RAON Rare isotope Accelerator complex for ON-line experiments

Tesla Technology Collaboration 2020
Feb 4-7, 2020

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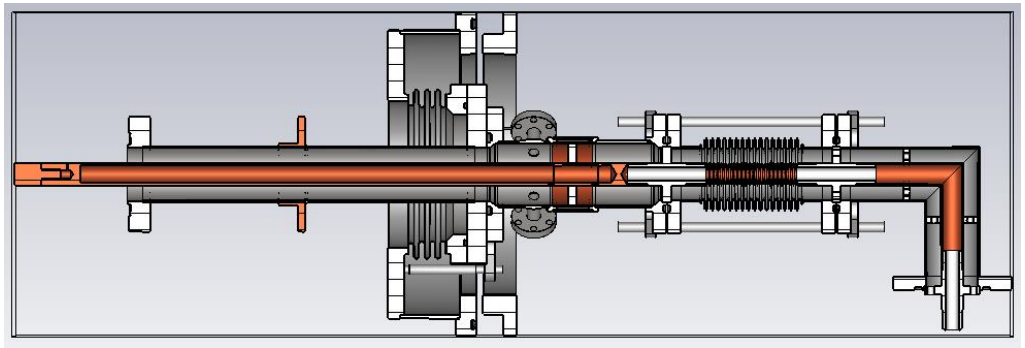
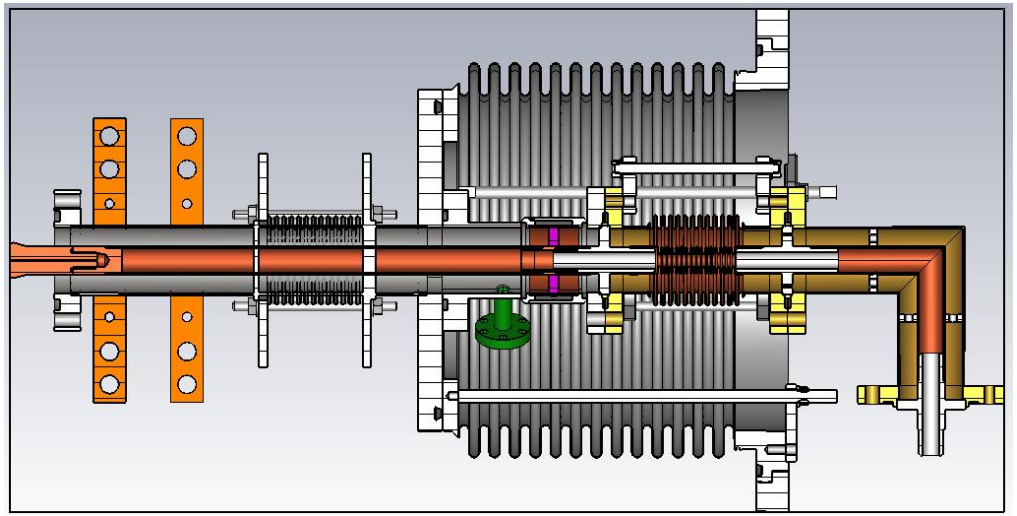
ibs 기초과학연구원 Institute for Basic Science

RISP 중이온가속기건설구축사업단 Rare Isotope Science Project

# RF power coupler for QWR and HWR cavity



◆ Layout of QWR RF power coupler



◆ Layout of HWR RF power coupler

| RF power coupler | QWR | HWR |
|---|---|---|
| Frequency | 81.25 MHz | 162.5 MHz |
| RF power | <4 kW | <4 kW |
| External Q | 3.0 ~ 5.0 x $10^5$ | 1.0 ~ 2.0 x $10^6$ |
| Cu plating (outer conductor) | No | No |
| TiN coating | Yes (5 ~ 10 nm) | Yes (5 ~ 10 nm) |
| # of product | 22 (20) | 106 (6) |

