



System Integration of Superconducting Tunnel Junction Detectors for Measurement of Unrevealed Material Information

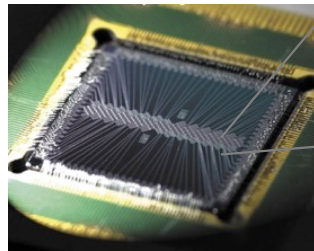


M. Ohkubo, M. Ukibe, S. Shiki, N. Zen, and G. Fujii

AIST, Japan



M. Ukibe, Exhibition



200 μm square

STJ

Nb/Al

G. Fujii, We-C-DET-05



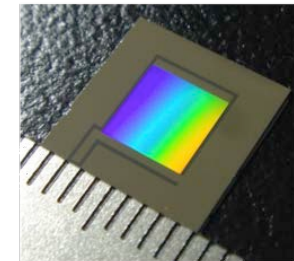
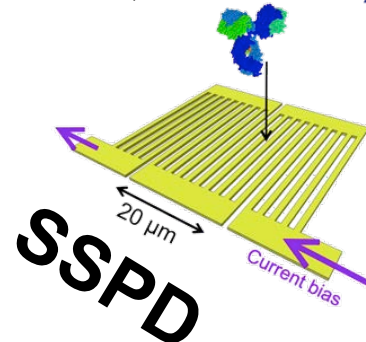
H. Shibata, Kitami



A. Casaburi
R. Cristiano
CNR, Italy

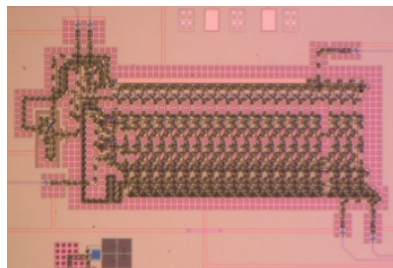


Z. Wang *et al.*
NICT, Japan



Nb, NbN, MgB₂

A. Casaburi, Fr-C-DET-01



N. Yoshikawa *et al.*, Japan

SFQ-TDC Time-to-digital converter
for ion detection in mass spectrometry





System integration

1995



Single pixel



Preamp.

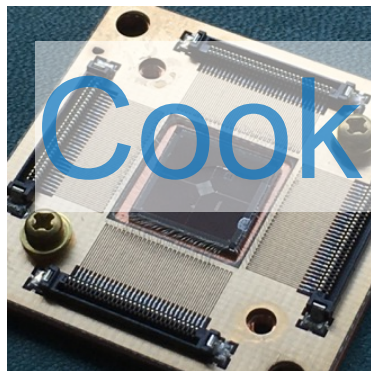


Shaping amp.



MCA

2015



100 ch. → 512 → 1024



wiring



Preamp.



Shaping amp. + MCA
FPGA-based DSP

Liquid N and He

Cooking with electricity





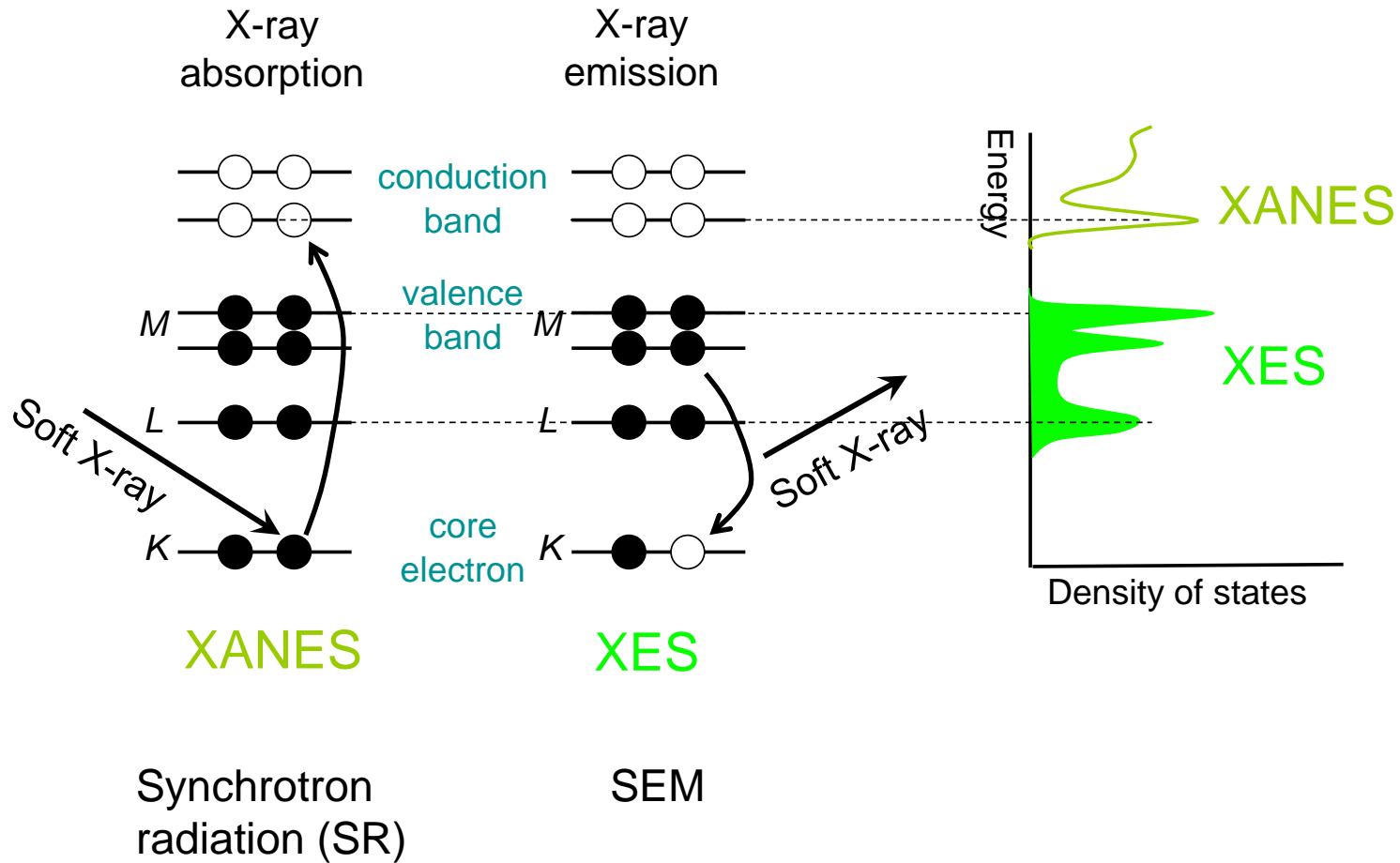
Superconducting detectors

	Two spectroscopic domains		
Type	Energy	Time (decay)	Temp.
Calorimeter TES, MMC...	Extremely high (1.2 eV@ 6 keV)	Slow (ms)	< 0.1 K
STJ	High (4.1 eV@ 392 V)	Fast (μ s)	0.3 K
SSPD (nano-strip)	N/A	Extremely fast (1 ns)	> 4.2 K

