

液体キセノングループ報告

前回 (2013年12月2日)以降

KEKDTP重点レビュー、2014年8月19日、KEK
田内利明 (7/15時点)

KEK：冷凍・純化システム、PMT、エンドプレート

田内利明、真木晶弘、田中秀治、三原智、佐伯学行

笠見勝裕(冷凍システム構築)、鈴木祥仁 (モニター:Labview)

佐賀大：TPC

杉山 晃

東大：DAQ、TPCテスト

森俊則

放医研：PETとしての性能仕様とシミュレーション

熊田雅之、富谷武浩、寅松千枝

横浜国大：液体キセノン基本特性、APD、ASICチップ

中村正吾、濱西 亮 (M2)、(岩崎 裕也 (M2))

協力支援：田中真伸氏(KEK素核研回路室)、池田博一氏(JAXA)

レビュワー：海野義信 (KEK)、柴村英道 (埼玉県立大)

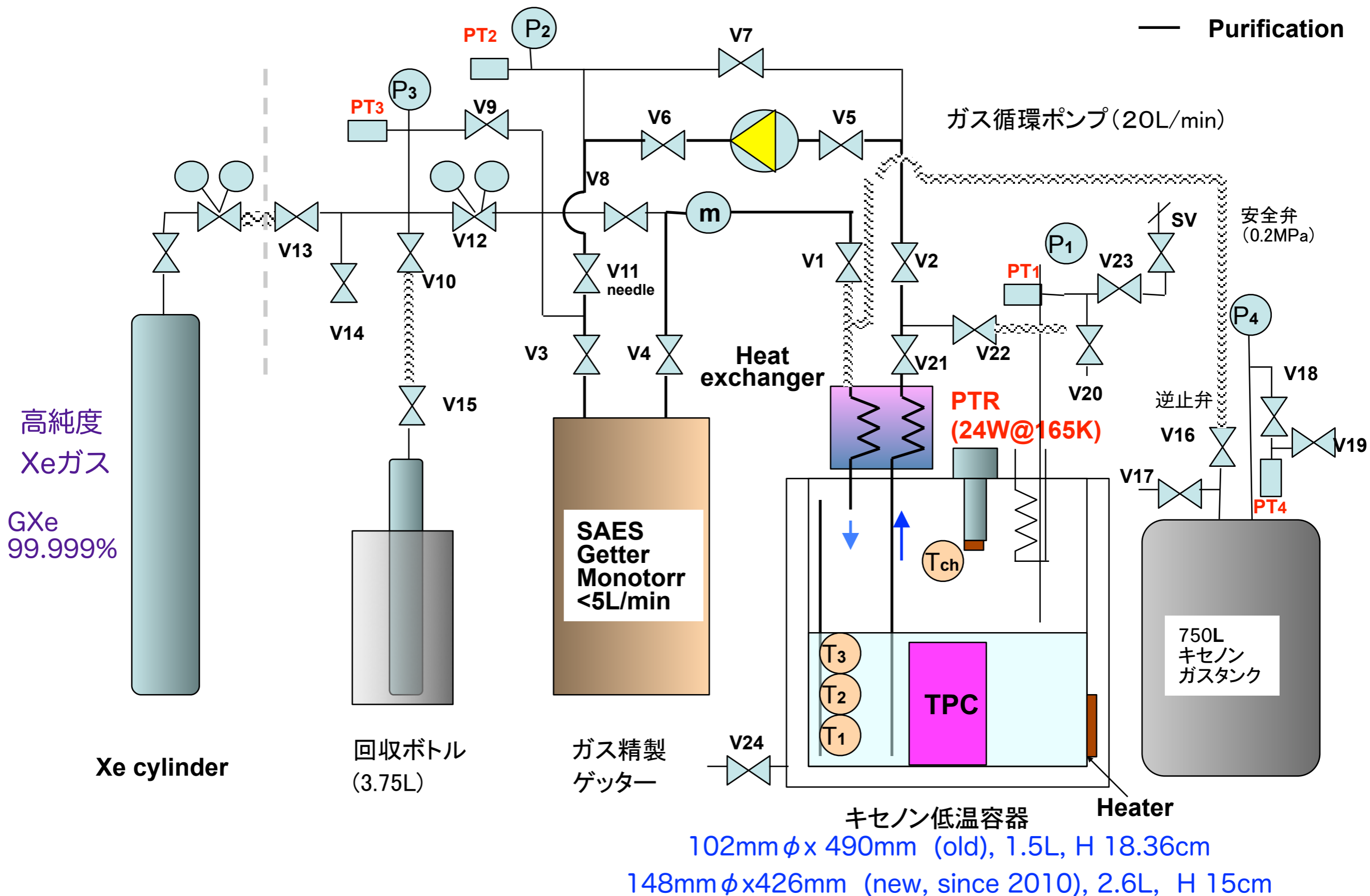
2013 - 2014年度

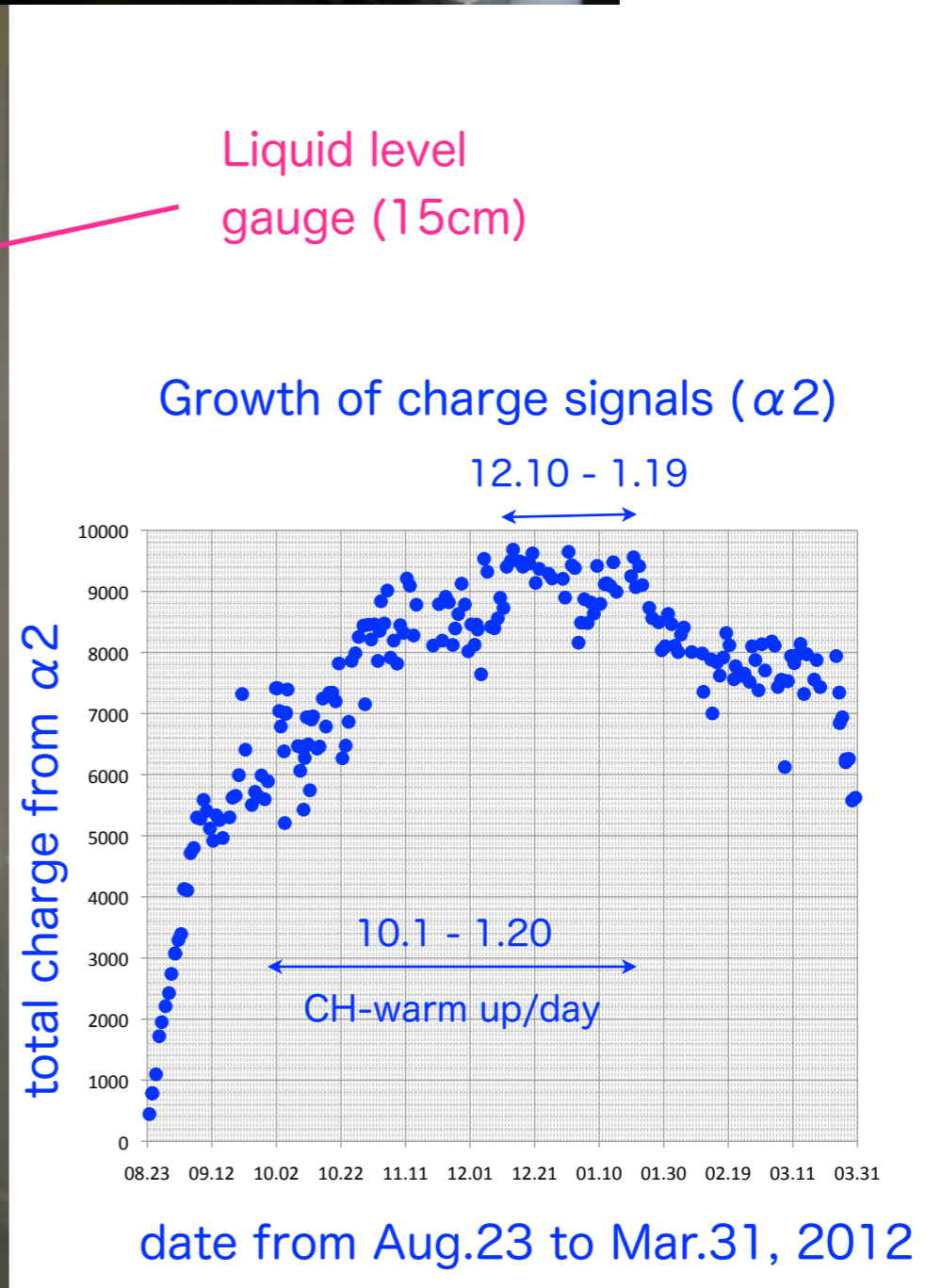
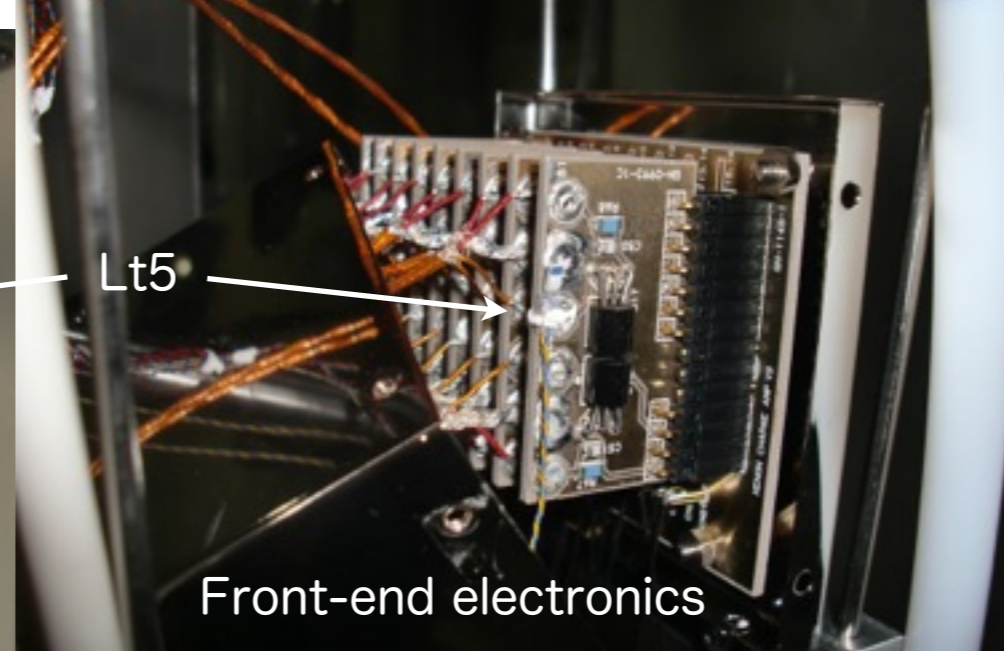
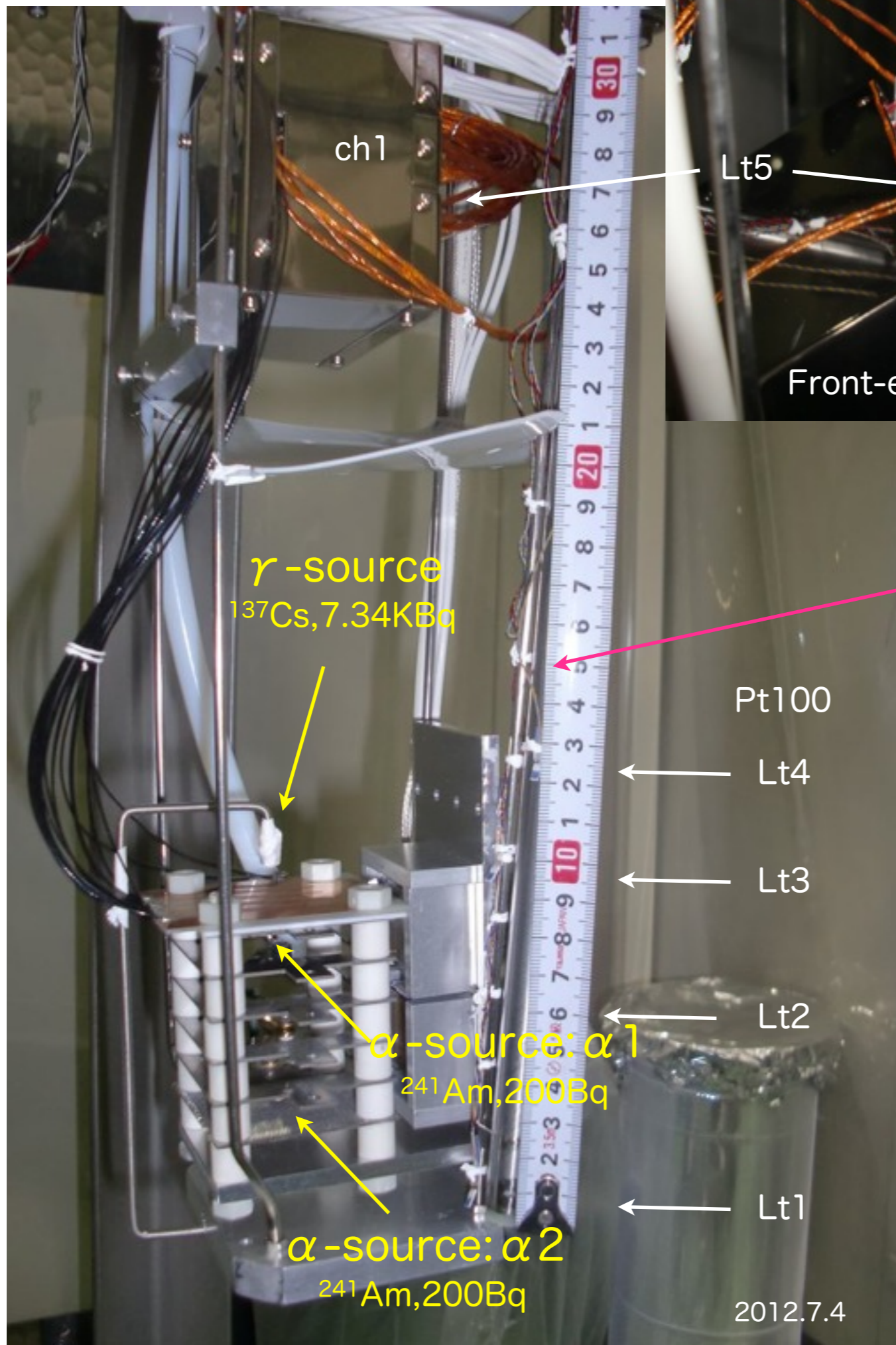
- 12/19 - 3/31 : キセノンガス予冷装置 (真空断熱器付) の設計と製作
- 6/13 : 修理後の予冷装置のKEKでの試験, 会社での試験結果を確認
- 1/24-3/26 Vincent Tran (Ecole de Mines de Nantesの大学院生 M1)
インターンシップ : 液体キセノン中でのWindowless-APD特性の研究
- 1/28 液化開始 : TPCFE09/LTCCボードによる電荷測定を試みるが失敗
- 1/4 - 2/11 : TPCFE09/LTCCボードのフロントエンドエレクトロニクス
のLTSpiceによるsimulation研究
- 12/11-3/19 Anode-PADs, TPCFE09, バッファアンプの三つのボ
ードからなる新しいフロントエンドエレクトロニクスシステムの設計・製作
- 3/27 - 6/3 : Windowless-APDの液体キセノン中での再測定
- 4/7 : キセノン液面の再測定 (PTR ON/OFF)
- 6/15 - 6/26 : Windowless-APDのワイヤボンディングの修正@ハマホト
- 6/26 - 7/11 : Windowless-APDの液体キセノン中での γ 線スペクトラム
の測定
- 1月~ : XEMIS2 のGATE/GEANT4によるシミュレーション研究

液化・純化システム

since June 2008

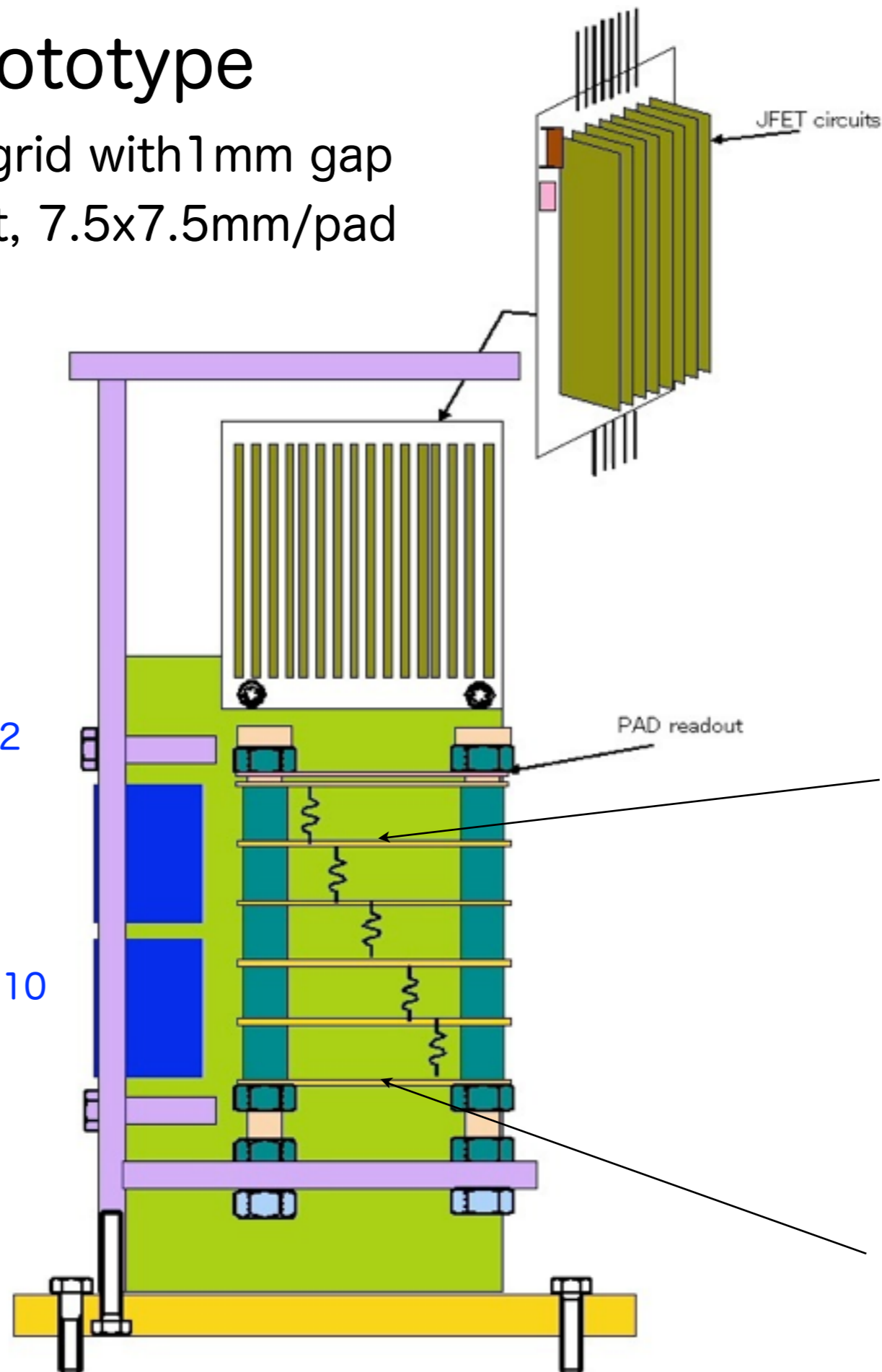
オイルフリー・ダイアフラムポンプ（エノモト）によるガス循環精製





TPC prototype

5cm drift, mesh grid with 1mm gap
4x4 pads readout, 7.5x7.5mm/pad



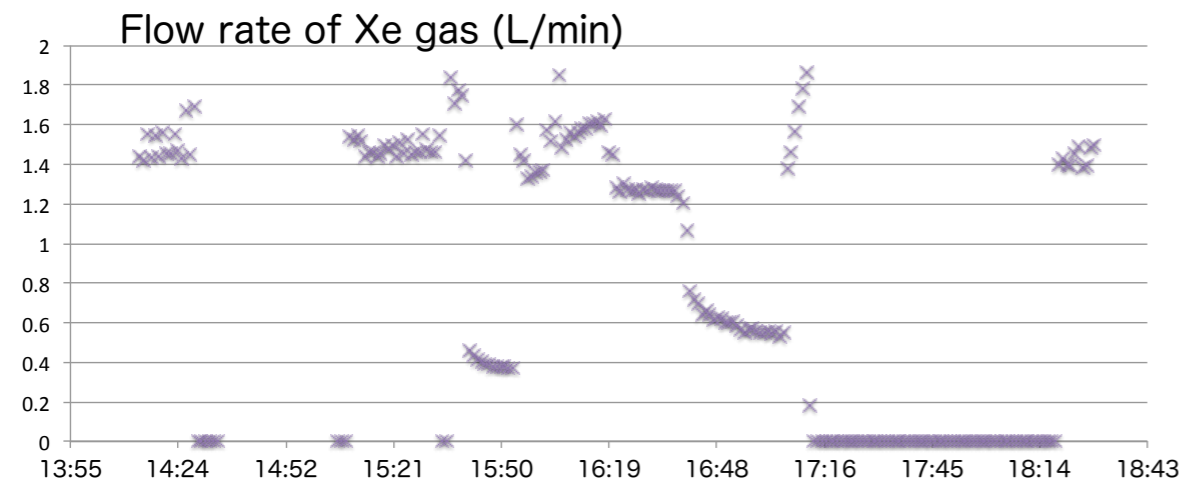
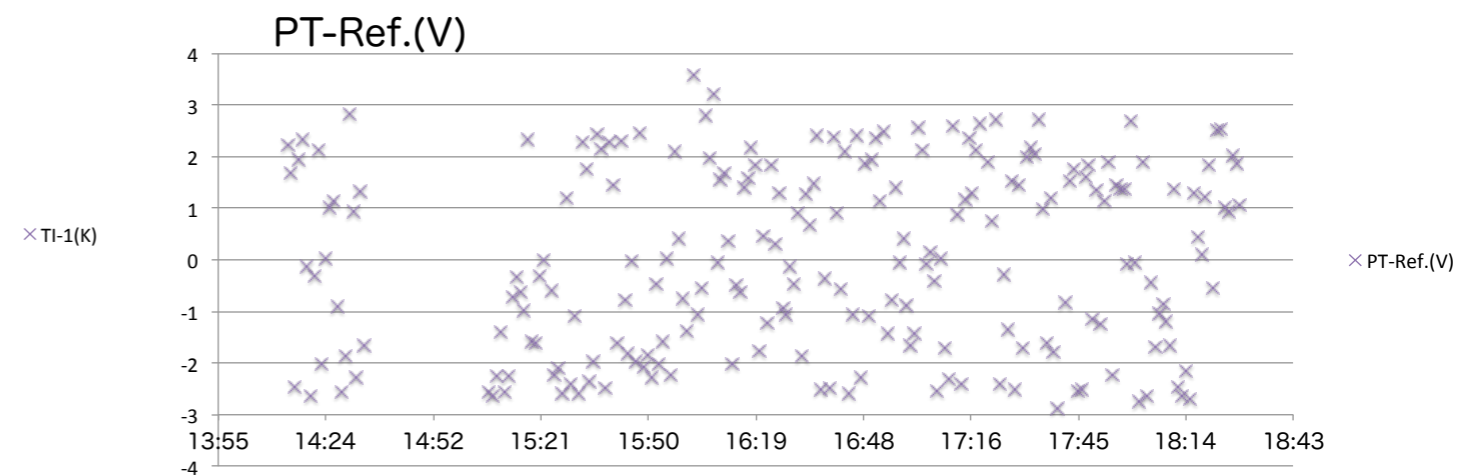
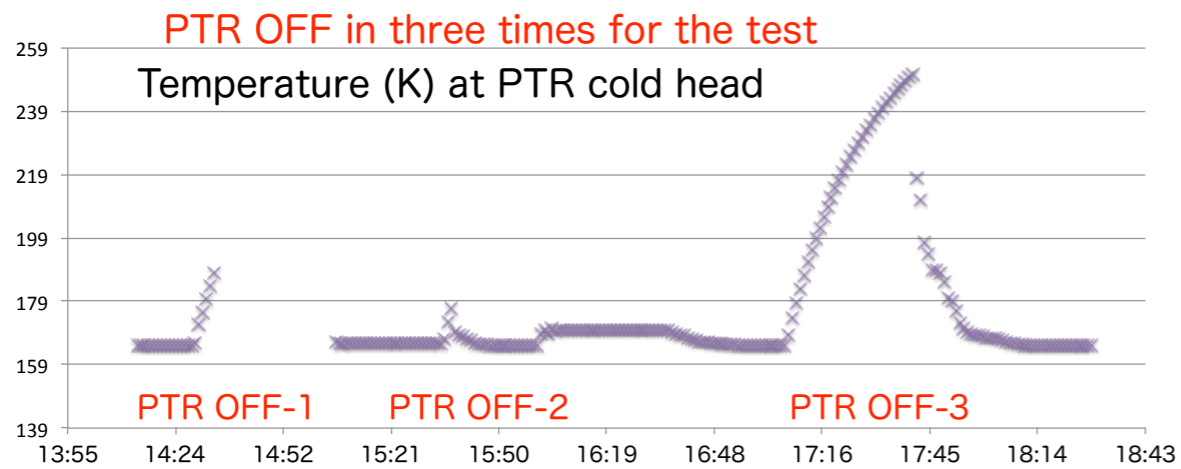
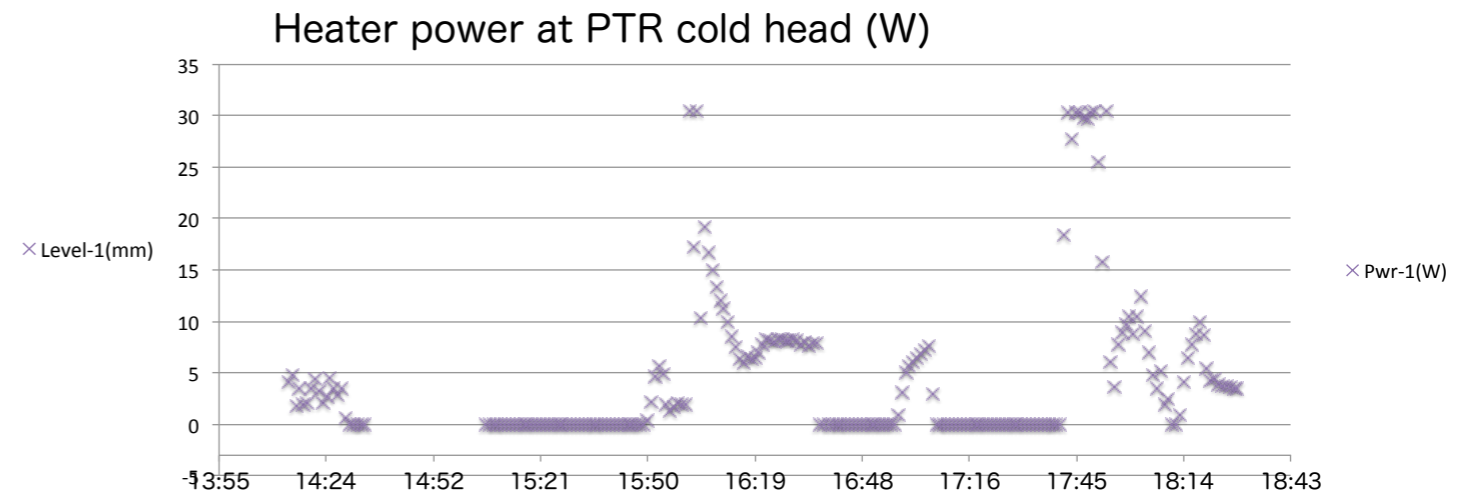
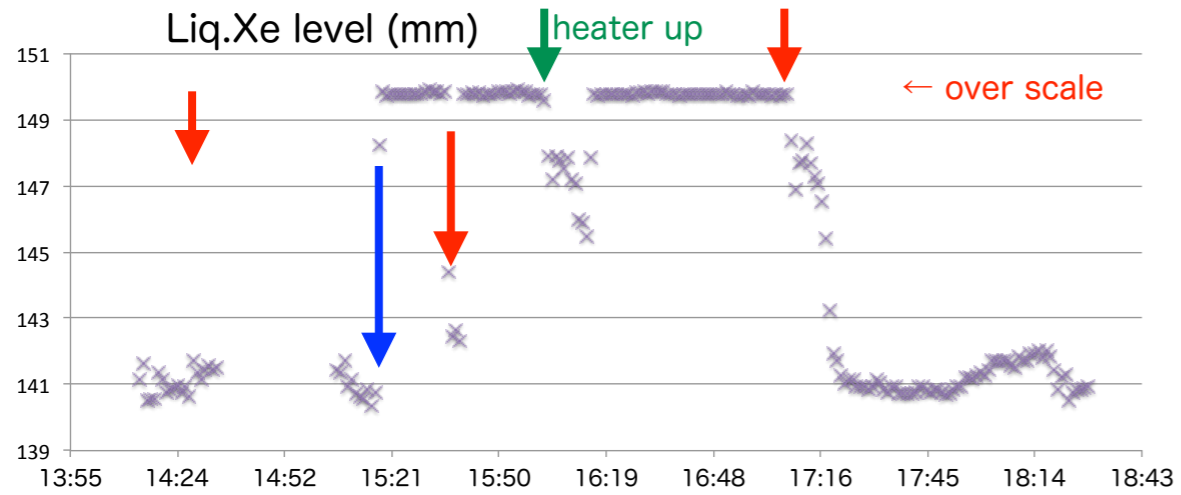
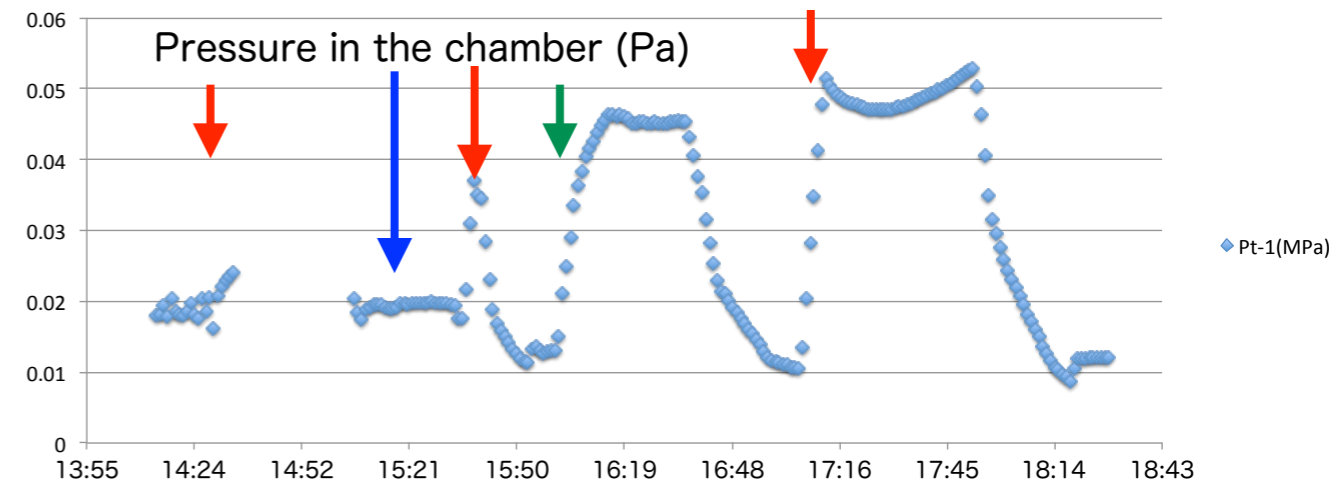
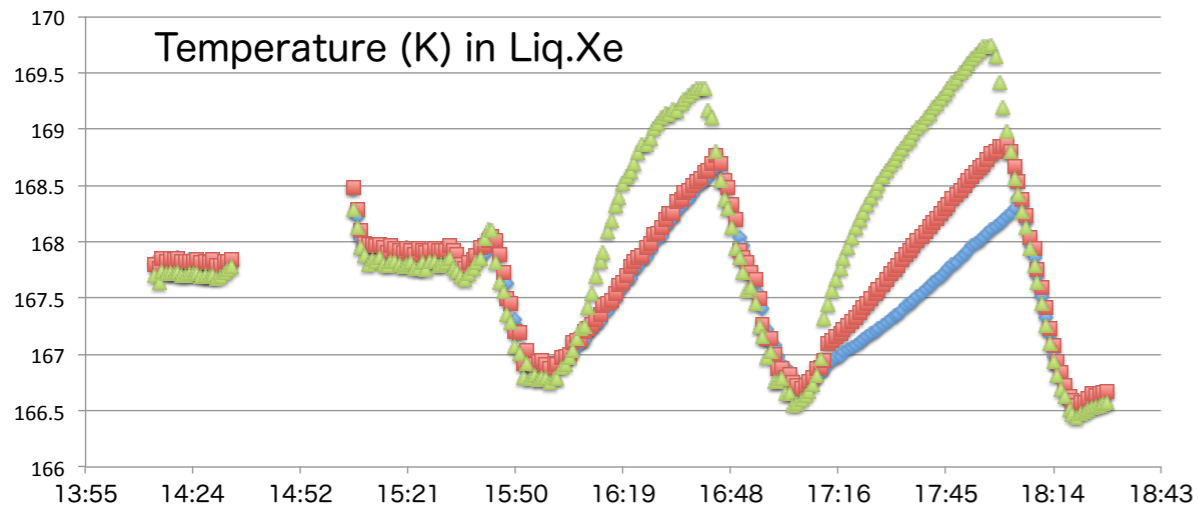
PMT1 (up) : R5900; DY1 - 12
20.7uA at +900V(max)
Q.E.=20%@175nm
(2003.11.28)

