# Development and Applications of "Mössbauer Cameras"

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3. "Mössbauer Camera" : **mapping** by MCX
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5. A running project to achieve **submicron resolution***
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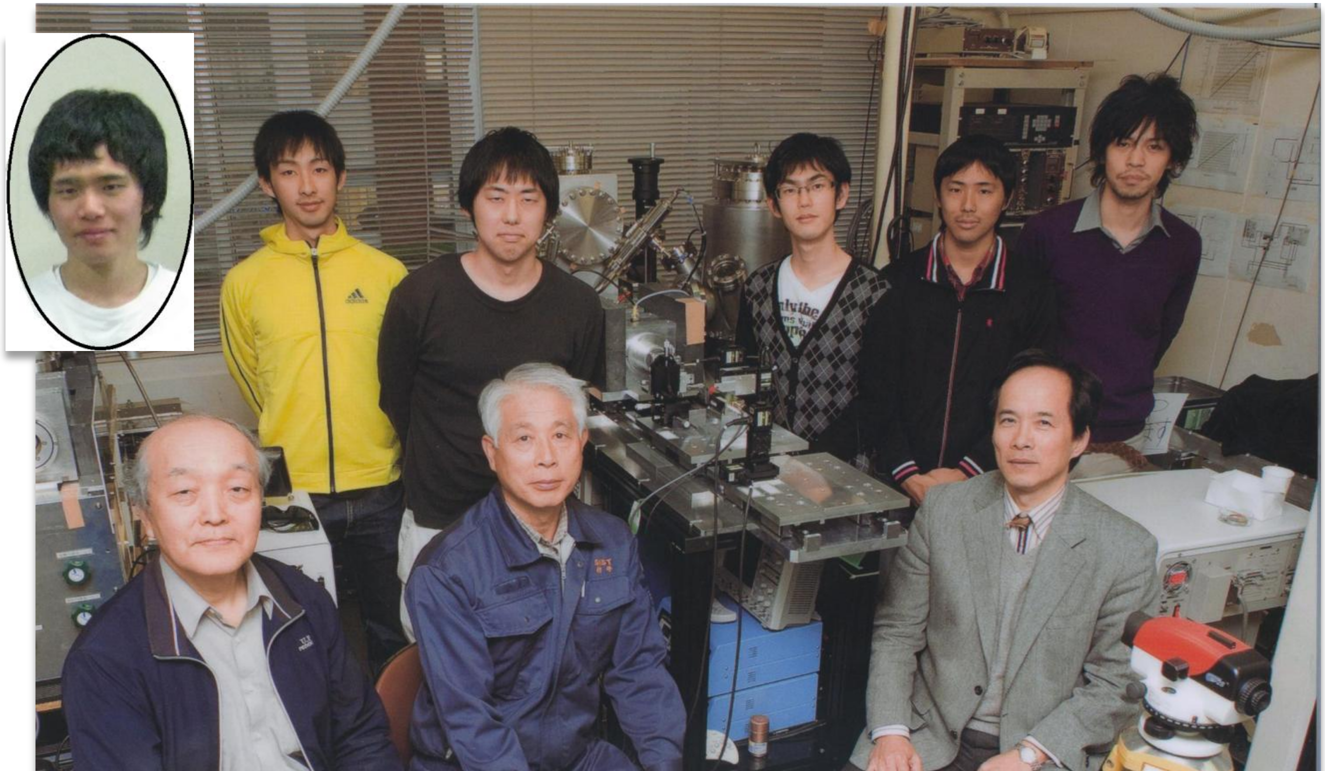
* Supported by JST

# Mössbauer Group at SIST



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Yuki Akiyama[1], Hiroto Kumabe[1], Hiroyoshi Soejima[2]

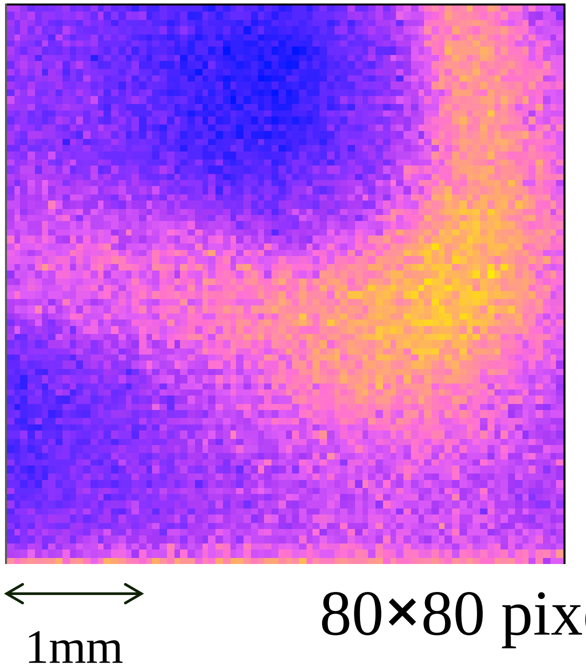
[1] Shizuoka Institute of Science and Technology, [2]Shimadzu Corporation

# "Mössbauer camera" to study microstructures in materials

**CCD camera**

800×800 pi

**Mössbauer camera**

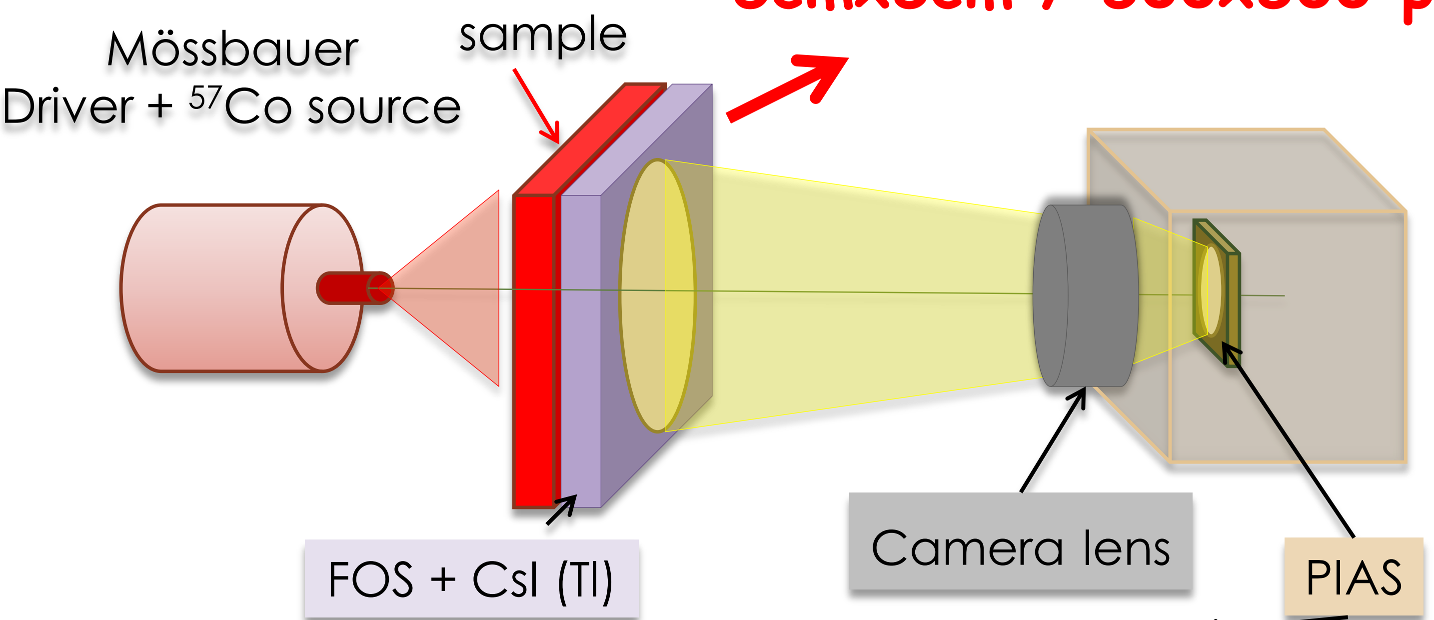



80×80 pixels

**Readout time is too slow in X-ray camera (30ms)**

# "Mössbauer Camera" using PIAS + FOS

**5cmx5cm / 500x500 pixels**



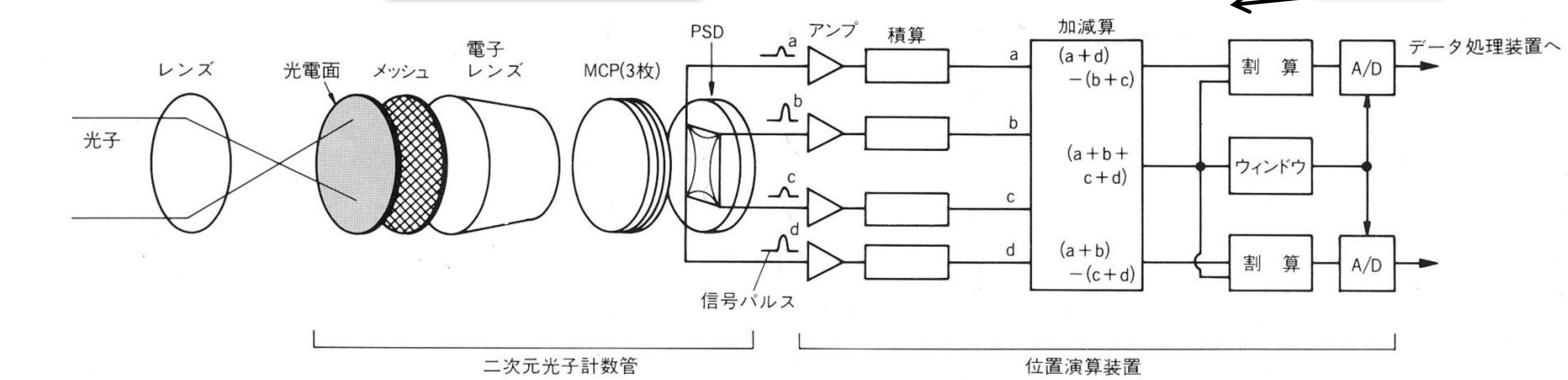
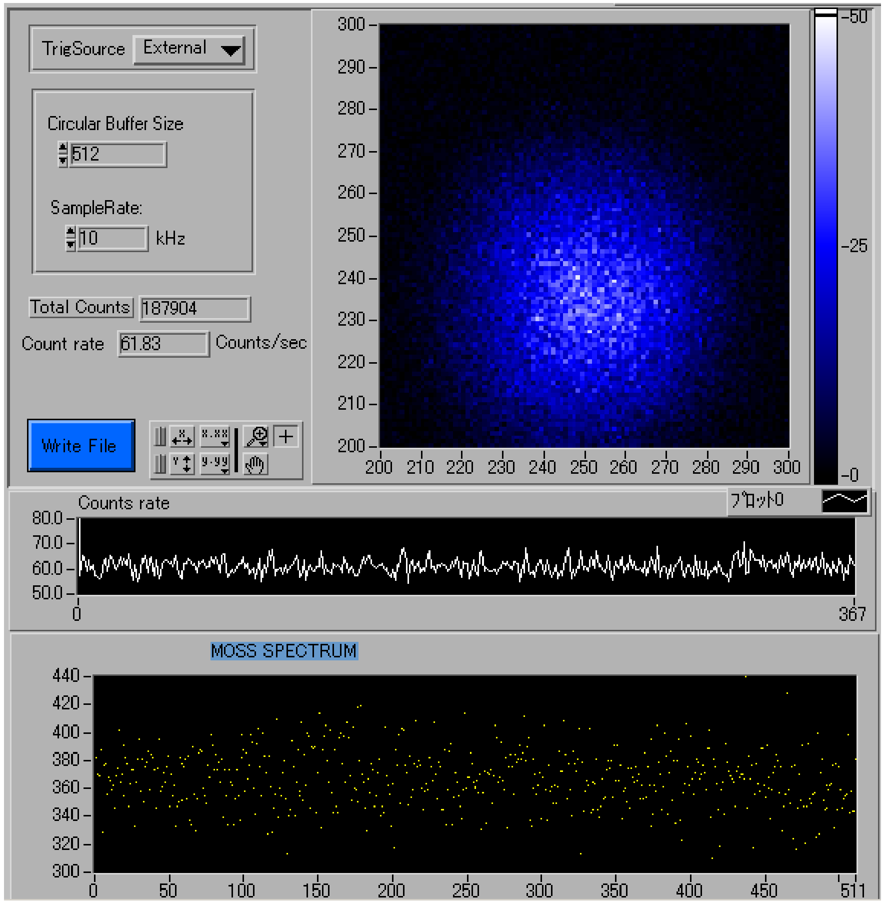




図7．PIAS-TIの動作原理図

# Imaging by PIAS + FOS



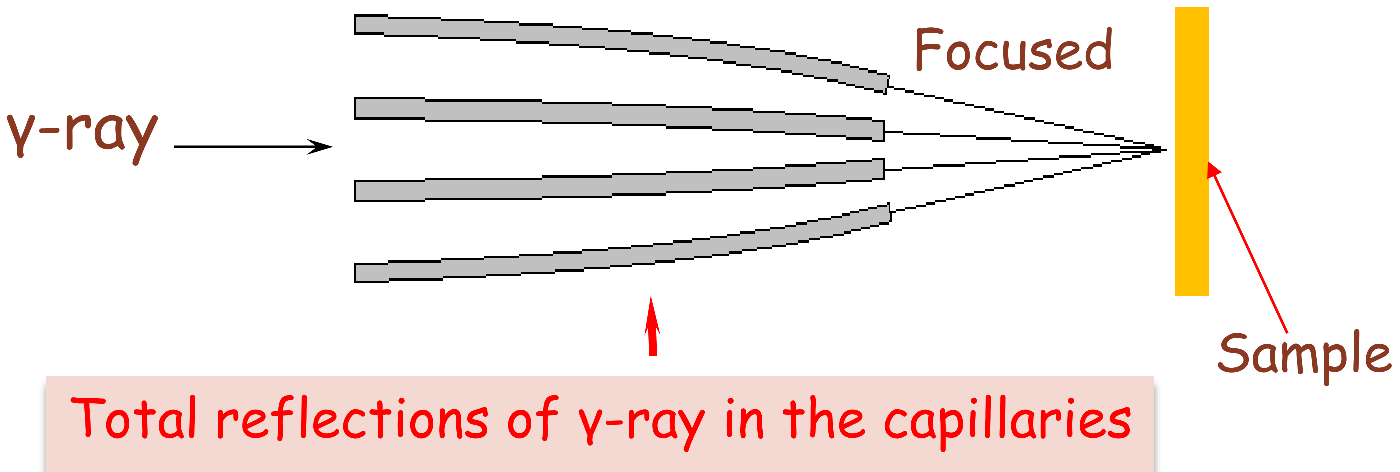
# "Mössbauer Camera" using a mapping Technique

## Main program with LabVIEW

# Mössbauer camera: mapping by focusing 14.4keV γ-ray

SIST Y. Yoshida, K. Hayakawa, K. Yukihira, K. Suzuki, K. Sakata, T. Kamimura
Shimazu H. Soejima

