Remote detector for high radiation fluences

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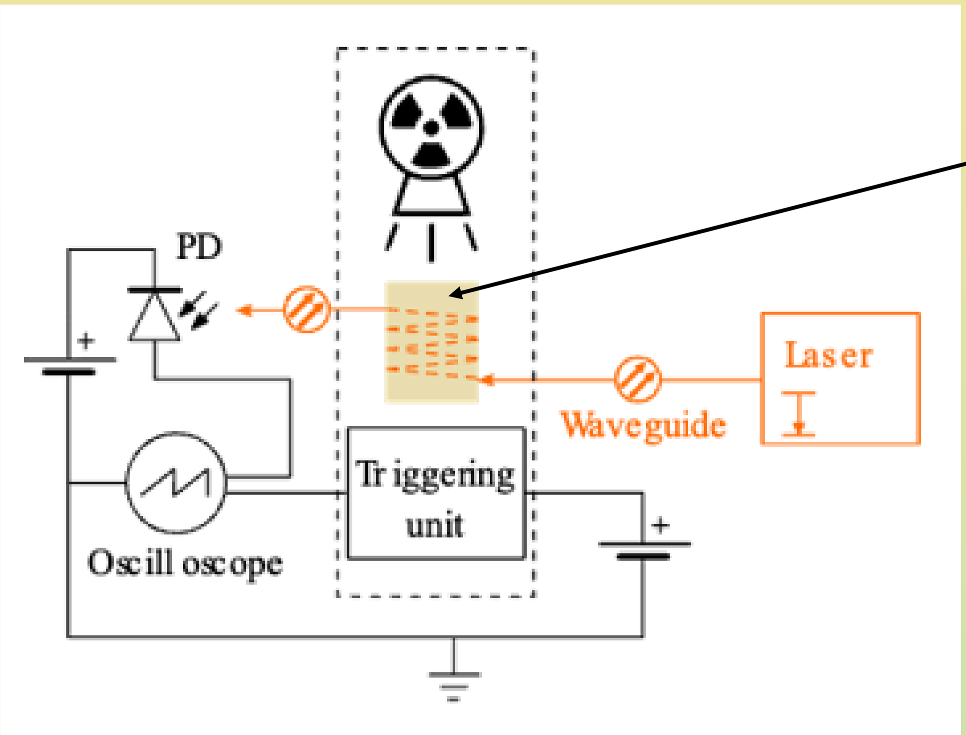
Motivation

- Low radiation hardness of electronic components limits the application of conventional radiation detectors at high radiation fluxes.
- Splitting the scintillation-based detector in a radiation-hard detection unit and a remote electronic signal detection unit is visionally prospective but fails to be efficient when exploiting the conventional scintillator detector scheme due to an inherent difficulty in focussing the radiation-induced scintillation light into a small apperture of the lightguide to transmit the light to a remote readout electronics.
- This study was aimed at developing the remote-sensing detector of ionizing radiation based on the change in the optical absorbance imposed by the ionizing radiation to be detected.