◆ Power Coupler Specifications

# Contents

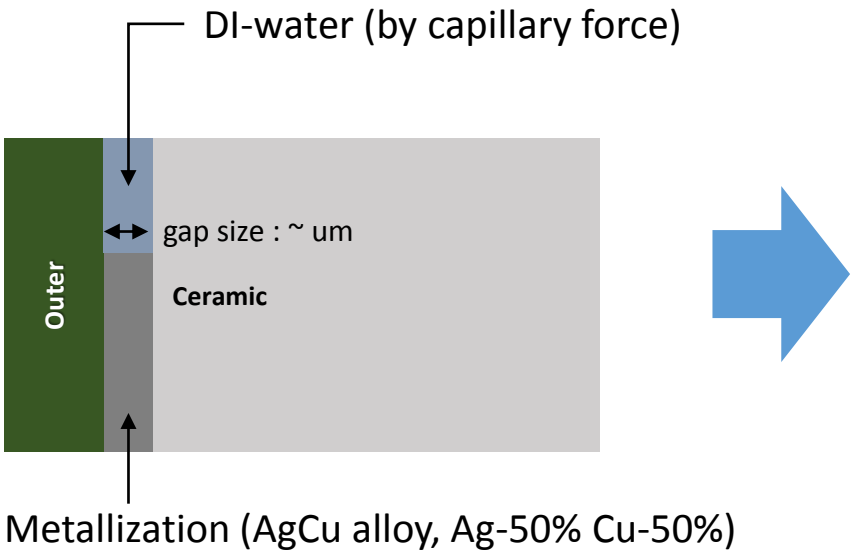
- ✓ Contamination of RF power coupler
- ✓ Uncertainty of external Q in HT

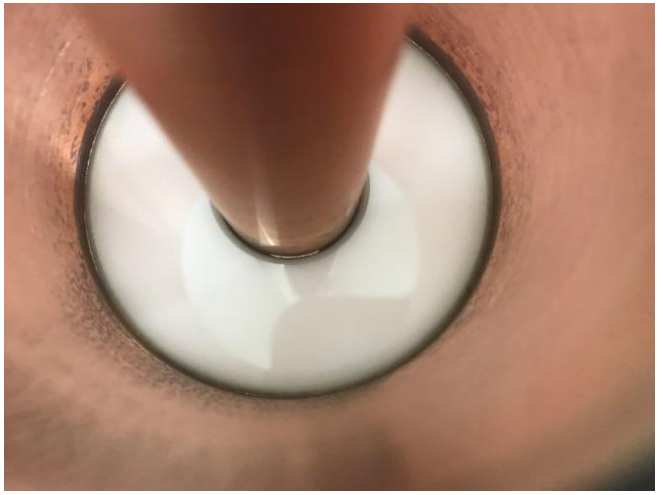
# Contamination of the RF power coupler

**USC with DI-water** → **Blowing**

- Frequency : 40 kHz
- DI-water resistance : > 15 MΩ
- Temperature : > 40 degree
- Time : 40 min

- $N_2$ gas(6N), 5 min



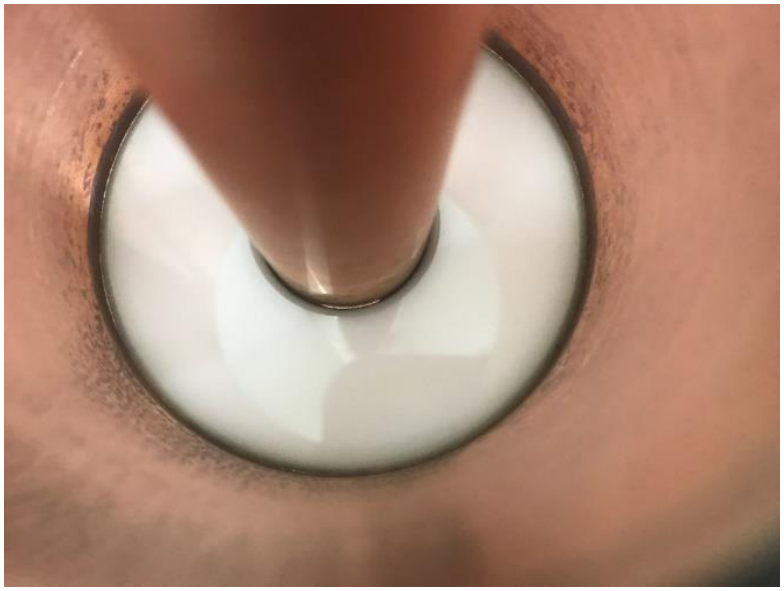
- DI-water can be remained in the gap by the capillary force after USC.

