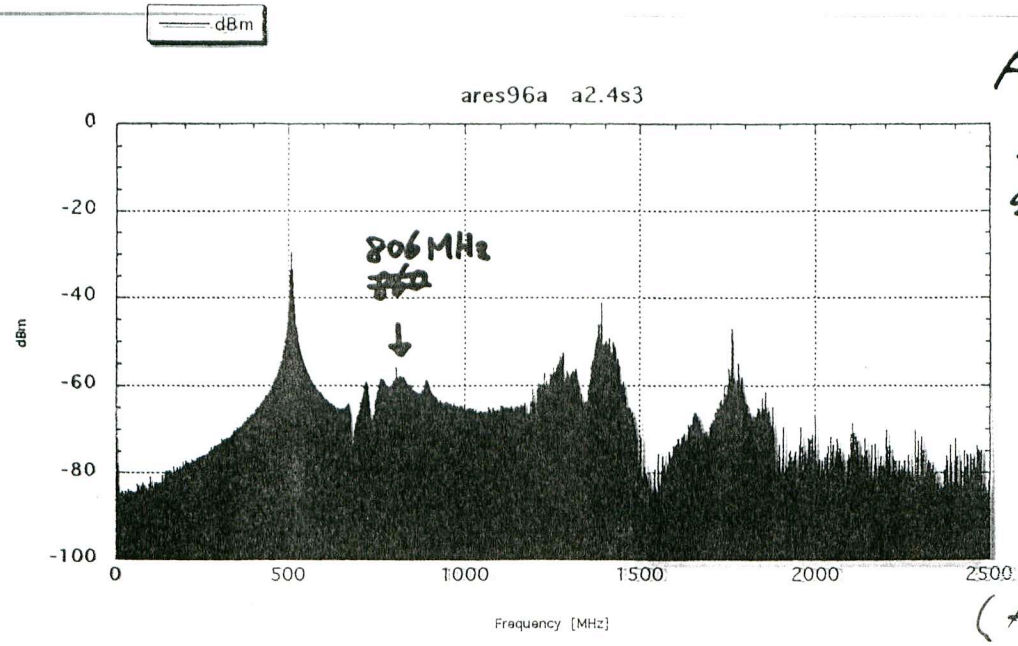
S

pickup
(Storage Cavity)

