RF absorber studies for cERL in Japan

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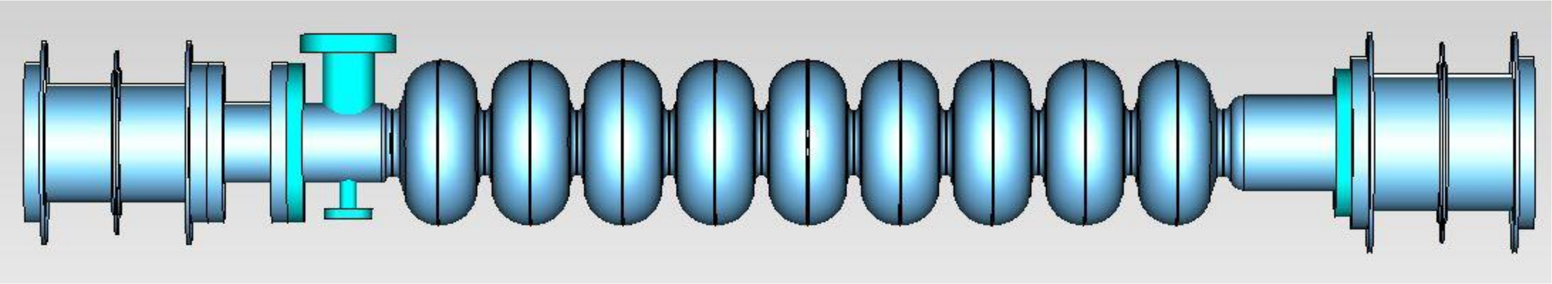
After ERL09



- No additional kinds of material were measured
  - Setup for measurement were modified to reduce influence of GM refrigerator operation

- Very rough resistance measurement at low temperature
  - Qualitative, not quantitative

Frequency and Temperature Property of RF Absorber

- Measurement Method
  - Nicolson-Ross Method
    - Using Network Analyzer
    - Coaxial Samples in 7mm-Connector-type sample holder
    - Calculate complex permittivity and permeability from S-parameters (S_{11},S_{21})
  - Cooling samples with GM refrigerator
    - From Room temperature to 40K

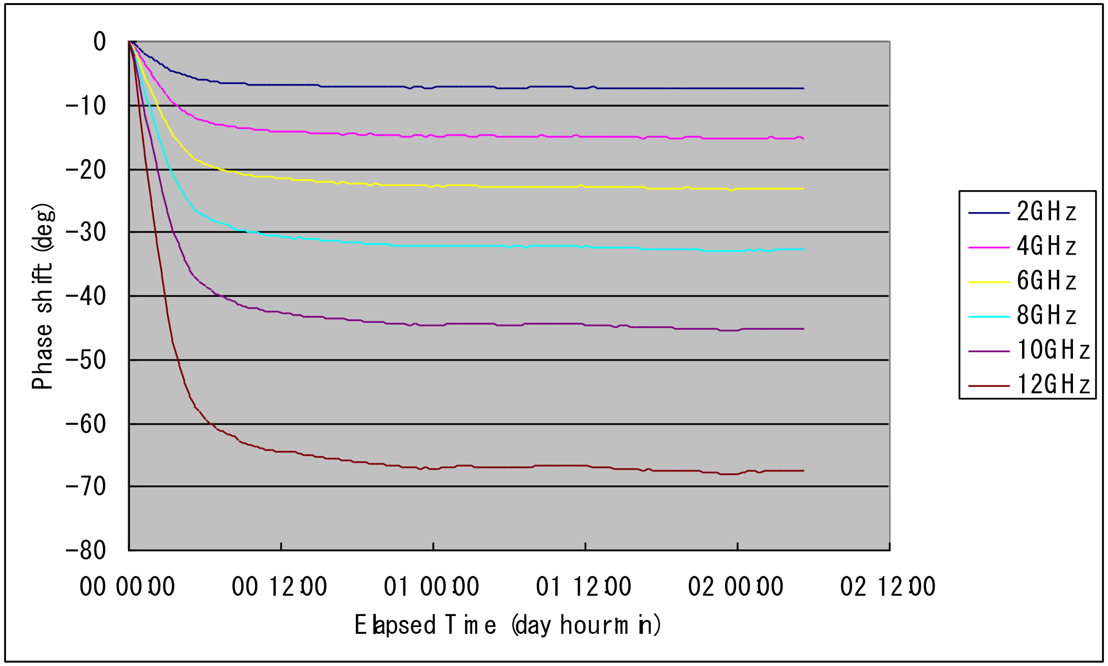
- Samples
  - Measured 8 kinds of ferrite and 1 kind of ceramics
    - Ferrite TDK Corporation old-type IB004 (used KEKB)
      new-type IB004 (Pb free)
      Trans-tech Inc. Co2Z、Ferrite50、TT2-111
      TT2-4000、TT86-6000
      Nikko Co.
    - Ceramics SiC

Procedure for low temperature measurement

- Calibration of network analyzer
  - Calibration coefficients vary with temperature mainly owing to RF cables
  - Measure S-parameters of each port changing temperature
    - Port1－Open(S_{11})　　Port2－Short(S_{22})
    - Port1－Short(S_{11})　　Port2－Load(S_{22})
    - Port1－Load(S_{11})　　Port2－Open(S_{22})
    - Port1－Port2 （Through) (S_{11}、S_{21}、S_{22}、S_{12}）
    - Port1－Port2 （Line) (S_{11}、S_{21}、S_{22}、S_{12}） no sample, only holder
- Calculate temperature-dependent calibration parameters with 10 measured data above (open-short-load-through or short-through-line)
  - Cable correction errors were included due to GM refrigerator operation
- Set sample on cold stage and cool down
- Measure S-parameters of sample while changing temperature
- Calibrate measured S-parameters with calibration coefficients and calculate permittivity and permeability

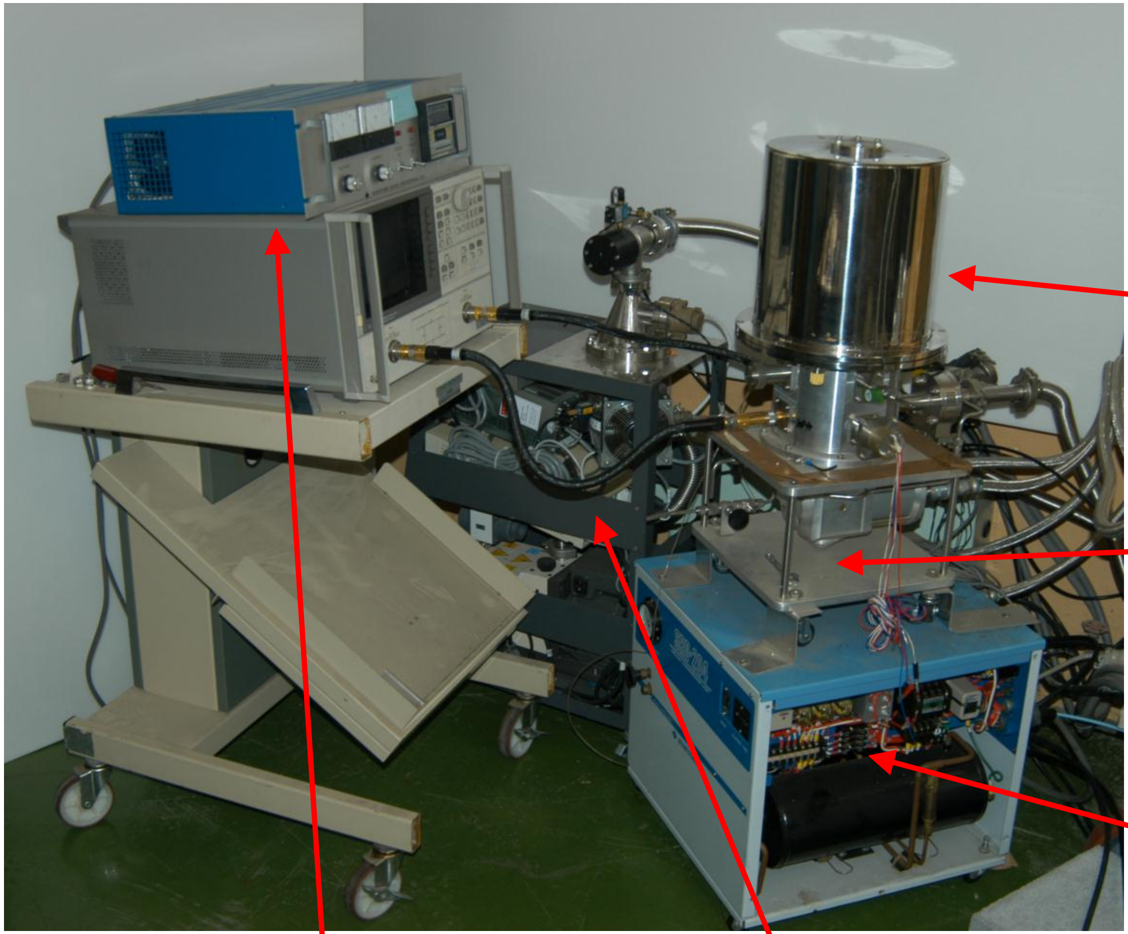
Influence of GM refrigerator

- When GM refrigerator turned on and cold stage were controlled to keep 280K



- In spite of constant temperature of cold stage, phase of S22 gradually drifted and took about 2 days to be constant
- Cable correction had errors due to these drifts
  - Maybe this is not fatal if every correction is carried out at the same timing