Third demand for superconductivity has emerged: high spatial resolution SSPD for synchrotron radiation facilities.

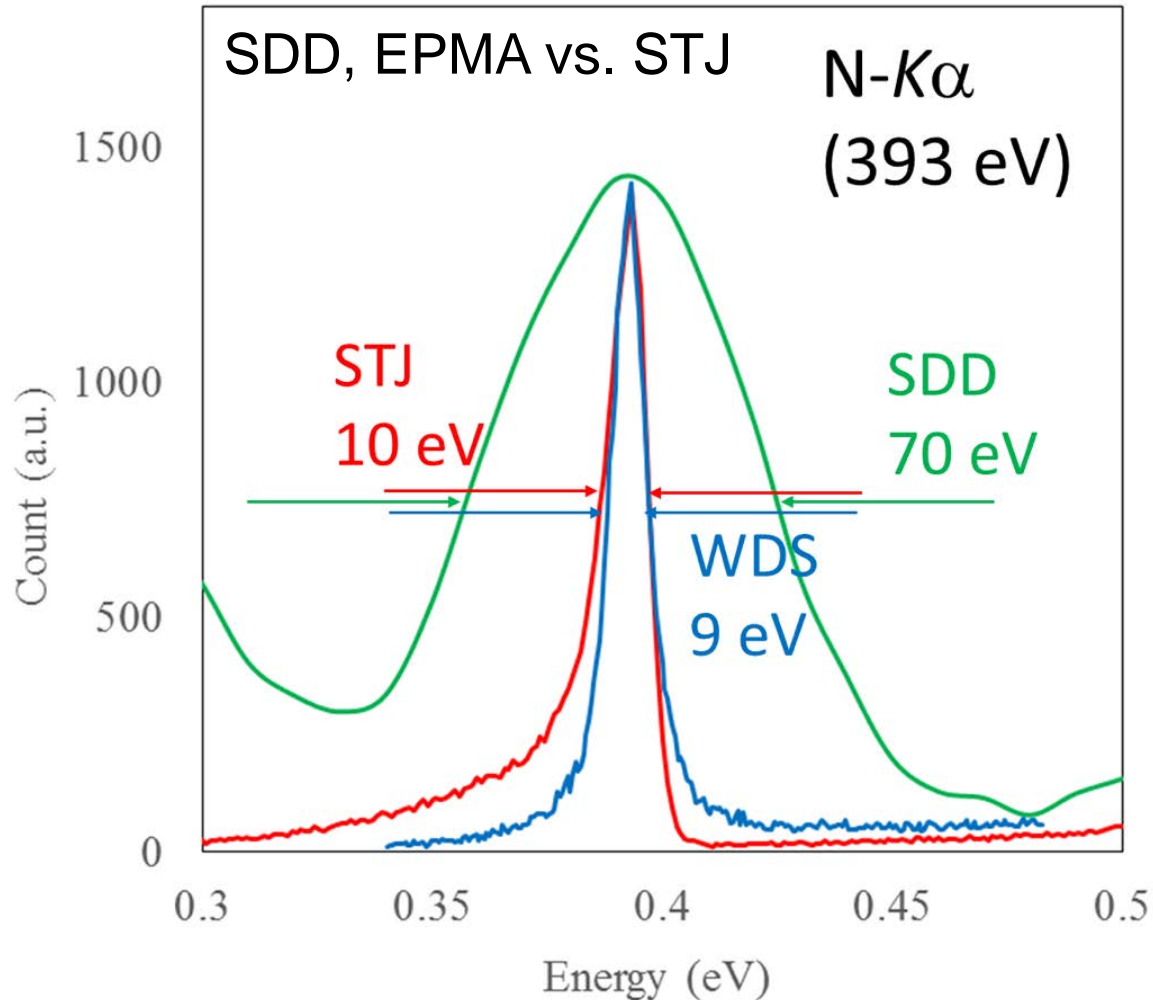


X-ray Absorption Near Edge Structure (XANES) and X-ray Emission Spectroscopy (XES)





High energy resolution is required for element selection and line shape

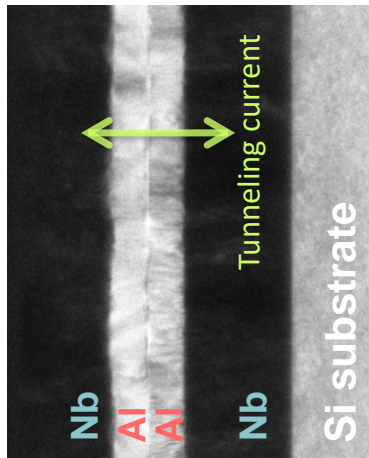
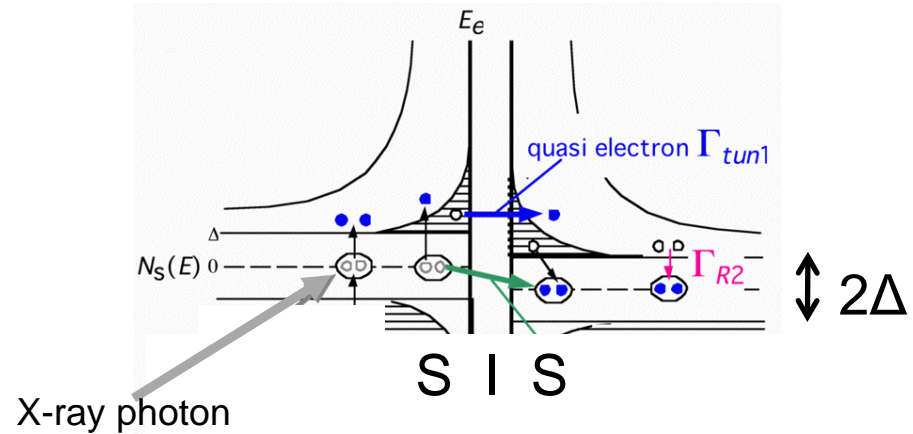




