Scintillation Fiber-Optic Detectors for Proton Beam Registration

P. Bilski[1]*, S. Witkiewicz-Łukaszek[2], B. Sobiech[3], A. Mrozik[1], M. Sądel[1], J. Swakoń[1], D. Wróbel[1], J. Winiecki[3,4], M. Akselrod[5], Y. Zorenko[2,3]*

[1]Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland
[2]Faculty of Physics, Kazimierz Wielki University, Bydgoszcz, Poland
[3]Franciszek Łukaszyk Oncology Center, Medical Physics Department, Bydgoszcz, Poland
[4] Collegium Medicum, Nicolaus Copernicus University, Bydgoszcz, Poland
[5] Department of Physics, Oklahoma State University, Stillwater, OK, USA

*Corresponding authors: pawel.bilski@ifj.edu.pl

Scintillation fiber-optic detectors (FODs) offer a compact, electrically passive, and real-time solution for proton beam monitoring in radiation therapy. In this work, we present a systematic comparison of FODs based on GAGG:Ce, Al_2O_3:C, and Al_2O_3:C,Mg crystal scintillators investigated under identical clinical proton irradiation conditions. The detectors were tested in a 60 MeV proton beam at the proton therapy facility of the Institute of Nuclear Physics PAS (Krakow, Poland), within a fully modulated spread-out Bragg peak. Measurements were performed over a clinically relevant dose range of 0.5–15 Gy, with radioluminescence (RL) spectra acquired at integration times down to 70 ms.

The GAGG:Ce-based FOD (Fig.1a, c) demonstrated the highest RL signal intensity, excellent stability under repeated irradiation cycles, and a fast temporal response, enabling reliable real-time proton beam monitoring. Linear dose dependence was observed for both short (70 ms) and longer (700 ms) acquisition times, highlighting the suitability of GAGG:Ce for applications requiring high temporal resolution, such as pencil beam scanning proton therapy.

FODs based on Al_2O_3:C and Al_2O_3:C,Mg (Fig.1, b, c, d) exhibited high sensitivity, reproducible dose–response characteristics, and near tissue-equivalent behaviour. Mg co-doping in Al_2O_3:C,Mg led to enhanced luminescence efficiency compared to Al_2O_3:C, while maintaining good response stability. All studied detectors showed stable operation and approximately linear dose dependence within the studied range.

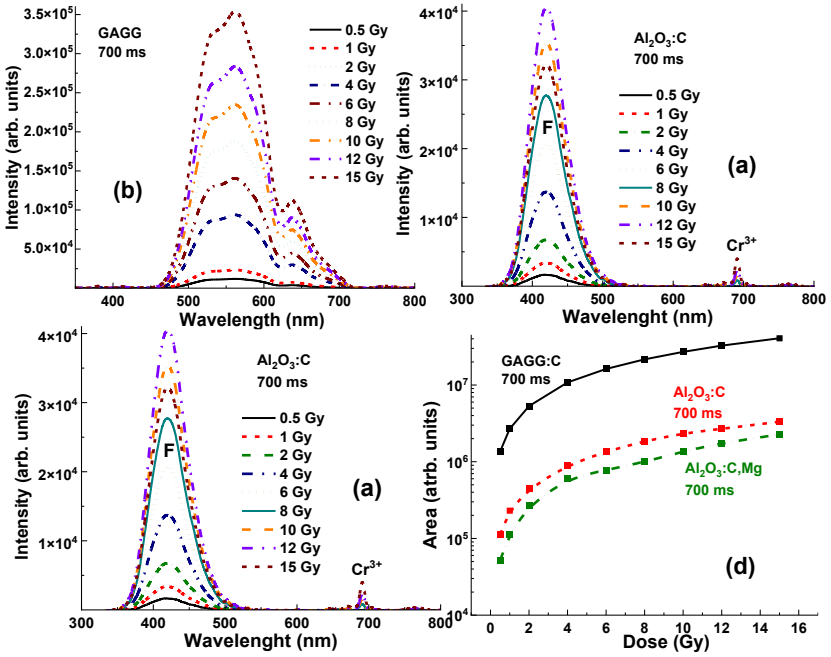

Fig.1. *Dependence of the RL spectral intensity of the FOD based on a GAGG:Ce (a), Al_2O_3:Ce (b) and Al_2O_3:Ce,Mg (c) crystal scintillators on the proton irradiation dose in the range of 0.5–16 Gy, registered with integration times of 700 ms. (d) - relationship between the integrated RL band intensity recorded with as a function of the proton irradiation dose for FODs based the mentioned crystals.*

These results demonstrate that scintillation FODs constitute a robust and versatile platform for proton beam diagnostics and dosimetry. GAGG:Ce-based detectors are particularly well suited for fast, high-signal applications, whereas sapphire-based detectors provide advantages for tissue-equivalent dosimetric measurements. The presented comparative study provides practical guidance for scintillator selection in real-time proton therapy beam monitoring systems and supports the integration of FODs into clinical quality assurance and beam diagnostics workflows.

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