Neutron detection system without radiation protection for criticality approach monitoring based on diamond sensors and radiation-resistive integrated-circuits

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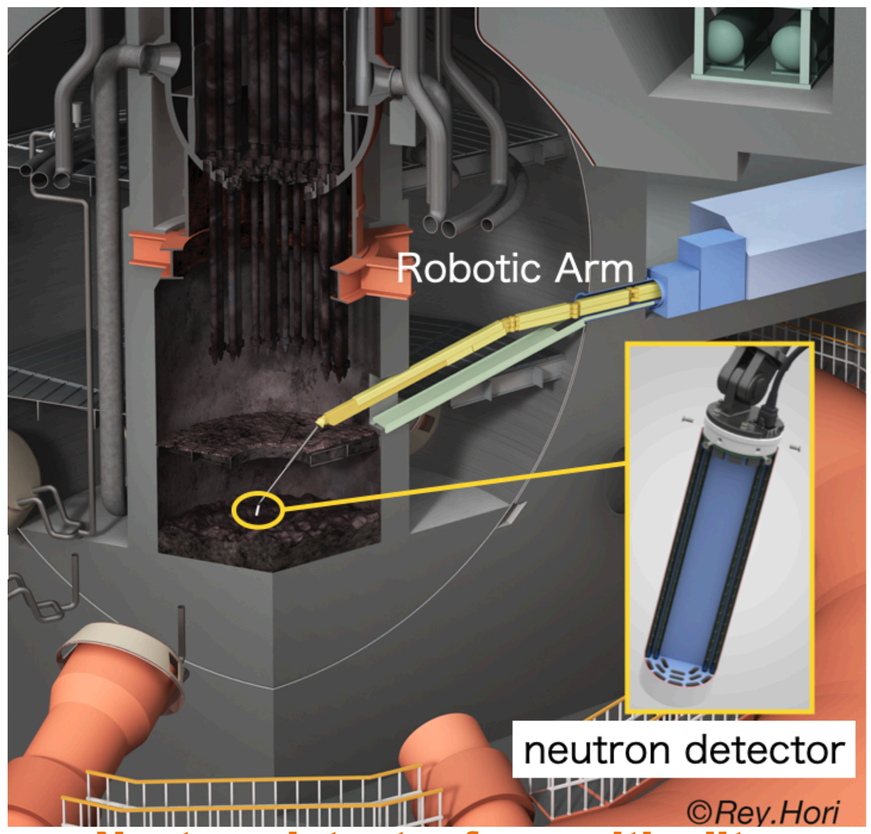
Abstract

This report summarizes the research results of the “Technology development of diamond-base neutron sensors and radiation-resistive integrated-circuits for shielding-free criticality approach monitoring system” conducted until FY2021. The project aims to design and evaluate neutron detection devices based on diamond sensors and a high radiation resistive signal-processing data-transfer system based on radiation resistive integrated circuit technologies and modification based on feedbacks from the view point of reactor noise analysis.

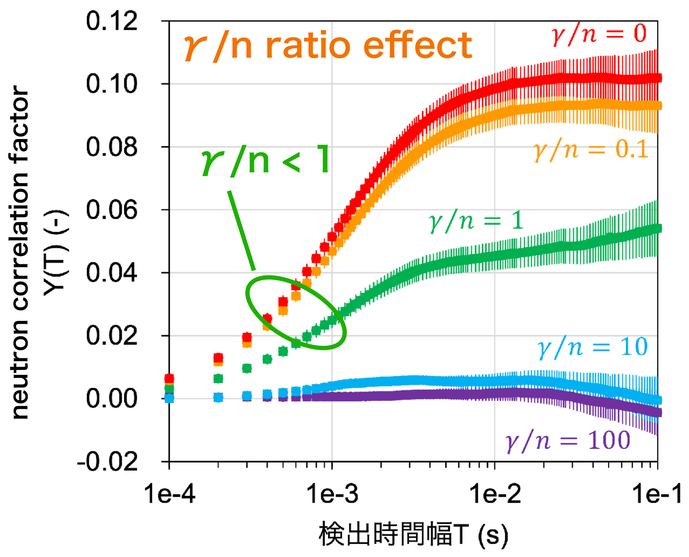
Goal for the critically approach monitor

TID	>1MGy	Diamond sensors, radtol LSIs
γ-ray background	**1kGy/h**	Thin diamond, Fast frontend
neutron efficiency	**a few count/nv**	>1000 neutron sensors
Weight	as light as possible	No radiation shield

