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LTD 18 LOW TEMPERATURE DETECTORS

Development of low threshold detectors for light dark matter detection

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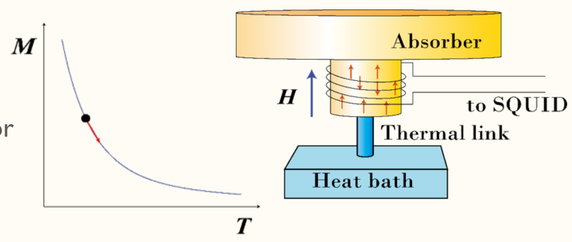
✳Metallic Magnetic Calorimeter (MMC)

- Paramagnetic material with superconducting measurement circuit

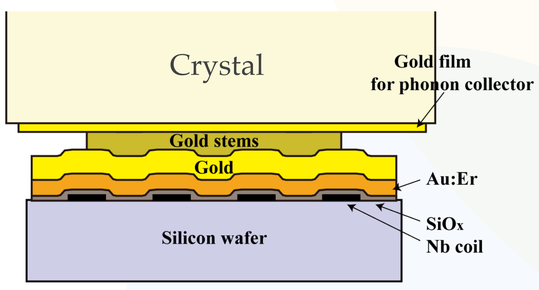
↯ δE : Occurrence of energy absorption in absorber.
- ➥ $\frac{\delta E}{C_{tot}} \propto \delta T$: Energy absorption -> Heat
- ➥ $\frac{\partial M}{\partial T}\frac{\delta E}{C_{tot}} \propto \delta M$: -> Magnetization of paramagnetic sensor
- ➥ $\delta M \propto \delta \Phi$: -> Magnetic flux change in a sensing SQUID.
- ➥ $\delta \Phi \propto \delta V$: -> Voltage signals

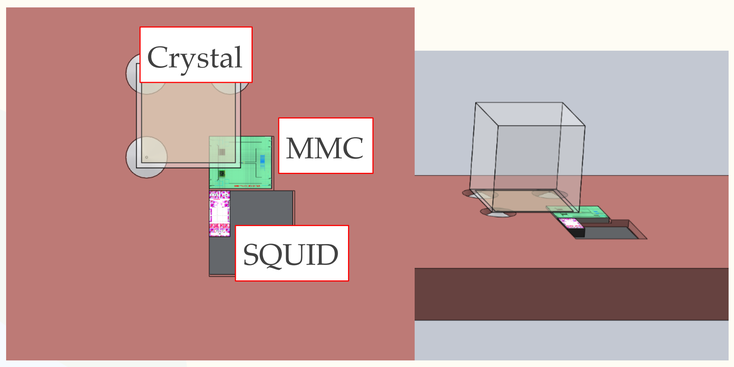


- What is advantage?

✓ high resolution, good linearity, absorber friendly and wide operating temperature.

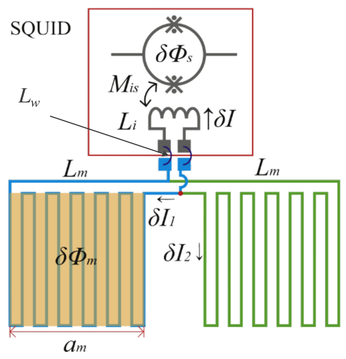
✳ Detector concept





✳MMC & SQUID inductance matching

SQUID	L_i	$1/M_{is}$	Relative signal size		
			a_m : 1 mm	a_m : 0.5 mm	a_m : 0.3 mm
CE1K2 (IPHT)	10 nH	1.6 μA/	1	1.82	2.21
VC1ABlue (IPHT)	4.5 nH	6 $\mu A/\Phi_0$	0.34	0.78	1.08
X114 (PTB)	2 nH	5.3 μA/	0.43	1.22	1.99
XS116 (PTB)	27 nH	2.3 μA/	0.42	0.59	0.64
SQ3006 (Star Cryogenics)	32.3 nH	6 $\mu A/\Phi_0$	0.15	0.19	0.21



$$\delta\Phi_s = M_{is}\delta I = \frac{M_{is}}{L_m + 2(L_i + L_w)}\delta\Phi_m$$