PMT2 (down) : R7600; DY1 - 10
23.9uA at +900V(max)
Q.E.=30%@175nm
(2009.06.15)

α source
(^{241}Am , 200Bq)
on a wire
at 1cm from
the anode

α -source
 ^{241}Am , 200Bq

液面再確認



PTR OFF/ON → 液面下降/上昇

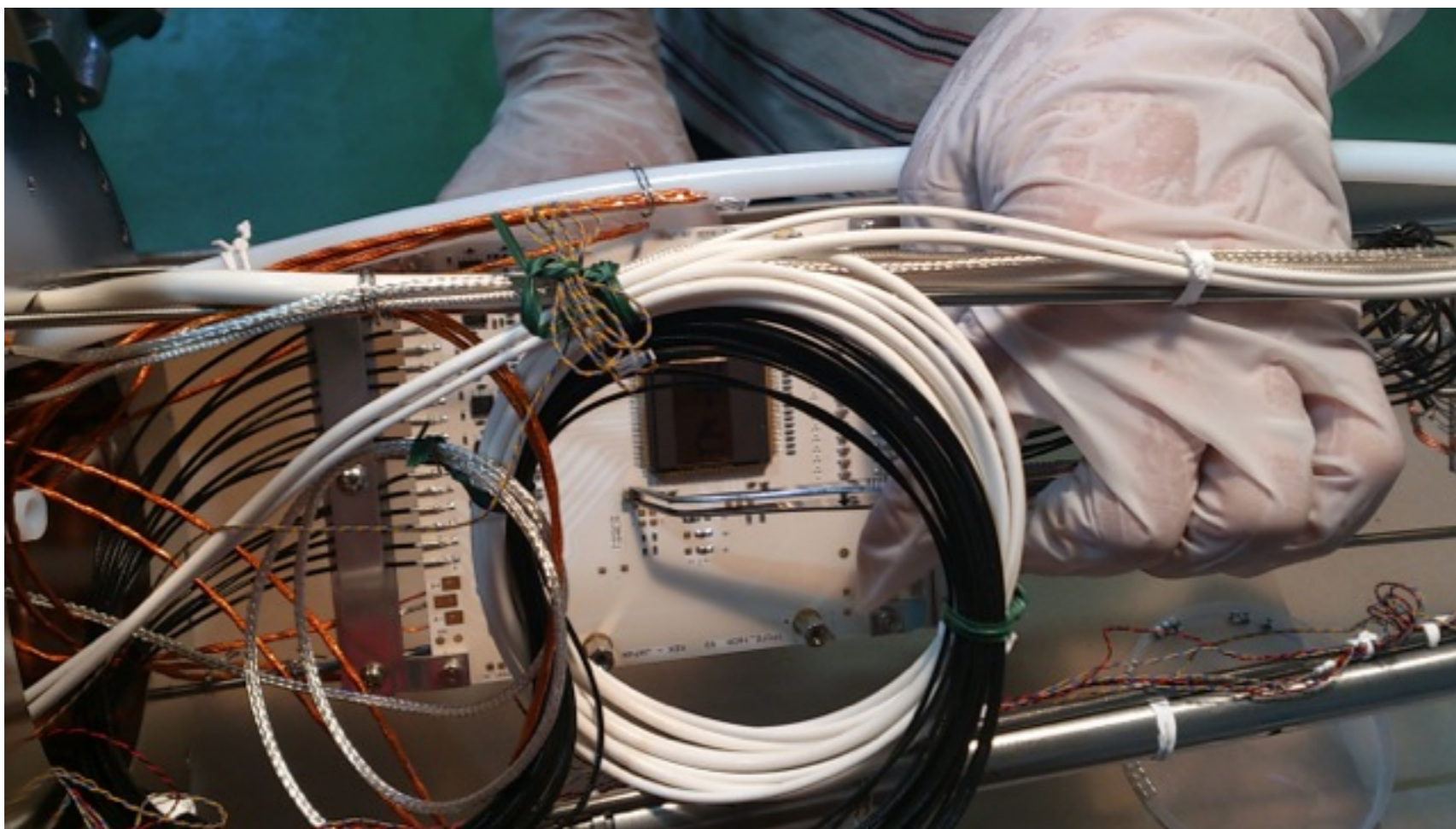
液面計 (Liquid Level Sensor, capacitance-based level sensing) : 直径0.5", 150mm長、SUSの二重管, 底面より12mmの側面に穴が開いているが、底面は開放されている

ASIC・

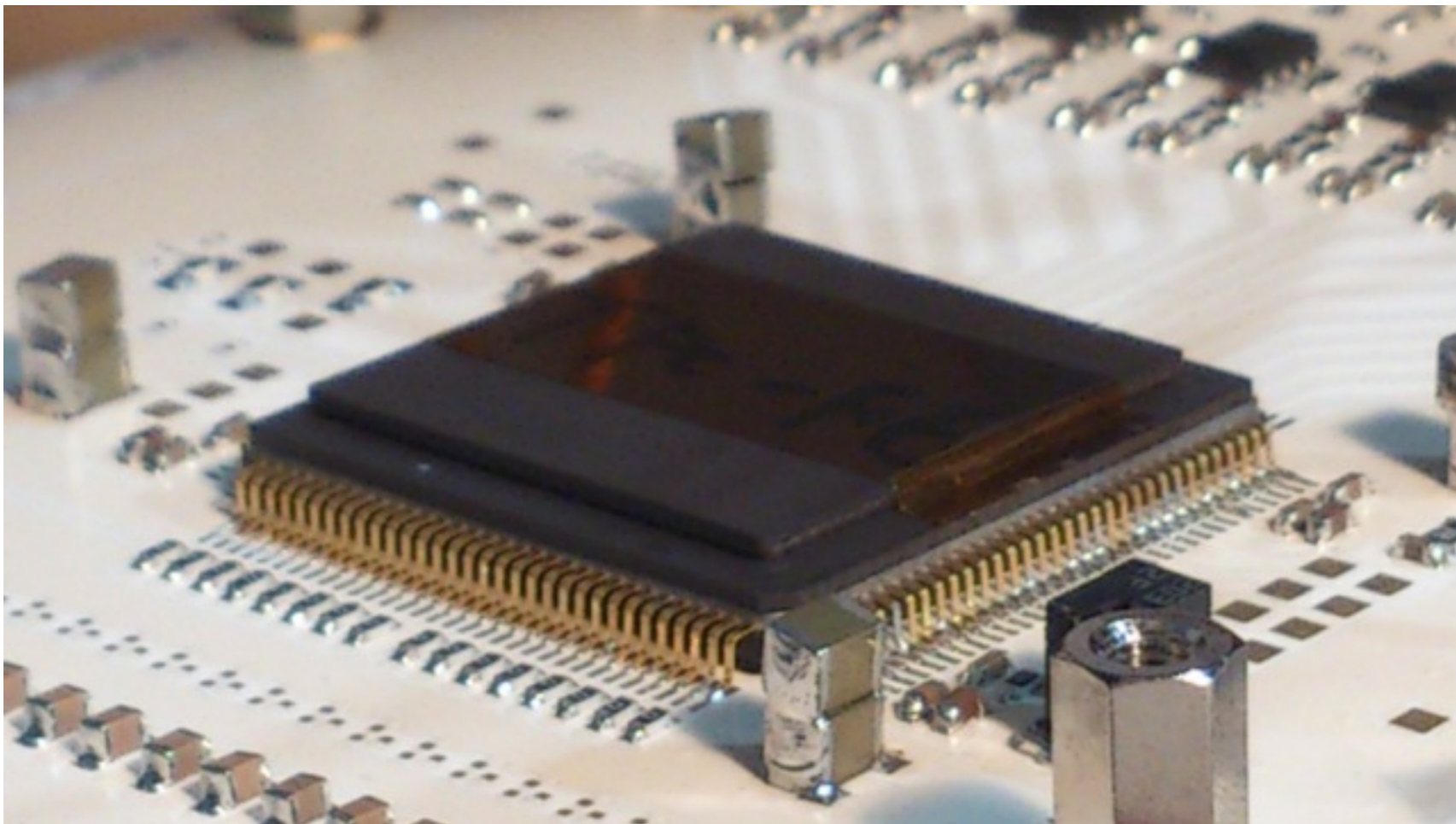
TPCFE09

フロントエンド・

エレクトロニクス

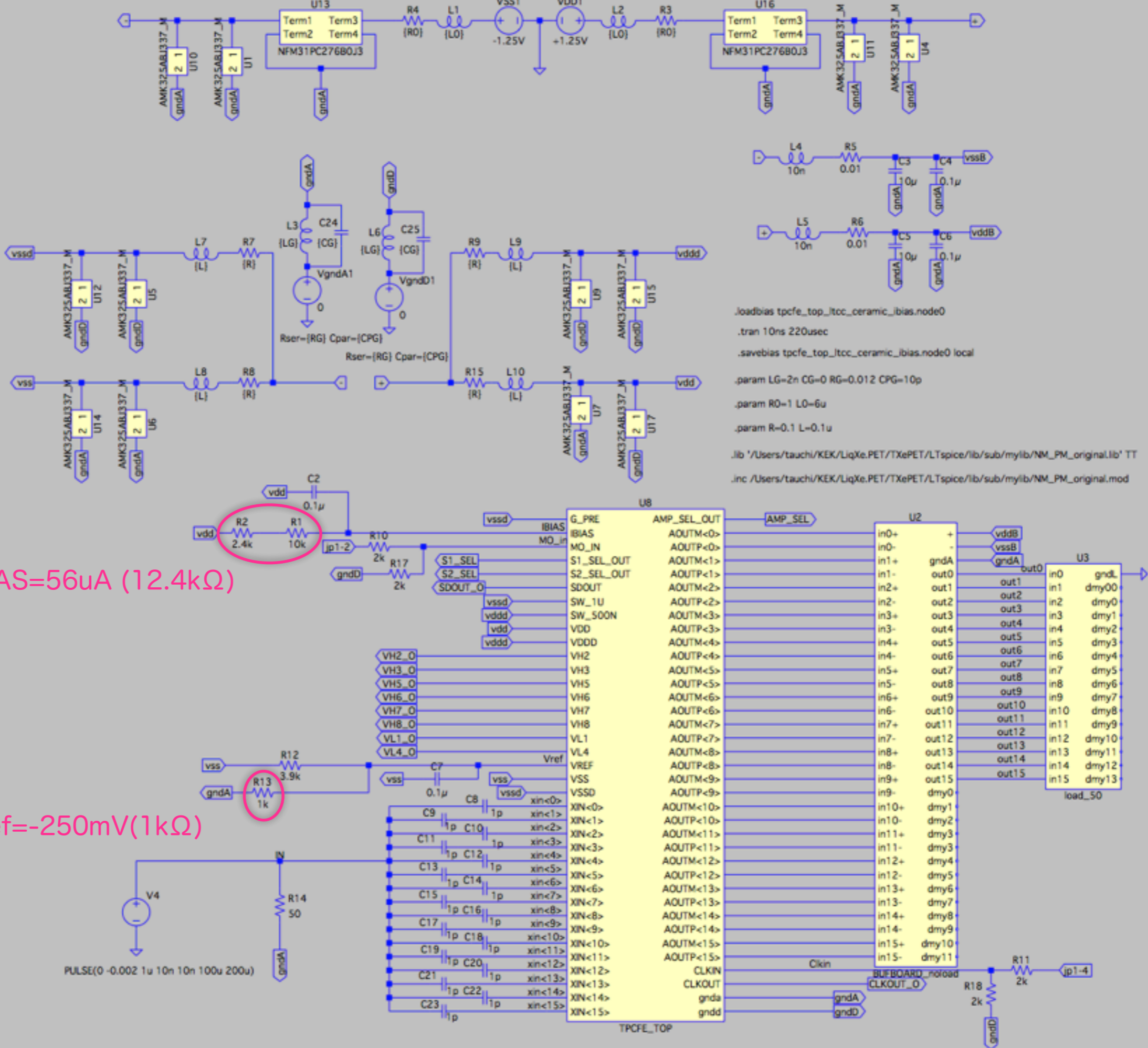


ASICチップ (TPCFE09) による読みだし



Multilayer Ceramic (
AMK324ABJ337MM,
330uF x 2, ESR=0.002Ω)
at each $\pm 1.25V$,
i.e. 6 points in total

LTspice model



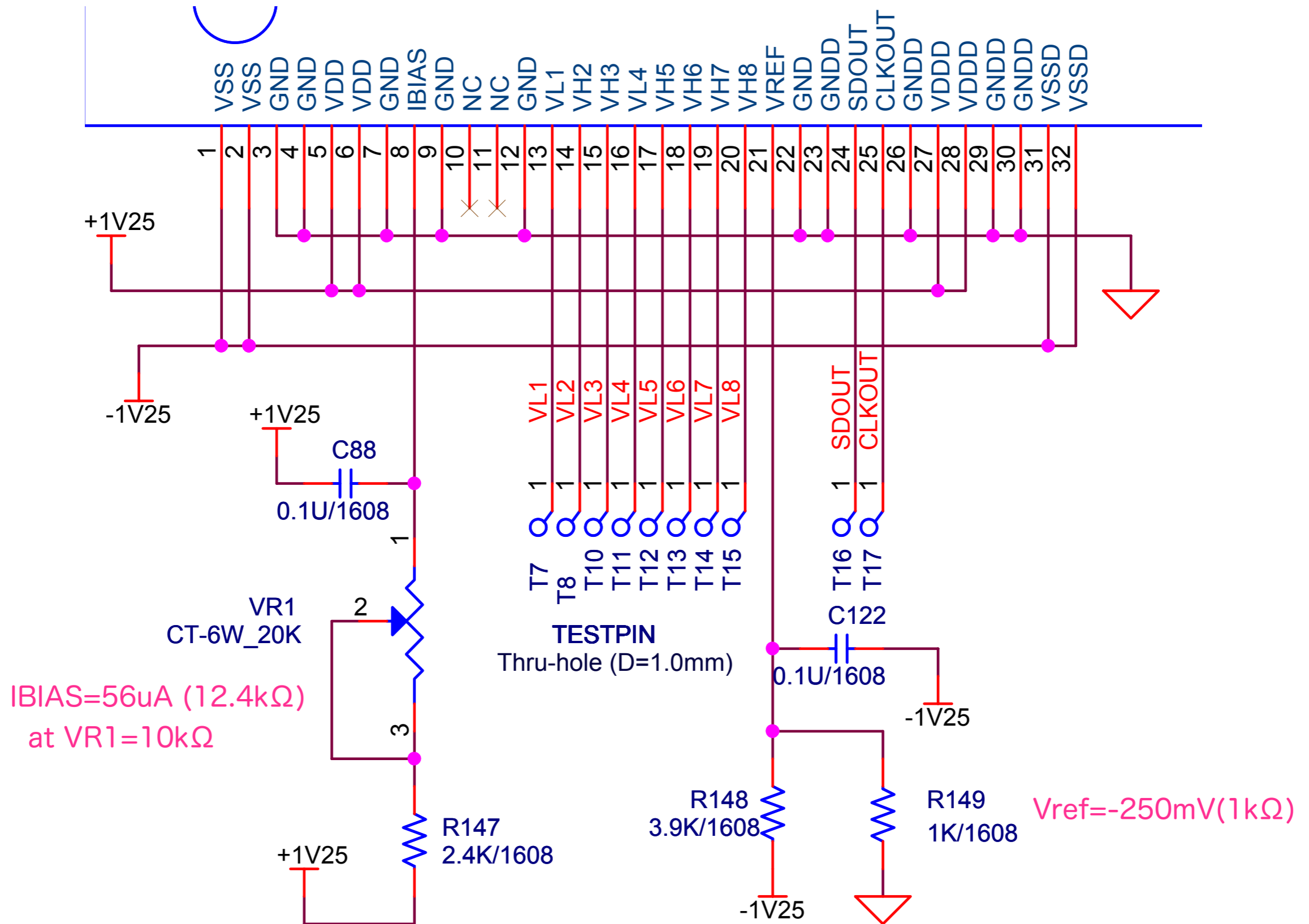
IBIAS=56uA (12.4kΩ)

Vref=-250mV(1kΩ)

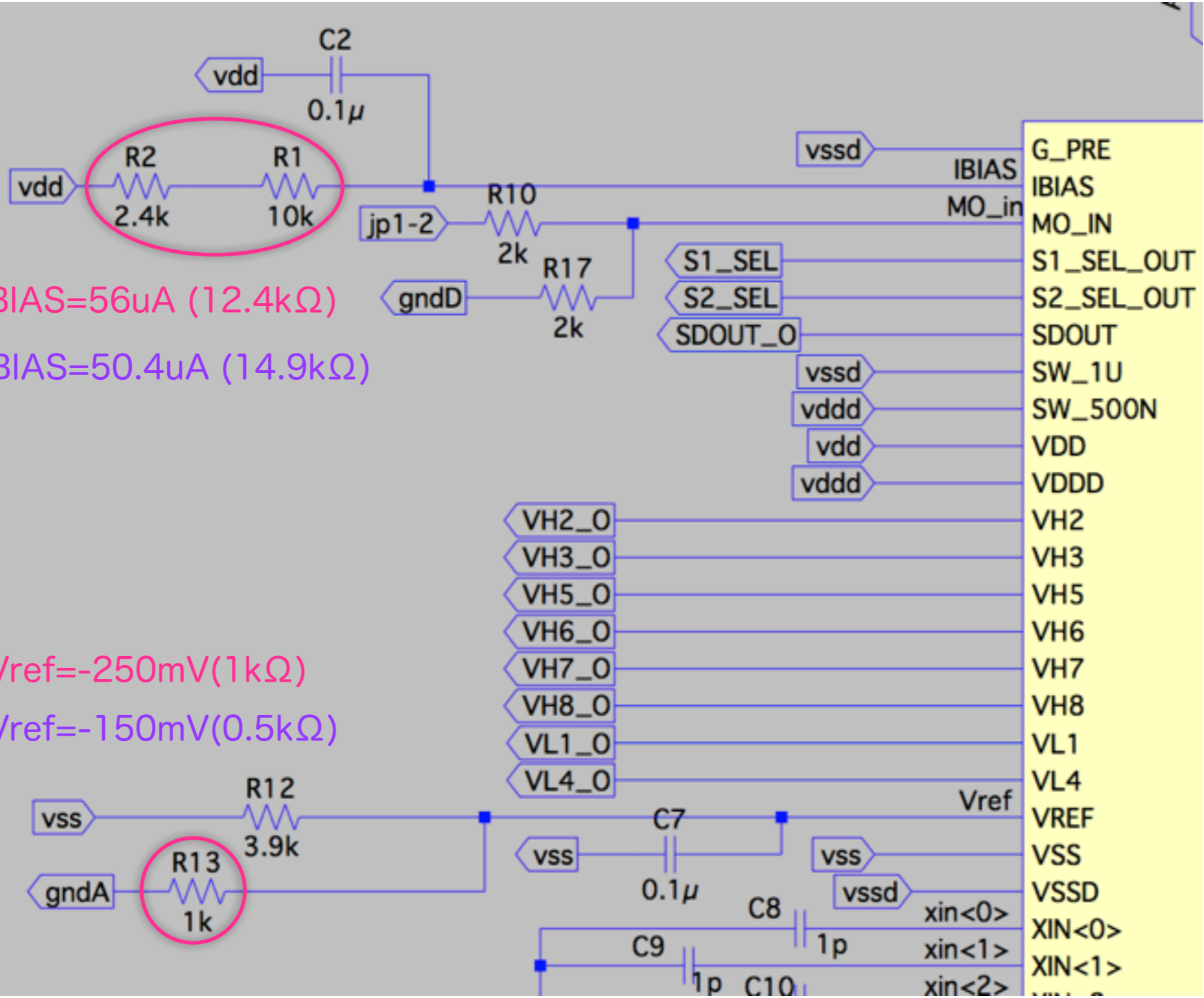
```

.loadbias tpcf_top_itcc_ceramic_ibias.node0
.tran 10ns 220usec
.savebias tpcf_top_itcc_ceramic_ibias.node0 local
.param LG=2n CG=0 RG=0.012 CPG=10p
.param RO=1 LO=6u
.param R=0.1 L=0.1u
.lib '/Users/tauchi/KEK/LiqXe.PET/TXePET/LTspice/lib/sub/mylib/NM_PM_original.lib' TT
.inc /Users/tauchi/KEK/LiqXe.PET/TXePET/LTspice/lib/sub/mylib/NM_PM_original.mod
    
```

IBIAS and Vref on the circuit board



IBIAS and Vref



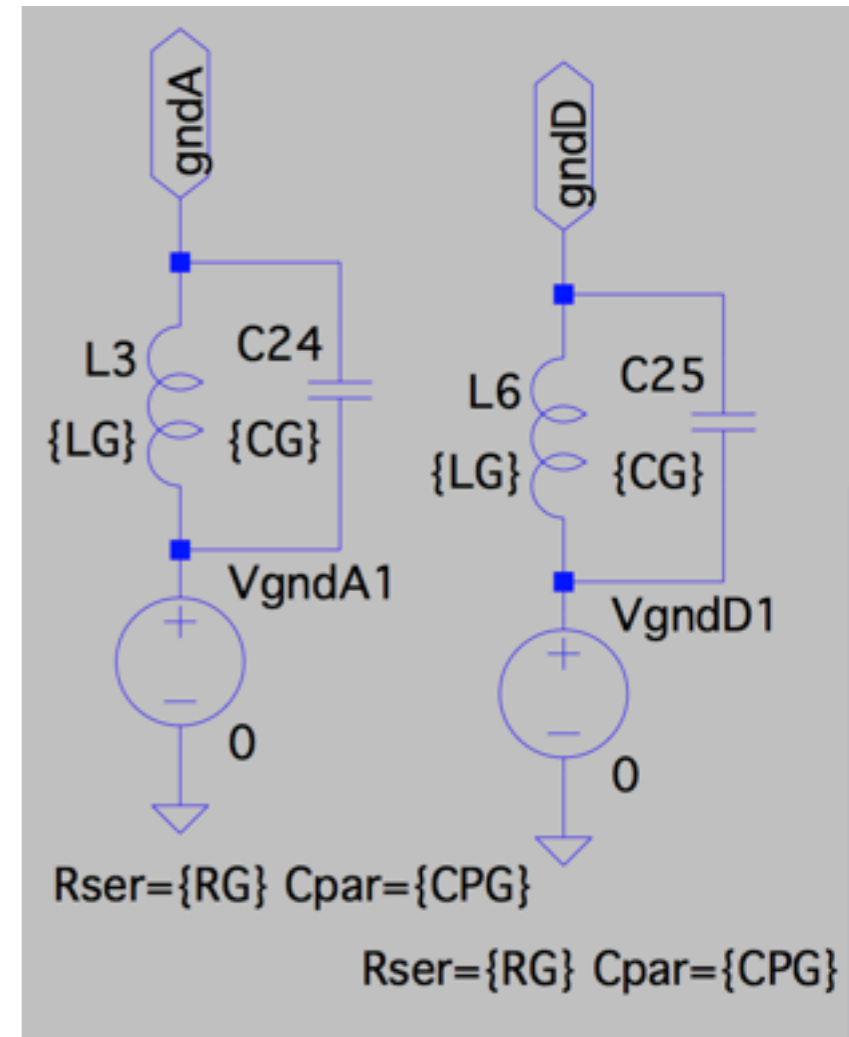
IBIAS=56µA (12.4kΩ)

IBIAS=50.4µA (14.9kΩ)

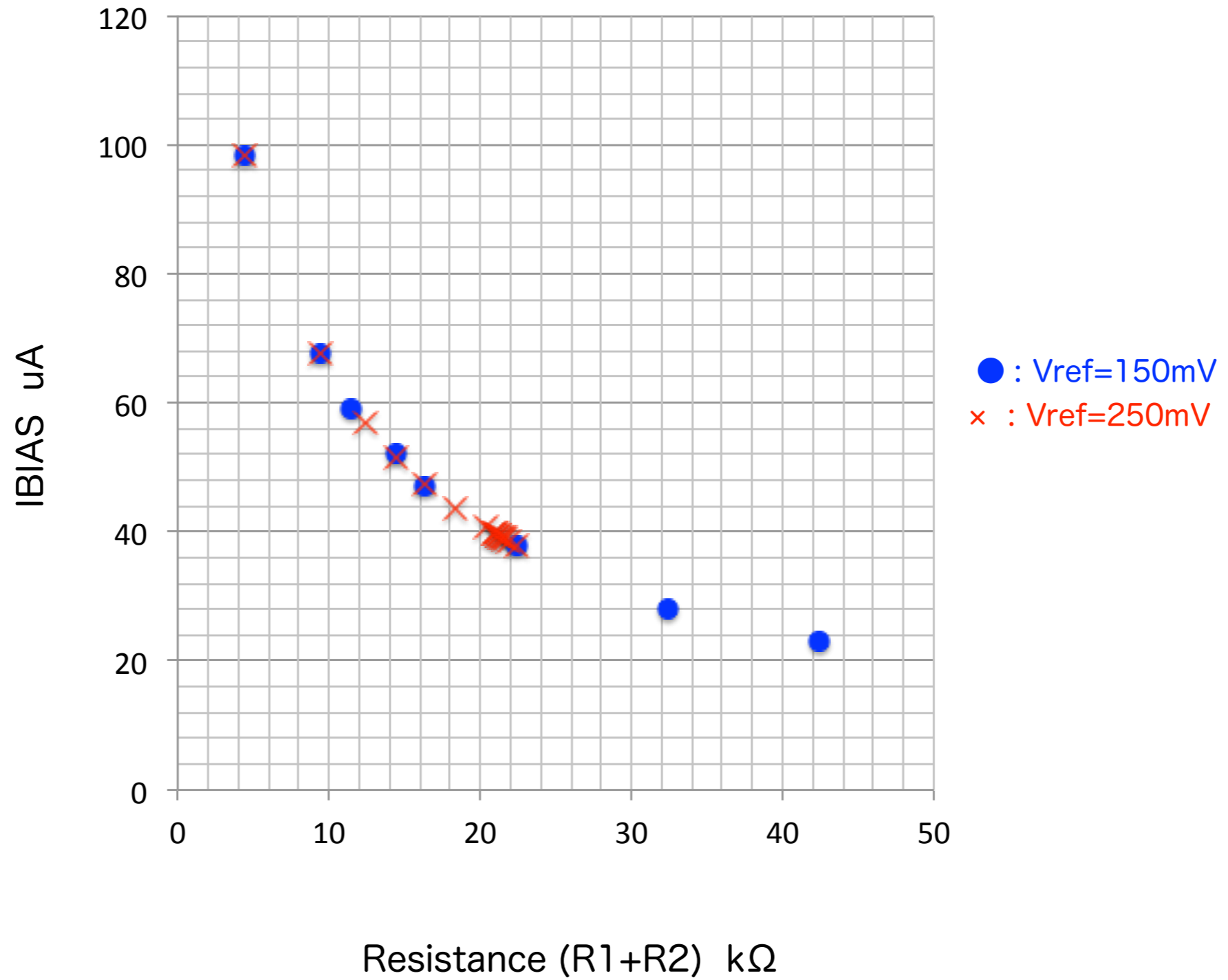
Vref=-250mV(1kΩ)

Vref=-150mV(0.5kΩ)

“Noise source”
 LG (CG) and RG
 at the ground line



Adjustment of IBAS current



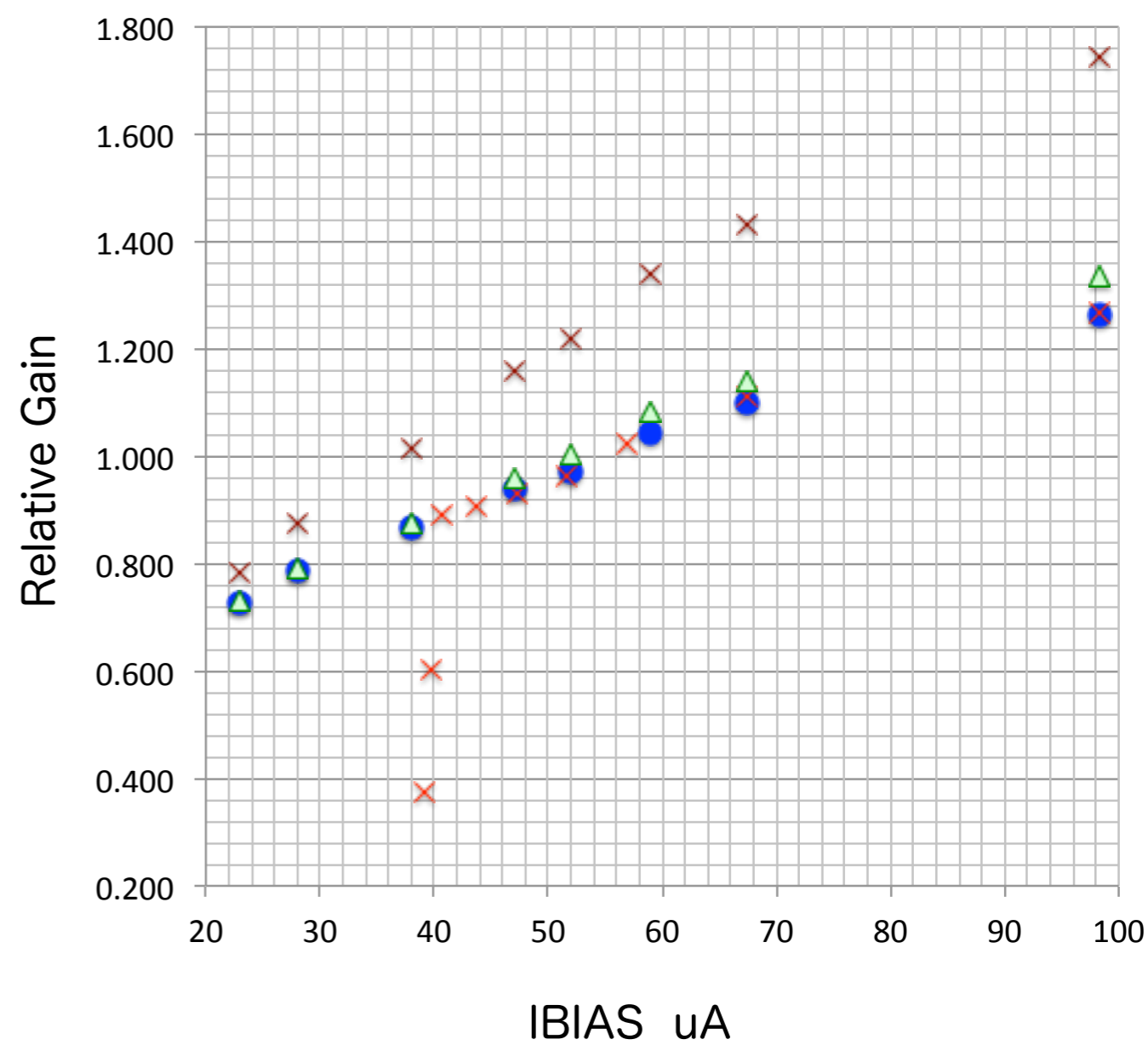
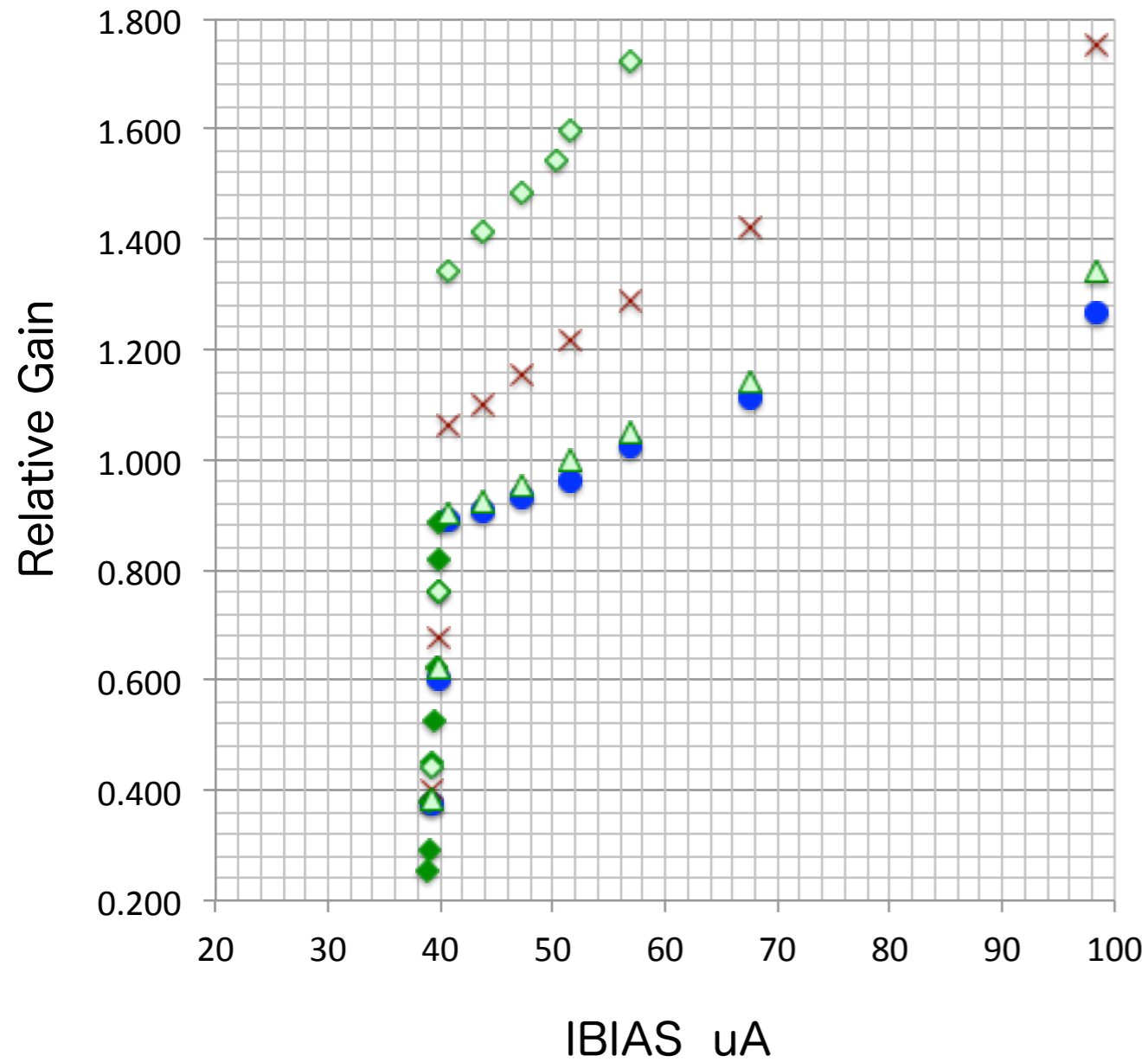
Bypass-Capacitor (Ceramic) =100uF

