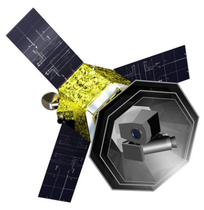
Irradiation tests of superconducting detectors and comparison with simulations



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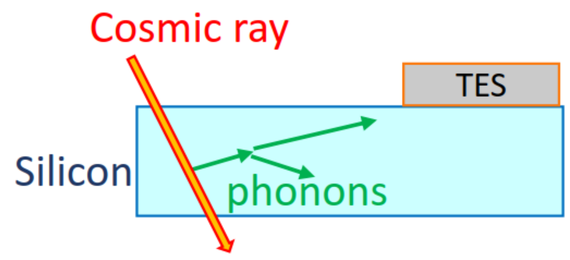
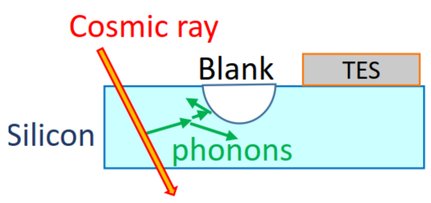
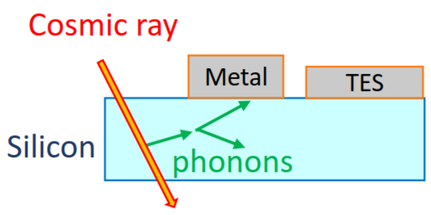
I. Introduction

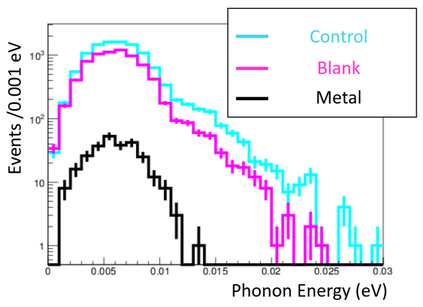
We target to realise a future satellite mission LiteBIRD which will observe full sky at the second Sun-Earth Lagrangian point (L2) and measure the polarisation of Cosmic Microwave Background (CMB). LiteBIRD plan to use Transition Edge Sensor (TES) bolometers to measure the polarisation signal. At L2, large flux of galactic cosmic rays is expected. Our concern is that the cosmic rays deposit energy in silicon substrate and the energy propagates to TES bolometers.







From phonon simulation, we see that putting metal layer on the silicon substrate or creating blank silicon volume can reduce phonon propagation.

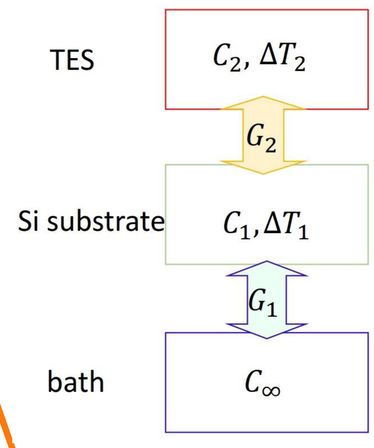


We model the system of TES bolometer, silicon substrate, and thermal bath. By solving equations from the model, we show that we can fit the signal gotten from TES bolometer with

$$-Ae^{-\frac{(t-t_0)}{\tau_A}} + Be^{-\frac{(t-t_0)}{\tau_B}}. \qquad (1)$$

And we can categorise the signals as:

- $A = B$: Charged particle hits silicon
- $A \neq B$: Charged particle hits TES



We try to validate these models with irradiation tests

Fit

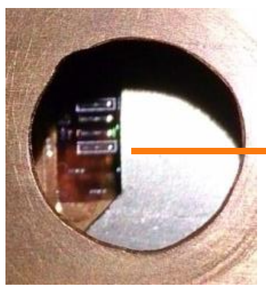
Ⅱ. Experimental setup: Irradiation test with two types of detectors

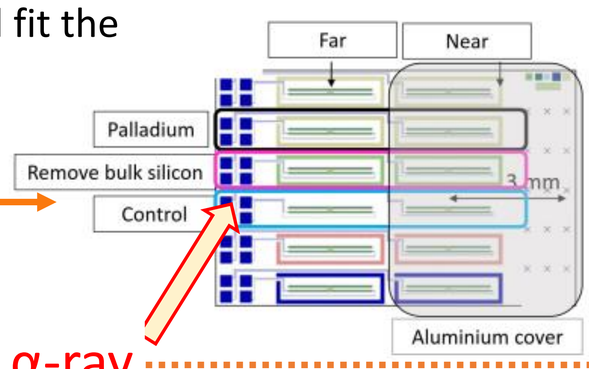
We prepare TES and Kinetic Inductance Detectors (KIDs) with mitigation ideas.

We prepare TES bolometers surrounded by palladium (metal) and nothing (control). We irradiate bolometers with Am^{241} α-ray source.

We take TOD of TES bolometers and fit the triggered events.

Setup of TES bolometers. α-rays are hit from top side of TES bolometers.