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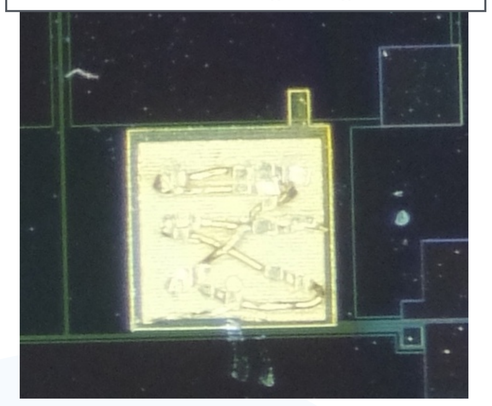
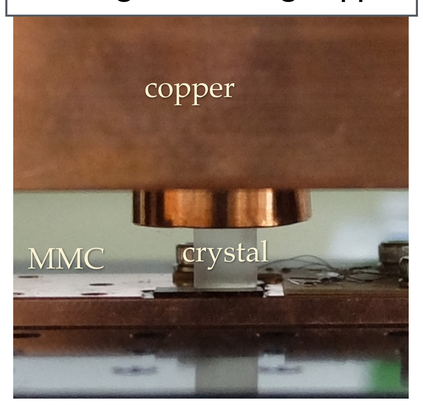
✳Thermal connection

The best thermal connection is through metal for fast rise time.

Gold wire bonding on gold layer

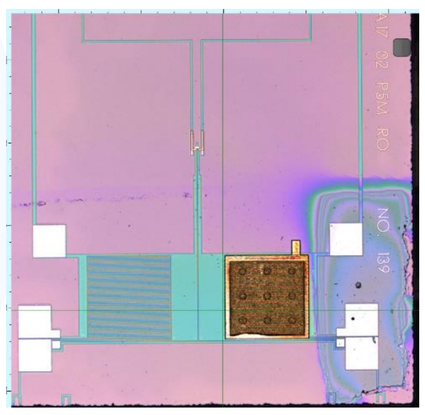


Pressing with 1.5 kg copper



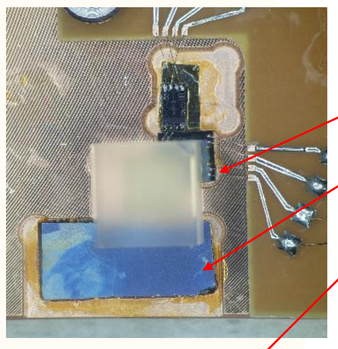
✳ SiO_2 evaporation on Nb bonding pad

Height : 1 μm



✳ Experimental set up

- Experimental temperature : 30 mK with ADR

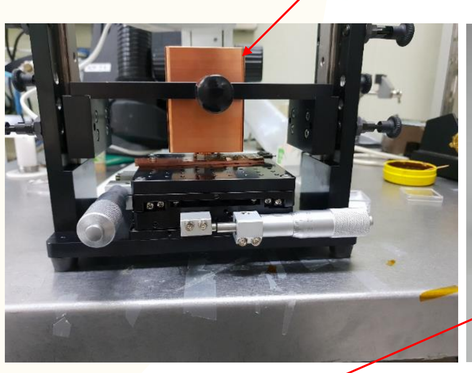


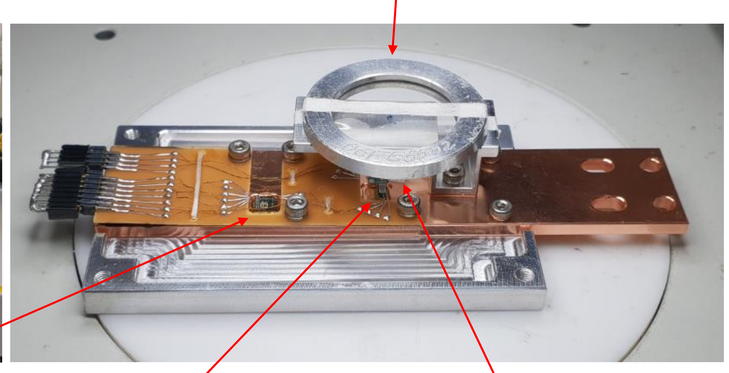
Glue : Ge varnish

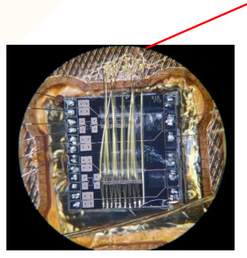
Height matching plate : MMC wafer piece

Pressing with 1.5 kg

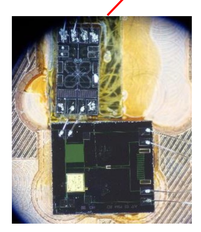
Internal radiation source : ^{55}Fe





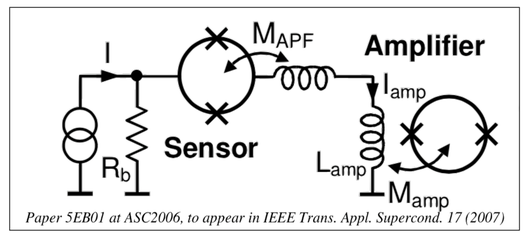


Amplifier SQUID : X16F (PTB)
16-SQUID array
It is separated to the MMC sensor.
→ There is no heat load.



