

 TOYO Corporation

 LakeShore

極低温プローバーによる
物性の電気特性評価

B-4

セミナーの概要

- なぜプローブステーションを使うのか
- プローブステーションの概要
- 冷却
- 微小電流測定
- 高周波測定
- 温度スイープ
- プローブステーションのバリエーション

用途と特徴

用途

- 半導体のホール効果
- ナノドット/ナノワイヤ
- 有機デバイス
- 超伝導体
- スピントロニクス
- トンネル接合

特長

- 直流の電圧/電流
- 高周波 67 GHz
- 磁場特性 2.5T
- 温度特性 1.5K – 675K
- 光の導入
- 高真空

極低温プローブステーションの概要

- 温度、磁場、電圧、電流、光など
- 複数のサンプル

極低温 1.5K ~ 高温 675 K



プローブ先端の動き



バリエーション

Horizontal Field



NEW!

水平磁場



Vertical Field



NEW!

垂直磁場



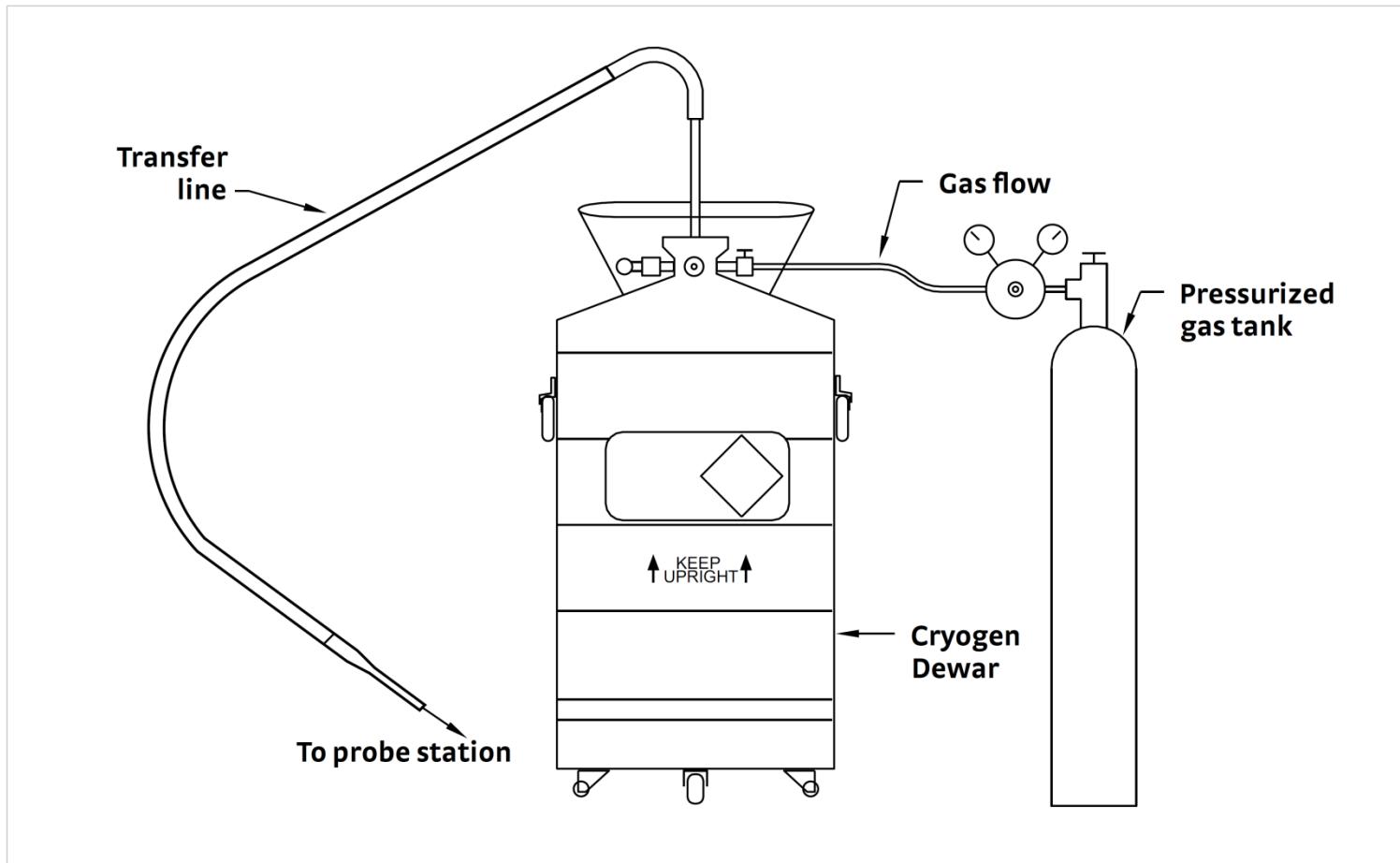
No Field



冷却

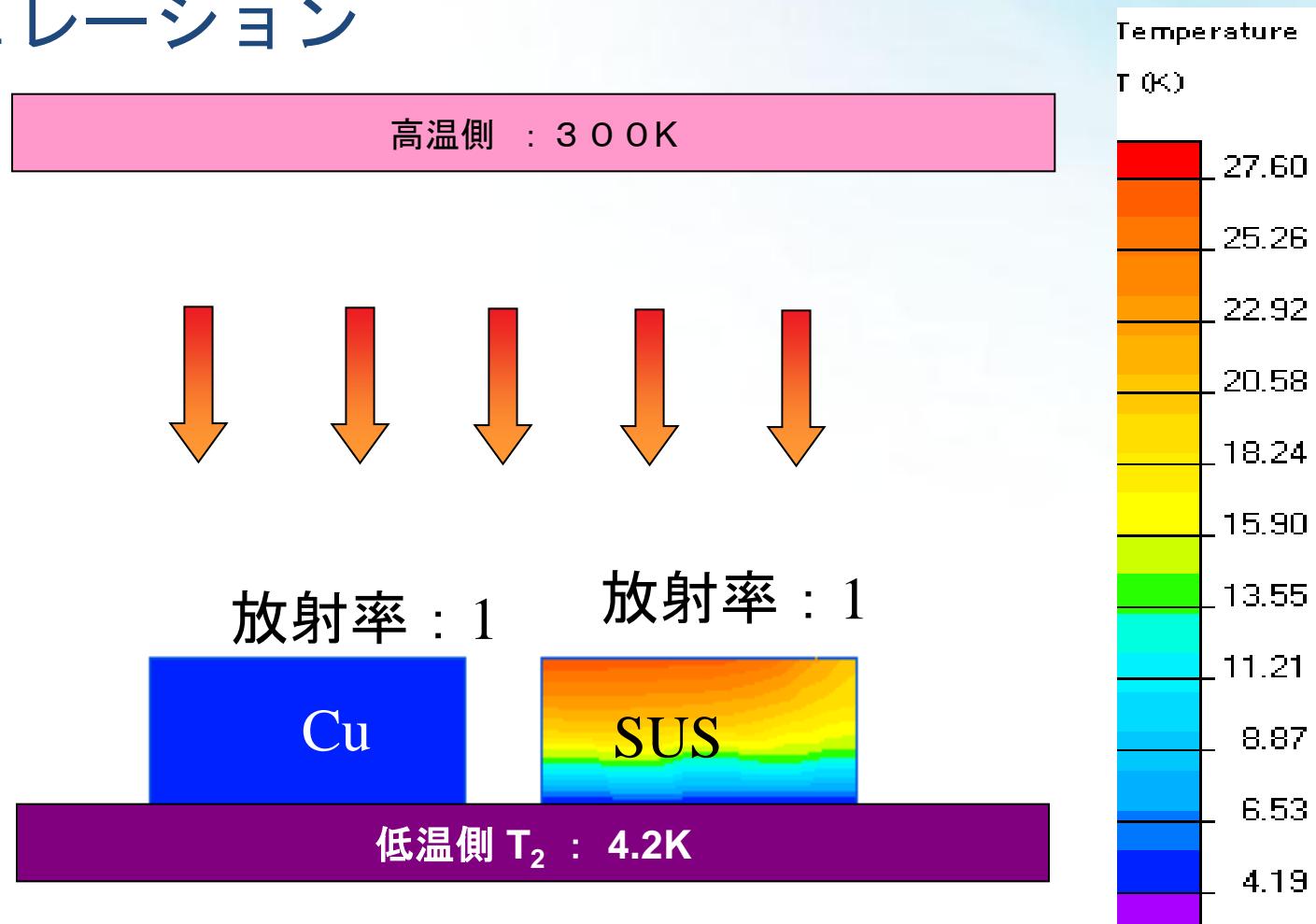
- 寒剤 or 冷凍機
- 放射熱とサンプルの温度

寒剤を使う場合



放射熱とサンプルの温度

シミュレーション



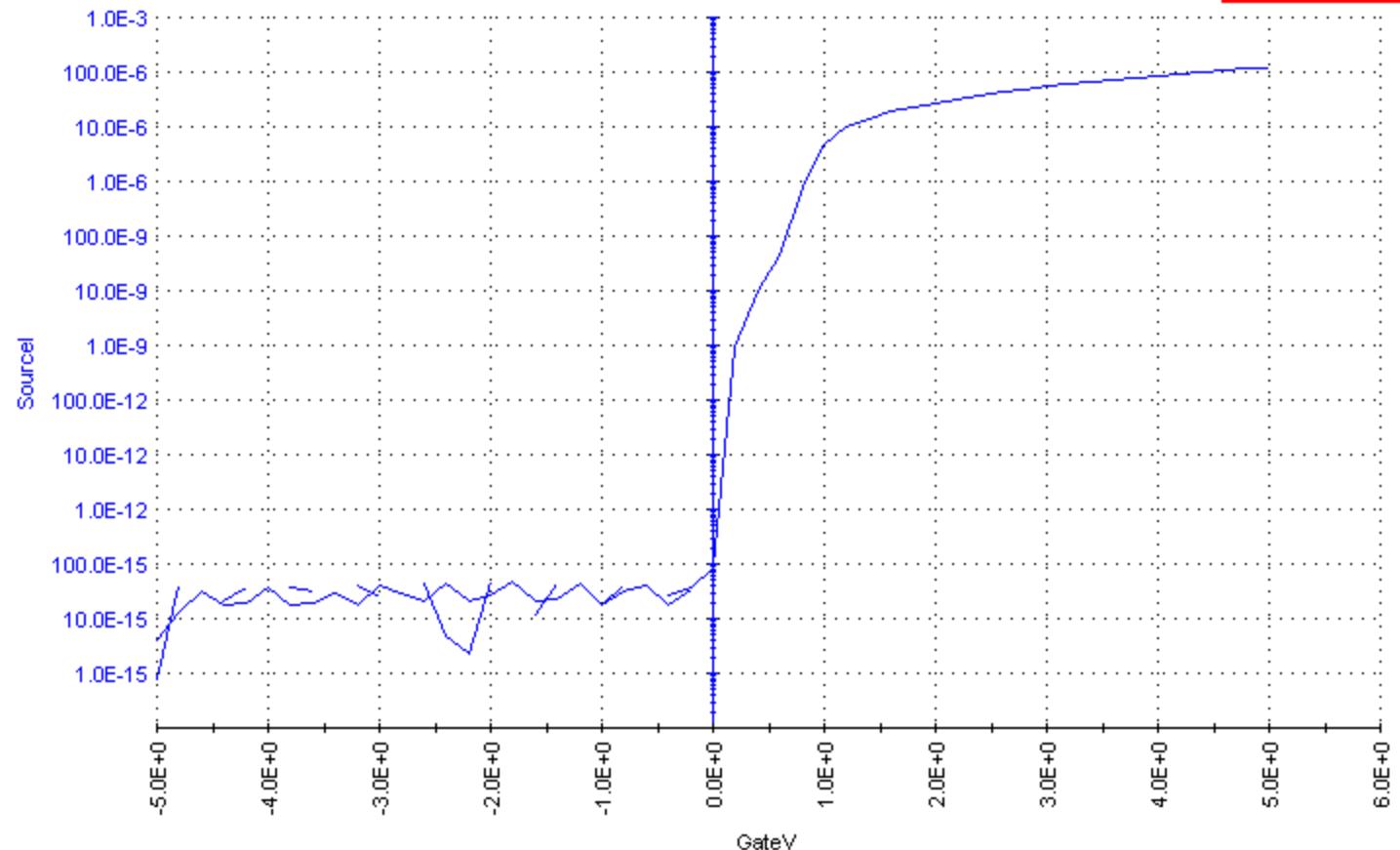
微小電流測定

- 低ノイズな微小電流測定ができること
- リーク電流が少ないこと

微小電流測定の実例

03/14/2013 16:06:23

KEITHLEY



使用機材

半導体パラメータアナライザ

- 4200-SCS



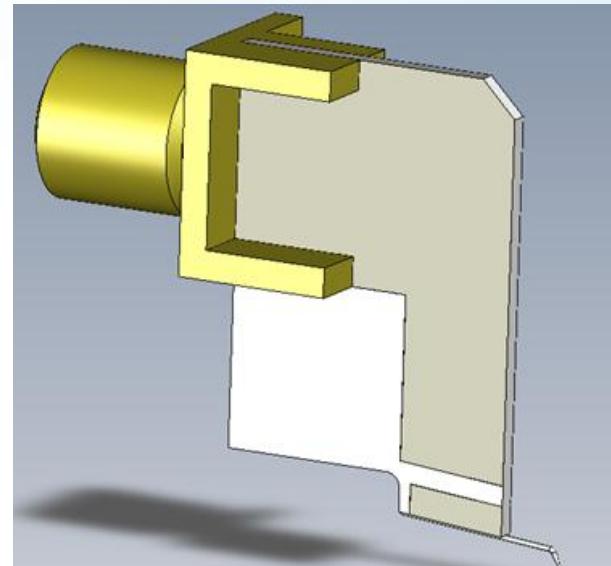
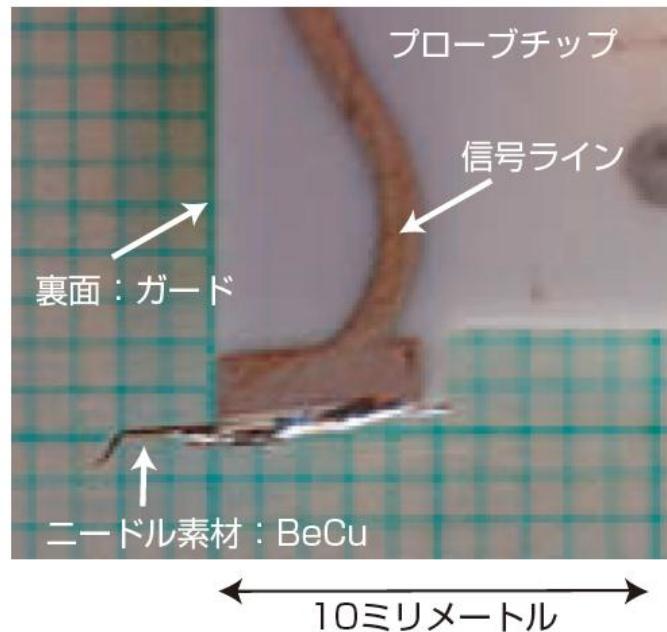
プローブステーション