Measurement Setup



Vacuum chamber

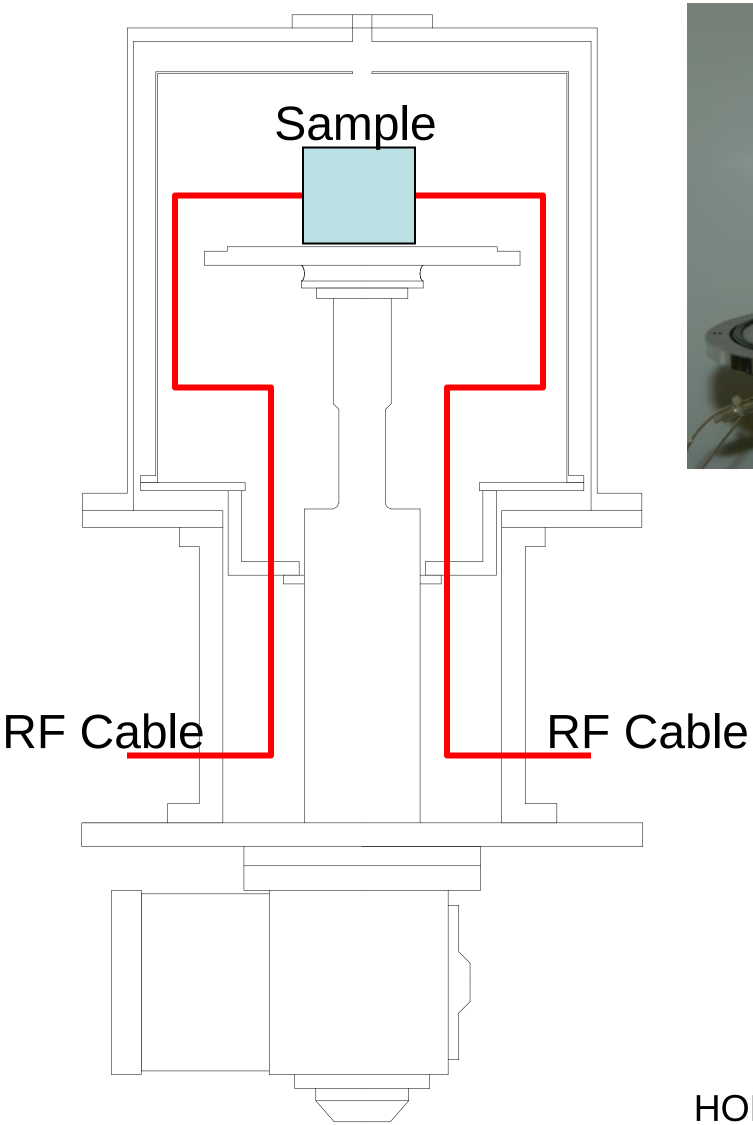
GM Refrigerator

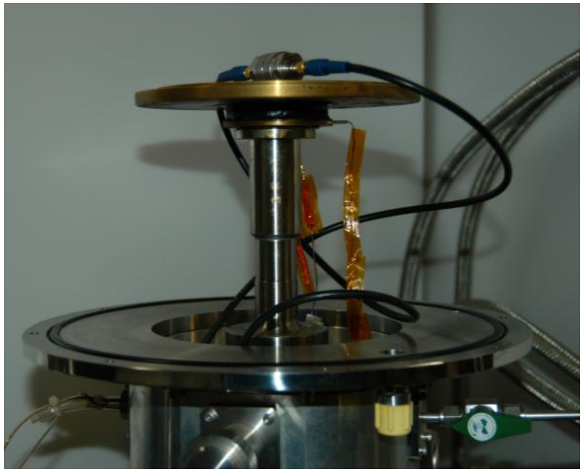
Compressor

Temperature control (heater control)

Vacuum pump

Before Improvement

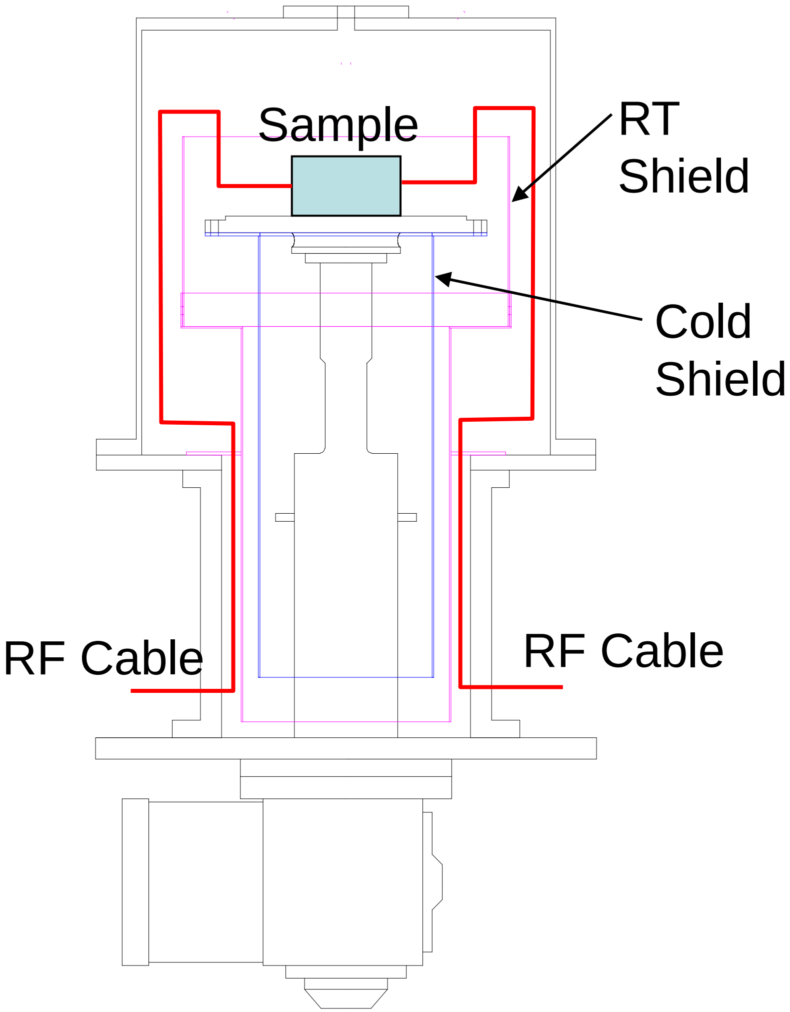




- RF properties such as loss and phase of RF cables changes gradually during measurement.

- RF cables were cooled slowly by heat radiation of GM refrigerator directly.

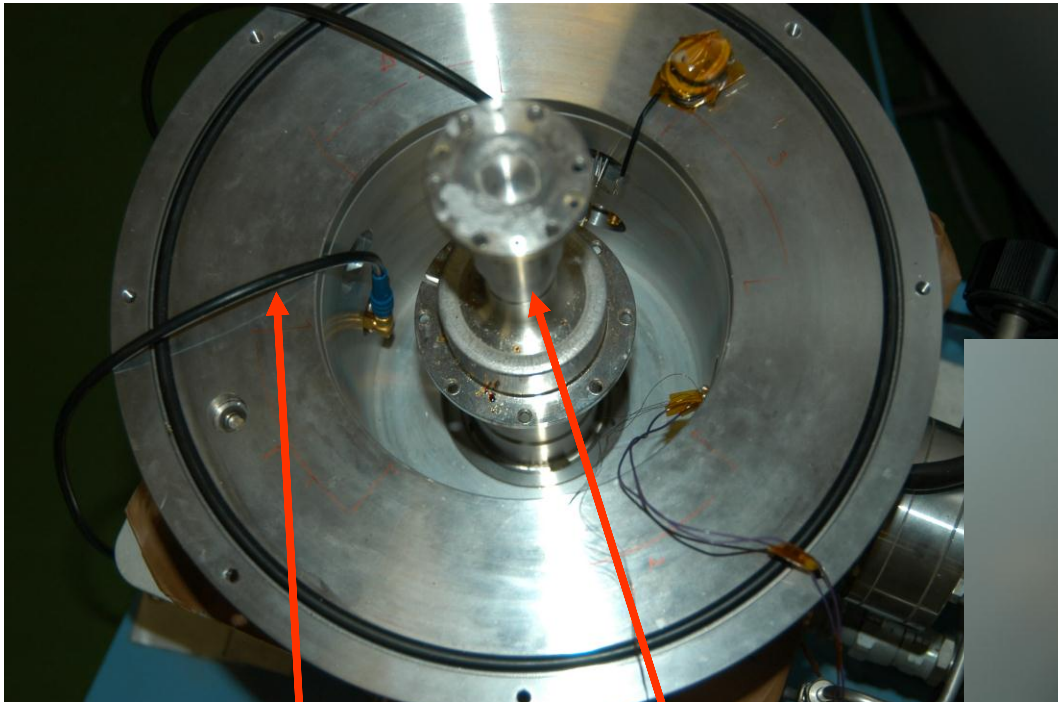
After Improvement



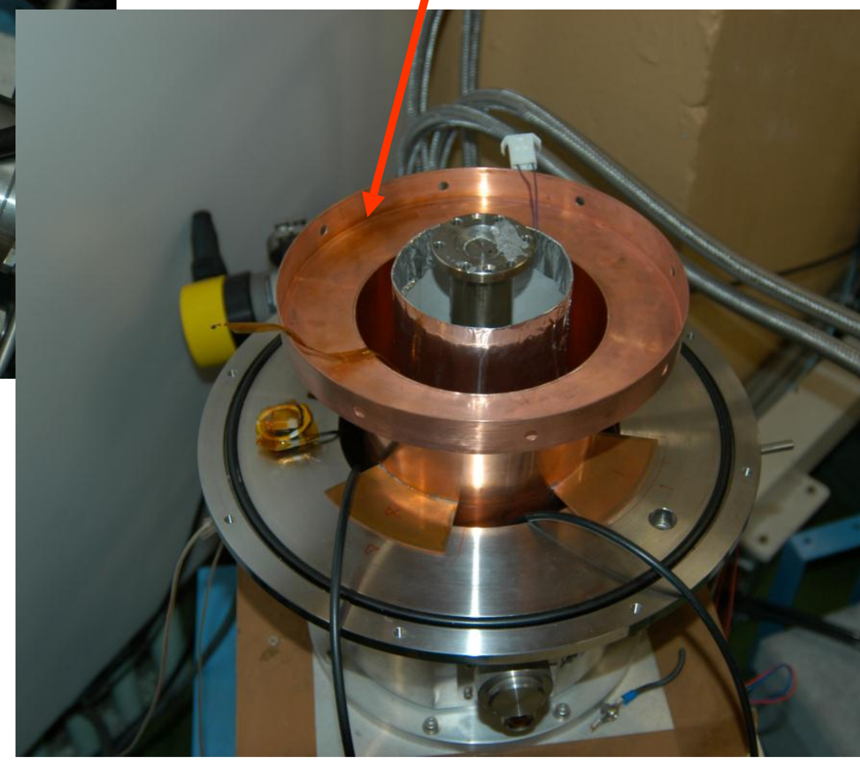
- Room Temperature shield and cold shield are installed for RF cables not to see GM refrigerator directly and reduce heat radiation