STJ detector



100-200 μm



$\epsilon = 1.7\Delta = 2.6 \text{ meV}$ ($\sim 1 \text{ eV}$ in Si)
 Debye energy (Σ_D) = 24 meV (Nb)
 The ϵ value, which is a threshold energy to create quasiparticles, is 1.7Δ , M. Kurakado, NIM (1969).

$$\frac{\Delta E}{E} \propto \frac{\sigma_N}{\langle N \rangle},$$

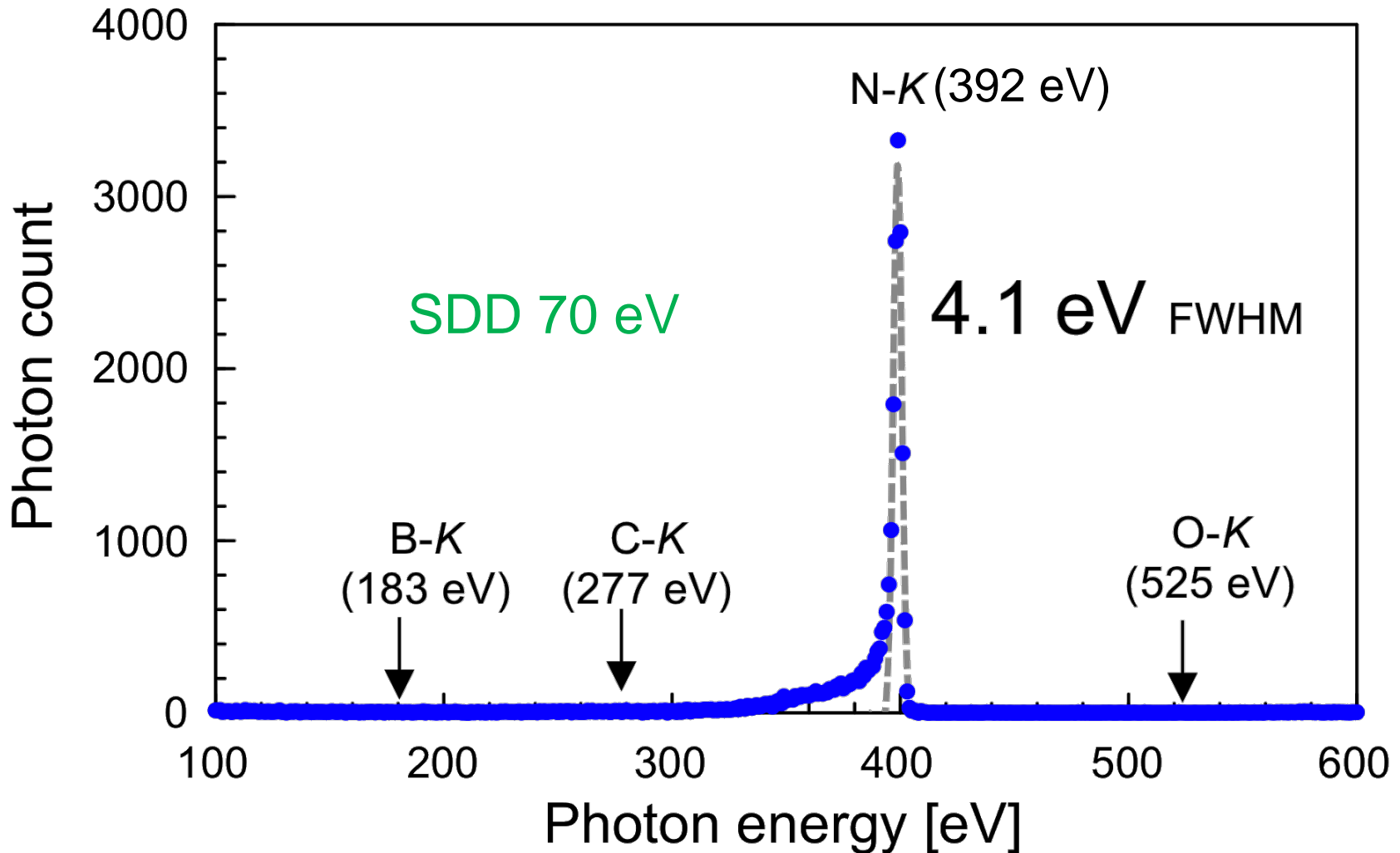
$$\Delta E_{\text{FWHM}} = 2.355\sqrt{F\epsilon E} = \sim 2\text{eV}@6 \text{ keV}$$