- CRX-4K



リーク電流が少ない理由

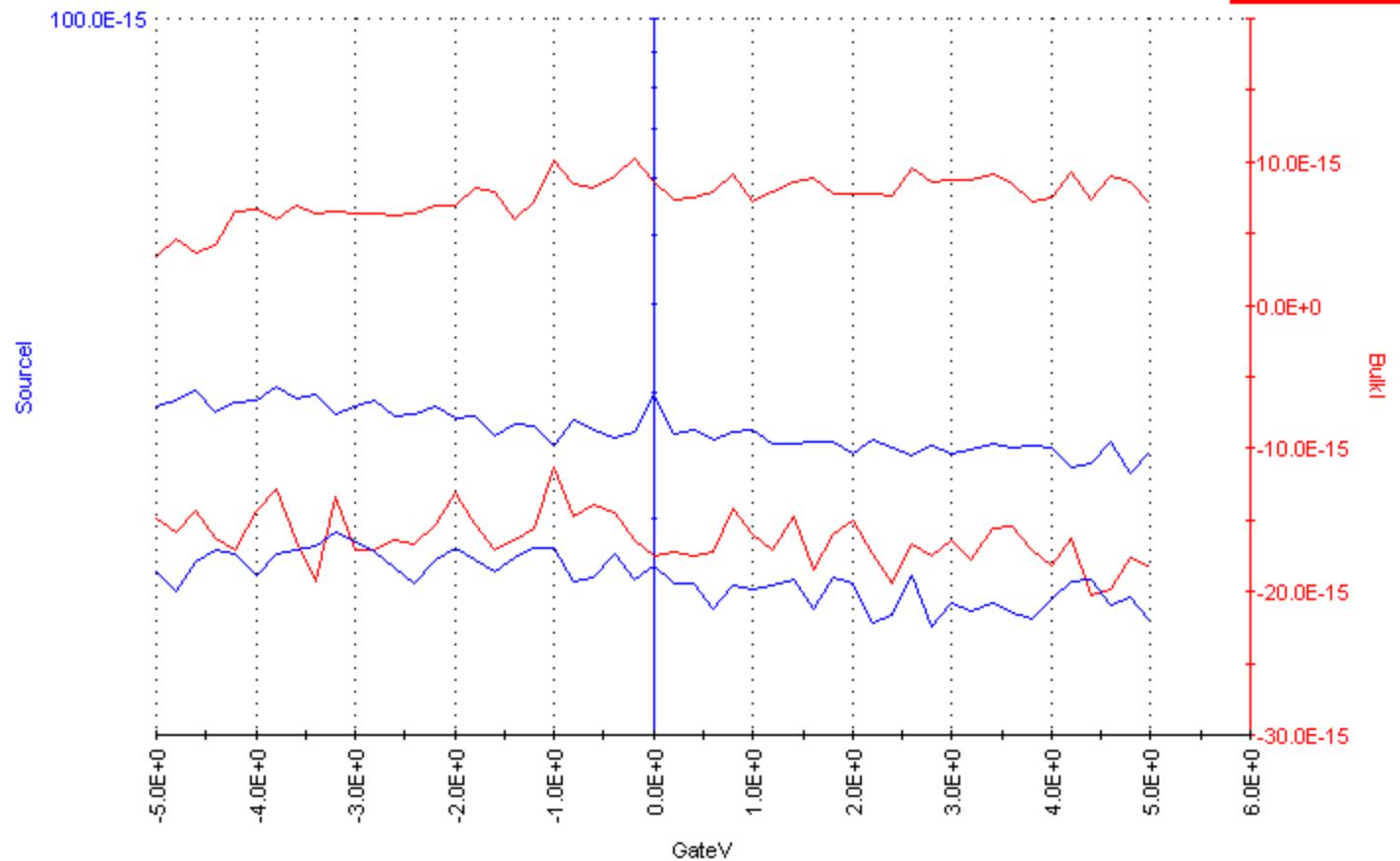
低ノイズプローブチップ(拡大写真)



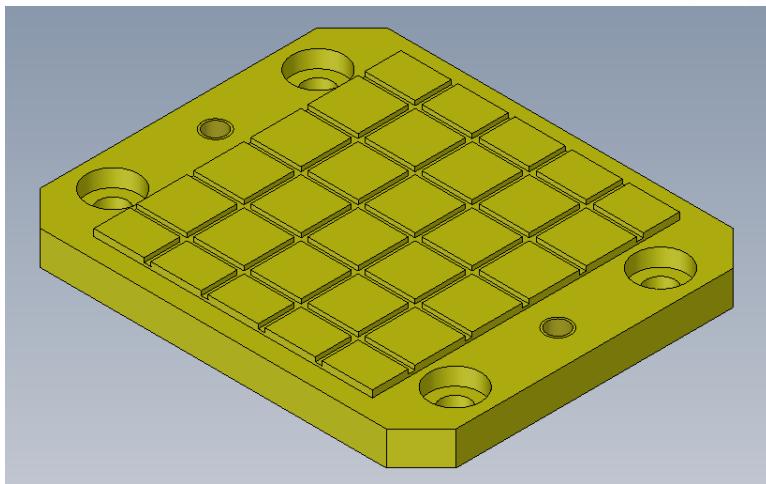
針先オープンでのリーク電流

03/14/2013 16:46:11

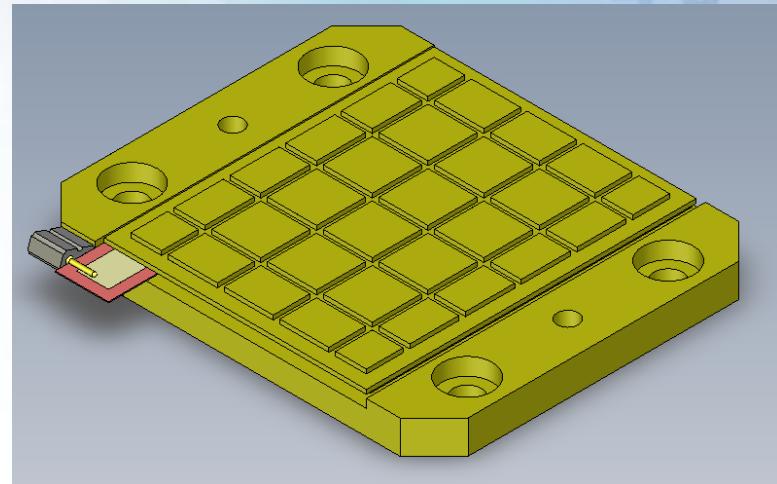
KEITHLEY



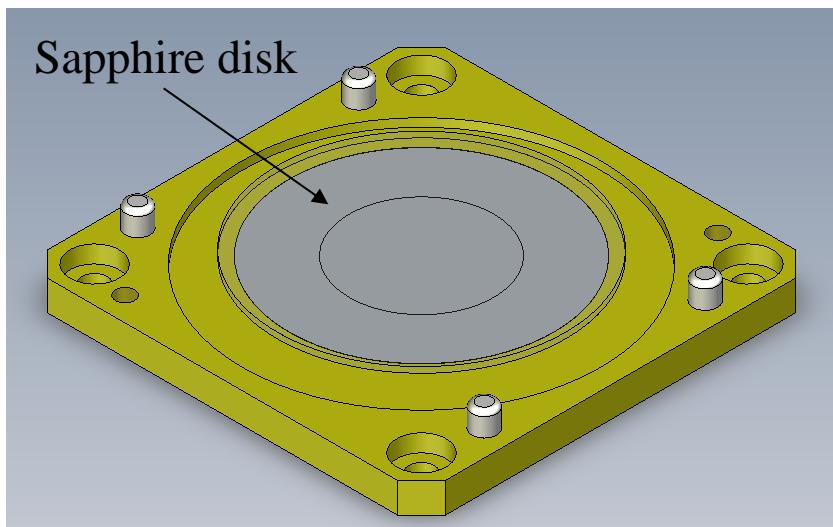
サンプルホルダー



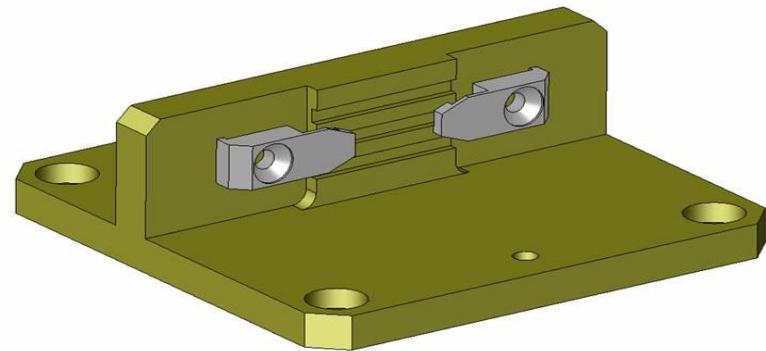
Grounded – direct contact to cold head



Coaxial/Triaxial – isolated conductive surface
(can control potential with external voltage)



