

産総研におけるGlass GEMの開発とその応用

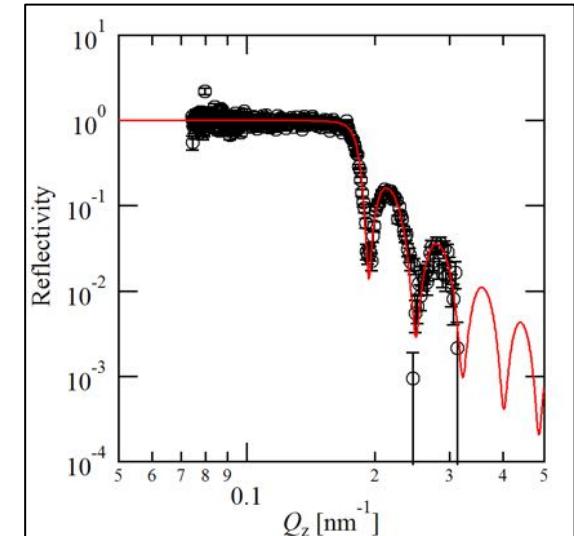
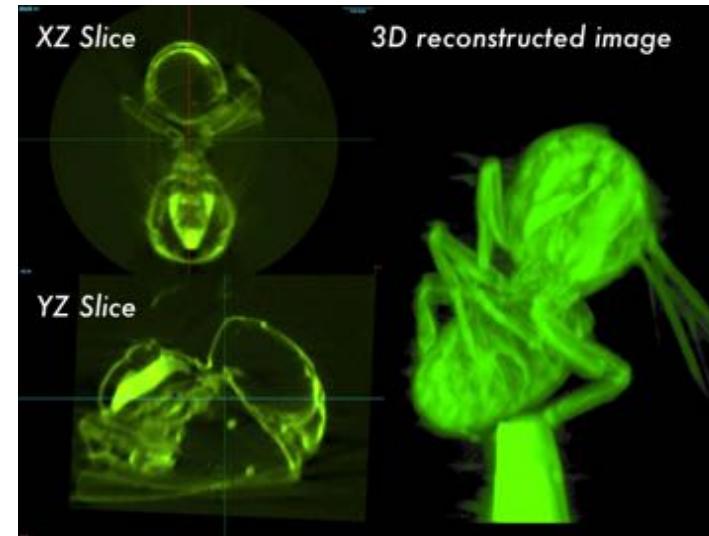
藤原 健¹、伏江 隆²

¹産業技術総合研究所

² (株) レジメントラボ

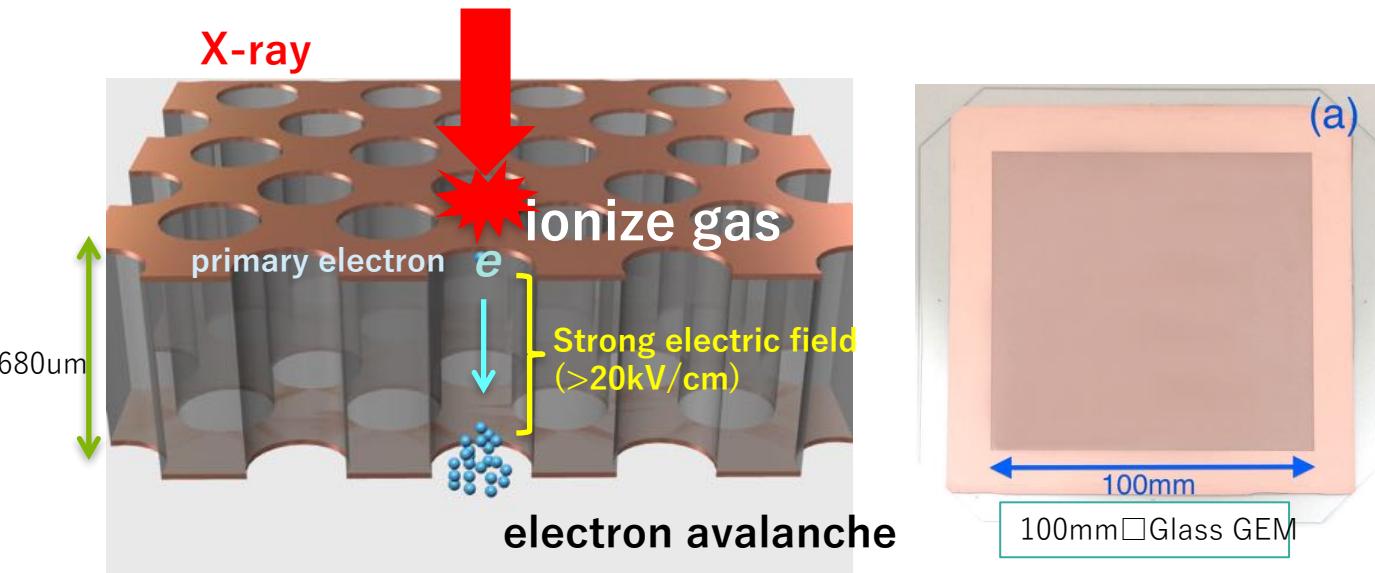
Outline

1. 背景
2. Glass GEMの新製造プロセス
3. 光読み出しGlass GEM
4. X線による実験結果
5. 中性子反射率計
6. まとめ



1. Background & Motivation - X-ray imaging with Glass GEM

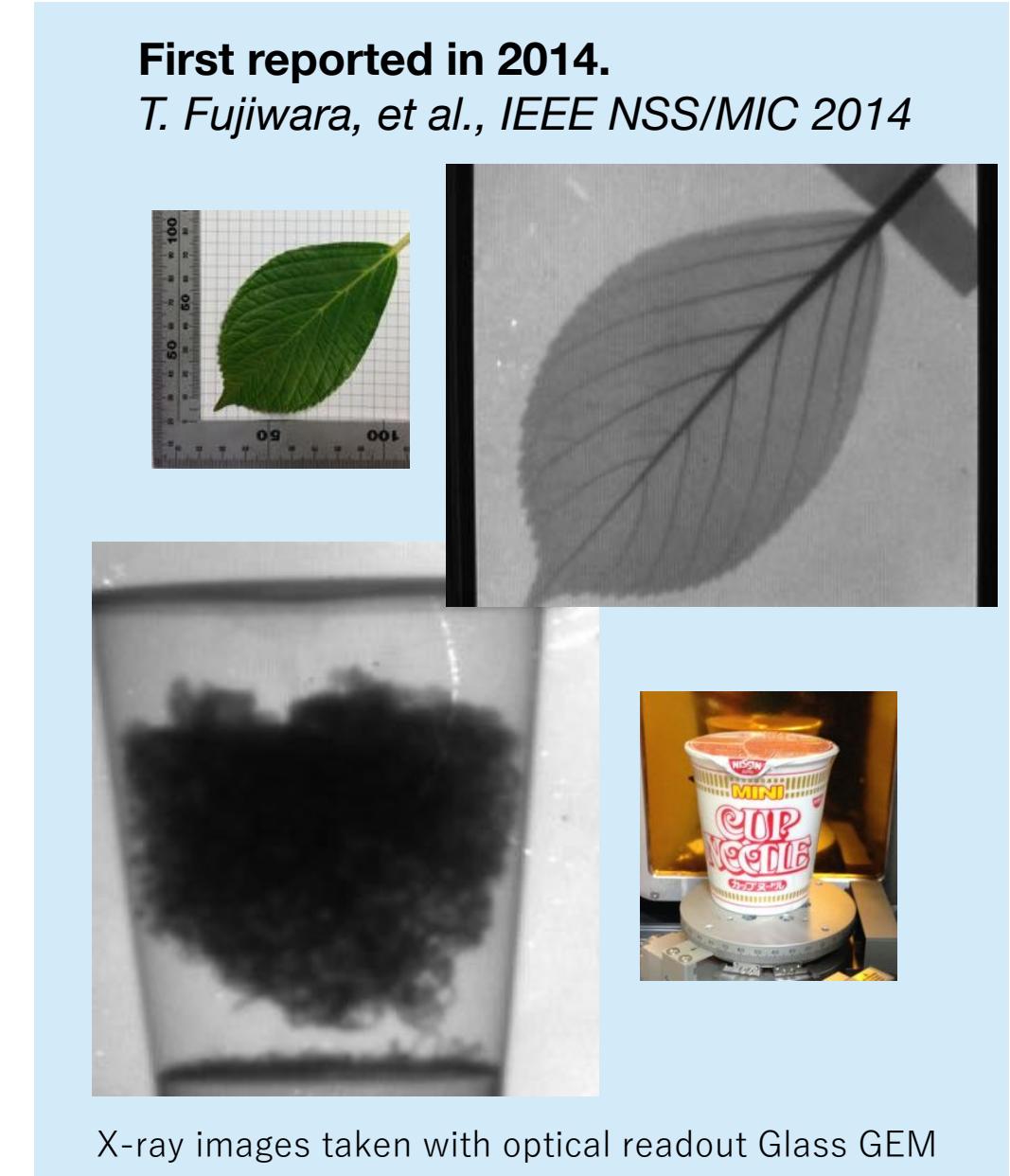
2



- ▶ ポリイミドに代わり、基板にガラスを用いたGEM^[1]を開発(Glass GEM)^[2]
- ▶ なぜGlass GEM ?
 - ▷ ロバスト性 – 炭化しにくいため高い放電耐性
 - ▷ 硬い– たわまないのでフレーム等がいらない、扱いが容易
 - ▷ 高いガスゲイン– 一枚で90,000以上のガスゲイン^[3]
 - ▷ 高空間分解能– 電荷の広がりが最小限に

First reported in 2014.