R13=1k Ω

Vref : 250mV

R13=0.5k Ω

Vref : 150mV



● : 1ch, LG=0.02nH, RG=0.00012 Ω

△ : 16ch, LG=0.02nH, RG=0.00012 Ω

× : 16ch, LG=2nH, RG=0.002 Ω

◆ : 16ch, LG=2nH, RG=0.012 Ω

◇ : 16ch, LG=2nH, RG=0.012 Ω , Bypass-cap.=660uF

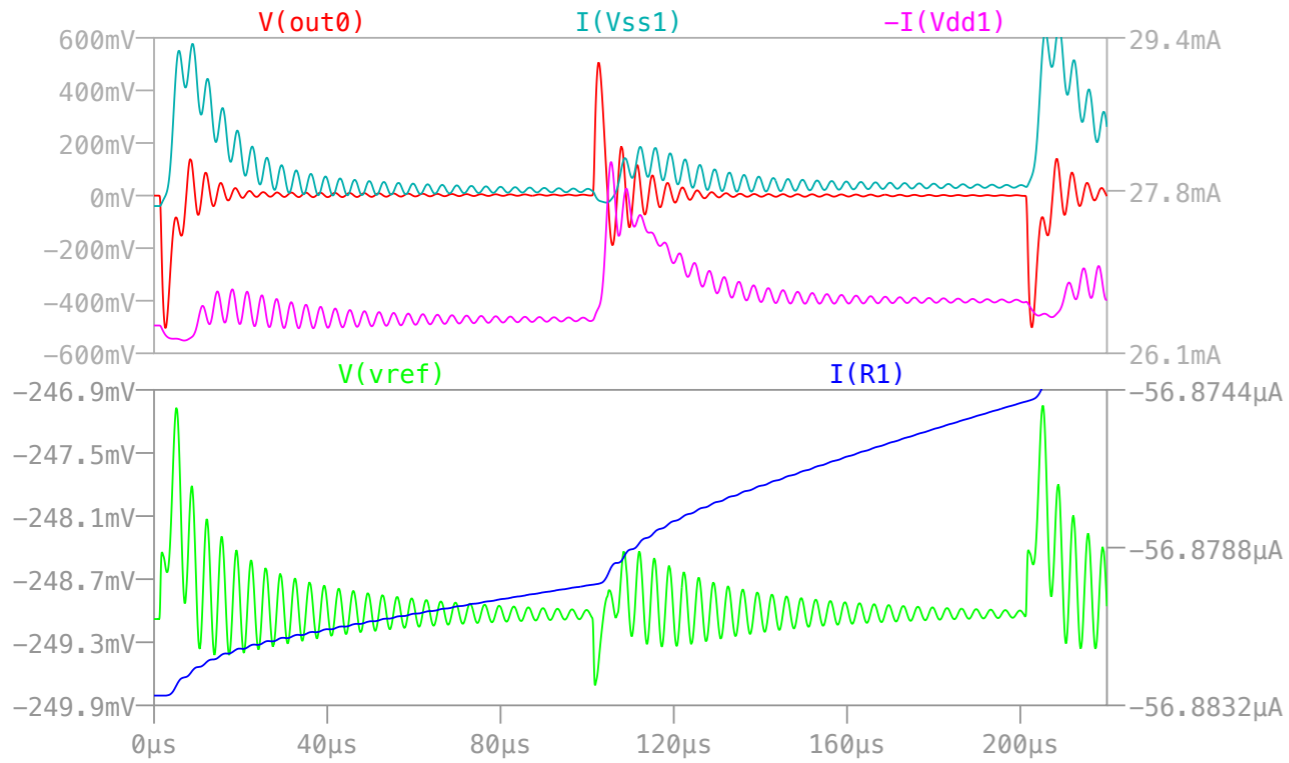
× is ● at Vref=250mV.

Effect of Kinds of Bypass-Capacitors (1)

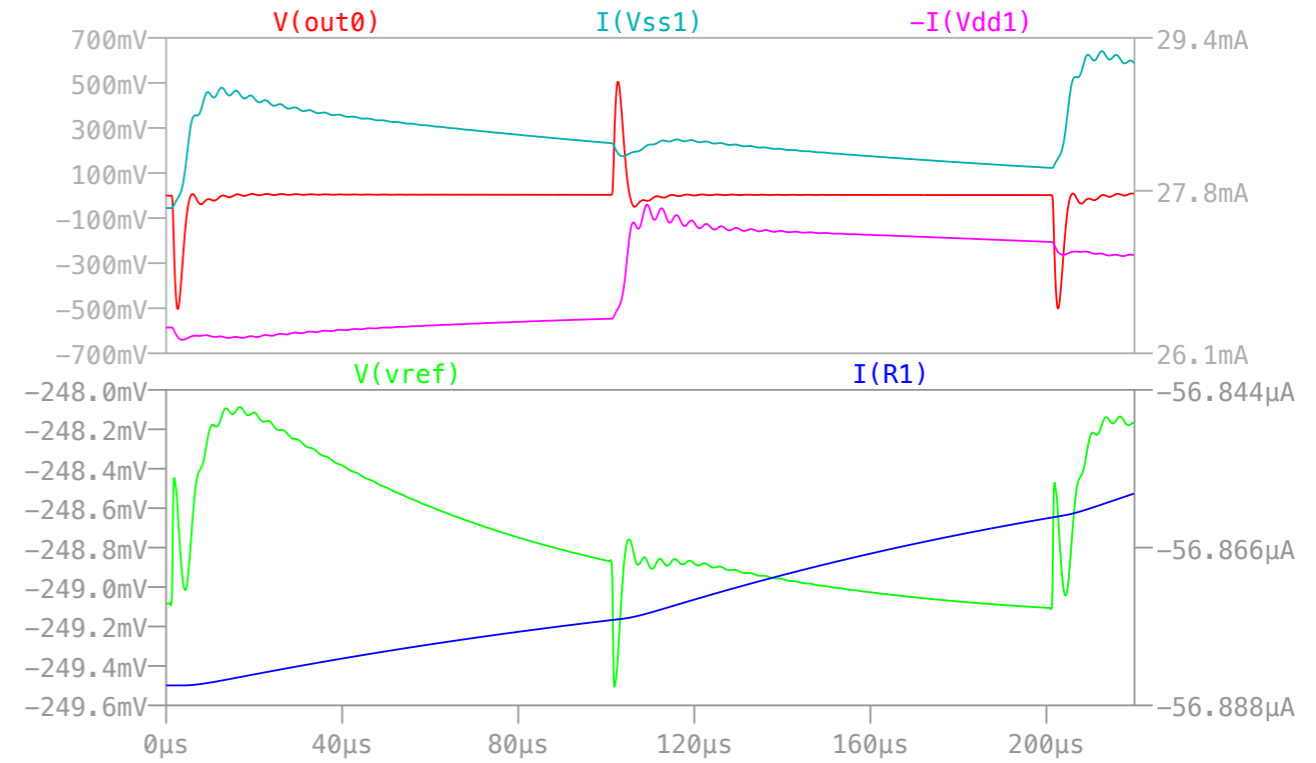
$V_{ref} = 250\text{mV}$

$L_G = 2\text{nH}$, $R_G = 0.002\Omega$

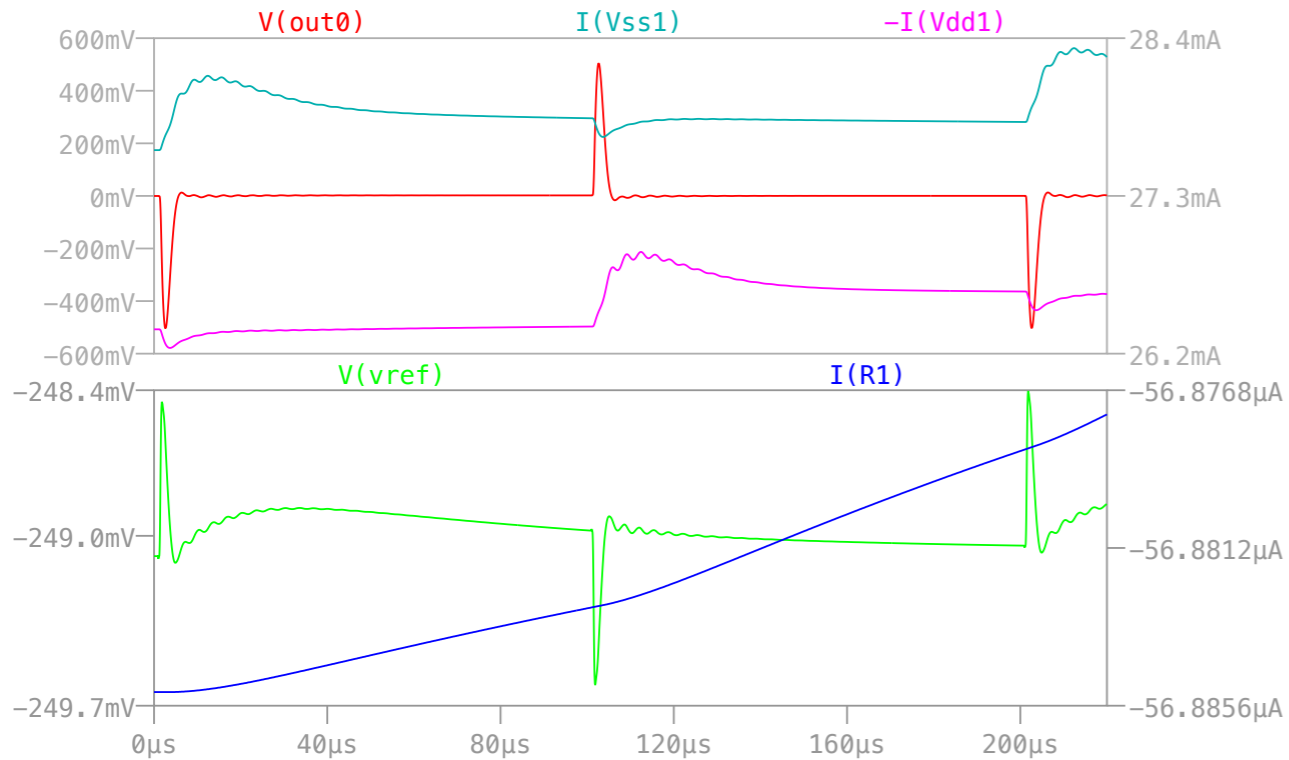
Solid Tantalum 660uF $I_{BIAS} = 56.9\mu\text{A}$



Ceramic 100uF $I_{BIAS} = 56.9\mu\text{A}$



Ceramic 660uF $I_{BIAS} = 56.9\mu\text{A}$



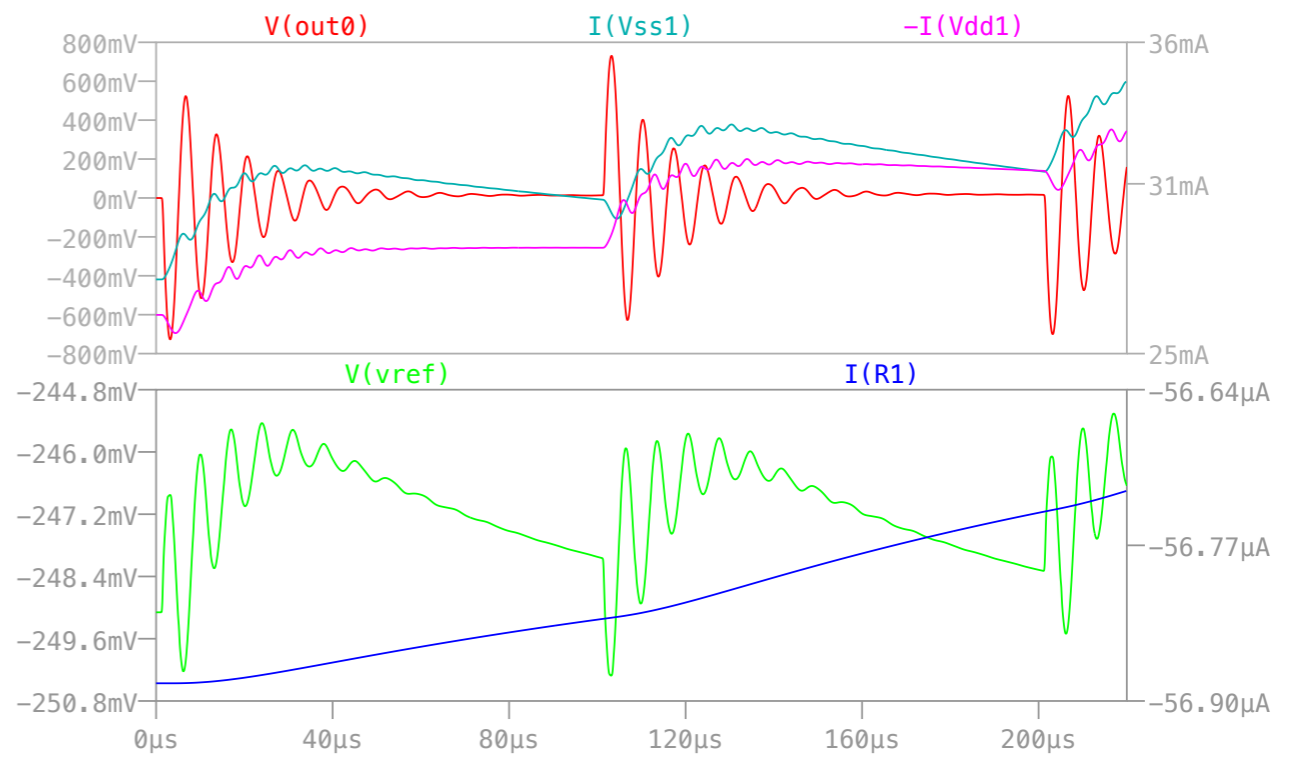
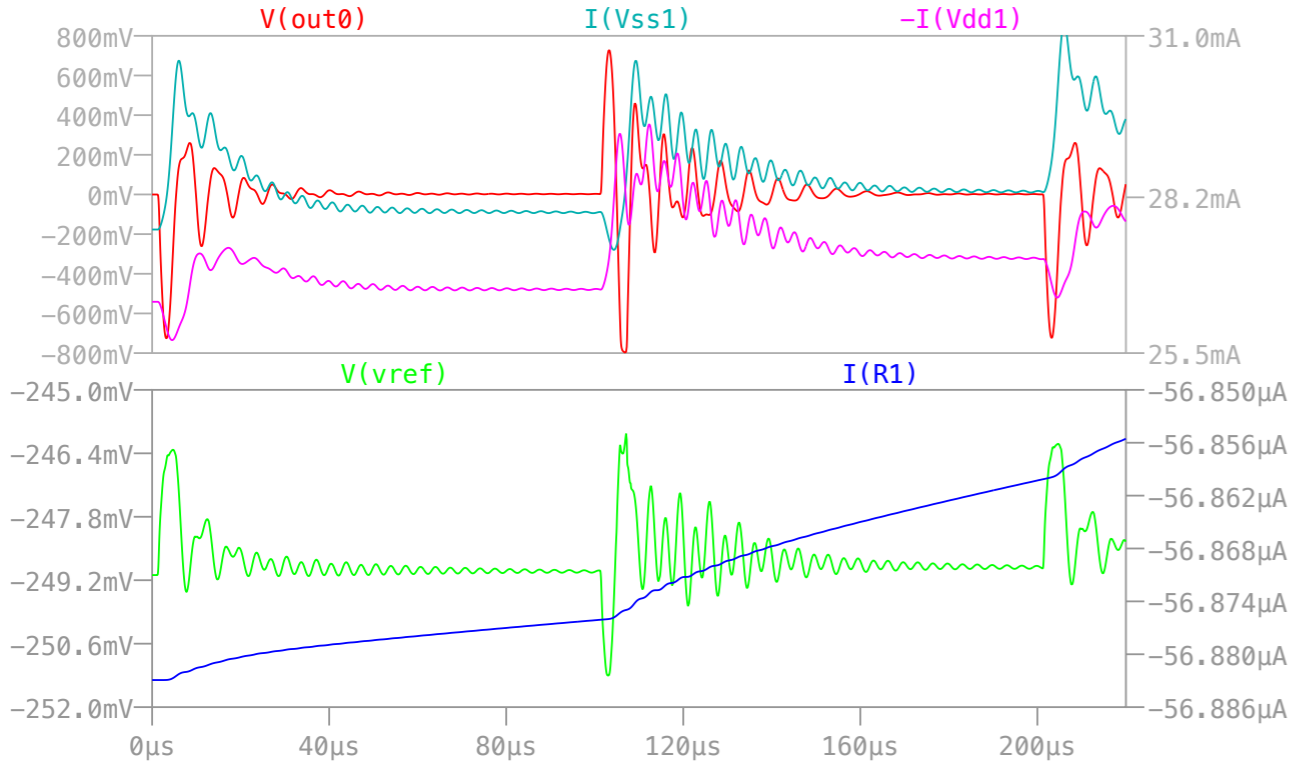
Effect of Kinds of Bypass-Capacitors (2)

$V_{ref} = 250mV$

$LG = 2nH, RG = 0.01\Omega$

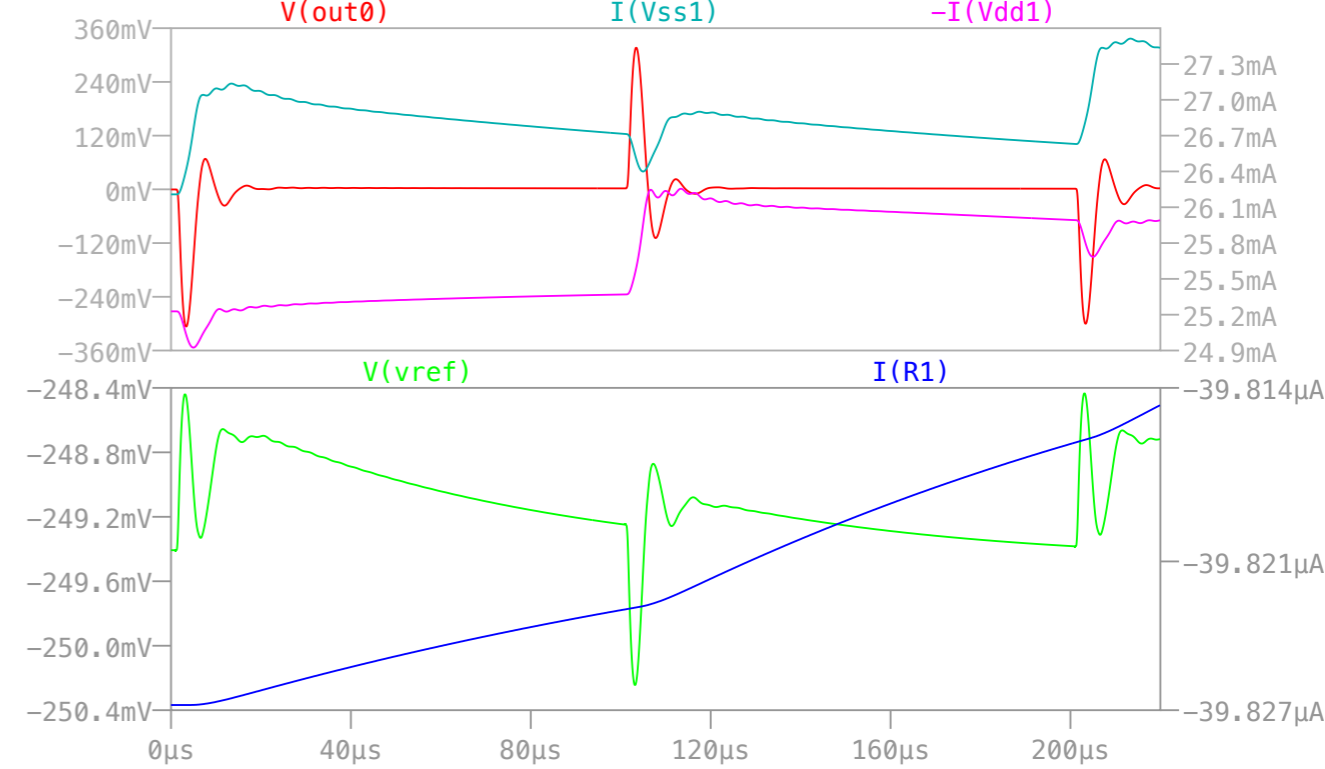
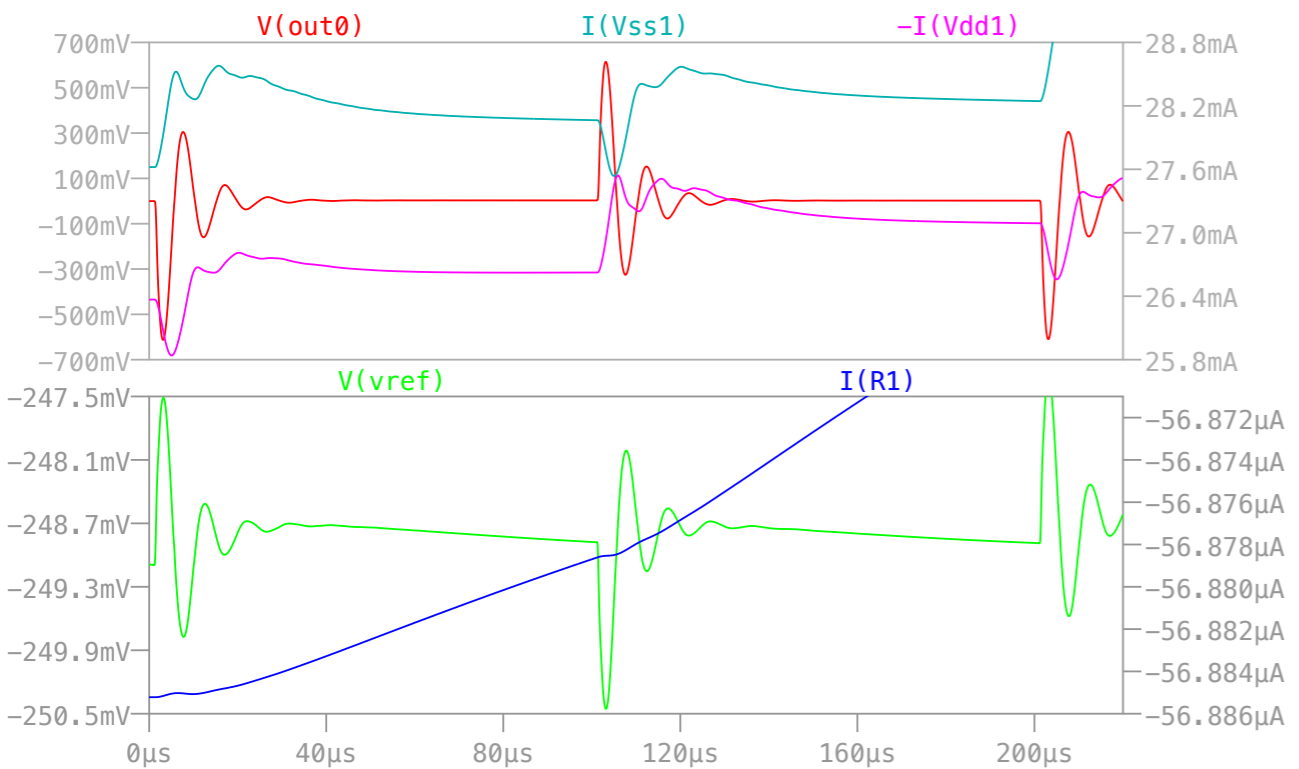
Solid Tantalum 660uF $I_{BIAS} = 56.9\mu A$

Ceramic 100uF $I_{BIAS} = 56.9\mu A$



Ceramic 660uF $I_{BIAS} = 56.9\mu A$

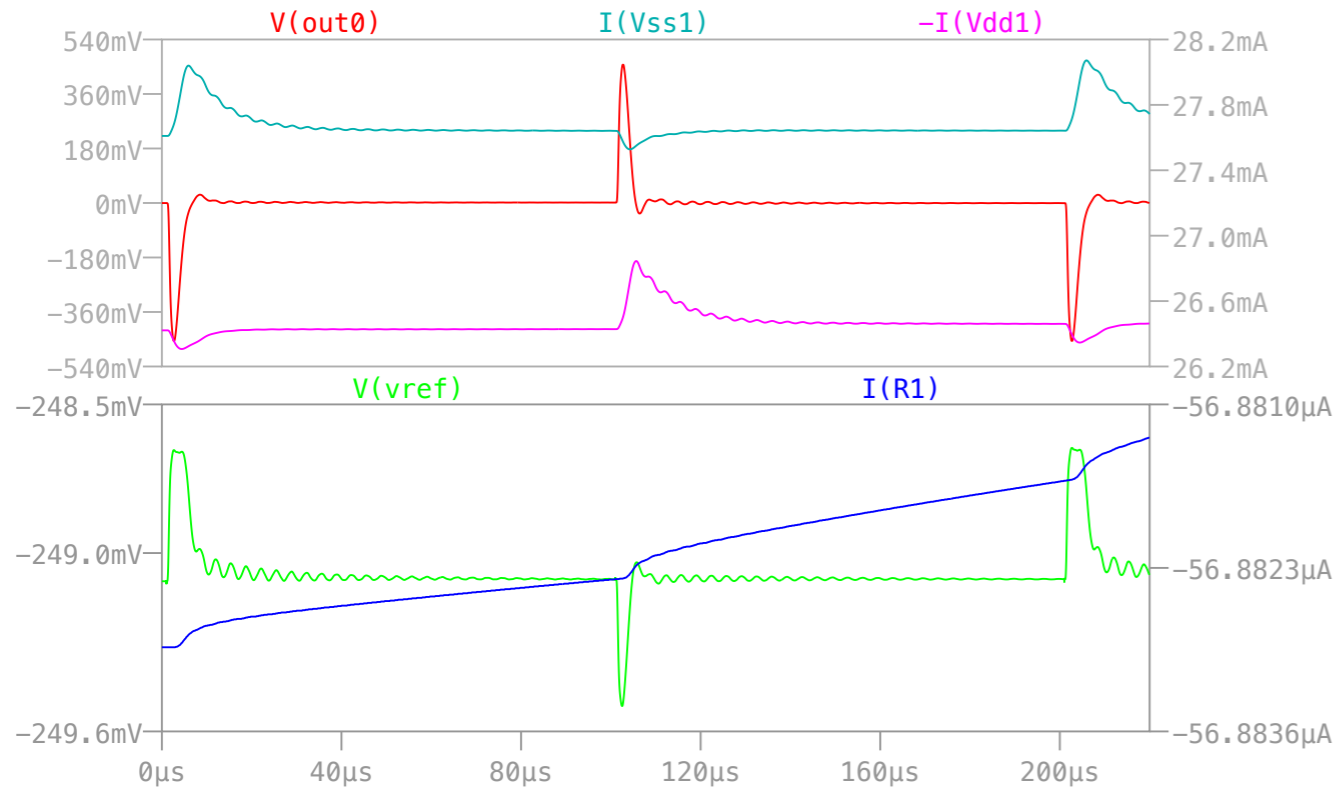
Ceramic 100uF $I_{BIAS} = 39.8\mu A$



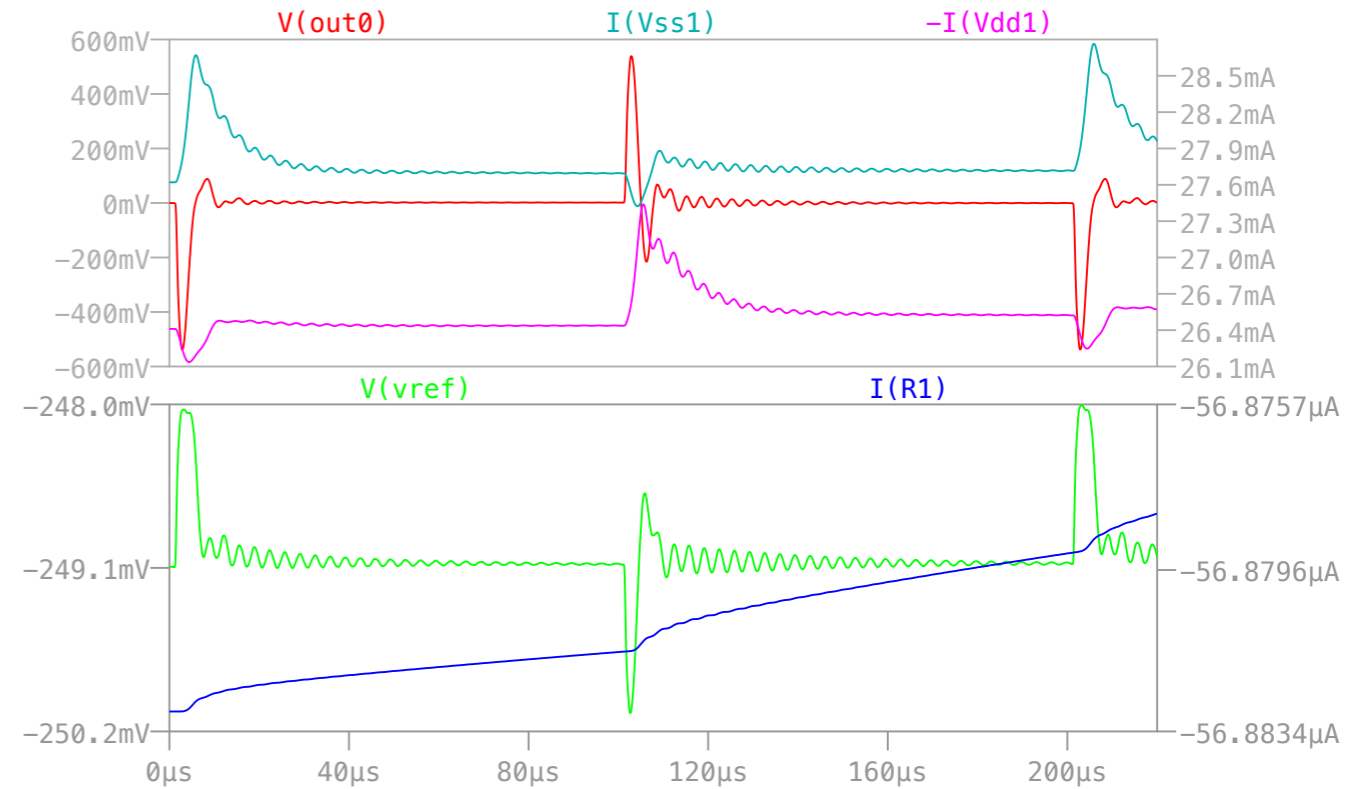
Solid Tantalum 660uF: IBIAS=56uA, Vref=-250mV

