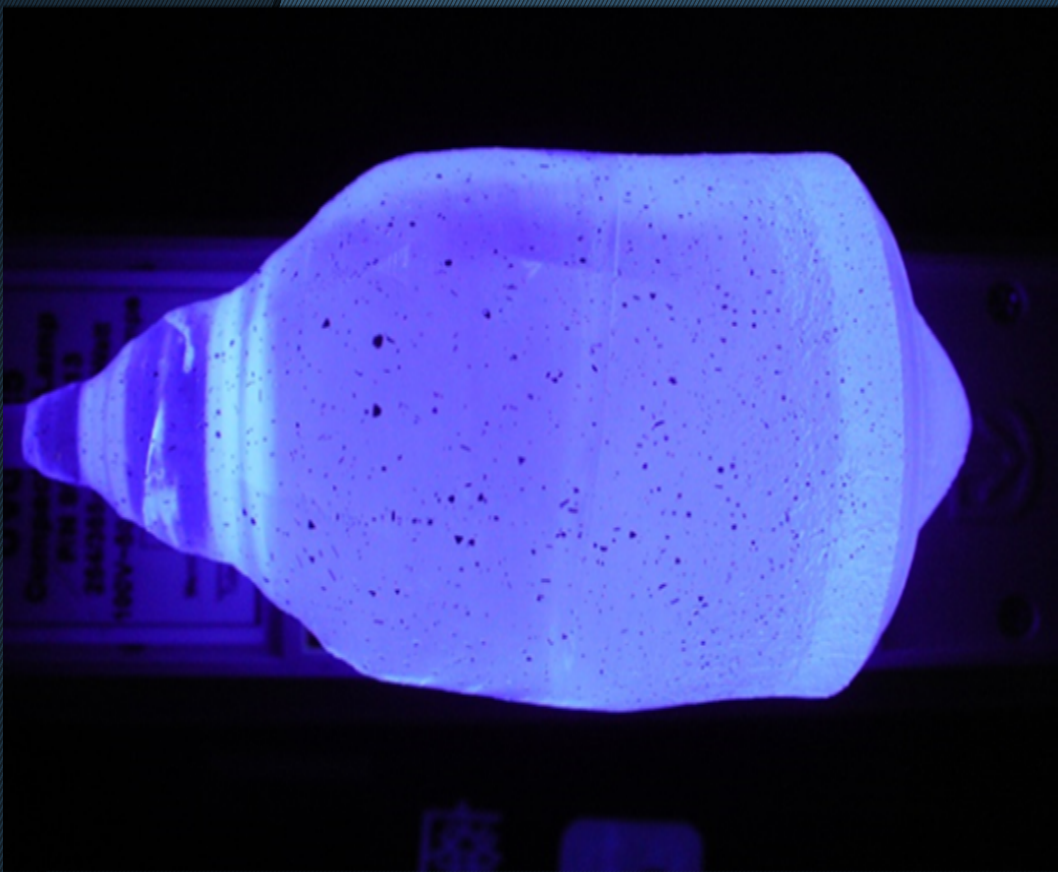
ANNUAL REPORT 2014

April 2014 - March 2015

ANNUAL REPORT 2014 Yoshikawa Lab., IMR, Tohoku Univ.



Yoshikawa Lab.

Since 2007

IMR, Tohoku University

Contents

Preface

Dear Colleagues,

Thank you for downloading the Annual Report of the *Yoshikawa Laboratory* in the Institute for Materials Research (IMR) and *Yoshikawa Project* in the New Industry Creation Hatchery Center (NICHe), Tohoku University. As usual, we have prepared the Annual Report as an electrical version so as to save couple of trees necessary for the paper production and to make it easier for you to access the copy of the Report at any time when you have your computer in your hands.