Sensor SQUID : CE1K2 (IPHT)
MMC Material : Ag:Er
Area size : 500x500 μm^2

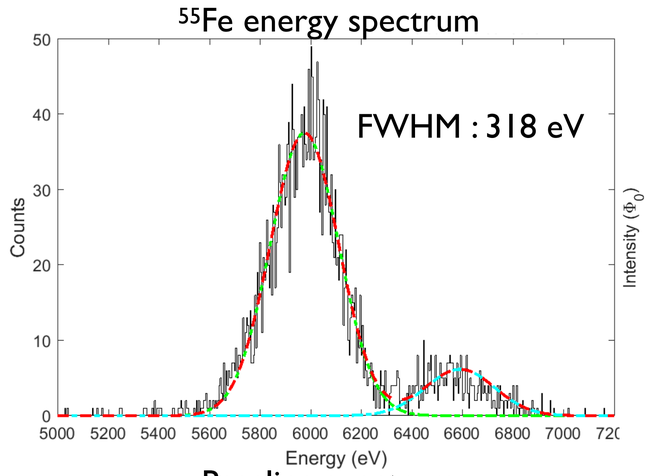
Crystal : CaF2
Size : 5x5x5 mm^3
Phonon collector size
Area : 3x3 mm^2
Height : 300 nm



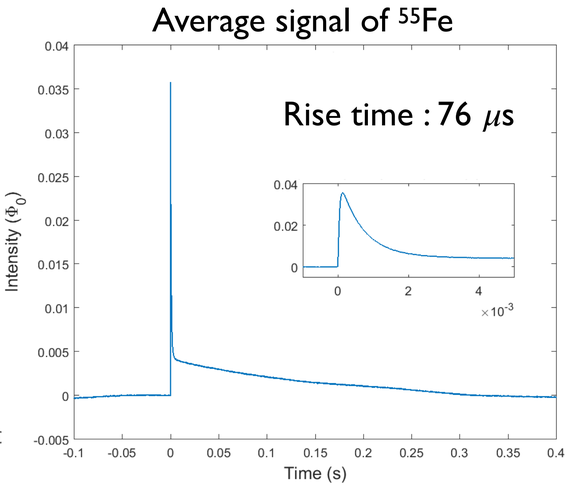
Paper 5EB01 at ASC2006, to appear in IEEE Trans. Appl. Supercond. 17 (2007)

✳ Results

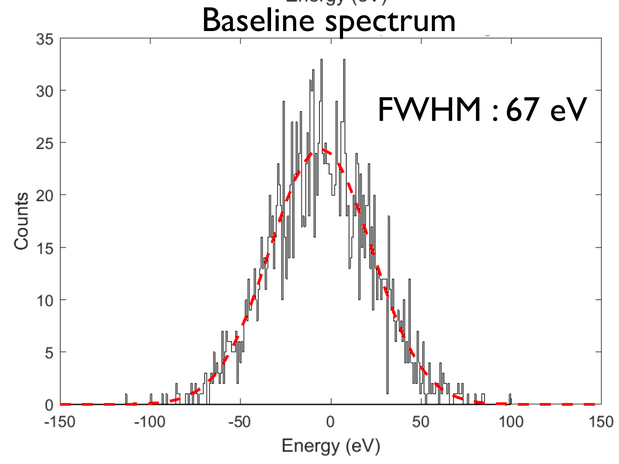
^{55}Fe energy spectrum

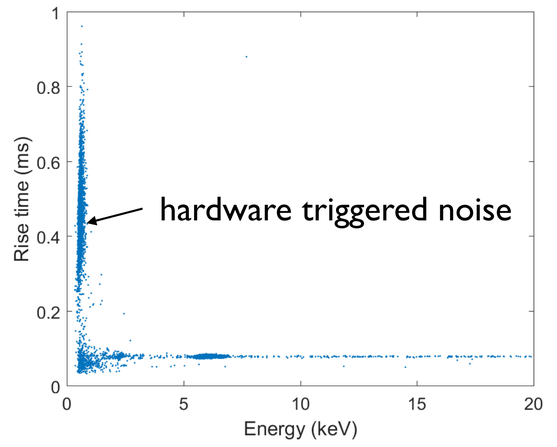


Average signal of ^{55}Fe



Baseline spectrum





✳Conclusion & Future Plan

- The low threshold detection system was studied with 5x5x5 mm^3 CaF_2 crystal at 30 mK temperature.
- The 76 μs rise time can be achieved by metallic thermal link and fast response of MMC sensors.
- The FWHM resolution was 318 eV about 5.9 and 6.5 keV X-ray of ^{55}Fe with 67 eV baseline resolution.
- Lower temperature experiments are planning for better energy resolution and lower threshold.
- We are planning the further study to understand signal shape of 2 decay components.