LG=2nH, RG=0.012Ω

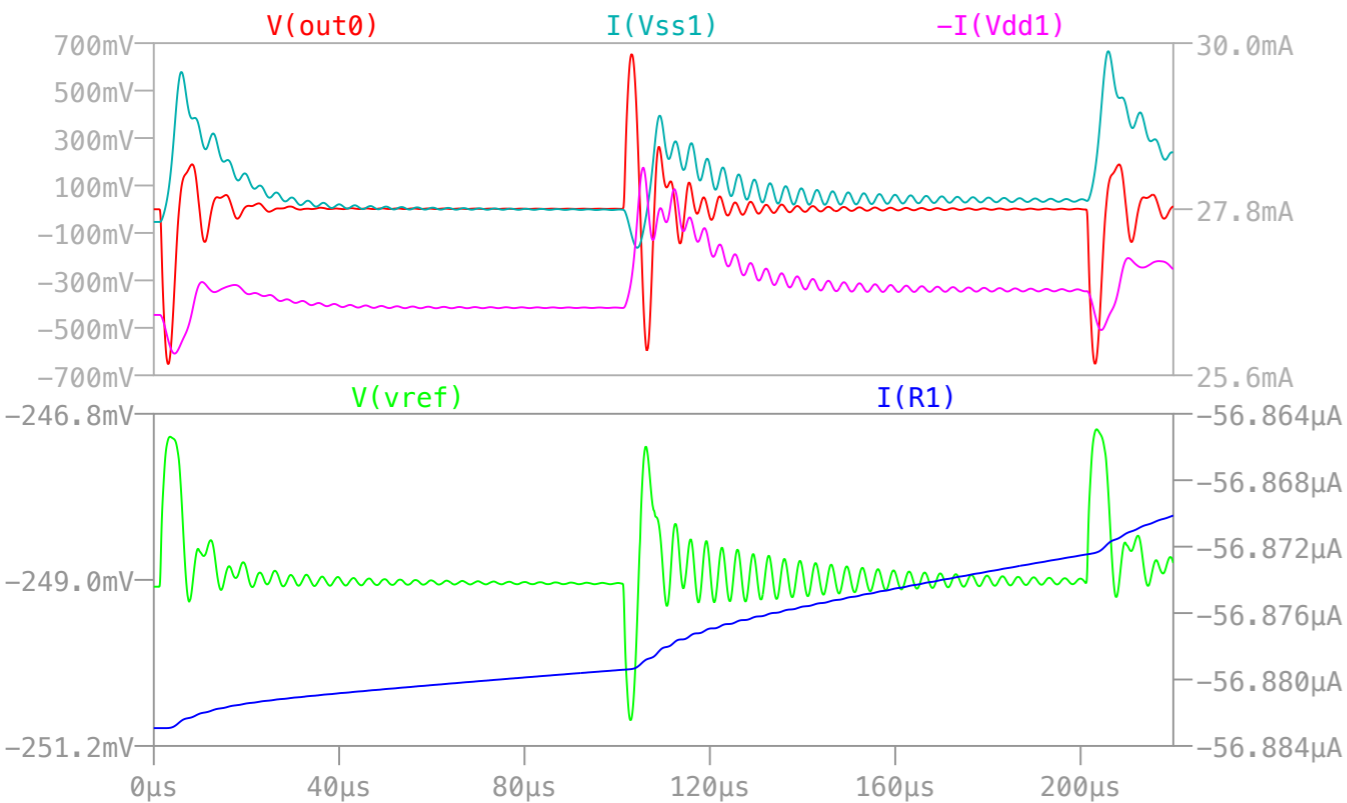
4ch terminated :



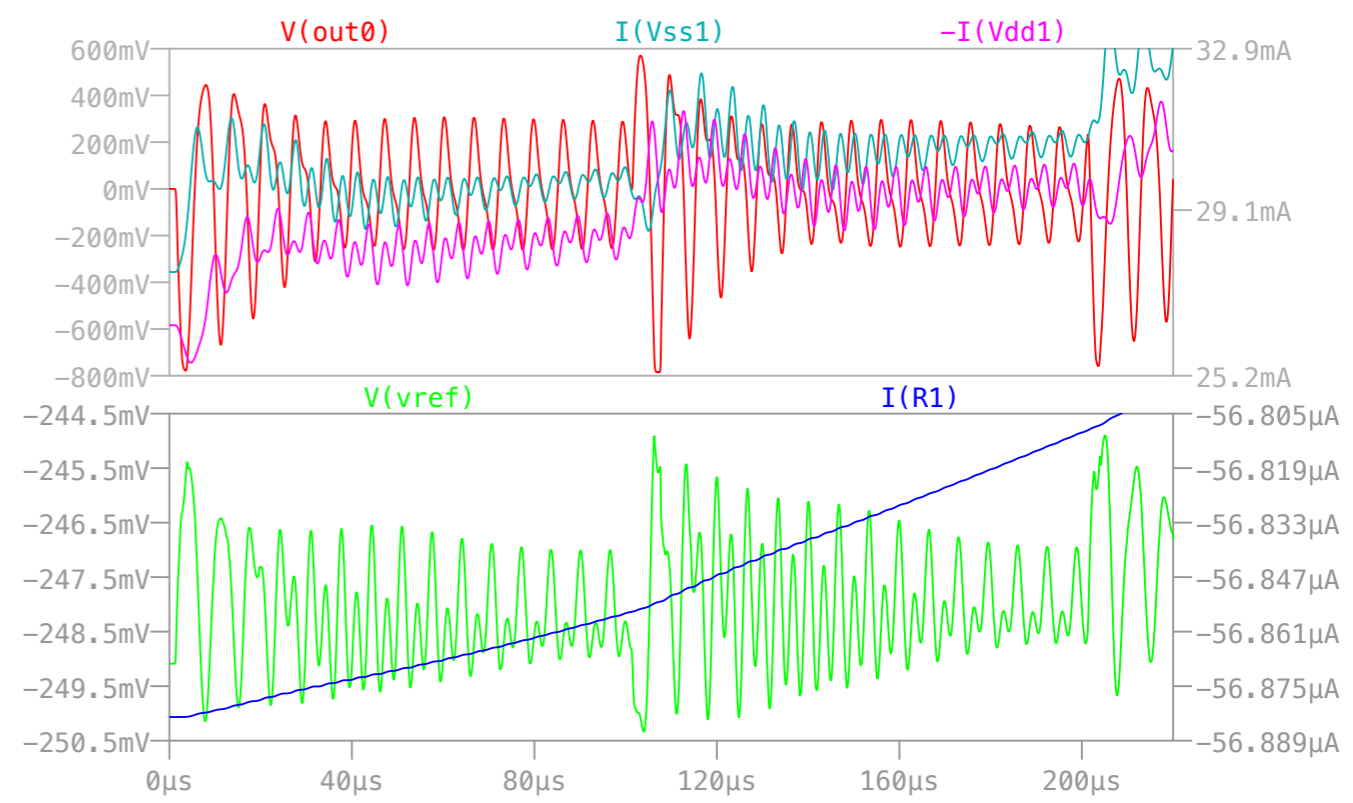
8ch terminated :



12ch terminated :



16ch terminated :

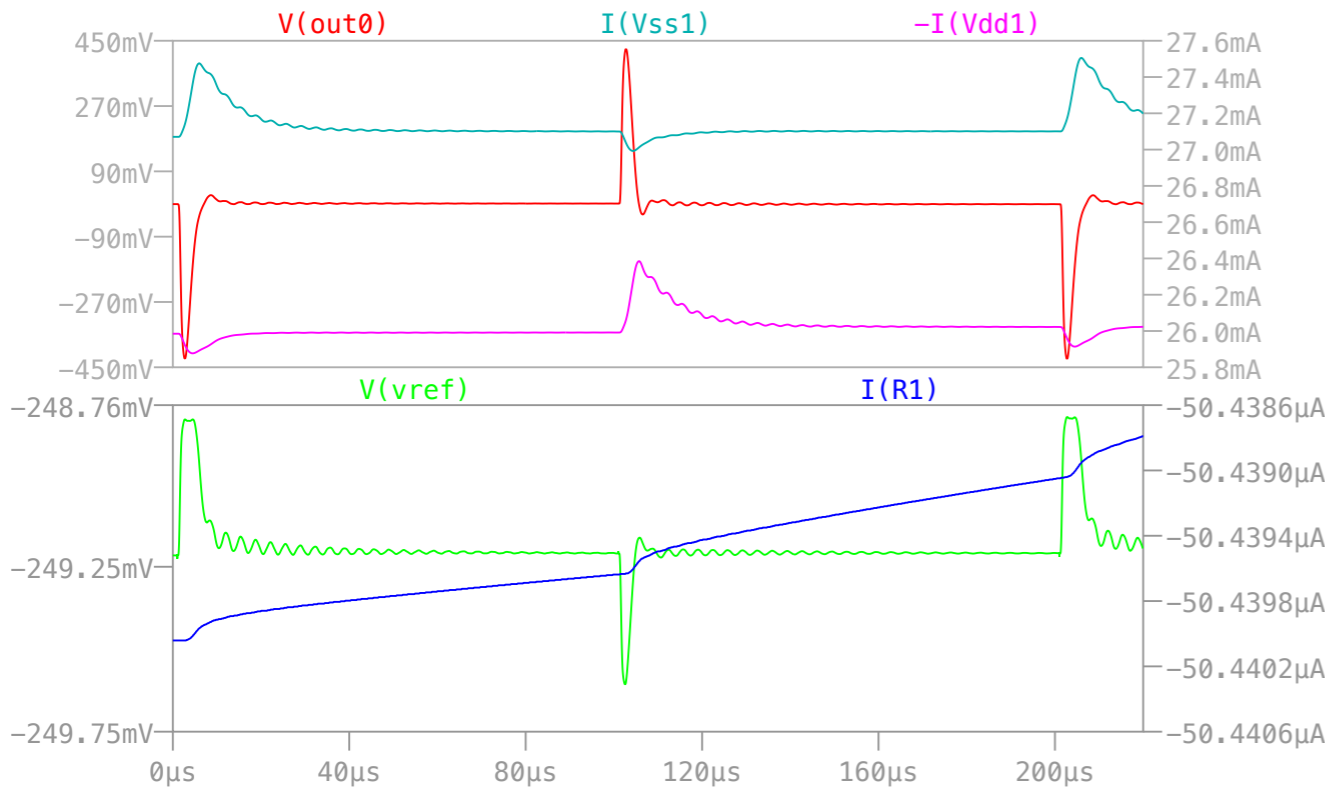


Solid Tantalum 660uF: IBIAS=50.4uA, Vref=-250mV

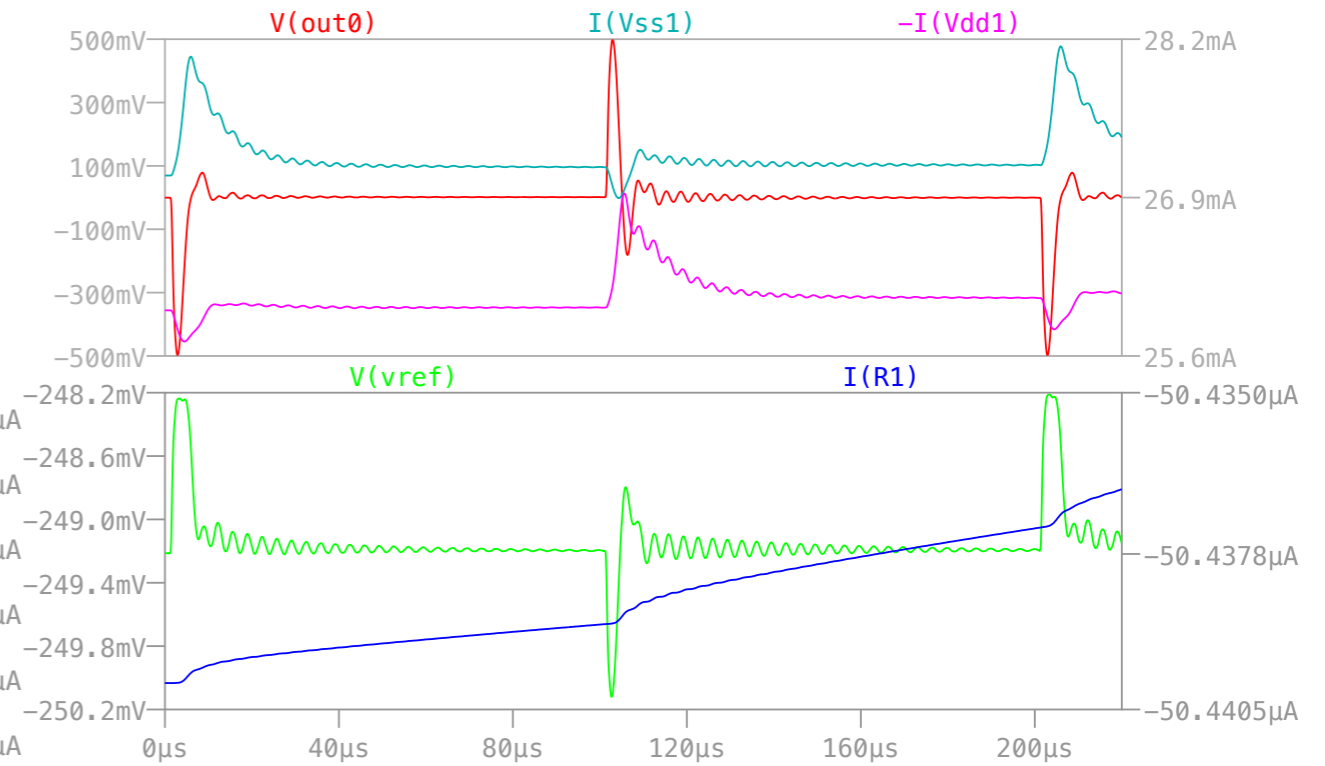
Vref=-250mV

LG=2nH, RG=0.012Ω

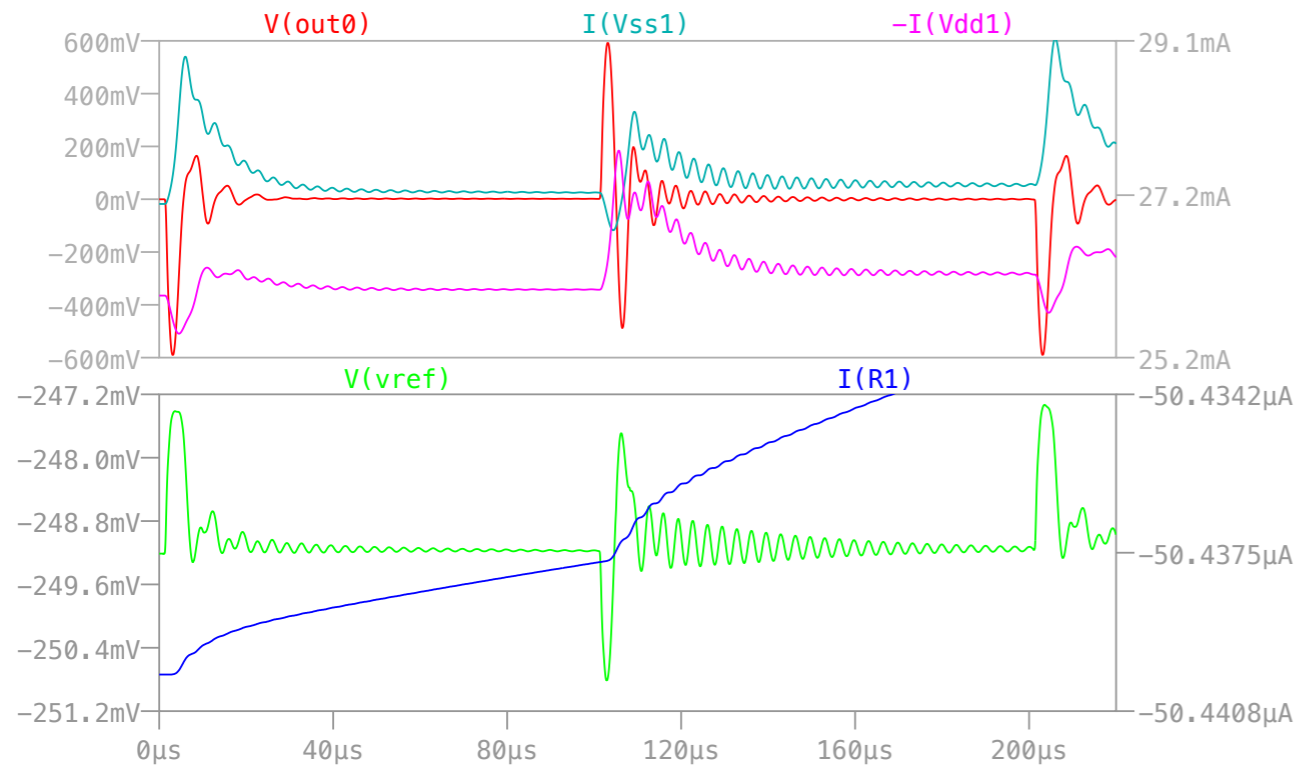
4ch terminated :



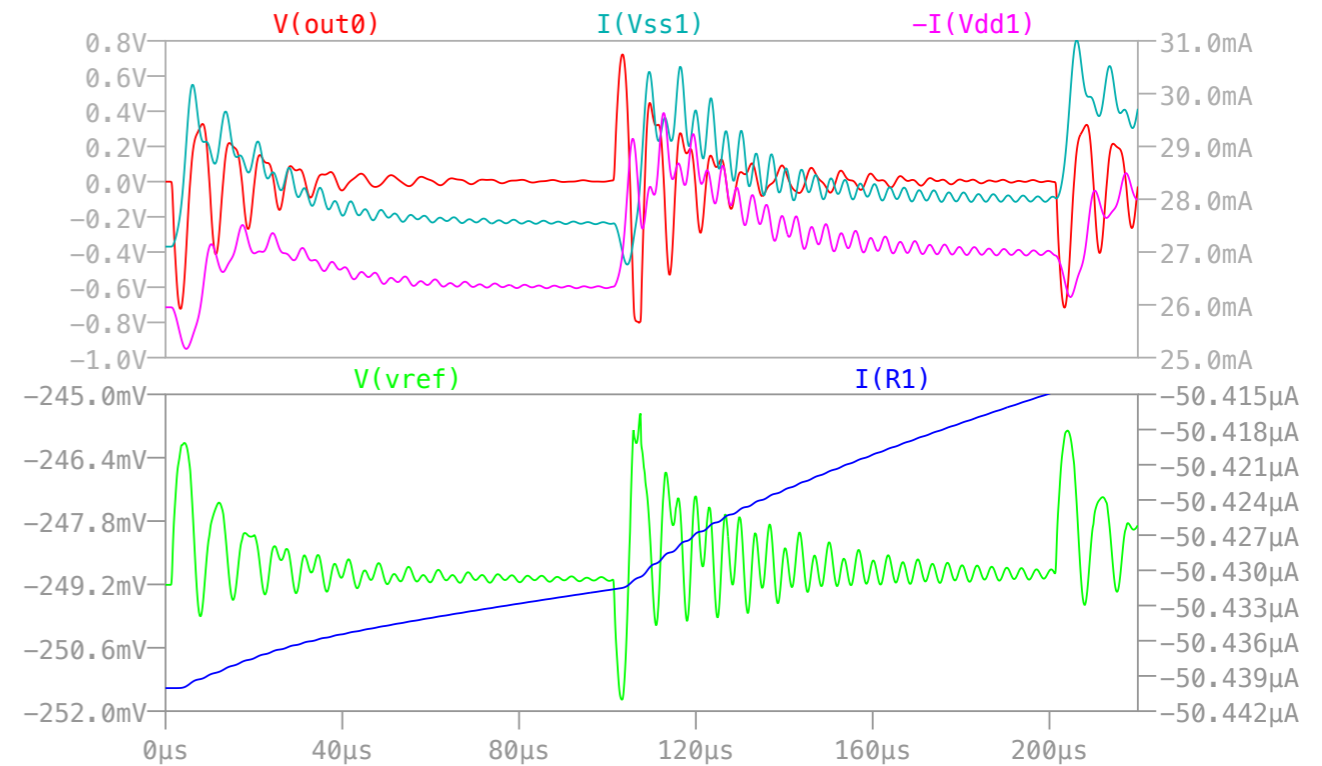
8ch terminated :



12ch terminated :



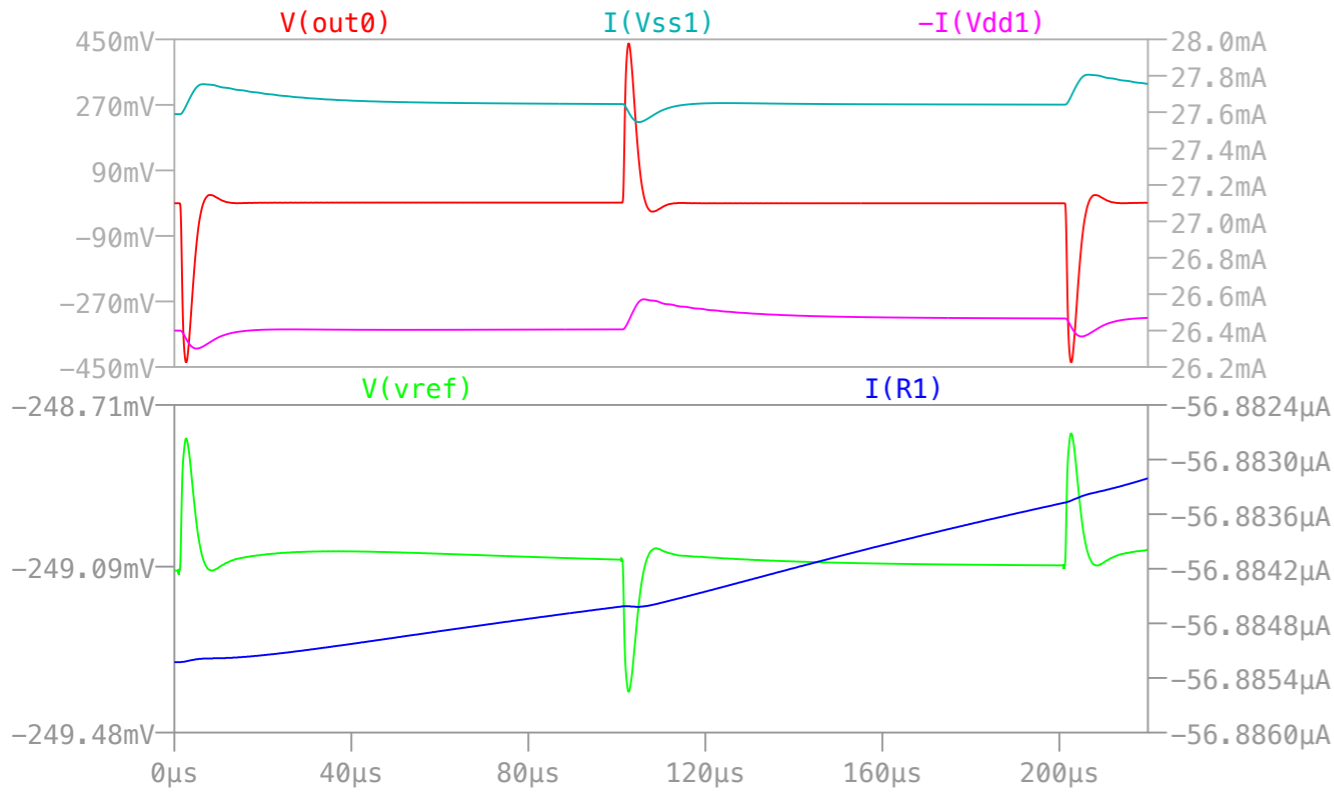
16ch terminated :



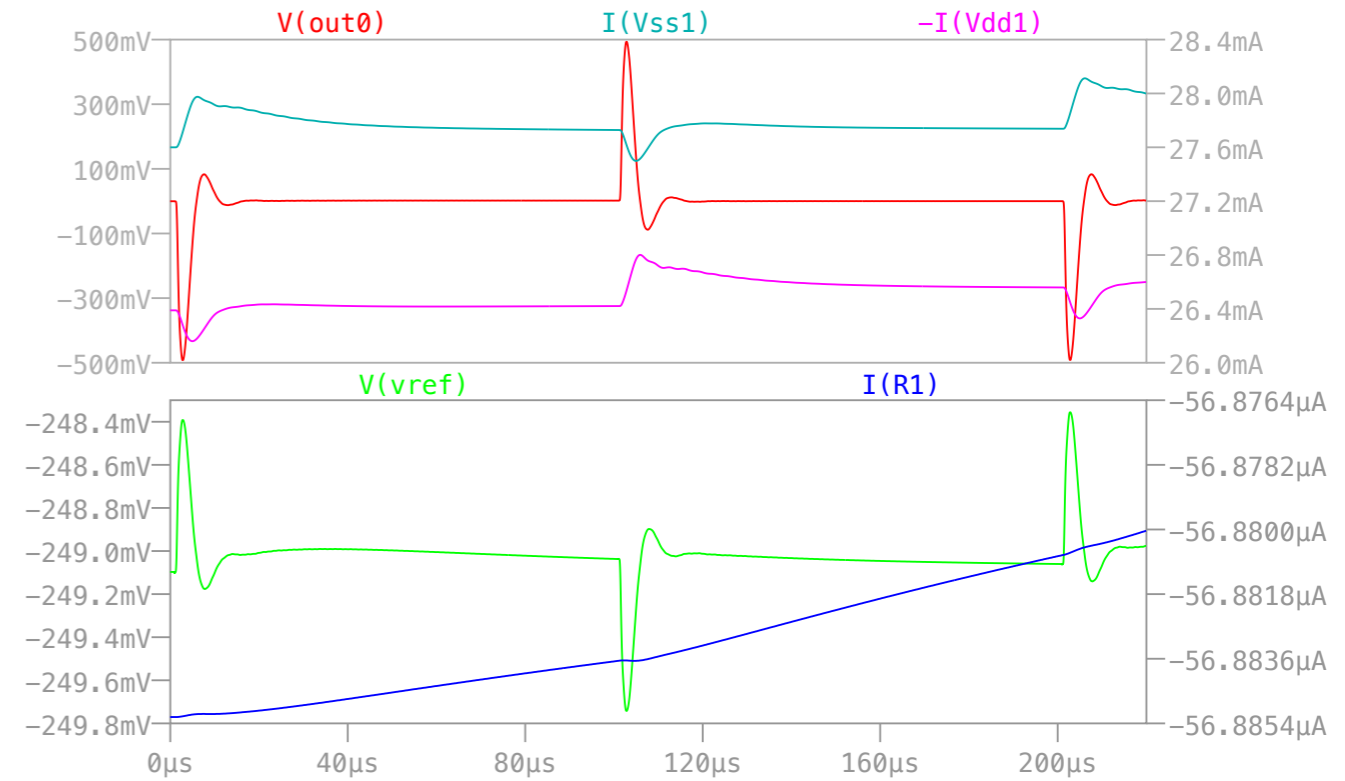
Ceramic 660uF: IBIAS=56uA, Vref=-250mV

LG=2nH, RG=0.012Ω

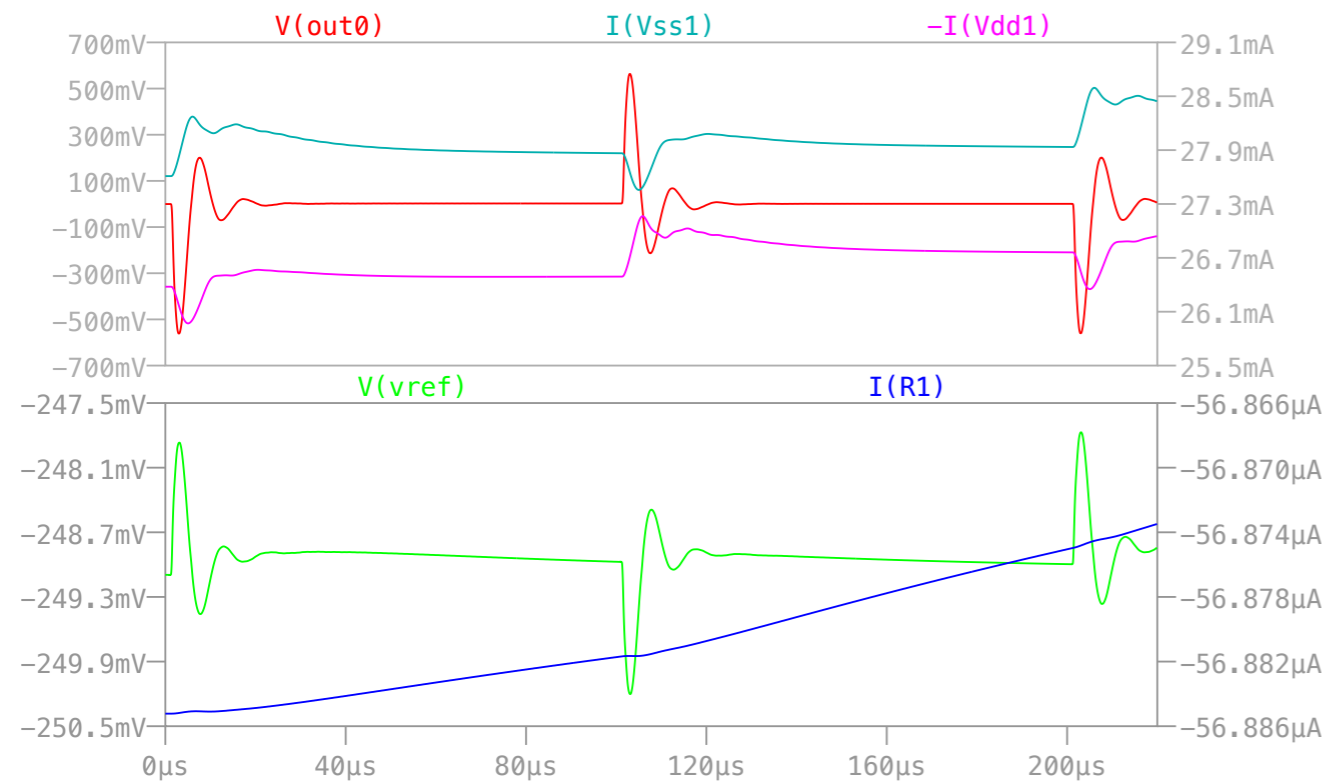
4ch terminated :



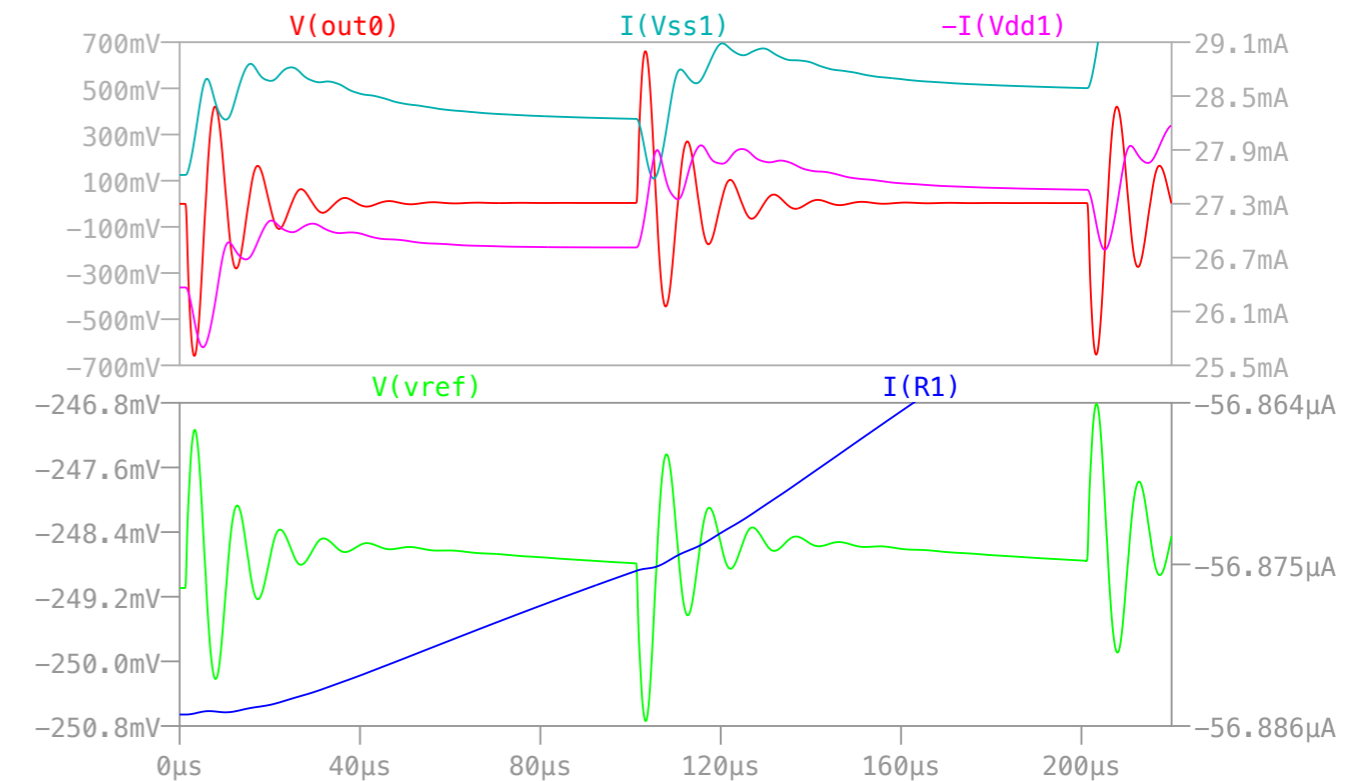
8ch terminated :