HOM spectra for ARES95

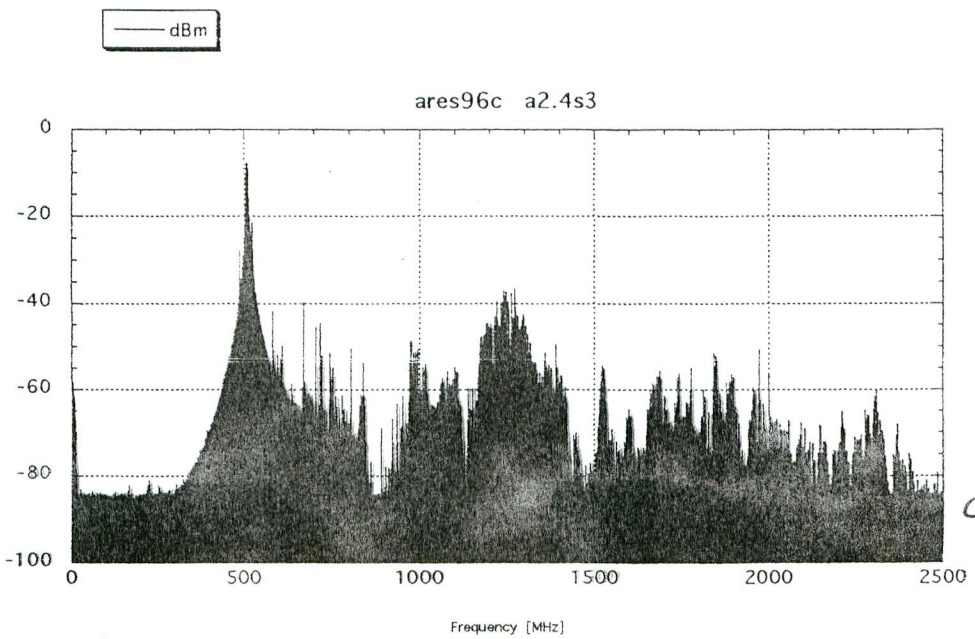
ARES 96

単バンチ 100mA
single bunch 100mA



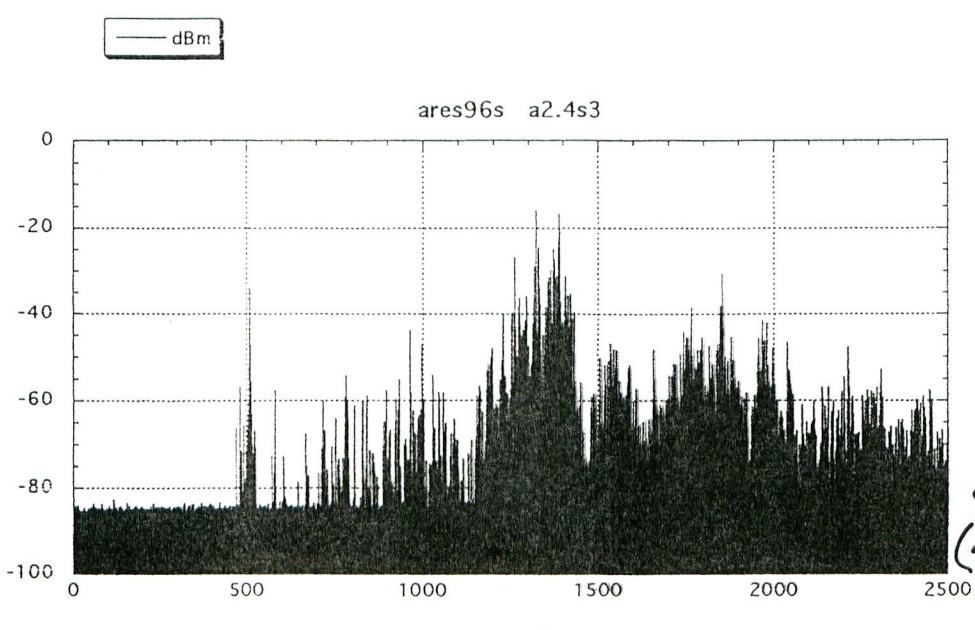
A

pickup
(Accelerating Cavity)



C

coupling cavity damper



S

pickup
(Storage Cavity)

HOM spectra for ARES 96

Maximum HOM Power Deposited on ARES's

17 Nov. 500 mA, 4x4 bunch

'96 ARES

	ΔT[deg]	w [l/s]	P [kW]
SiC duct (Cu)	>5.0	3.5	1.2
C-cav damper	-	7.0	(3.2)
WG damper	1.0	3.0	0.2

Total Deposited Power = 1.2 x 2 + (3.2) + 0.2 x 4 = 3.2 + (3.2) [kW]

'95 ARES

	ΔT[deg]	w [l/s]	P [kW]
SiC duct (Al)	4.5	2.8	0.9
SiC duct (Cu)	4.5	3.5	1.1
C-cav damper	3.0	15.0	3.2
4 SiC bullets	1.4	3.5	0.34

Total Deposited Power = 0.9 + 1.1 + 3.2 + 0.34 x 4 = 6.6 [kW]

Loss Parameter from '95 ARES

k = 0.33 [V/pC]

(c.f. k = 0.22 [V/pC] for ARES-A from Jul. '96 study)