$$0.5 \text{ eV}@400 \text{ eV (N-K line)}$$

Photon counting rate = > 1000 cps/pixel



Real energy resolution @ synchrotron radiation

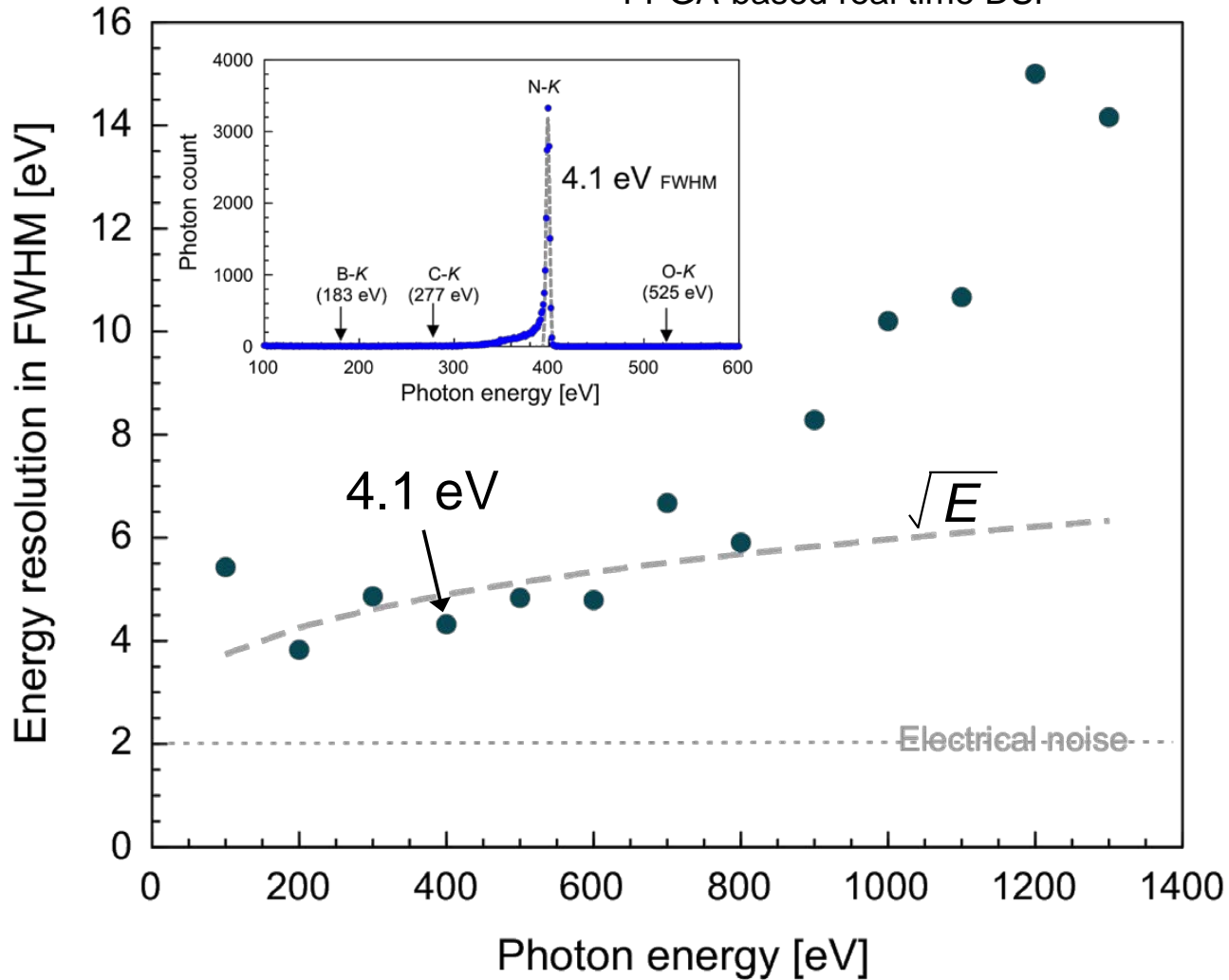




Energy resolution vs. photon energy of the best pixel

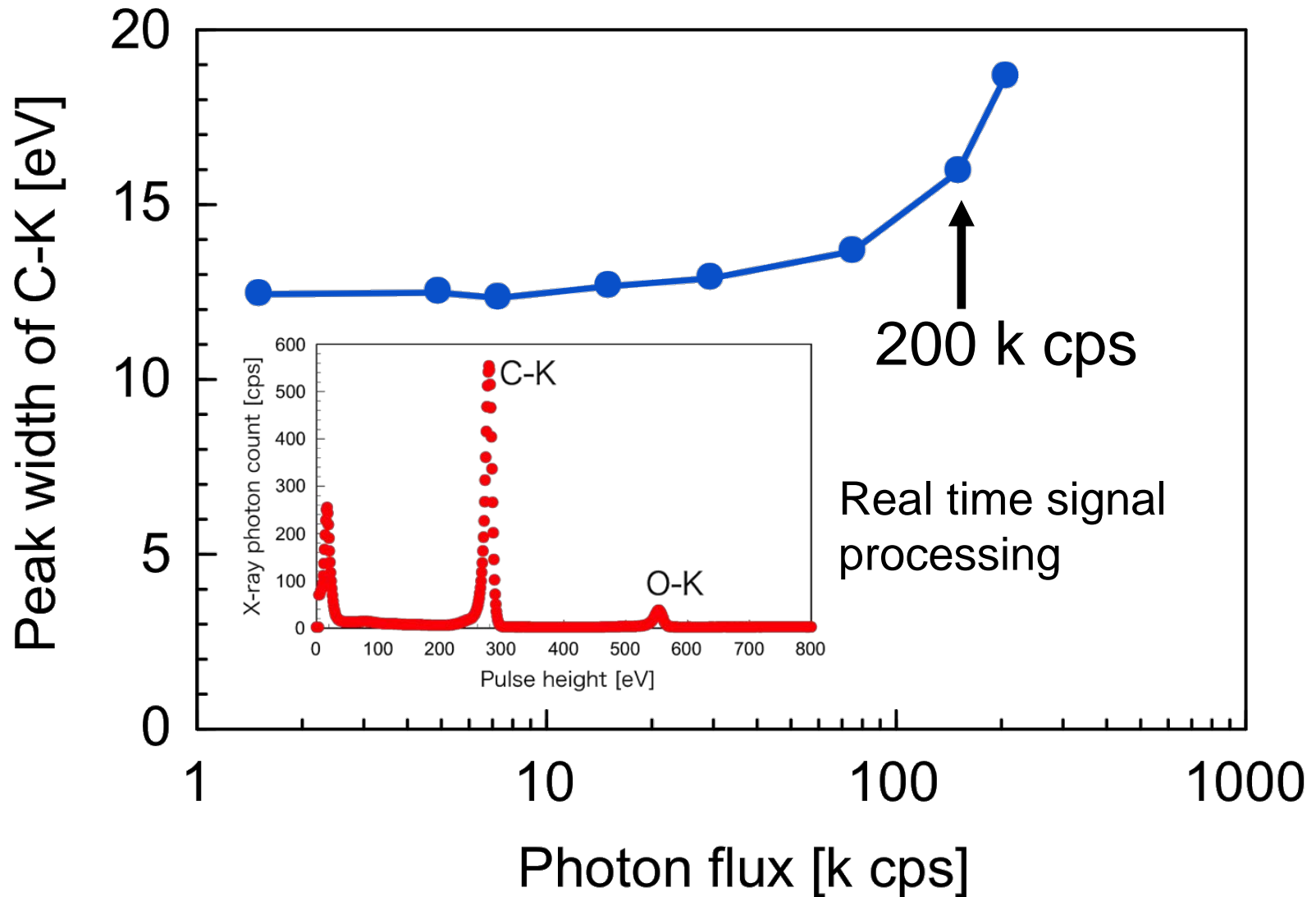