- Reduce changes of RF properties due to GM refrigerator operation

Measurement setup



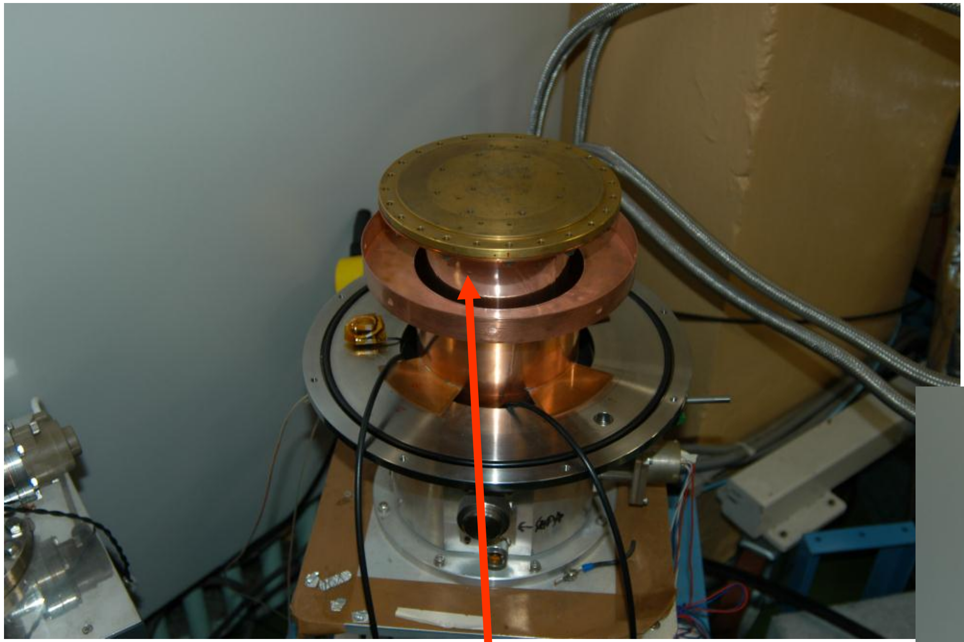
RT Shield



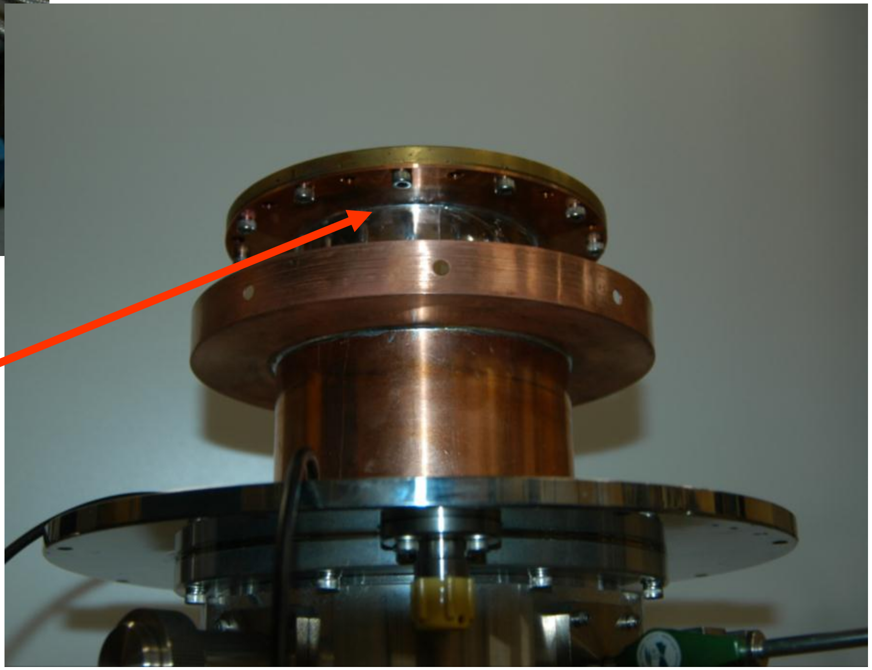
RF cable

GM refrigerator

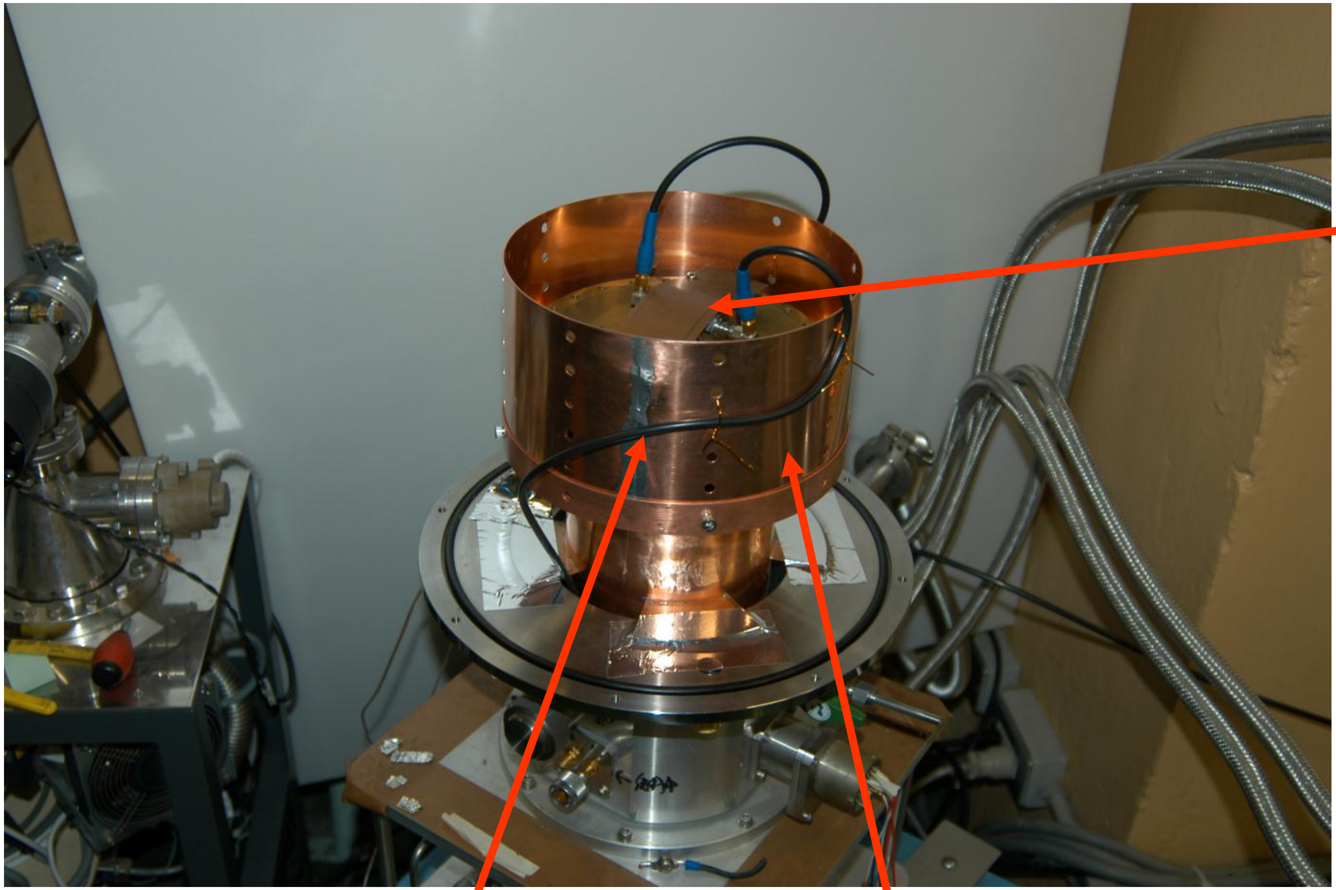
Measurement setup



Cold shield



Measurement setup