HOM absorbers

- Bullet-shape sintered SiC ceramic absorbers

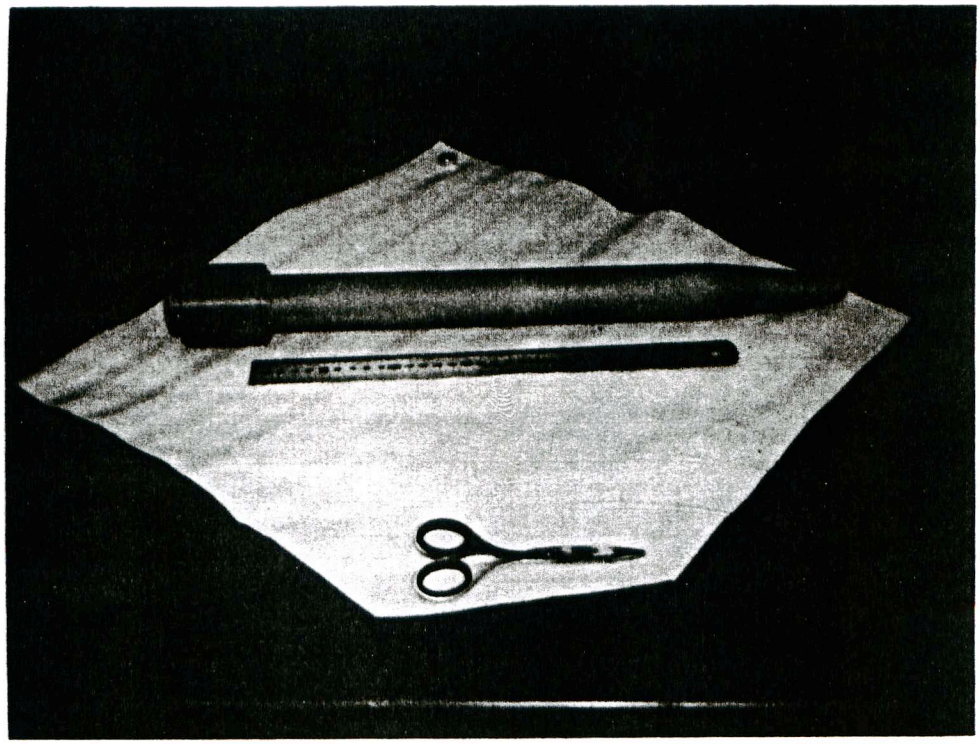
Sixteen absorbers (ϕ 40mm x 400mm) for the coaxial-waveguide HOM load of ARES95
Two absobers (ϕ 55mm x 400mm) per rectangular waveguide for ARES96