It contains a summary of our research activities and selected papers published in FY2014. Current issue covers our progress within academic year from April 2014 to March 2015. Within this period we had continued development of our basic technologies considering both practical and fundamental points of view. Some of our achievements are summarized below:

- Further progress in studies of Ce: GAGG crystals for their application as gamma-ray scintillators. It should be noted that the performance was further enhanced by divalent ion codoping and explained by the stabilization of Ce^{4+} center and its participation in scintillation mechanism. This strategy appeared successful in case of aluminum garnets and orthosilicates. Food survey monitoring system and gamma camera for environment inspection are under development.
- Establishment of crystal growth technology of halide materials. As an example, Eu:SrI_2 crystals were grown by the micro-pulling down method including crystals of one inch in diameter.
- Development of La-substituted GPS crystal that has exceptionally high temperature stability.
- Bulk crystal growth of langasite type crystals. Al-substituted CNGS and CTGS crystals are studied for their application in oscillators, resonators, and combustion pressure sensors. The homogeneity as well as material constants were evaluated by the UMS technology.

Our long term strategy is to develop chains of research capabilities that connect three areas of expertise including (1) materials production (crystal growth and solid-state synthesis), (2) materials physics and characterization, and (3) application of the materials in contemporary devices. Such chain was already built for the scintillating materials. Now we are on the way to apply this strategy to piezoelectric materials.

Our projects are always supported by our colleagues from all over the world, and we note that this collaboration is in most cases very successful. The details of their contribution can be found in the papers published within the above period and included into the Report.

Many laboratory members took part in preparation of this Report. I appreciate their efforts and kind help very much. I wish also thank all of our colleagues from Japan and overseas that had participated in our research projects and significantly contributed to their progress.

We will do our best to contribute to the human happiness in order to return a favor from all of you.

Akira YOSHIKAWA

Professor,
Institute for Materials Research (IMR), Tohoku University
New Industry Creation Hatchery Center (NICHe), Tohoku University
March, 2015