Isolated – isolated non-conductive surface

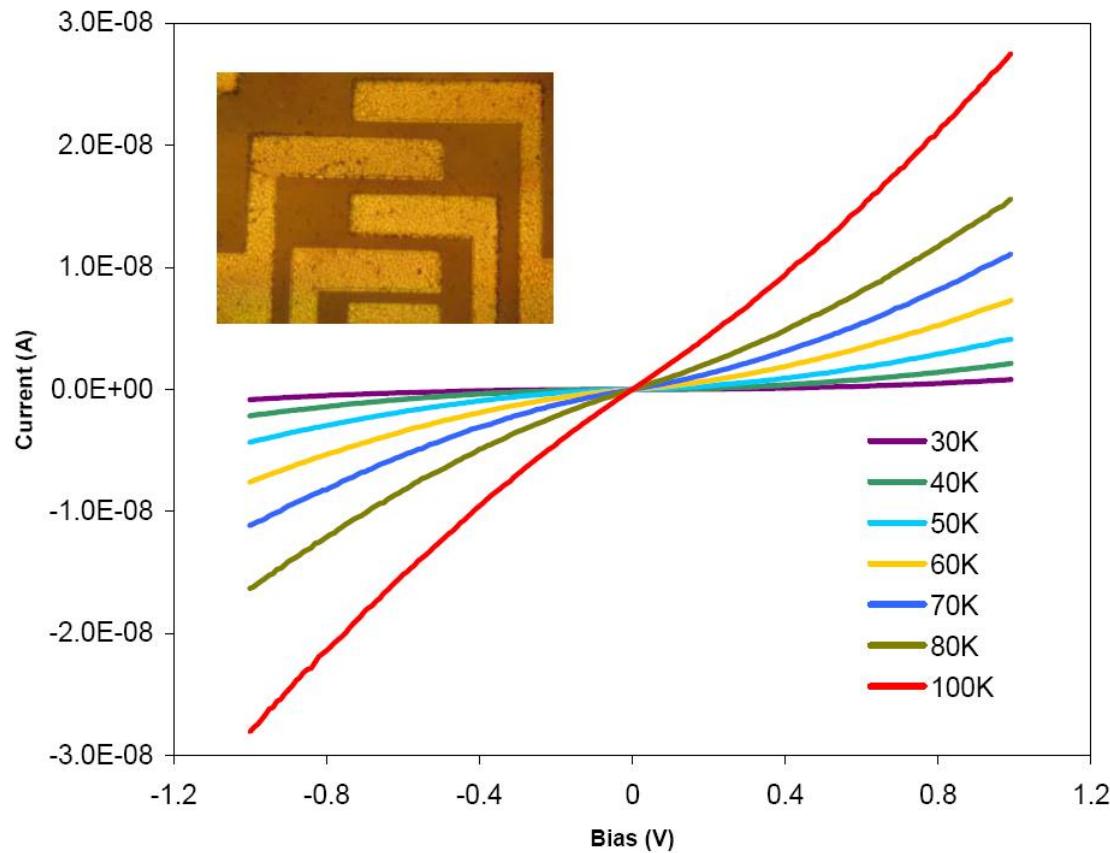


Custom – 90 degree in plane for Vertical Field

GaNナノワイヤの測定例

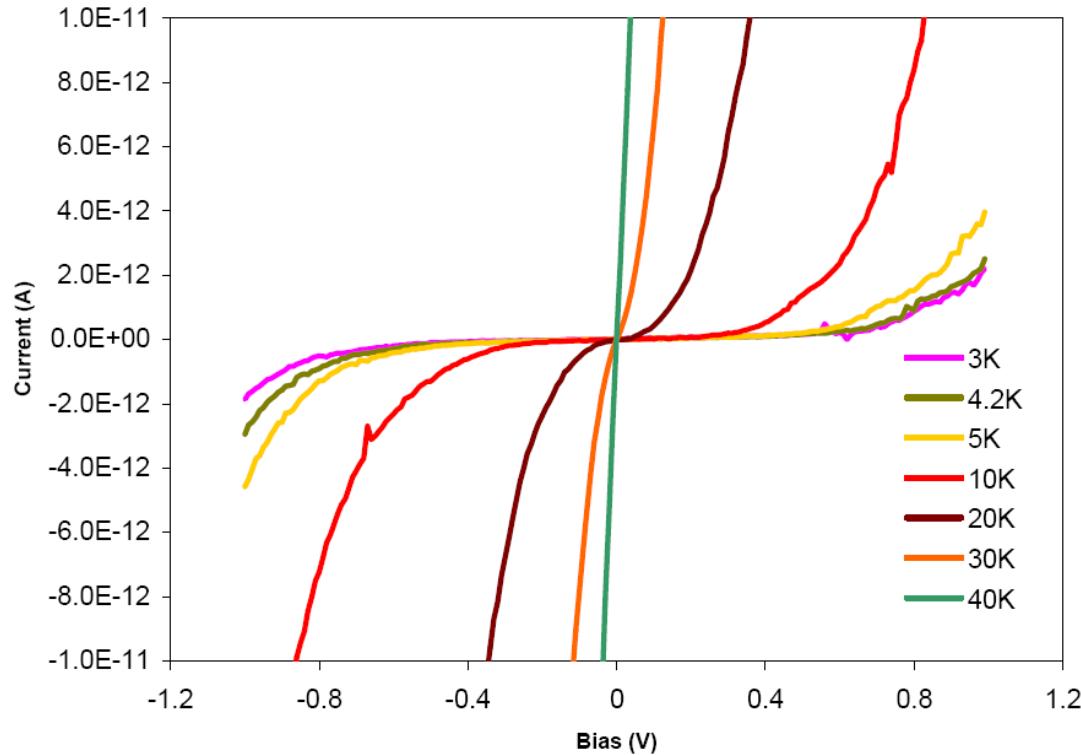
Nanowire

Typical (I-V-T) Results – GaN Nanowire (NIST)



Nanowire

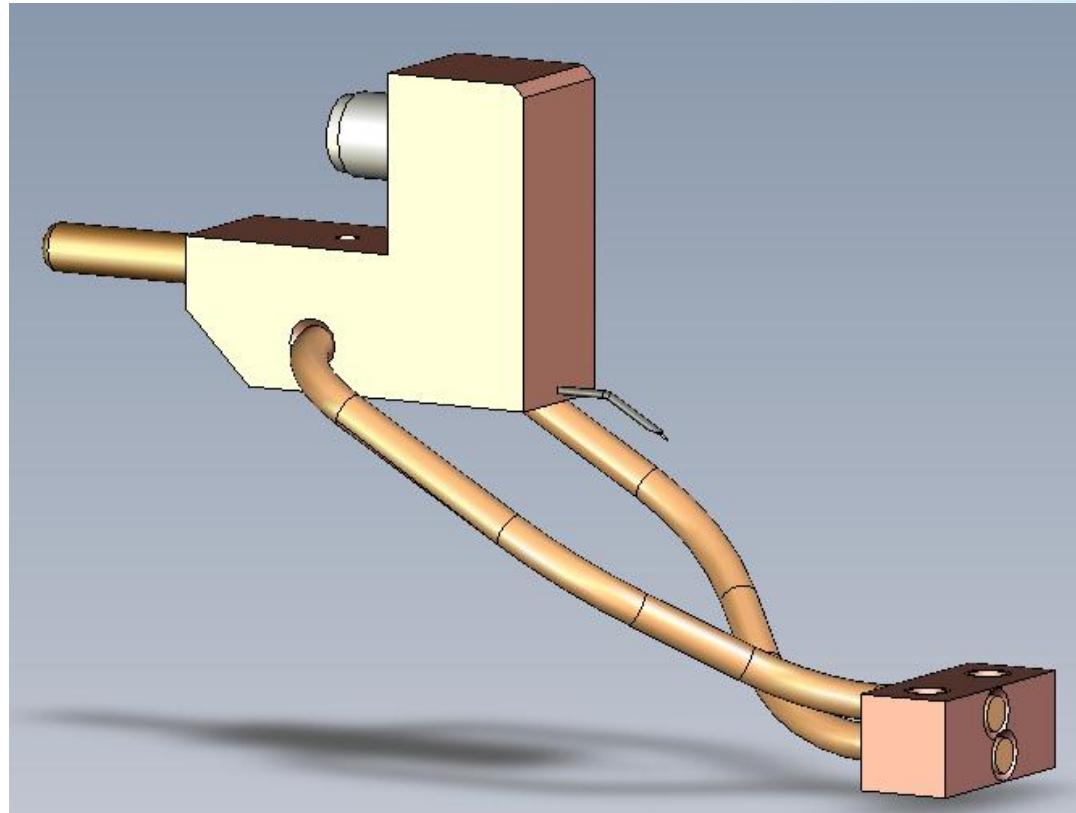
Typical (I-V-T) Results – GaN Nanowire (NIST)



高周波測定

- 反射やロスの少ない測定ができること
- 校正ができること

GSG マイクロウェーブプローブ



GSG microwave probe tip optimized for cryogenic operation

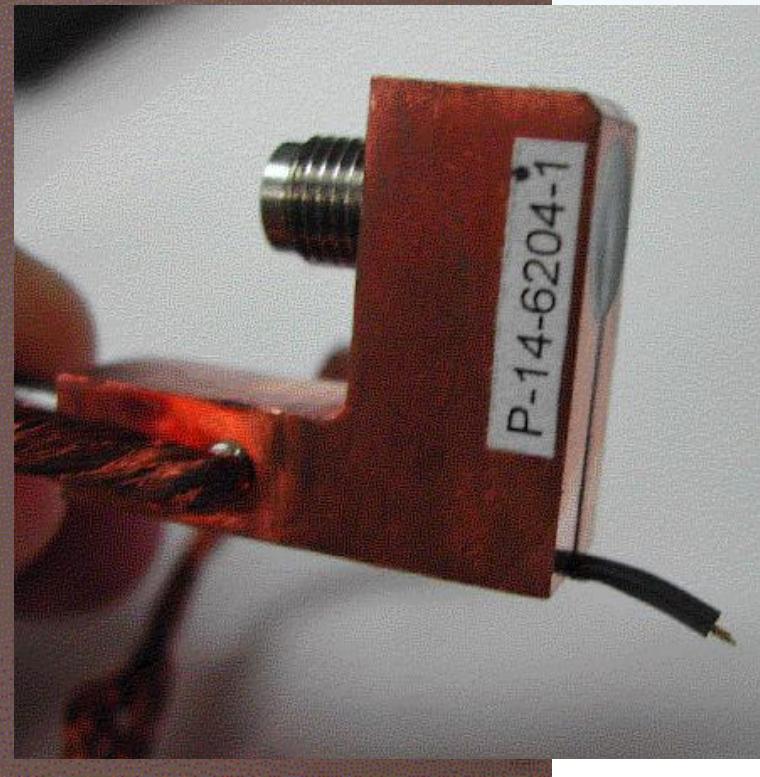
Ground Signal Ground (GSG) Microwave Probe

3/7/07

P-14-6204-9 S/N 69198

Post 48 hr. under vacuum only. Not mated to cable

1	2-Points:	101.97	mi
2	2-Points:	99.54	mi



VNAとの組み合わせ

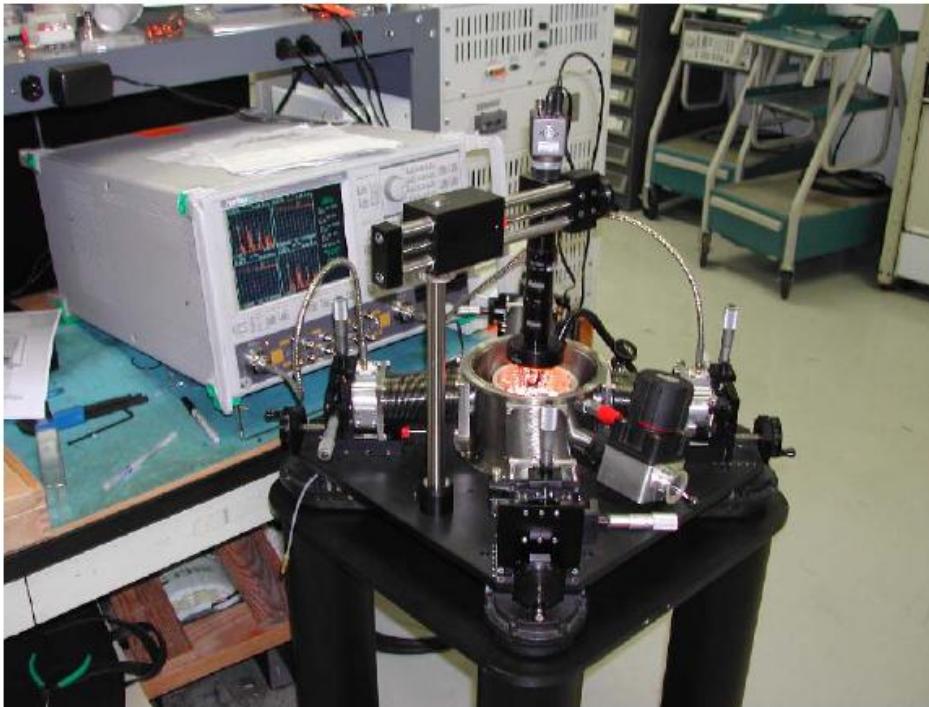
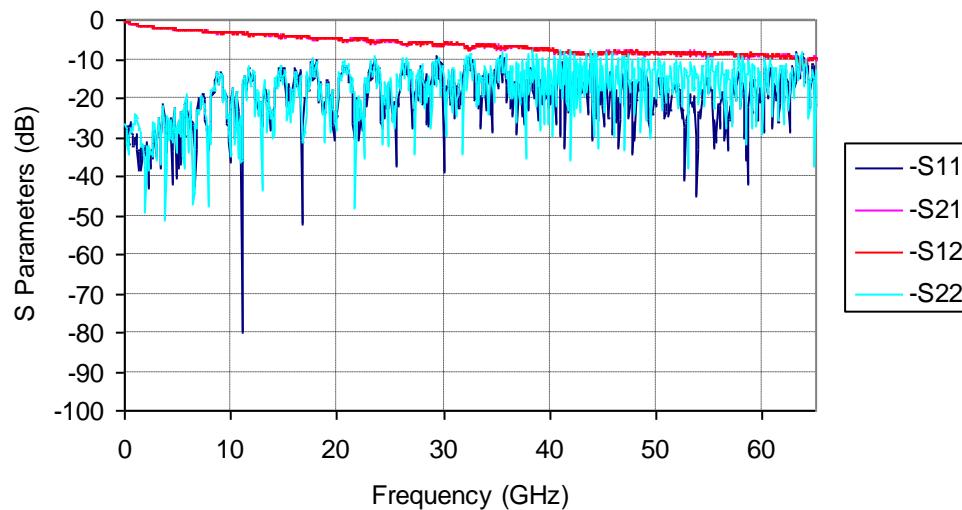
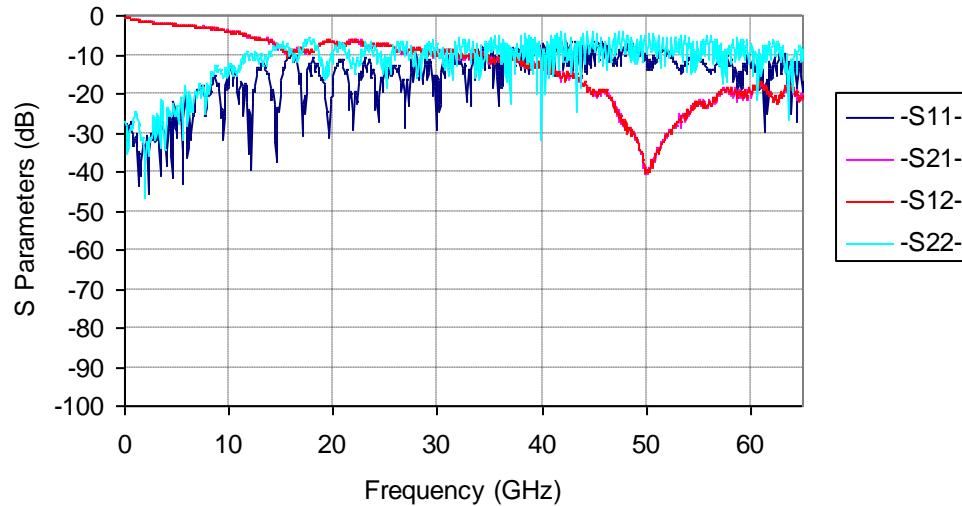
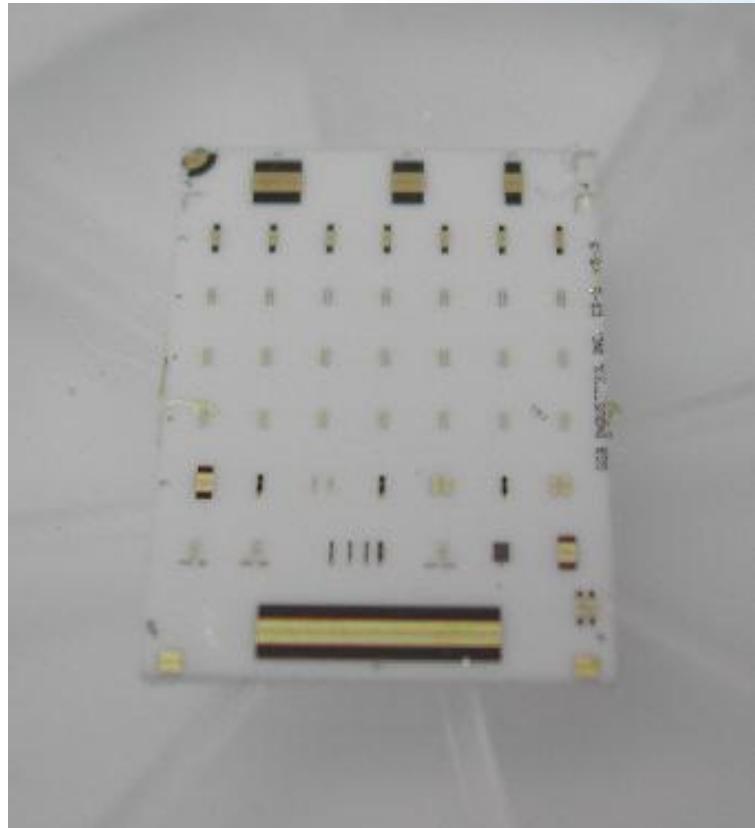