Power capability tested up to 2.5kW(CW) per absorber

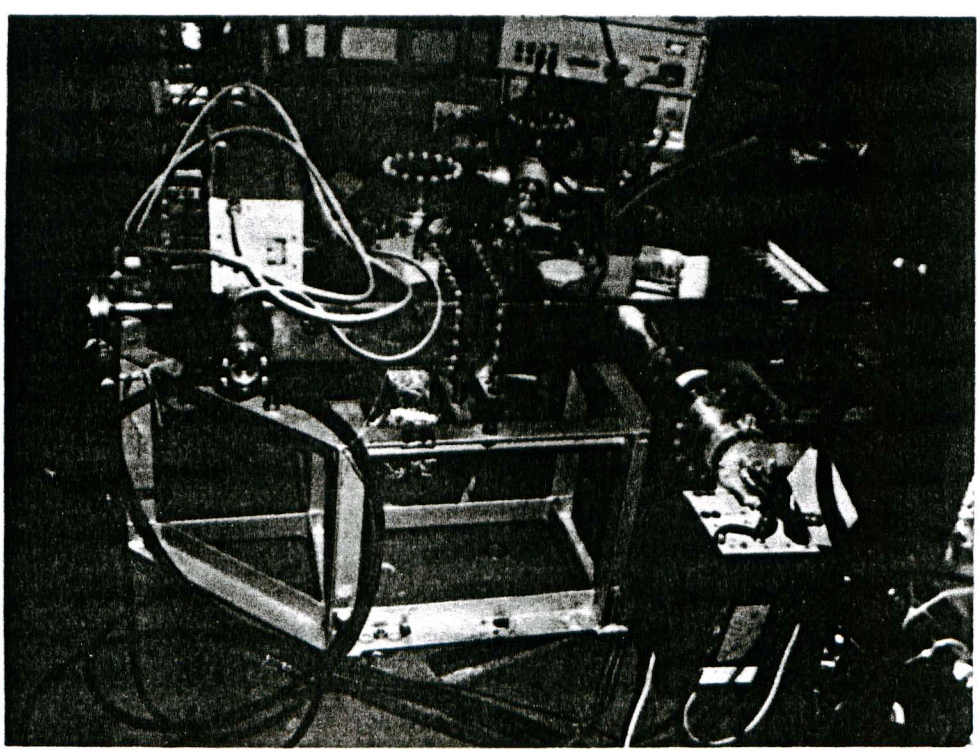
- SiC tiles for GBP HOM load of ARES96

Eight tiles (48x48x20mm^3) per groove

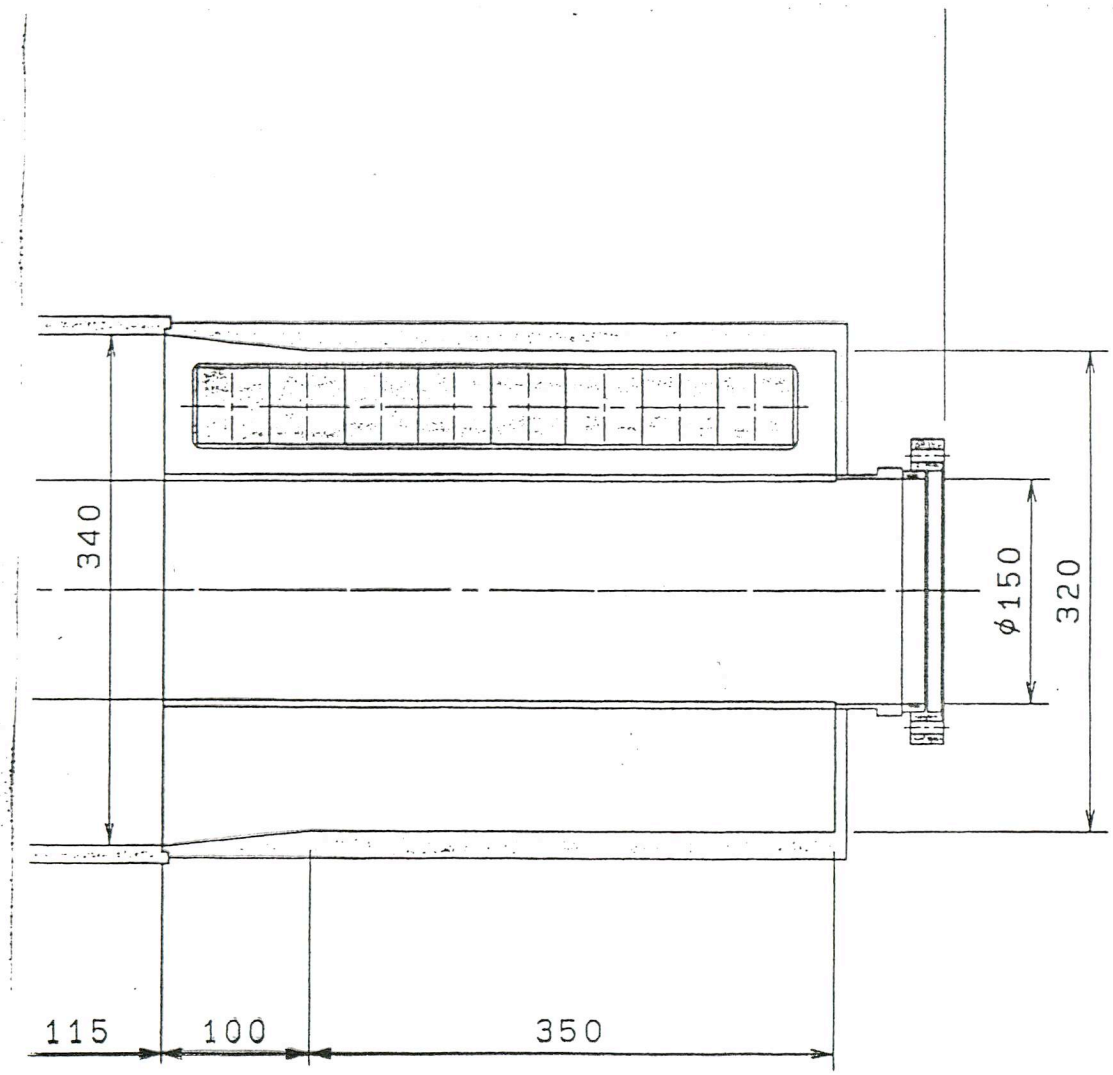
Power capability tested up to 0.5kW(CW) per groove