12ch terminated :



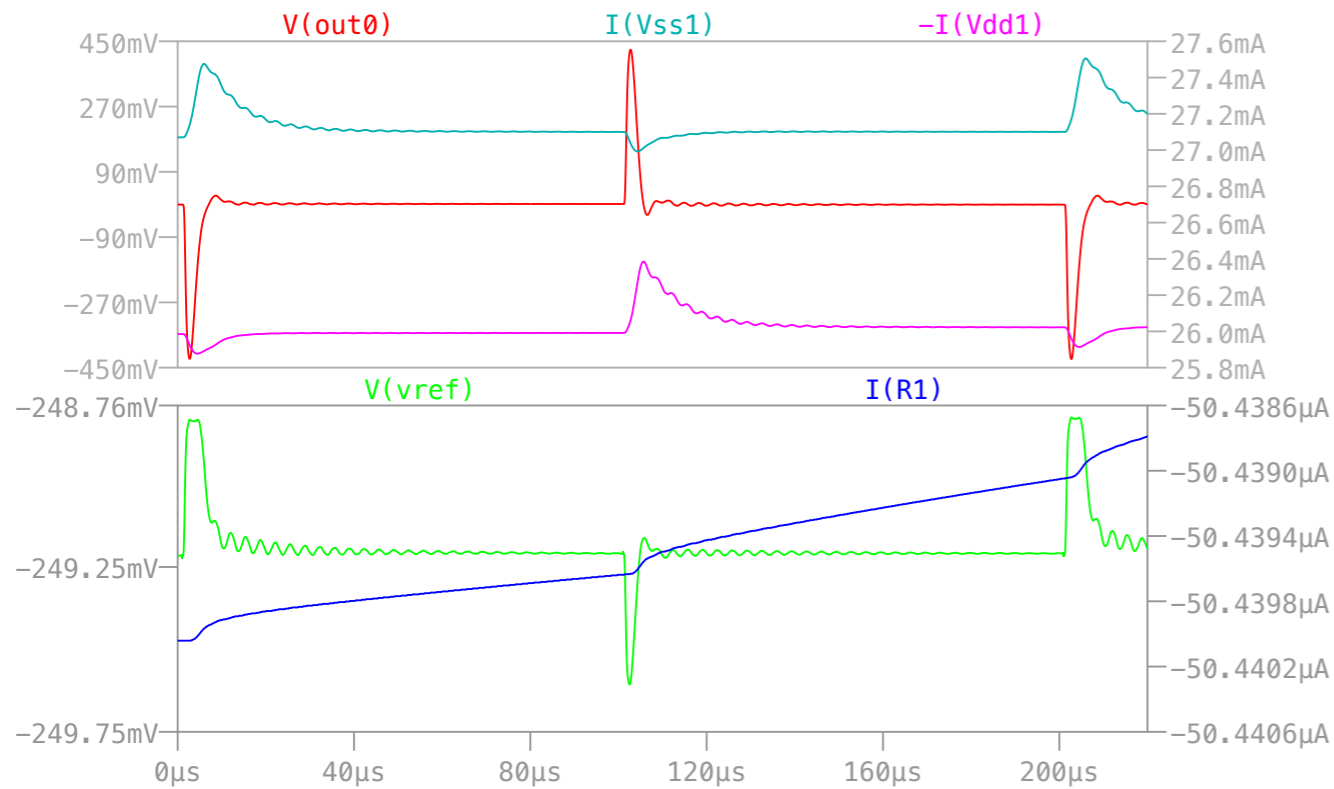
16ch terminated :



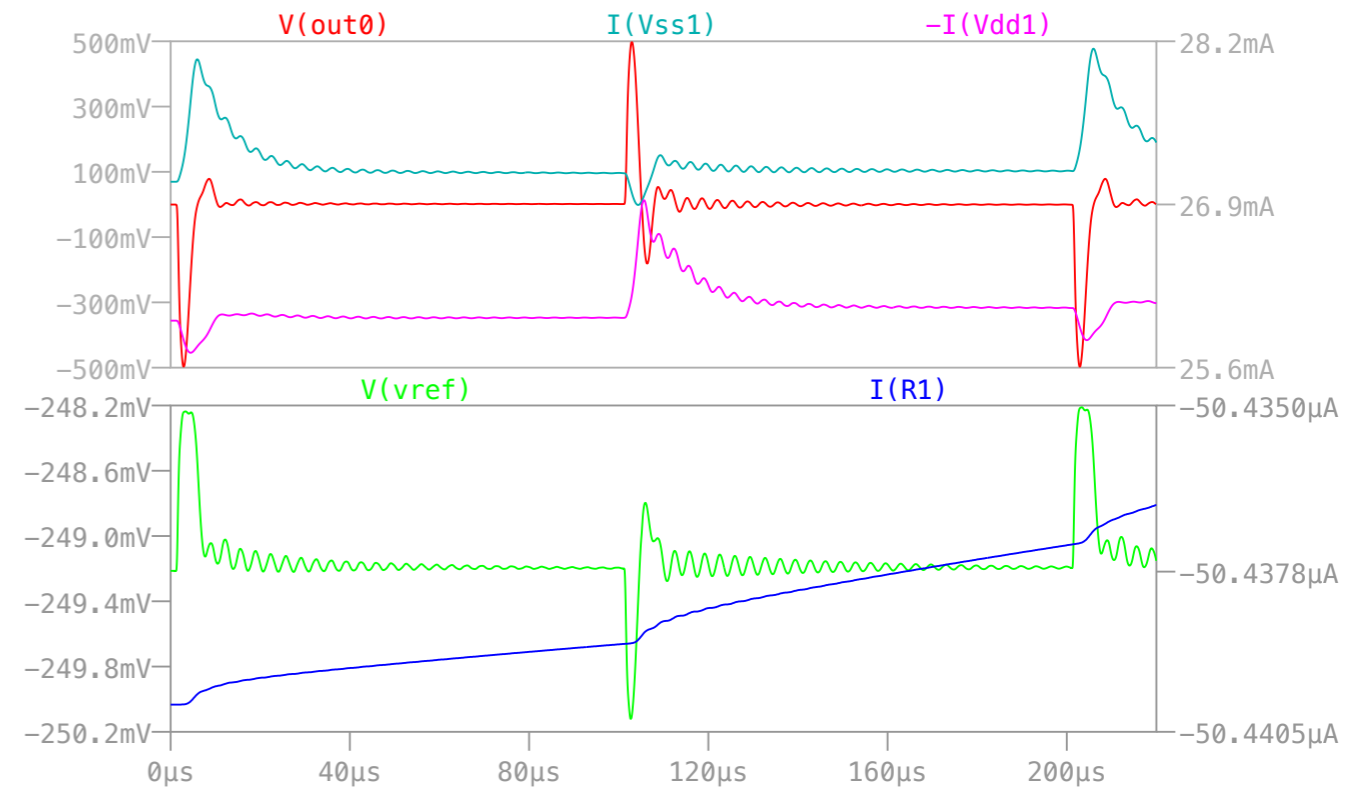
Ceramic 660uF : IBIAS=50.4uA, Vref=-250mV

LG=2nH, RG=0.012Ω

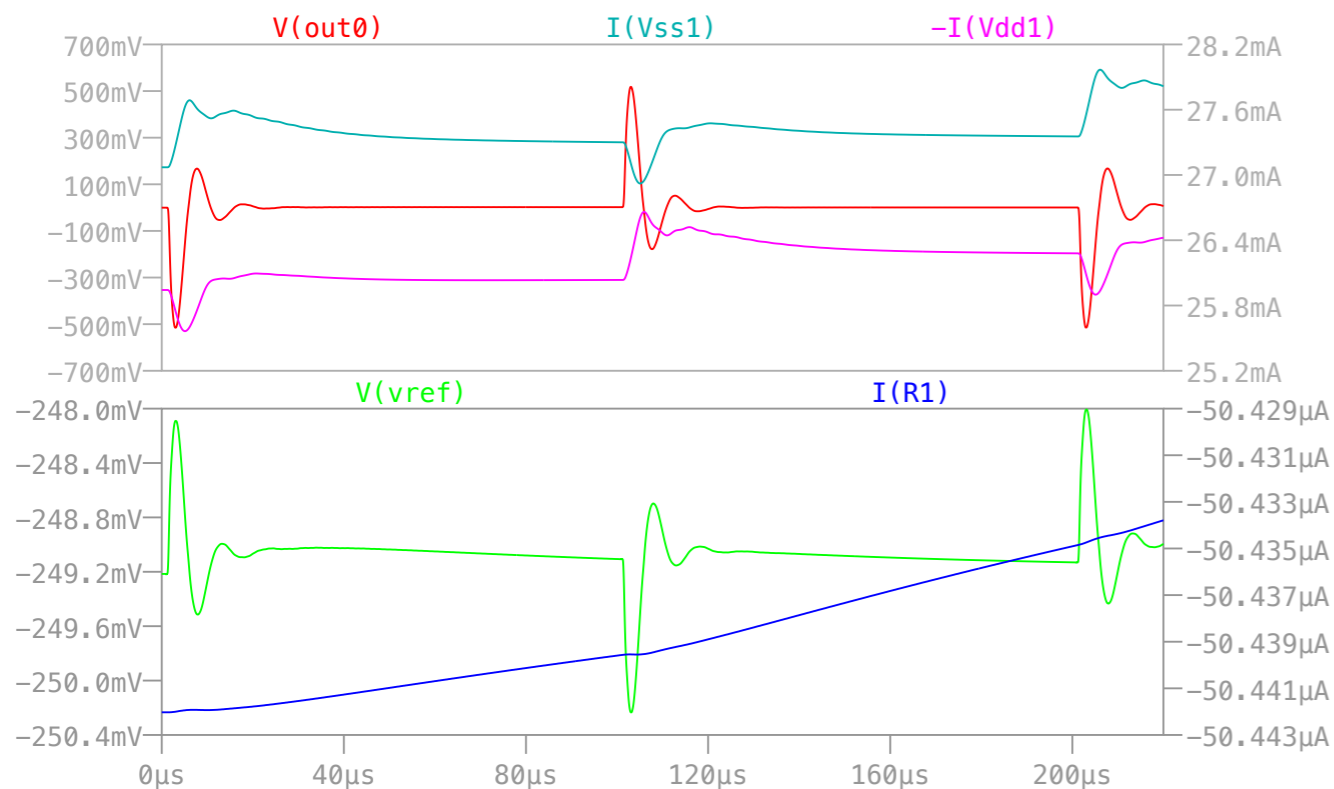
4ch terminated :



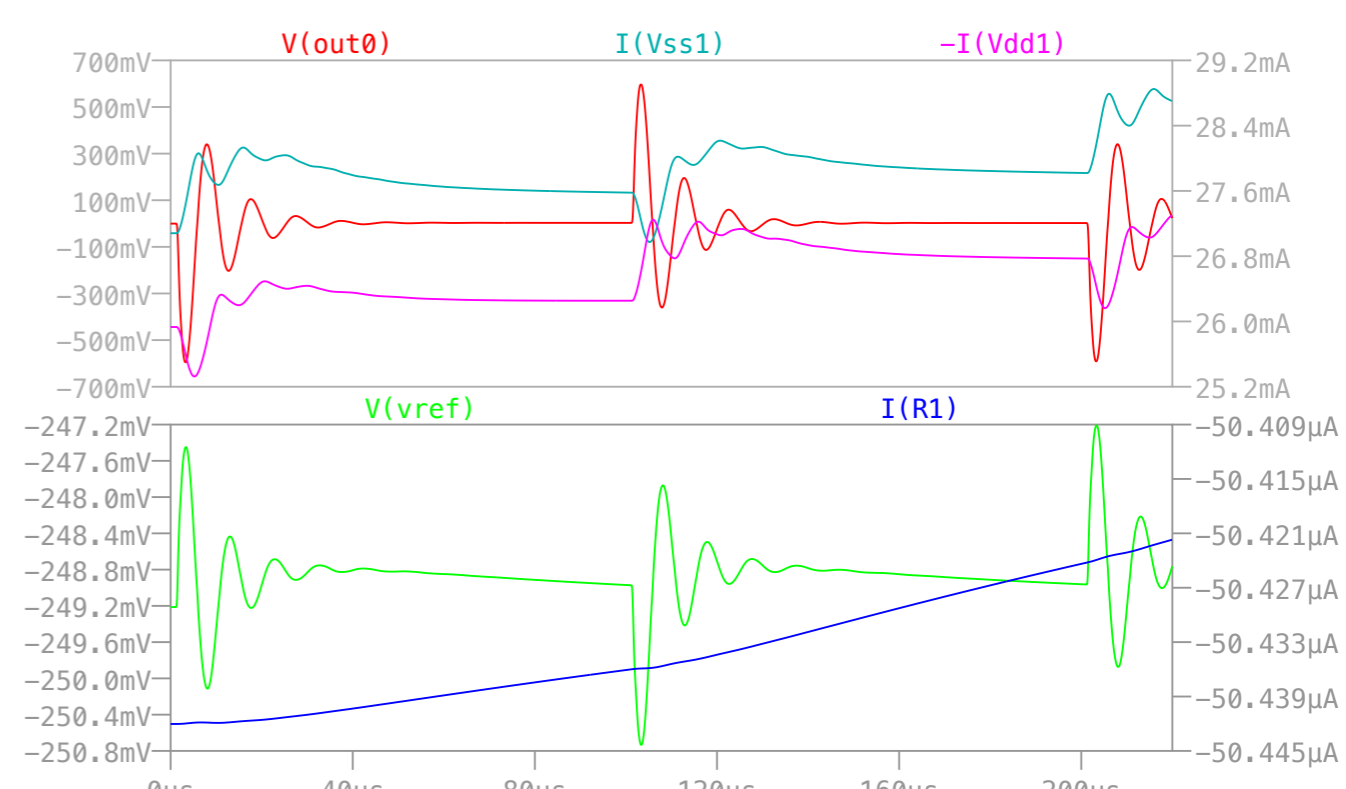
8ch terminated :



12ch terminated :



16ch terminated :

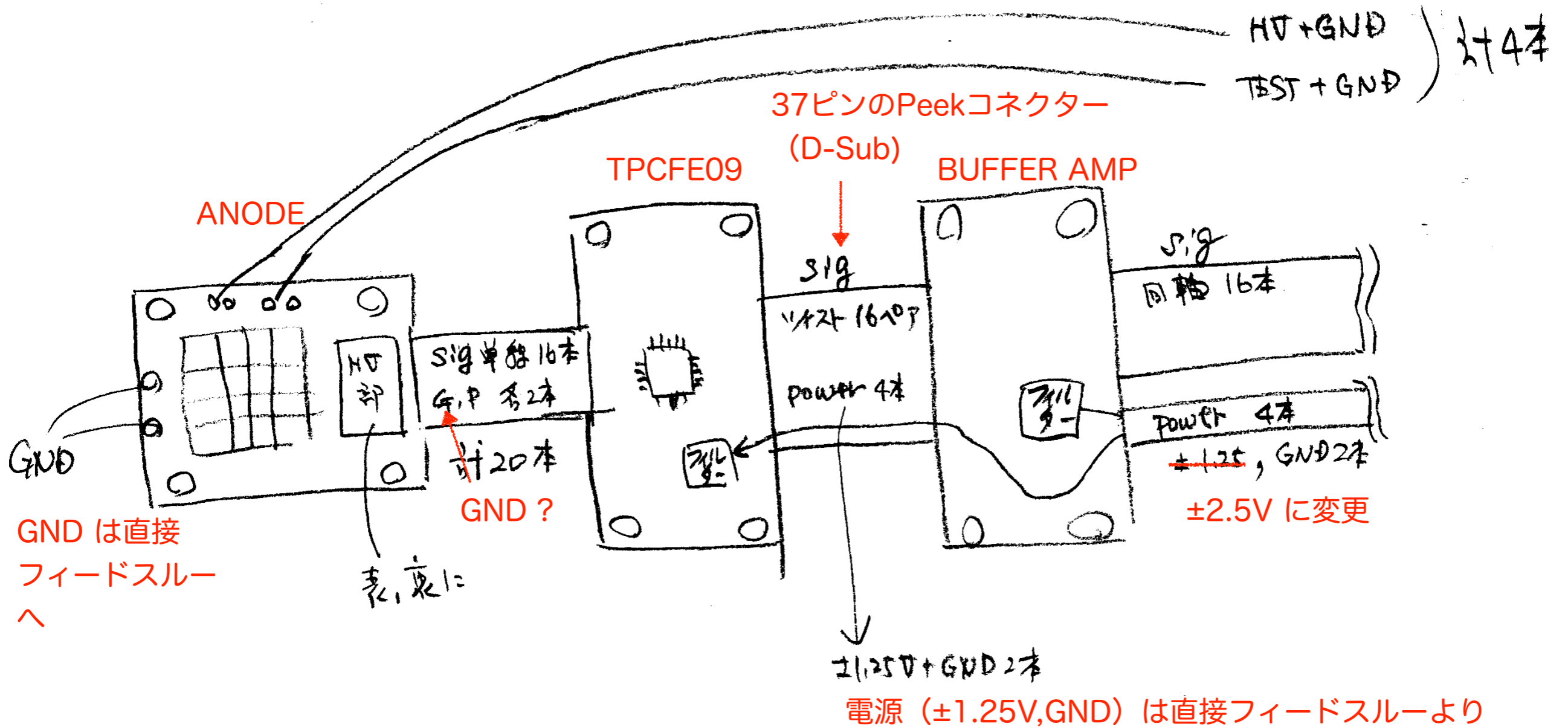


まとめ

(1) 固体タンタルでの発振の波形は実際のものとは違っているが、発振の出現するチャンネル数依存の振る舞いは再現できていると思われる。このことはIBIAS, VrefそしてLG, RGのパラメータに強く依存している。

(2) セラミックの場合、定性的な振る舞いを再現できていると思われる。例えば容量が大きい方が発振しにくくなるなど。特に、RG依存性が強いので、低温にした場合の容量の減少とともに、抵抗値の変動が発振を誘発しているかも知れない。

フロントエンドエレクトロニクスの構成：三つのボード (Rogers, セラミック)



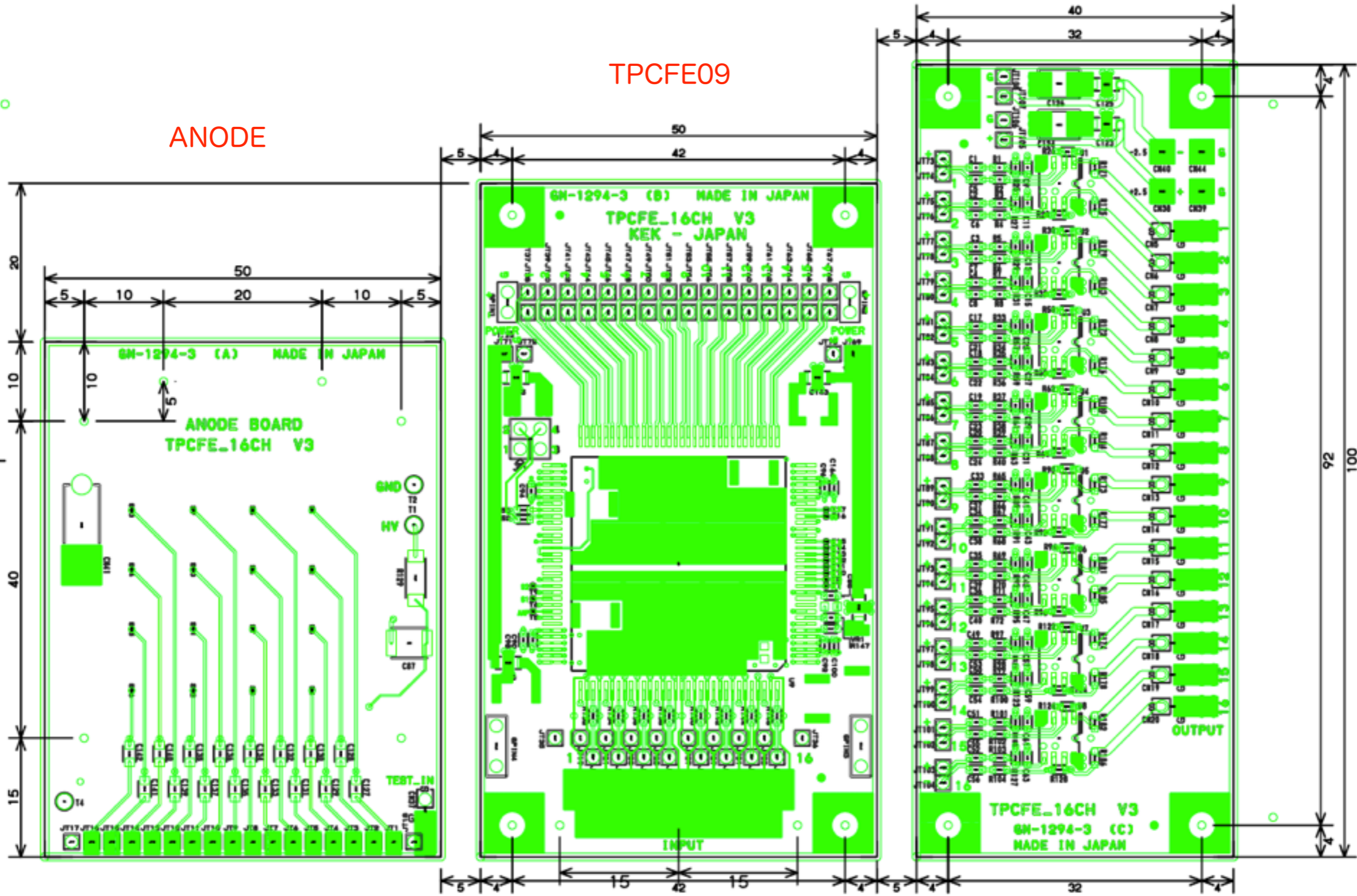
基板の構成

ANODEとTPCFE09の二つのボードはできるだけ近くに設置すること

BUFFER AMP

TPCFE09

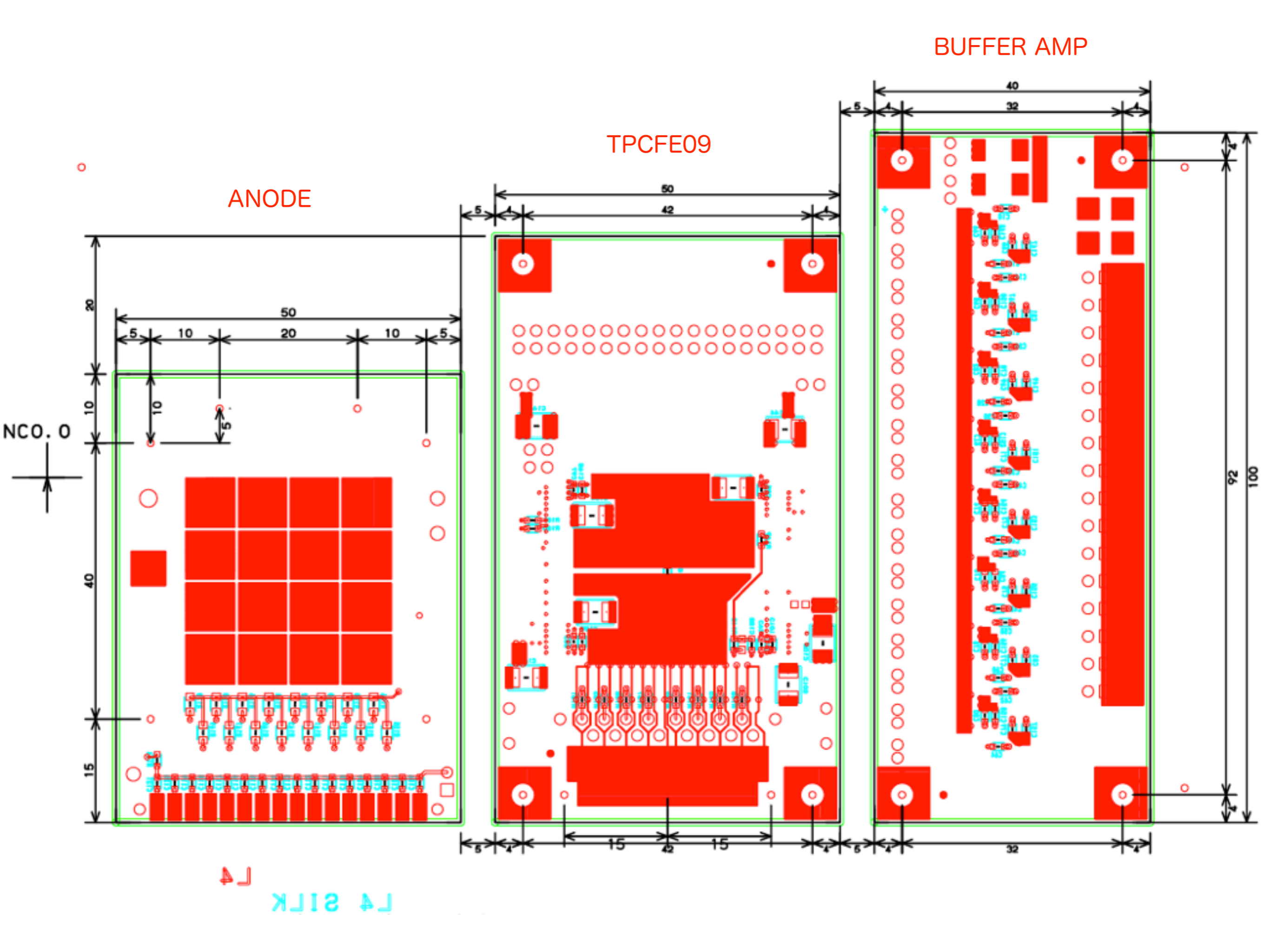
ANODE



NCO. 0

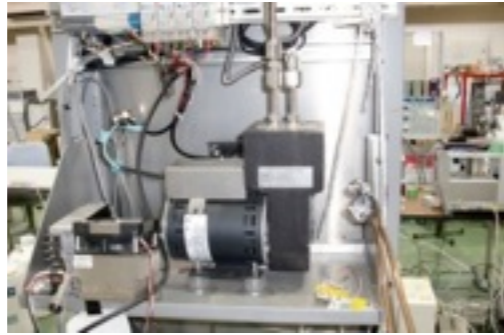
L1

L1 SILK



予冷装置

ガス循環サーキュレーター



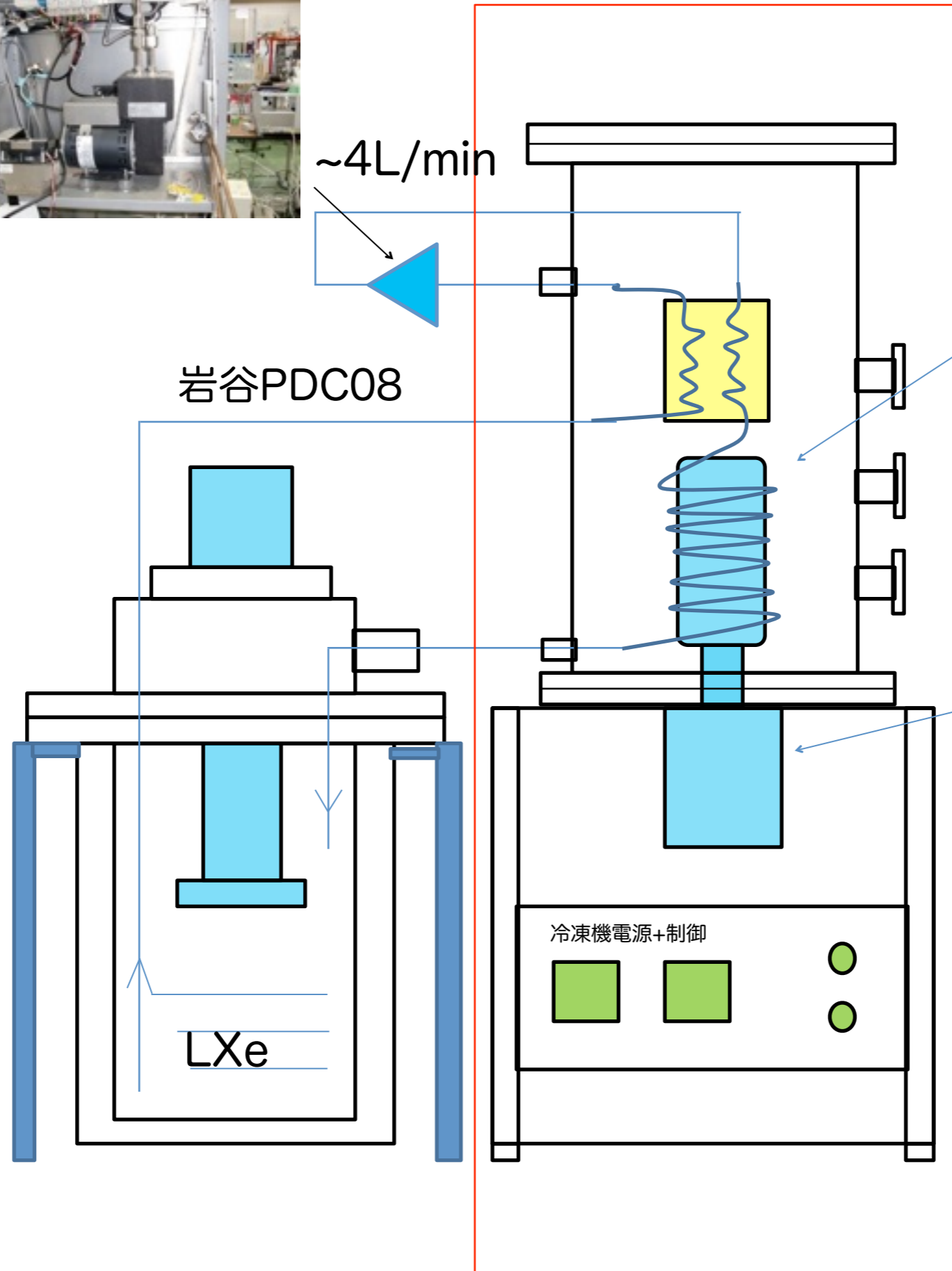
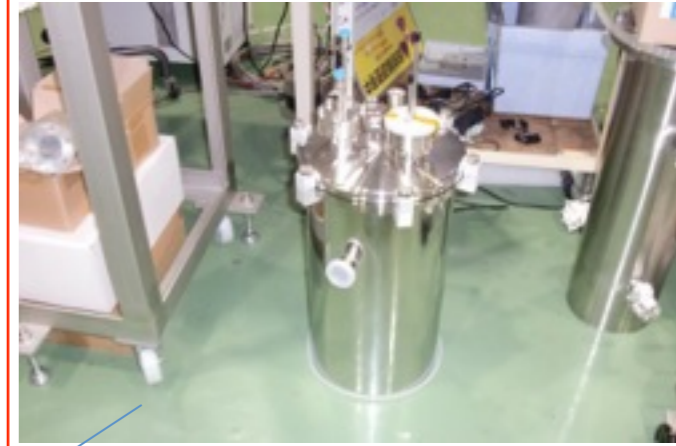
ガスハンドリングパネル