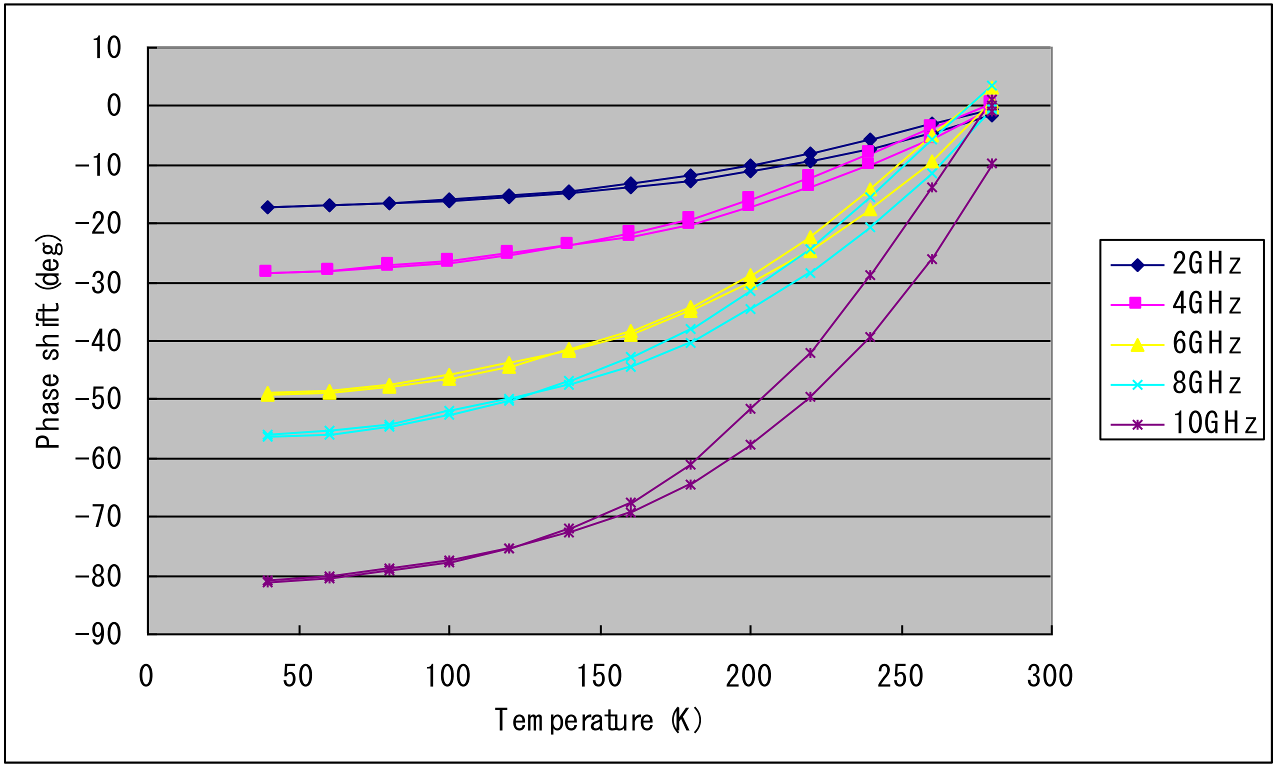
sample

7mm Coaxial
sample holder

RF cable

RT shield

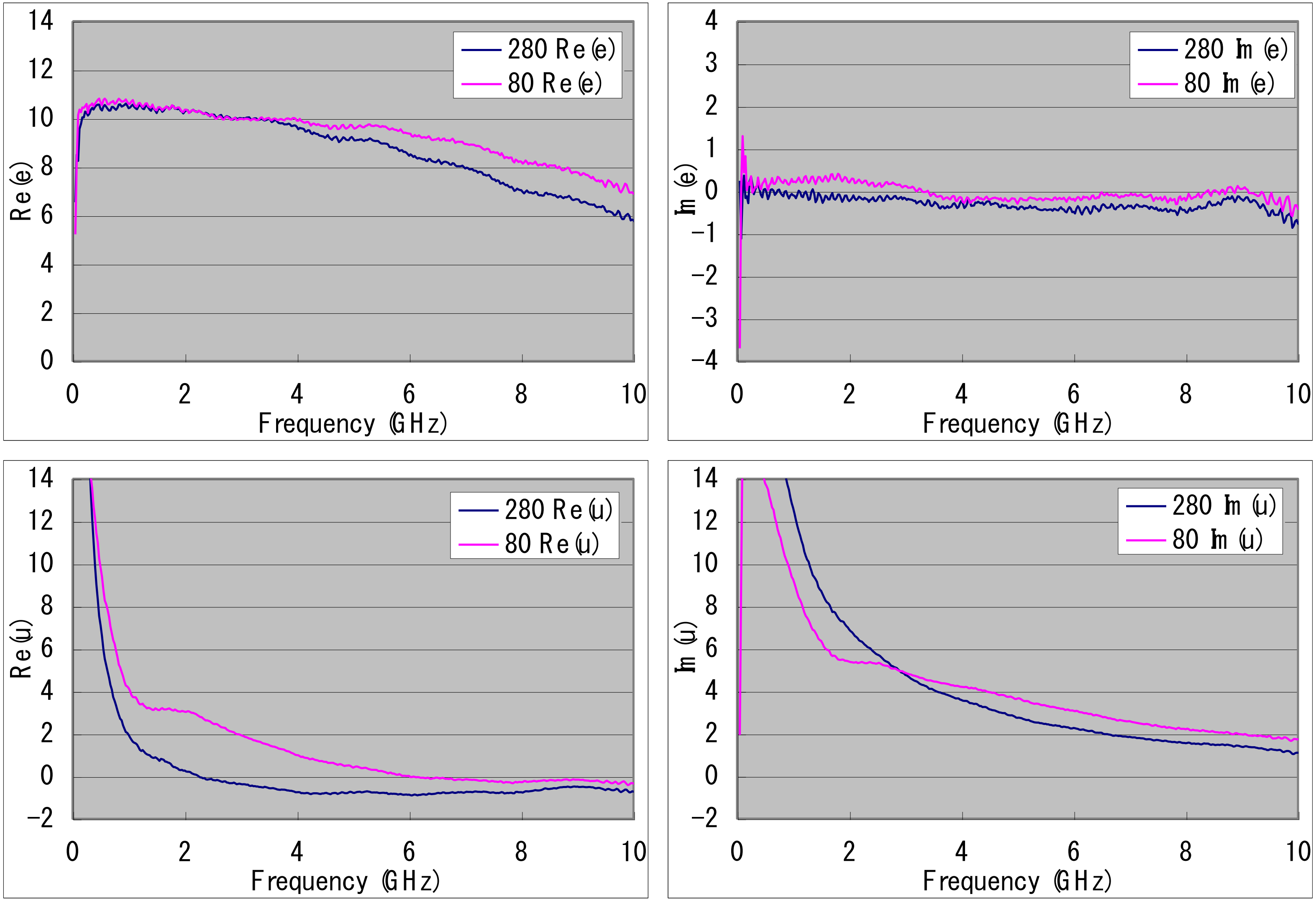
Cable correction error



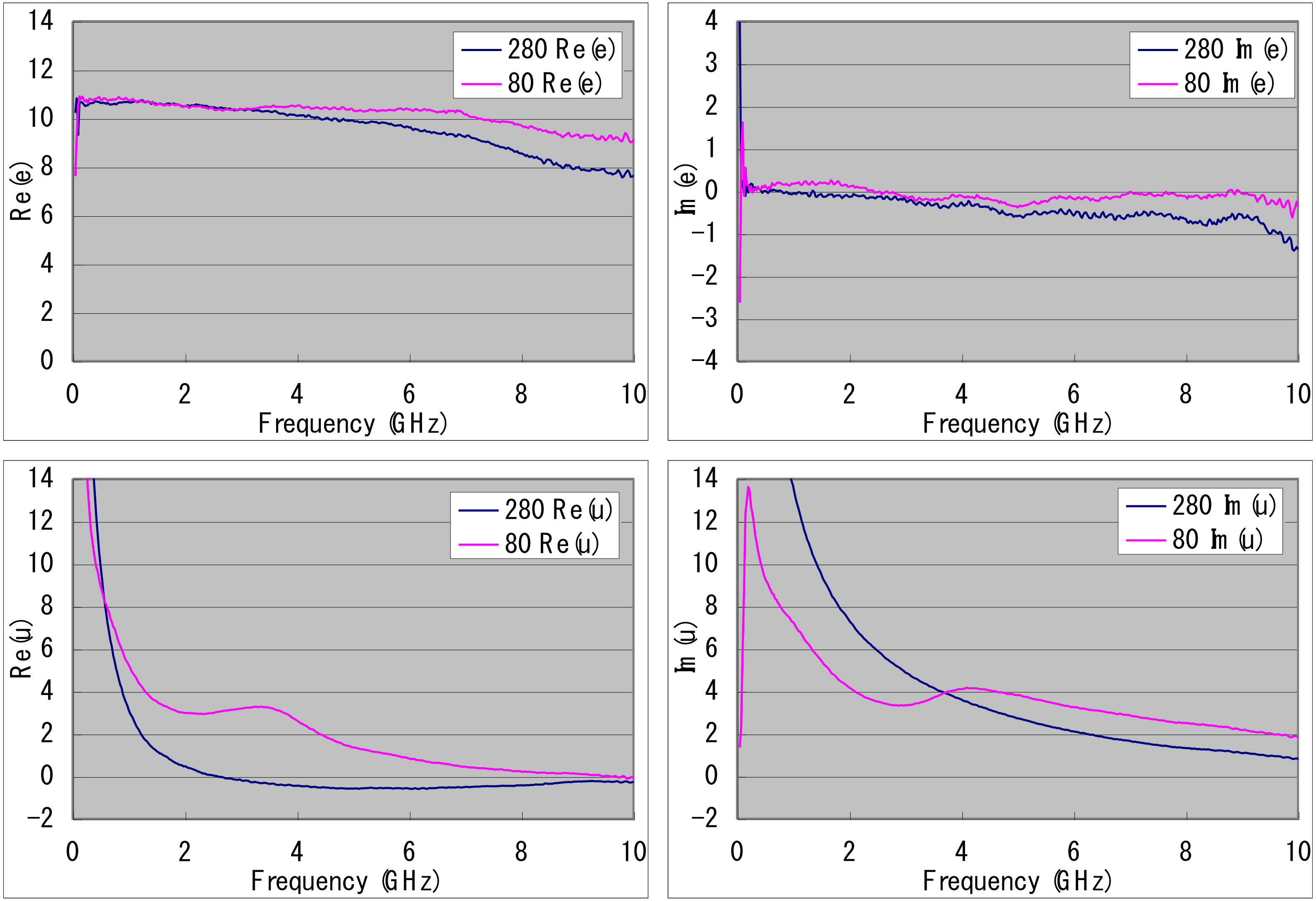
- Temperature of cold stage was changed from 280K to 40K and from 40K to 280K
- Phase become almost same during cooling down and warming up