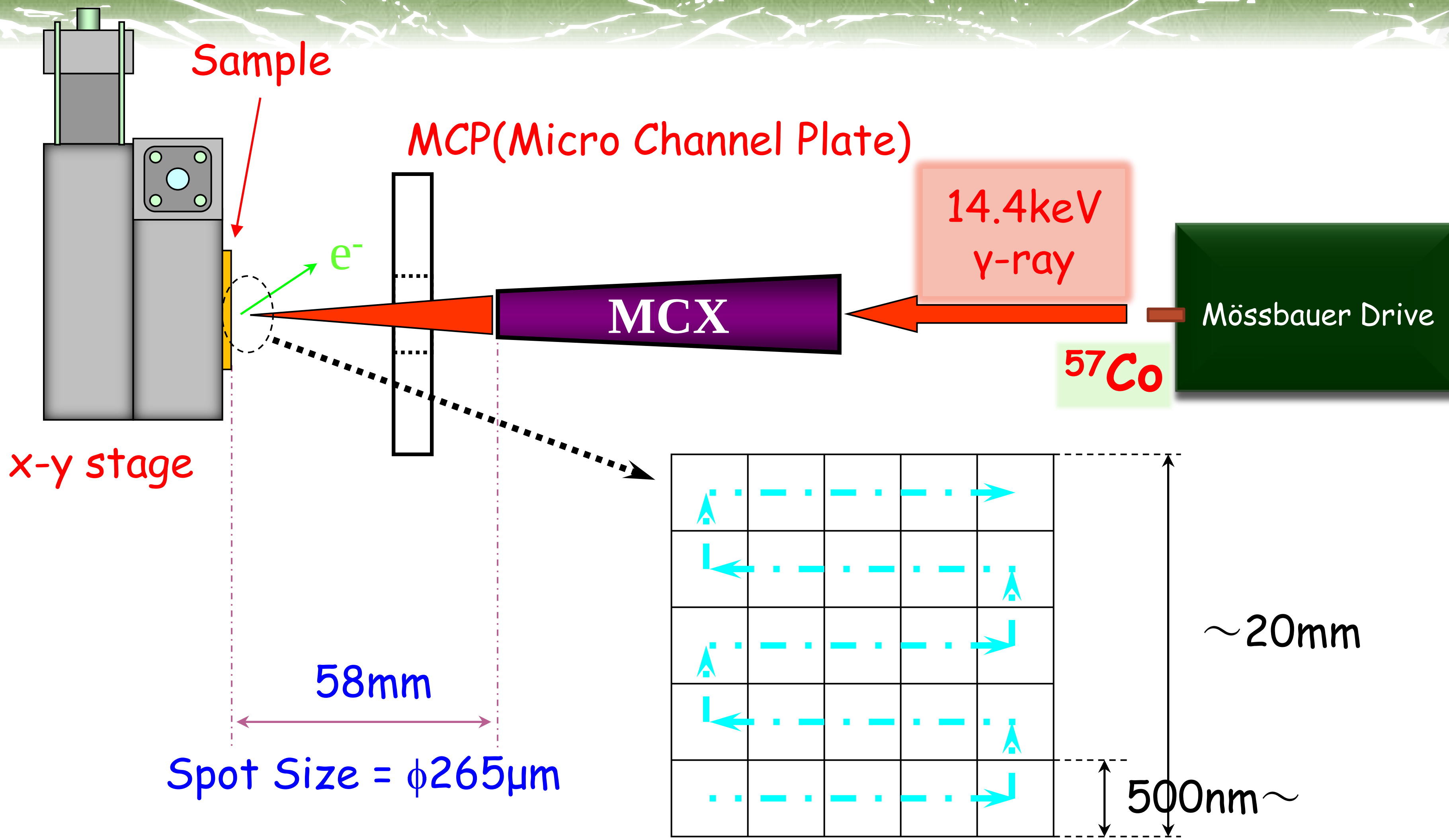
14.4keV γ-ray emitted from a $^{57}Co$-in-Rh source (50mCi) are focused on a sample by **MCX lens (Soejima-Kumakov lens)**




- focal distance : 58mm
- entrance diameter: 4mmϕ
- spot size : 265μmϕ
- transmission : 41% for 14.4keV

H.Soejima,Japan Patent 2014379(1986);2001797(1988)

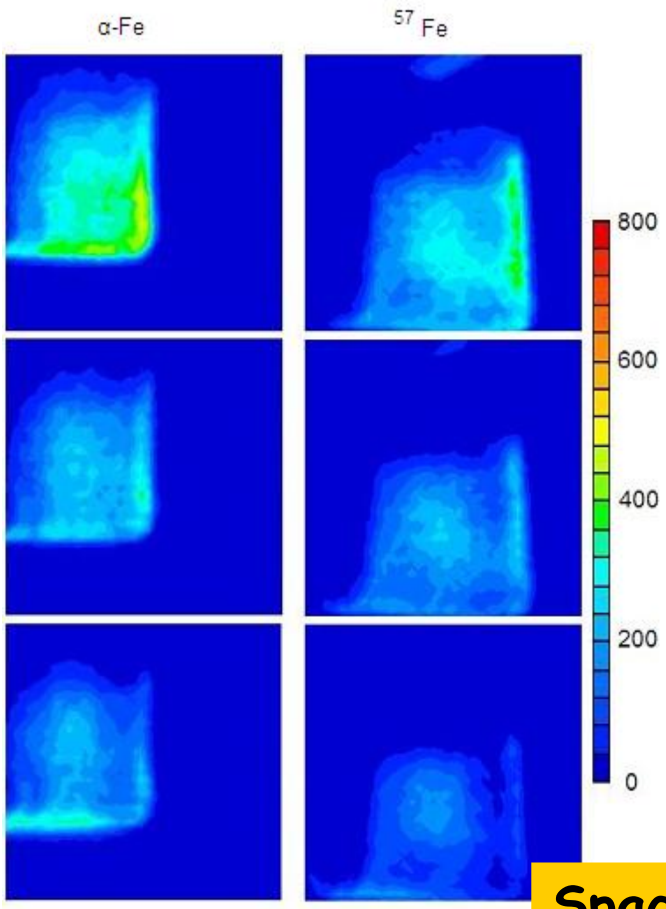
# A mapping technique for Mössbauer spectroscopy

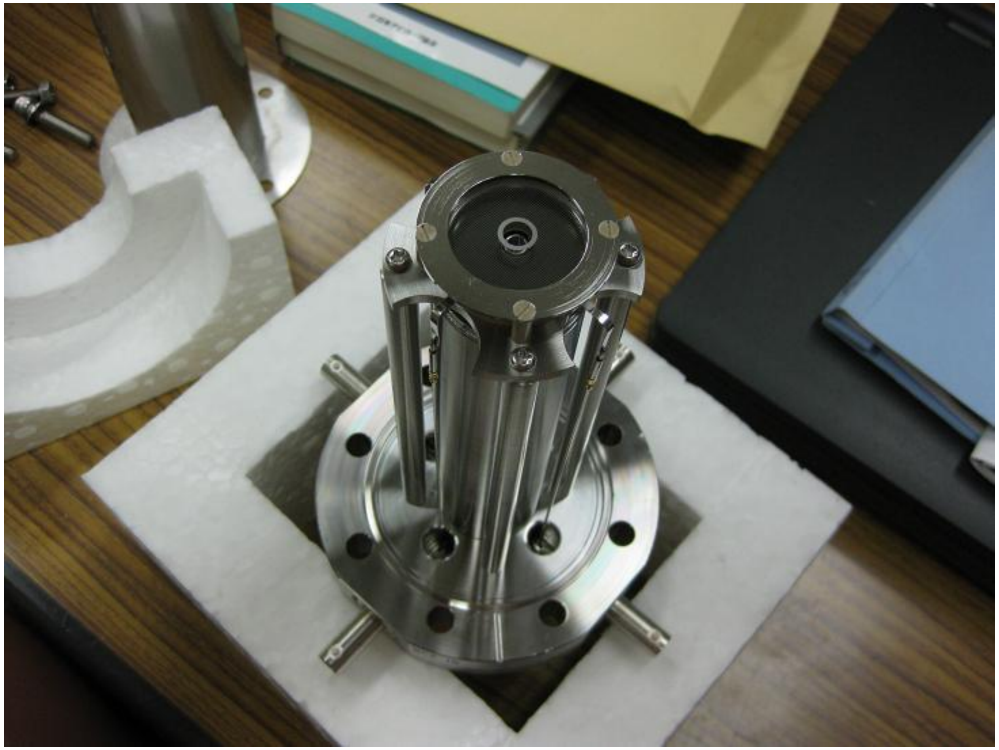



A measurement position is varied with a step size between 250μm and 25μm

# Three stage MCP with a center hole and a grid

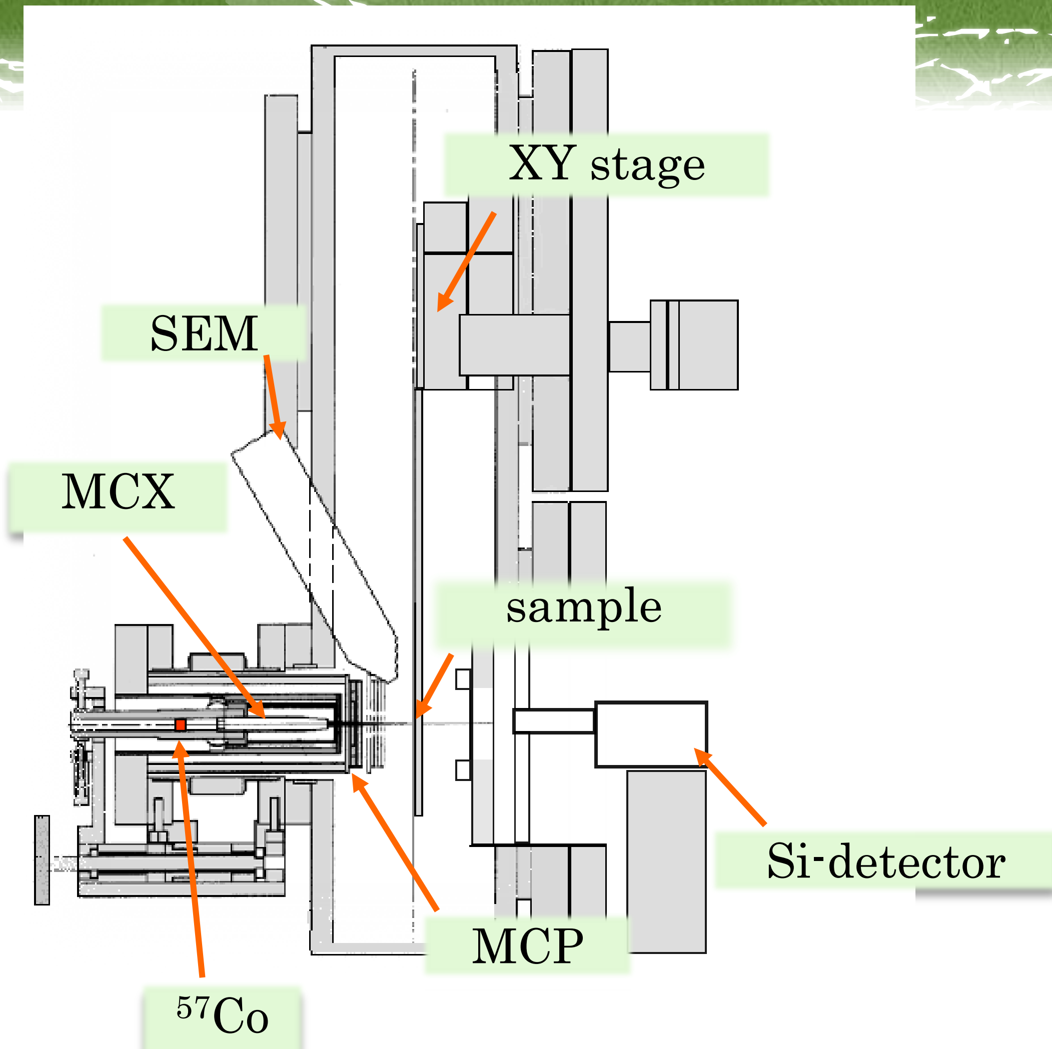
Hamamatsu Photonics K.K.

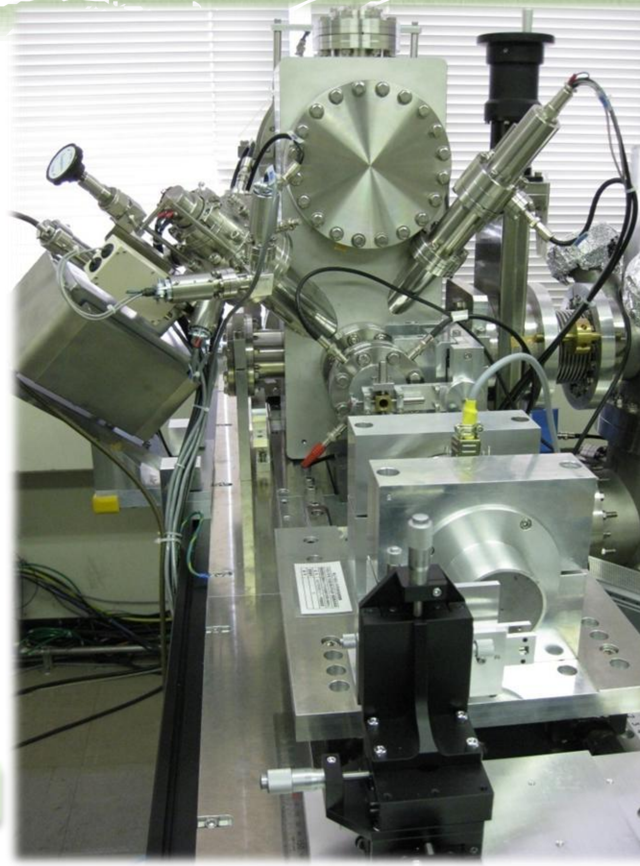


**Space resolution : 50~ 100μm**
**The images are distorted at boundaries!**

# Instrumental set-up

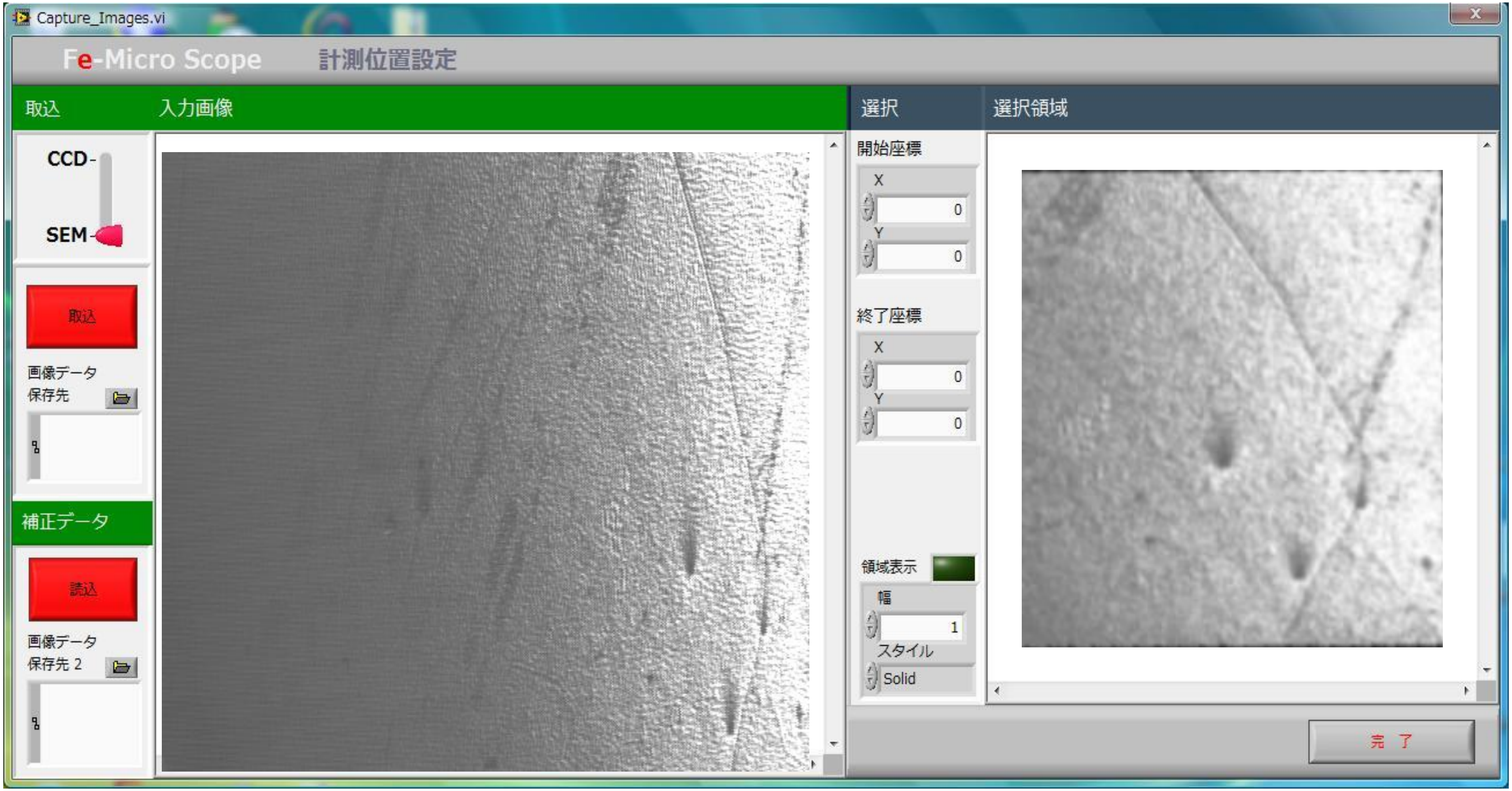


Vac ~ $10^{-5}$ Pa

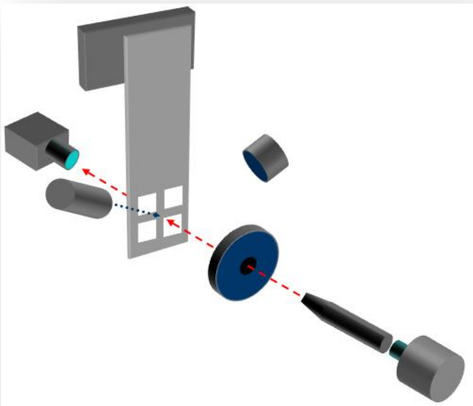
# Mössbauer Camera using a mapping Technique

