PhD thesis

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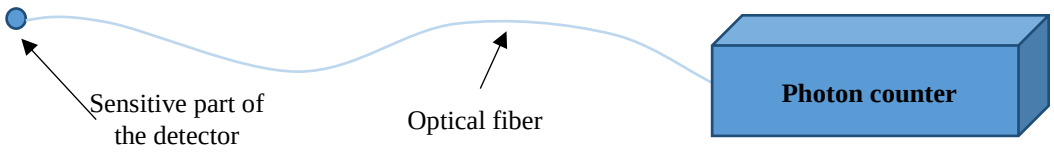
Sujet : Ultra compact and ultra sensitive detectors for ionizing radiation

PhD proposal:

CINaM has developed a micrometer-scale detector for high-accuracy characterization of the irradiation field profiles used in radiotherapy and brachytherapy. The idea is based on the conversion of ionizing radiation into visible light in a passive sensitive part, with a volume of less than 1 mm^3, grafted at an optical fiber tip. This fiber guides the visible light to a photon counter (see figure), enabling long-distance measurement without signal loss.



Micrometer-scale detector

The number of visible photons emitted by the sensitive part is proportional to the incident flux of ionizing radiation. CINaM has produced several prototypes to achieve proof of concept (detector linearity, repeatability, reproducibility) under end-user conditions on radiotherapy and brachytherapy machines. This detector was the object of two patents and several papers.

In order to achieve micro-dosimetry, the team aims to reduce the size of the sensitive part to obtain a sphere with a diameter of less than 40 µm, while maintaining a good signal-to-noise ratio. Numerical simulations will be carried out in parallel to optimize the detector geometry and quantify the expected signal. These detectors will be endoscopy-compatible in order to perform micro-dosimetry on Organ-on-Chip, then on animal models.
They will also be tested on emerging radiotherapy equipment such as Flash-radiotherapy (pulsed X-beam), proton therapy and hadrontherapy, through collaborations that CINaM has already developped for several years (IPHC Strasbourg, IRSN Cadarache, Institut Paoli

Calmettes Marseille, Paul Scherrer Institute, Zürich). Other applications for this detector will be investigated. The thesis work will include proofs of concept for these applications.

A linear multi-fiber device will also be designed to quickly and accurately measure the profile of fields smaller than 5x5 mm². Measurements will be carried out to quantify cross-talk between fibers.

Relevant references from the team:

1. 'Signal amplification of fiber integrated X-ray detector and energy independence', S.B.C. Debnath, J. Darreon, A. Tallet, A. Goncalves, D. Tonneau, C. Fauquet, IEEE Sensor J., 21(17), p.18793 (2021) http://dx.doi.org/10.1109/JSEN.2021.3091660.
2. 'Dosimetric characterization of a small-scale (Zn,Cd)S:Ag inorganic scintillating detector to be used in radiotherapy', S.B.C. Debnath, D. Tonneau, C. Fauquet, A. Tallet, A. Goncalves, J. Darreon, Physica Medica, Vol 84, 15-23 (2021). https://doi.org/10.1016/j.ejmp.2021.03.022
3. 'High resolution small-scale inorganic scintillator detector: HDR brachytherapy application S.B.C. Debnath, M. Ferre, D. Tonneau, C. Fauquet, A. Tallet, A. Goncalves, J. Darreon, Medical Physics (2020), http://doi.org/10.1002/mp.14727
4. 'High spatial resolution inorganic scintillator detector for high-energy X-ray beam at small field irradiation', Sree Bash Chandra Debnath, Carole Fauquet, Agnes Tallet, Anthony Goncalves, Sébastien Lavandier, Franck Jandard, Didier Tonneau, Julien Darreon, Medical Physics (2019). https://doi.org/10.1002/mp.14002
5. 'Ultracompact x-ray dosimeter based on scintillators coupled to a nano-optical antenna, Z. Xie, H. Maradj, M.A. Suarez, L. Viau, V. Moutarlier, C. Filiatre, C. Fauquet, D. Tonneau, and T. Grosjean', Opt. Lett. 42(7), 1361-1364 (2017)