T. Fujiwara, et al., IEEE NSS/MIC 2014

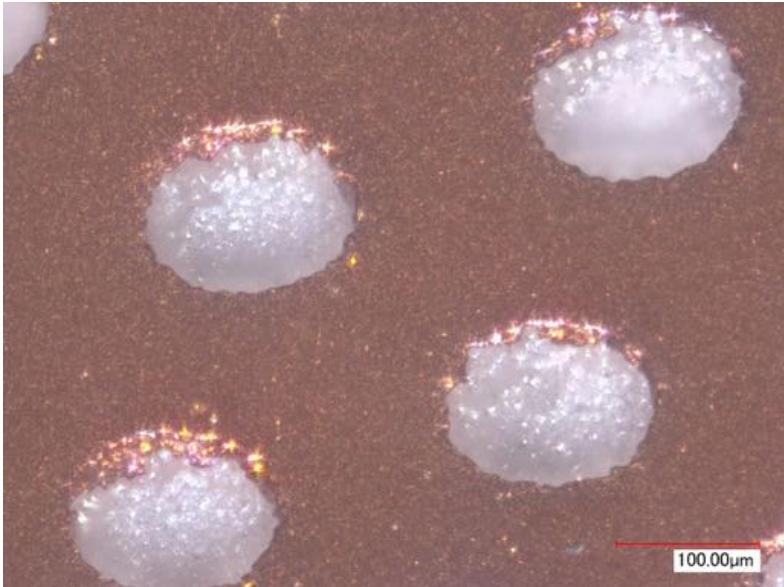


[1] F. Sauli, NIM A, vol. 386, no. 2, pp. 531–534, (1997)

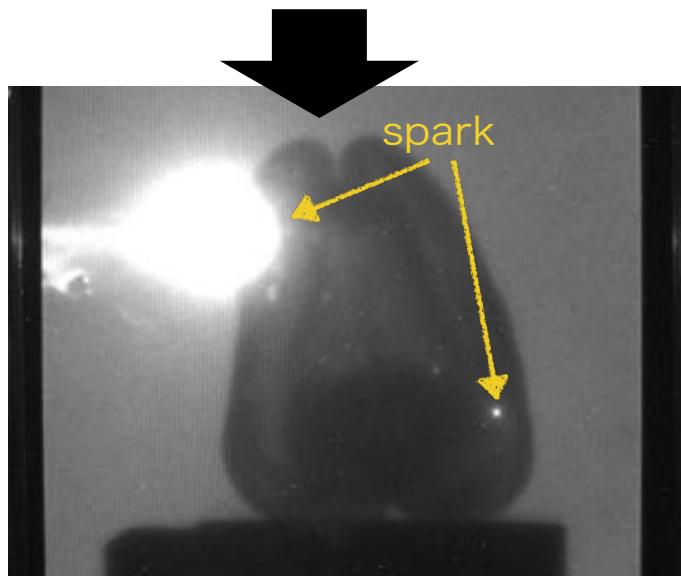
[2] H. Takahashi, et al., NIM A, vol. 724, pp. 1–4, (2013)

[3] T. Fujiwara, et al., JINST, vol. 9, pp. 11007 - 11007, (2014)

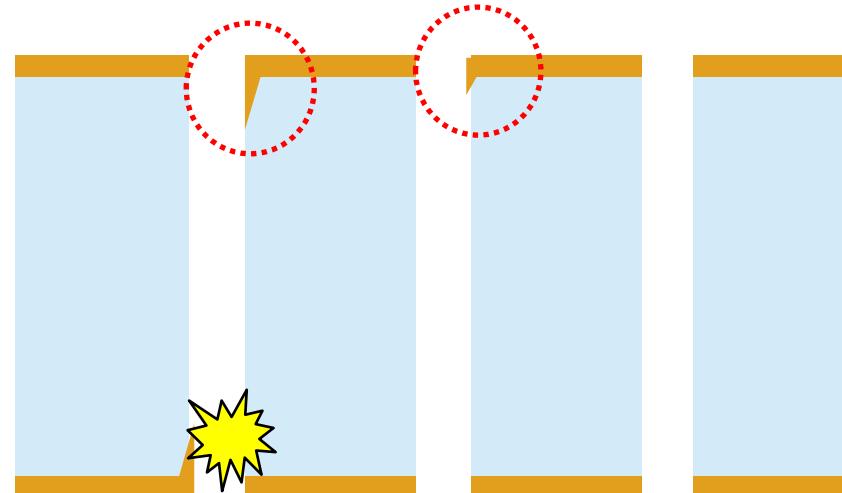
1. 背景 – Glass GEMの安定性の向上のために



過去に作成したGlass GEM



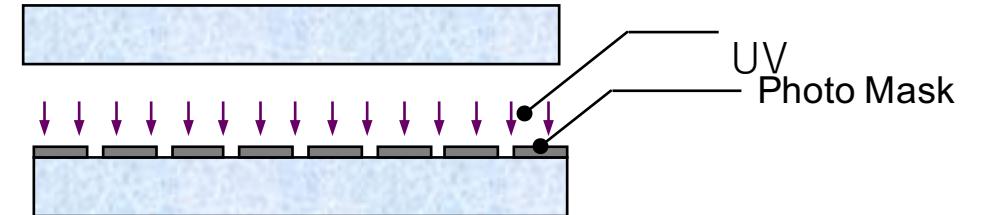
孔内に入った電極が放電を誘発



損傷した電極

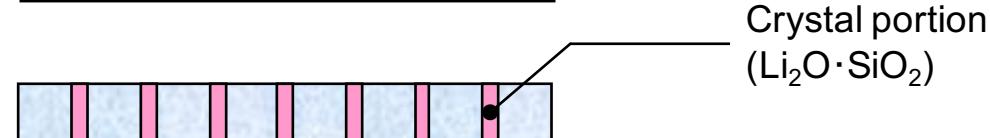
2. Glass GEM : 内製プロセスで開発

1. Glass Substrate

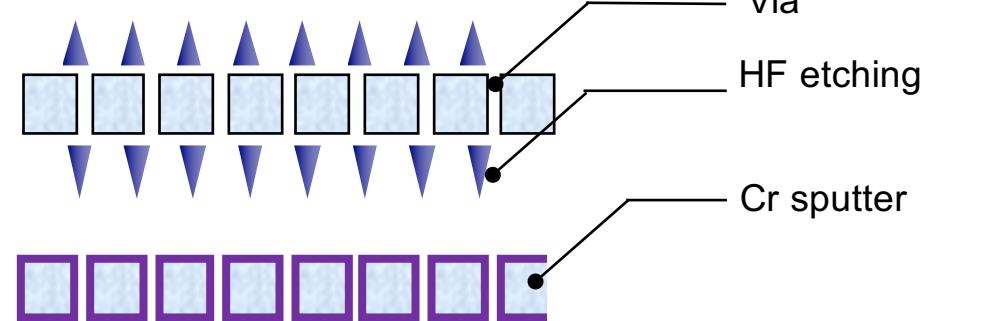


2. UV exposure (1st_exp)

3. Crystal formation
(heat treatment)



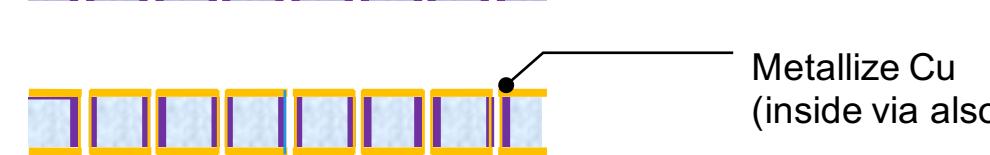
4. Via etching
(Hydrogen Fluoride wet etching)