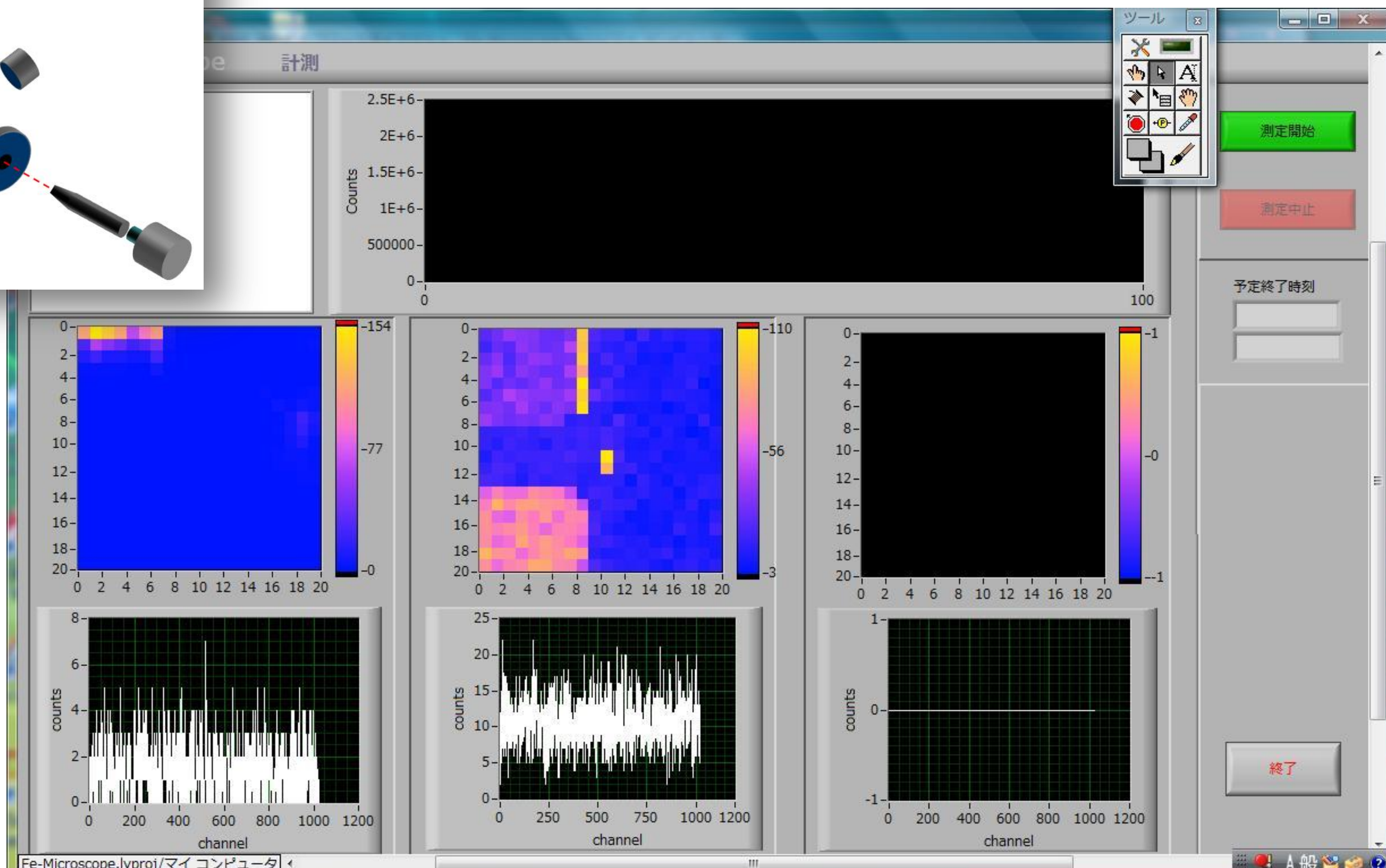
## How to select an observation area by FE-SEM?



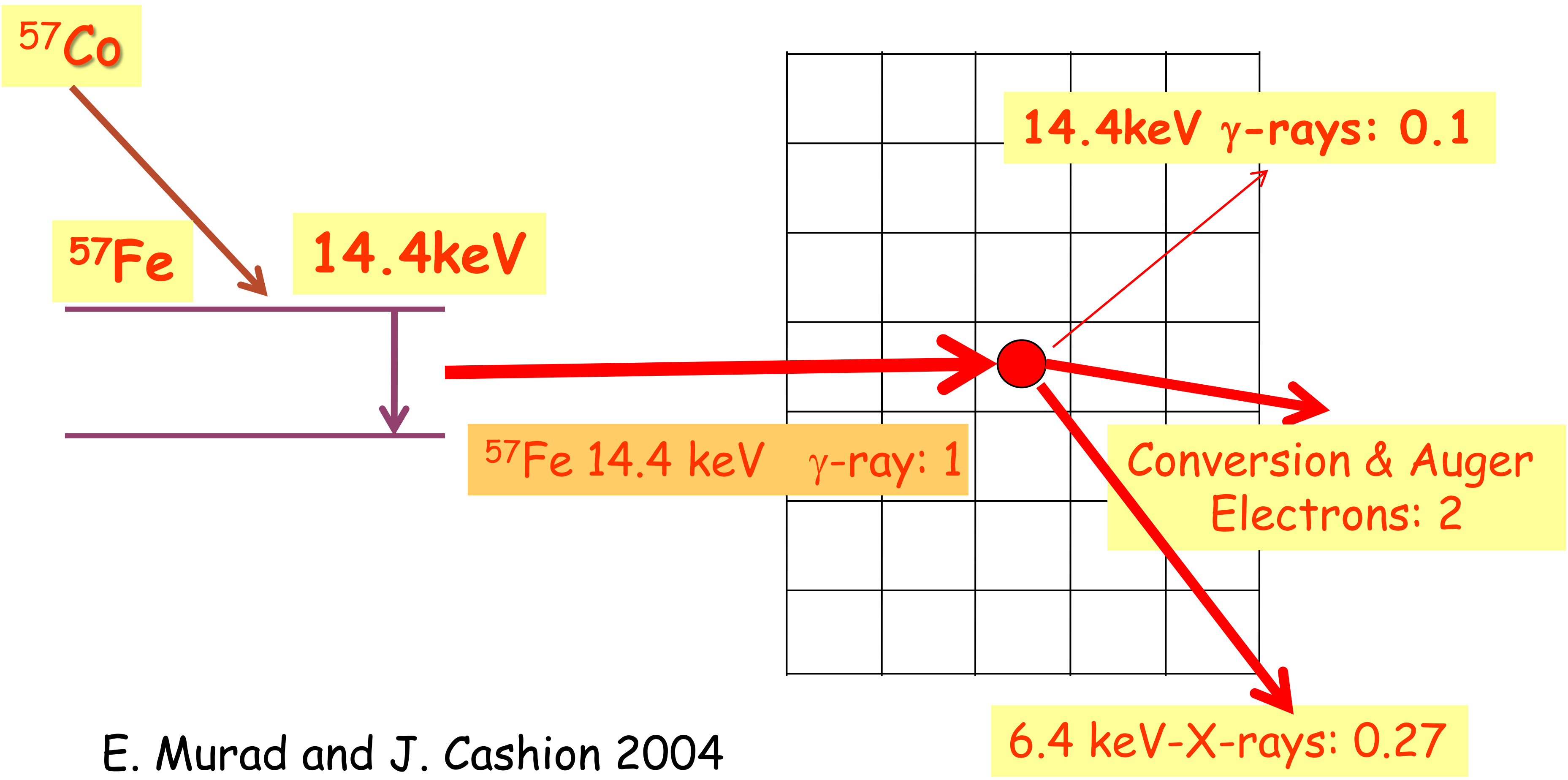
# Mössbauer Camera

How to proceed the microscope operation corresponding three different input?





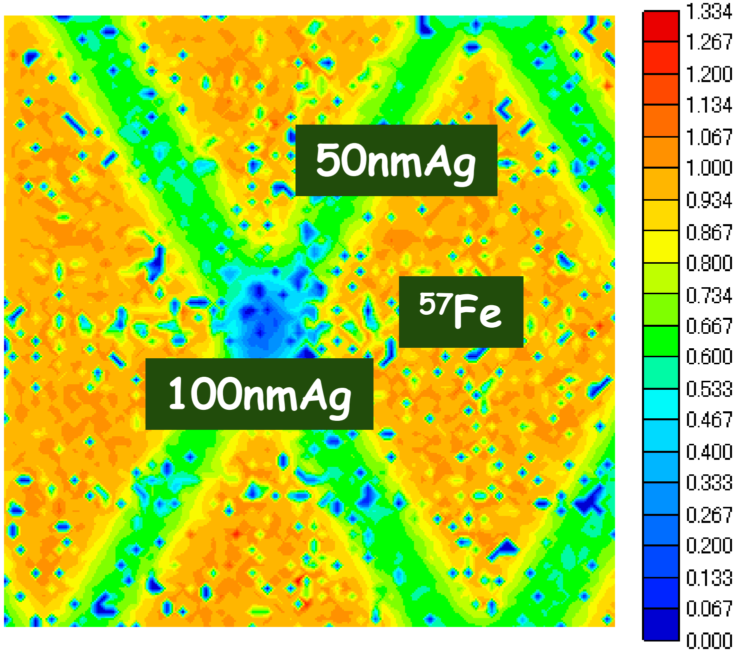
# $^{57}$Fe Mössbauer Effect



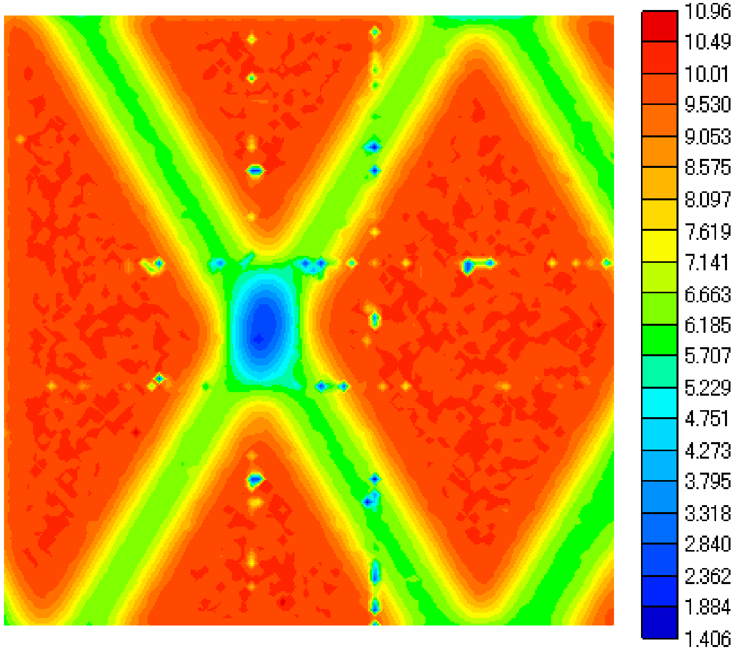

E. Murad and J. Cashion 2004

# Image Simulations for 100nm$^{57}$Fe+50/100nm-Ag in the case of conversion and Auger electrons mapping

emission ( Counts=1±1)

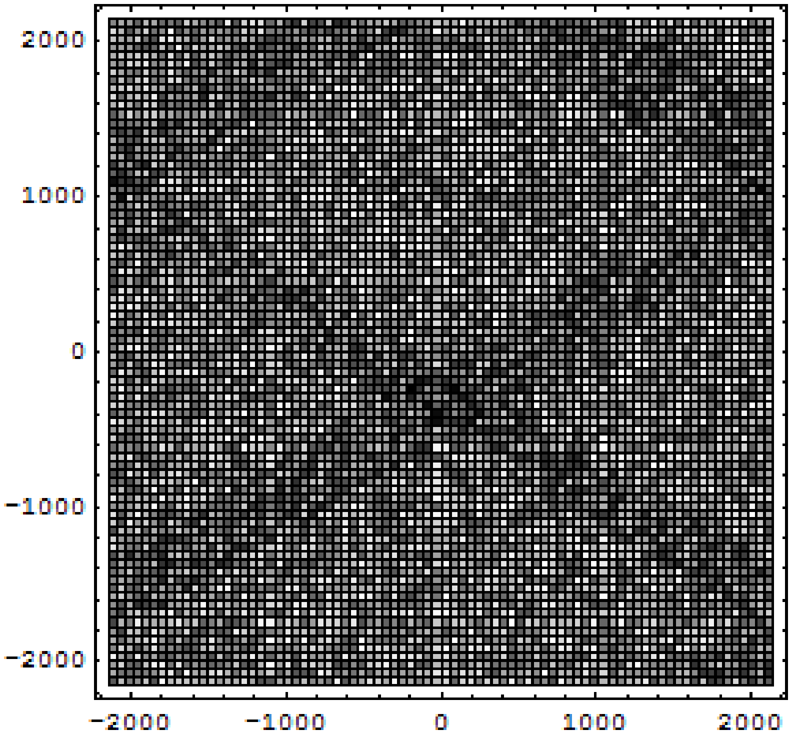



emission ( Counts=10±3)

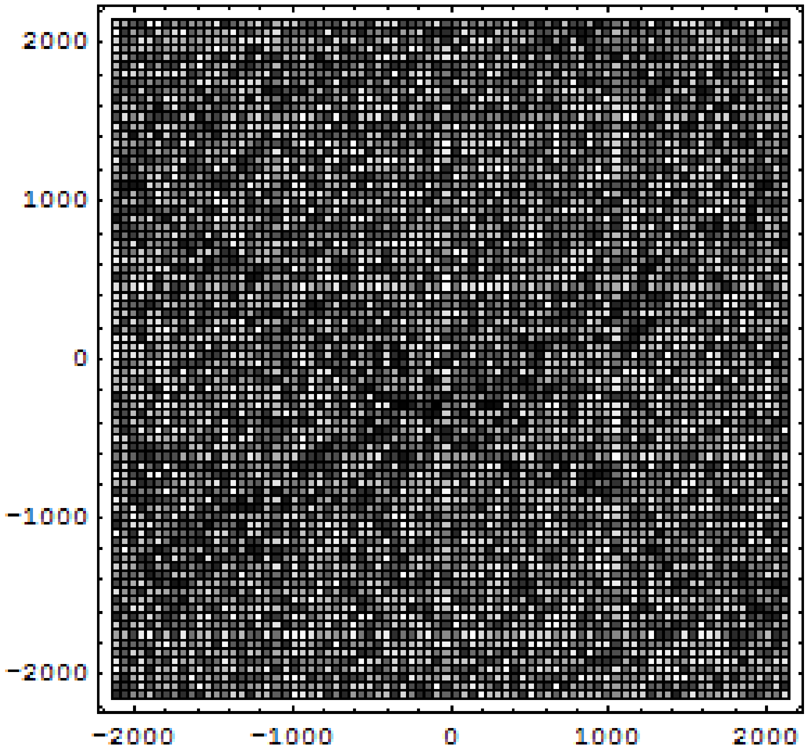


# Image Simulations for 100nm $^{57}Fe$+50/100nm-Ag in the case of transmitted 14.4keV-γ-rays mapping

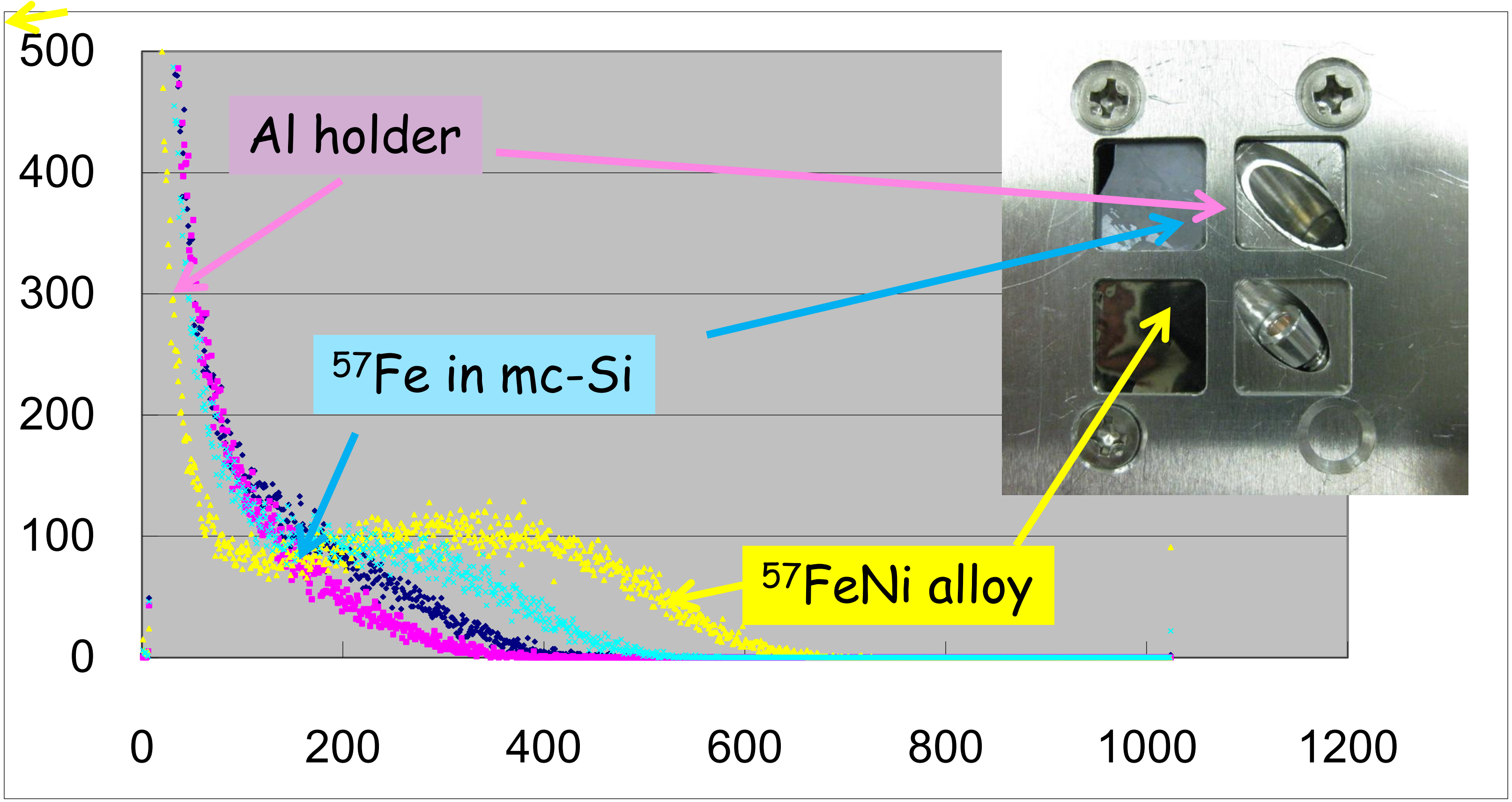
transmission
( Counts=50000±224)




transmission
( Counts=10000±100)