FIGURE 5: TTP4 Probe Station Microwave Measurement Setup with Anritsu 37397D Lightning VNA

プレーナライゼーション

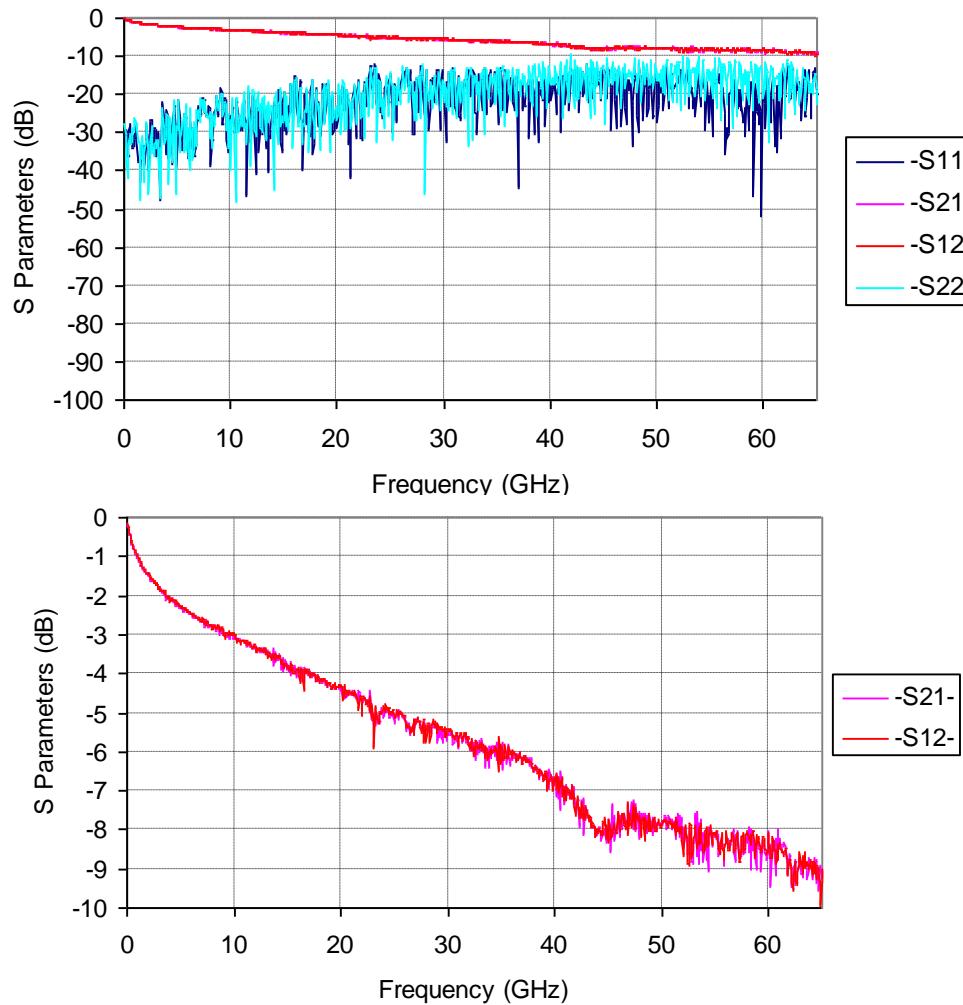


校正用基板

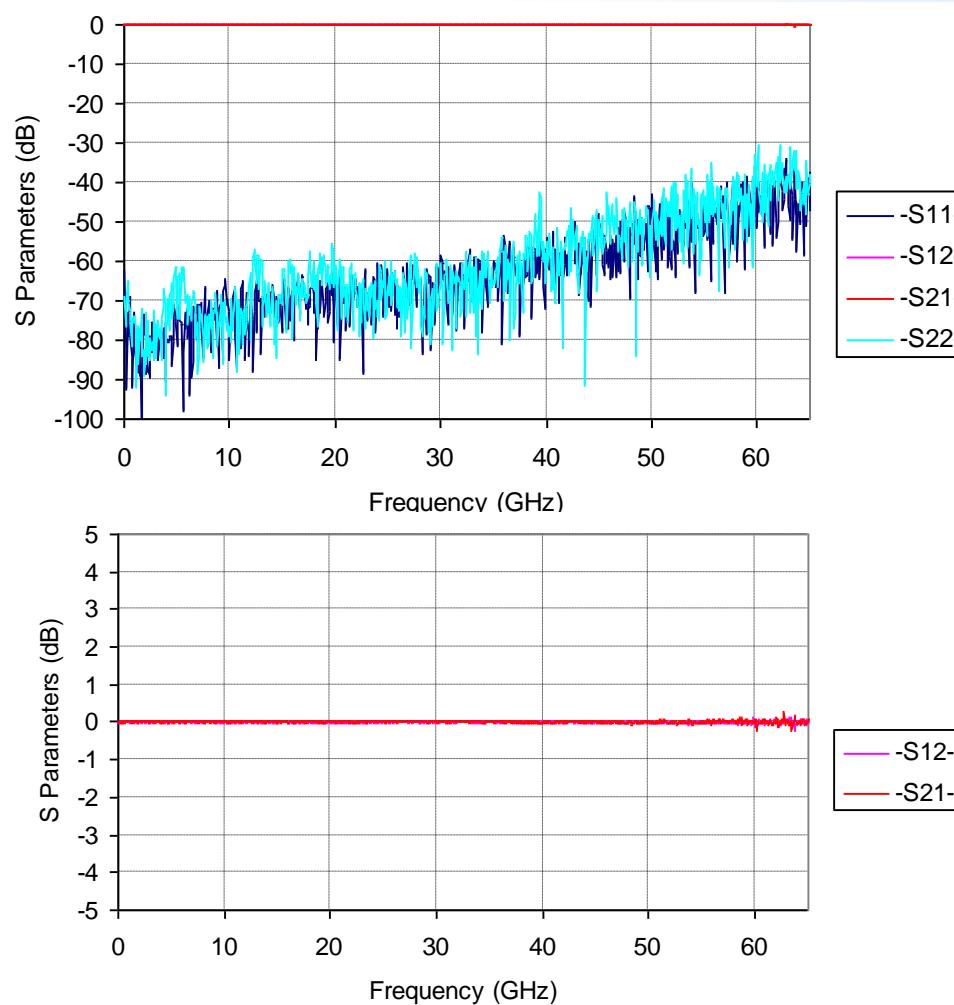


Standard substrate supports SOLT, TRL, TRM calibrations

Probe Station Uncalibrated Frequency Response (67 GHz probes with 1.85 mm connectors)



Probe Station Calibrated Frequency Response (67 GHz probes with 1.85 mm connectors)



Probe Station Calibrated Frequency Response Stability Over Temperature (67 GHz probes with 1.85 mm connectors @ 4.3K)

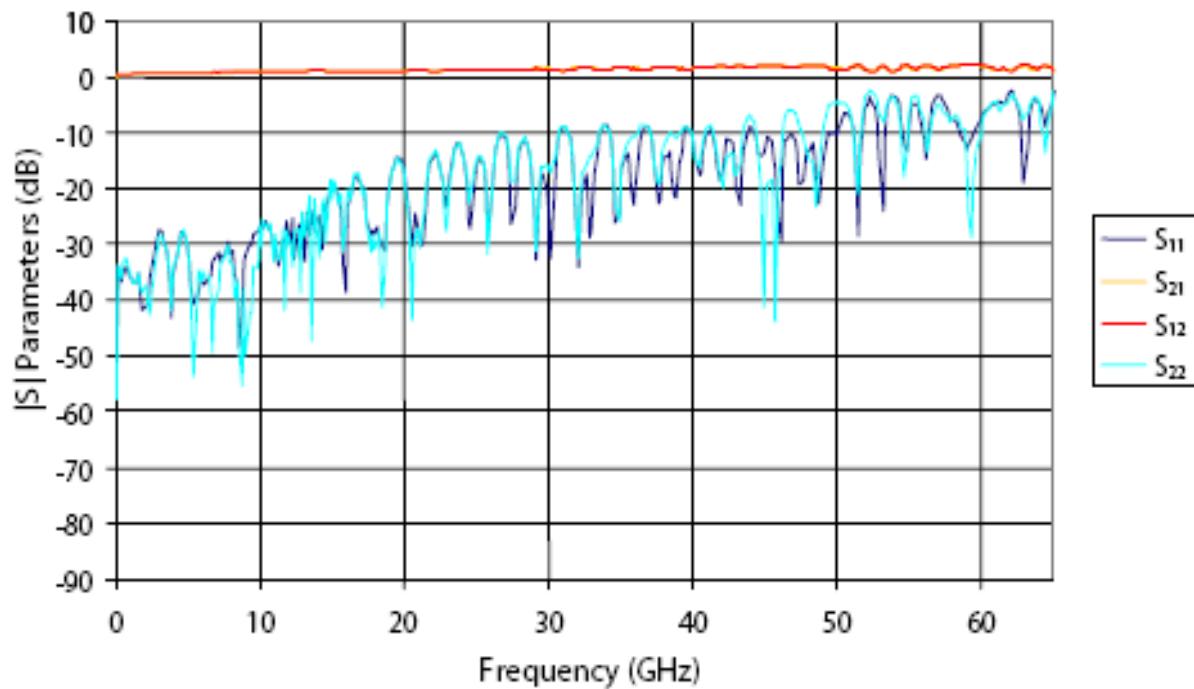


FIGURE 18: Microwave probes measured at 4.2 K after calibration with CS-5 substrate performed at 300 K

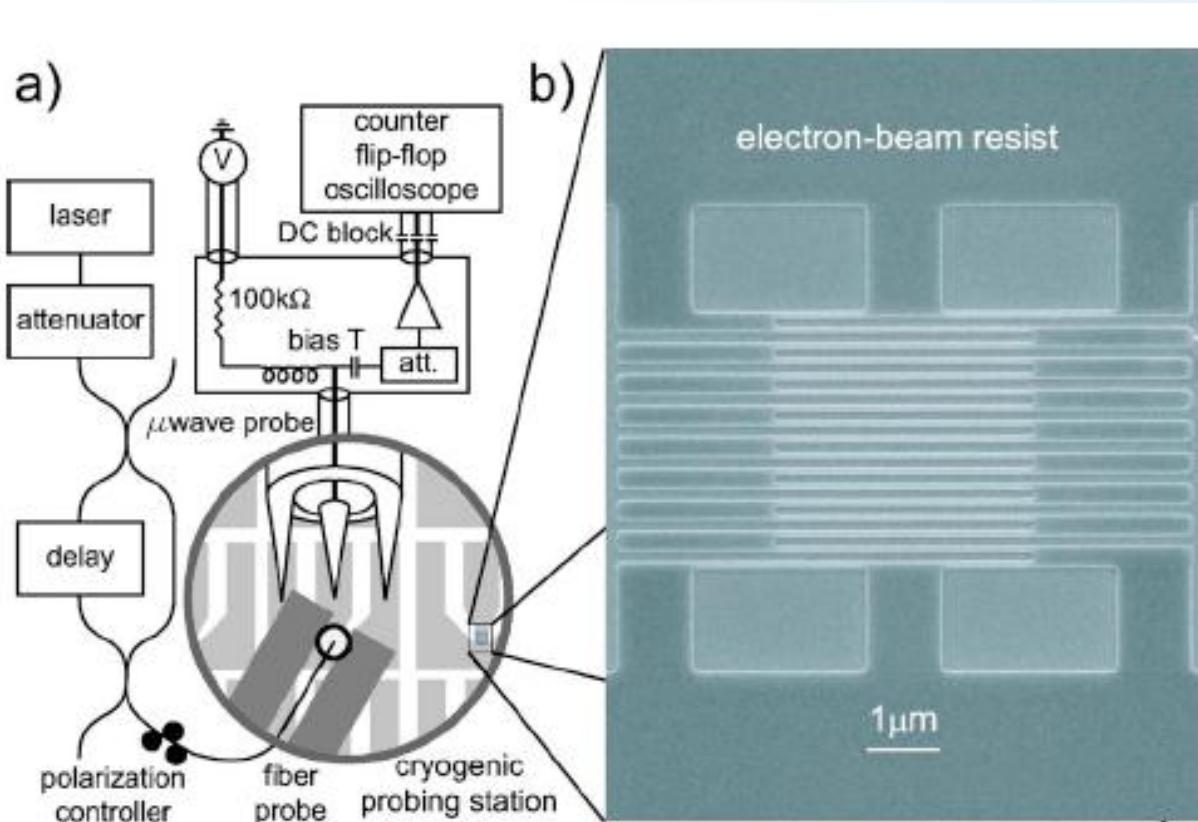
Recommend to calibrate at measurement temperature