# Contamination of the RF power coupler

**USC with ethanol** → **Blowing**

- Frequency : 40 kHz
- Ethanol : > 99.9 %
- Temperature : 40 ~ 50 degree
- Time : 40 min

- $N_2$ gas(6N), 5 min



- USC with DI-water

- USC with the ethanol (volatility)

# Uncertainty of external Q in HT

**Loaded Q (HT)**

$$Q_0 \gg Q_{ext,in} \rightarrow \quad Q_{ext,in} \approx Q_L$$

**Decay time measurement**

- Non-linearity?

**VNA measurement**

- Resolution?

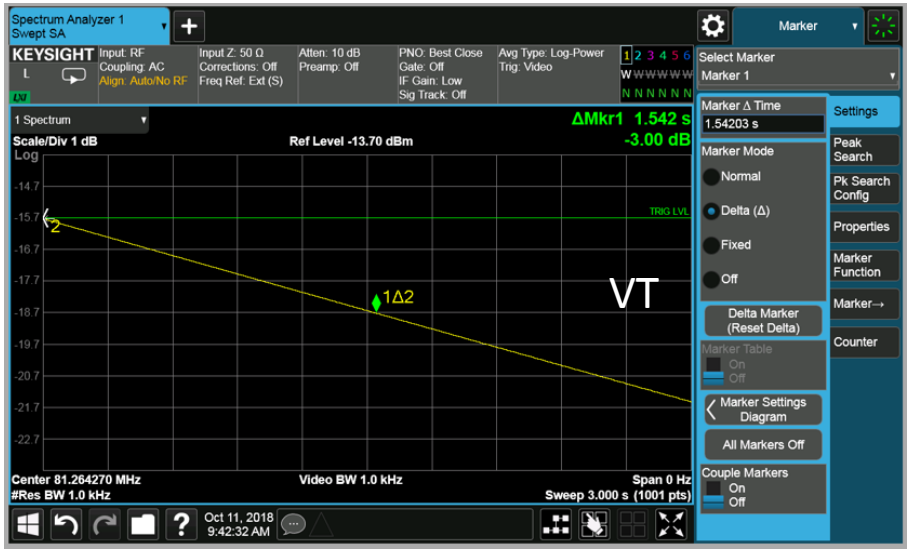
$$Q_L = Q_{ext,in} = \frac{\omega\tau}{ln2}$$

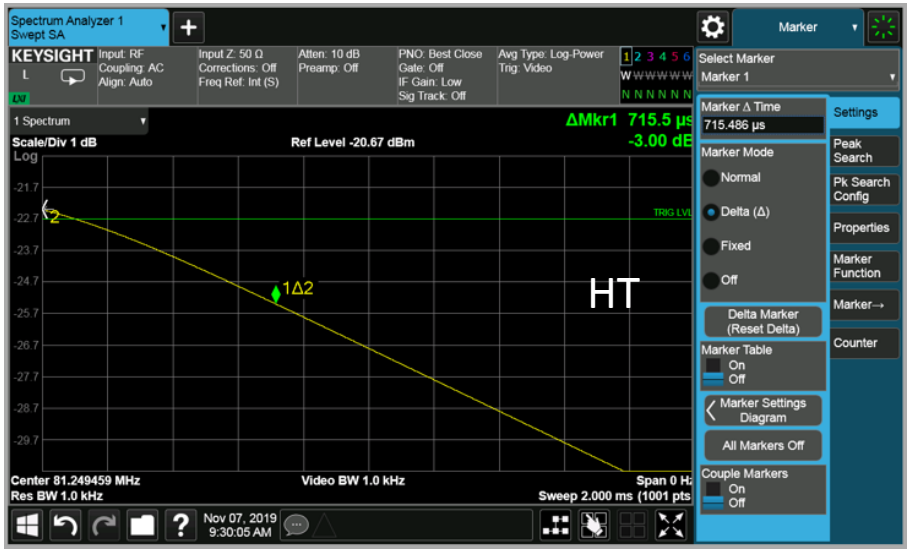
**RF power measurement**

- Circulator?