# PHA spectra from MCP which depend on the energy of electrons ?

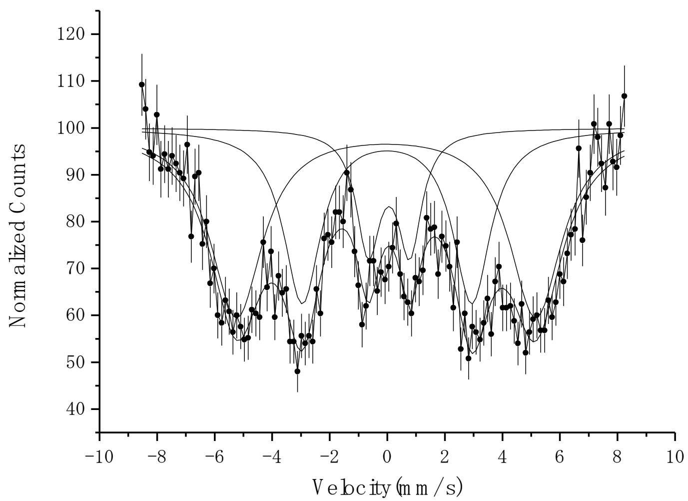


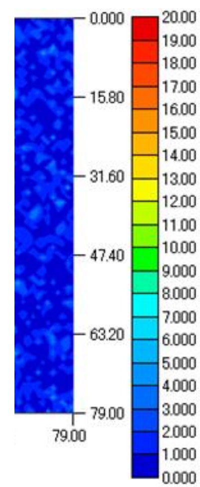
# Simultaneous measurements of mapping images using transmission and emission geometry

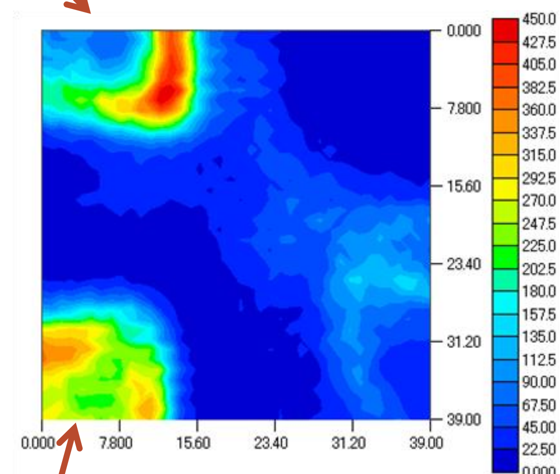
$^{57}Fe$ deposited mc-Si

14.4keV-γ-rays

electrons

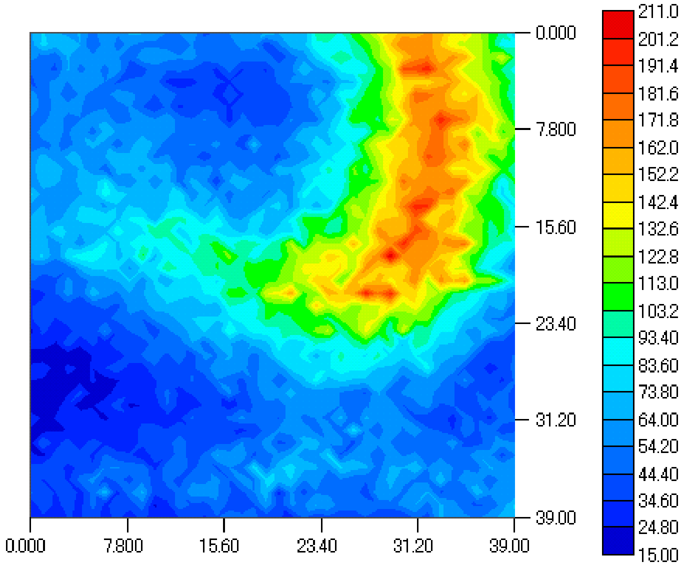


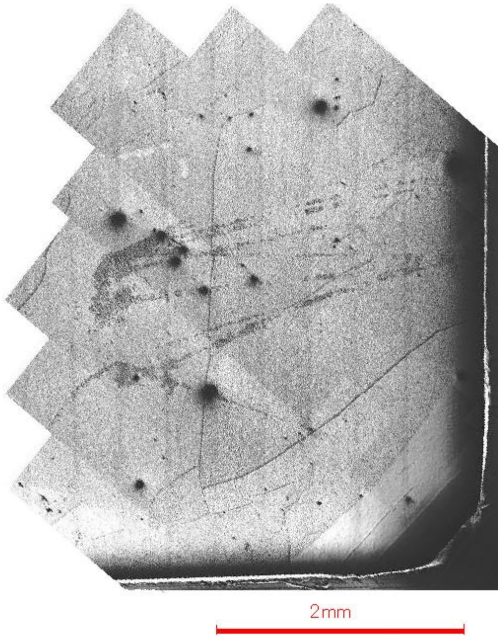



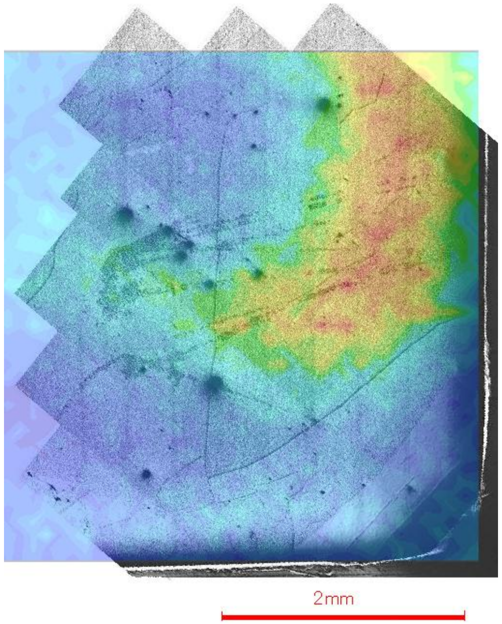




$^{57}Fe$ enriched FeNi alloy

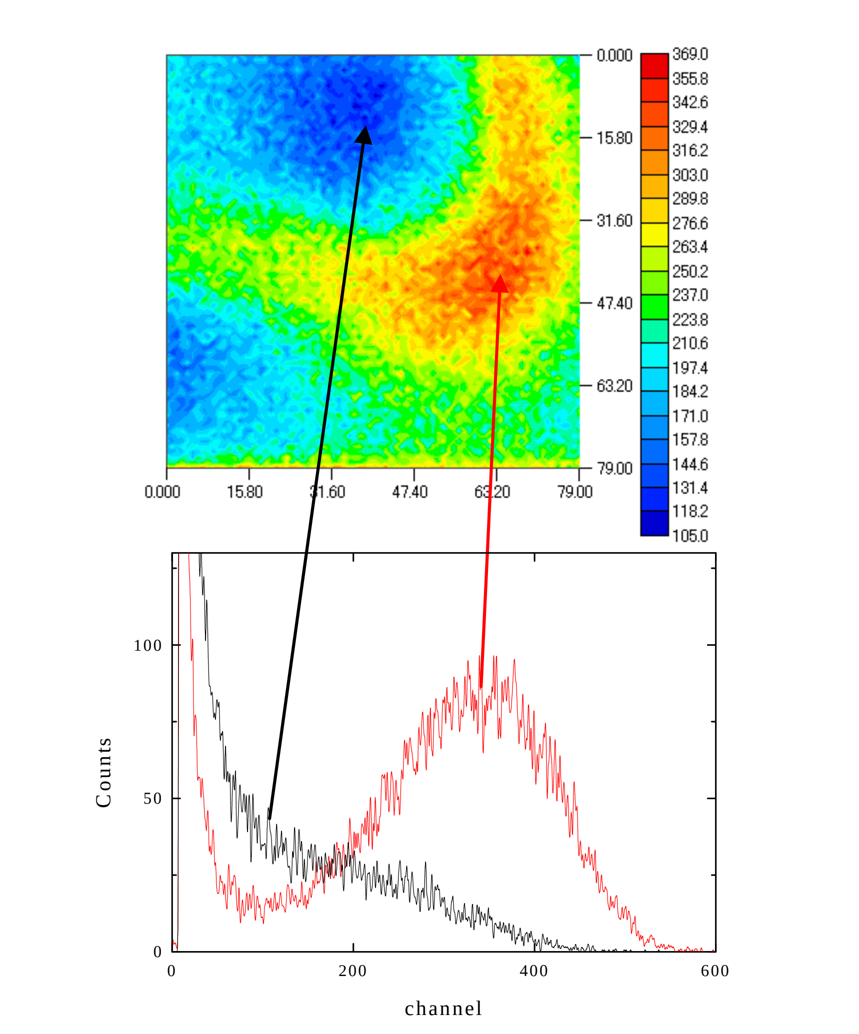
# A mapping image of electrons and FE-SEM picture