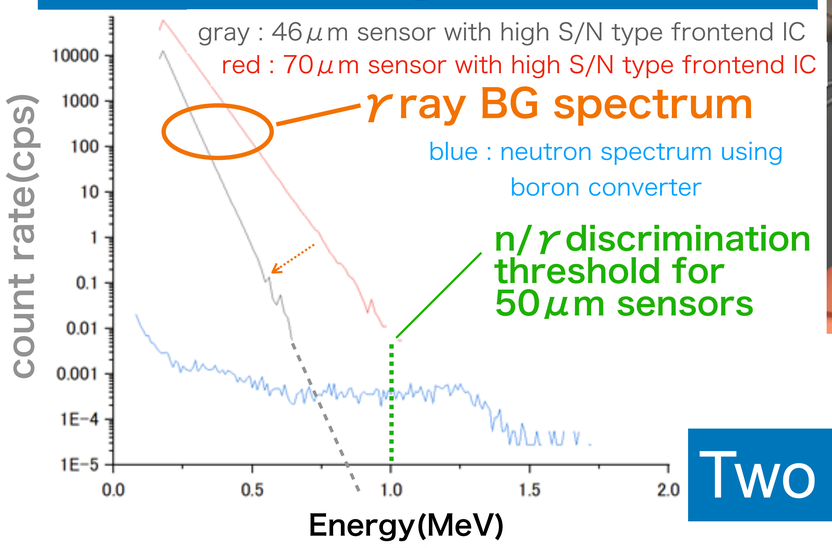


Neutron detector for a criticality approach monitoring system

“γ-ray/neutron<1” assures success of the monitoring

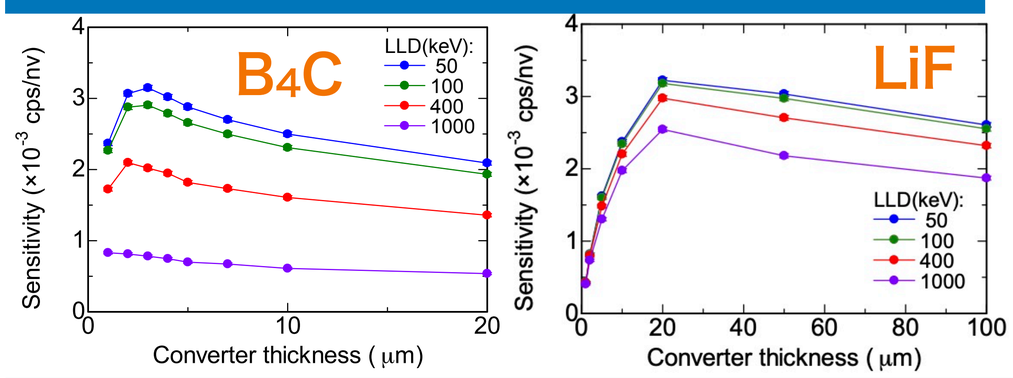


Thiner sensor has low γ-ray BG spectrum@1kG/h

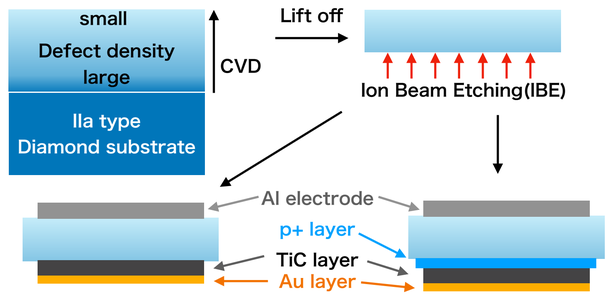


Two processes for sensor R&D

>1000 sensors achieve detection-eff.

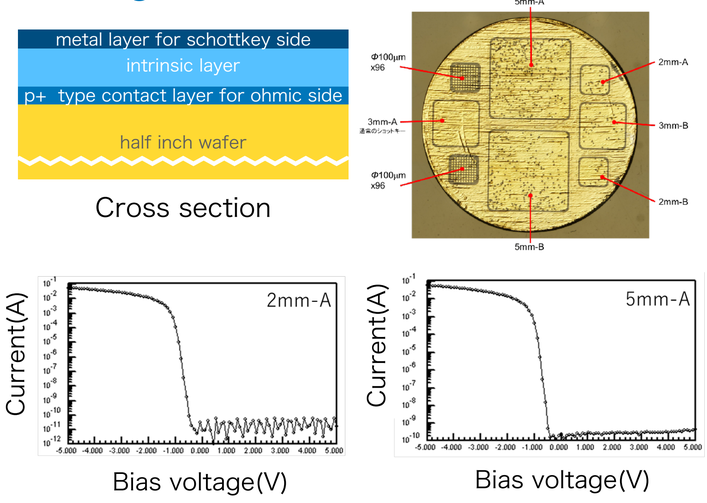


(I) ~50um thin diamond sensors are successfully working under 1kGy/h



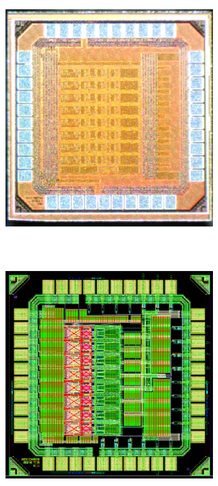
	charge collection eff(%)		energy resolution(%)	
	electron	hole	electron	hole
w/o IBE	99.8	99.0	0.820	0.472
IBE10μm	99.5	98.5	0.796	0.520
IBE10μm p+layer	97.57	97.5	0.793	0.377
IBE20μm	98.6	97.5	0.871	0.471

(II) ~5um thin diamond sensors show good I-V characteristic.