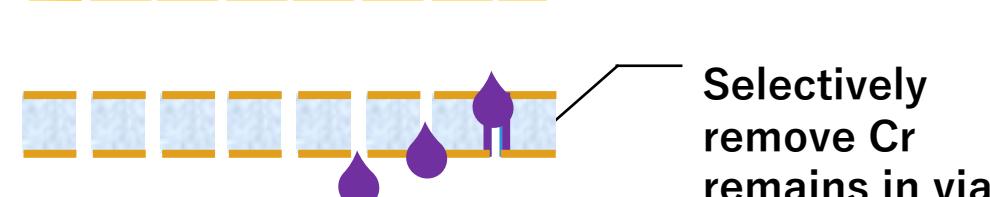
5. Poison Metallization



6. Remove metal except in via



7. Metallization process II (Cu)



8. Selectively etch metal in via

2. Glass GEM : 産総研内製プロセス



UV exposure machine



Etching machine



DC sputtering machine for Cr



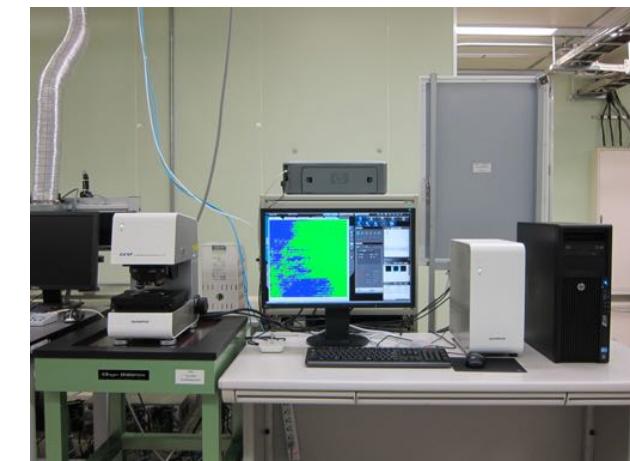
DC sputtering machine for Cu



Polishing machine



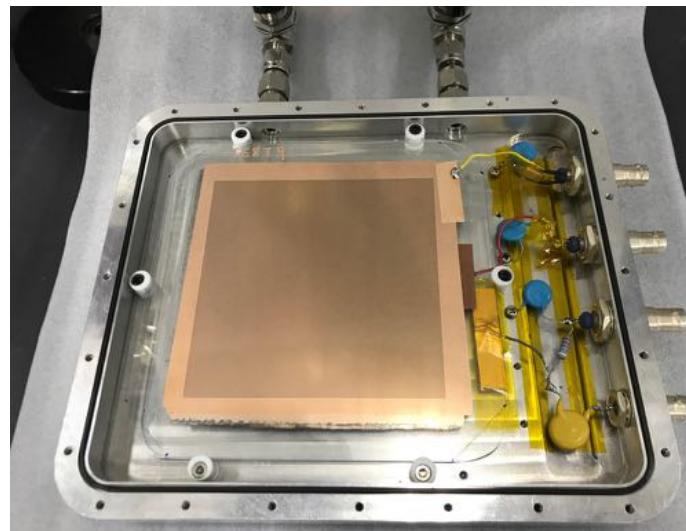
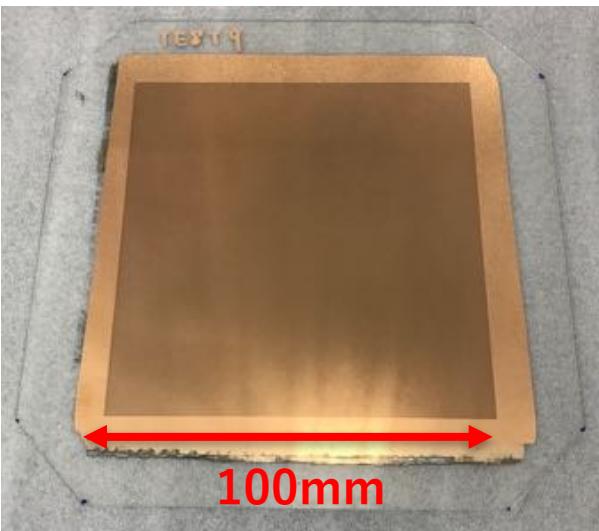
Plating machine



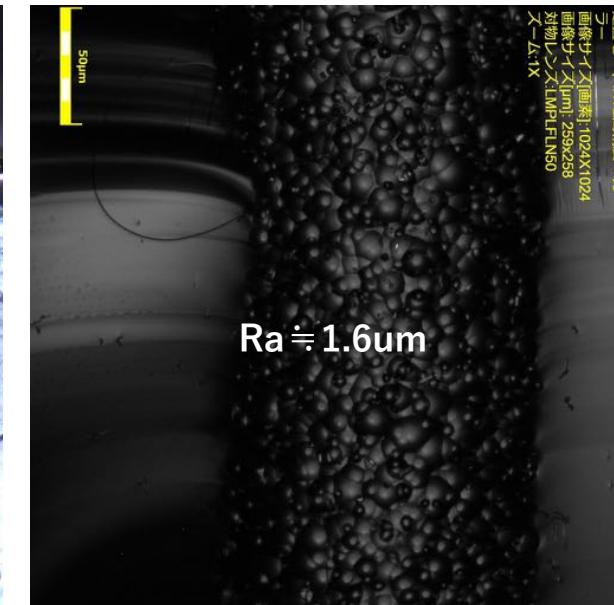
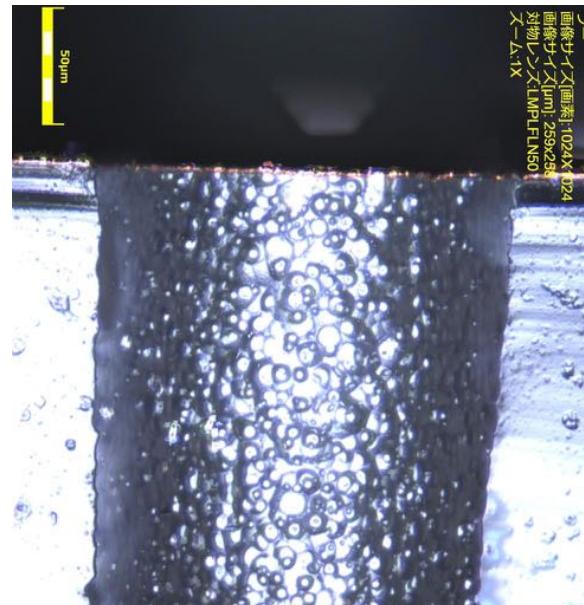
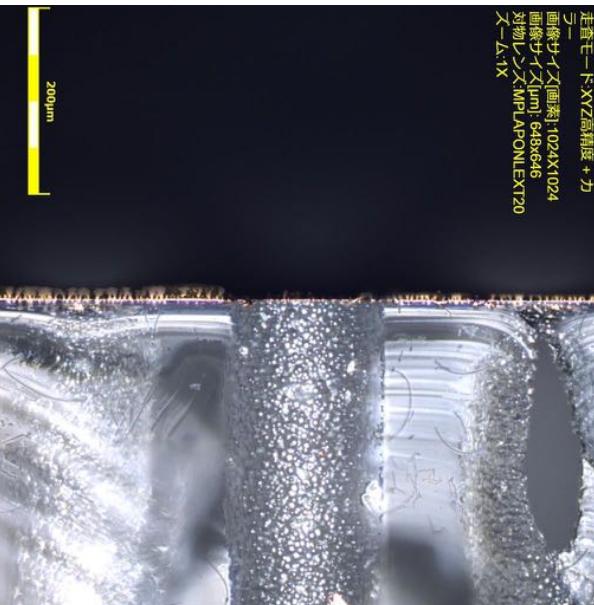
Laser microscope