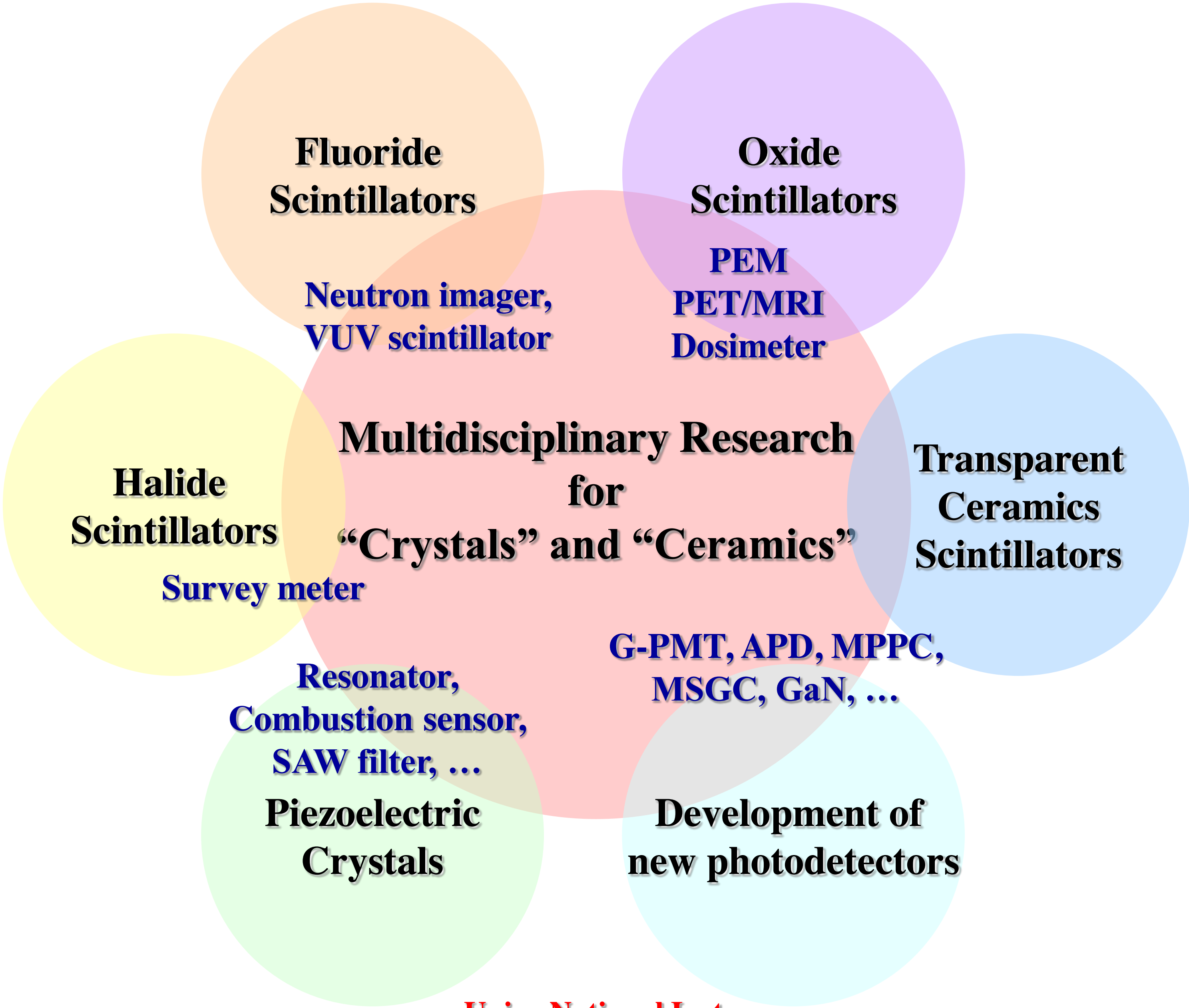
Research digest

Research Activities in 2014

Development of scintillators, lasers, piezoelectric crystals and crystal growth technology

Int'l collaboration

Inst. Phys. (Czech), Pisa Univ. (Italy), Milan-Bicocca Univ. (Italy),
Ecole Polytechnique (France), Univ. Lyon 1 (France), General Physics Inst. (Russia)
Soltan Institute for Nuclear Studies (Poland), Delft Univ. (New Zealand)



Univ., National Inst.

Univ. of Tokyo (Kamiokande, Takahashi Lab.), Kyoto Univ. (Tanimori Lab),
Osaka Univ. (Sarukura Lab), Nagoya Univ. (Iijima Lab, Uritani Lab, Iguchi Lab),
Hiroshima Univ. (Fukazawa Lab), Kyushu Univ. (Ishibashi Lab), JAEA (Fukushima headquarters)

Company

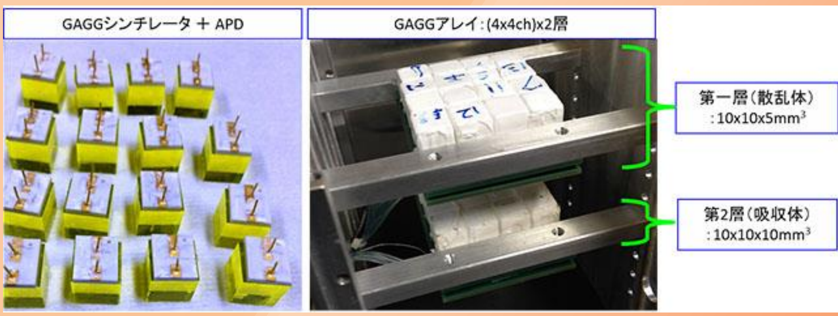
Tokuyama, Furukawa, TDK, Hamamatsu Photonics, Canon, Mitsui Kinzoku,
Chiyoda Technol, Nihon Kessho Kogaku, Hitachi-Aloka Medical, Pony Industry, Oxide, GES
Tanaka Kikinzoku Kogyo, Furuya, Star seiki, TEP, Toei Scientific Industrial

OXIDE SCINTILLATORS

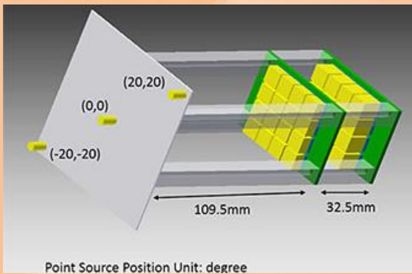
γ-ray detection
(PET, SPECT, Gamma-camera, oil logging)