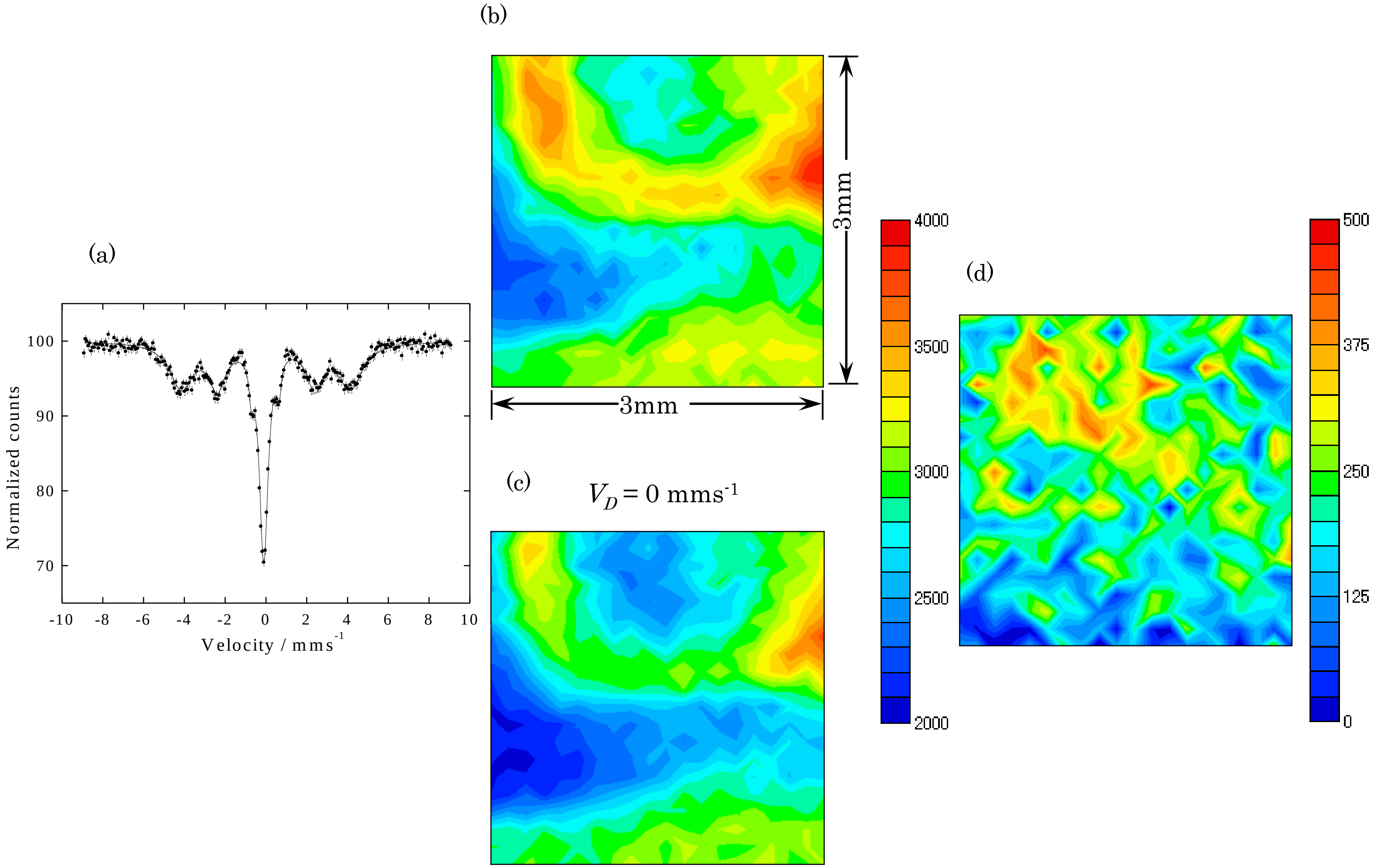



# PHA spectrum of MCP corresponding to the measuring points

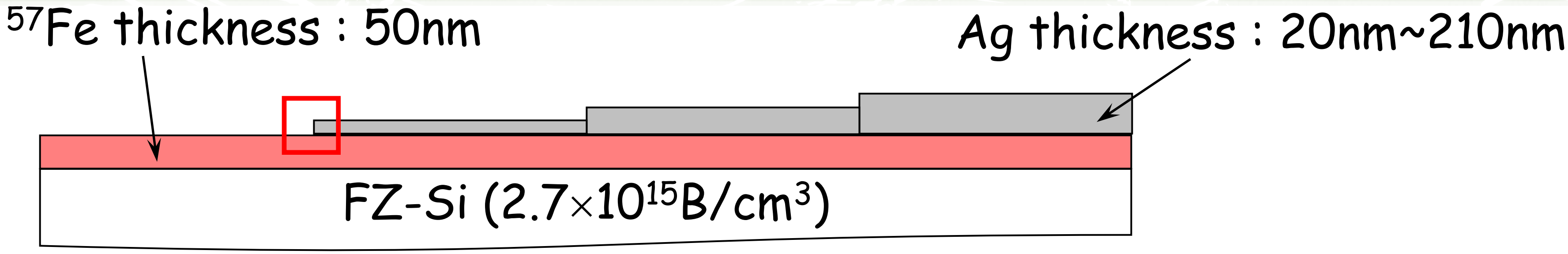


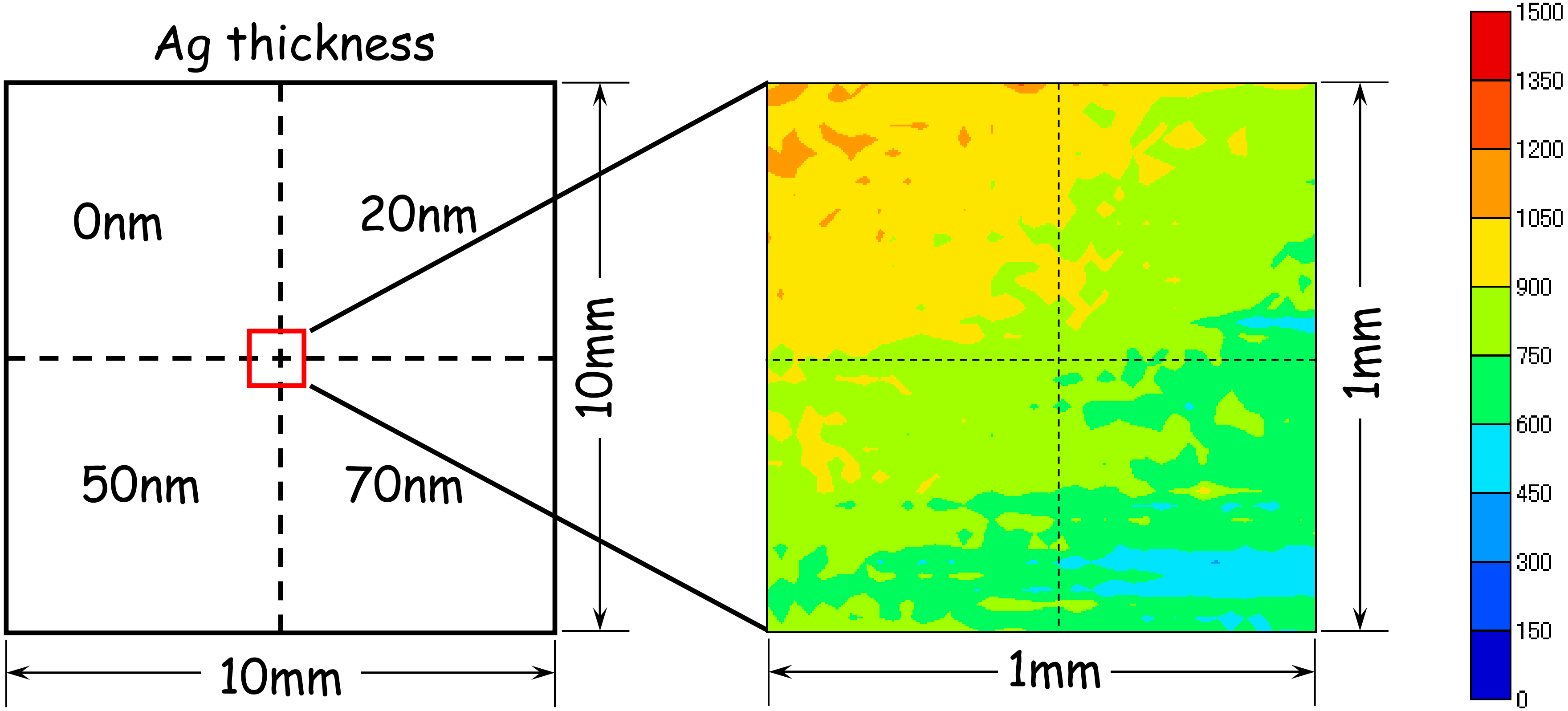
# Mapping picture of SUS304



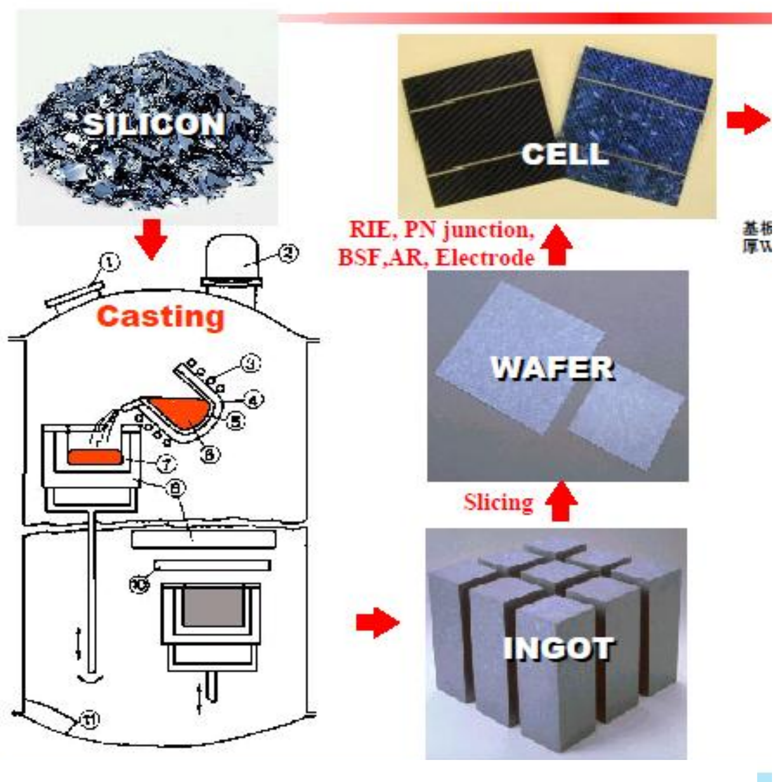
# Observed image of $^{57}Fe$ + Ag deposited FZ-Si

**3D mapping may be possible !**

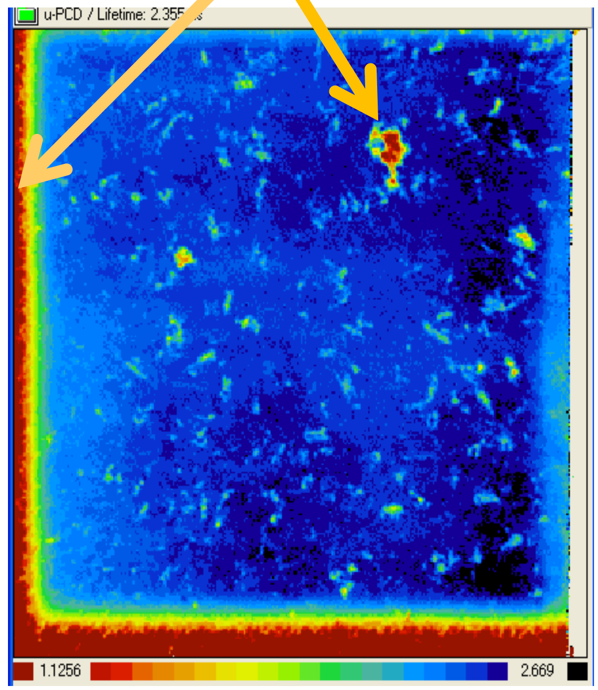


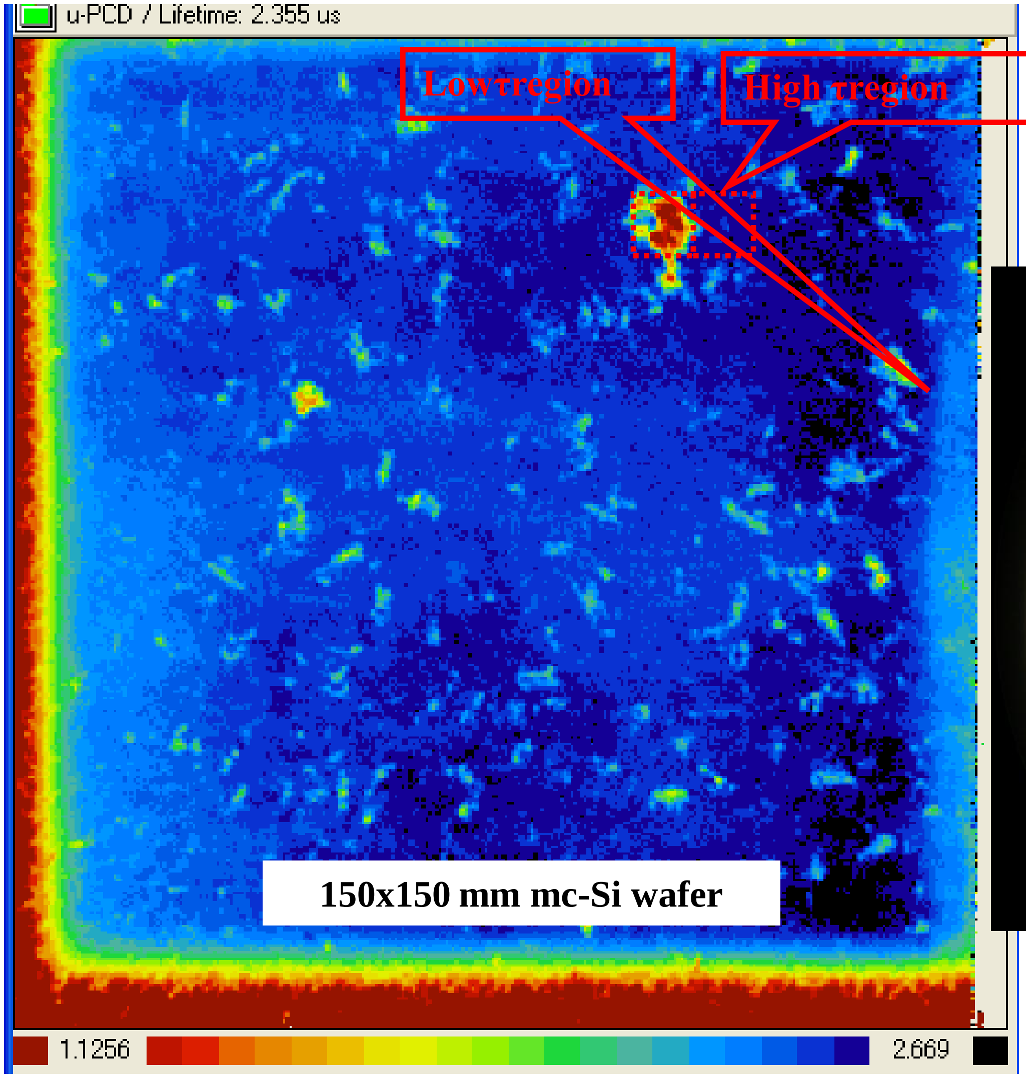
# Application for Fe contamination in mc-Si solar cell

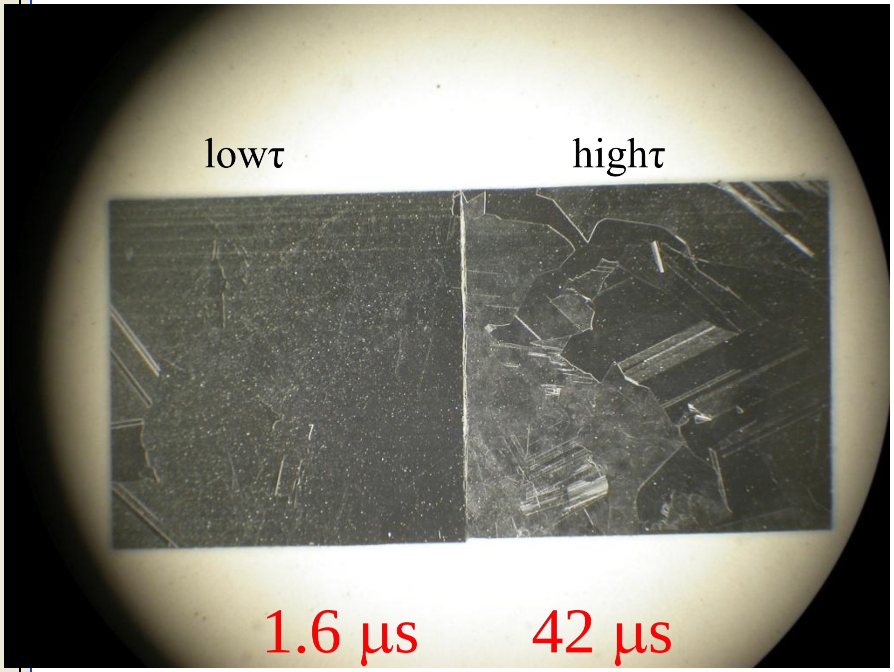



Low efficiency due to defects

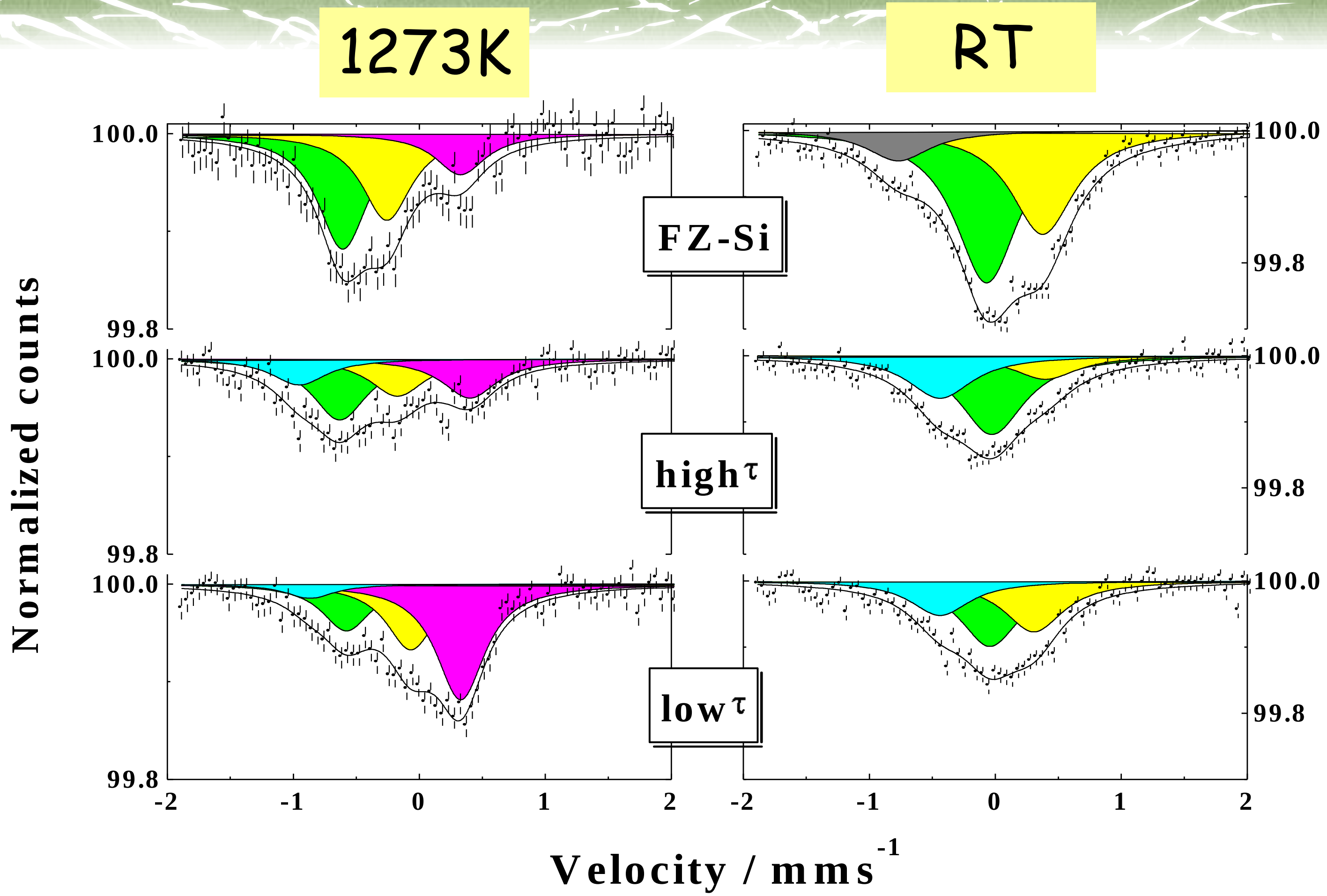


# Mc-Si wafer contains a region with low minority carrier life time



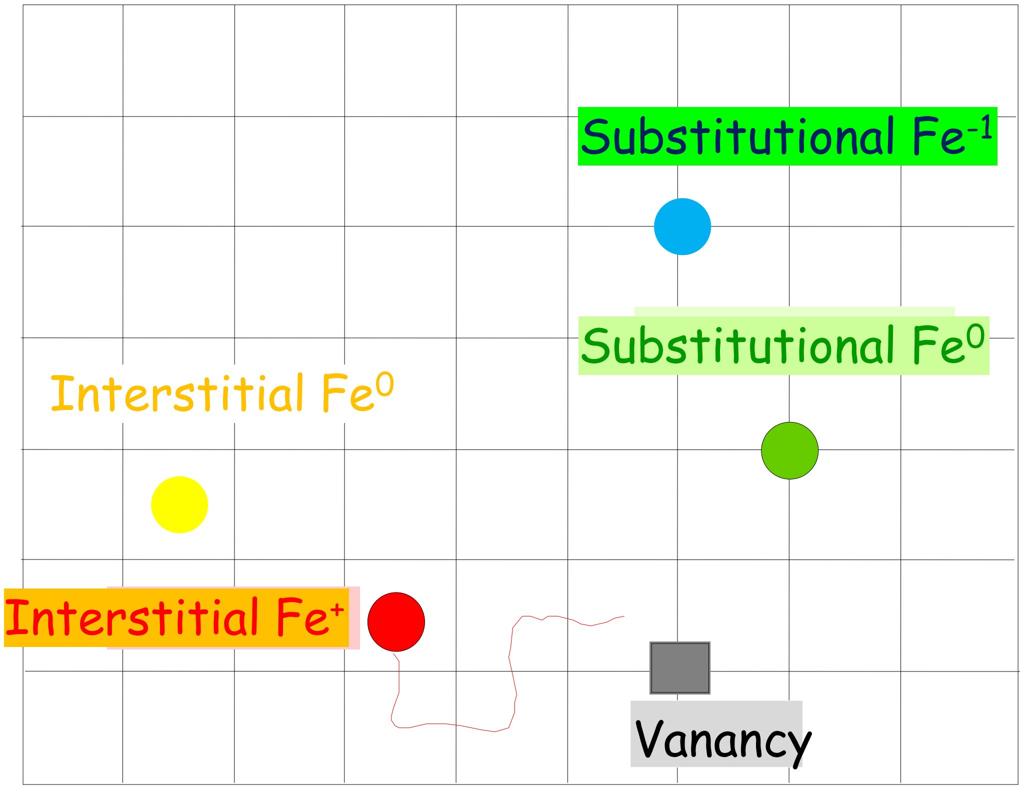
# Mössbauer spectra of $^{57}$Fe doped FZ-Si, mc-Si