全行程の約 80 % を産総研内の設備で対応

2. 内製プロセスで製作したGlass GEM

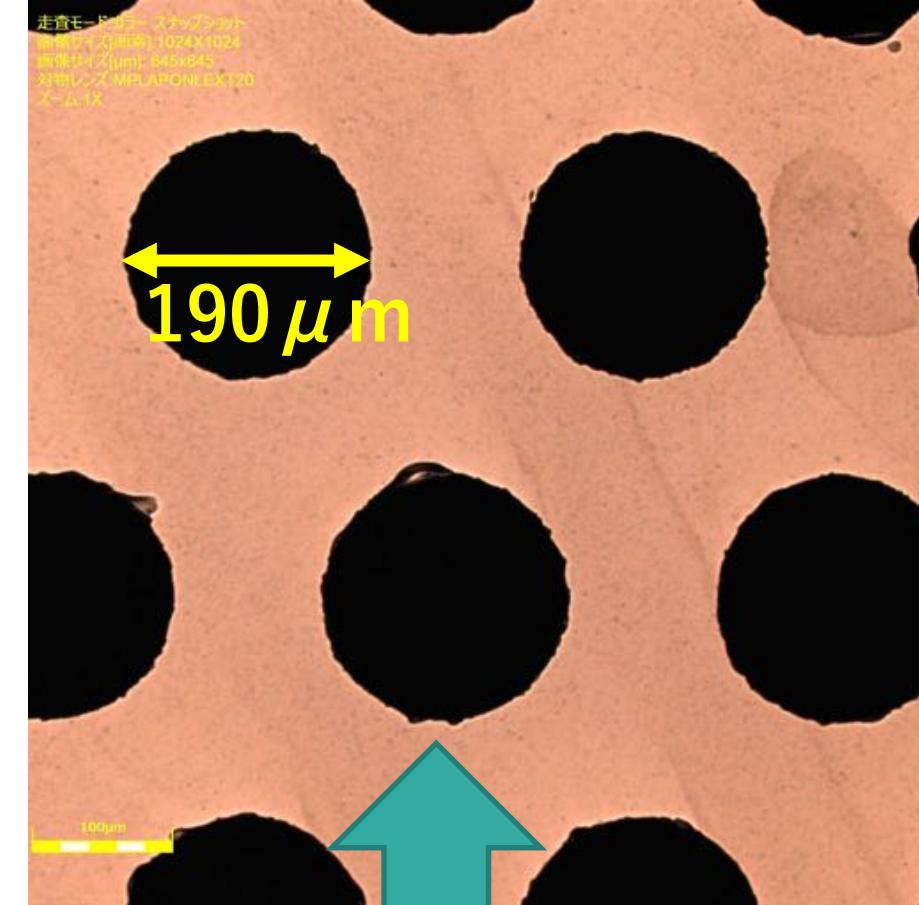


100 * 100mm Glass GEM



孔の断面：孔内の金属のみを選択的に除去することに成功

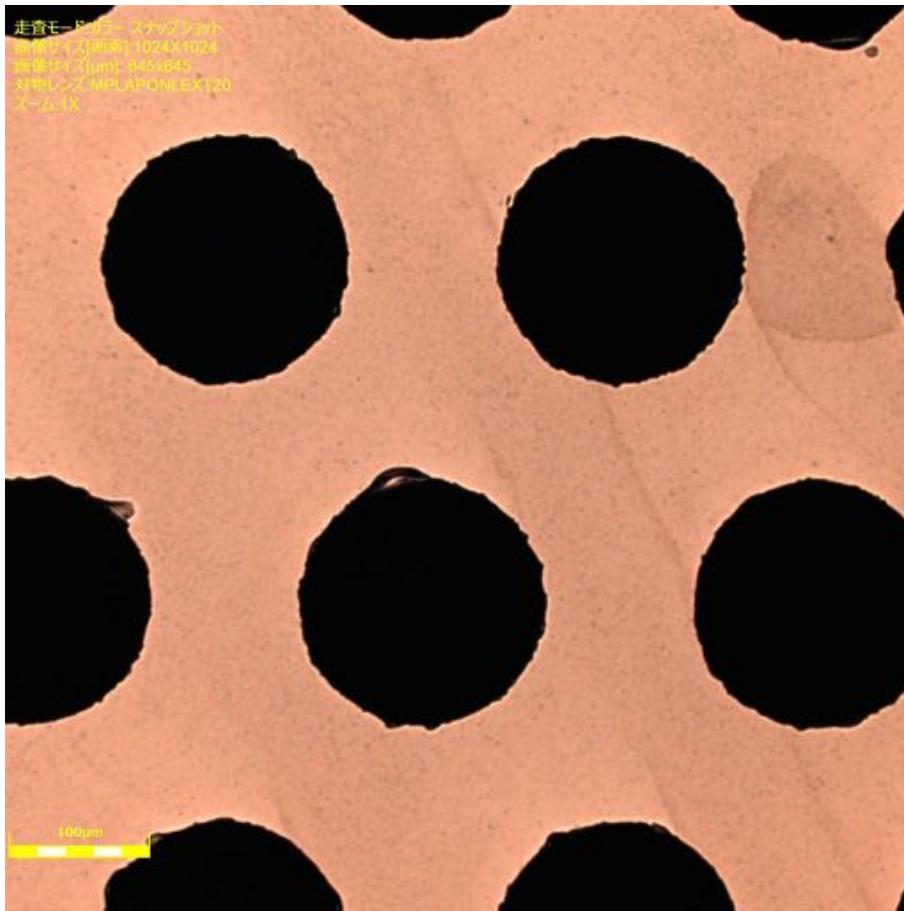
2. 内製プロセスで製作したGlass GEM



Rough electrode

2. 内製プロセスで製作したGlass GEM

Old process



The New process



Smooth electrode: Uniformity of the electric field improves, and the GEM's stability improves

