Project report 2020

INTELUM

Advanced scintillating fibres and Cerenkov fibres for new hadron and jet calorimeters for future colliders

MAIN PARTICIPANTS

			
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OVERVIEW *(keep within this page)*

Starting year: 2016 **Current researchers** (permanent/non-permanent): 5 person-month/year

Positioning *(Multiple selection allowed – total 100%)*	**Transportation**	**Energy**	**Eng. for Health**
Materials and structure design		100	
Surfaces and interfaces			
Simulation and modeling			

Other:

Include partner from ☒ Outside ELyT ☒ Industry

Main funding source(s)
☒ Public project(s) ☒ Industrial ☒ Own resources

IFS CRP/LyC project? ☐ Yes ☒ No

For main projects: European project, Intelum Rise2020. International and intersectoral mobility
Intelum is an European Marie Skłodowska-Curie Research and Innovation Staff Exchange (RISE)
agreement No 644260 (Intelum), under Grant Agreement no. 654168 (aida 2020).ERC Advanced Grant no. 338953 (TICAL), by ASCIMAT project under Grant agreement no. 690599 and by COST Action TD1401 (FAST)

Highlights & Outstanding achievements *(3-5 bullet points)*

- Raw powders from several producers were tested and many tens of fibres of both Ce^{3+}-doped $Lu_3Al_2Al_3O_{12}$ (LuAG:Ce) /$Y_3Al_2Al_3O_{12}$ (YAG:Ce) (Length up to 1 m; 1-2 mm Φ round-shaped; 2x2 mm square fibres) have been delivered to CERN.
- The feasibility of producing between 20-200km of fibres with degradation of their optical properties below 10% at 1 MGy level and well defined production costs, has been demontrated.
- A novel optimization concept, related to the development of based on Mg^{2+} or Li^{+} codoping of Ce-doped garnets (LuAG,YAG and novel GAGG hosts) provided a new technological way to obtain faster scintillation response and higher light yield.
- We were mainly involved by the growth and the optical and XANES basic characterizations of Ce^{4+} in Ce^{3+}, Mg^{2+}-co-doped $Gd_3Al_2Ga_3O_{12}$ garnet crystals.

PROJECT DESCRIPTION

Background (10 lines max; Calibri 11)

Currently, new concepts are being considered for hadron and jet calorimetry in high energy physics experiments, in order to improve the energy resolution of these detectors by a factor of at least two. This is a prerequisite for future studies at the high luminosity, large hadron collider as well as at future electron and proton colliders: from LHC Large Hadron Collider (2008) to HL-LHC (2026). High Luminosity- Large Hadron Collider Amongst the few concepts being proposed, scintillating and Čerenkov fibres are considered very promising candidates. The collaboration between Lyon and Sendai is focused on the academic exchanges to develop micro-pulling-down crystal growth and other new types of fibre technology.

This project was completed in 2020. Another one has been launched with IMR-Tohoku and ILE (Institute of Laser Engineering) in Osaka on fast scintillators to detect neutrons.

Key scientific question (2 lines max; Calibri 11)

-demonstrate feasibility of producing crystalline fibres with consistent quality and defined costs
-demonstrate sufficient radiation hardness of the fibres

Research method (8 lines max; Calibri 11)

Commun research activities of both (ILM) at UCBLyon1 and IMR & NICHe of Tohoku University are based on engineering process, developments and applications in the field of scintillators and crystal growth. The teams are now two leading groups in both, crystal growth fibres and shaped crystals using micro-pulling down (µ-PD) and Czochralski techniques, structural and spectroscopic characterizations as well as mechanism analysis in scintillating crystals. The two teams have created novel or improved materials based on Ce^{3+}-doped $Y_3Al_5O_{12}$ (YAG), Ce^{3+}-doped $Lu_3Al_5O_{12}$ (LuAG) and Ce^{3+}, Mg^{2+}-co-doped $Gd_3Al_2Ga_3O_{12}$ garnets that match the challenging requirement specifications informed by CERN in view of the use in high energy. The project also lead to important impacts in other domains such as functional medical imaging and homeland security.