LXeクライオスタット



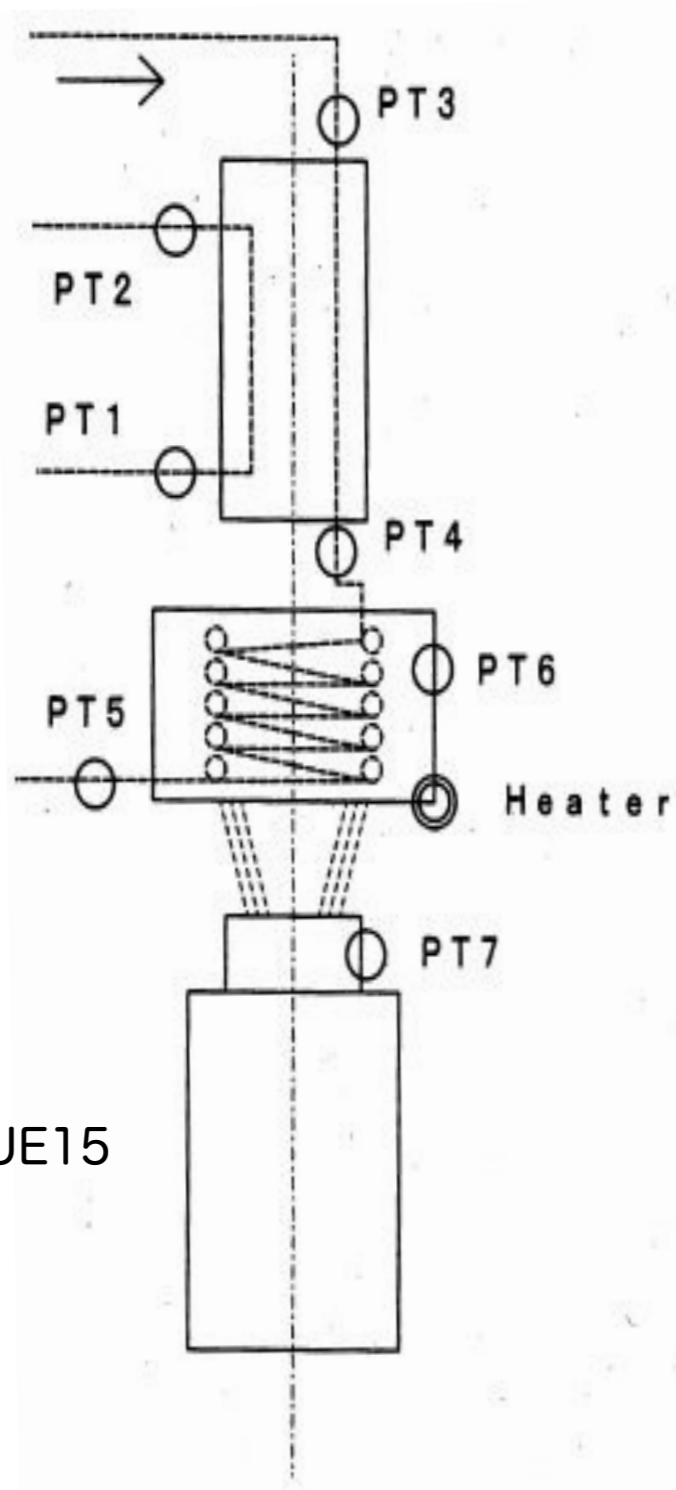
真空断熱・熱交換器



冷凍機インバーター
ノイズ大?。

TWINBIRD SC-UE15
173K@30W

Thermal
exchanger
in vacuum



TWINBIRD SC-UE15
173K@30W

Xe Precooling system



“Improvement of xenon purification system using a combination of a pulse tube refrigerator and a coaxial heat exchanger”, Chen W_-T. et al., Proceedings of ICEC24 - ICMC 2012, Fukuoka, May 14-18 2012

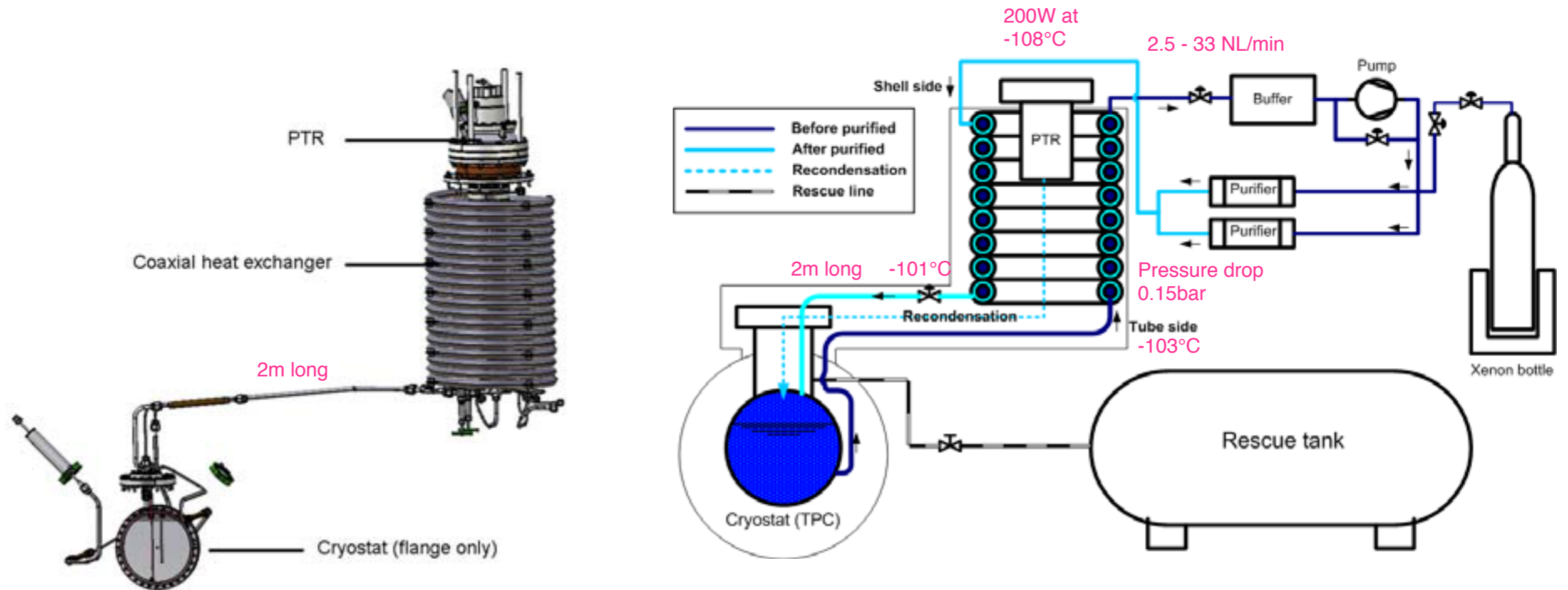


Figure 1: (left) 3D drawing of the PTR, heat exchanger and the connection with cryostat. (right) Schematic of XEMIS cryogenic system.

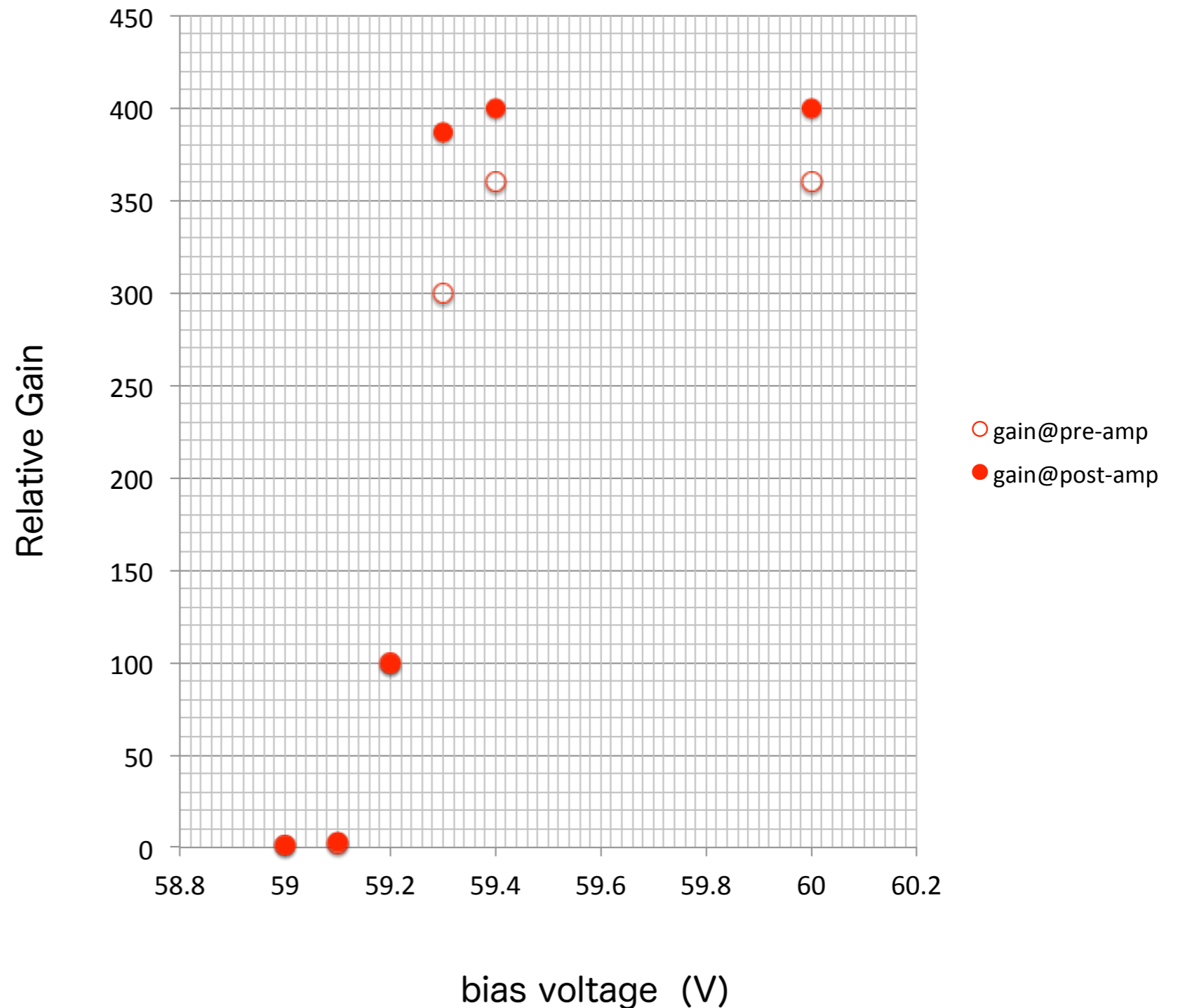
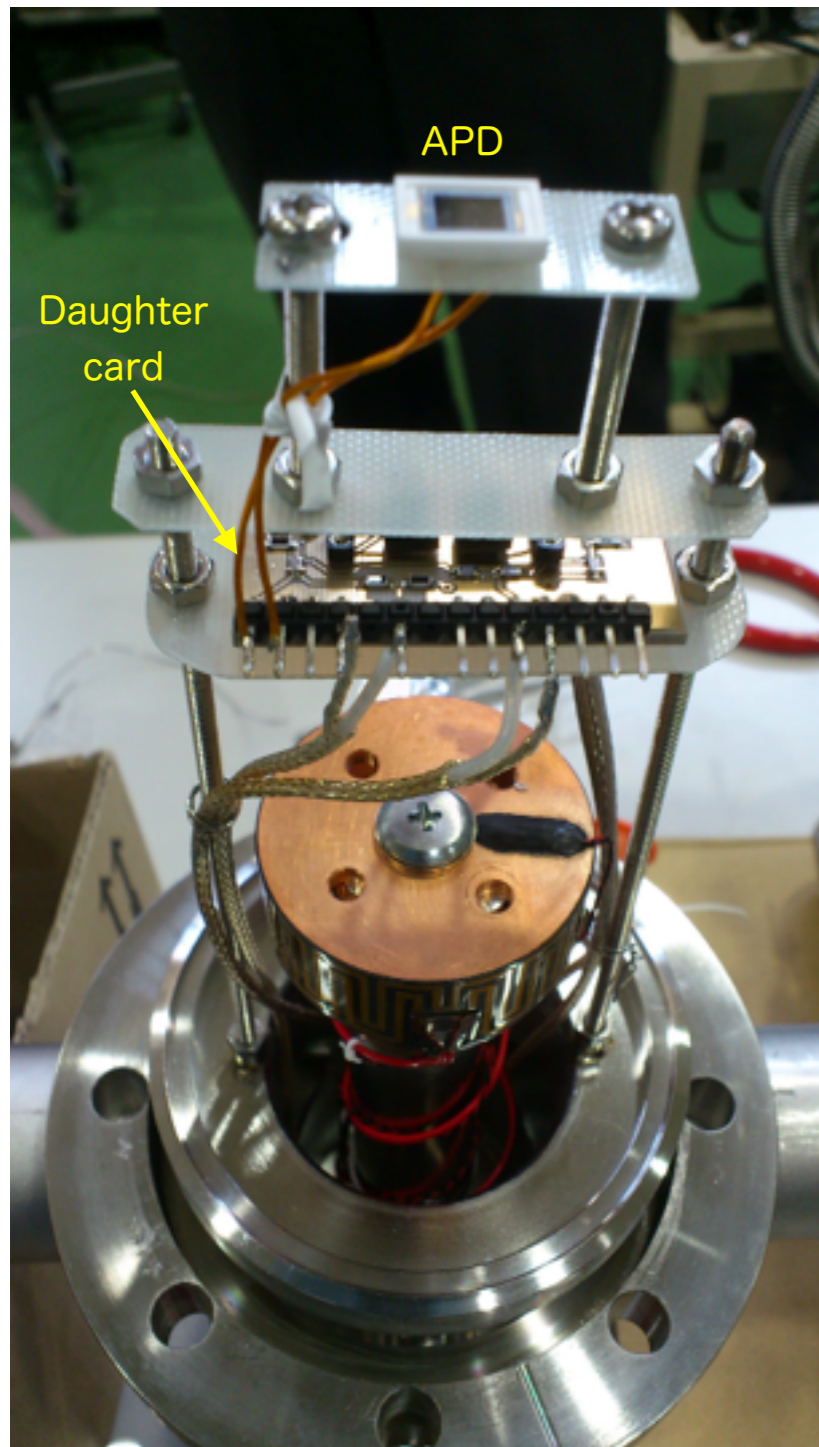
Abstract : We have developed a compact cryogenic system with a pulse tube refrigerator and a coaxial heat exchanger. This liquefaction-purification system not only saves the cooling power used to reach high gaseous recirculation rate, but also reduces the impurity level with high speed. The heat exchanger operates with an efficiency of 99%, which indicates the possibility for fast xenon gas recirculation in a high pressurized large-scale xenon storage with much less thermal losses.

Windowless

APD

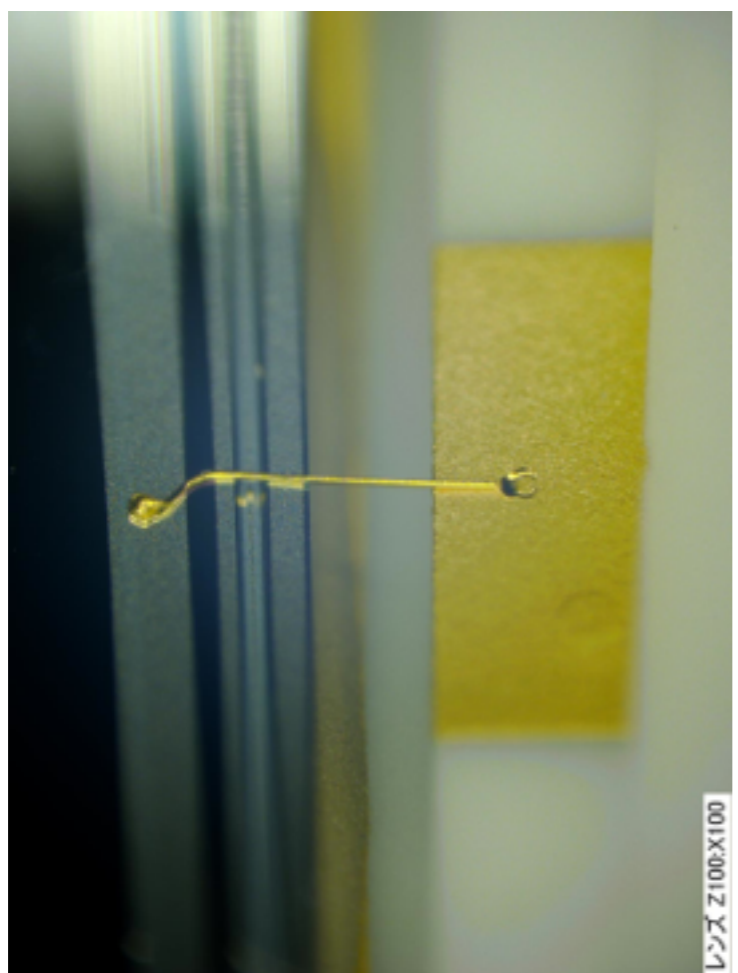
Windowless No.2 in the chamber

APD (S10937-9390(x)) with ^{137}Cs in Liquid Xe
with the feedback capacitor of 1pF

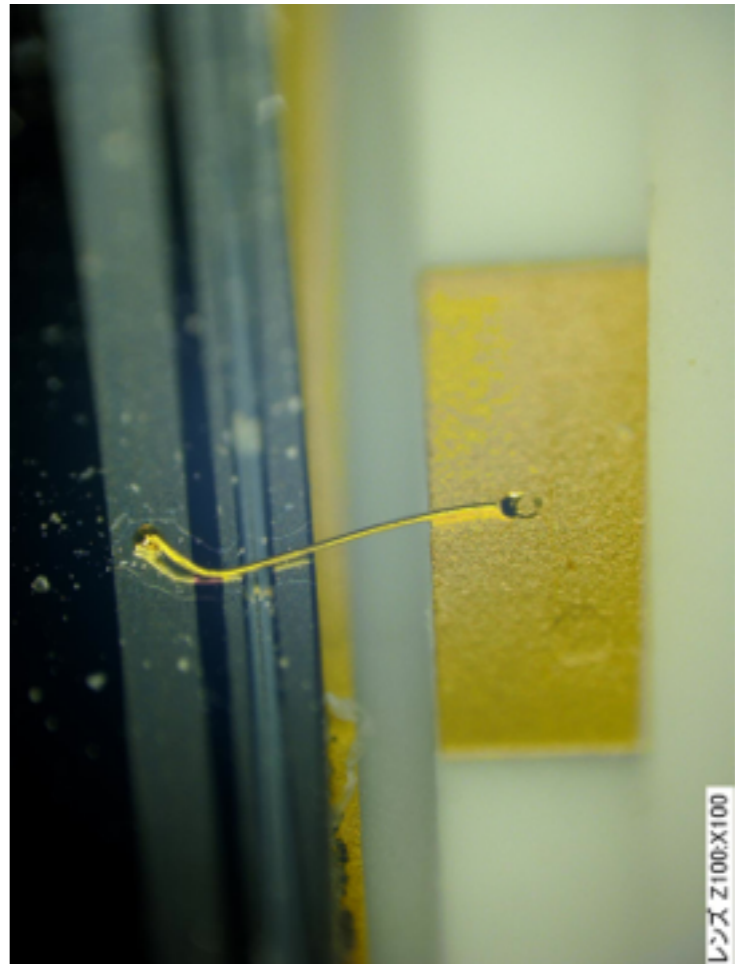


Before the re-wire-bonding until 20 June 2014

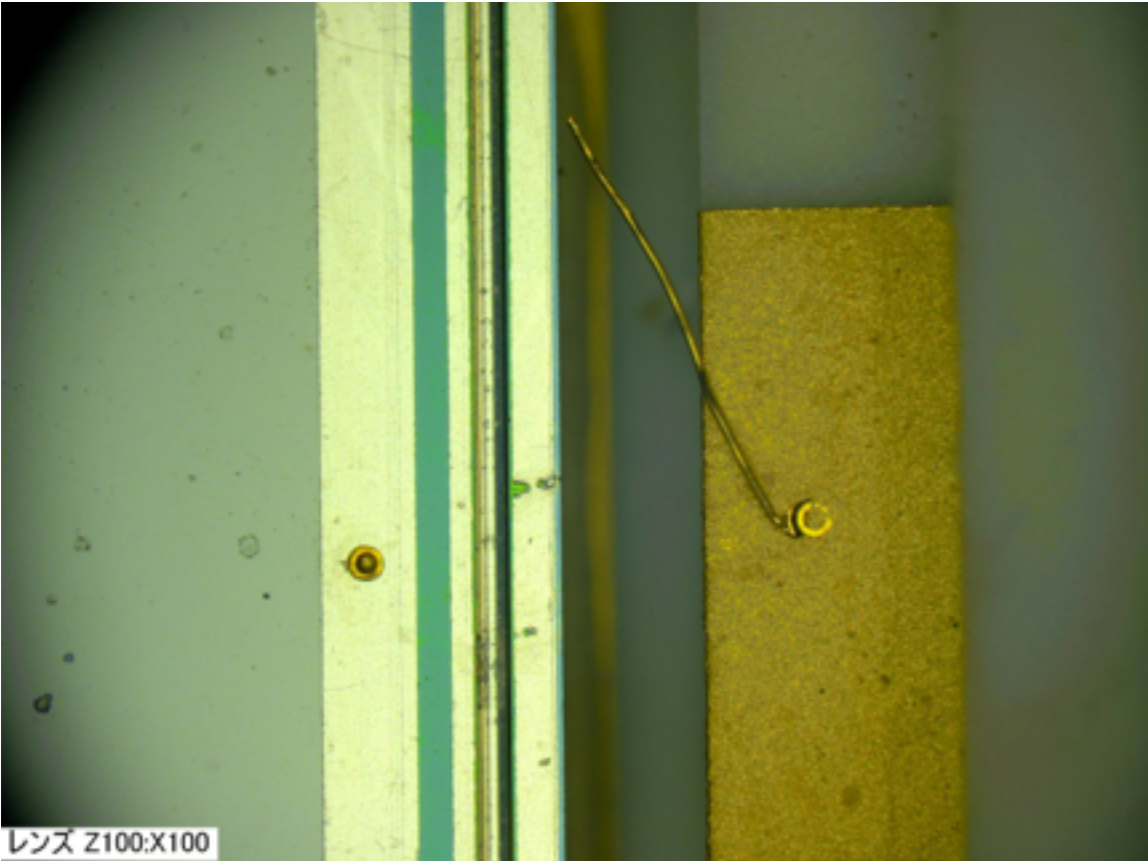
No.1



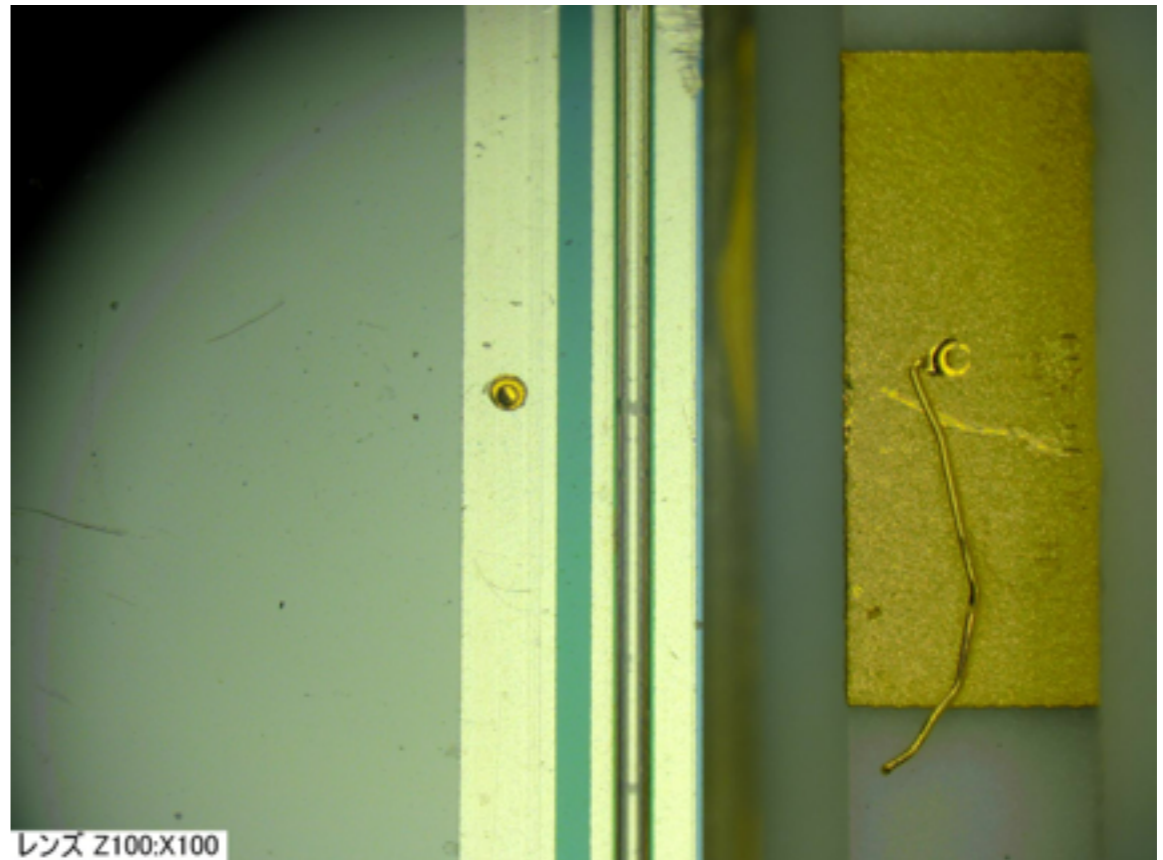
No.2

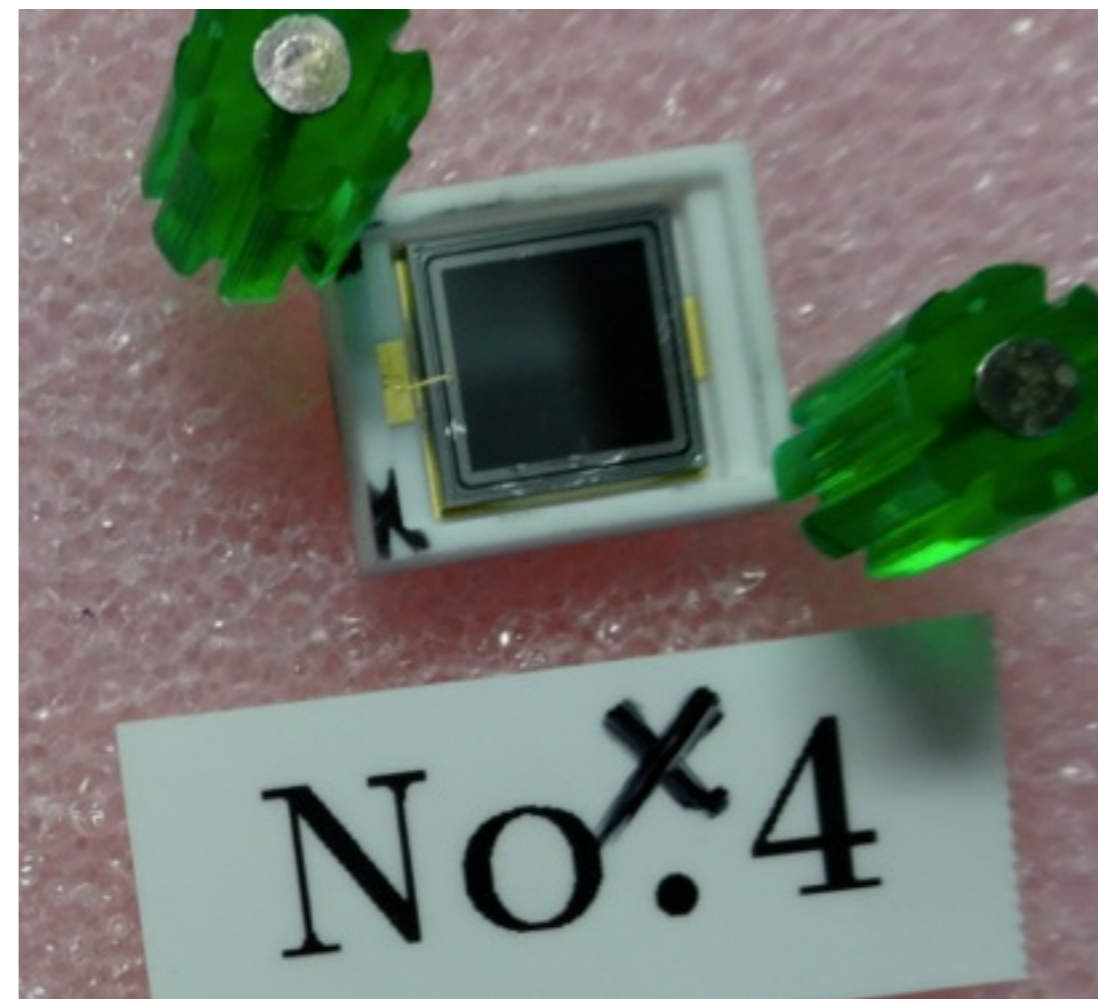
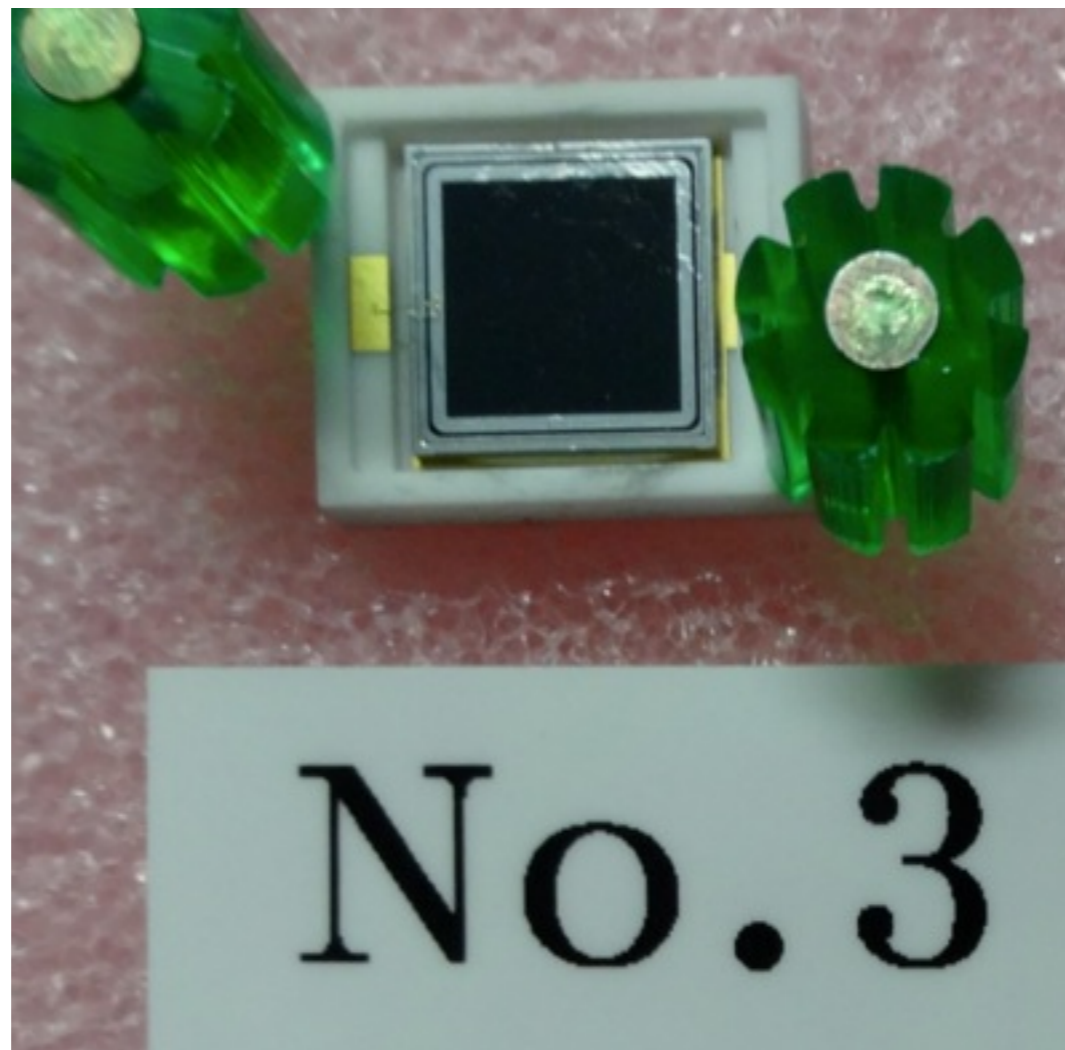
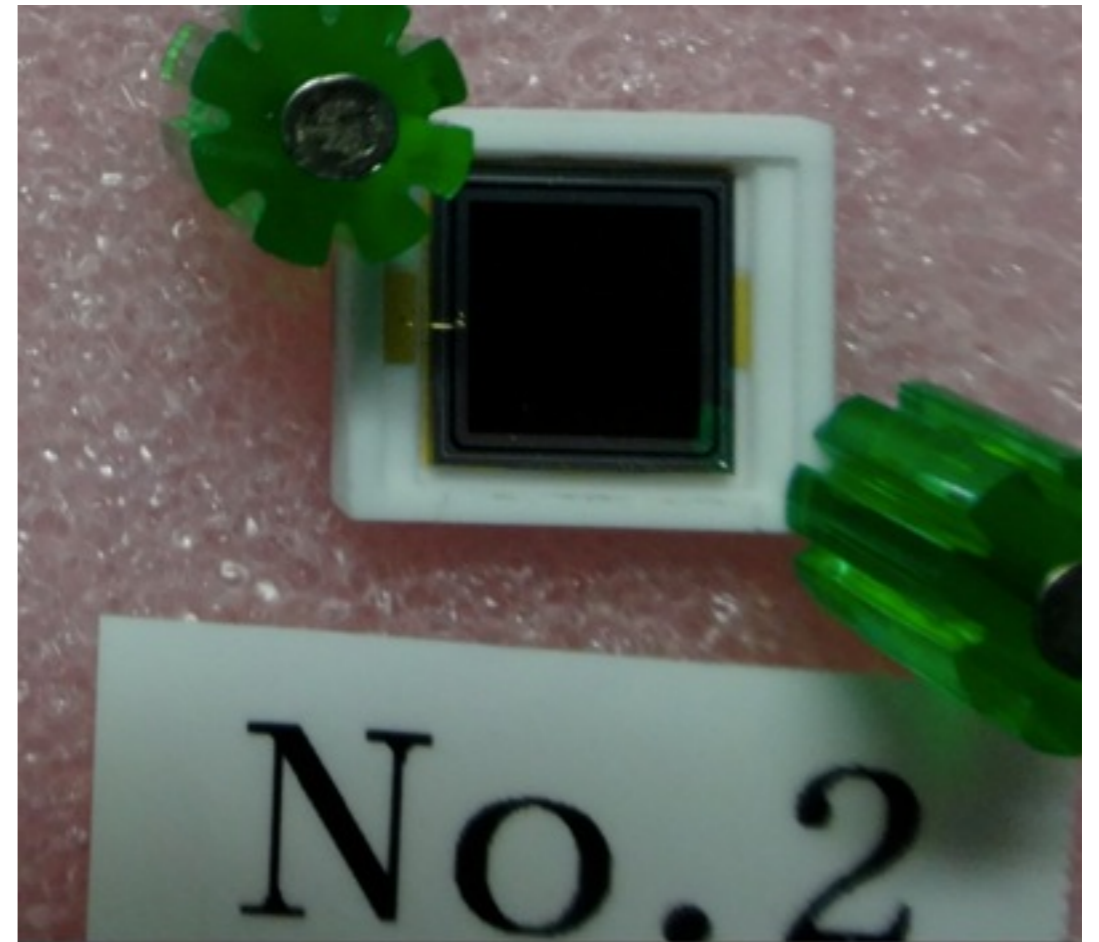
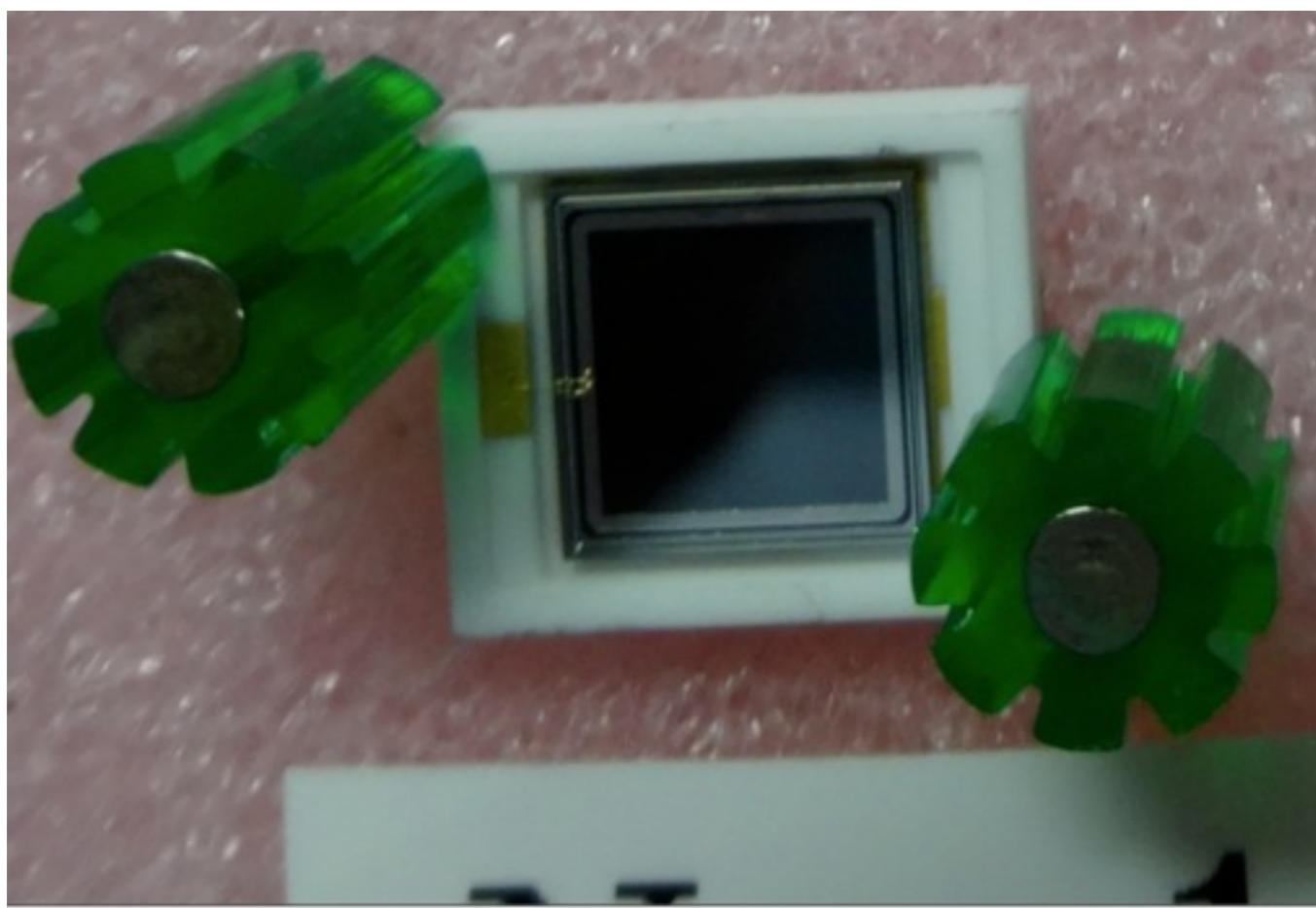