2. 内製プロセスで製作したGlass GEM

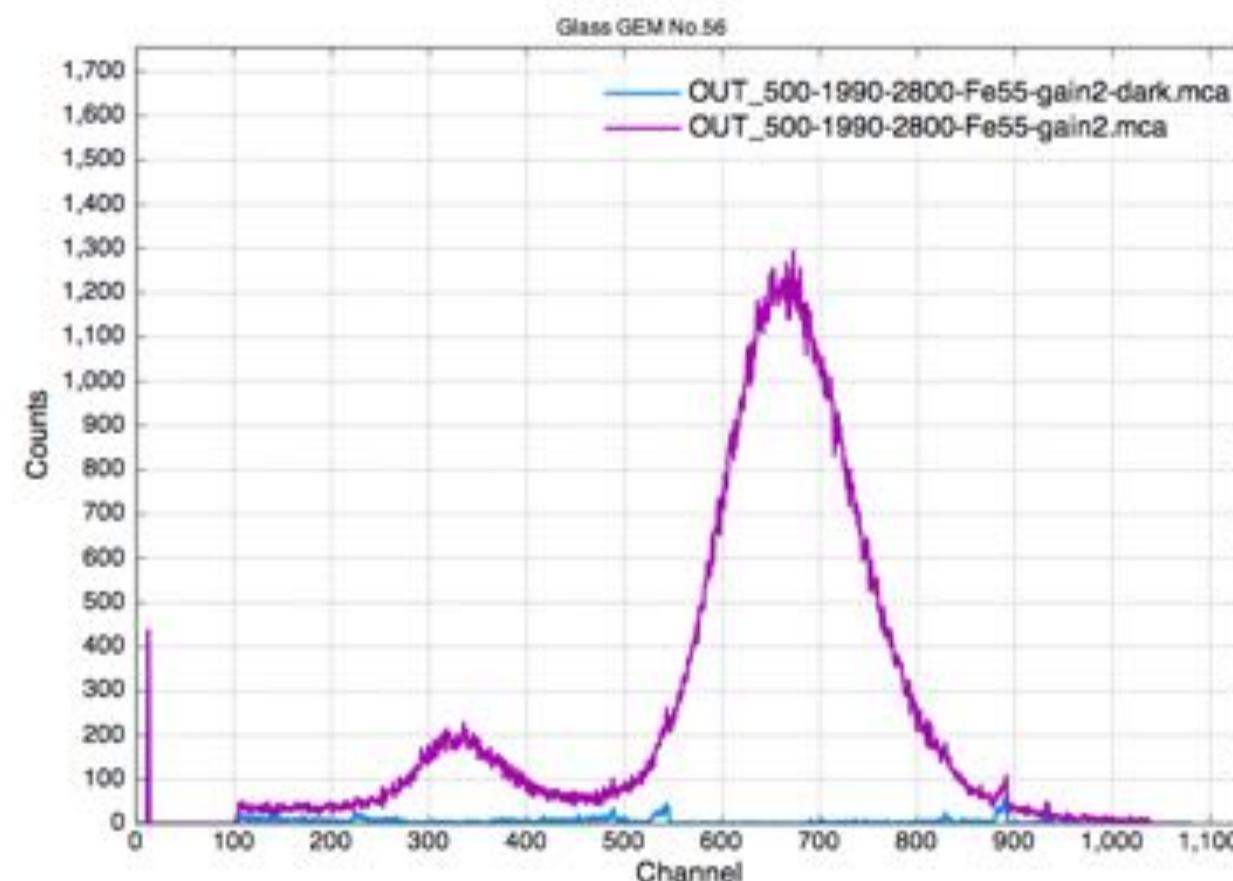


Fig.1 Pulse height spectra of 5.9 keV
Energy resolution 19%, gas gain 10,000

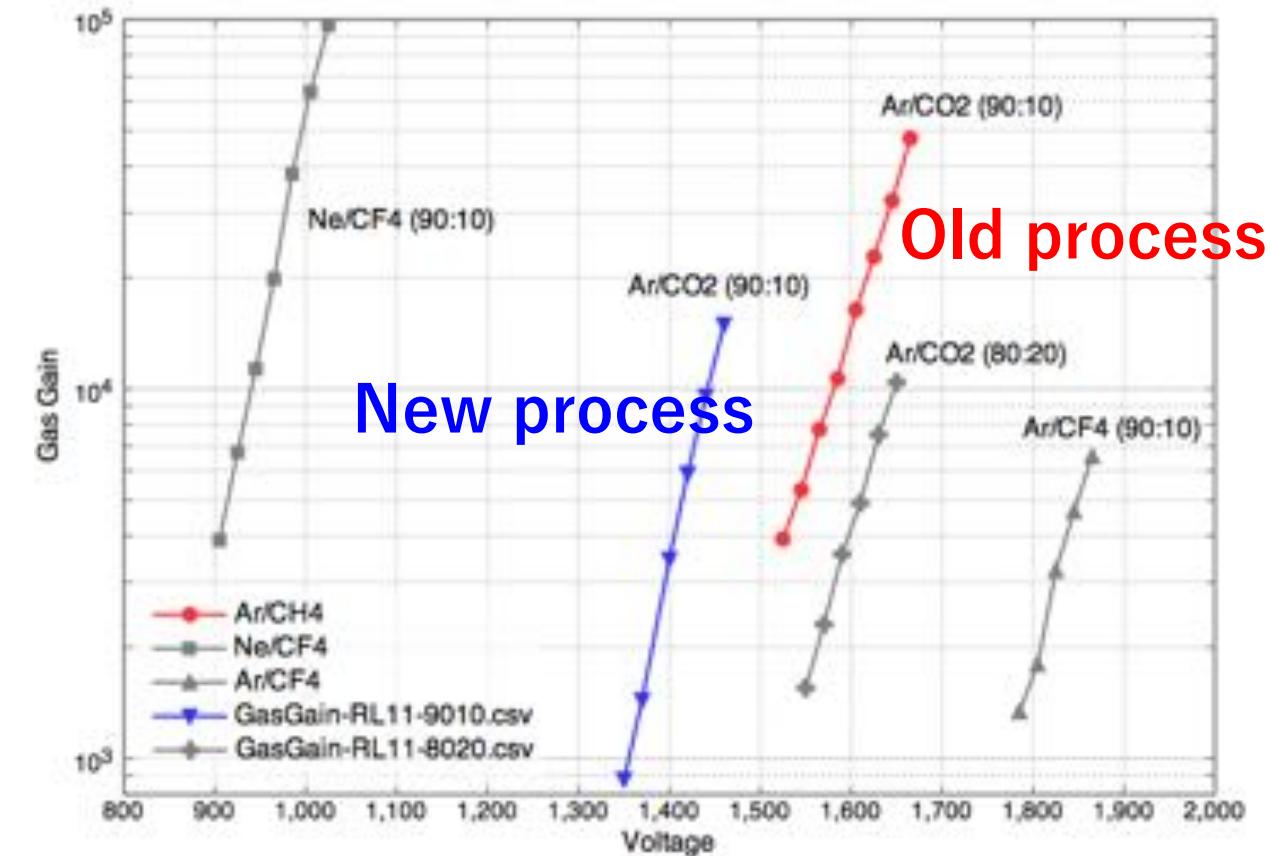
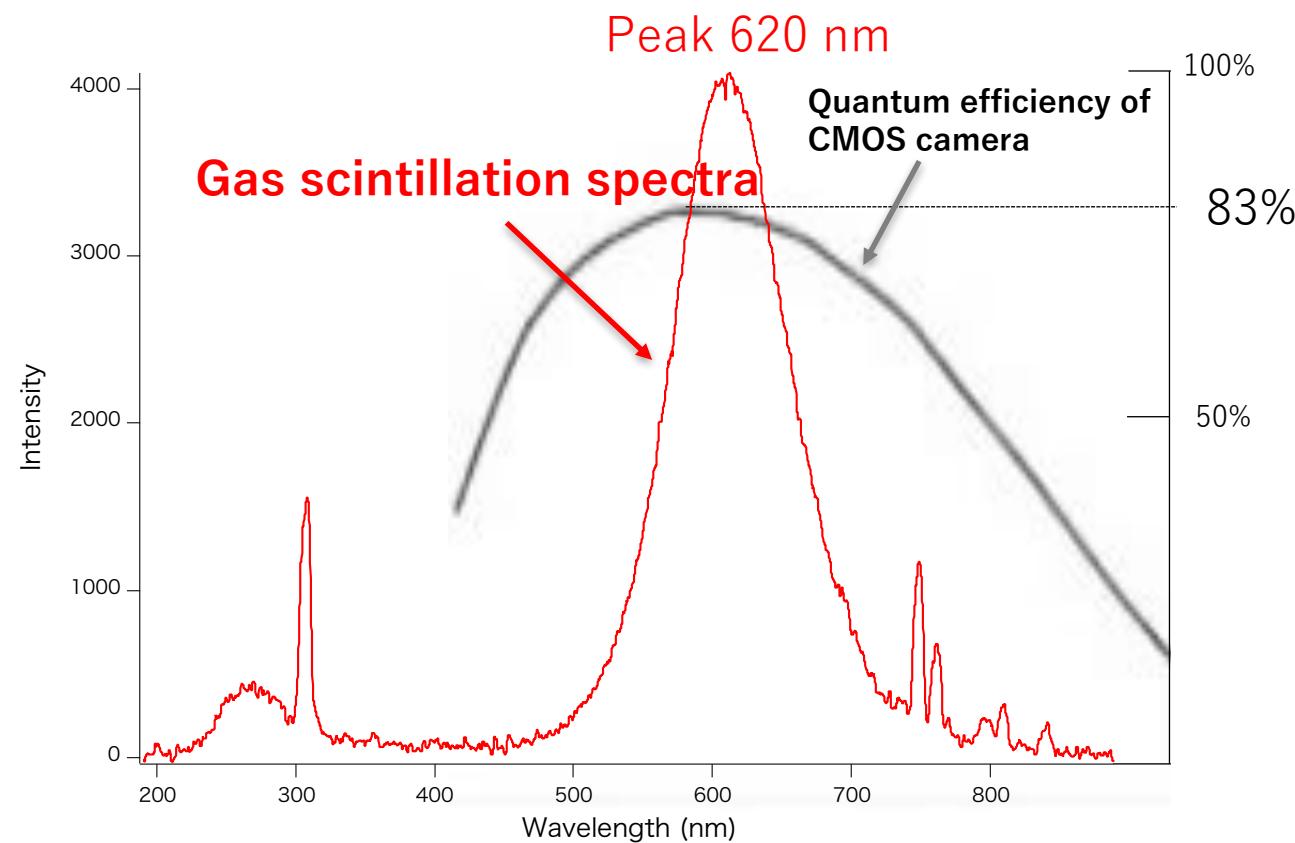
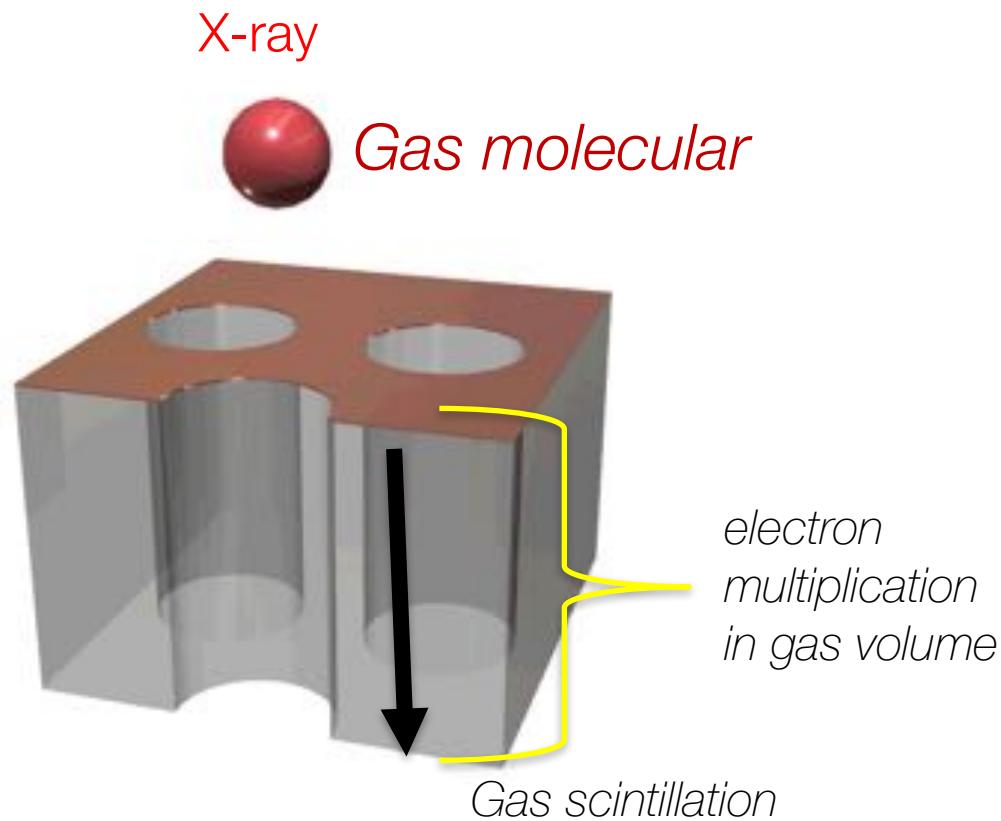