Synchrotron radiation @ 400 eV
FPGA-based real time DSP



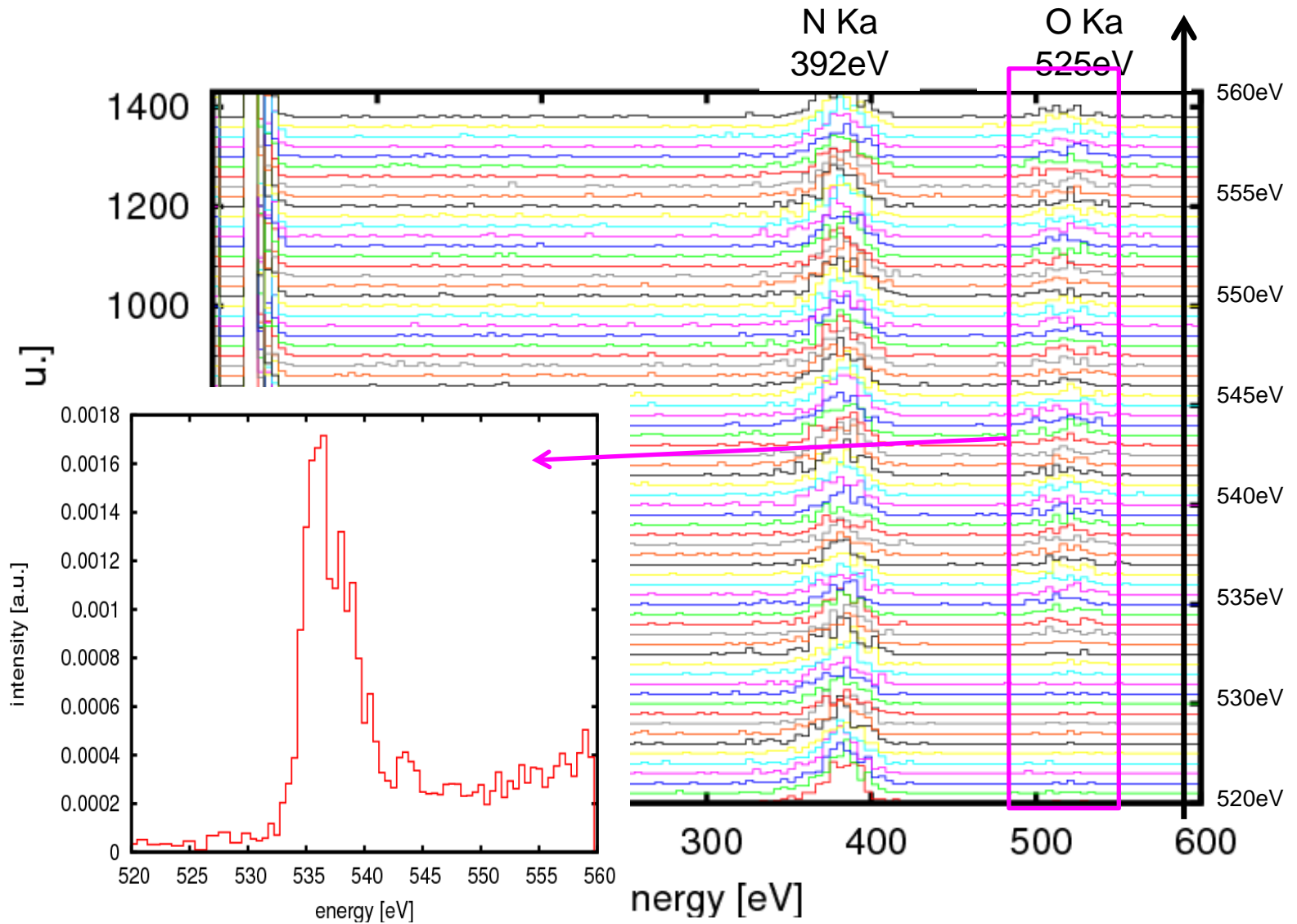


High count rate of the 100-ch STJ system



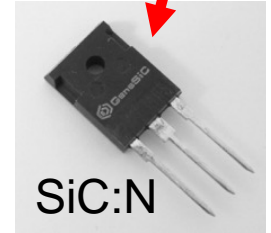
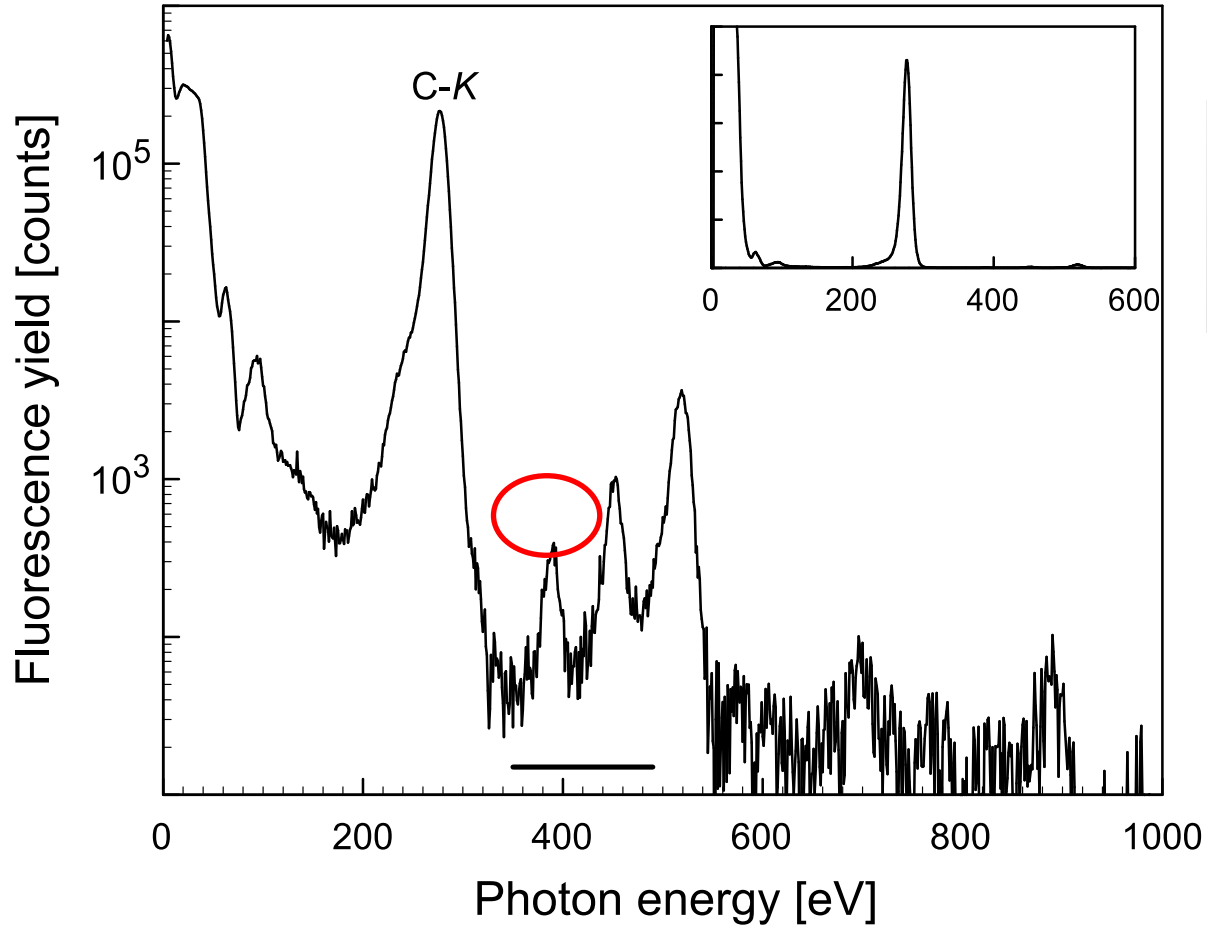