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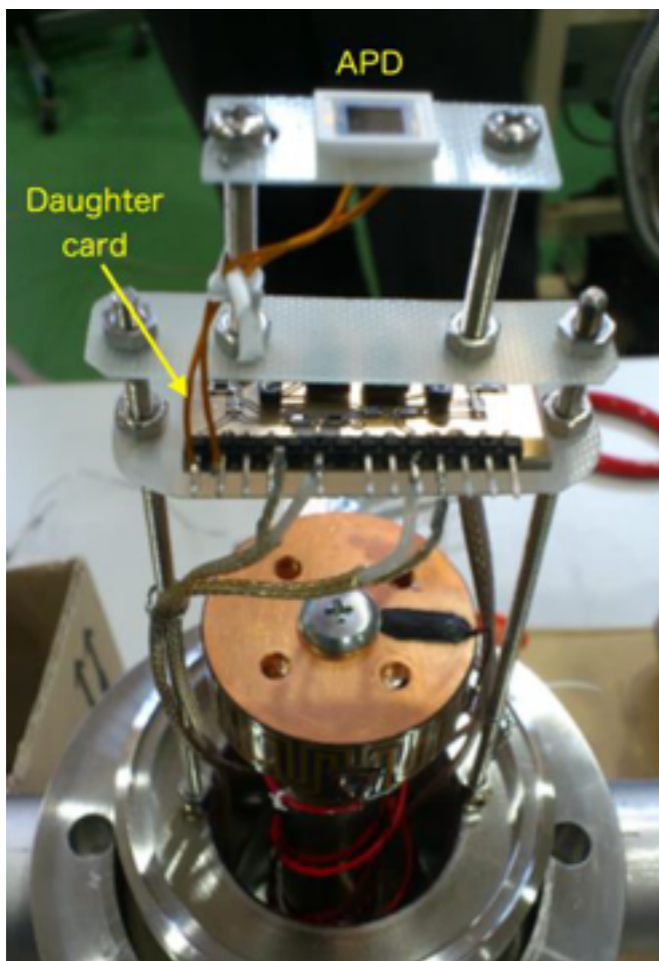


No.4



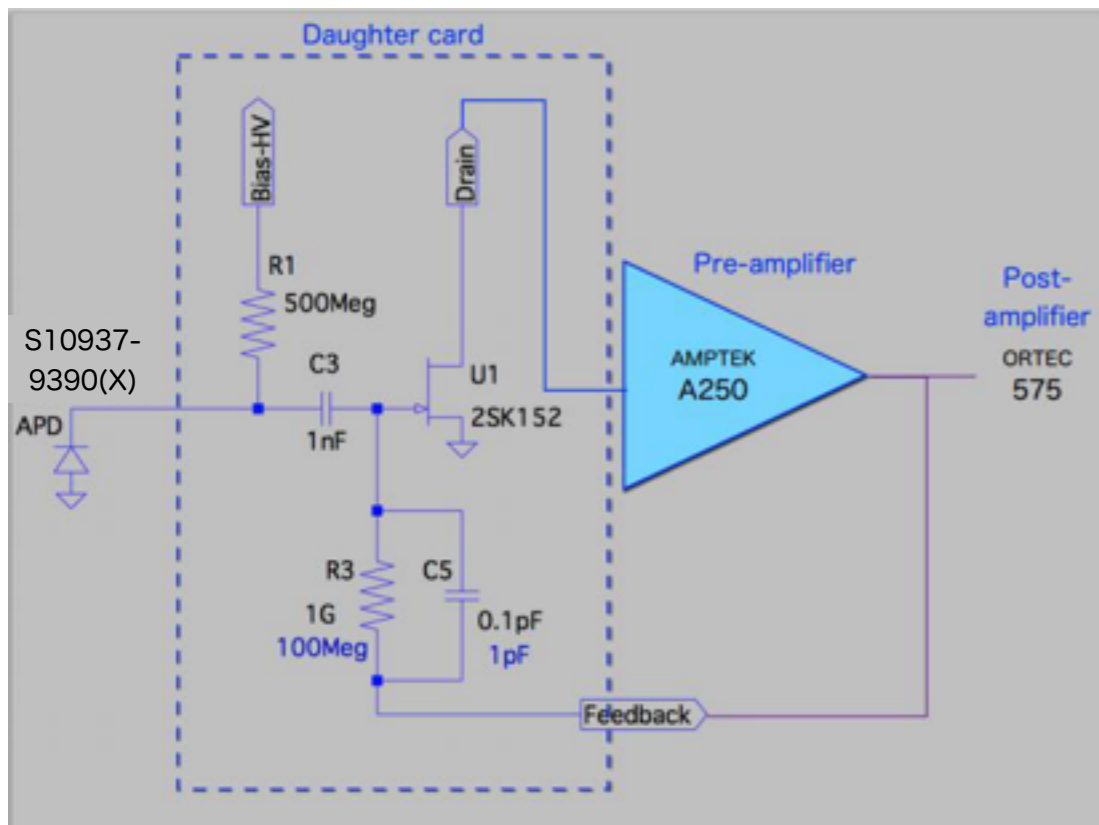


After the re-wire-bonding,
20 June 2014



windowless APD
S10937-9390(X)
(5x5mm²)

Measurement of γ ray spectrum



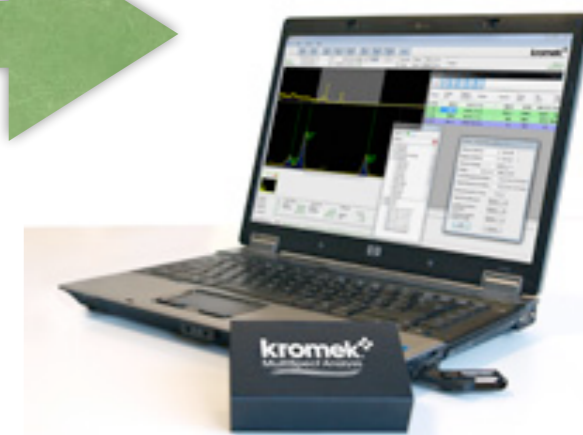
APD(5x5mm²) and frontend electronics



Post-amplifier ORTEC 575A

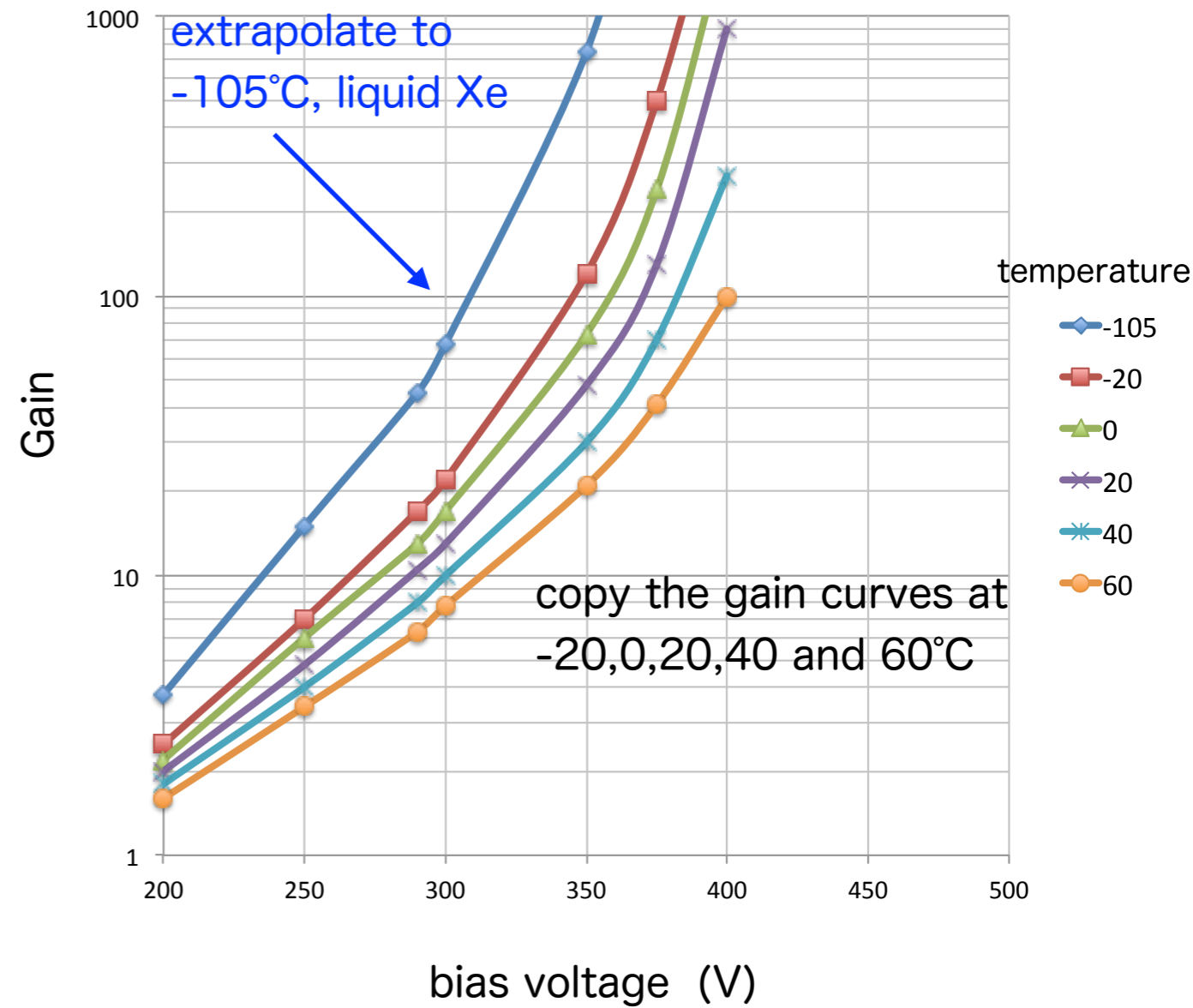
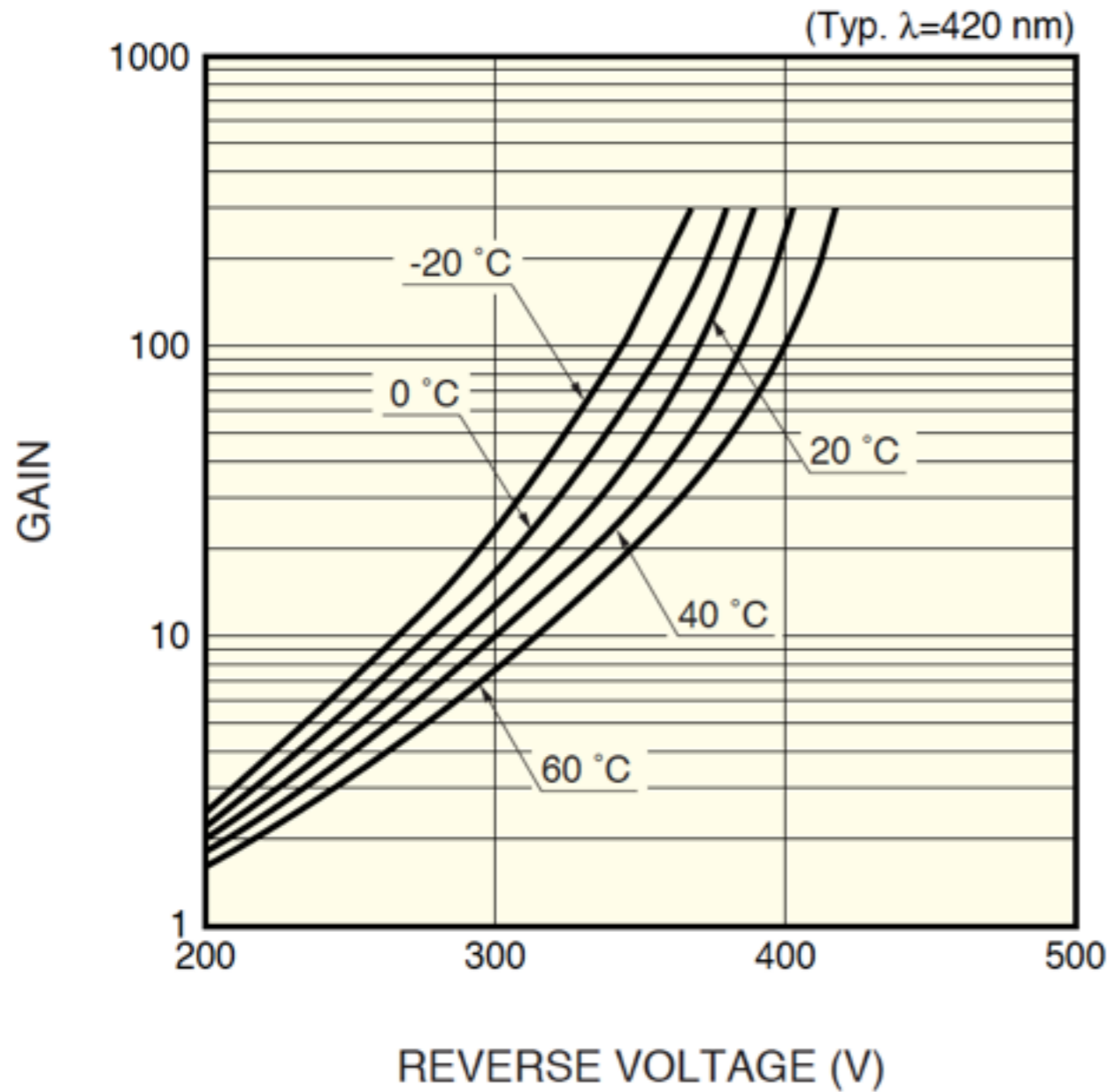


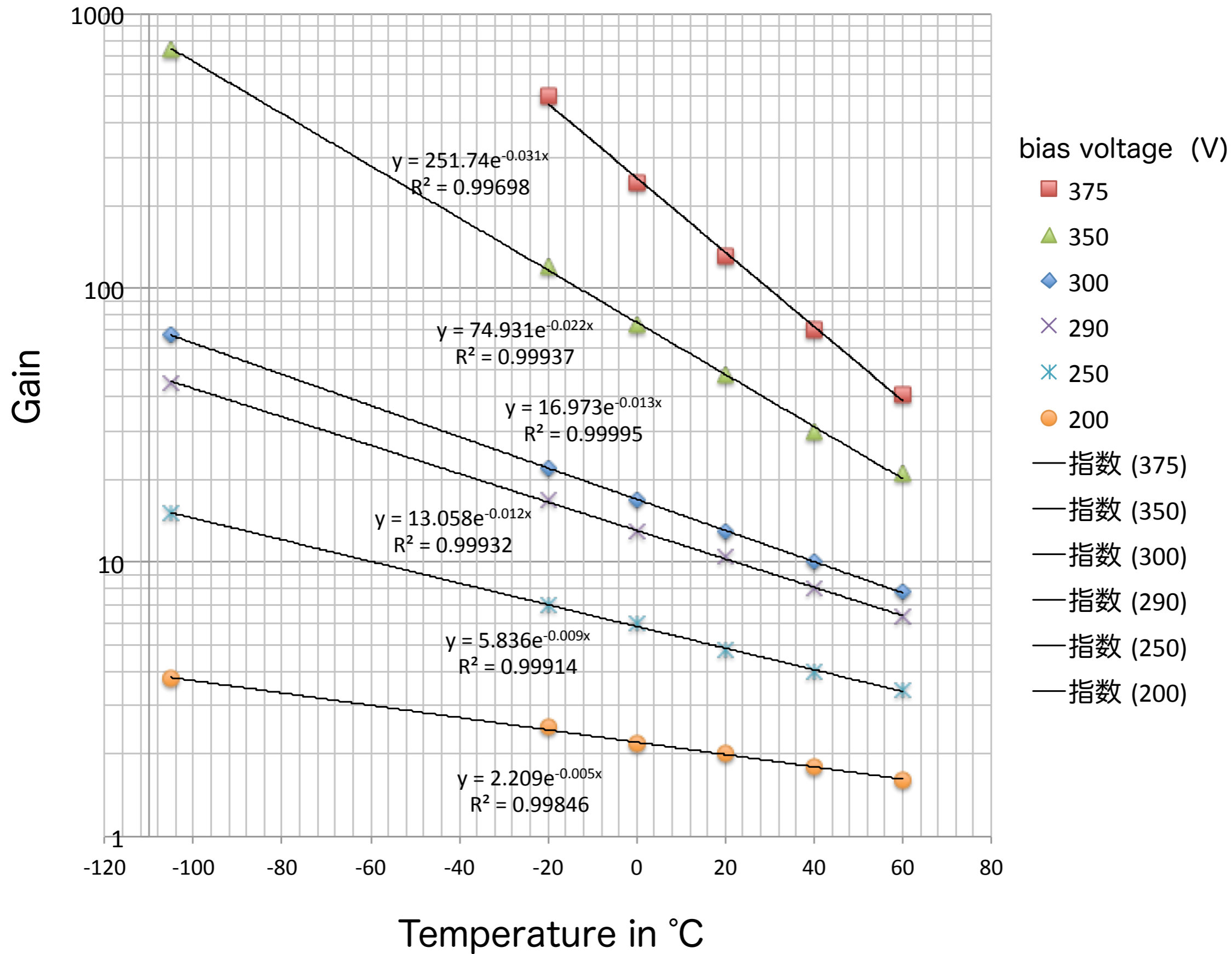
K102

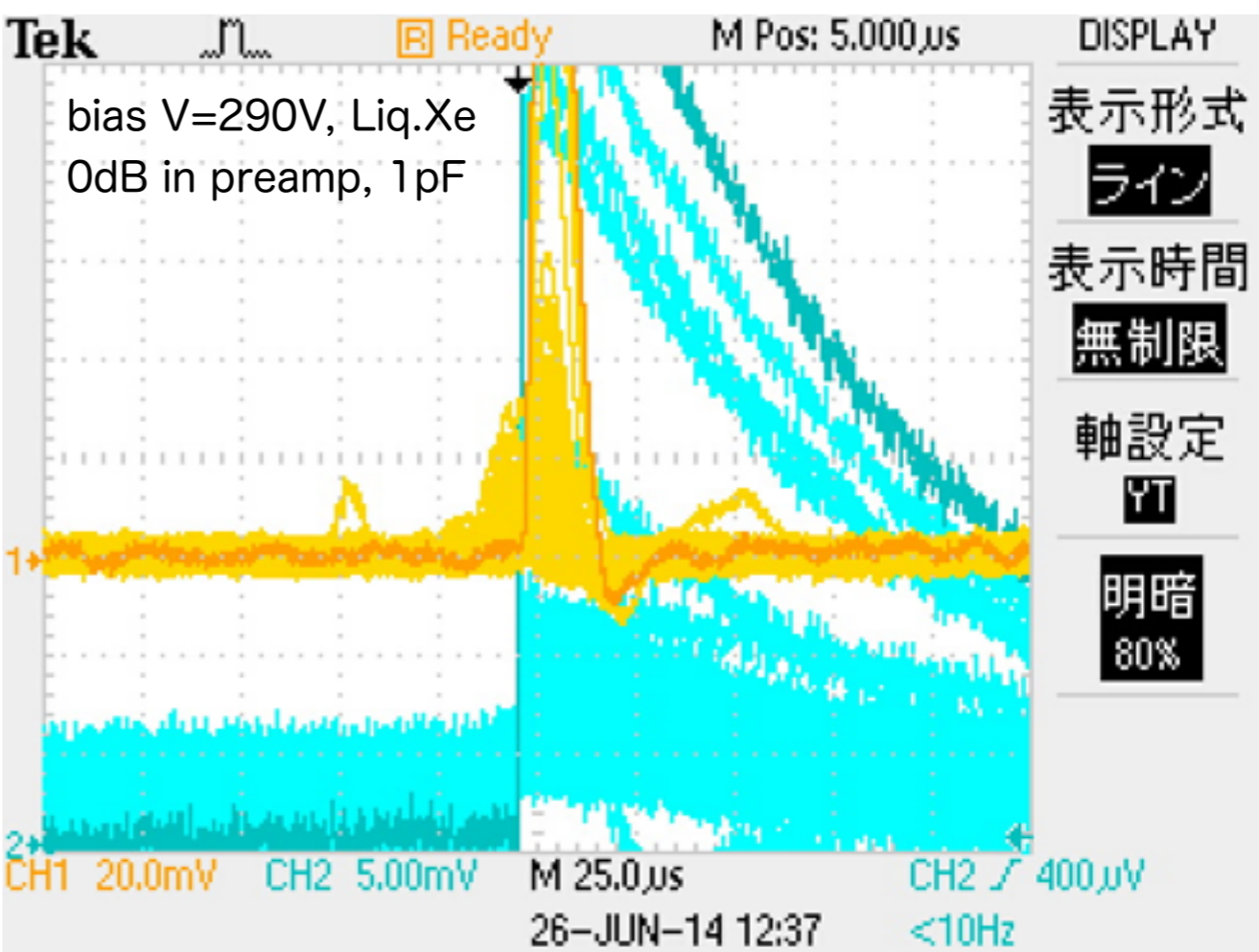
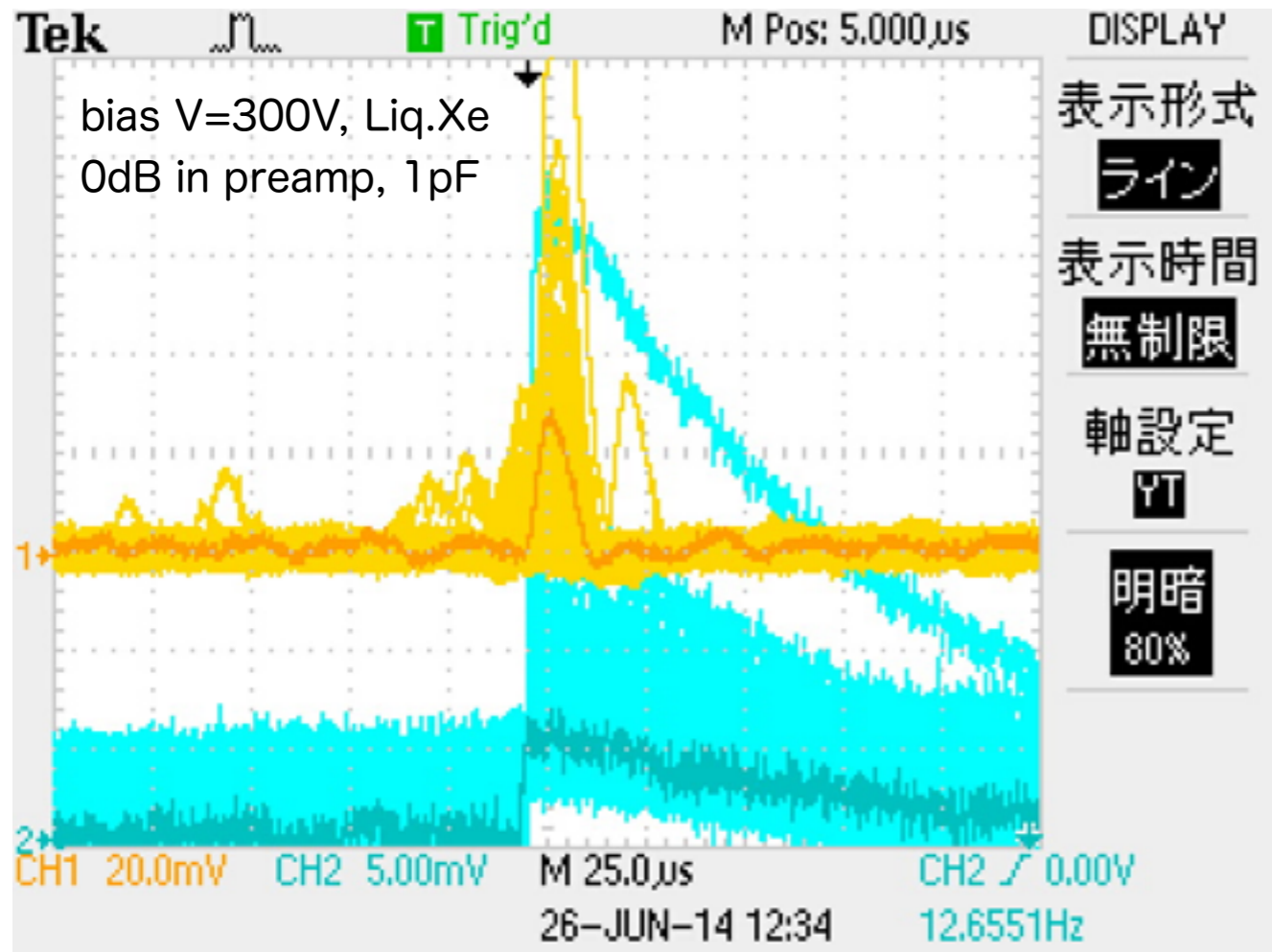
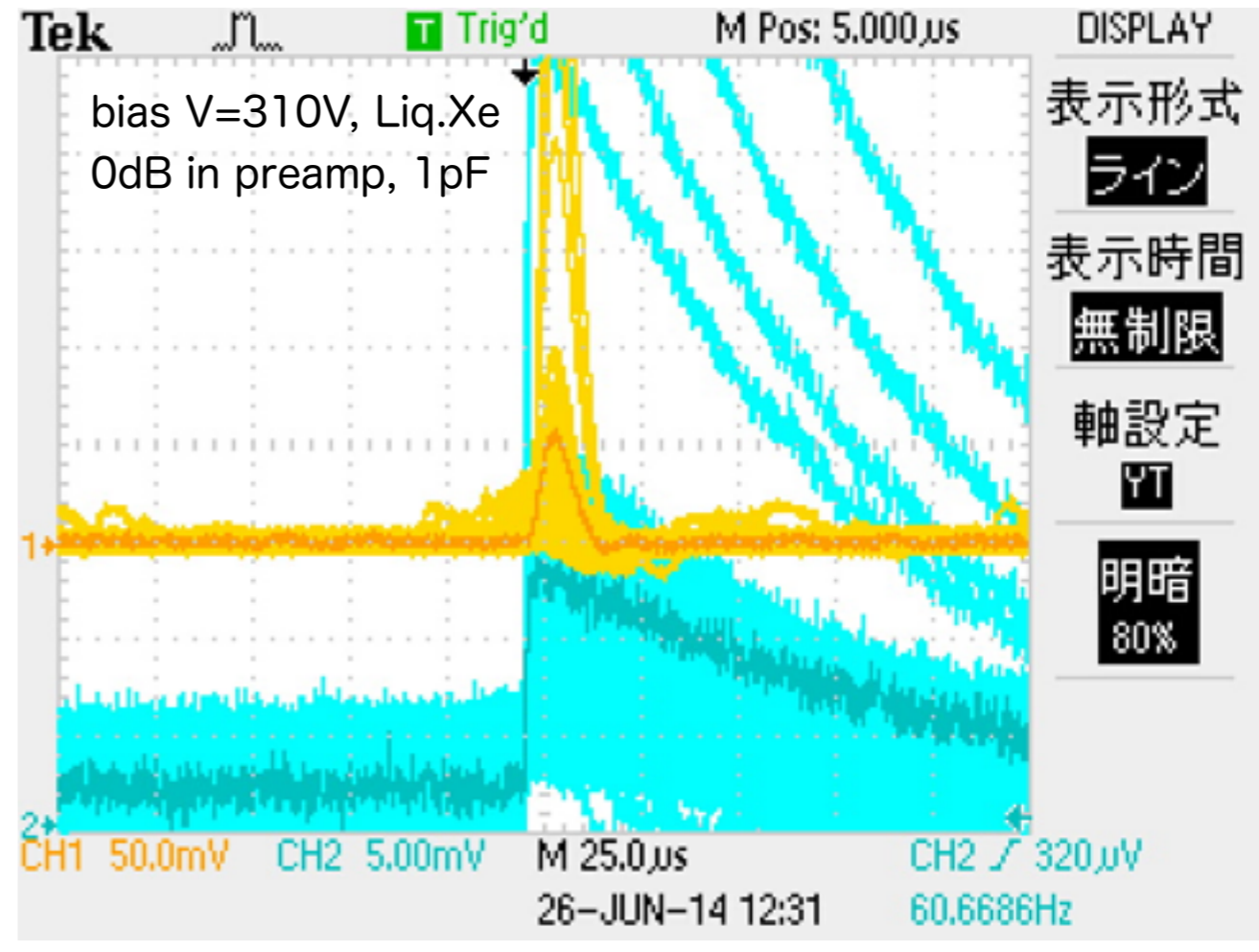
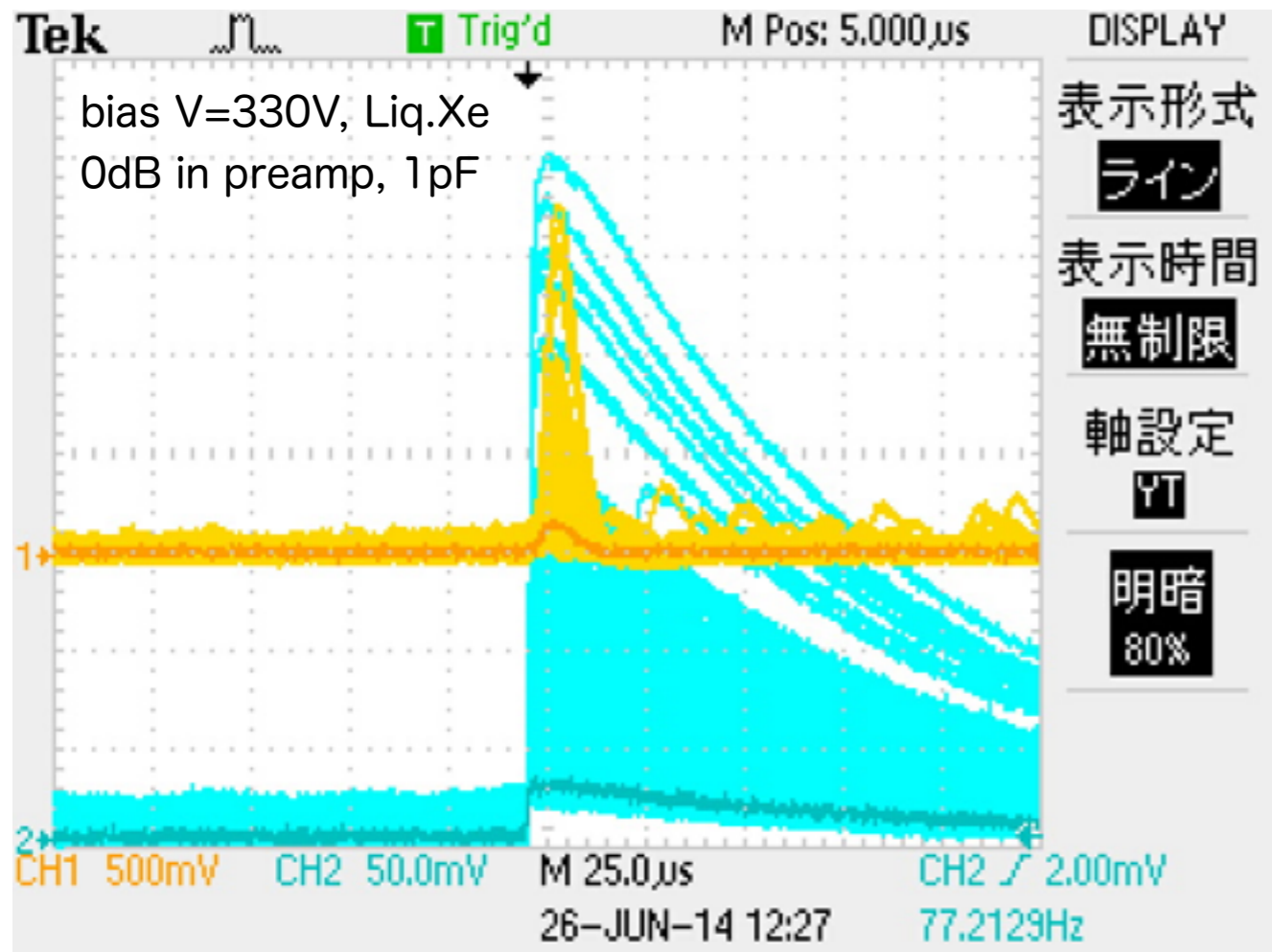