$$P_{inc} = \frac{V_{acc}^2}{4 \cdot {}^{R}/_{Q}\, Q_{ext}} \left[ \left( 1 + \frac{R}{Q} Q_{ext} \frac{I_{beam}}{V_{acc}} cos\phi_{beam} \right)^2 \right.$$

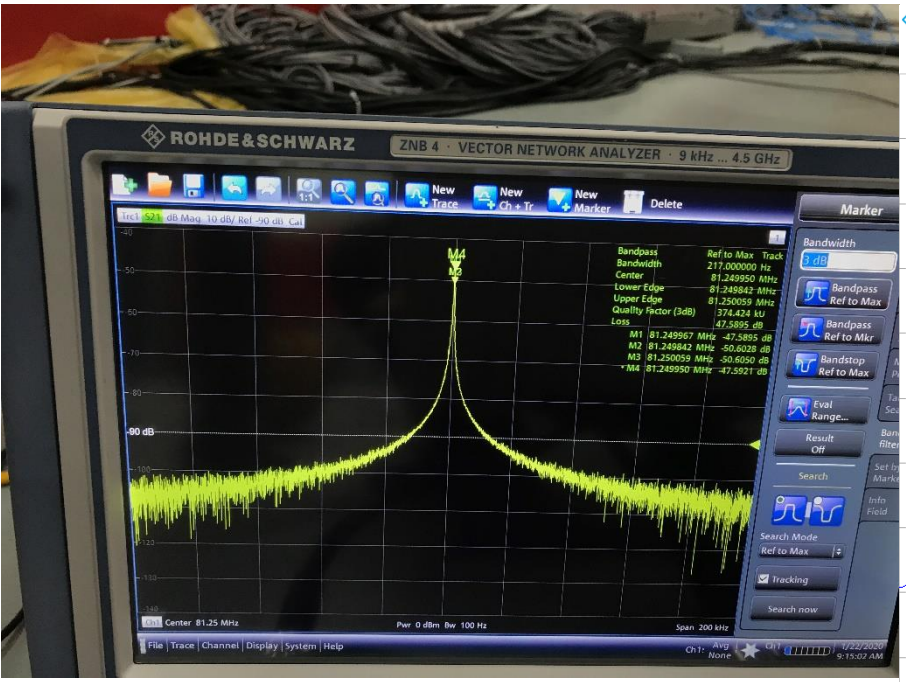
# Uncertainty of decay time measurement in HT