高周波測定の実例

Nanowire

Kinetic-inductance-limited reset time of superconducting nanowire photon counter

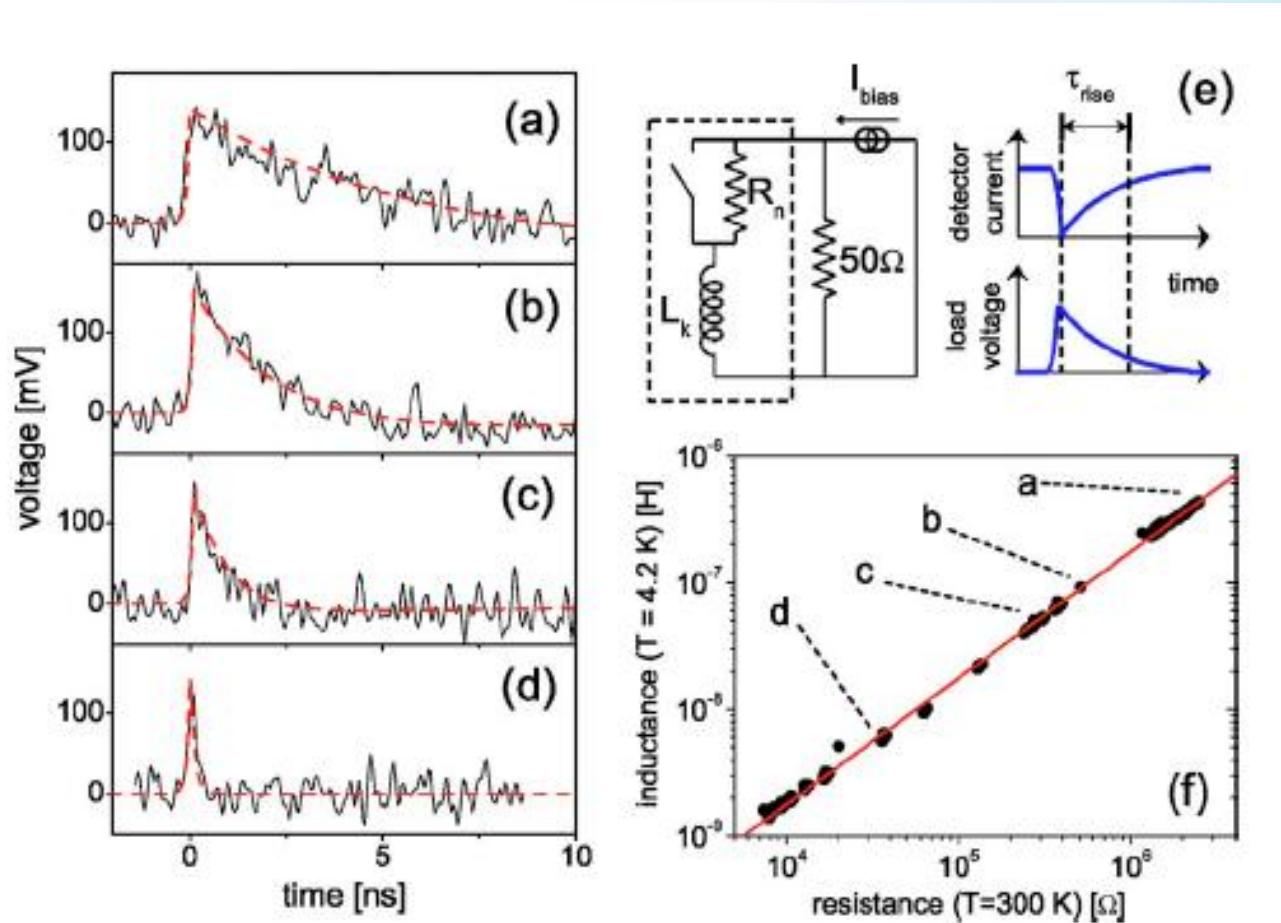
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Nanowire

Kinetic-inductance-limited reset time of superconducting nanowire photon counter

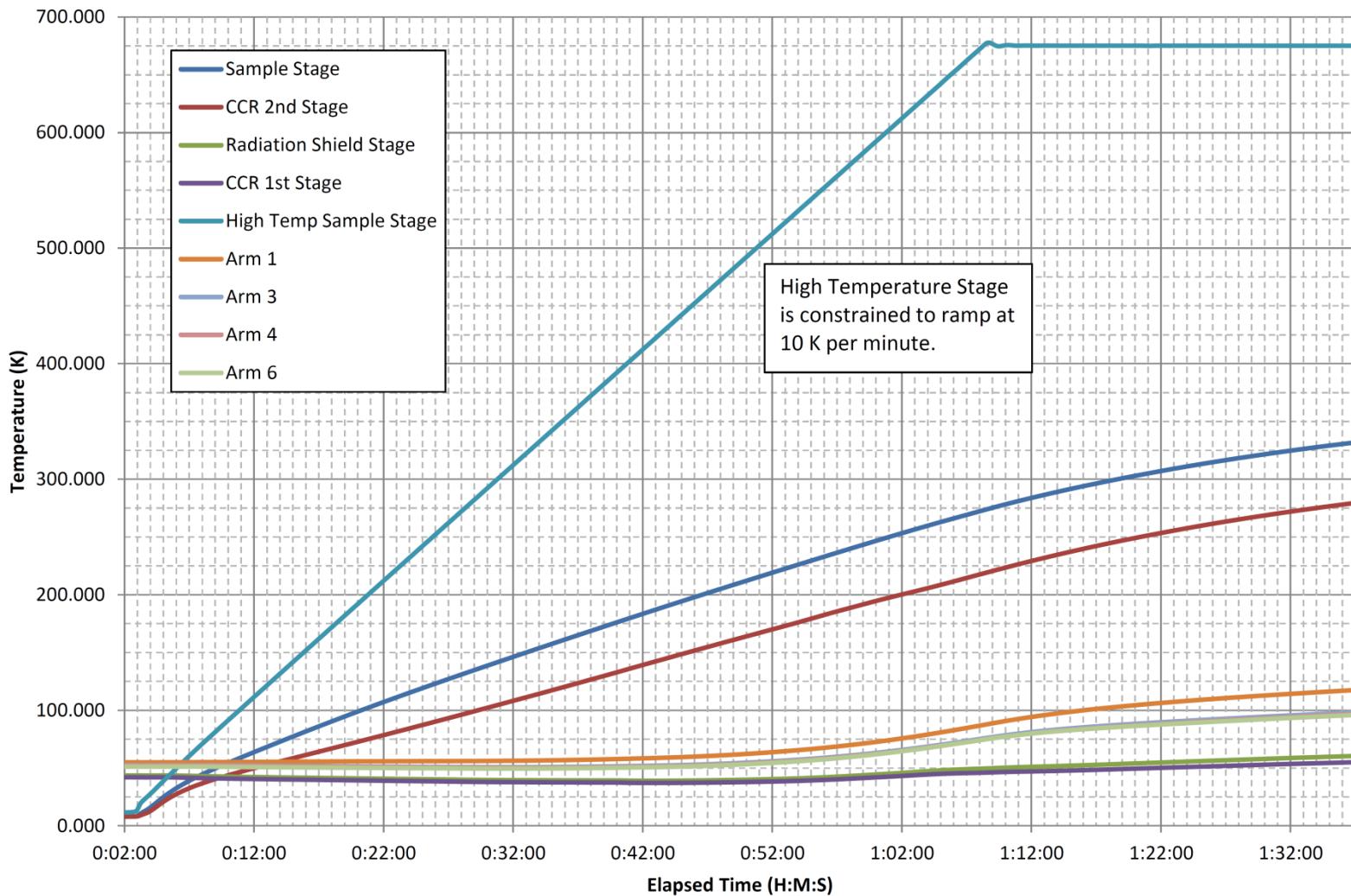
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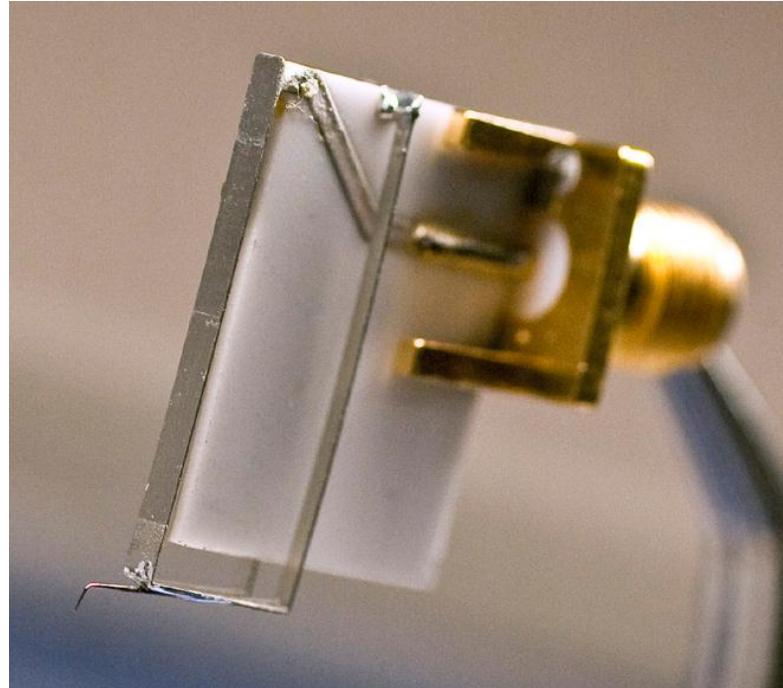
温度スイープ

- 温度勾配を一定に保つこと
- 針先が移動しないこと

High Temp Data - Verification Test 18: High Temperature Sample Holder 4 Arms tied to Radiation Shield