Result of Measurement of ε and μ

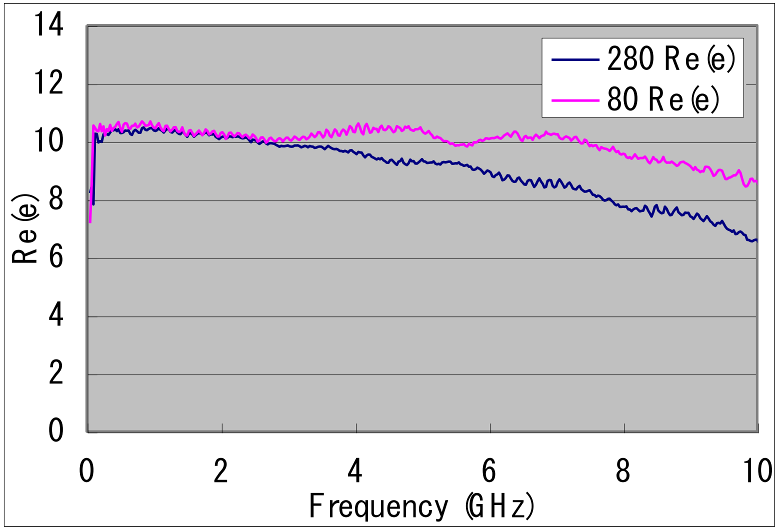
Old-type IB004



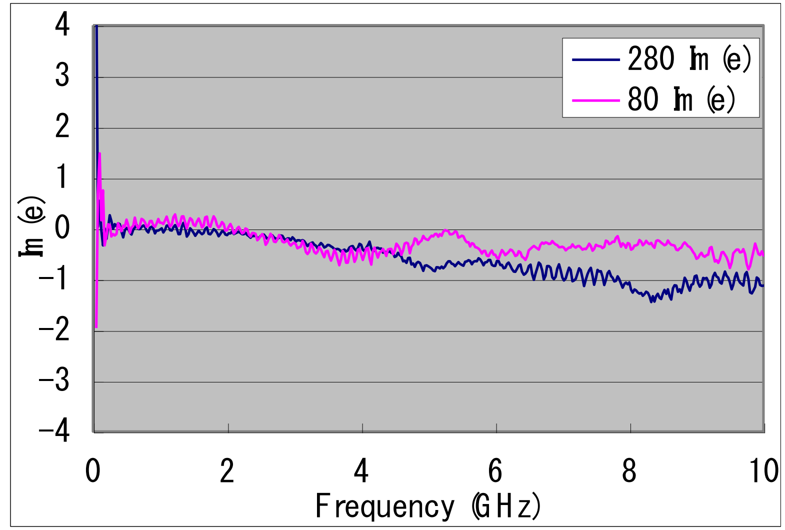
New-type IB004



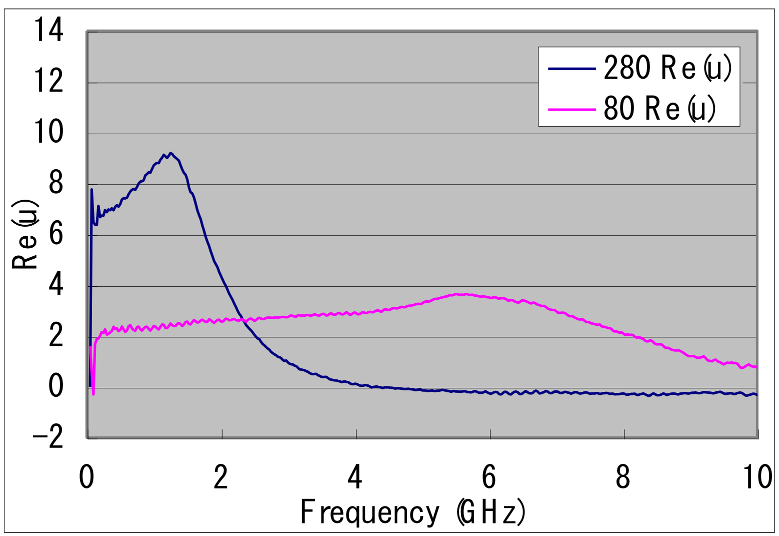
Co2Z



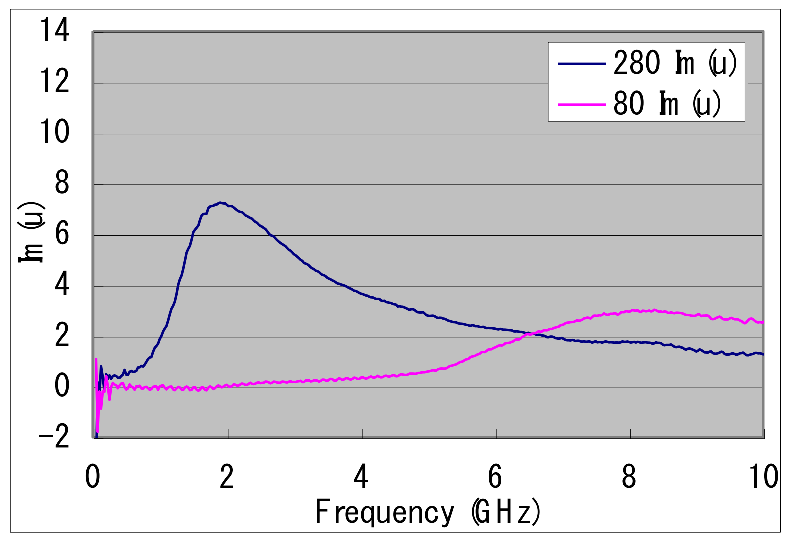
280 Re(e)
80 Re(e)
Re(e)
Frequency (GHz)



280 Im (e)
80 Im (e)
Im (e)
Frequency (GHz)



280 Re(u)
80 Re(u)
Re(u)
Frequency (GHz)



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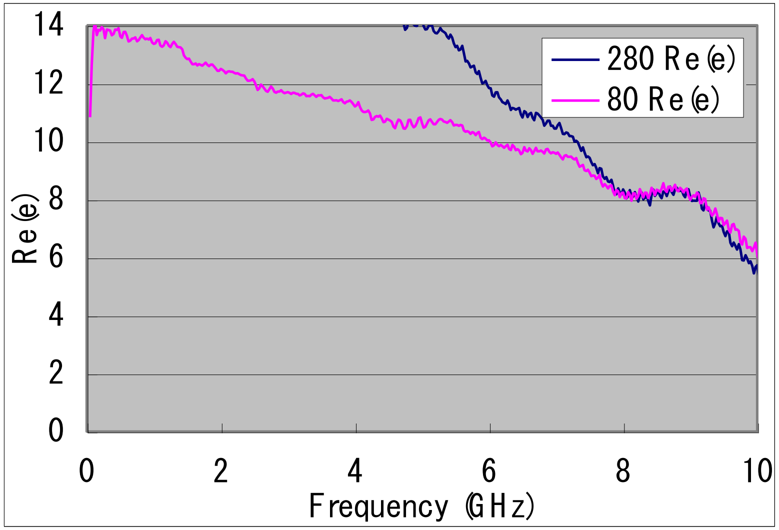
Im (u)
Frequency (GHz)

Ferrite50



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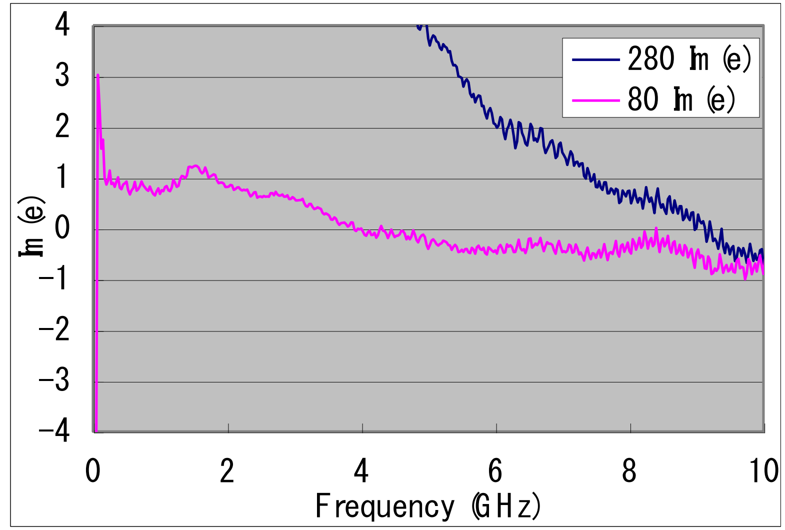
Re(e)
Frequency (GHz)



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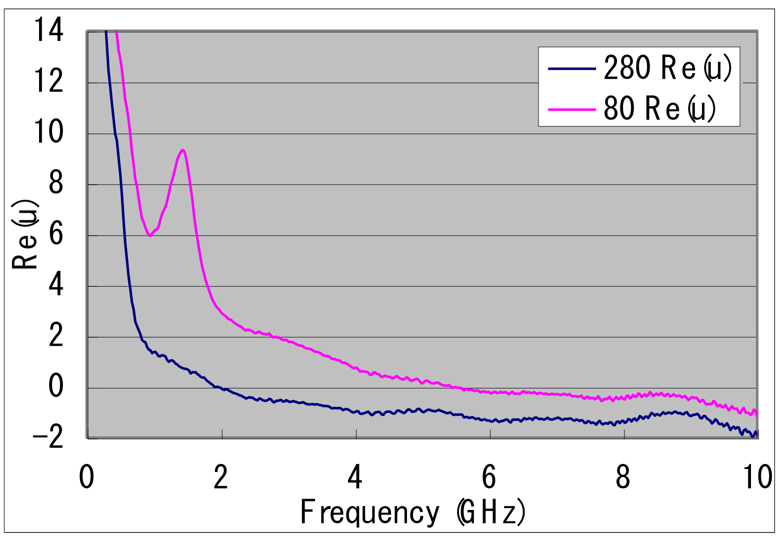
Im(e)
Frequency (GHz)