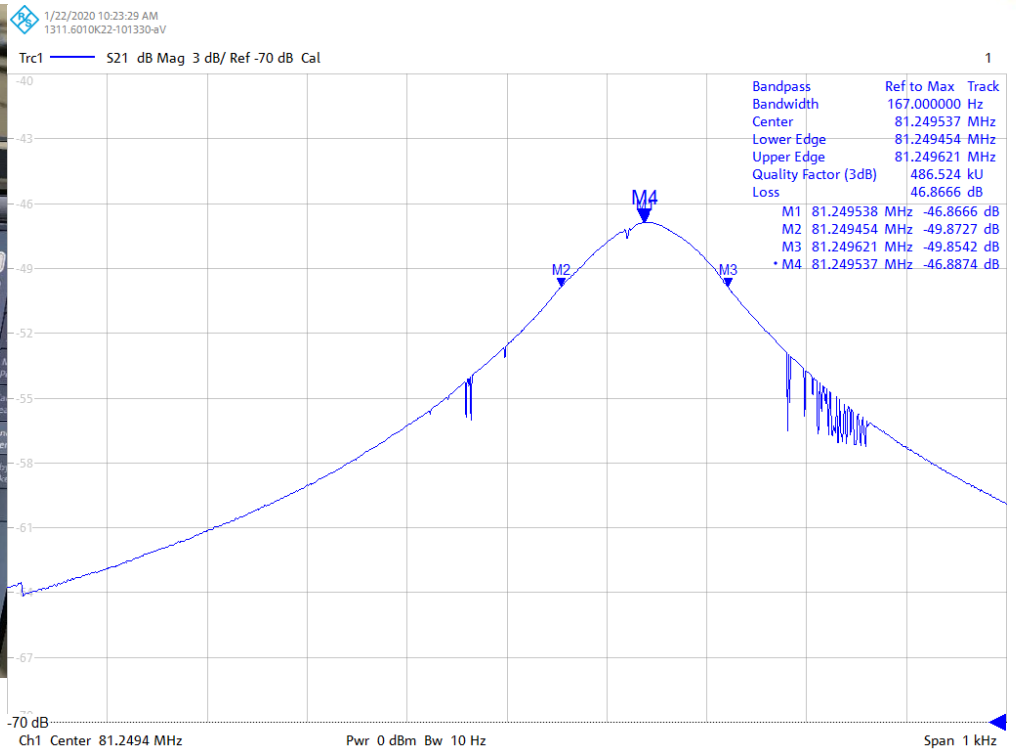



- There is no non-linearity of the decay time measured in VT.
- Non-linear of decay time is observed only in HT.
- The longer decay time causes the error of the loaded Q and external Q of RF power coupler.
- The linear part of measured decay time is now used for calculation of loaded Q.