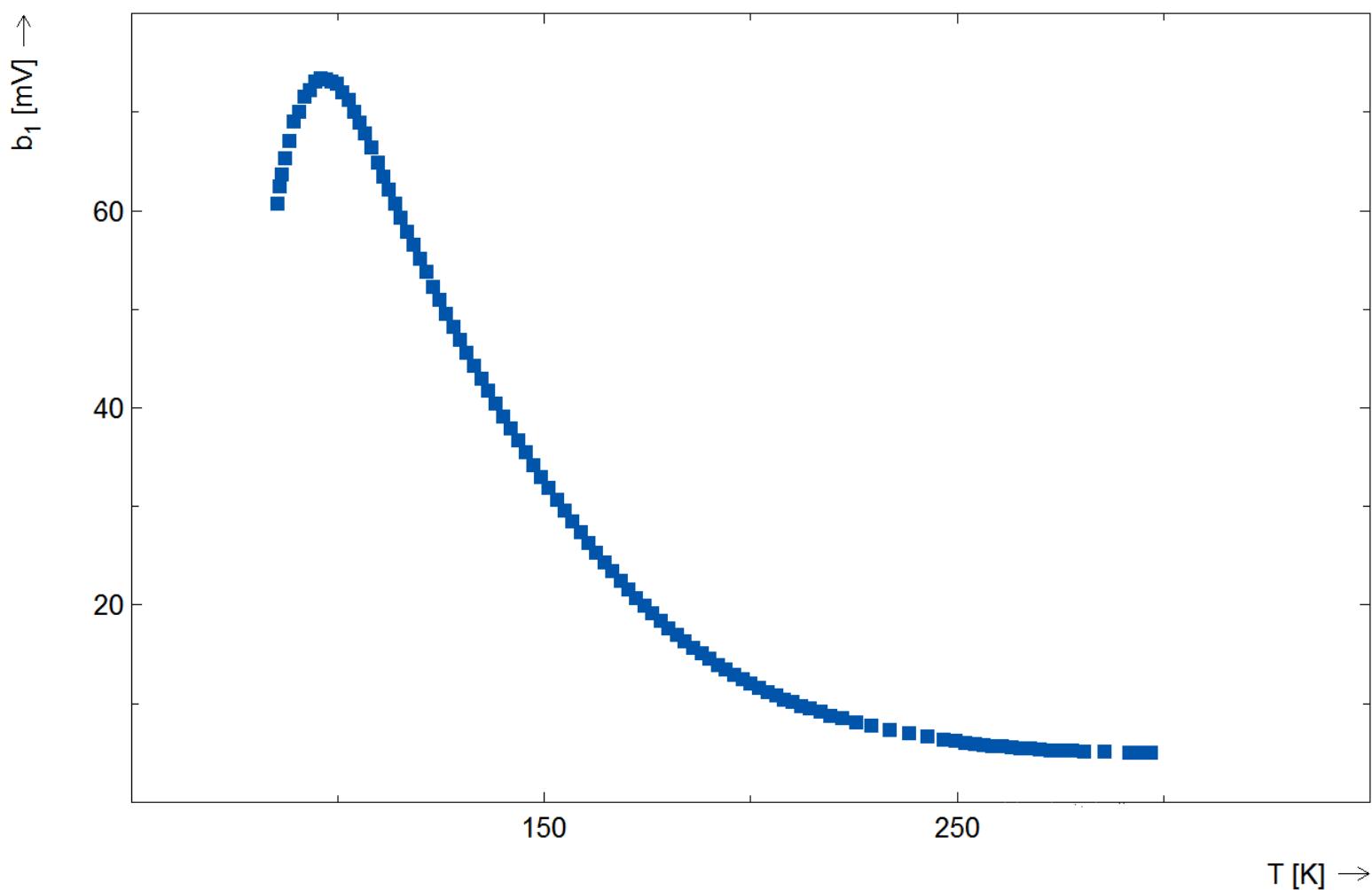


プローブの熱収縮問題と その解決策



CVTプローブで解決します

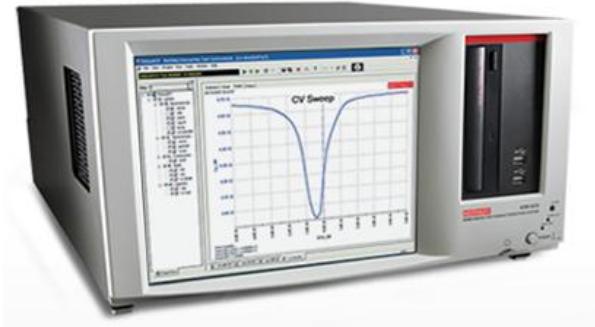
DLTS信号の測定例



自動測定ソフトウェア

半導体パラメータアナライザ

- 4200-SCS



プローブステーション

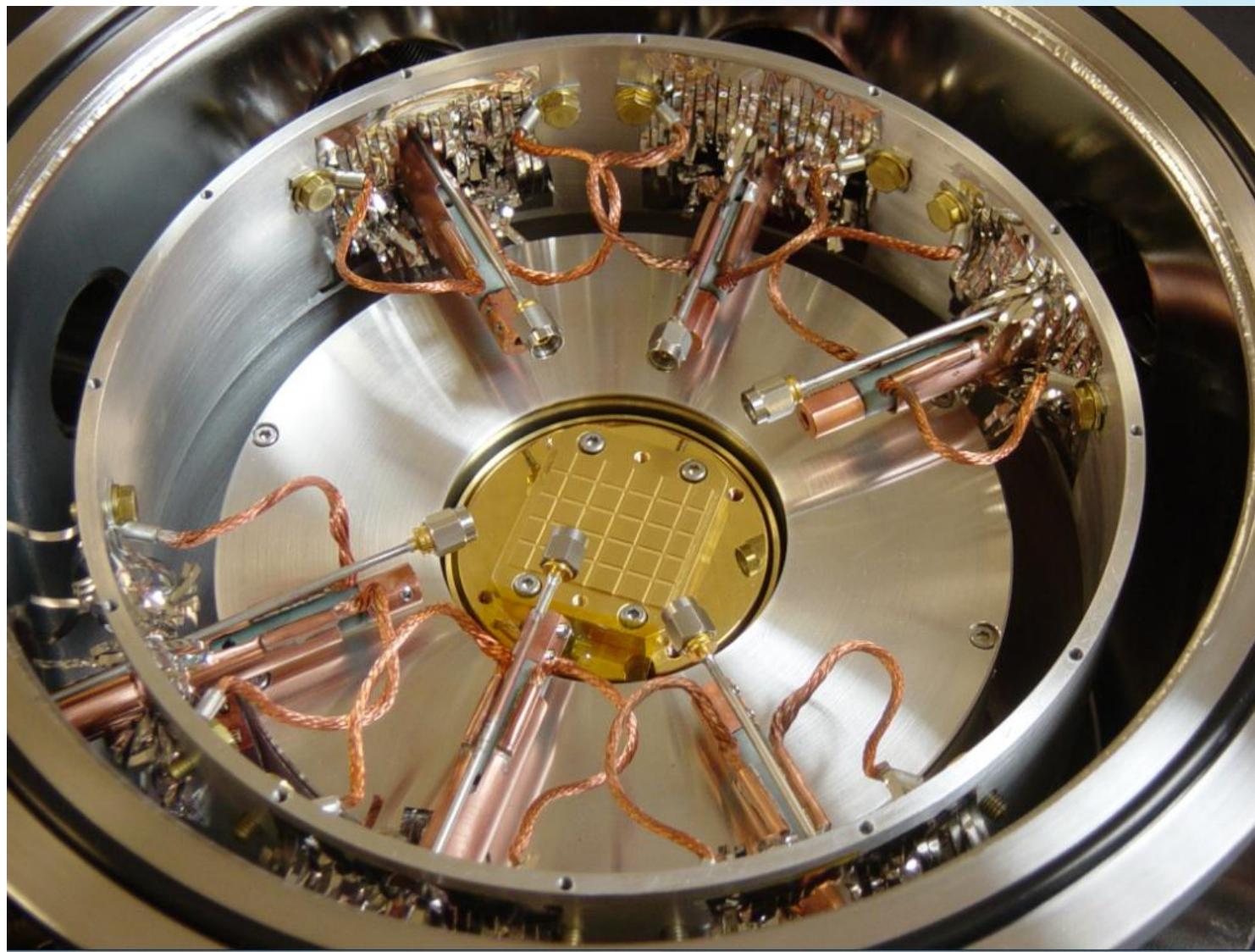
- CRX-4K



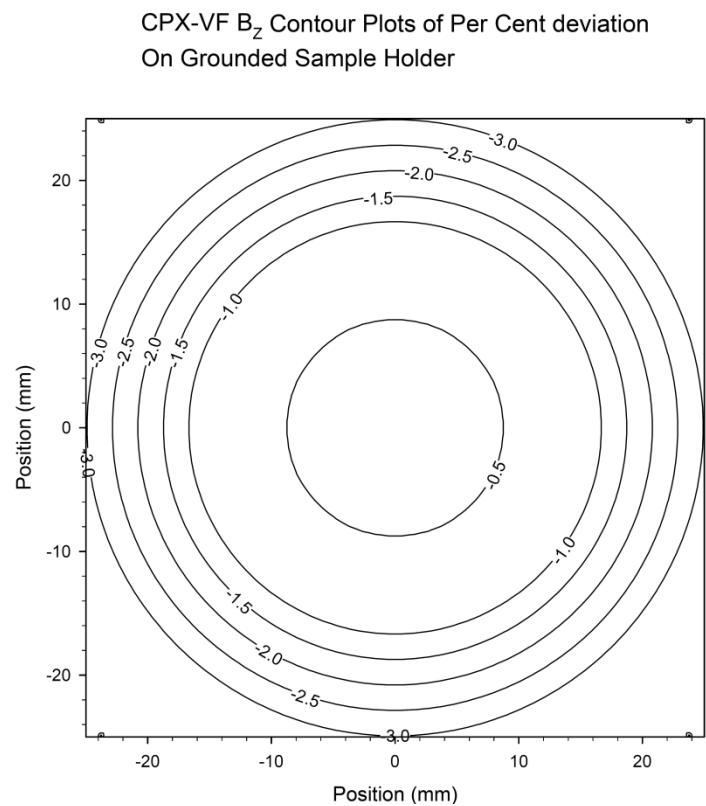
プローブステーションの バリエーション

- 磁場
- 機械式冷凍機
- 特殊なプローブアーム
- 光の導入
- ロードロック

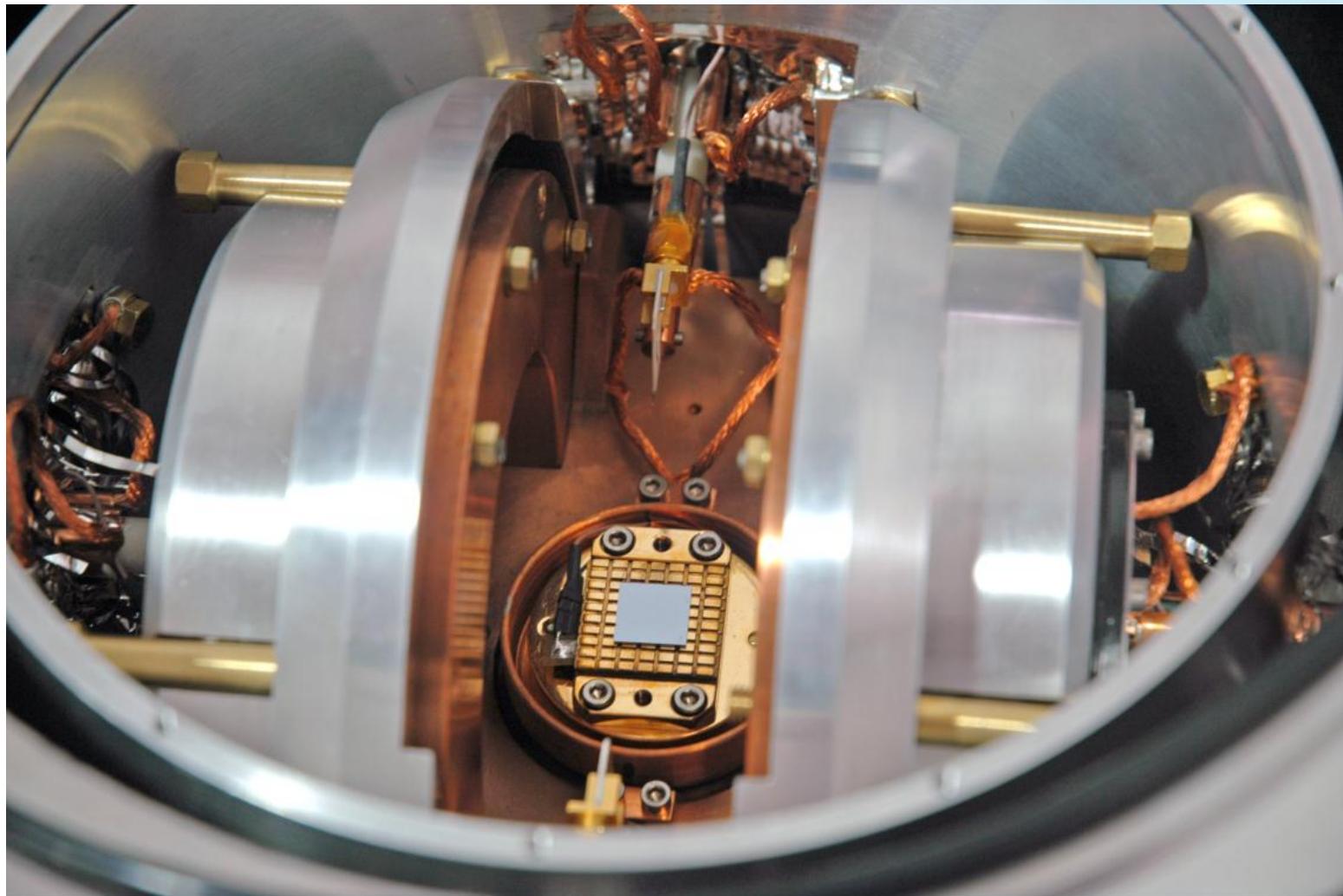
CPX-VF 縦磁場 2.5 テスラ



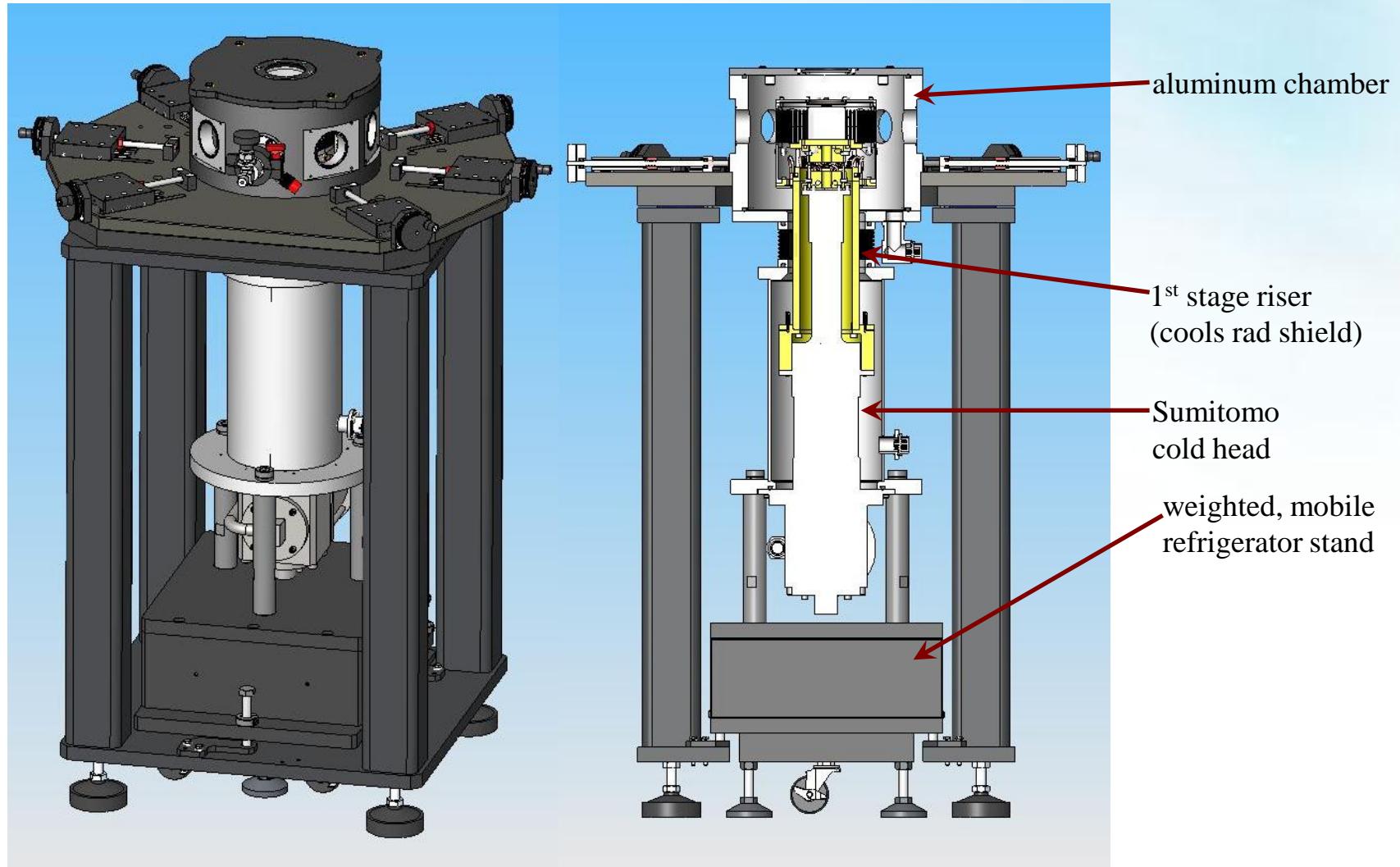