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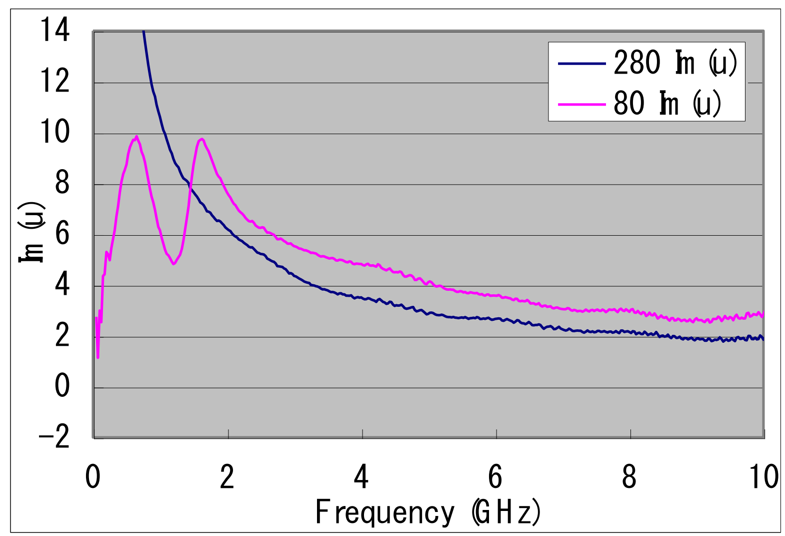
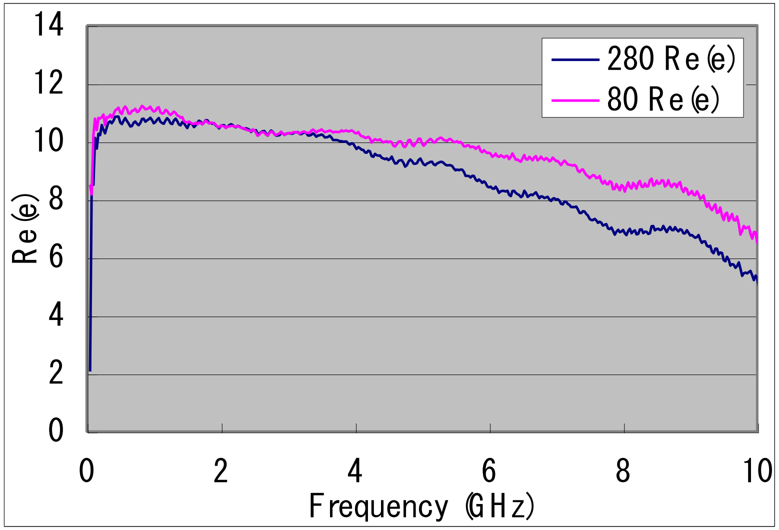
Re(u)
Frequency (GHz)



280 Im(u)
80 Im(u)
Im(u)
Frequency (GHz)

TT2-111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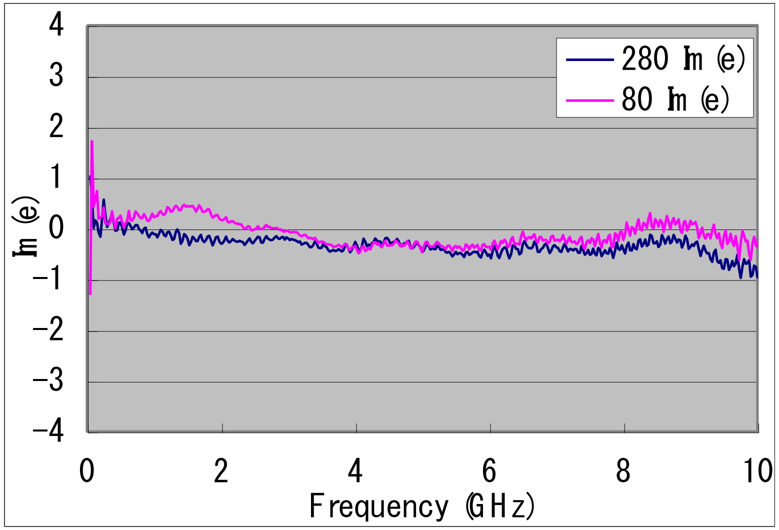
Re(e)
Frequency (GHz)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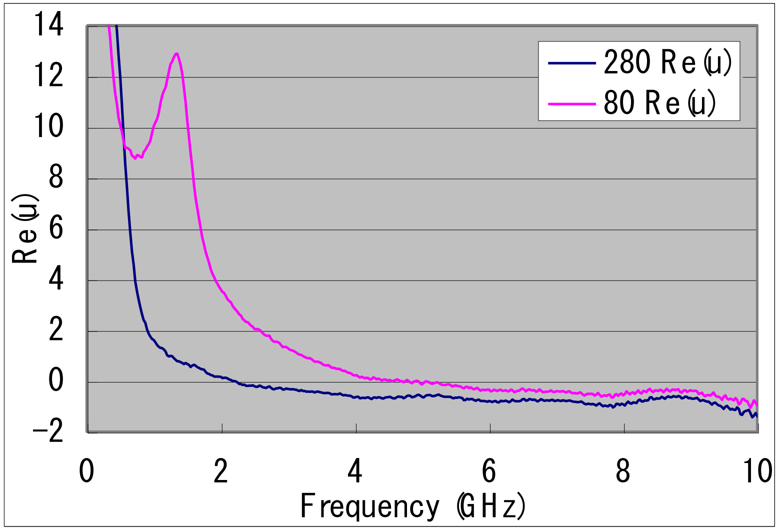
Im(e)
Frequency (GHz)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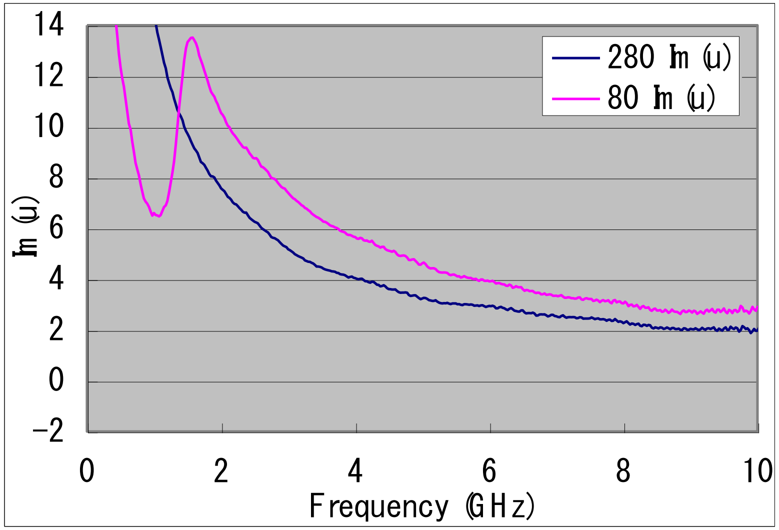
Re(u)
Frequency (GHz)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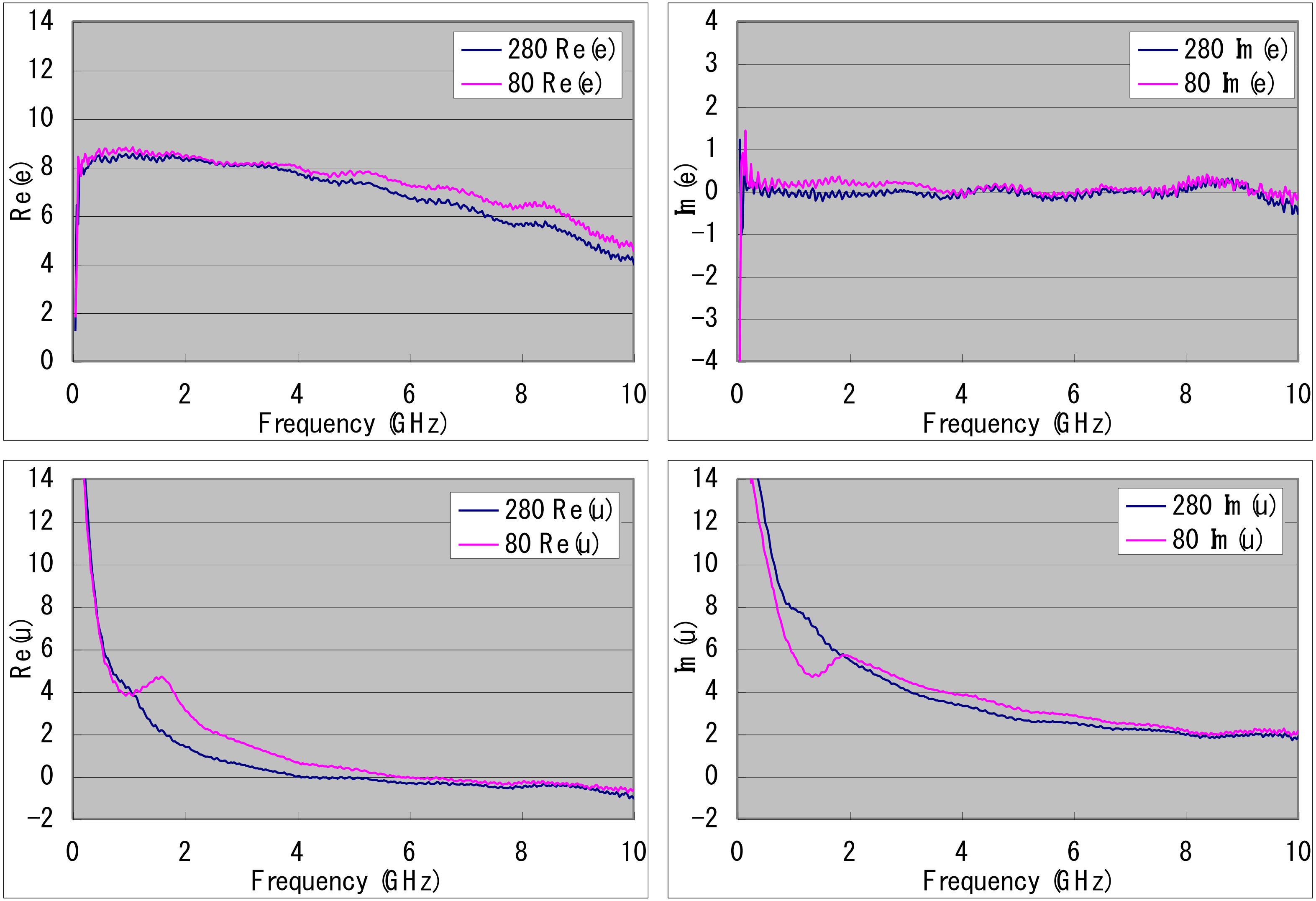
80 Im(u)
Im(u)
Frequency (GHz)