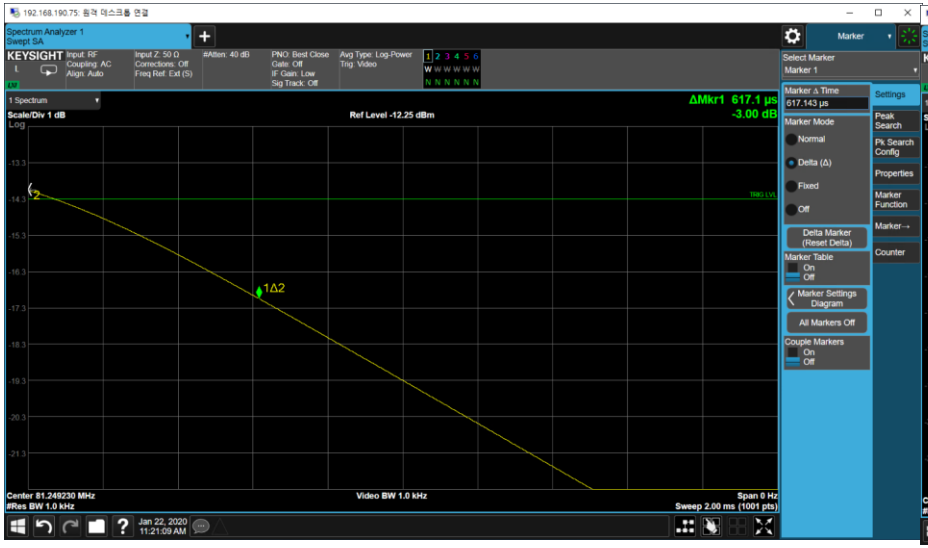
# Uncertainty of VNA measurement in HT

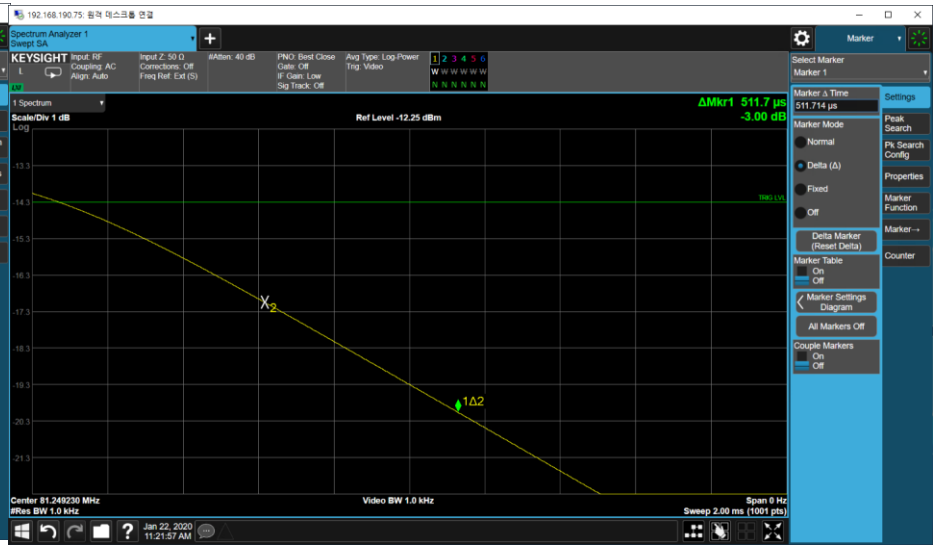



| VNA | Setting A | Setting B |
|---|---|---|
| Bandwidth (IF) | 100 Hz | 10 Hz |
| Span | 200 kHz | 1 kHz |
| # of points | 4001 | 1001 |
| Loaded Q | 3.7 E5 | 4.8 E5 |

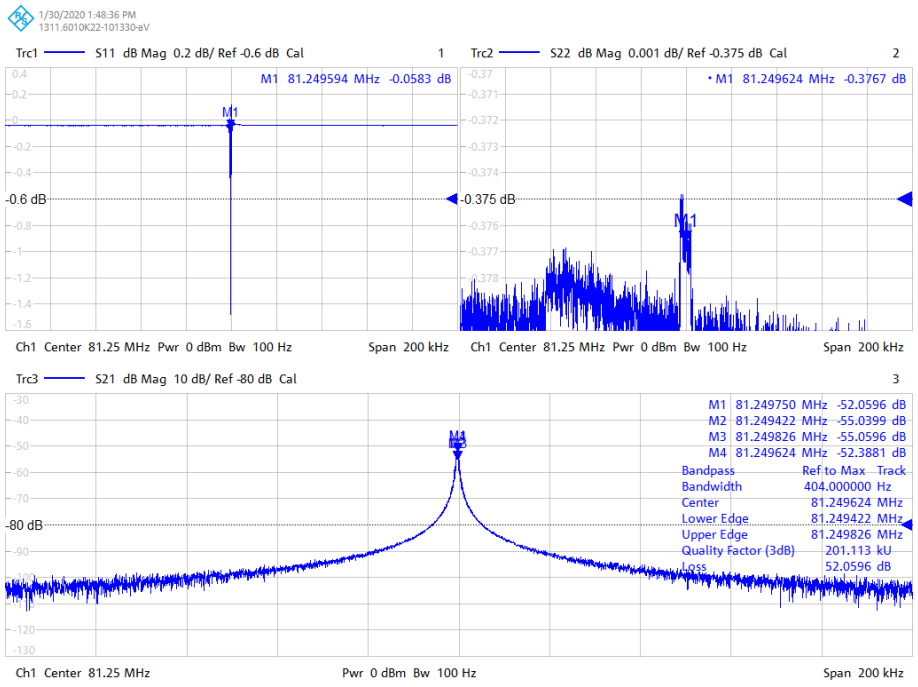
# Uncertainty of decay time measurement in HT