Fluorescence Yield-XAFS





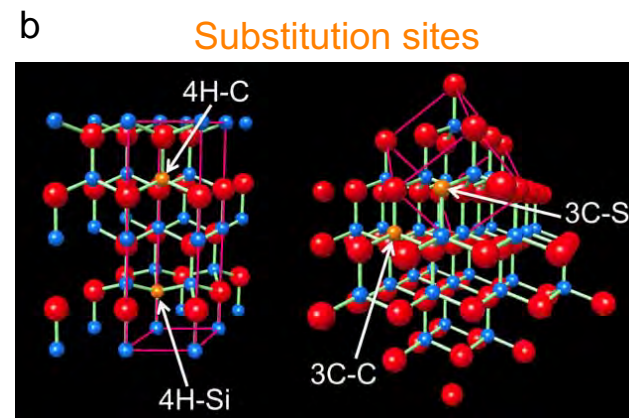
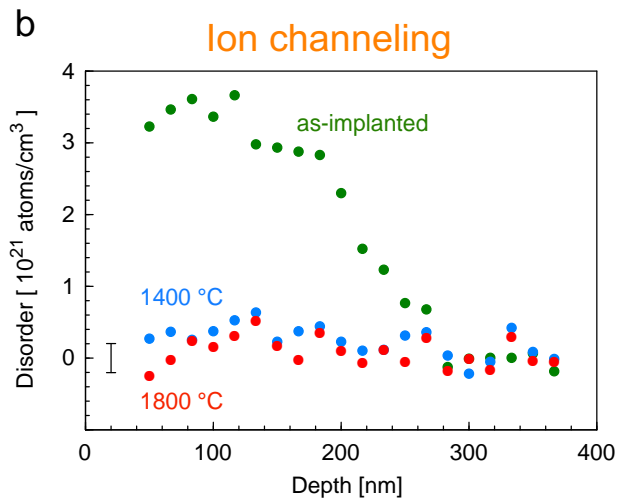
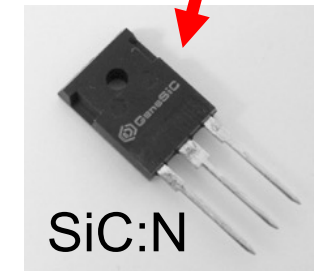
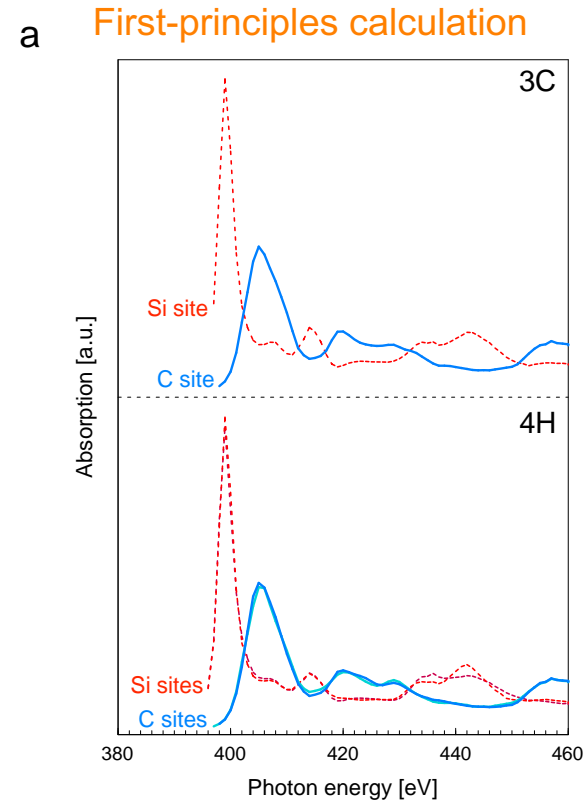
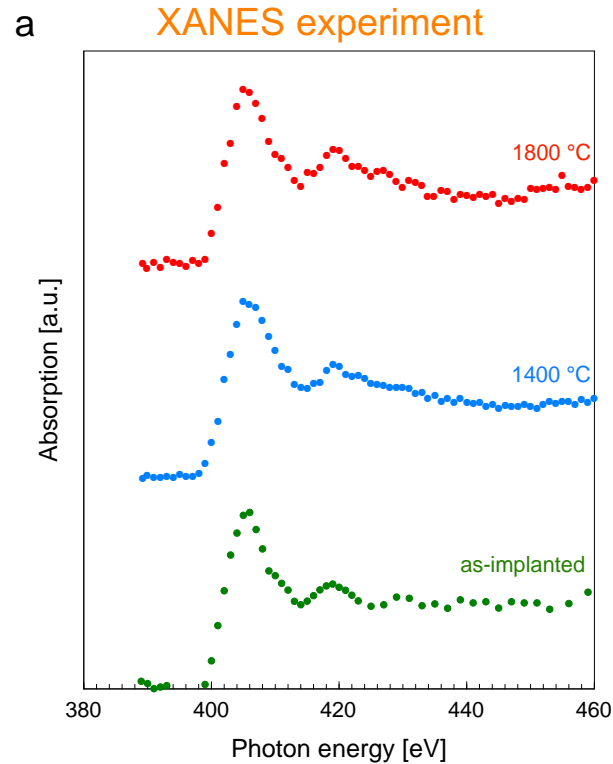
Summation of 100 pixels data at 453 eV