CPX-VF 垂直磁場分布



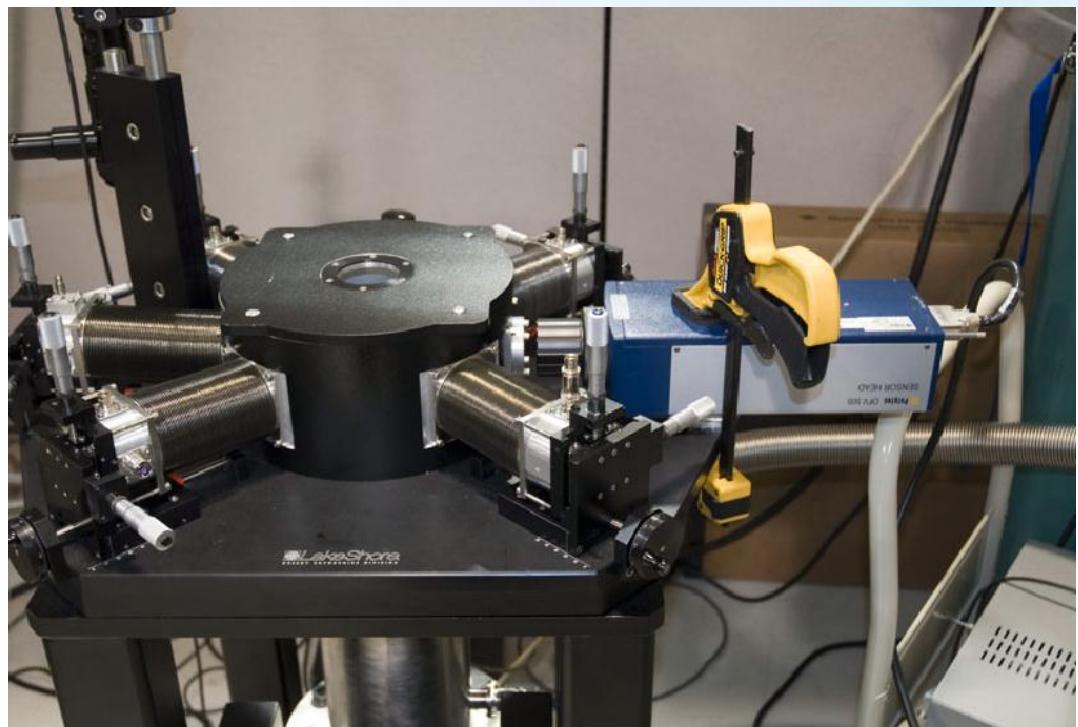
CPX-HF 水平磁場 1 テスラ



機械式冷凍機タイプ

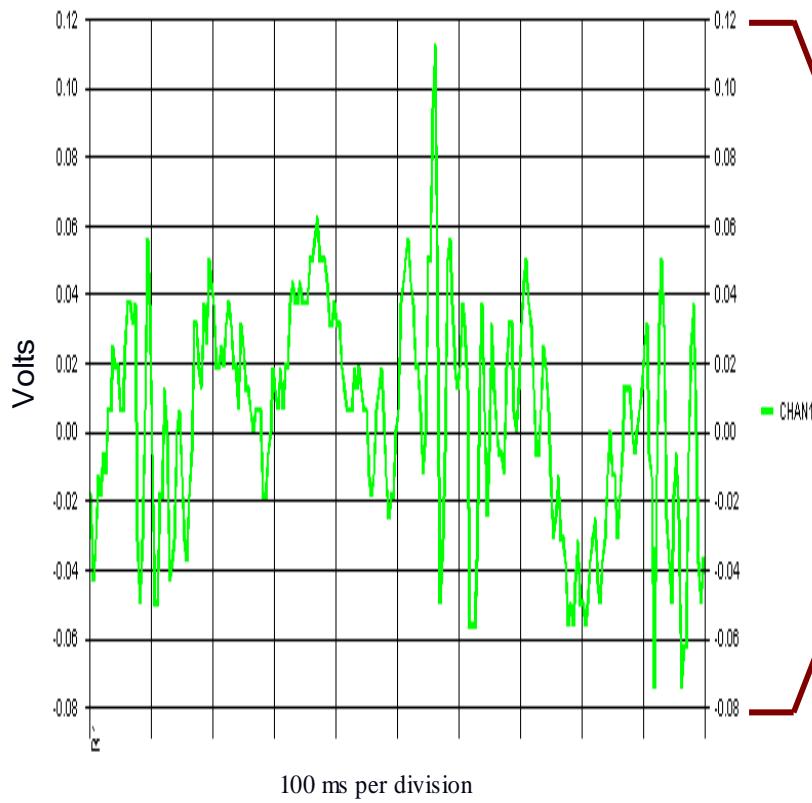


振動の測定方法 レーザー変位計

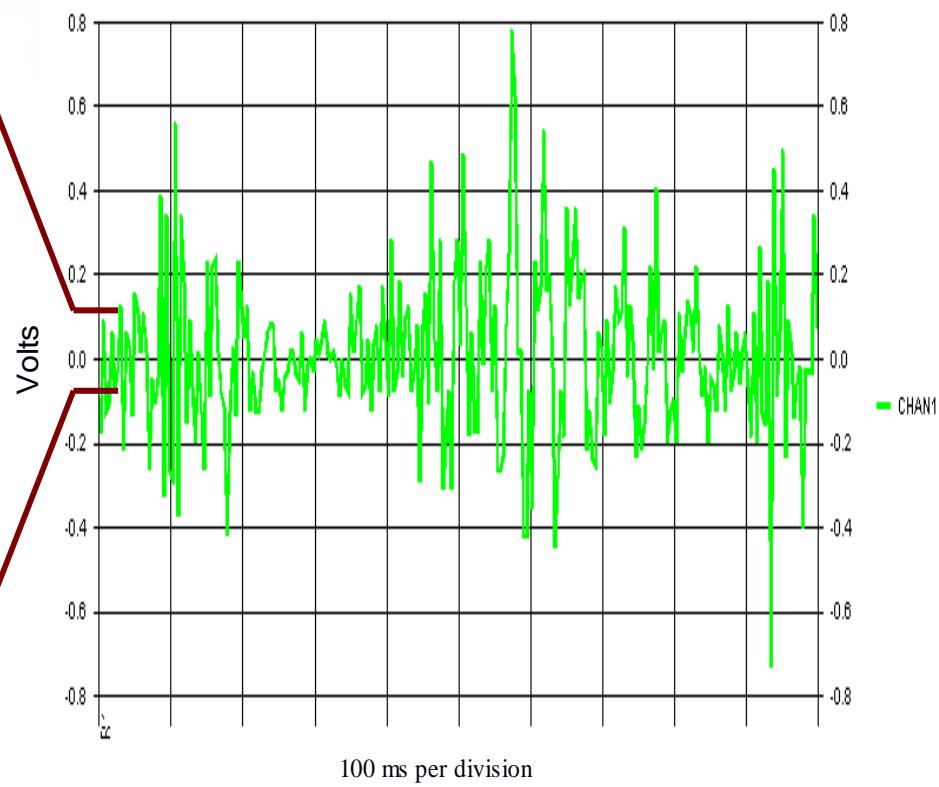


振動の測定例

- (a) Z-axis vibration less than $0.1 \mu\text{m}$ peak-to-peak
- (b) XY-axis vibration less than $0.8 \mu\text{m}$ peak-to-peak



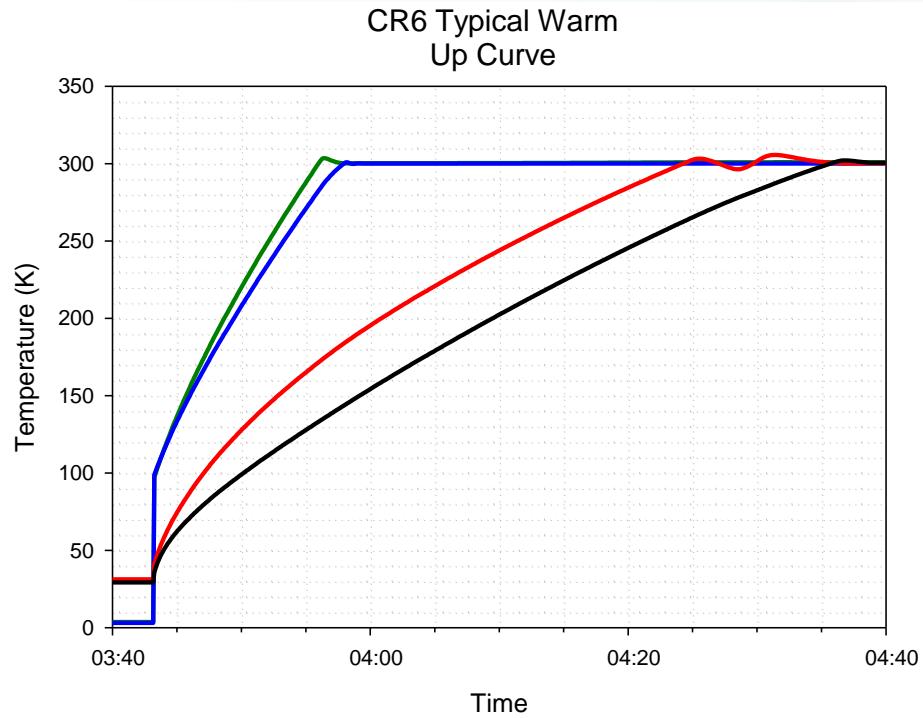
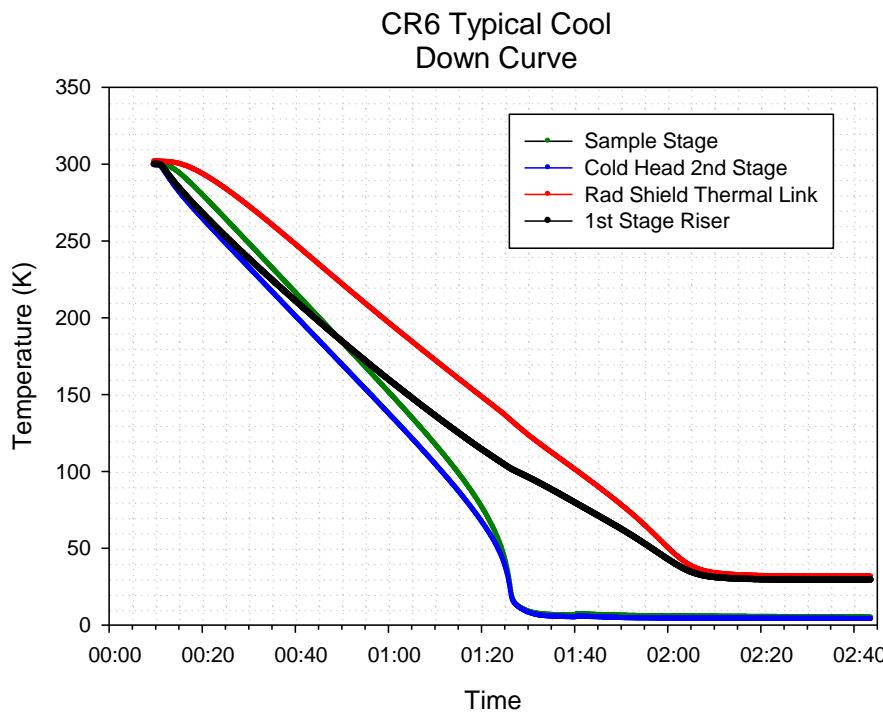
(a)