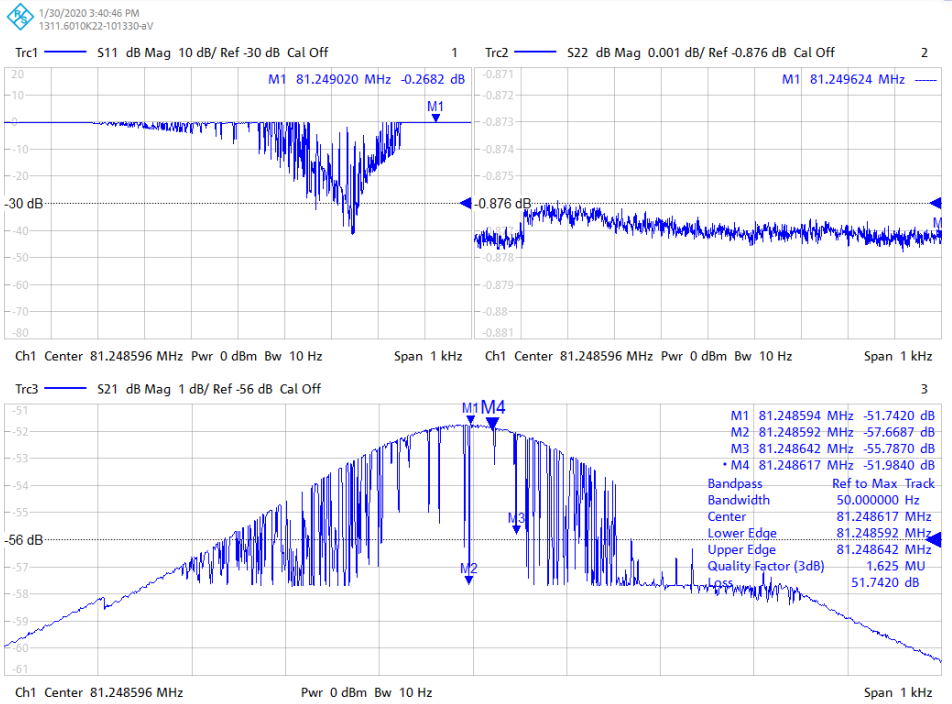



| | VNA measurements | | Decay time measurements | |
|---|---|---|---|---|
| | Setting A | Setting B | Non-linear | Linear |
| Bandwidth (IF) | 100 Hz | 10 Hz | | |
| Span | 200 kHz | 1 kHz | | |
| # of points | 4001 | 1001 | | |
| Decay time | | | 617.1 us | 511.7 us |
| Loaded Q | 3.7 E5 | 4.8 E5 | 4.6 E5 | 3.7 E5 |