Fig. 2 Gas gain curve
Operation voltage decreased from the past process

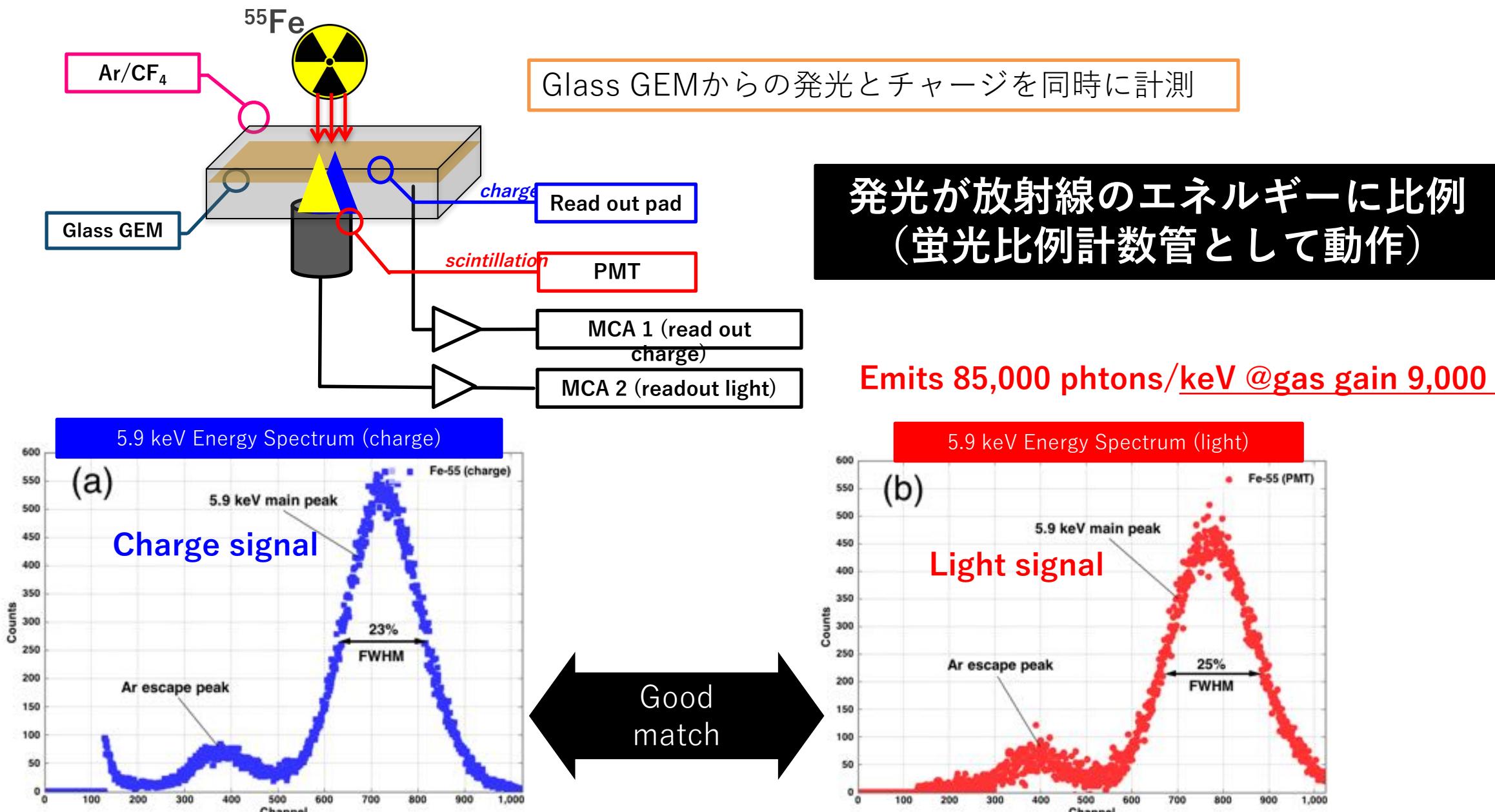
3. 蛍光ガスを用いたGlass GEMの光読み出し



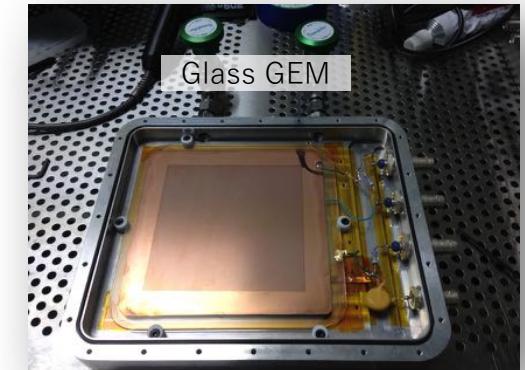
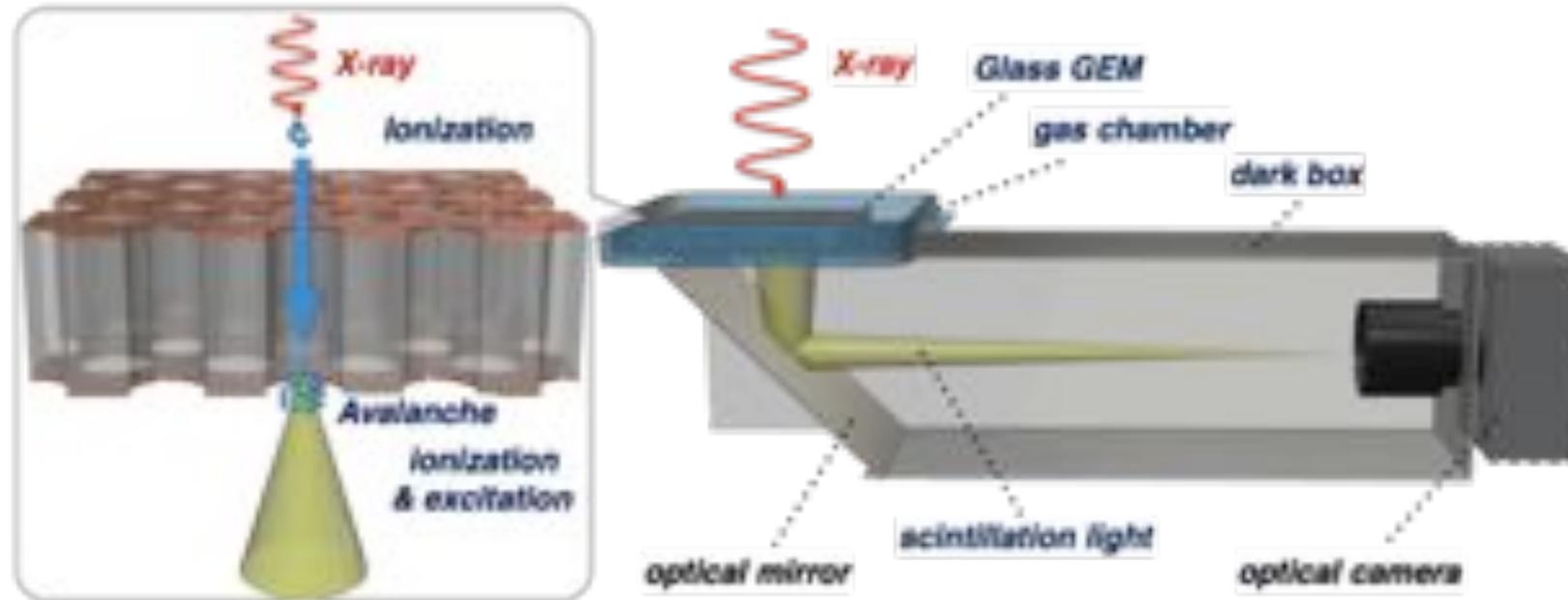
- ▶ Ar + CF₄ is known as a good scintillation gas. Firstly reported by Fraga in 1999^[6]
- ▶ Large amount of scintillation photons would be produced during Glass GEM's high gain avalanche process
- ▶ Gas scintillation can optically readout with CMOS camera