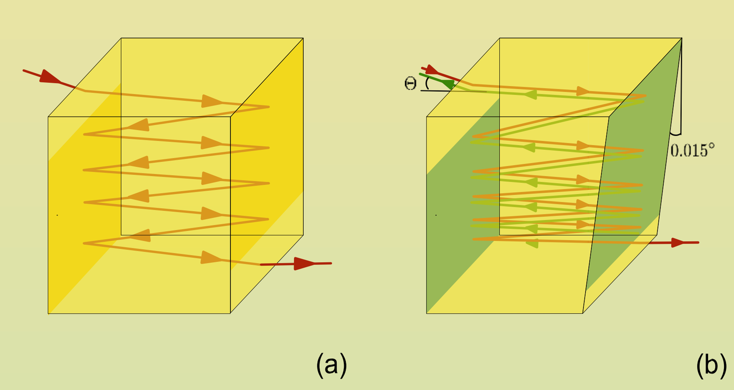
Results



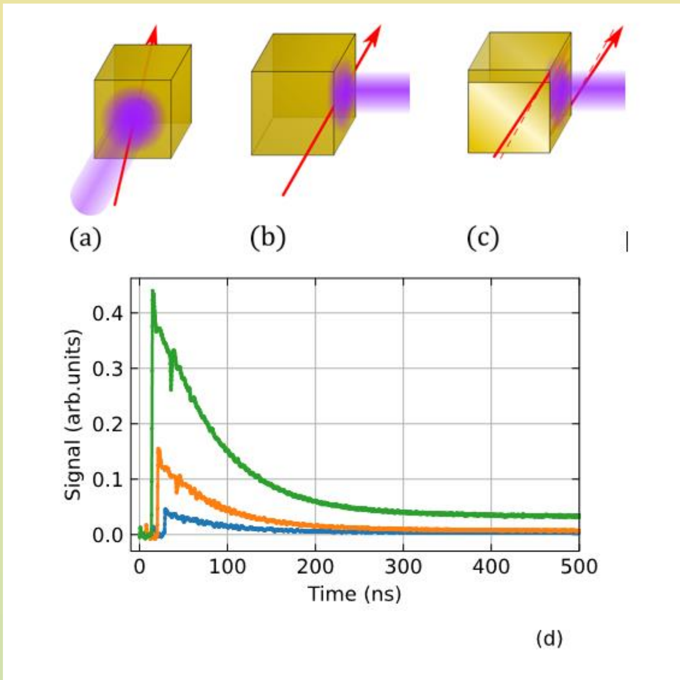
Outline of the system for detection of ionizing radiation based on radiation-induced optical absorption and remote readout

✓ **$Gd_3Al_2GA_3O_{12}$:Ce (GAGG:Ce)** exhibited the best performance among other wide-band-gap semiconductors and scintillators tested (GaN, SiC, PbWO4 (PWO), Lu_2SiO_5:Ce (LSO:Ce), $Y_3Al_5O_{12}$:Ce (YAG:Ce))

✓ **$Gd_3Al_2GA_3O_{12}$:Ce is an efficient neutron absorber ⇒ good for the detection of high neutron fluxes**