Nitrogen dopant (300 ppm) in SiC



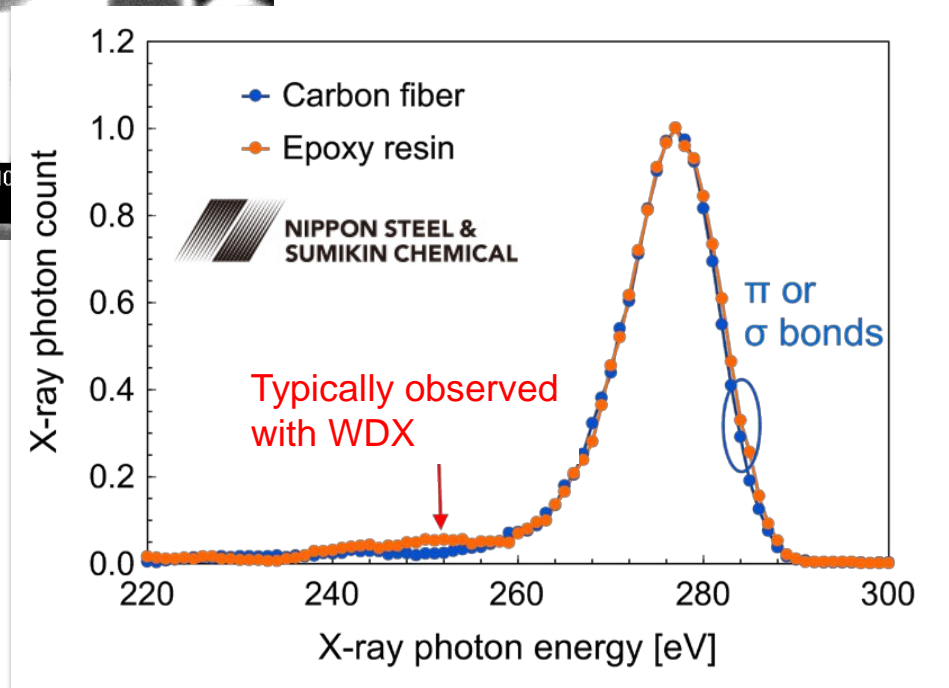
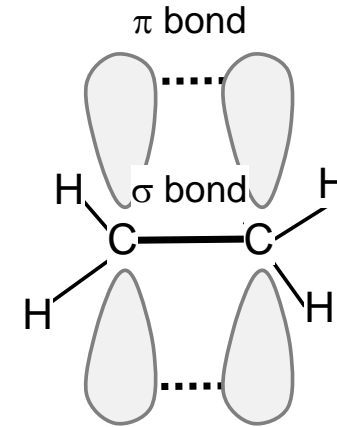
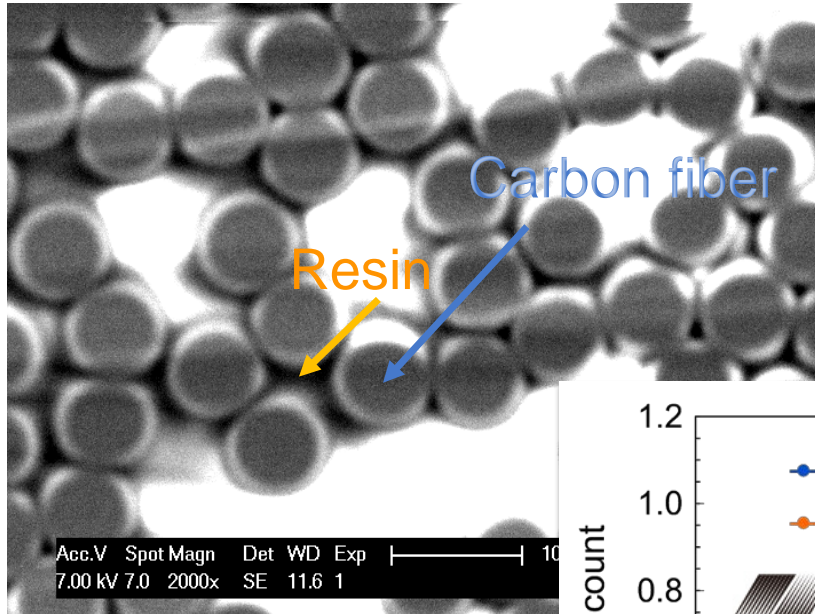
XAFS of N dopant in SiC ($4 \times 10^{19} \text{ cm}^{-3}$)



