Photonic Crystal Enhances Scintillation Light Extraction: Can It Improve Timing Resolution?

Bipin Singh[1], Matthew S. J. Marshall[1], Carlos Pina-Hernandez[2], Keiko Munechika[2], Matteo Salomoni[3], Rosalinde Pots[3], Paul Lecoq[3], and Vivek V. Nagarkar[1]

[1]*Radiation Monitoring Devices, Inc., 44 Hunt Street, Watertown, MA 02472, USA*
[2]*Abeam Technologies, 22290 Foothill Blvd, St. 2, Hayward, CA 94541, USA*
[3]*CERN, CH-1211, Geneva 23, Switzerland*

Abstract

Improving scintillator brightness, and energy and temporal resolution is important in virtually all radiation detection applications, including nuclear medicine, homeland security, and classification of X-rays, γ-rays, or neutrons. Historically, increasing the brightness has required the development of new scintillator materials, which is a long and expensive process. Here, we demonstrate an alternative approach to increase the fraction of usable light produced by the scintillator. Our approach does not require development of new scintillator materials, but instead dramatically increases the effective brightness, energy resolution, and potentially timing resolution of existing scintillators by modifying the exit surface of the scintillator crystal. This improvement capitalizes on reducing the mismatch of the refractive indices between the high refractive index (RI) scintillator, and the low refractive index window of the photodetector.

There are several state-of-the-art scintillation materials that exhibit remarkably bright emissions and superior energy resolution arising from their unprecedented response linearity over a wide range of incident radiation energies. However, these scintillation crystals have high refractive indices, and current techniques to couple such crystals to the underlying photodetector with low-RI windows using coupling grease allow only a fraction of the scintillation light to be used in the detection process. Specifically, the light generated by the interaction of a γ-ray in the scintillator undergoes multiple total internal reflections (TIRs) before exiting to the photodetector, whereby only 30% of the light is detected. This loss of signal degrades the energy resolution (ER), and multiple total internal reflections also delay the exit of scintillation photons towards the photodetector, substantially degrading timing performance.

Nanostructures such as photonic crystals (PhCs) maximize extraction of usable scintillation light that is otherwise lost when a high-RI scintillator is coupled to a photodetector with low RI window. The PhC gradually changes the RI between the window and photodetector, thereby substantially improving the light extraction efficiency, as well as the energy and timing resolution. Here, we report on ~50% improvement in the light extraction and ~40% improvement in the energy resolution of existing inorganic scintillators using PhCs nanoimprinted in high RI polymers. Investigations are underway to determine the impact of PhCs on timing performance. Details of the design, fabrication and characterization of the PhCs, the high RI polymers, and their impact on scintillator performance will be presented at the workshop.

Acknowledgements

This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract(s) HSHQDC-13-C-B0040. This support does not constitute an express or implied endorsement on the part of the Government.