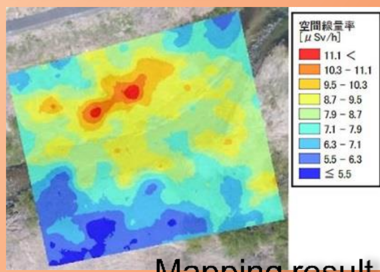
Ce:GAGG $Ce:Gd_3(Ga,Al)_5O_{12}$

Cerium doped gadolinium aluminum gallium garnet



Elements of the detector and their constitution





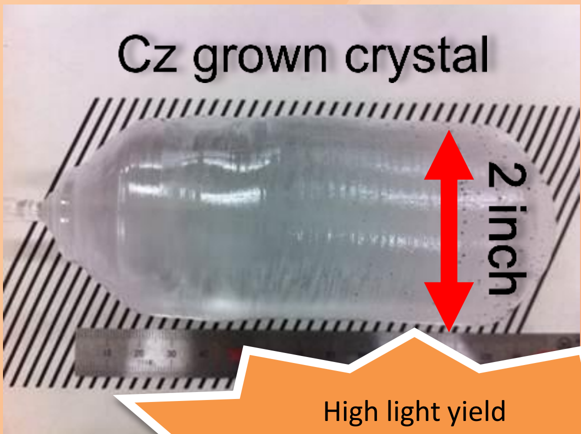
Mapping result

GAGG equipped gamma camera on unmanned helicopter succeeded in mapping the radioactive Cs at Fukushima.

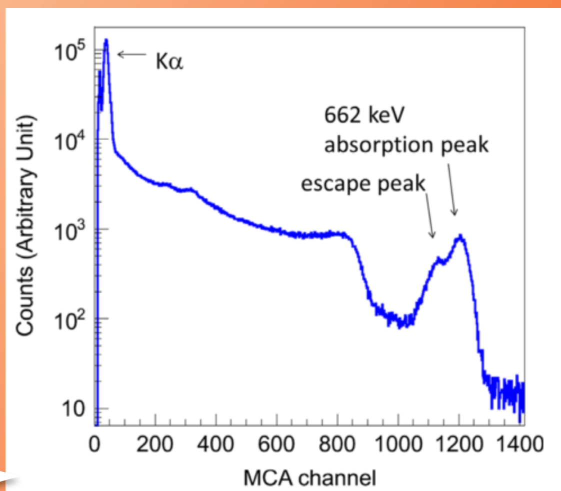
Reference：http://www.jst.go.jp/pr/announce/20140905/index.html

Ce:La-GPS $Ce:(La,Gd)_2Si_2O_7$

Cerium doped lanthanum admixed gadolinium pyrosilicate



High light yield (~40,000ph./MeV) and high energy resolution (~5% FWHM) for 662 keV



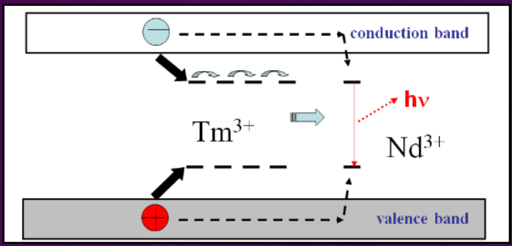
Pulse height spectrum

Good thermal stability until high temperature (>150°C)

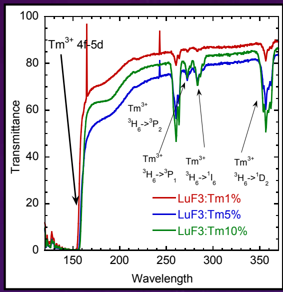
Fluoride scintillators

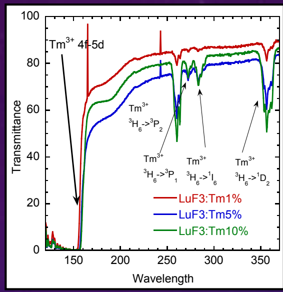
VUV scintilltors

Schematic of energy transfer from Tm^{3+} to Nd^{3+} observed in some fluoride crystal hosts