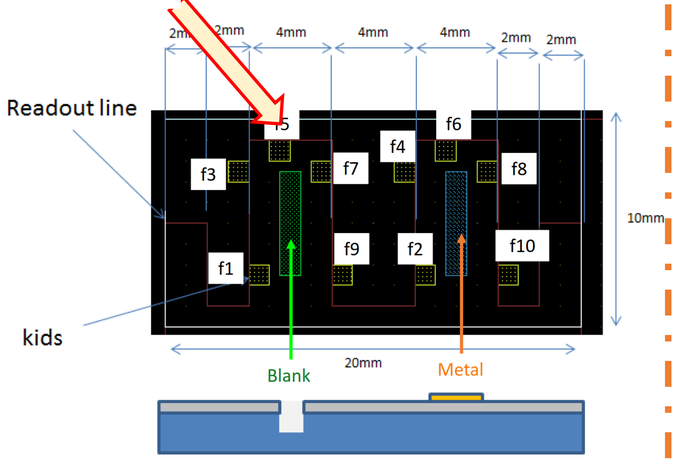


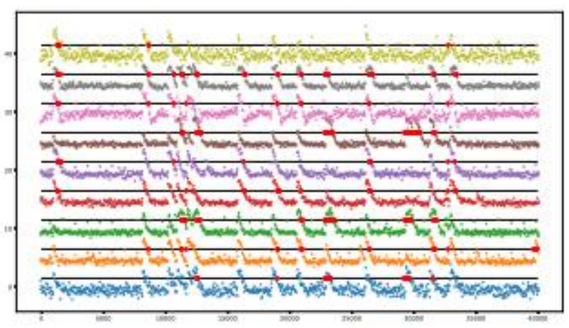


α-ray

We prepare ten KIDs with two mitigation ideas. We take difference of resonant amplitudes of KIDs.

We take TOD of nine KIDs with exposure to Am^{241} α-ray source



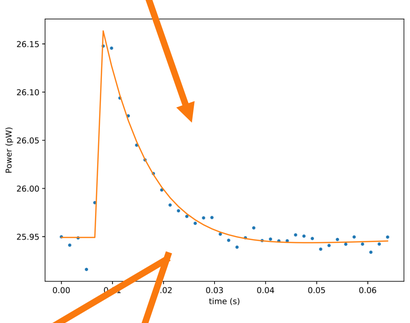


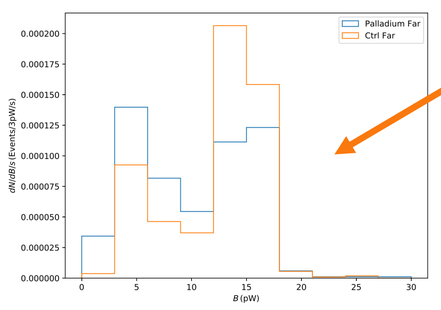
TOD from KIDs. Most of events are from hits of charged particle at aluminium ground plane.

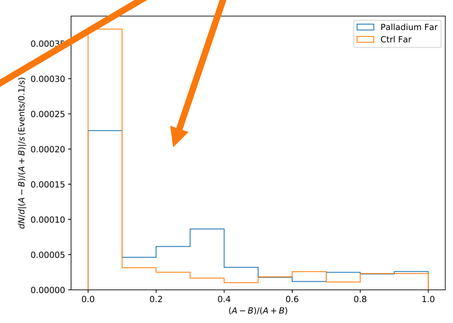
Ⅲ. Results

Fit all the signal events and see the behaviors of fitted parameters.

It shows that most of events are $A = B$ and event rate for Pd surrounding TES bolometer is smaller.

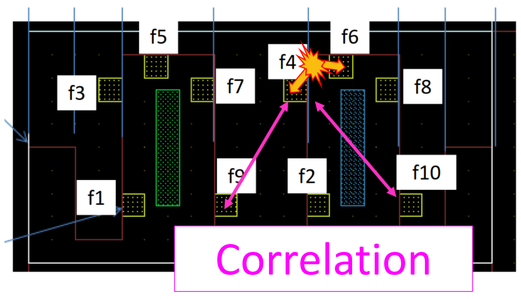






Trigger

We make analysis using correlation between KIDs. At first apply trigger to select events which likely to hit top two KIDs. After that, calculate correlation across the mitigation area and control area.



Target	Triggering	Combination	Correlation
Control	f5 & f7 f6 & f4	f7 & f2 f4 & f9	0.712 0.534
Blank	f5 & f3	f3 & f9	0.576
Metal	f6 & f4 f6 & f8	f4 & f10 f8 & f2	0.326 0.379

Ⅳ. Conclusions

From the correlation analysis of irradiation tests with KIDs, putting metal on silicon substrate can reduce the energy propagation as shown in phonon simulations.

From the analysis of TES bolometers, Pd surrounding TES bolometer can reduce the particle-hit events. And, TES model is consistent with the assumption that most of charged particles hits silicon substrate.

Ⅴ. Discussions and Future works

In the TES bolometer test: (1) we would like to see more bolometers for detailed analysis.

In the KIDs test: (1) Irradiate from backside to reduce the hits of charged particle to the ground plane. (2) Increase the number of KIDs to readout.

In both detectors, collimation of α-ray is required.