Multichannel analyser

windowless APD : S10937-9390(X) (5x5mm²)

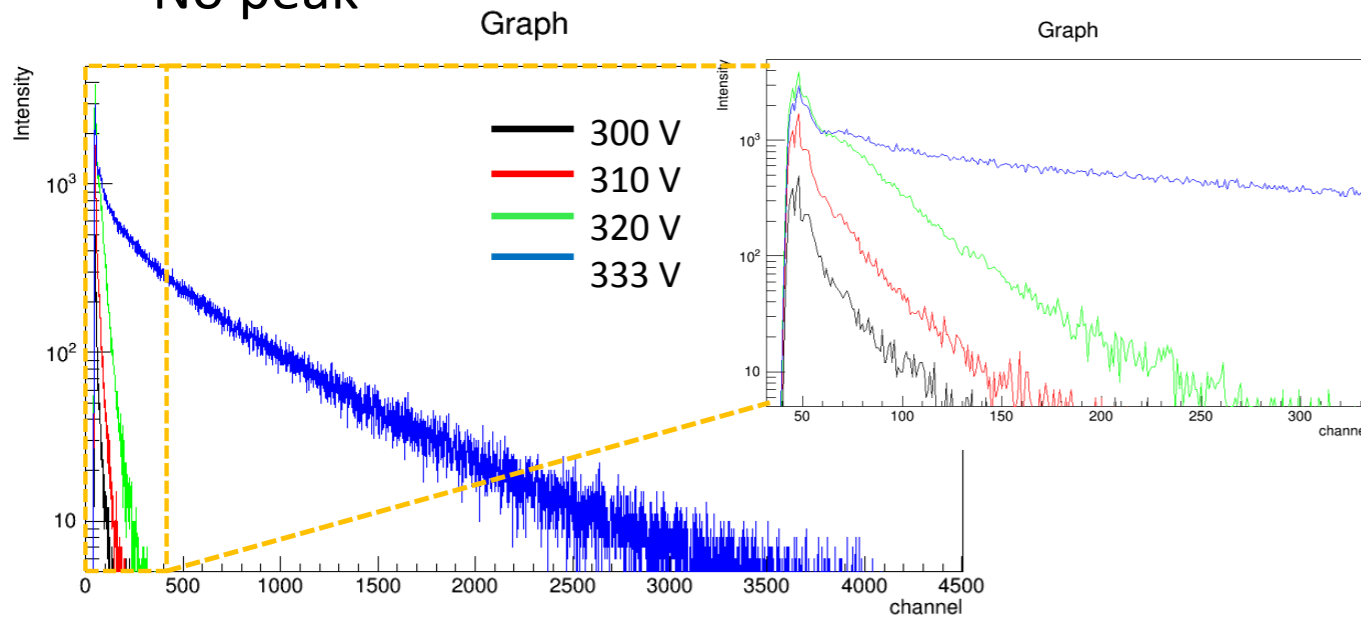






Measured results with a windowless APD : S10937-9390(X) (5x5mm²)

- ¹³⁷Cs & LXe (time : 1800 s)
 - No peak



Number of photon is very low... ?

Compare to the PMT measurements (EDIT2013)

PMT 2" square R7600

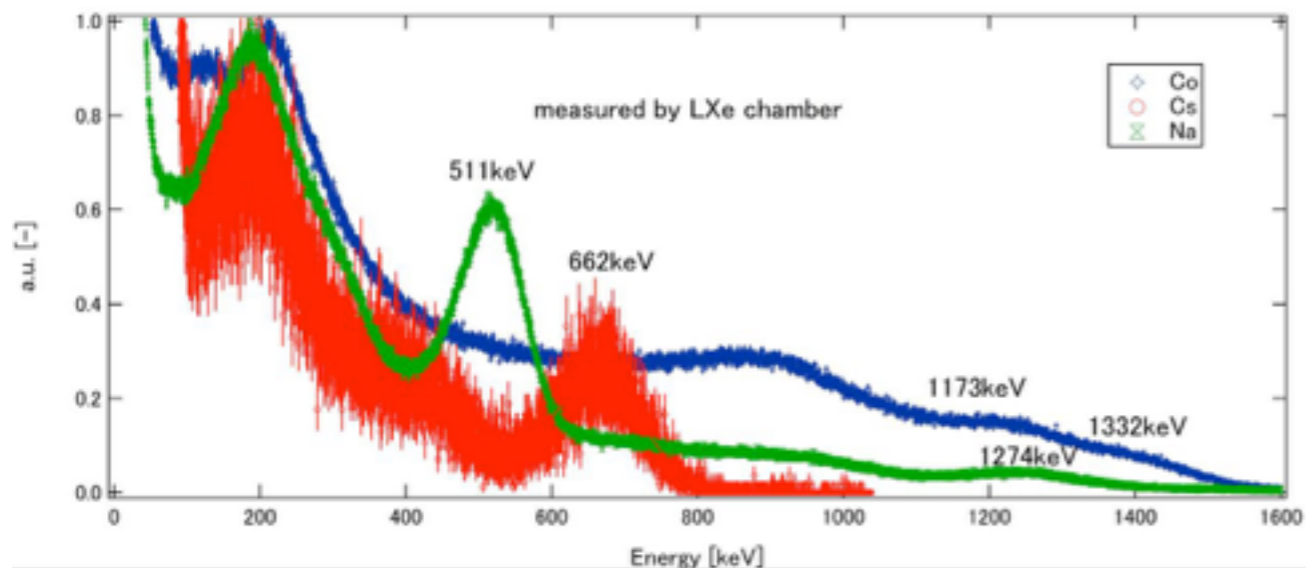
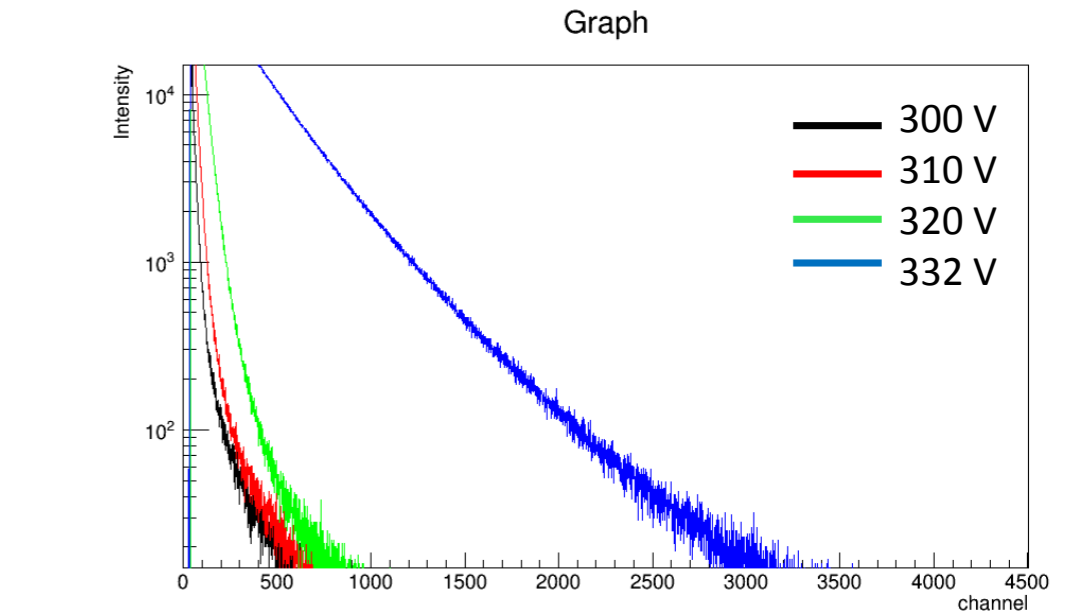


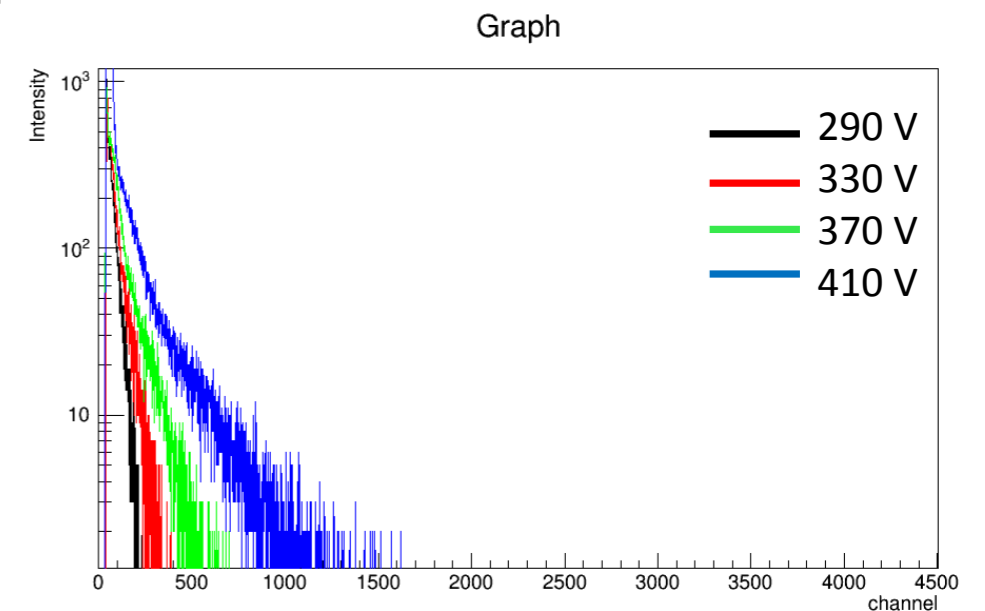
Fig5. Results of gamma(²²Na, ⁶⁰Co, ¹³⁷Cs) spectrum measurements

- ²²Na & LXe (time : 1800 s)
 - No peak



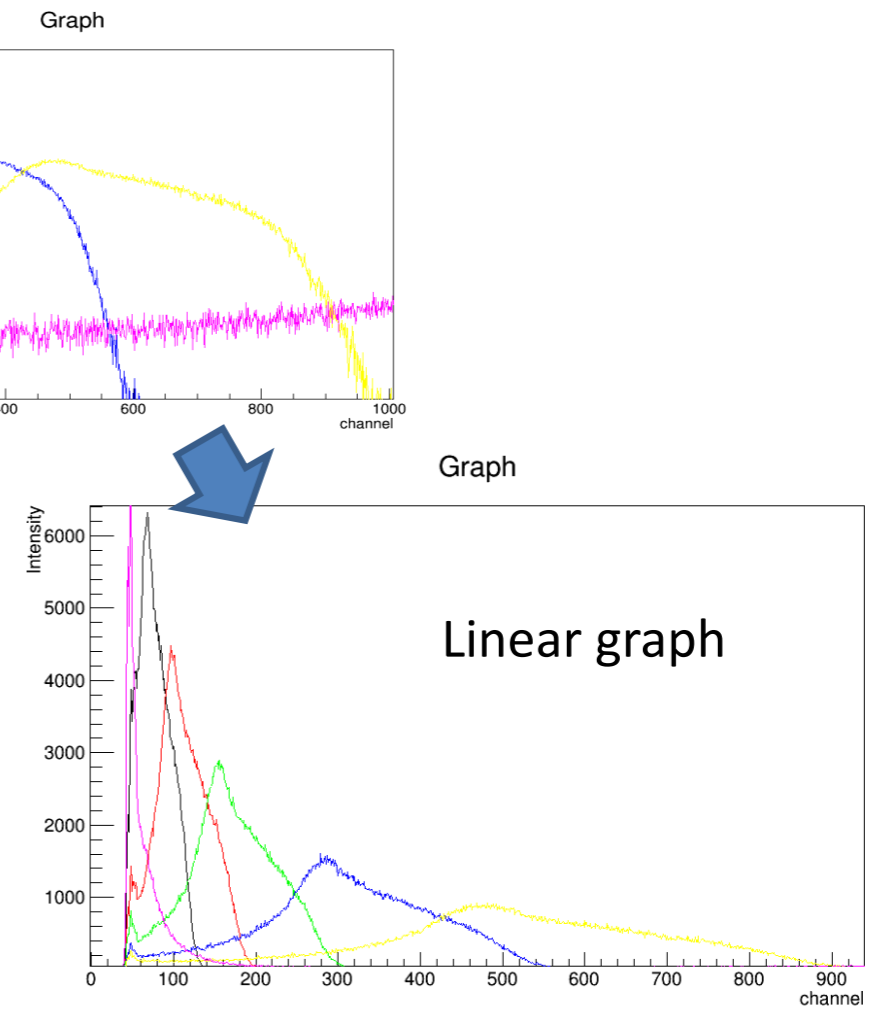
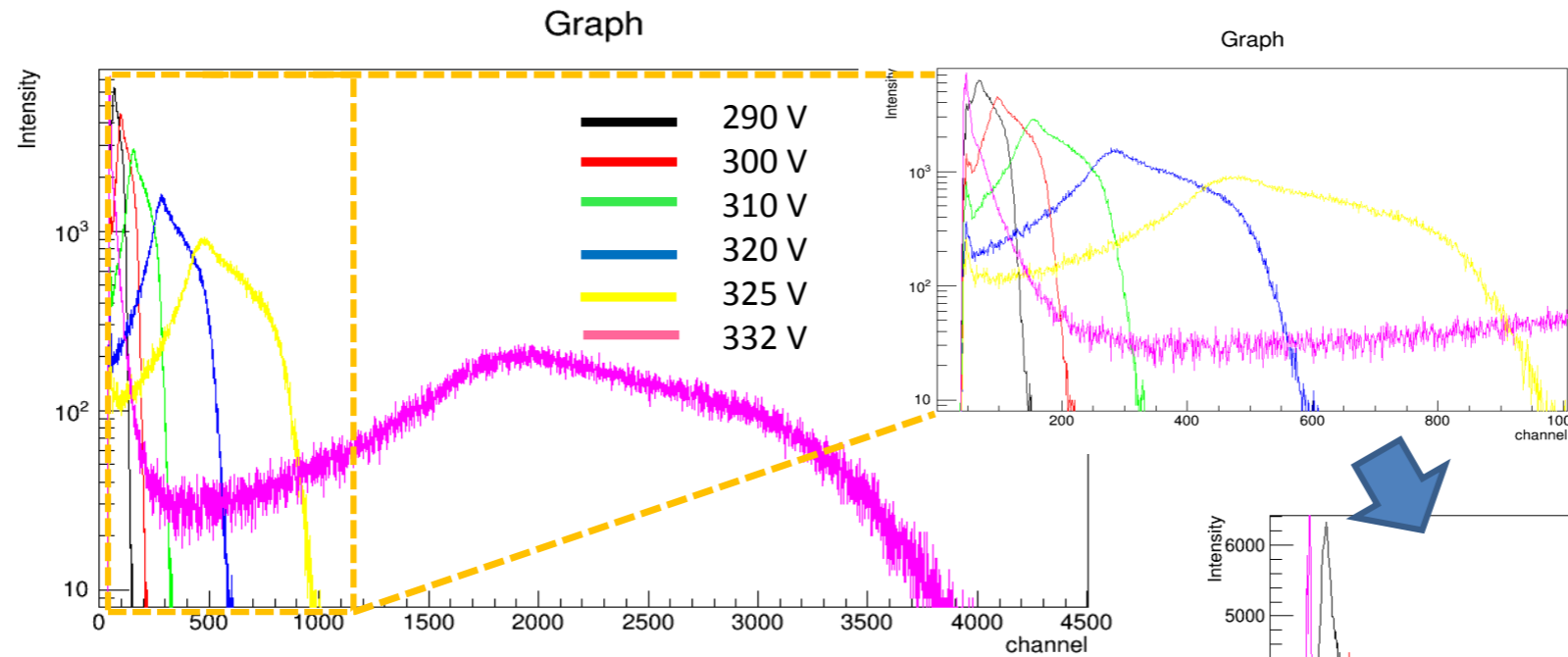
- Y-axis is set to log scale.
- It has almost same shape as ¹³⁷Cs case.

- ²²Na & GXe (time : 1800 s)
 - No peak

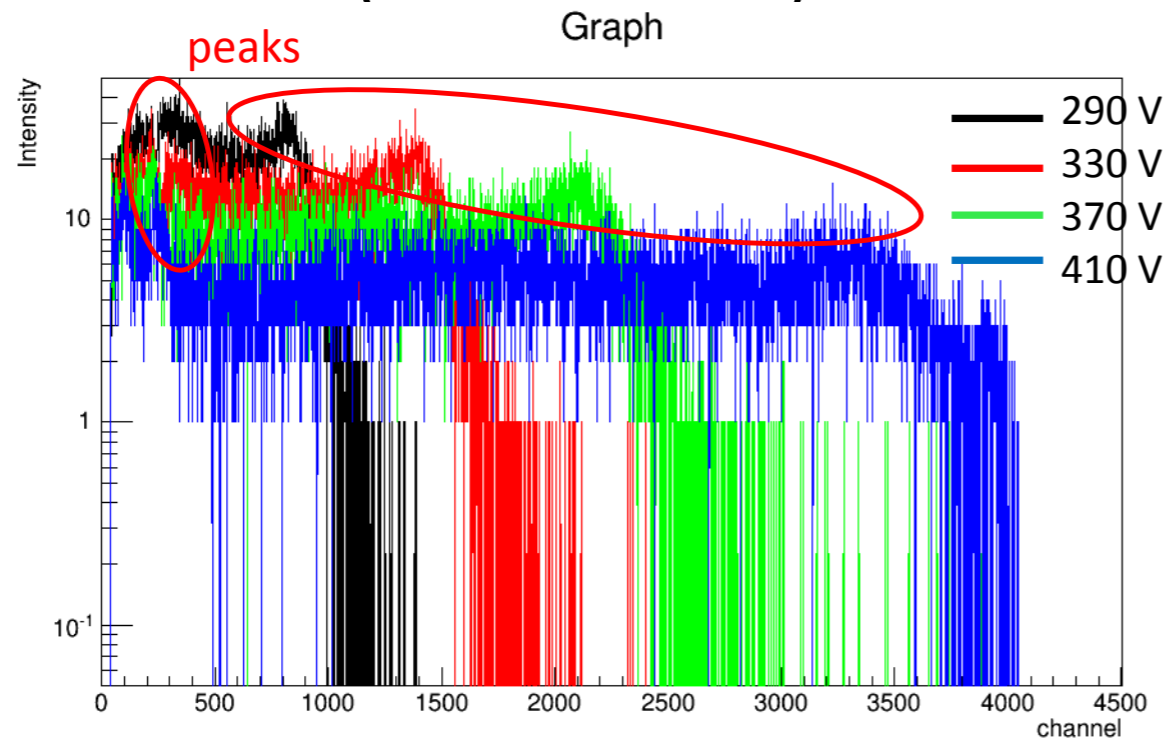


- Y-axis is set to log scale.
- It has almost same shape as ¹³⁷Cs case.

- ^{241}Am & LXe (time : 1800 s)
 - One peak?

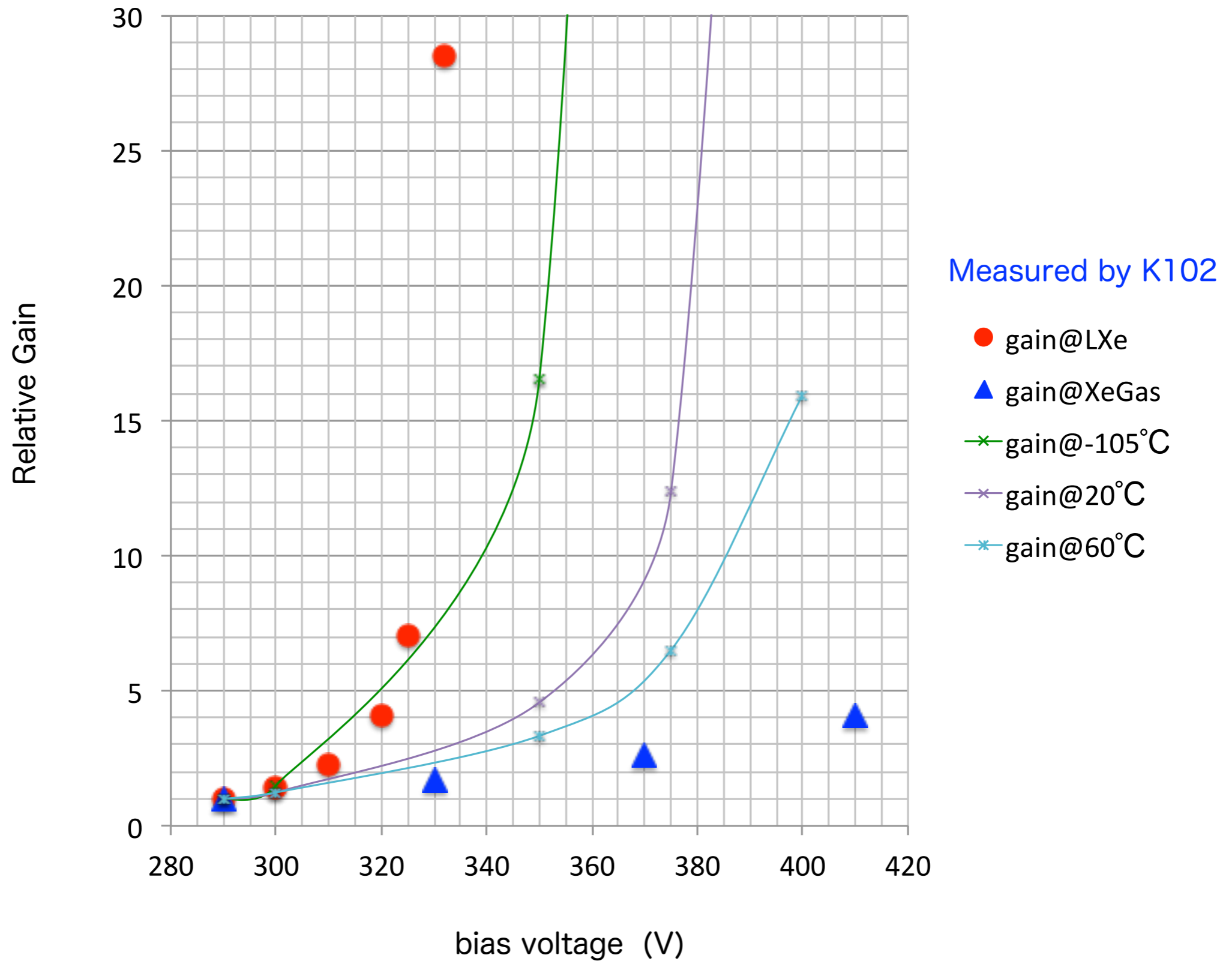


- ^{241}Am & GXe (time : 1800 s)

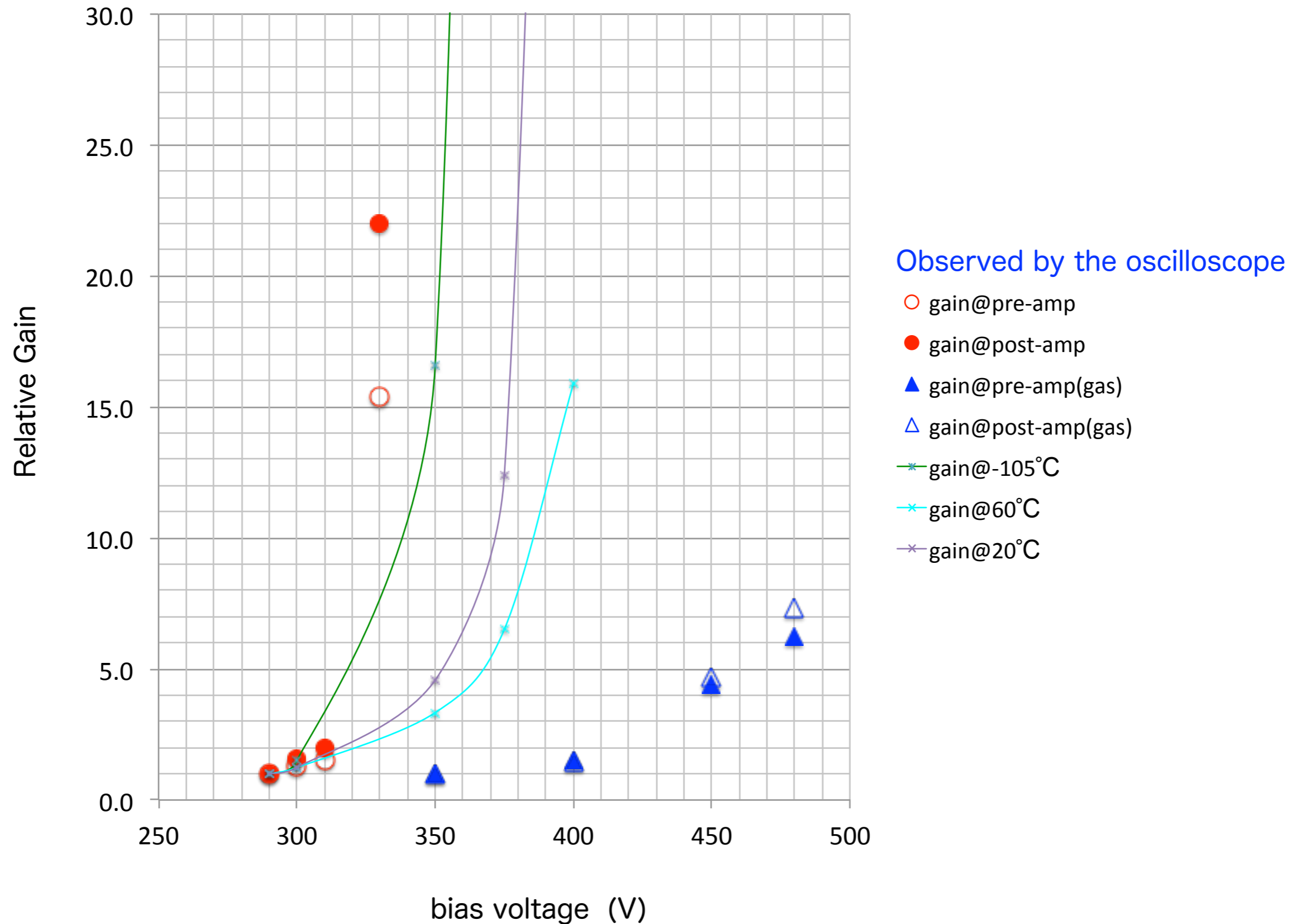


- Y-axis is set to log scale.
- Count rate is very low. (about ~ 10 cnt/s)

APD with ^{241}Am in Xe at Liquid and Gas ($P_{\text{abs}}=4\text{atm}$) phases with the feedback capacitor of 1pF



APD with ^{137}Cs (10kBq) in Xe at Liquid and Gas ($P_{\text{abs}}=4\text{atm}$) phases with the feedback capacitor of 1pF



まとめ

1. TPCFE09/LTCCボードでの読みだし不成功, Xe純化不足?, TPCFE09故障
2. LTspiceによる回路シミュレーション, 発振などの現象の再現を試みた
3. 2014年1月より約3ヶ月の間,Subatechよりインターンシップの学生を受け入れた
液体キセノン中でのAPD (Windowless)の特性測定
4. Windowless APDによる液体キセノン中での γ 線スペクトラムの測定
5. PTRのON/OFFでのキセノンの液面測定, 約1cmの不定性(上昇)を観測
6. 3つのボード(Rogers, セラミック板)よりなる新フロントエンドエレクトロニクス
システムの設計と製作
7. キセノン純化等の効率化のため予冷装置の設計と製作
8. GATE/GEANT4シミュレーションにより, 日仏共同研究のXEMIS2 (小動物用PET) の
PTMシステム最適化を行っている