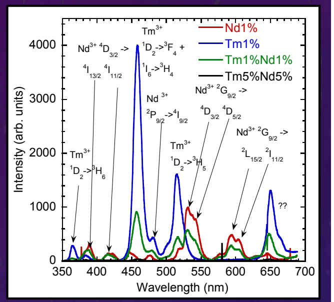
Transmittance



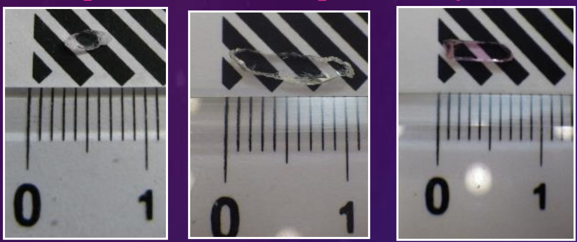


Radioluminescemce

(X-ray 40Kv40mA CuKα)



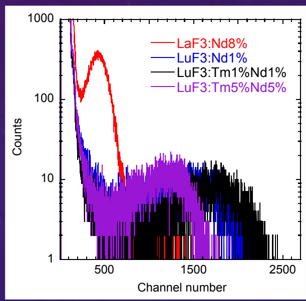
Examples of the cut and polished crystals



LuF_3:Nd1% LuF_3:Tm1% LuF_3:Tm5%Nd5%

Light yield

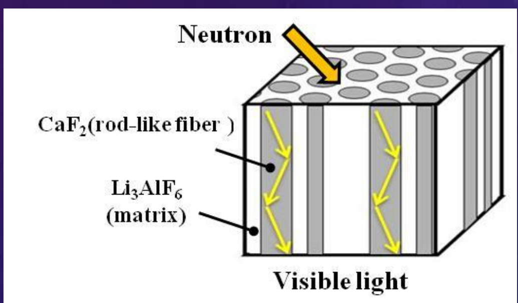
(241 Am 5.5 MeV alpha rays, shaping time 500ns)



Channel numbers:
LaF_3:Nd8% : 421
LuF_3:Nd1%: 1550
LuF_3:Tm1%Nd1%: 1670
LuF_3:Tm5%Nd5%: 1230

Eutectic composite scintillators

Concept of eutectic composite scintillators for neutron detection

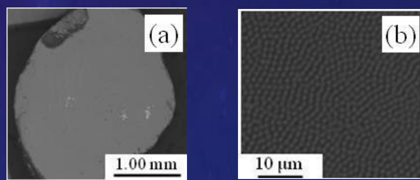


As-grown eutectic composite scintillators

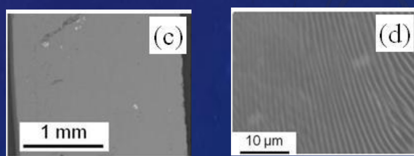
Eu doped CaF_2/Li_3AlF_6 eutectic crystal

Backscattered Electron Images

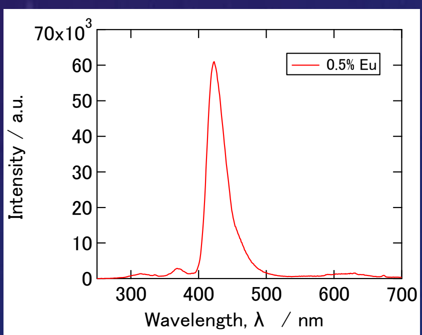
Transverse cross-section



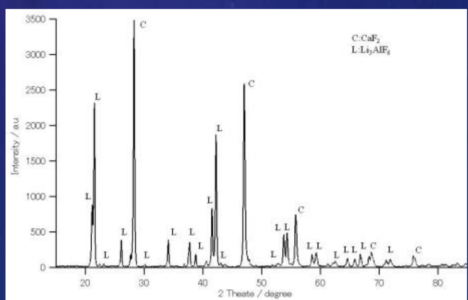
Vertical cross-section along the growth direction