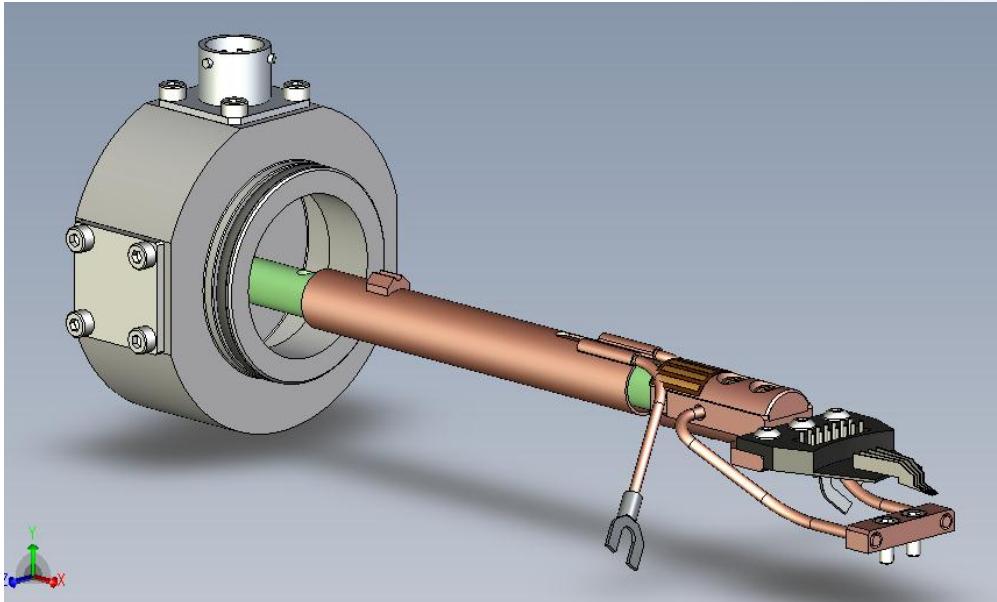
(b)

サイクルタイム

- Typical cycle time: < 3.5 h total
 - <1 h pump down (typically <20 min)
 - <2 h to cool to base temperature
 - <1 h to warm to room temperature

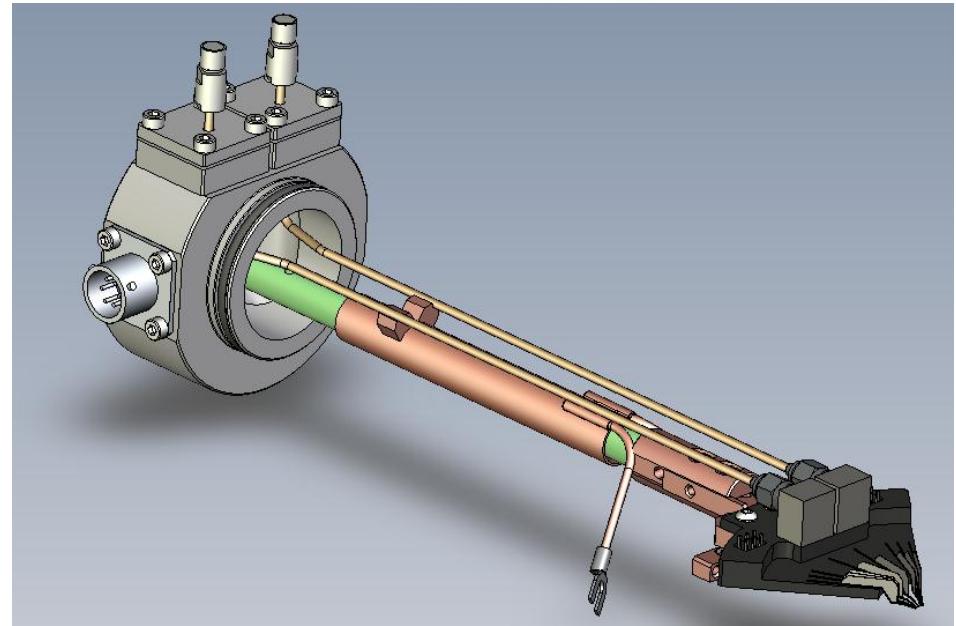


Custom DC & RF Probes & Cables



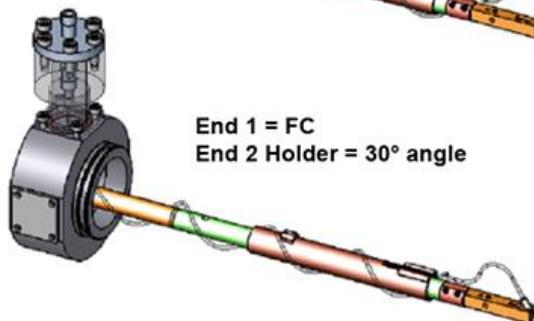
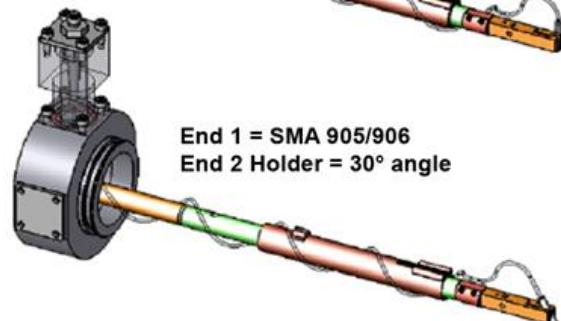
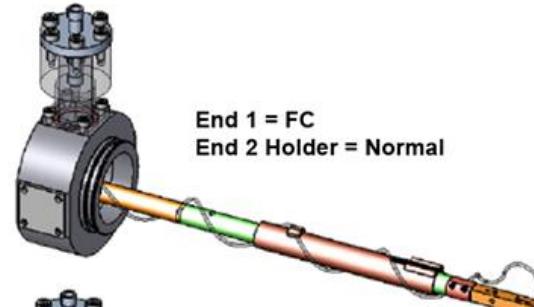
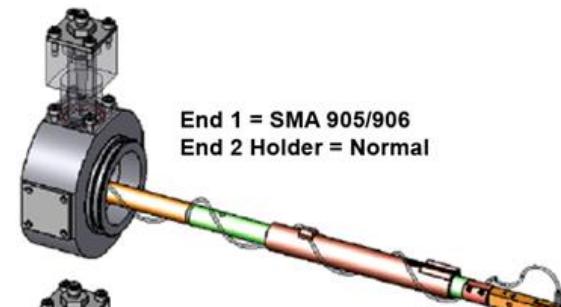
Multiple probe tip
DC probe

Combination of DC
and RF probe tips

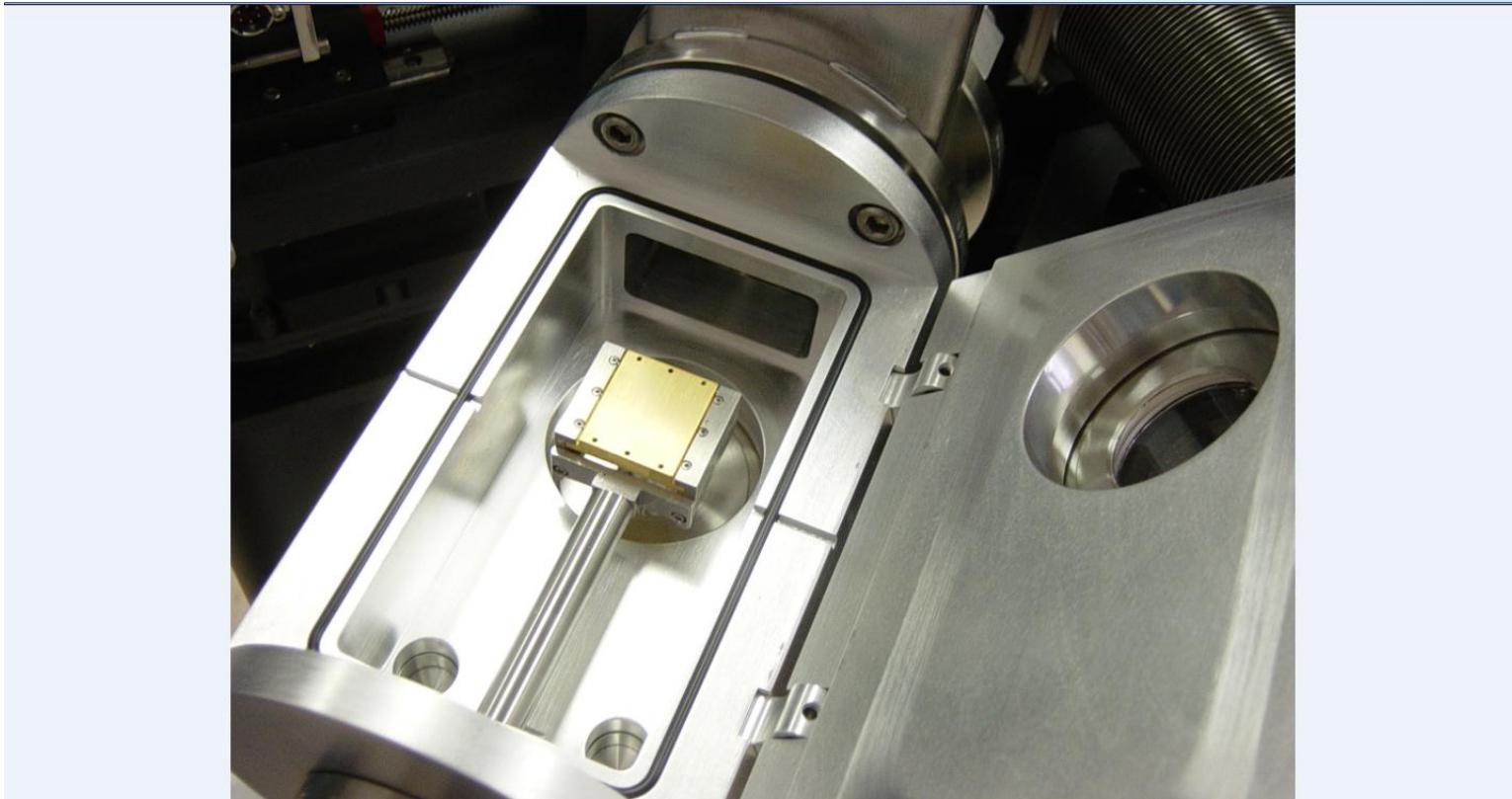


光ファイバー

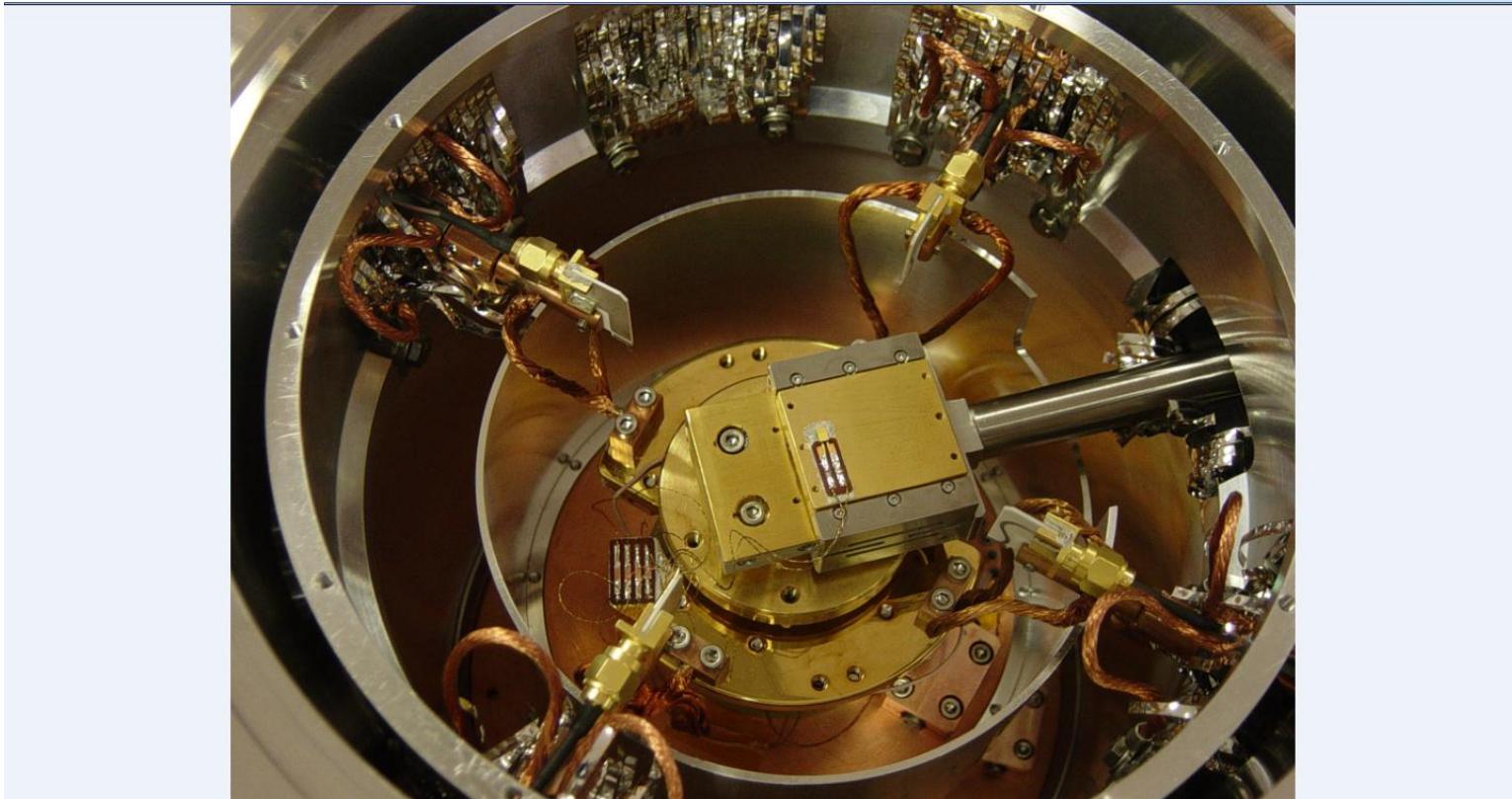
Examples of PS-FOA Configurations



ロードロック



ロードロック



用途と特徴

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- 半導体のホール効果
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