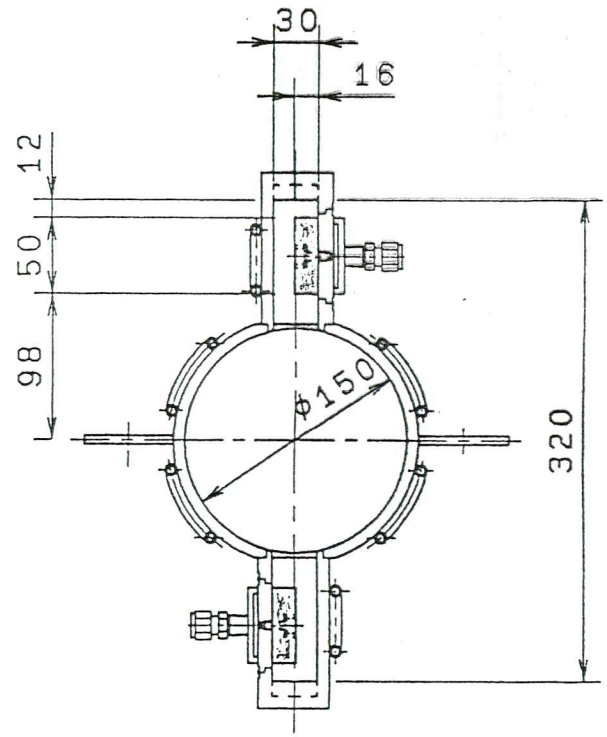


Bullet shape SiC absorber



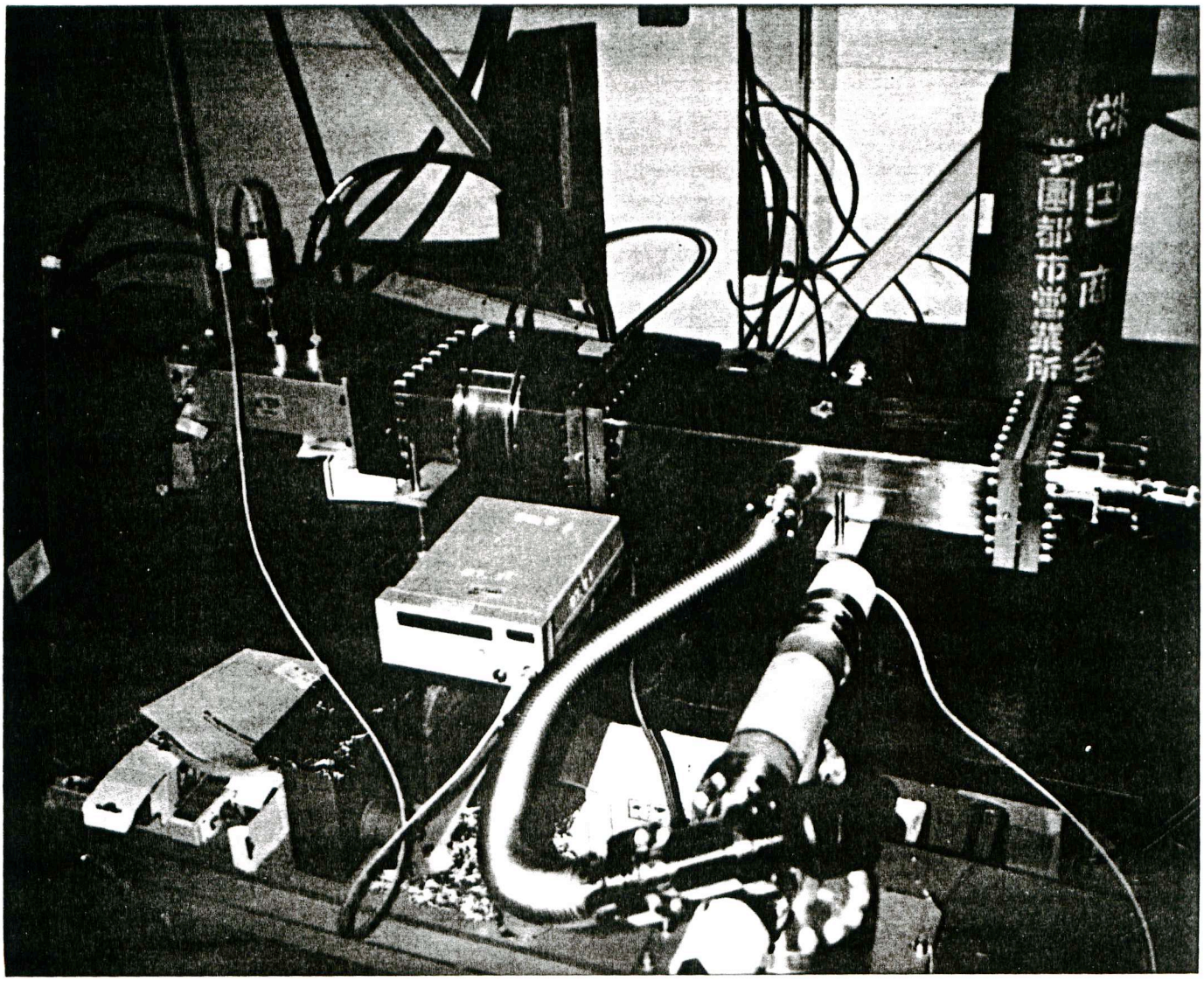
High-power test bench
1.3 GHz





C – C

SiC tiles in GBP for ARES96