Research students involved *(gray color for previous years)*

Ph.D. candidates (years, institution):

- Bouita Rekia iLM, UCBL (2016-2019)

Post-Doc:

- Omar BENAMARA (iLM, UCBL) (2018)
- Guillaume ALLOMBERT-GOGET (iLM, UCBL) (2018)

Visits and stays *(gray color for previous years)*

FR to JP (date, duration):

-K.Lebbou (DR CNRS) July 14 to August 14 2018 (one month)

-P.Veber (IR CNRS) August 2018 (one month)

-G. Boulon (Pr UCBL) Feb 2016, Feb 2017, Feb 2018, March 2019, Oct 2019, (3 weeks)

JP to FR (date, duration):

-A. Yoshikawa (Pr) (IMR) one week Feb 2017

-N. Sarukura (Pr) (ILE-Osaka) two weeks Nov 2017
-M. Empizo (Ass. Pr.ILE-Osaka) two weeks Nov 2017, Nov 2018, June 2019, one month Feb 2020

COMMUNICATIONS AND VALORIZATION

Journal publications *(gray color for previous years)*

	Authors	Title	Journal	Vol.	pp. / ID	Year	DOI
1	G. Dantelle, G. Boulon, Y. Guyot, D. Testemale, M. Guzik, S. Kurosawa, K. Kamada, A. Yoshikawa	Research of efficient fast scintillators. Evidence and XANES characterization of Ce^{4+} in Ce^{3+}, Mg^{2+}-co-doped $Gd_3Al_2Ga_3O_{12}$ garnet crystals	Physica Status Solidi B	257 n°8	1900510 (7 pages)	2020	DOI: 10.1109/TNS.2018.2840160
2	M. Yoshino, K. Kamada, V.Kochurikhin, M. Ivanov, M. Nikl, S. Okumura, S. Yamamoto, J. Yeol Yeom Y. Shoji , S. Kurosawa, Y. Yokota, Y. Ohashi, A. Yoshikawa	Li^+, Na^+ and K^+ co-doping effects on scintillation properties of Ce:$Gd_3Ga_3Al_2O_{12}$ single crystals	Journal of Crystal Growth 491, 1–5	491	1-5	2018	https://doi.org/10.1016/j.jcrysgro.2018.03.004
3	C. DUJARDIN, E. AUFFRAY, E.BOURRET, P. DORENBOS, P. LECOQ, M. NIKL, A. N.VASIL'EV, A. YOSHIKAWA, REN-YUAN ZHU	TRENDS AND ADVANCES IN INORGANIC SCINTILLATORS,	IEEE TRANSACTIONS ON NUCLEAR SCIENCE	65(8)	1977	2018	https://doi.org/10.1002/pssb.20190051
4	K. Kamada, Y. Shoji, V. Kochurikhin, A. Nagura, S. Okumura, S. Yamamoto, J. Yeom, S. Kurosawa, J. Pejchal, Y. Yokota, Y. Ohashi, M. Nikl, M. Yoshino, A. Yoshikawa	Large Size Czochralski Growth and Scintillation Properties of Mg2+ Co-doped Ce:Gd3Ga3Al2O12	IEEE Trans. Nucl. Sci.	*63(2)*	443	2016	**DOI:** 10.1109/TNS.2016.2521399

Conferences *(gray color for previous years)*

	Authors	Title	Conference	Date	City	Country	DOI *(if applicable)*
1	G. Boulon,G.Dantelle, Y. Guyot, D. Testemale, M. Guzik, S. Kurosawa, K. Kamada, A. Yoshikawa	Ce^{4+} evidence in the fast scintillation mechanism of Ce^{3+}, Mg^{2+}-co-doped garnet crystals	International Conference on Scintillating Materials and their Applications SCINT 2019, Sendai, Japan Plenary lecture	26Sept-9Oct, 2019	Sendai	Japan	http://www.scint2019.imr.tohoku.ac.jp/
2	G. Boulon,G.Dantelle, Y. Guyot, D. Testemale, M. Guzik, S. Kurosawa, K. Kamada, A. Yoshikawa	Evidence of Ce^{4+} ions by XANES spectroscopy in the new fast scintillator crystal: Ce^{3+}, Mg^{2+}-co-doped $Gd_3Al_2Ga_3O_{12}$ garnet	8th International workshop (PRE) :Photoluminescence in Rare Earths: Photonic Materials and Devices	4-6 Sept 2019	Nice	France	https://pre19.sciencesconf.org/
3	G. Boulon,G.Dantelle, Y. Guyot, D. Testemale, M. Guzik, S. Kurosawa, K. Kamada, A. Yoshikawa	XANES evaluation of Ce^{4+} ions in Ce^{3+}-doped YAG and Ce^{3+}/ Ce^{3+}-Mg^{2+}/ Ce^{3+}-Li^{+}-doped either $Lu_3Al_5O_{12}$ or $Gd_3Ga_3Al_2O_{12}$ garnet crystals for scintillators	8th Symposium on Optical Materials (IS-OM8) Honorary Chair	9-14 June 2019	Wroclaw	Poland	https://is-om8.chem.uni.wroc.pl/