[6] F.A.F. Fraga, NSS MIC IEEE, 1999

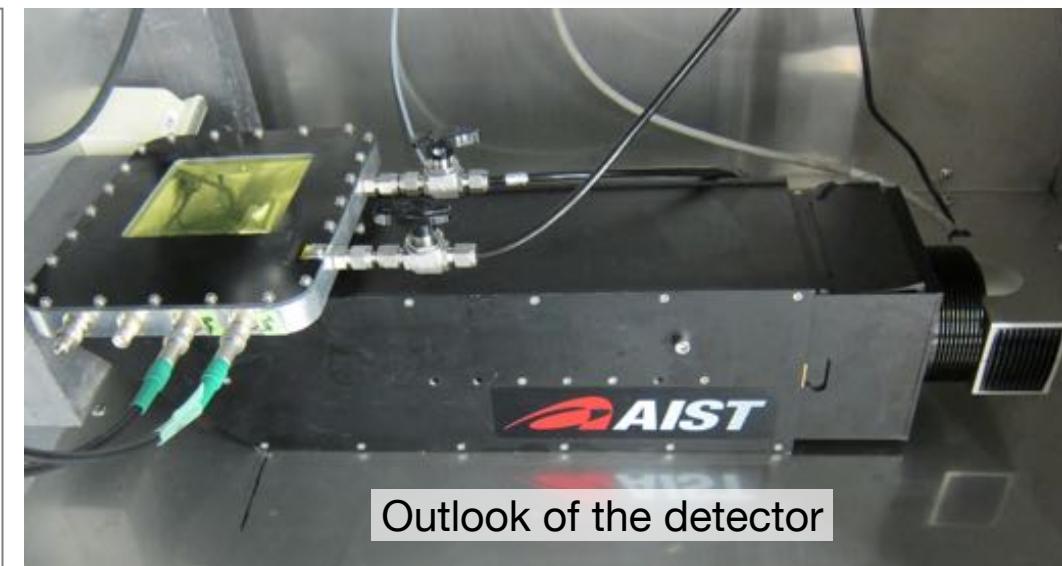
3. 蛍光ガスの原理実証： ^{55}Fe (5.9 keV X-rays)を用いた発光測定^[2]



The detector design^[8,9]



- ▶ Glass GEM × 蛍光ガス × ミラー × CMOSカメラ
- ▶ 放射線を可視光に変換して撮像する新しいX線カメラ
- ▶ ミラーで90度方向に反射させることで直接X線がCCDカメラに入射するのを回避
- ▶ カメラを用いることで安価・高速・簡便なイメージングが可能



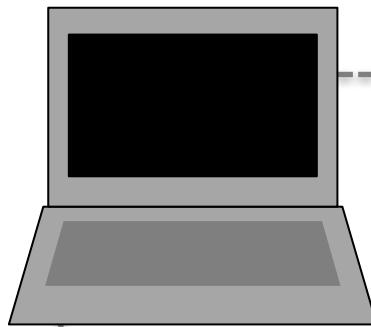
[8] T. Fujiwara, et al., JINST, Vol. 8, No. 7 (2013)

[9] T. Fujiwara, et al., NIM A, 850 (2017)

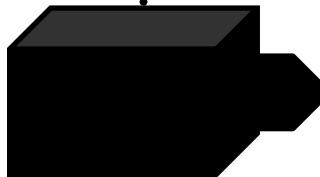
4. Experimental result – Imaging setup

13

DAQ and control PC

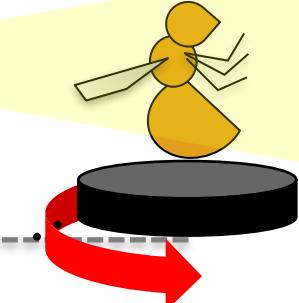


X-ray tube
20 kV, 100 uA



Rotating stage

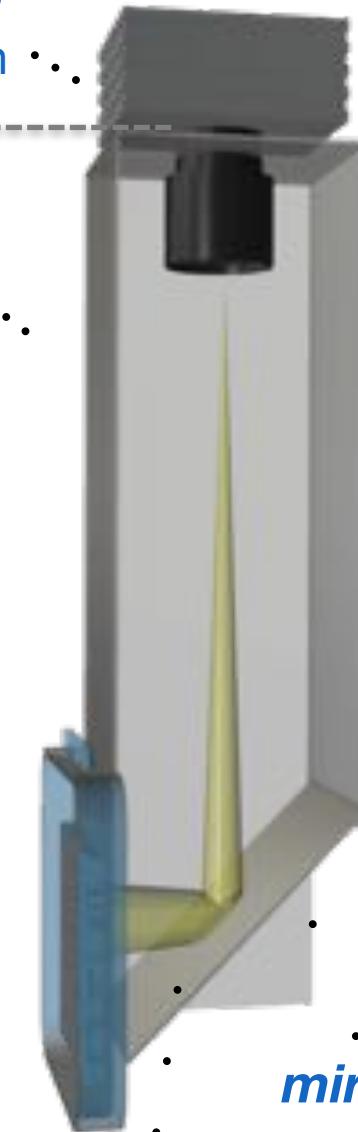
Object (a hornet)