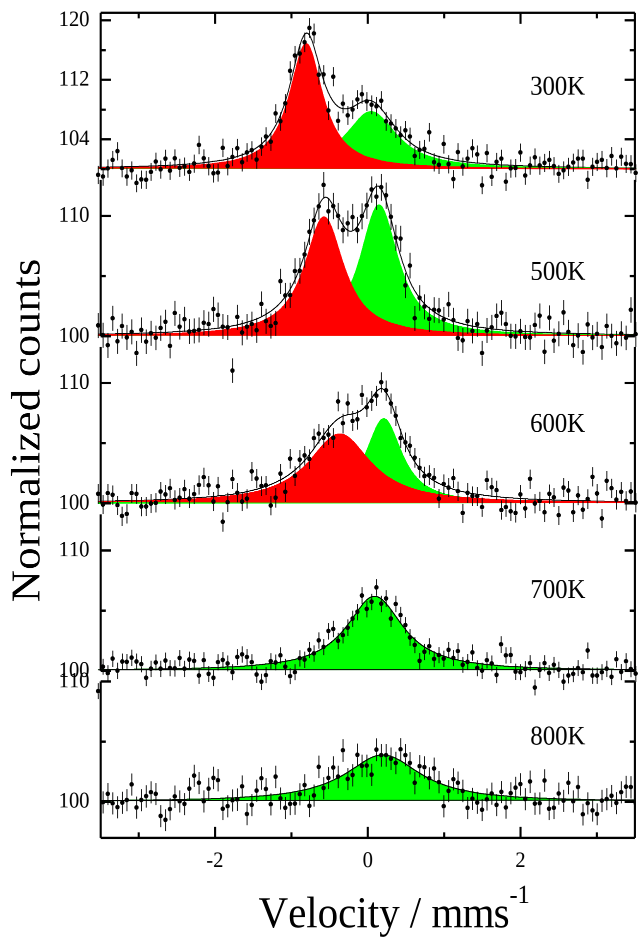

Y. Yoshida, S. Horie, K. Niira, K. Fukui and K. Shirasawa, *Physica B*, 376-377 (2006) 227.

# Atomistic information on $^{57}Fe$ through Hyperfine interactions between $^{57}Fe$ nucleus and electrons

Fe impurities in mc-Si solar cells



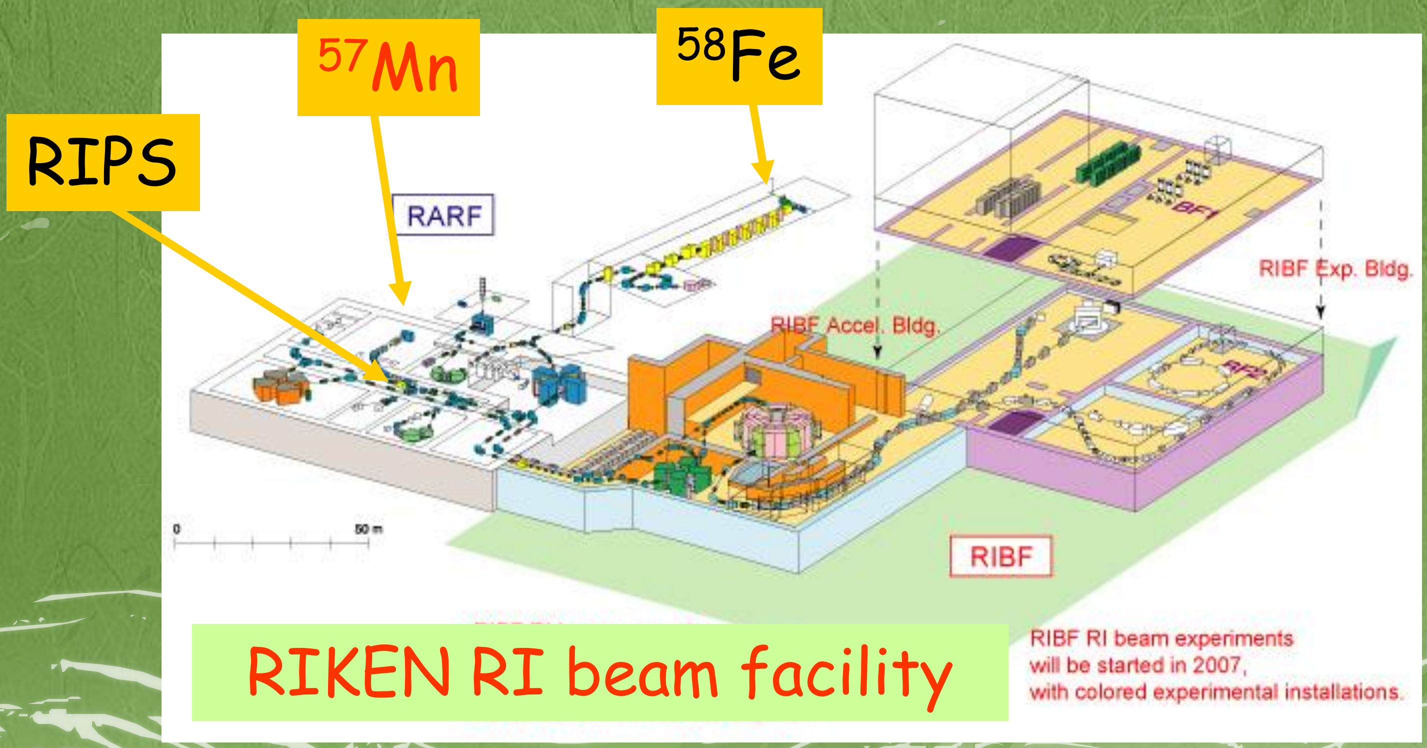

$^{57}Mn/^{57}Fe$ in Si



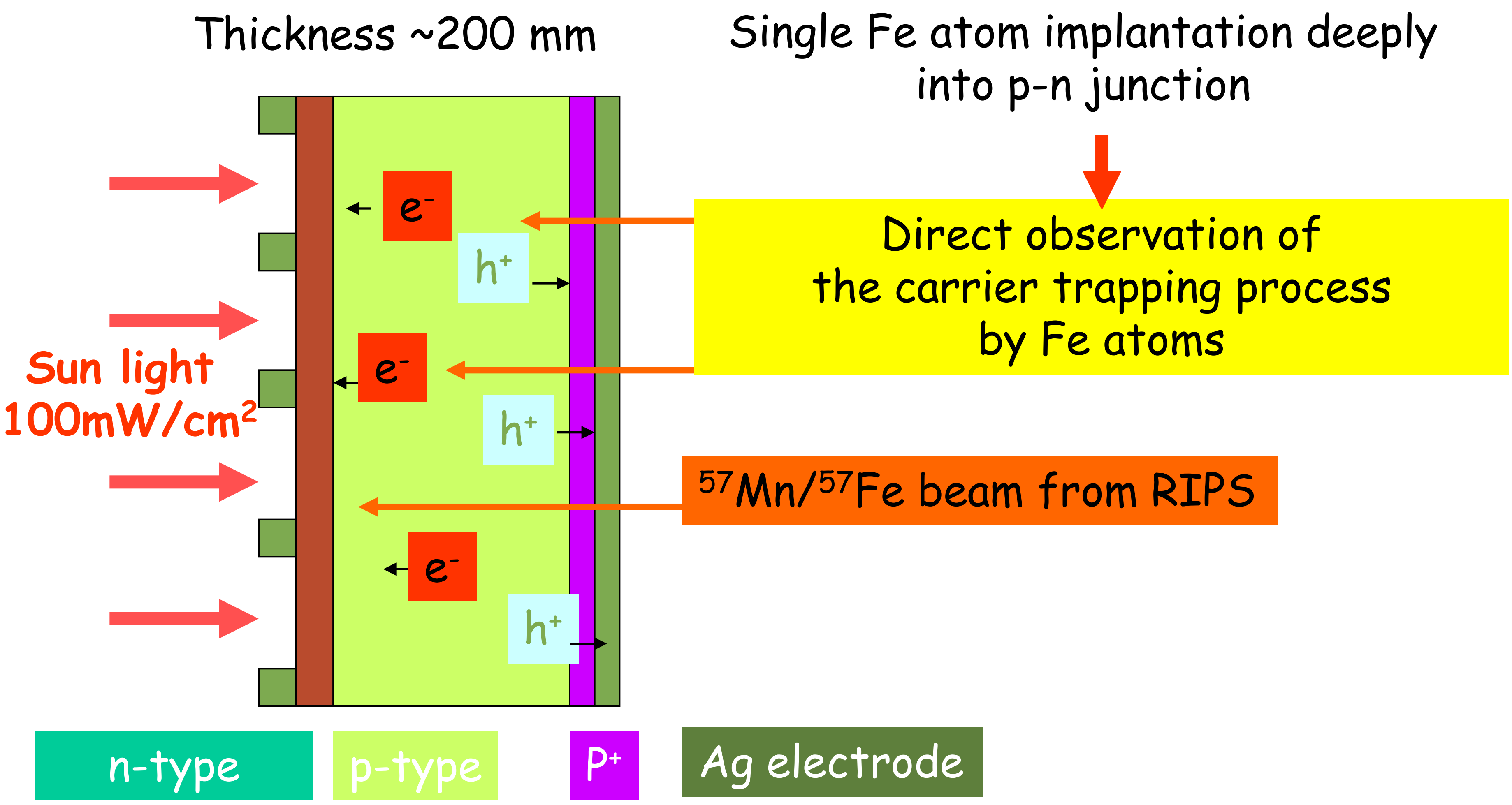
# FINAL LATTICE SITES AND CHARGE STATES OF $^{57}Mn$ / $^{57}Fe$ GeV- IMPLANTATION INTO Si

Y. Yoshida[1], Y. Kobayashi[2], K. Yukihira[1], K. Hayakawa[1], K. Suzuki[1], A. Yoshida[2], H. Ueno[2] A. Yoshimi[2], K. Shimada[2], D. Nagae[2], K. Asahi[3] and G. Langouche[4].

[1] Shizuoka Institute of Science and Technology, Shizuoka, Japan ,[2] RIKEN,Japan, [3] Tokyo Institute of Technology, Japan, [4] Katholieke Universiteit Leuven, Belgium