# Uncertainty of VNA measurement in HT

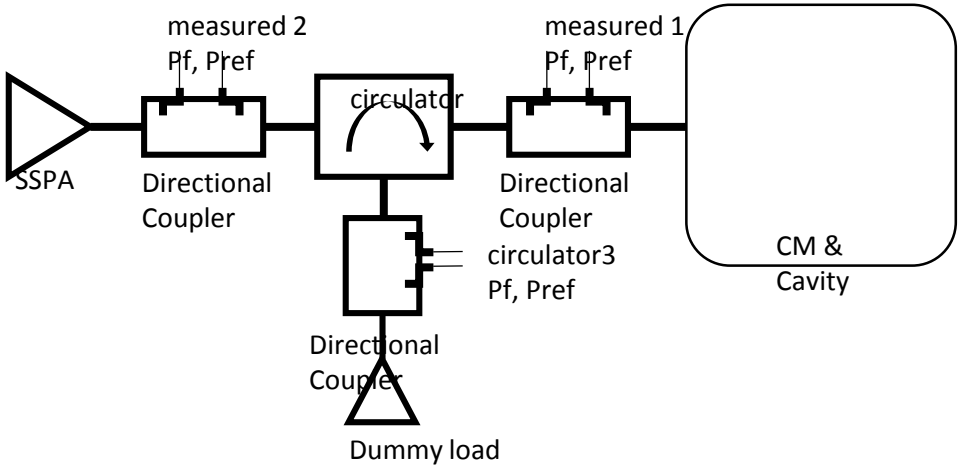


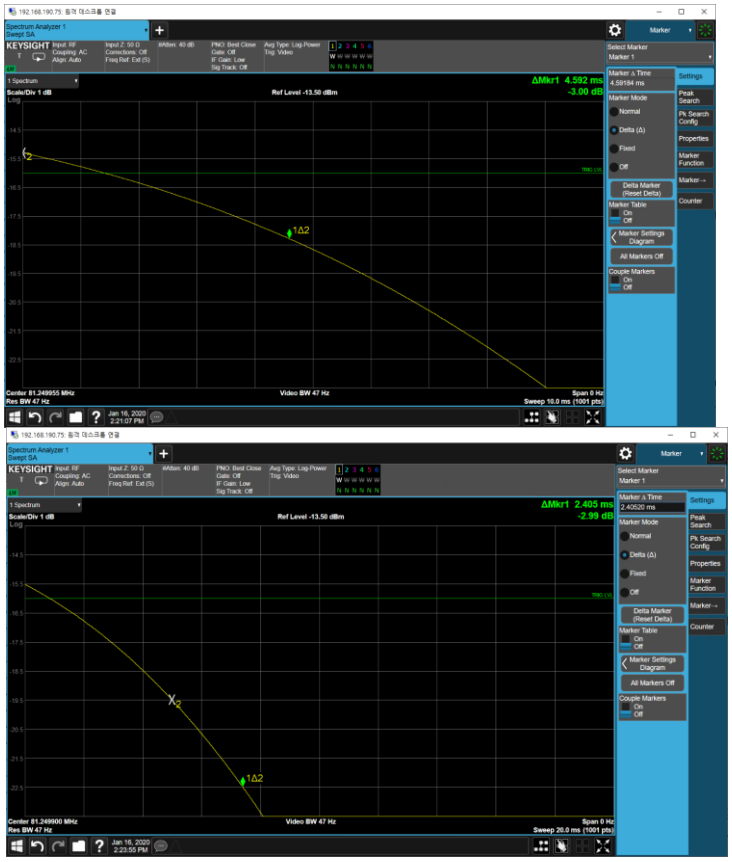

| | VNA measurements | |
|---|---|---|
| | Setting A | Setting B |
| Bandwidth (IF) | 100 Hz | 10 Hz |
| Span | 200 kHz | 1 kHz |
| # of points | 4001 | 1001 |
| Loaded Q | 2.0 E5 | - |

Higher resolution of the VNA setting could not measure the loaded Q?

# Uncertainty of RF power levels in HT




| Coupler coupling | | | |
|---|---|---|---|
| Qext,in | 5.0 E5 | Qext,t | 9.5 E10 |
| | | | |
| Eacc [MV/m] | Pg (calculation) | Pf (measured 1) | Pf (measured 2) |
| 1 | 31.22848881 | 31 | 59 |
| 2 | 127.2235634 | 148 | 244 |
| 3 | 287.9958022 | 309 | 461 |
| 4 | 513.5452052 | 524 | 752 |
| 5 | 801.9288806 | 795 | 1100 |
| 6 | 1151.983209 | 1053 | 1400 |
| 6.1 | 1175.373134 | 1100 | 1490 |
| | | | |
| 1 | 31.22848881 | 28.8 | 35 |
| 2 | 127.2235634 | 115.4 | 121 |
| 3 | 287.9958022 | 263.9 | 251 |
| 4 | 513.5452052 | 477 | 430 |
| 5 | 801.9288806 | 766 | 674 |
| 6 | 1151.983209 | 1121 | 986 |
| 6.1 | 1175.373134 | 1159 | 1017 |



Loaded Q : 5.0E5 confirmed by measured RF powers and the calculation.

loaded Q : 1.77E+06 by decay time (linear part)

# Summary

- ✓ Contamination of RF power coupler
  - ➢ DI-water infiltrates to the gap between the outer conductor and the metallization. This caused the contamination of the RF power coupler. Substitute the ethanol for the DI-water, the contamination is not occurred after the USC procedure.
- ✓ Uncertainty of external Q in HT
  - ➢ The loaded Q in HT is obtained by the decay time measurements or VNA measurements in RISP.
  - ➢ The non-linear part of decay time makes the uncertainly of loaded Q.
  - ➢ The resolution of VNA makes the measurement errors of loaded Q.
  - ➢ The circulator causes the errors in the measurement of RF power levels.
  - ➢ Theses errors cause the uncertainty of the loaded Q.


노벨상 향한 대장정 스타트
중이온가속기 라온
가속기는 '노벨상의 산실'로 불린다. 기초과학 연구에는 필수 실험시설이자, 산업계에는 새로운 기술 개발의 터전이다. 머리카락 한 올 두께보다 작은 나노미터(nm·1nm는 10억 분의 1m)와, 이보다 100만 배 더 작은 펨토미터(fm·1fm는 1000조 분의 1m)의 세계를 보여주는 최첨단 '현미경'이기도 하다. 한국형 중이온가속기 '라온(RAON)'이 2021년 완공을 목표로 구축에 들어갔다. 빅뱅 3분 뒤의 우주를 재현하고, 한국의 이름을 붙인 새로운 원소 '코리아늄'을 발견해 주기율표에 등재하겠다는 포부도 세웠다.
Thank you
Merci