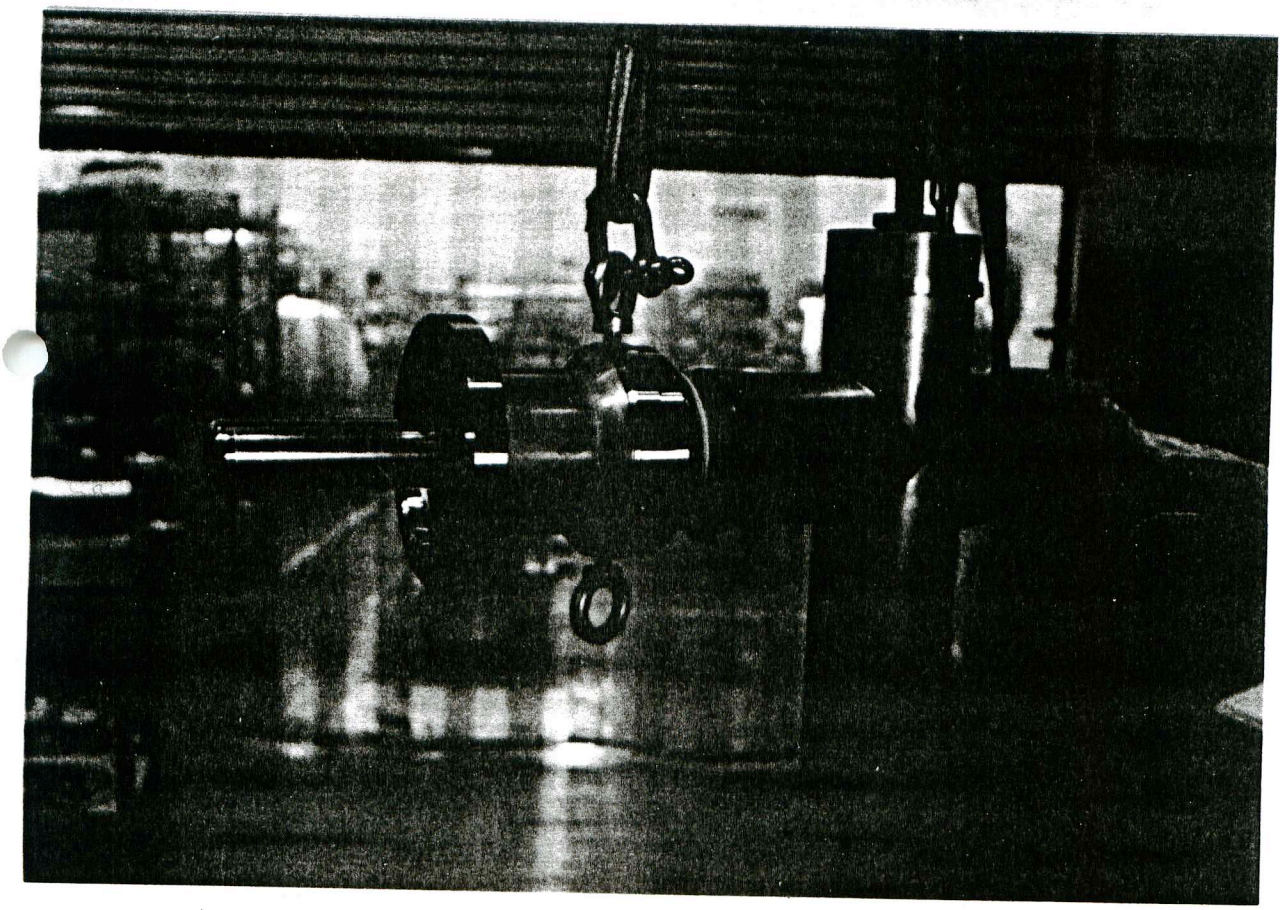
SiCタイル 電力テストベンチ

High-power test of SiC-tile load (1.3 GHz)

Coaxial antenna damper for coupling cavity

RF power is extracted (Qext ~50) through a coaxial waveguide (120D) with