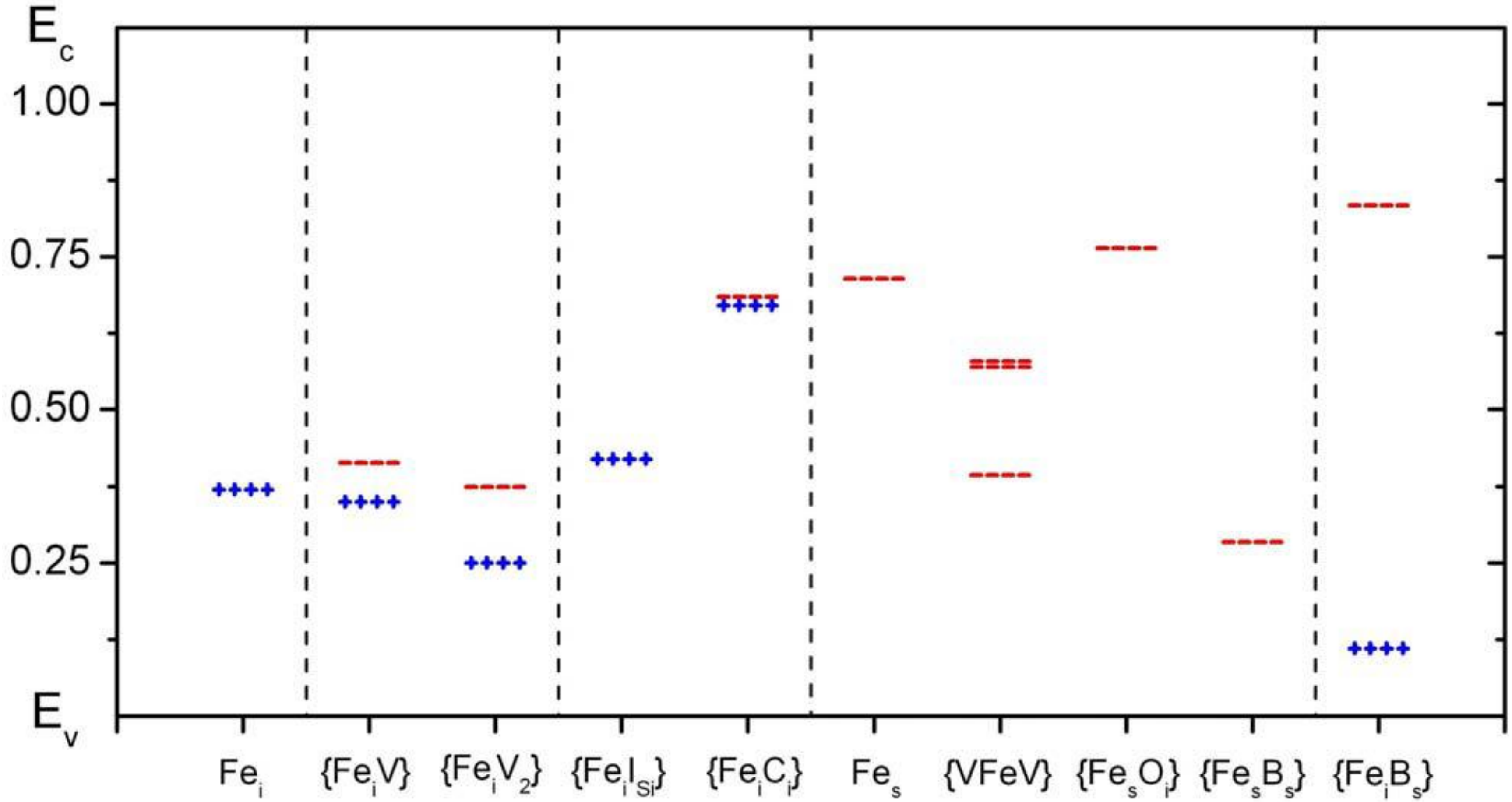


# Direct Observation of Fe states in the p-n junction of solar cells during operation under light illumination

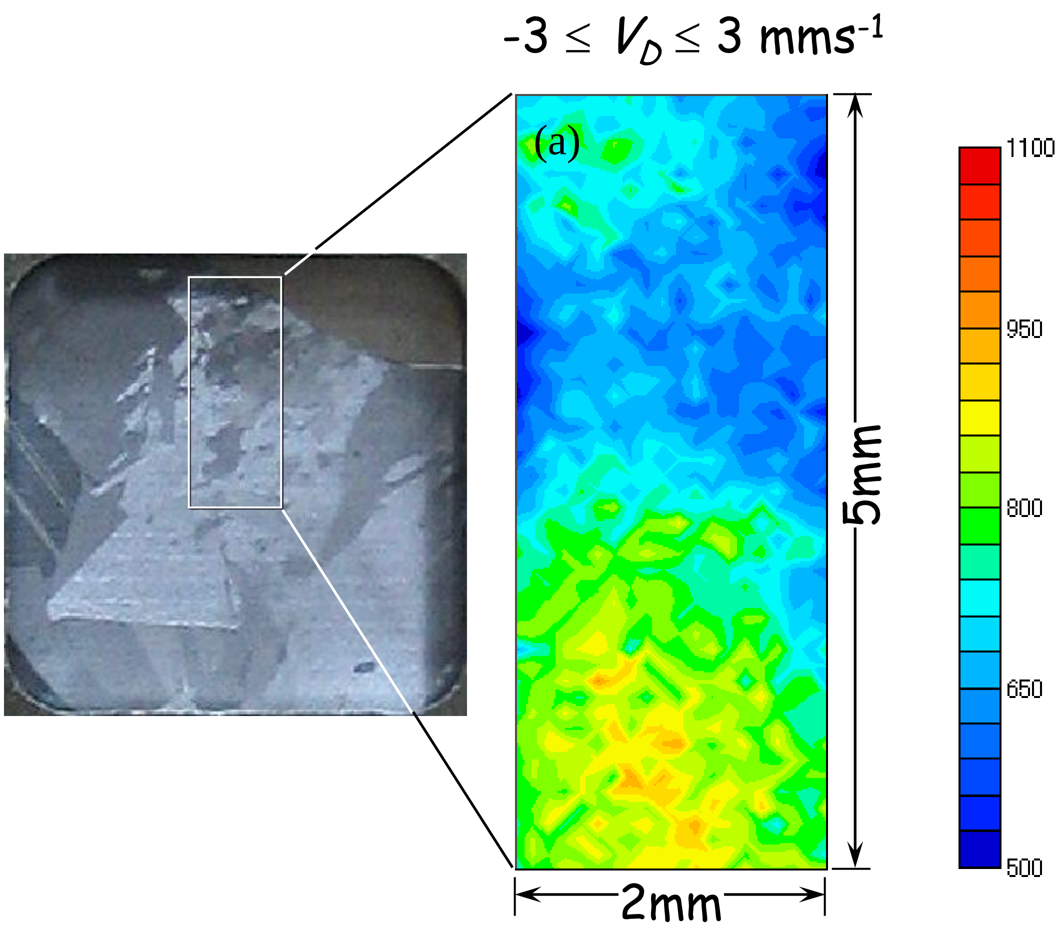


# Iron in silicon: Interactions with radiation defects, carbon, and oxygen

S. K. Estreicher,* M. Sanati, and N. Gonzalez Szwacki
PHYSICAL REVIEW B 77, 125214 2008

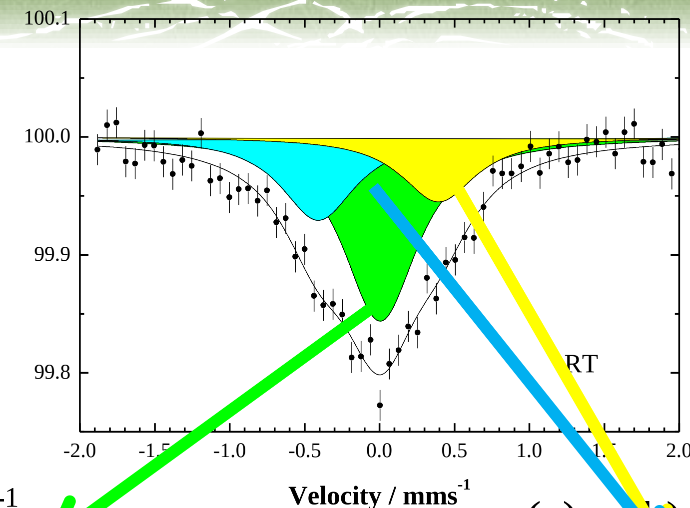


# Observed images of 1.5 nm-$^{57}$Fe deposited mc-Si (intentionally contaminated with $^{57}$Fe)



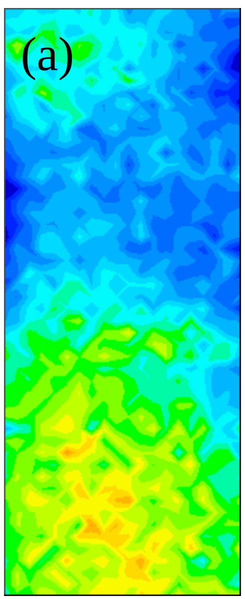

Clearly shown is that $^{57}$Fe distribute differently in different crystal grains

# Different resonance conditions provide different images

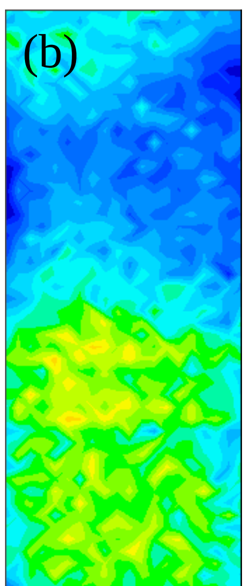



All $^{57}$Fe components

$-3 \leq V_D \leq 3$ mms$^{-1}$

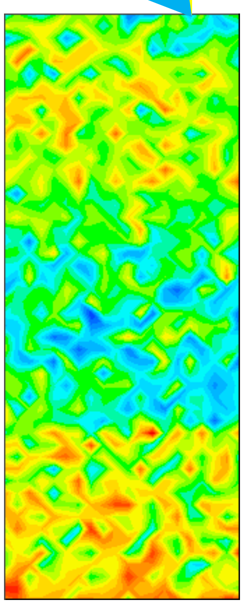



$V_D = 0$ mms$^{-1}$



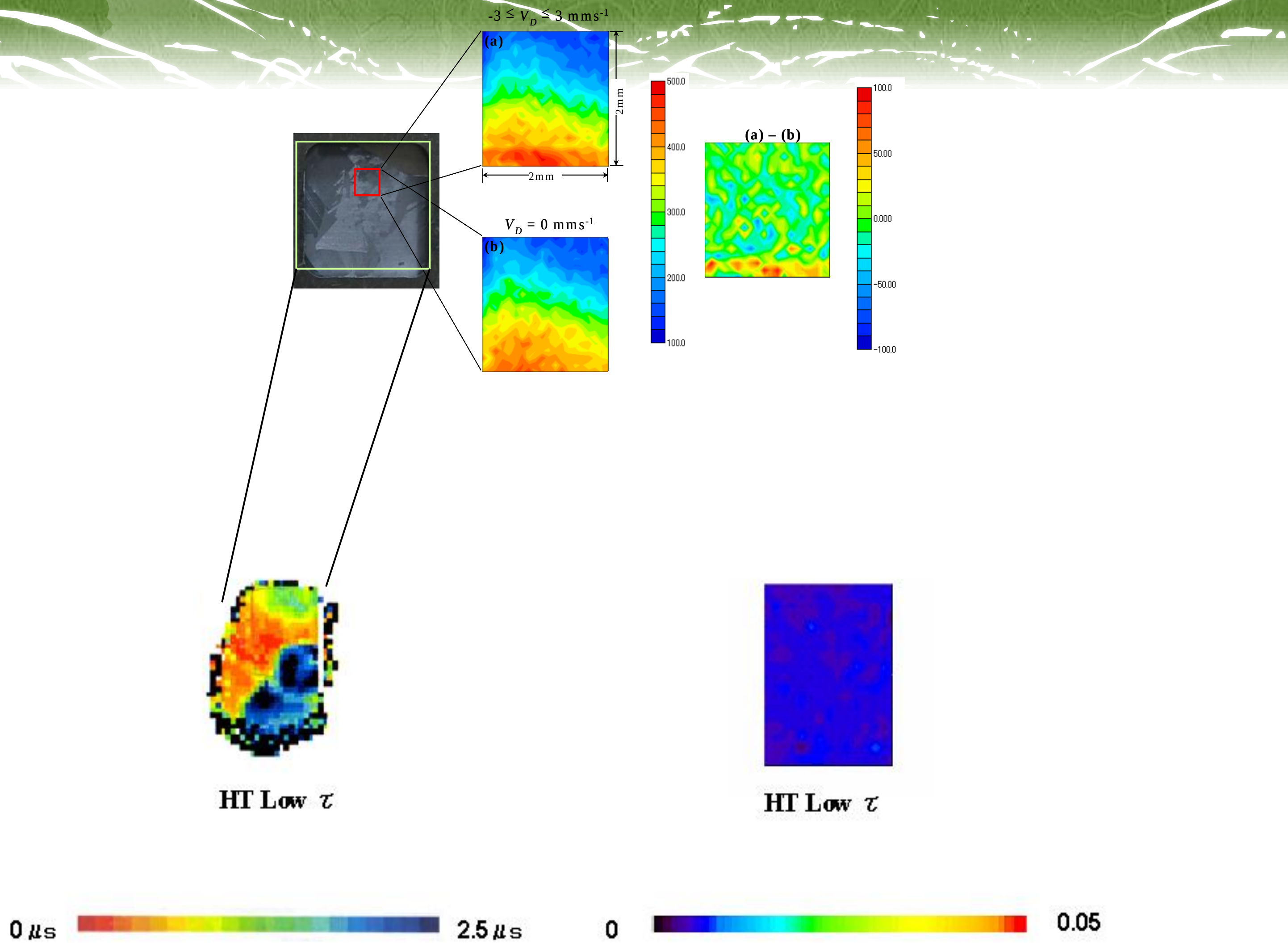

The image mainly corresponding to substitutional $^{57}$Fe component

(a) – (b)



The image mainly corresponding to interstitials and other clusters

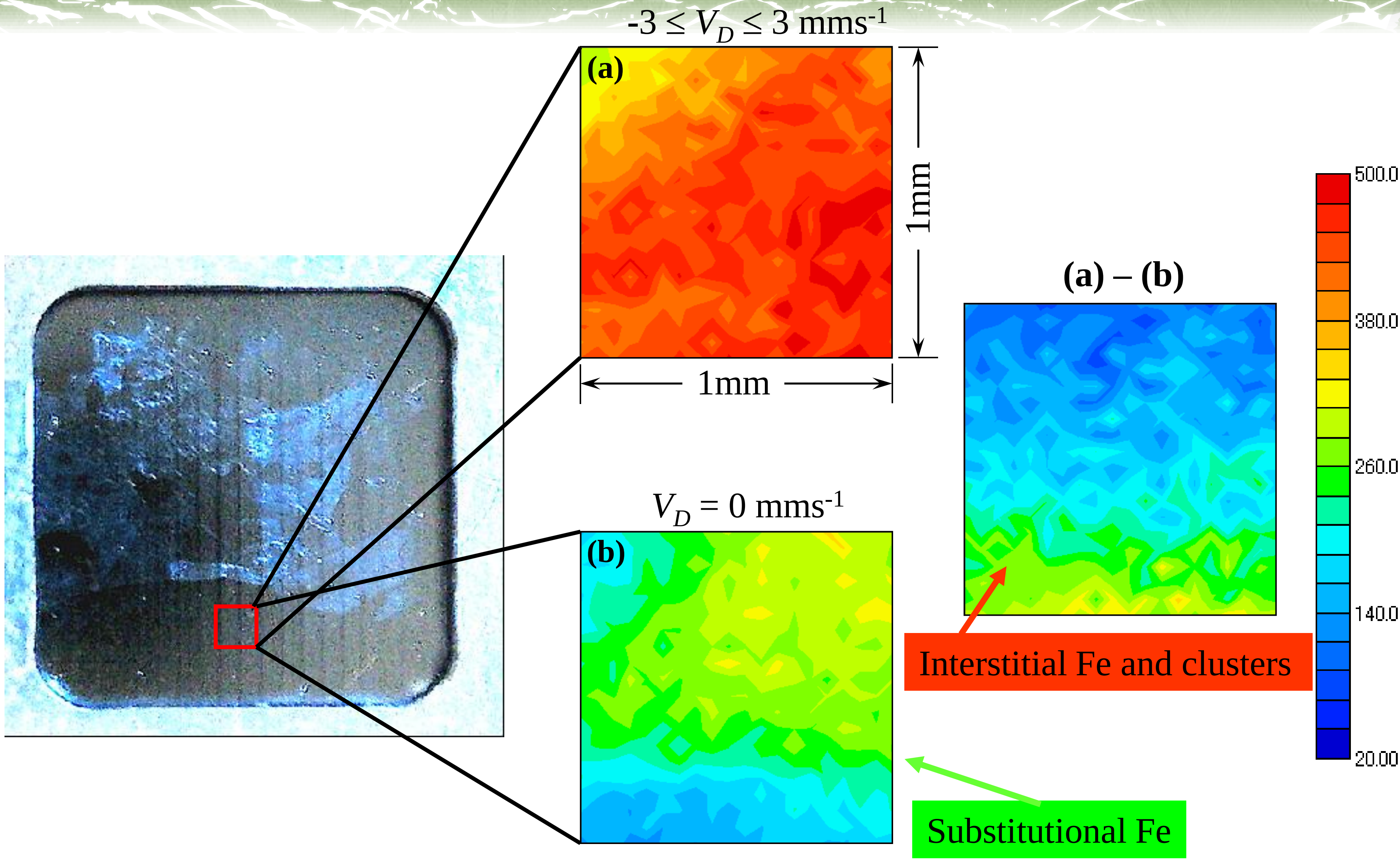
# Comparison with the results from minority carrier life-time & FTIR