CMOS Camera

10 sec integration

dark box



Scintillating gas filled chamber

**Glass GEM
(100×100mm)**

X-rays

Gas scintillation



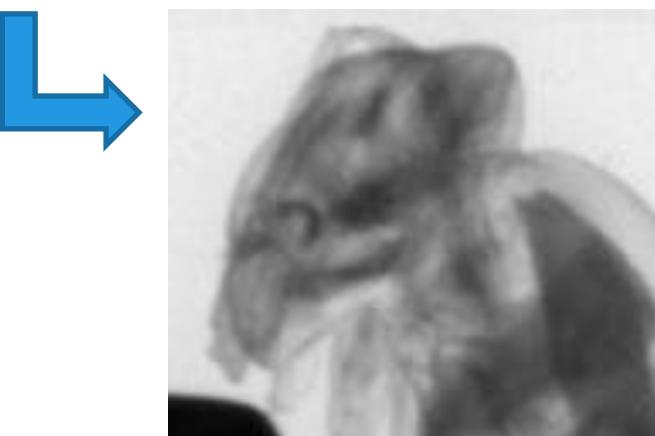
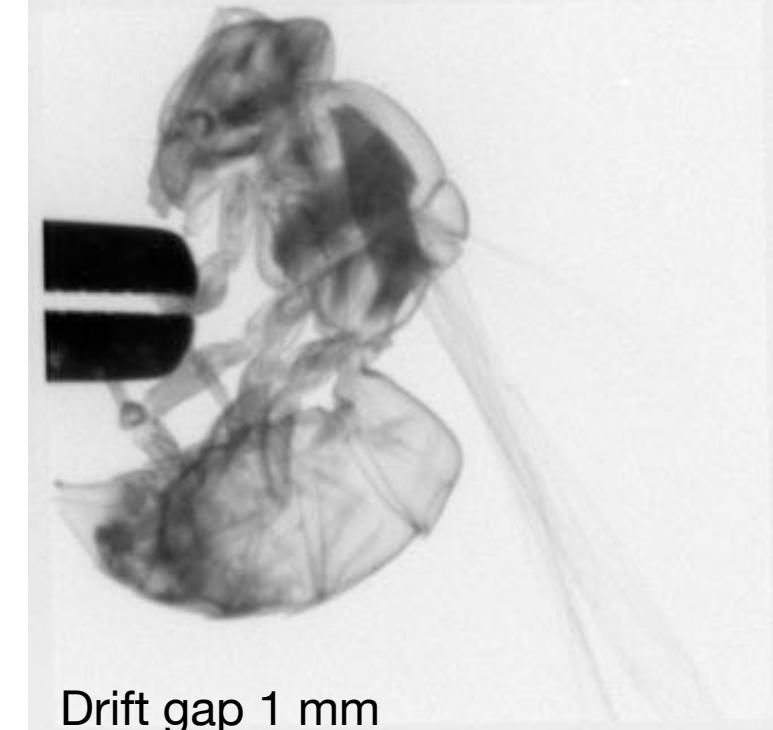
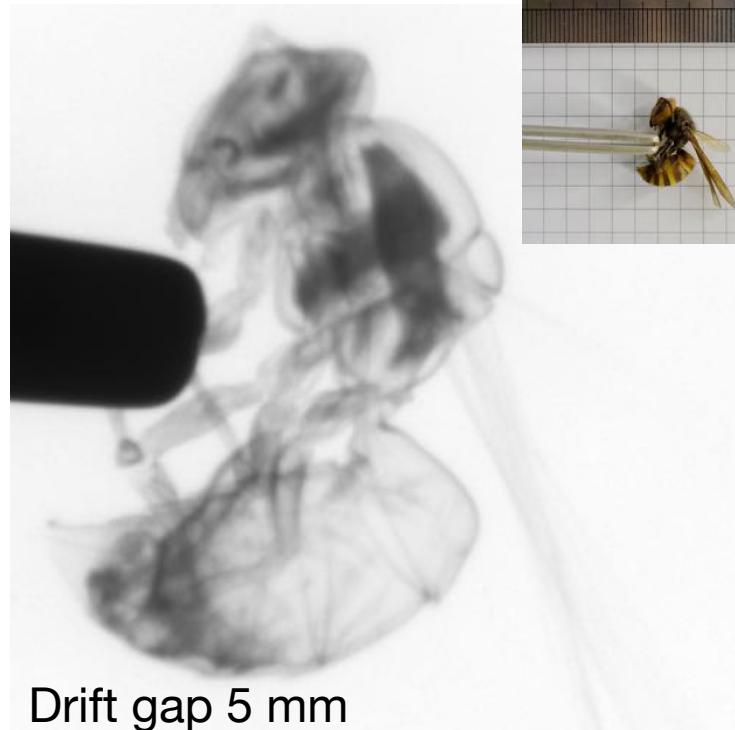
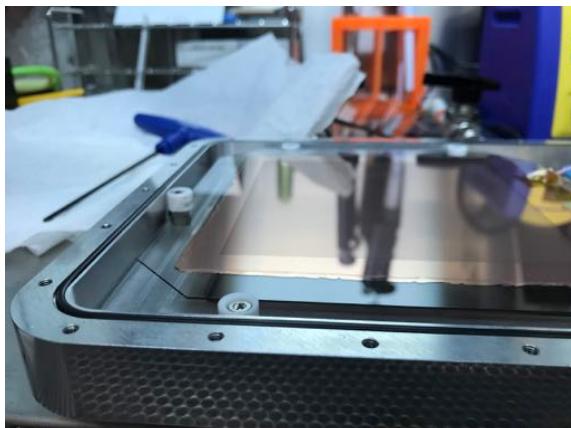
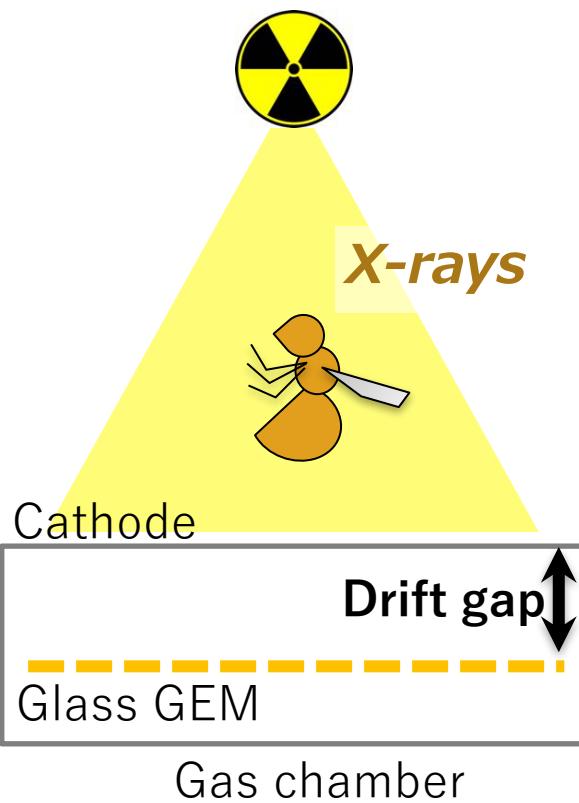
CMOS Camera
Hamamatsu
ORCA-Flash4.0 V3



X-ray tube
Hamamatsu
L9631

4. Experimental result – Drift gap

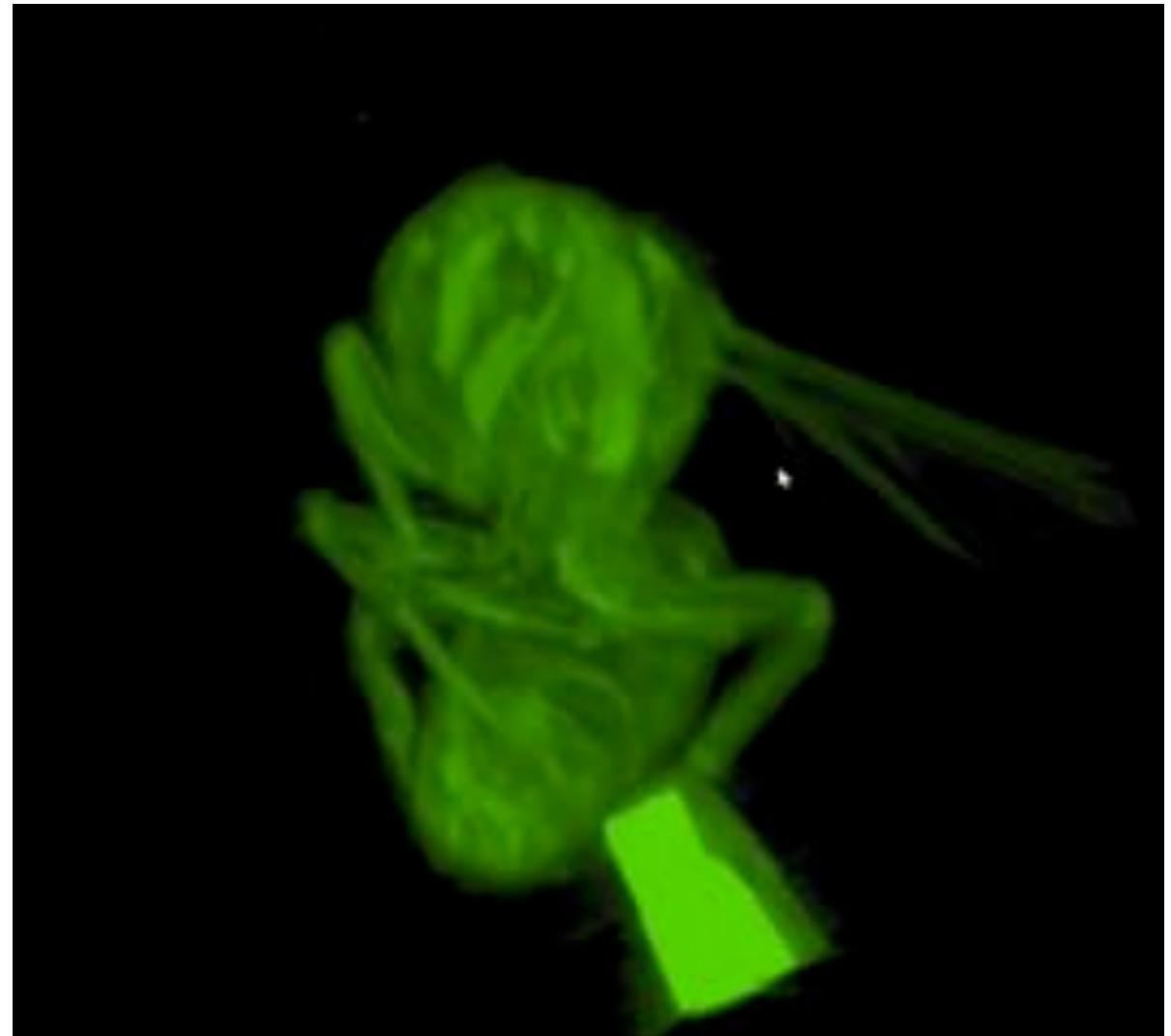
14



4. Experimental result – 3D X-ray Computed Tomography (CT)

16

- ▶ Reconstructed with 360 X-ray images taken with Glass GEM
- ▶ 2 sec exposure time
- ▶ Took 20 minutes
- ▶ Filtered back projection method
- ▶ GEMs can easily amplify small signals with gains of up to 10^4 .
- ▶ This feature of GEMs is highly advantageous for large-area soft-X-ray imaging.



- ▶ 内製プロセスを用いてGlass GEMの製作を開始→成功
- ▶ 光読み出し法を用いて、高分解能X線イメージングと3D CTへの応用を紹介
- ▶ **3Dスキャンとモデリングという新しい応用を提案**
 - ▷ 生物学、医療研究への応用
 - ▷ 中性子反射率計用にベゼル部分を切り取ったGlass GEMを開発
 - ▷ タイリングにより大面積化が可能
- ▶ Collaborators are always welcome!