a disk-type ceramic window and a cross stub support.

Power capability
tested up to ~8kW (CW)
~20kW (peak power)



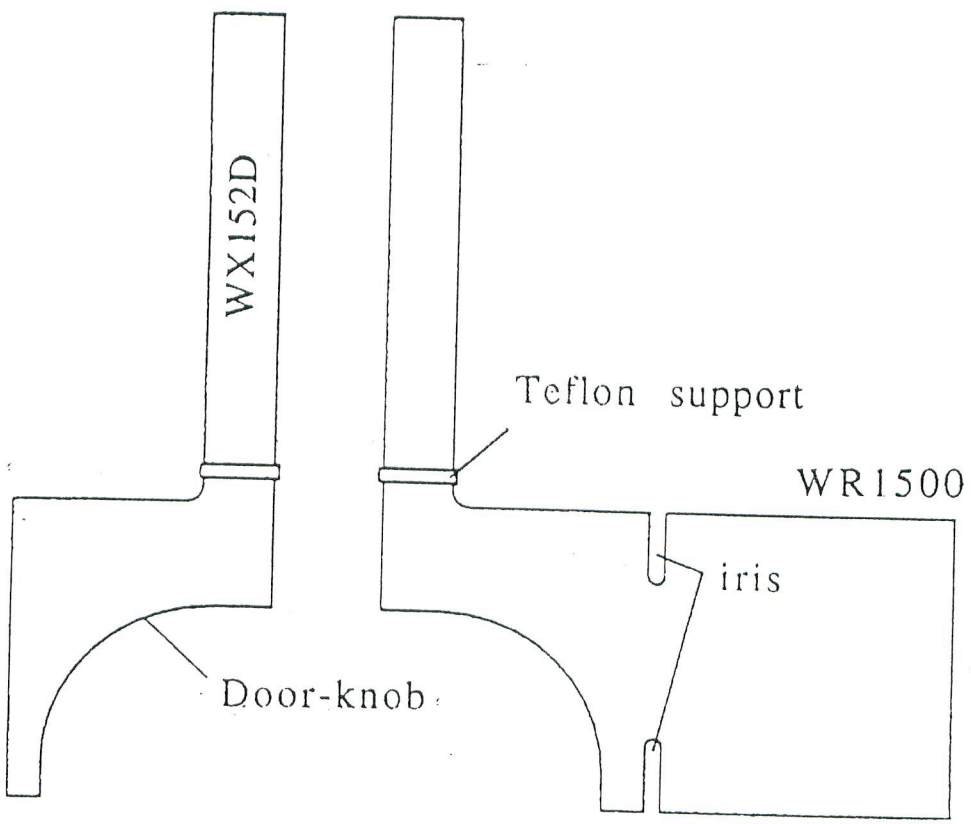
Coaxial antenna damper for coupling cavity