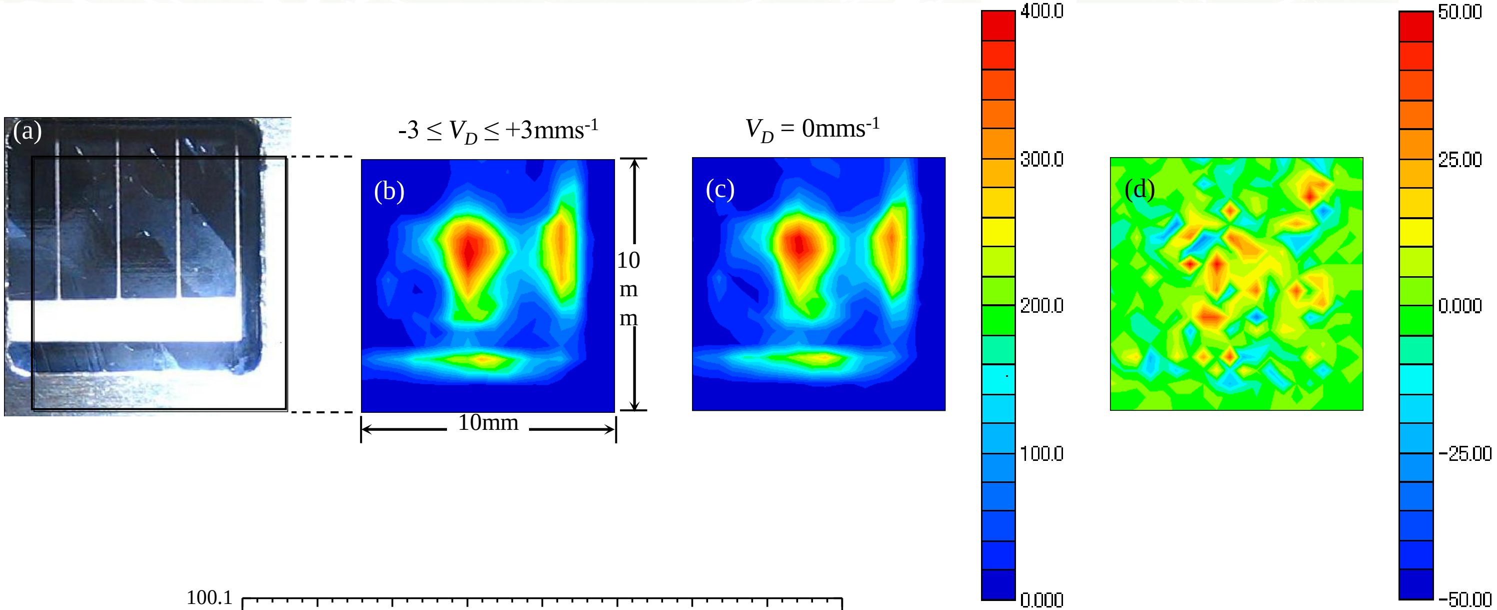

Life time

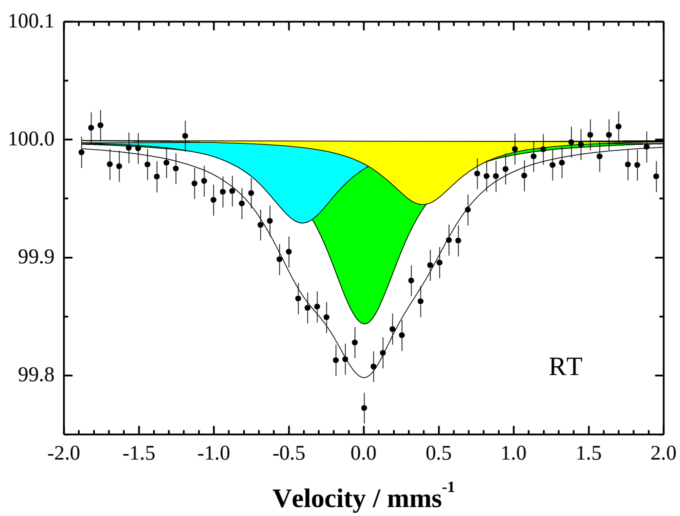
FTIR mapping for isolated $O_{int}$

# Observed images of mc-Si as received without intentional $^{57}$Fe contamination



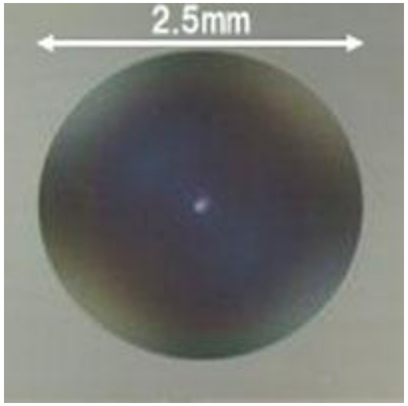
# pn-junction Si as received

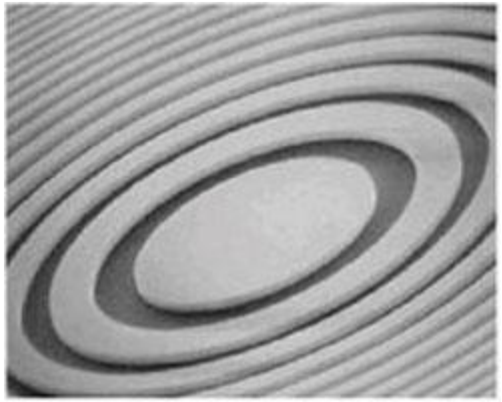


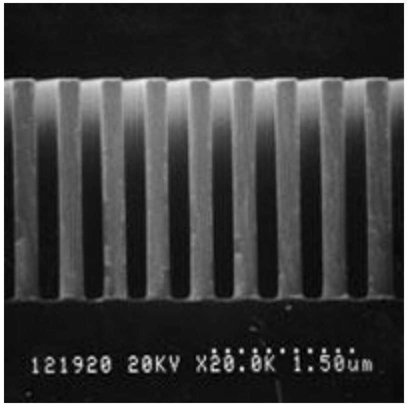



# A running project to achieve submicron spot size

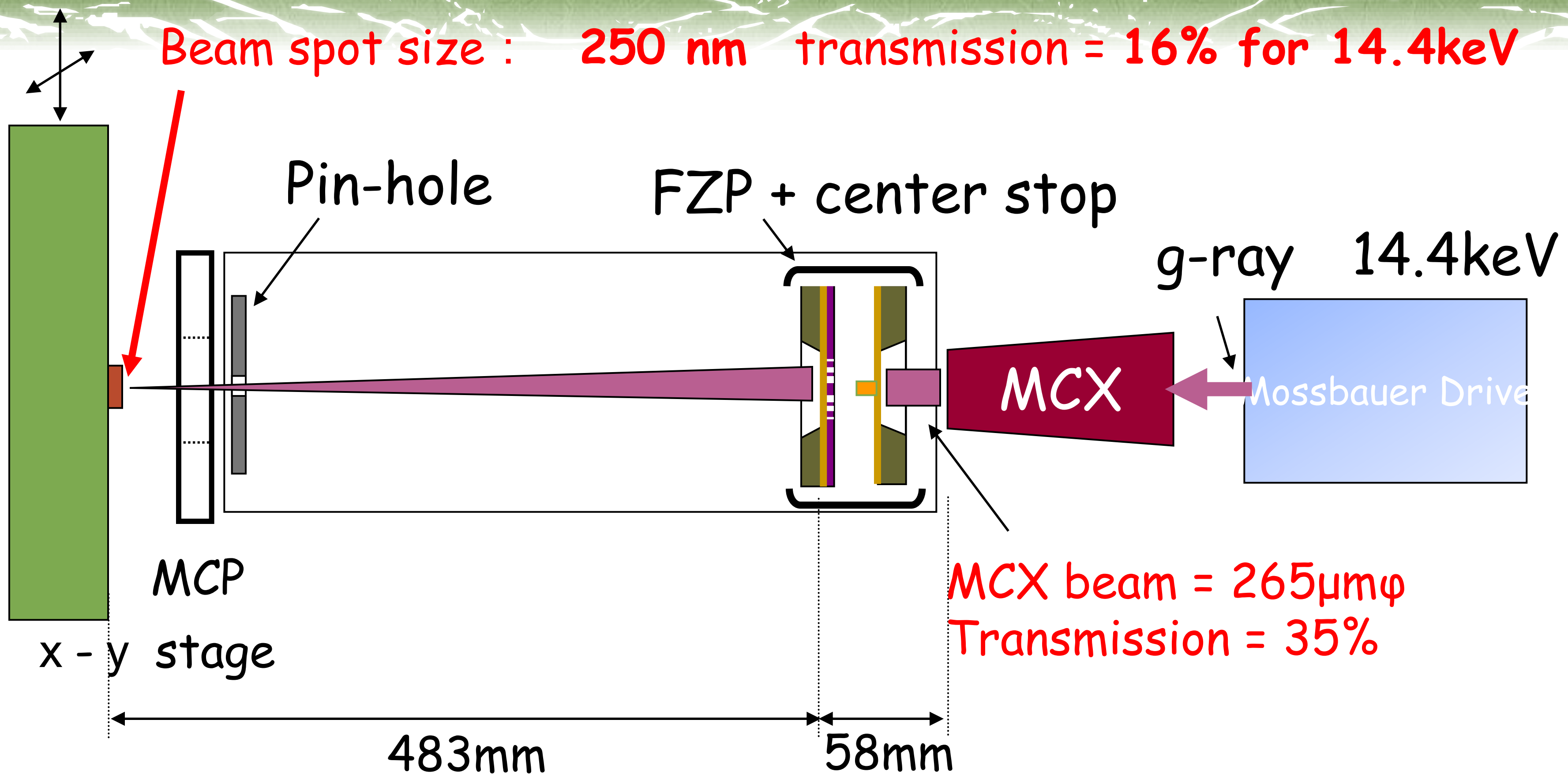
Fresnel Zone Plate： φ250μm,Ta thickness=2.5μm, width of most outer zone= 250nm, membren： SiN 2.0μm



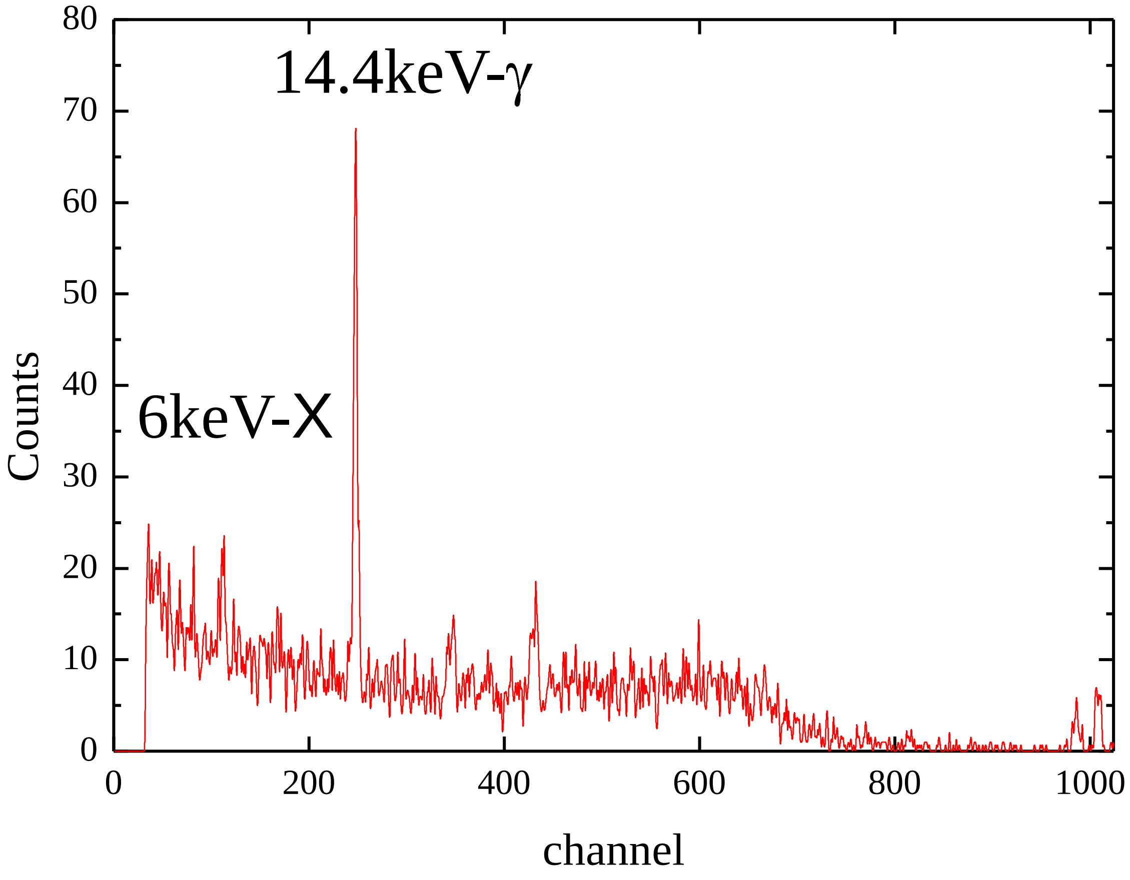



# Fresnel Zone Plate combined with MCX

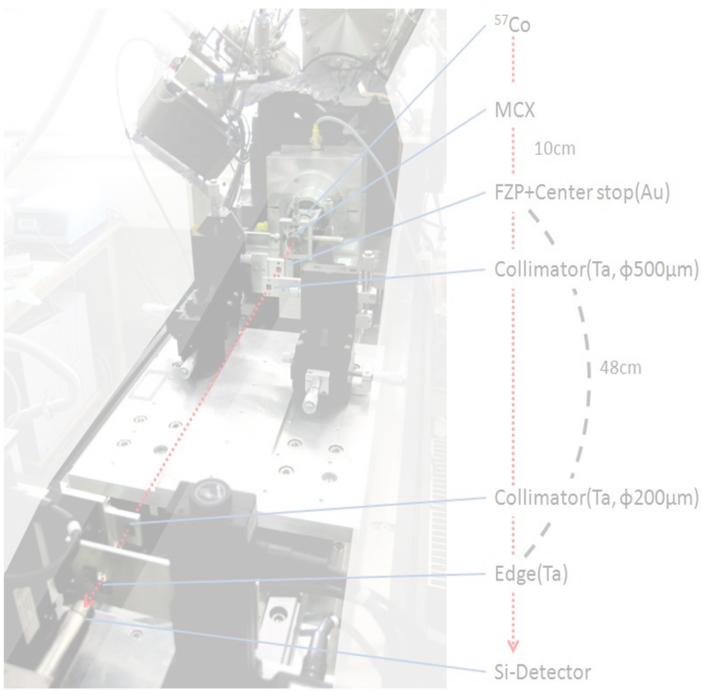


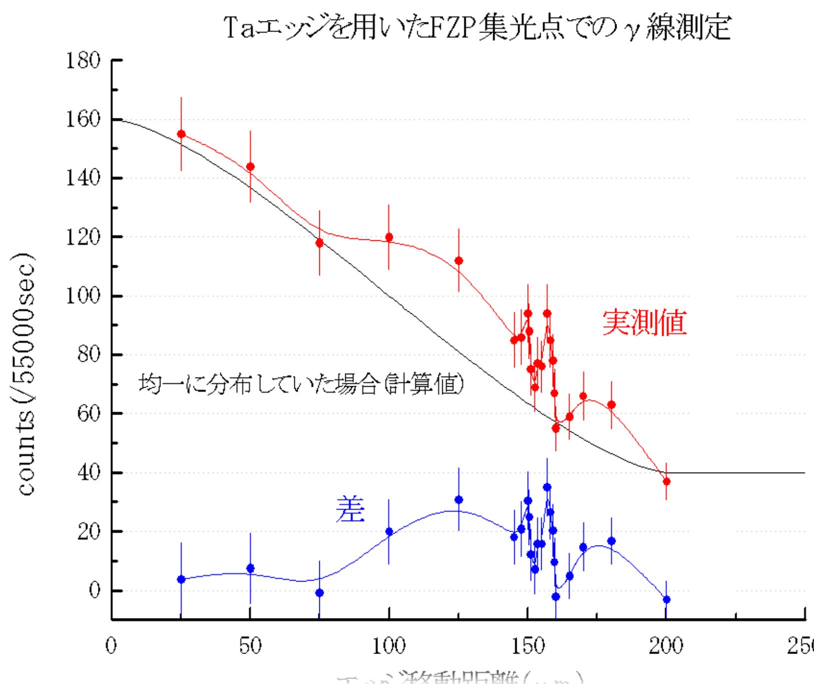

FZP ( ATN/FZP-200/206 ) focal distance = 483mm

# PHA spectrum of MCX+FZP at focal point

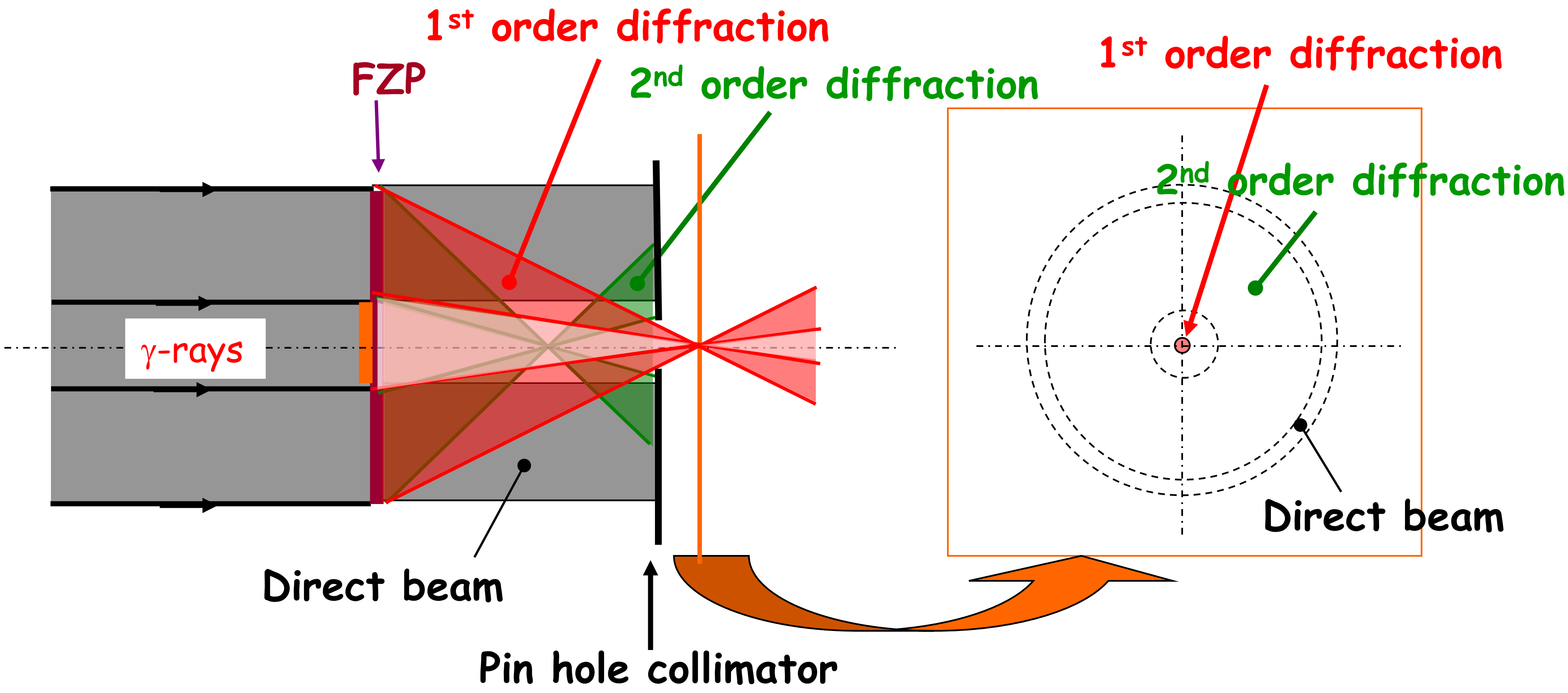


# The spot size reaches down to 3 μm.



# Beam focus by FZP and other elements



# Summary: "Mössbauer Camera"

1. **Imaging** by PIAS+FOS
   » Monochrometer for 14.4keV $\gamma$-rays

2. **Mapping** by MCX: spatial resolution of 50 $\mu$m
   » distortion of image

3. Applications for Fe impurity in Si-solar cells
   » mapping under light illumination

4. **Mapping** by MCX + FZP: spatial resolution of 3 $\mu$m
   » vibration of the set-up

# ICAME2011 in Tokyo

## supported by YAMADA Science foundation

## to create the next generation of ICAME