TT2-4000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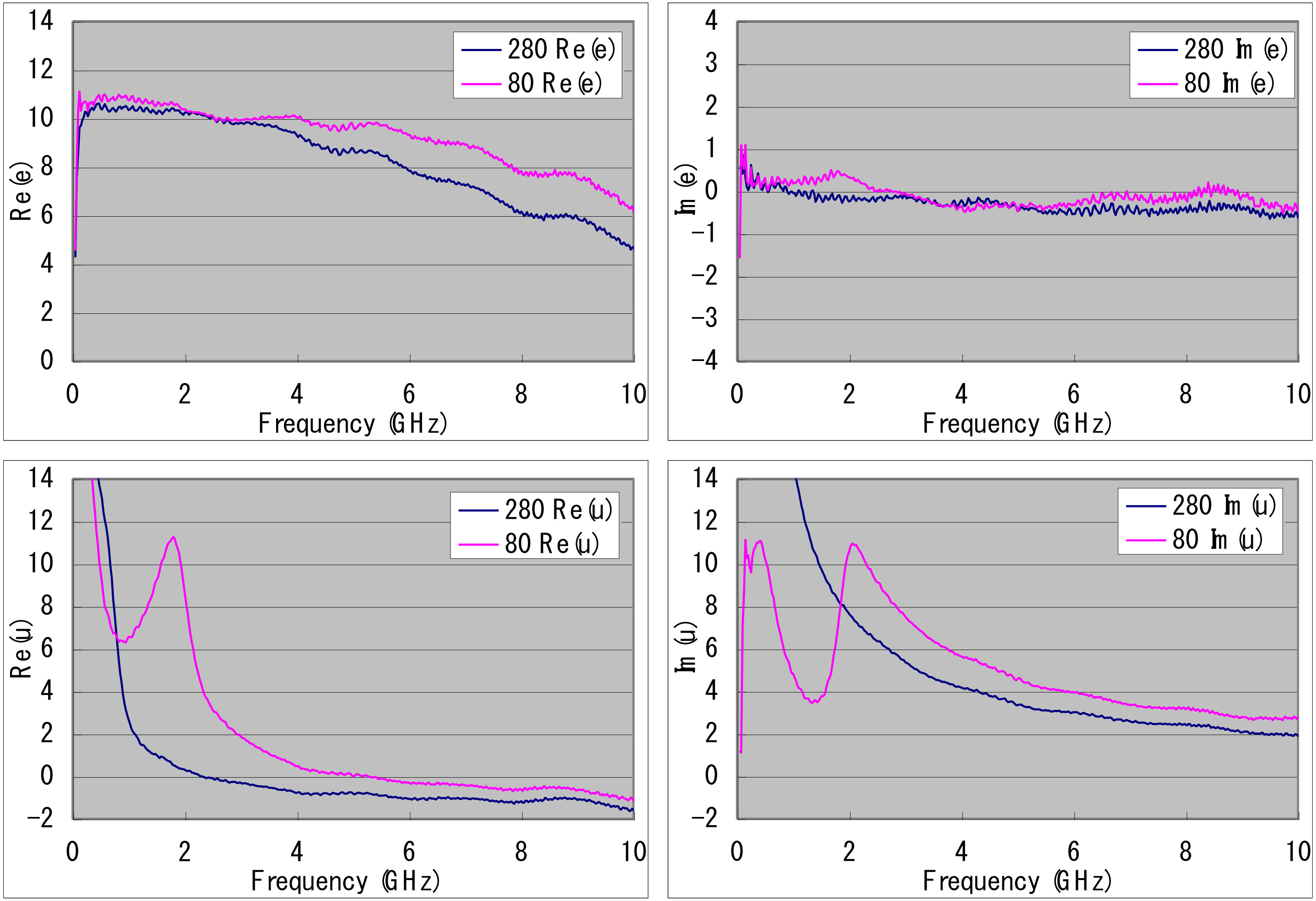
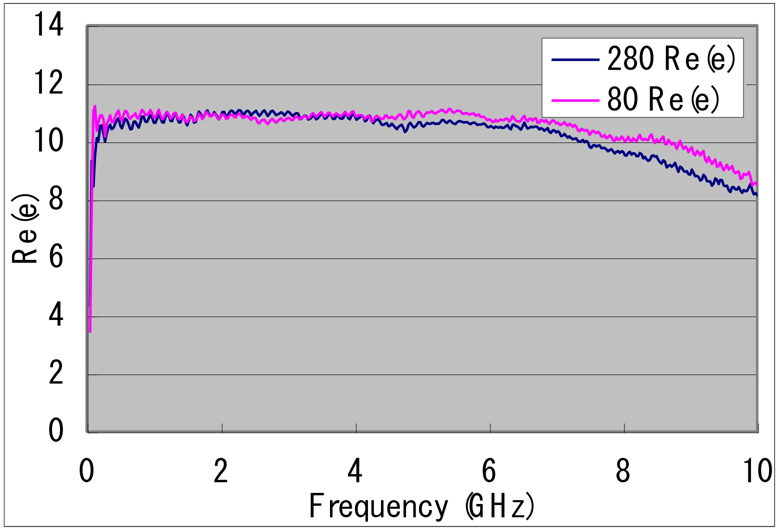
80 Re(e)
Re(e)
Frequency (GHz)
280 Im(e)
80 Im(e)
Im(e)
Frequency (GHz)
280 Re(u)
80 Re(u)
Re(u)
Frequency (GHz)
280 Im(u)
80 Im(u)
Im(u)
Frequency (GHz)

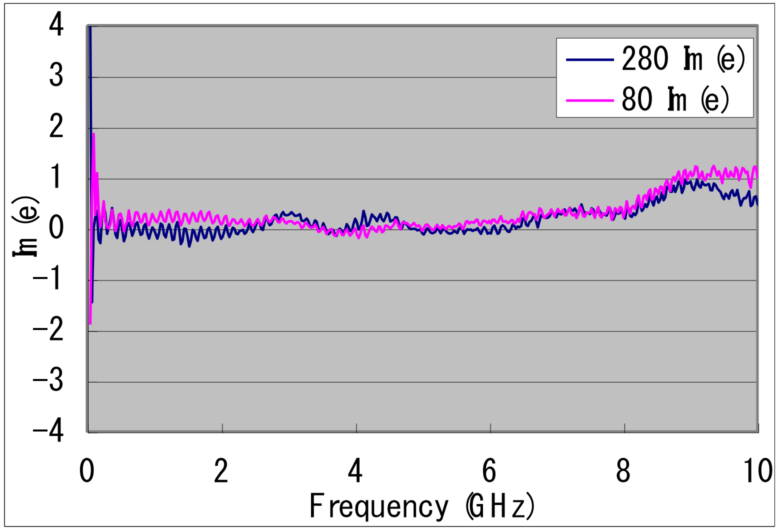
TT86-6000


280 Re (e)
80 Re (e)
Re (e)
Frequency (GHz)
280 Im (e)
80 Im (e)
Im (e)
Frequency (GHz)
280 Re (u)
80 Re (u)
Re (u)
Frequency (GHz)
280 Im (u)
80 Im (u)
Im (u)
Frequency (GHz)

Nikko



280 Re(e)
80 Re(e)
Re(e)
Frequency (GHz)



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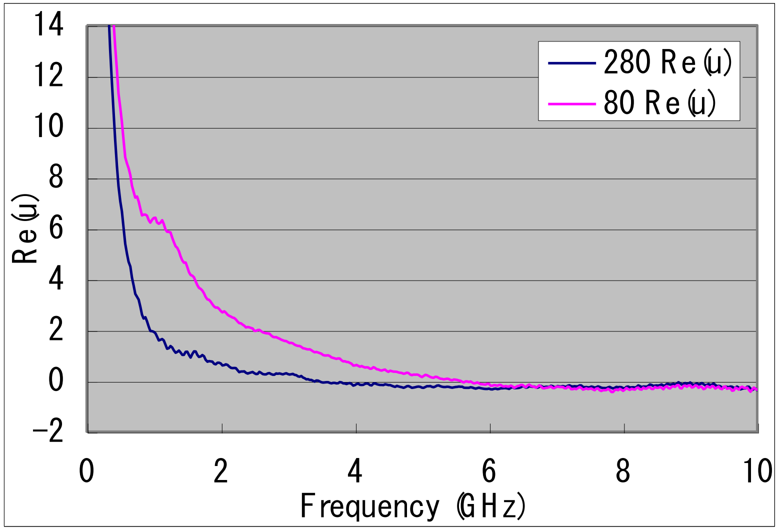
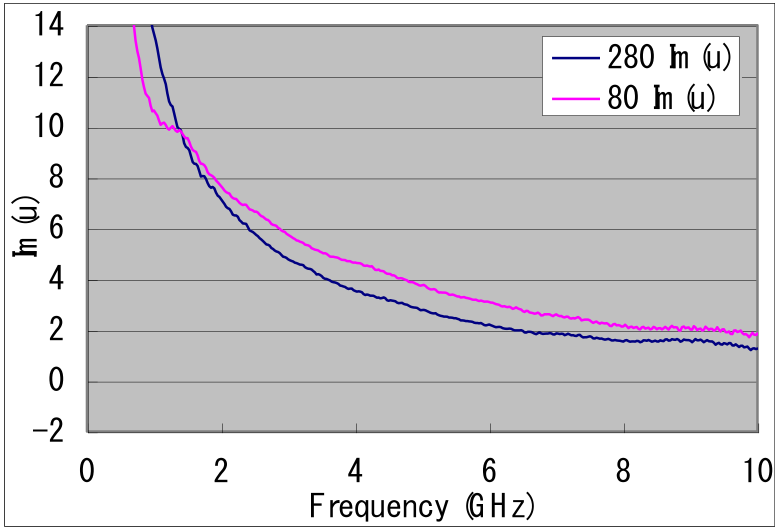
80 Im (e)
Im (e)
Frequency (GHz)

