Integrated Project: Development of the Next Generation Detector for High Energy Physics

The next-generation detectors for high energy physics experiment including ILC and hadronic detector have triggered the search for novel scintillating materials. Therefore we have developed a new fiber scintillator with a fine spatial resolution and good light output in this project using a micro pulling down method and also other methods.

The Standard Model of particle physics is a theory unifying the electromagnetic, weak and strong interactions, as well as classifying all the known subatomic particles. Later, Prof. S. Sakata, Prof. M. Kobayashi, Prof. H. Masukawa and other Japanese researchers significantly contributed to this model. Although this model assumes that neutrino mass is zero, Japanese and other researchers found the evidence of the neutrino mass related to the neutrino oscillation. Moreover, we cannot describe dark matter by this model up to now. Thus, new theory should be developed, especially with focus on the description of weak interaction.

New theories have emerged recently, such as Supersymmetric theory, extra dimensions theory and so on, however, their experimental proof is missing.

The particle identification, which means to discriminate generated particle such as pion, proton, neutron, electron and others at the moment of the collision, is important to evaluate the collision event. At this collision event, we can find new physics or new particle. The position-sensitive detector can be used for the particle identification.

For position–sensitive detectors fiber type scintillators can be used. The candidates for the new materials are inorganic crystals such as oxides due to their higher radiation hardness when compared o organic materials such as plastic ones which are usually used in the form of fibers for high energy physics experiments [1, 2].

Our ICC-IMR teams including IMR/Tohoku University are members of "Intelligentsia supporting world-famous research institute to develop next-generation particle detectors" project (INTELUM) which is one of the CERN-coordinated projects with focus on development of the next-generation detectors for high energy physics experiment including ILC and hadronic detector. In this project, we develop a new fiber scintillator with a fine spatial resolution and good light output using our original crystal growth technique: the micro-pulling-down method [3].

The final purpose of the ICC-IMR project is to search for new scintillation materials and to develop the fiber crystal growth technology for a position-sensitive calorimeter (particle tracking detector) to detect generated particles from electron-positron collisions in the ILC project. Moreover, these materials can be applied to the next-generation hadron colliders (hadron-hadron collisions, post LHC).

Our Team members from Institute of Physics /Czech Academy of Sciences, University of Milano-Bicocca (Italy), General Physics, Institute of Russian Academy of Sciences, Université Claude Bernard Lyon 1 (France) and IMR/Tohoku University, and most of our members join INTELUM project.

We grew several inorganic fibers such as RE-doped CaF_2, RE:$(Gd, Lu)_3(Ga, Al)_5O_{12}$, RE:$(Gd, La)_2Si_2O_7$ by the micro-pulling down method as shown in Fig.1., where RE are rear-earths such as Ce or Nd.

After, the the light outputs and decay times of the cut and/or polished samples were evaluated in IMR/Tohoku Univ. To evaluate the scintillation properties, we have developed and assembled some photon detector systems using Si-based diodes (i.e. Si-avalanche photo-diode, Si-photo-multiplier) and circuits such as a pre-amplifier, shaper, etc. (Fig. 2).

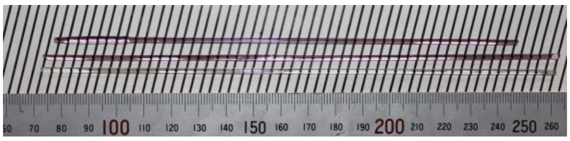

Fig.1 Photograph of fiber scintillator.

Moreover, we showed that some materials co-doped with Mg or other alkali metals have shorter decay times, and radiation hardness of some samples was improved [4]. Thus, Ce: $(Gd, Lu)_3(Ga, Al)_5O_{12}$, Ce:$(Gd, La)_2Si_2O_7$ codoped with Mg or other metals were also grown and their scintillation properties were investigated.

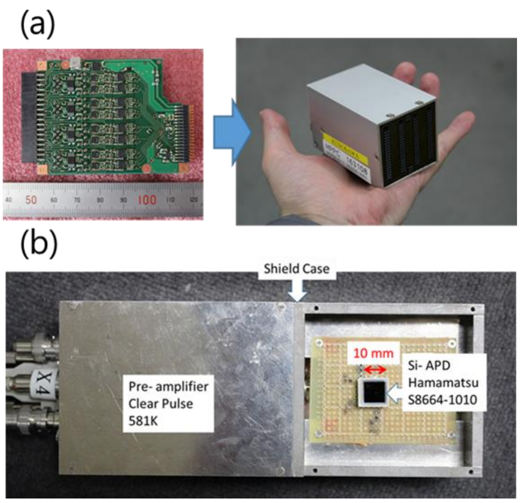

Fig. 2 photograph of evaluation system for light outputs, energy resolution: Si-Photo Multiplier (a) and Si-Avalanche photodiode (b)

Additionally, 1-cm long fiber samples of Ce/Mg:$Lu_3Al_5O_{12}$ and Ce/Mg:$Y_3Al_5O_{12}$ with 3x3 mm^2 cross-section or 3 mm diameter with Mg concentration 0, 3,000 and 6,000 ppm prepared in Tohoku University were supplied to CERN and Czech team. They also tested the scintillation properties such as light output or decay time.

Up to now, we succeeded in growing several fibers with good light outputs of over 30,000 photons/MeV, fast decay time of 40 – 90 ns and good radiation hardness of over 1 Gy/h for some samples, which means that the goal of the ICC-IMR project were achieved. Thus, our results have supported INTELUM activities, and our teams could play a very important role in the INTELUM.

As for the next steps, we grow longer fiber with a length of over 200 mm in order to use it in the experiment. The photon-self-absorption is one of the big issues for such a long fiber. Thus, we studyied how to suppress the photon-self-absorption. We suppose to find the candidate material for the next-generation experiment by 2019 at the latest, therefore we continue the searching the novel materials.

Appendix and acknowledgement

Regarding the ICC-IMR project and INTELUM projects, over 10 foreign researchers have visited in Sendai in the past 2 years, while 9 Japanese researchers including 5 students visited collaborating laboratories such as CERN, Institute of Physics /Czech Academy of Sciences, University of Milano-Bicocca and Université Claude Bernard Lyon 1. Additionally, INTELUM meeting was held in Sendai in 2016. Travel expenses of some researcher were supported by this ICC-IMR project. Moreover, we have published several papers [5-8] regarding as this project.

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