Radioluminescemce spectrum

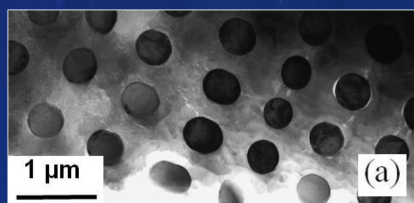


Powder X-ray diffraction pattern

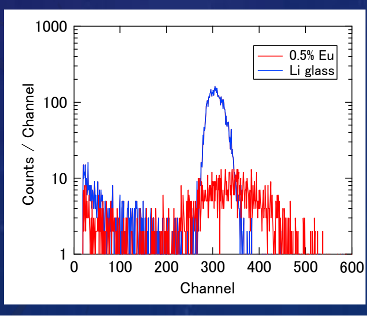


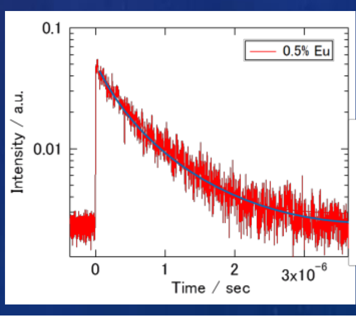
Transmission Electron Microscope analysis

Transverse cross-section

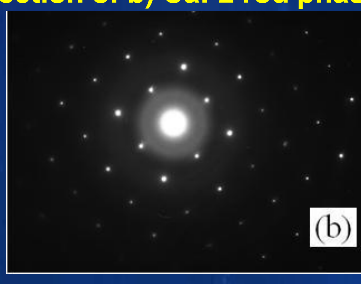


Pulse height spectrum and decay curve under ^{252}Cf neutron excitation





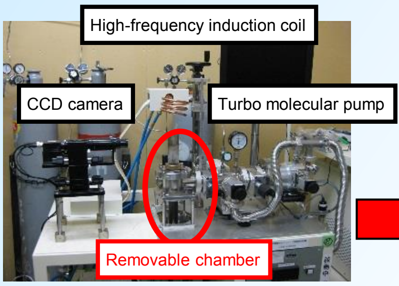
Electron diffraction pattern from [001] incidence direction of b) CaF2 rod phase



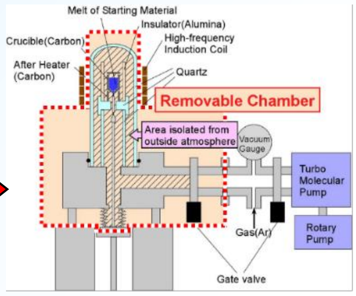
Halide scintillators

Aim of this work was to prepare new halide materials for radiation detectors (scintillators and photodetectors) and study their optical properties. Single crystals of In:SrI_2, Sn:SrI_2, Eu:SrI_2, Pr:$CeBr_3$, were prepared by the atmosphere-controlled modified micro-pulling-down (μ-PD) method and by the vertical Bridgman method.

Experimental arrangement of halide μ-PD machine.



Crystal growth

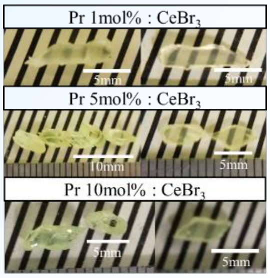


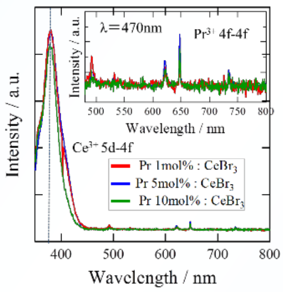
Removable chamber

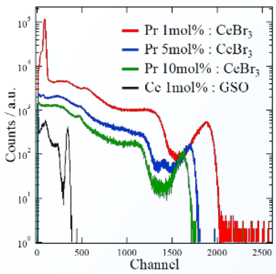
Setting of experiment in globe box

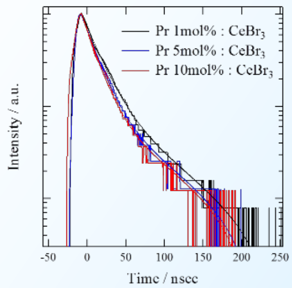
Halides are hygroscopic materials which easily reacts with air and air moisture under formation of oxy- and hydroxy-halides, therefore careful handling of starting materials under protective argon atmosphere in a globe box is required.