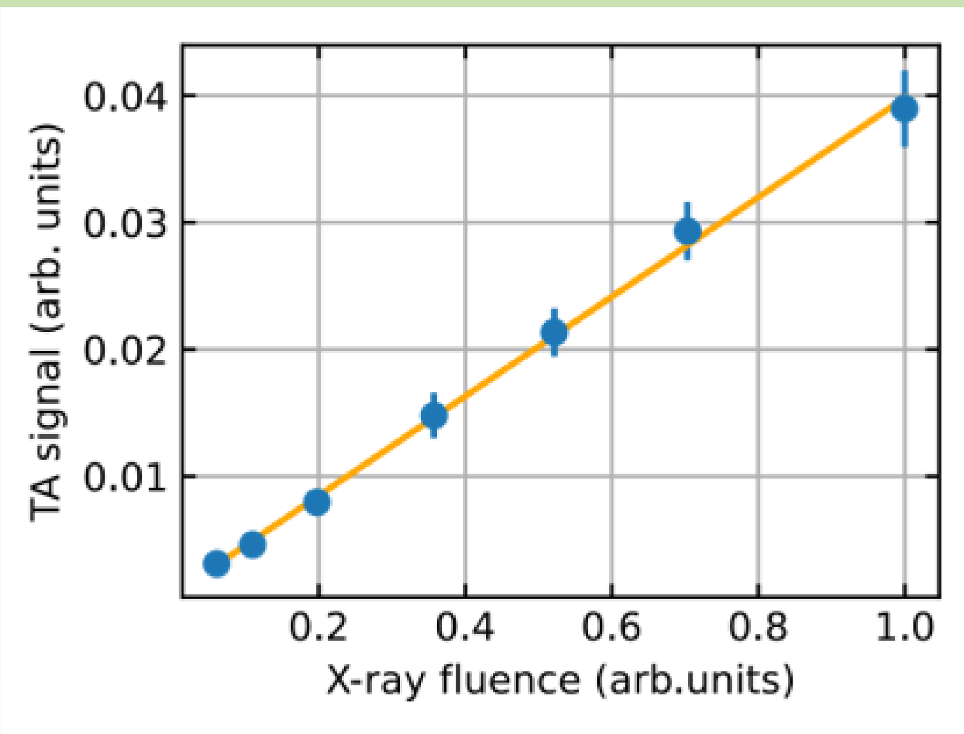


Two configurations of detecting unit based on GAGG:Ce crystal:
(a) “cube” configuration with the multi-pass trajectory of the probe beam and the entrance and exit on the opposite sides;
(b) “wedge” configuration with one surface inclined by 0.015 deg to enable probe multi-pass transitions and the entrance and exit through the same window.



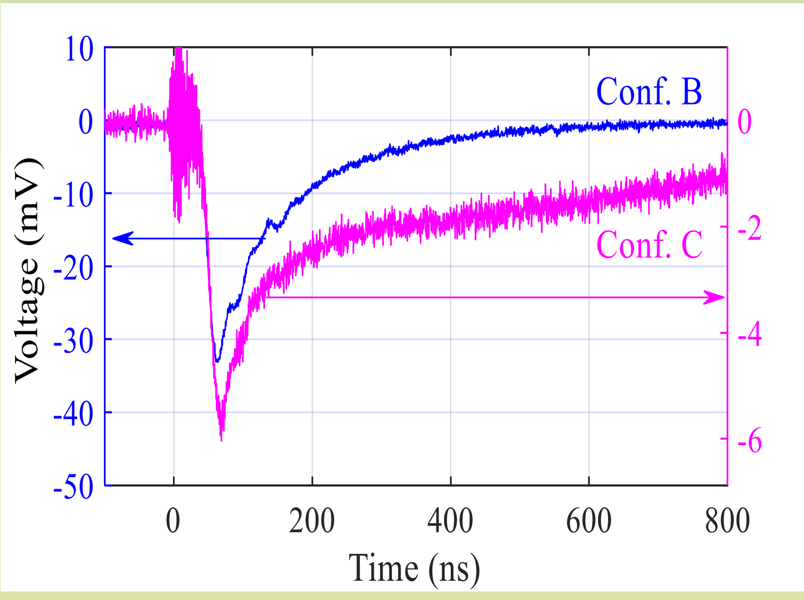
Three probing configurations:
(a) with nearly colinear propagation of pump and probe beams, (b) the probe traveling across the photoexcited volume, and (c) with multi-pass transition.
The transients of TA signal for three probing configurations (d) corresponding to (a), blue curve; (b), red curve, and (c), green curve). The curves are slightly shifted in time for clarity

Linearity of optical response to irradiation fluence was tested at X-ray excitation



Dependence of the amplitude of TA signal on the photon fluence of X-ray pulses.

X-ray source: Golden Engineering XRS4; max photon energy of 370 keV, 10 ns-long pulses; resulting exposure of 5.5 mR at 30 cm from the source.



Oscilloscope waveforms read out from photodetector as a result of an X-ray pulse detected by using the detection unit in configurations with the wedge-shaped sample when only the forward transition of the probe beam with multiple reflections is employed (B), and with the wedge-shaped sample passed with multiple reflections forth and back (C).

Conclusions

- A novel detection system based on measuring radiation-induced optical absorption to monitor high-intensity ionizing radiation without subjecting any irradiation-sensitive components of the system to the radiation to be detected is designed and optimized.
- Single crystal of GAGG:Ce has been selected for the detection unit subjected to radiation and separated by optical fibers from the probing laser and readout parts of the system.
- Due to gadolinium in the crystal composition, GAGG:Ce is favorable for the detection of high-intensity neutron fluxes.
- The capability of the system to monitor ionizing radiation and the linearity of the measured response to irradiation flux has been demonstrated using a pulsed X-ray source.

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