M. Ohkubo, *et al.*, Sci. Rep. 2, 831 (2012); DOI:10.1038/srep00831.



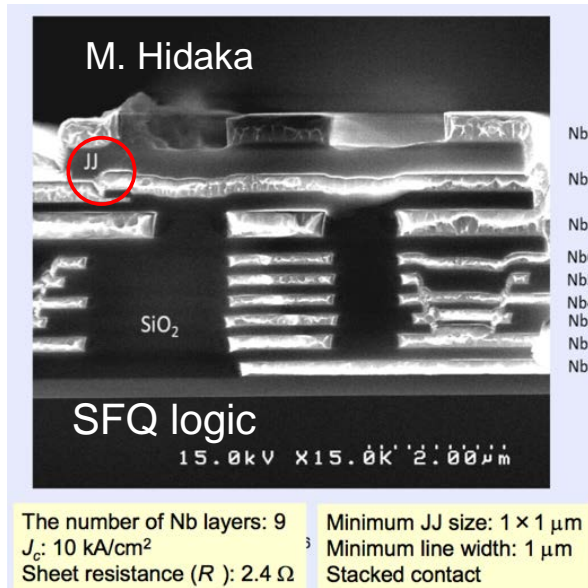
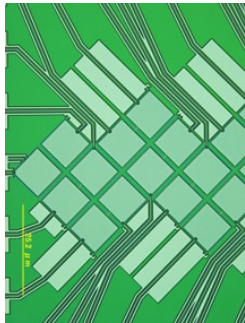
X-ray emission spectroscopy of C-K



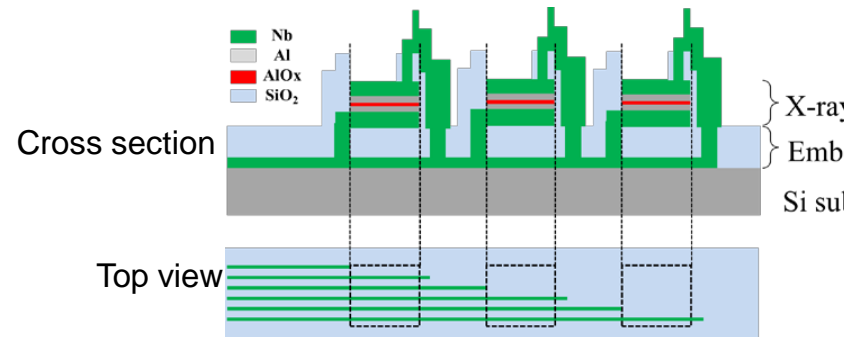
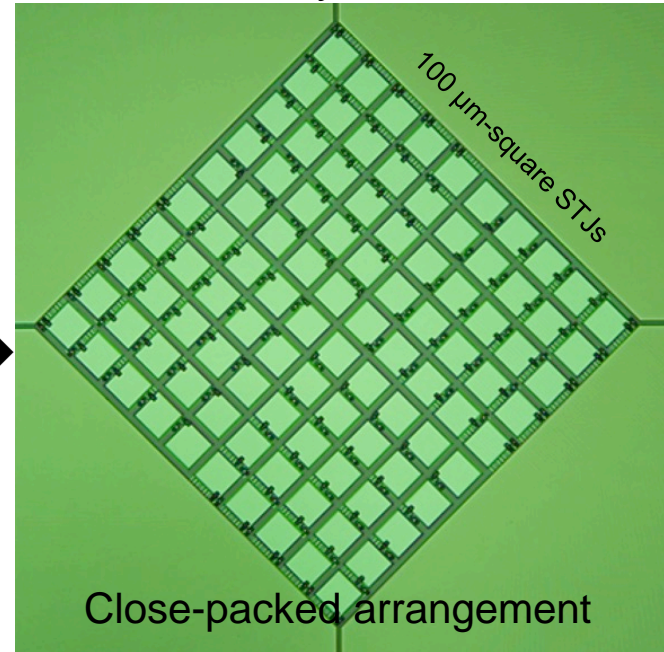


Latest STJ array detector for XAFS and PIXE

2D layout

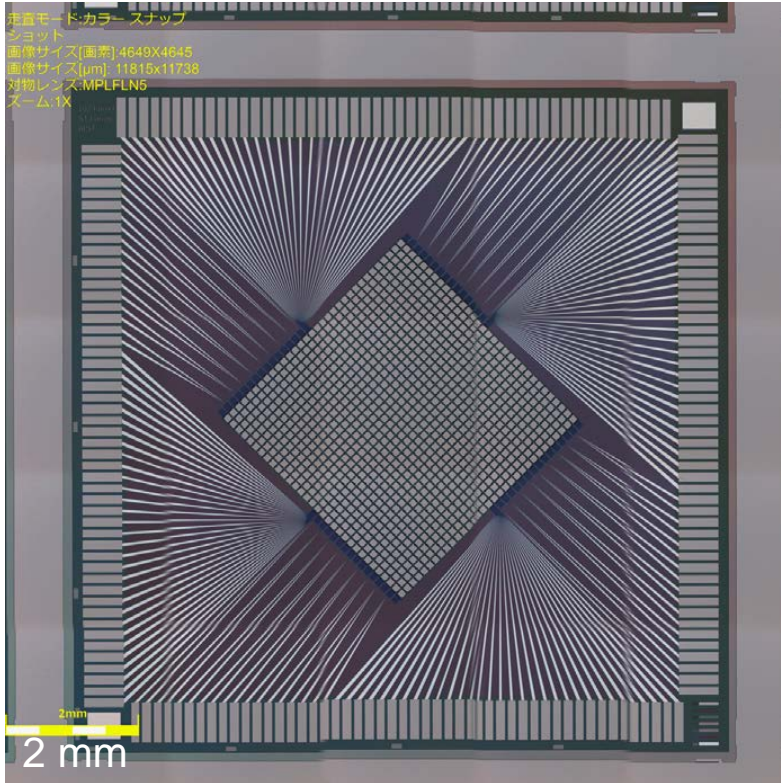


3D layout





Upgrade to 512-1024 pixels



G. Fujii and M. Ukibe 1024 pixels



6 MeV Van de Graff accelerator



筑波大学
University of Tsukuba

S. Shiki

Microbeam Particle-Induced X-ray
Emission (PIXE) with 512 STJs



Summary

- **SR:** X-ray absorption spectroscopy (XAS) for light elements
- **SEM:** X-ray emission spectroscopy for light elements
- **Ion accelerator:** Particle induced X-ray emission (PIXE)
- **Astrophysics:** neutrino mass determination by far-IR photon spectroscopy (15 - 30 meV range) with Tsukuba Uni.
- Atmospheric escape from planets (FLUXONICS)
- Prebiotic organic molecule in universe (FLUXONICS)
- **New trend of SSPD:** high spatial resolution (5 meV)