Rad tol LSIs, CMOS65nm process

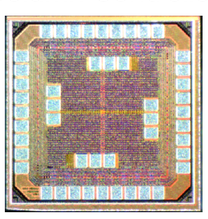
Frontend ASIC(High S/N type and High speed type)



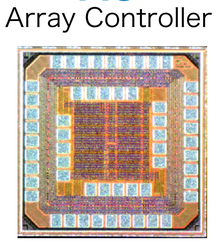
Nu-K_NCH	
Type	charge sensitive
Peaking time	50nsec(t_w~100nsec)
Noise	~800 e @Cdet=5pF
S/N	~350@Cdet=5pF
Status	**using for sensor eval.**

Nu-K_TIA	
Type	current sensitive
Peaking time	**<2nsec@Cdet=5pF**
Noise	0.3uA@Cdet=5pF
S/N	40@Cdet~5pF
Status	under development

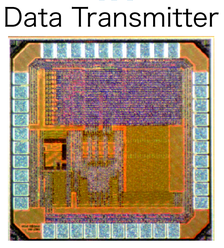
CC Column Controller



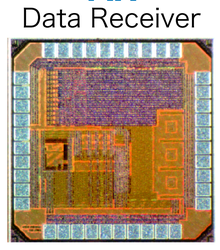
AC Array Controller



Tx Data Transmitter



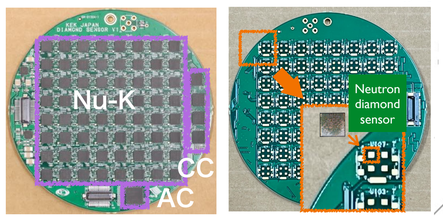
Rx Data Receiver



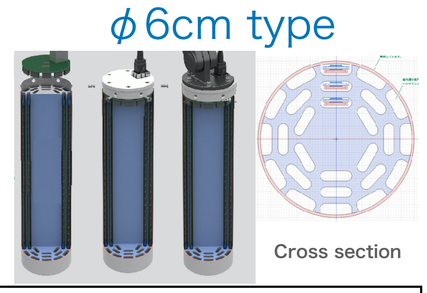
336Mbps 24hrs 70m confirmed

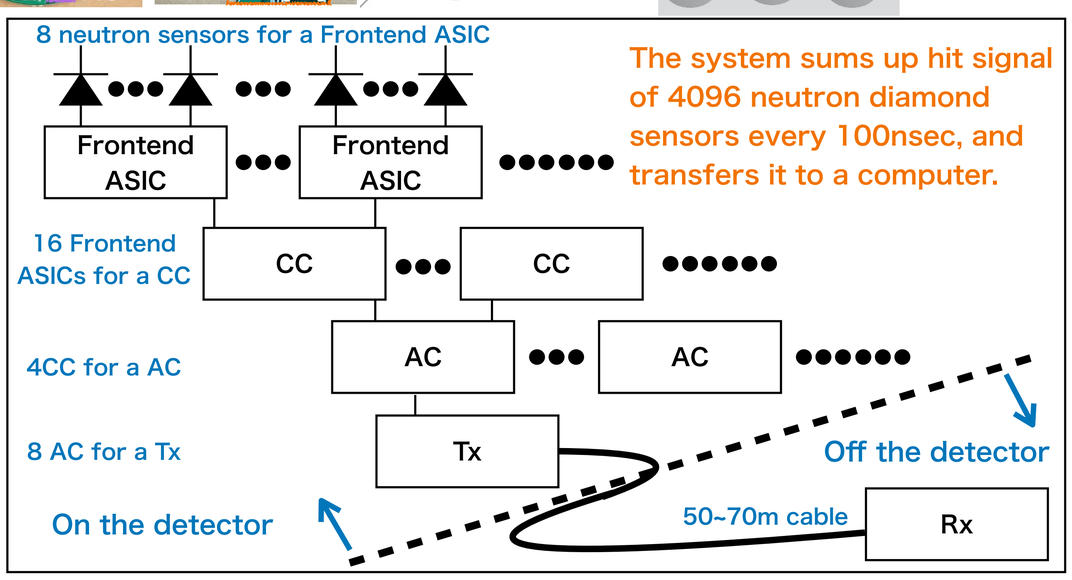
Neutron detection system

ϕ15cm type



ϕ6cm type





Acknowledgement

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References

[1] Reports of FY2021 Nuclear Energy Science & Technology and Human Resource Development Project, to be published.