1. PHD PROJECT DESCRIPTION (4000 characters max., including the aims and work plan)

Project title: Optimization of Scintillation Properties of Novel Oxide and Halide Materials

1.1. Project goals

1.1.1. To recognize new materials (crystals or ceramics) producing both fast and efficient scintillation when exposed to ionizing radiation

1.1.2. To recognize scintillation mechanisms and optimize scintillation parameters of selected oxide and halide materials which are at the moment after preliminary characterization

1.2. Outline

Scintillation is a phenomenon of light flash generation inside a material which is exposed to ionizing radiation. Substances that produce scintillations are termed *scintillators*. The area of scintillator applications consecutively extends its limits, hence larger volumes of scintillator materials are needed and new requirements appear, which motivates scientific research and growth technology development. For many years interest has been focused on insulating crystals, based on intrinsic emissions (e.g. PWO, BGO) or activated with rare-earth ions (e.g. $LaBr_3$:Ce, LuAG:Pr). However, recently some changes in this respect have been observed, i.e. semiconductor crystals are also considered, as well as other than crystalline forms are studied (e.g. ceramics).

The basic topical problem related to development of modern scintillators is a possibility of combining high efficiency and short scintillation lifetime in one material. On the one hand there is a group of efficient scintillators with long emission decay times, on the other hand a group of fast but low efficient ones. Our recent grant aimed at improving the scintillation properties of β-Ga_2O_3 has shown that such a combination is simply not possible for this compound: by adjusting the free electron concentration we obtain either an efficient but slow scintillator, or a fast but not efficient one. Some recent discoveries (e.g. $LaBr_3$:Ce) seem to fulfill the condition of being both fast and efficient, but their growth technology is expensive and mechanical properties are poor. Still, various new materials which will be studied in frames of this PhD project inspire hope that a candidate for such an universal scintillator can finally be found.

The project is based on a close collaboration with the following institutions:

- King Mongkut's University of Technology Thonburi (KMUTT), Bangkok, Thailand

Our collaboration with KMUTT (group of Prof. Weerapong Chewpraditkul) was initiated in 2018 and is formal (i.e. based on a signed official memorandum). KMUTT delivers crystalline and ceramic samples of oxide scintillators (insulating) activated with rare-earth ions. 10 joint papers (NCU & KMUTT) have been published so far.

- Łukasiewicz Research Network - PORT (LNR-PORT), Wrocław, Poland

Our collaboration with LNR-PORT is simply a prolongation of an informal collaboration with Nanyang Technical University (NTU), Singapur (group of Dr. Muhammad D. Birowosuto), which was initiated in 2015. From 2022 Dr. Birowosuto works at LNR-PORT as a principal investigator at Photonic Materials & Structures Group. LNR-PORT delivers crystalline samples of novel lead and lead-free halide scintillators (insulating). 16 joint papers (NCU & NTU and NCU & LRN-PORT) have been published so far.

- Leibniz-Institut für Kristallzüchtung (IKZ), Berlin, Germany

Our collaboration with IKZ was initiated in 2015. Now it is informal, but in 2017-2022 we were conducting a joint project (NCN/DFG Beethoven 2). IKZ delivers crystalline samples of oxide scintillators (semiconducting). 8 joint papers (NCU & IKZ) have been published so far.

1.3. Work plan

The samples delivered periodically by KMUTT, LNR-PORT or IKZ (other institutions are also thinkable) will be characterized in Toruń. First their scintillation properties in response to X-rays (radioluminescence) and gamma radiation (pulse height spectra, scintillation time profiles) will be evaluated. Then, to shed light on the distribution of defect levels inside the material, low and/or high temperature thermoluminescence will be measured. These results will provide a feedback for further growth series. In this way, by choosing optimal growth conditions and material components, an enhancement of efficiency and/or speed of the studied scintillator is likely to be achieved.

1.4. Literature

- W. Chewpraditkul et al., *Radiat. Phys. Chem.* **208** (2023), 110951
- D. Zhu et al., *J. Adv. Ceram.* **11** (2022), 1825
- W. Chewpraditkul et al., *Opt. Mater.* **134** (2022), 113186
- D. Kowal et al., *Mater. Today Chem.* **29** (2023), 101455
- F. Maddalena et al., *J. Mater. Chem.* **C10** (2022), 11266
- L.J. Diguna et al., Mater. Adv. **3** (2022), 5087
- A. Bachiri et al., *Opt. Mater. Express* **13** (2023), 1345
- M.E. Witkowski et al., *Opt. Mater. X* **16** (2022), 100210
- W. Drozdowski et al., *Opt. Mater. X* **15** (2022), 100157
- Z. Galazka et al., *J. Alloys Compd.* **818** (2020) 152842

1.5. Required initial knowledge and skills of the PhD candidate

The candidate is expected to have a theoretical background in solid state physics and spectroscopy on academic level, as well as to have sufficient expertise in measurement techniques and data analysis. Experience in optical and gamma spectroscopy will be a chief asset. Some programming skills (Python) are welcome. Basic knowledge in electronics is also desired, since the student will carry on measurements using various experimental setups, all of them full of electronic items and devices.

1.6. Expected development of the PhD candidate's knowledge and skills

The student will master several experimental techniques used to study scintillation properties, as well as he/she will learn the fundamentals of scintillator-related physics. He/she will improve his/her skills in programming, data analysis and drawing conclusions from data.