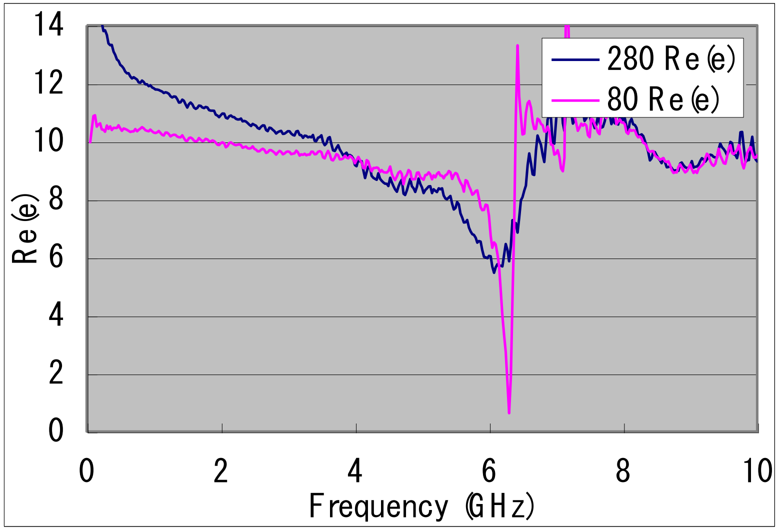


280 Re(u)
80 Re(u)
Re(u)
Frequency (GHz)



280 Im (u)
80 Im (u)
Im (u)
Frequency (GHz)

SiC


280 Re (e)
80 Re (e)
Re (e)
Frequency (GHz)
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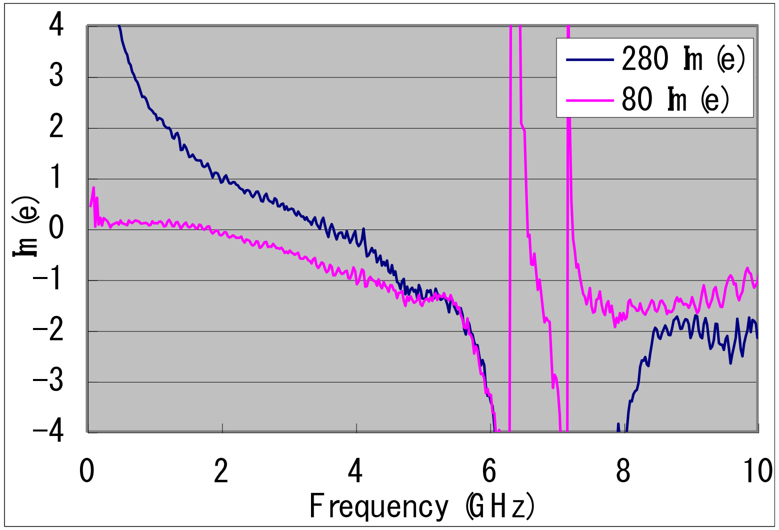
2
4
6
8
10
12
14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Im (e)
Frequency (GHz)
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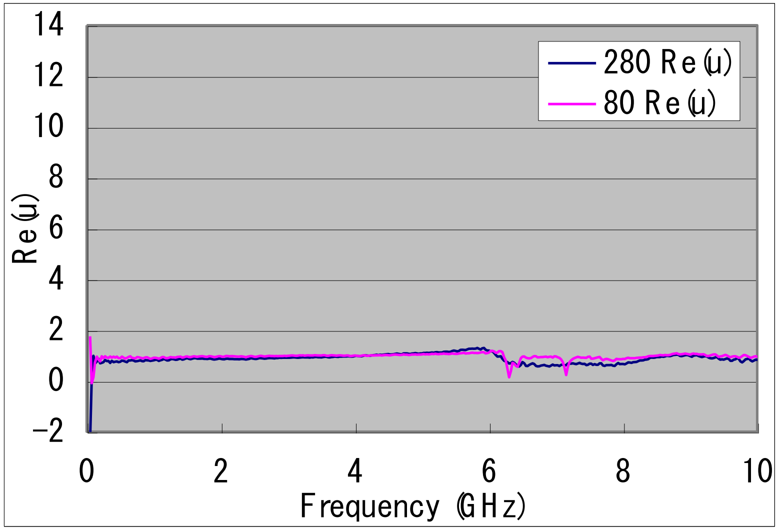
3
2
1
0
−1
−2
−3
−4


280 Re (u)
80 Re (u)
Re (u)
Frequency (GHz)
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0
2
4
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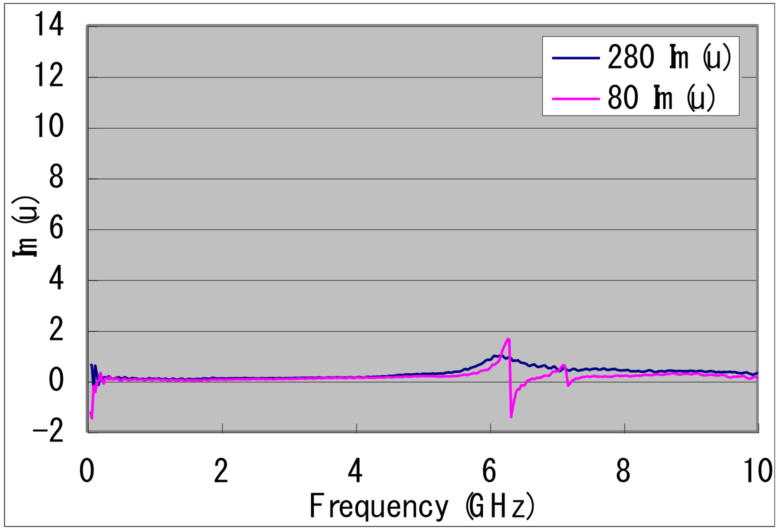
10
12
14


280 Im (u)
80 Im (u)
Im (u)
Frequency (GHz)
−2
0
2
4
6
8
10
12
14

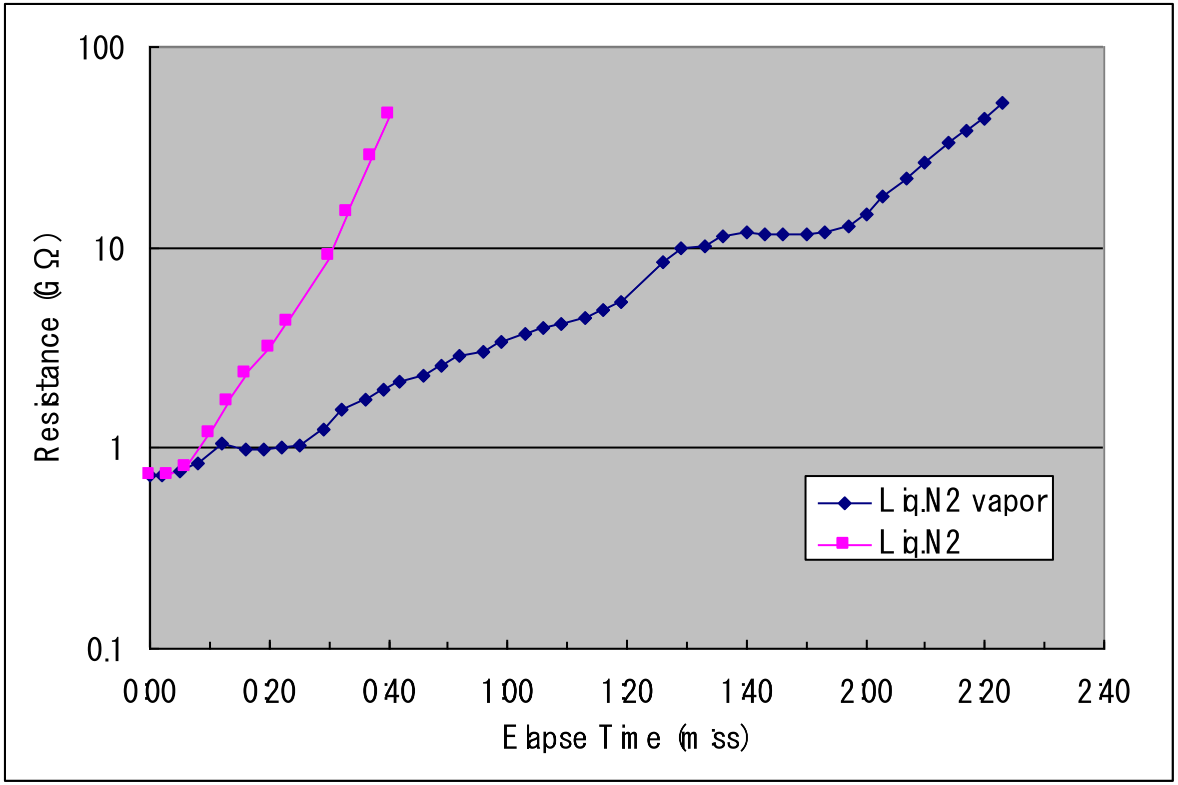
Resistance measurement at Low Temperature

- We roughly observed ferrite resistance change at low temperature
- Material：Old-type IB004
- Device: ADVANTEST Ultra High Resistance Meter
  – Measurable up to about 50GΩ

Setup

- Connected electrodes with crips
  - Ferrite was soaked into Liq. N2
  - Ferrite was kept in Liq. N2 vapor
    - -154℃ by contact thermometer

Result



- Unknown absolute temperature, but temperature decreased with time
- The lower temperature, the higher resistance
- More than 2 order

Conclusion

- ε and μ Ferrite materials were measured

Similar trend at RT and 80K	Old-type IB004 New-type IB004 TT2-4000 Nikko
Appear peak at low frequency at 80K	Ferrite50 TT2-111 TT86-6000
Decrease μ of low frequency at 80K	Co2Z

- Ferrite resistance was roughly measured at low temperature
  – The lower temperature, the higher resistance