Input coupler

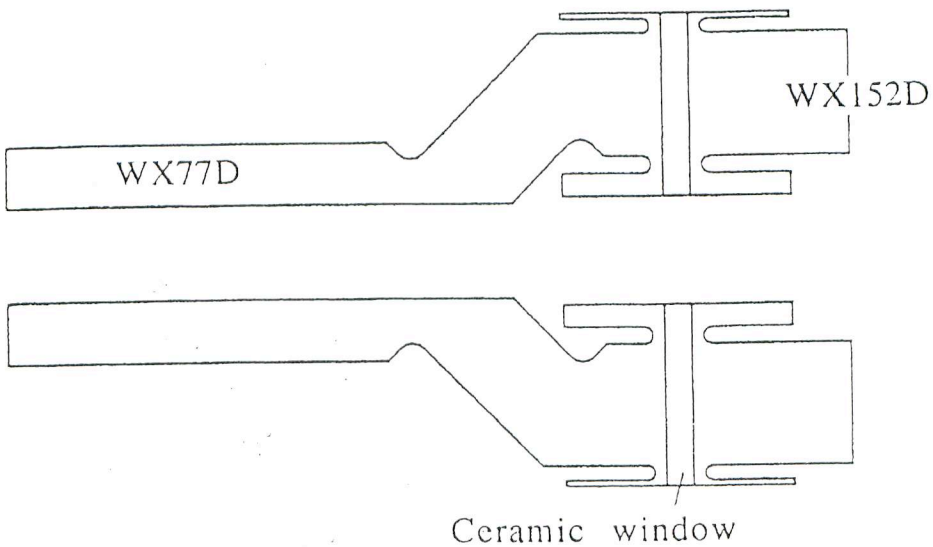
door-knob transition with a capacitive iris
from the rectangular waveguide WR1500
to the coaxial waveguide WX152D

a disk-type ceramic window
in the coaxial waveguide (WX152D)
(Two types of window matching structures were developed.)

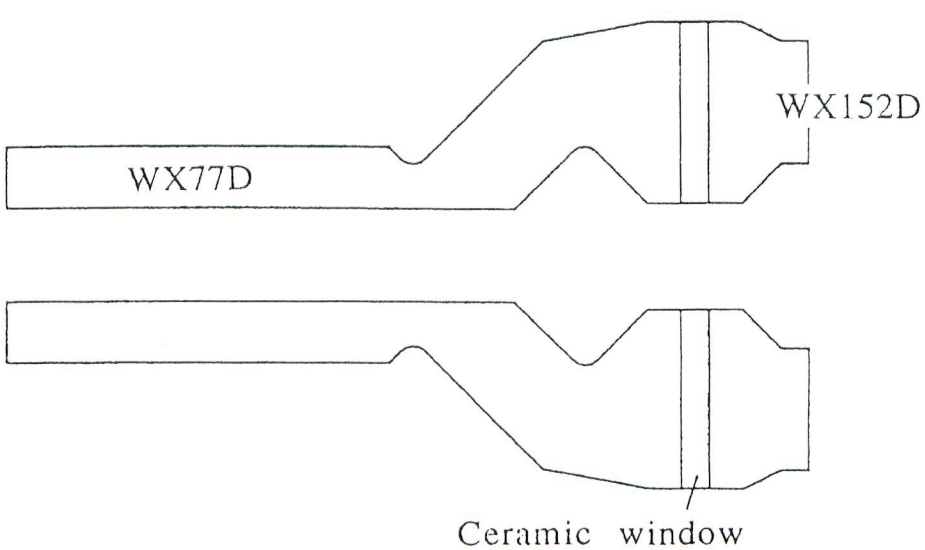
taper section of coaxial waveguide
(from WX152D to WX77D)



Schematic view of the door-knob transition.



Choke structure of the ceramic window with the transition between the coaxial waveguides.



Over- and under-cut (OUC) structure of the ceramic window with the transition between the coaxial waveguides.

High-power test of input coupler

The first high-power prototype with the over- and under-cut matching section was installed into ARES95 and tested up to 240kW, limited by the power capability of the cavity.

Construction of a high-power test bench for input couplers is underway.

Summary

The ARES scheme was demonstrated in high-power and high-current beam tests.

The HOM loads of SiC ceramics satisfying the requirements for KEKB LER were developed.

The coaxial antenna damper for the coupling cavity was successfully tested over the design power level.

The input coupler was tested up to 240kW (CW). High-power testing over ~400kW is an urgent matter. Construction of a test bench is underway.

Final design of the production cavity based on ARES96 is being in progress. More than 20 production cavities in 1997 FY.