Crystals prepared by micro-pulling-down method



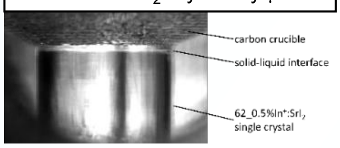




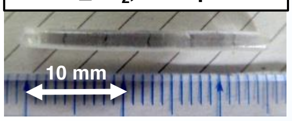


As grown **Pr^{3+}:$CeBr_3$** single crystals prepared by μ-PD method doped with Pr^{3+} in nominal concentrations 1, 5, and 10 mol%. Crystals were characterized by measuring the photoluminescence emission spectra (λ_{ex}=340 nm), pulse height spectra (γ-ray source ^{137}Cs at 662 keV), and scintillation decay time.

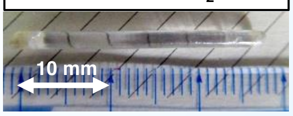
Growth of SrI_2 crystal by μ-PD



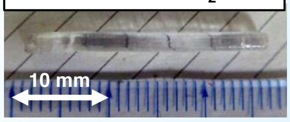
66_SrI_2, undoped

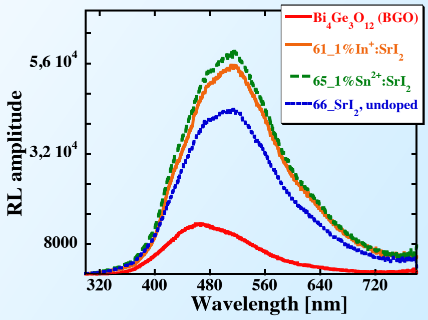


61_1%In:SrI_2



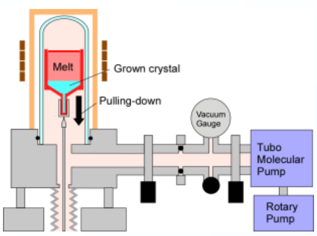
65_1%Sn:SrI_2





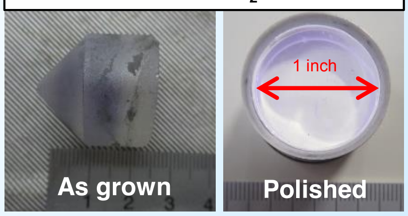
SrI_2 single crystals doped with **ns^2 ions** (In^+ and Sn^{2+}) were grown by the μ-PD method. Radioluminescence spectra were measured showing one broad emission band at 510 nm related to the SrI_2 host.

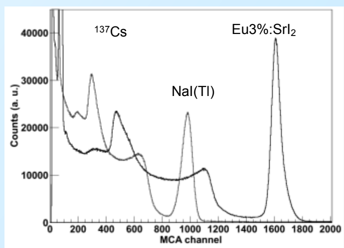
Crystals grown by vertical Bridgman method using modified μ-PD furnace



Eu:SrI_2 single crystals were grown by vertical Bridgman method using modified μ-PD furnace. Light yield for Eu3%:SrI_2 reached of 78,000 ph/MeV with energy resolution of 4.4 % at 662 keV.

Eu3%:SrI_2



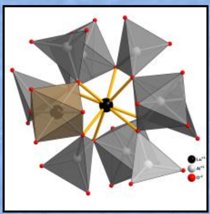


Transparent ceramic scintillators

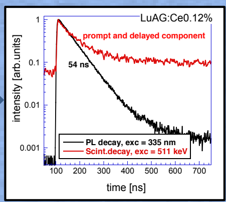
Introduction

Advantages of ceramics

- Better chemical uniformity than single crystals.
- Can be produced with high dopant concentration.
- Economical especially for high-melting materials.
- Defects present in single crystals due to high melting temperature (for example anti-site defects in $Lu_3Al_5O_2$:Ce lead to sub-microsecond slow components in scintillation decay)



Anti-site defect (Lu resides on octahedral Al site)

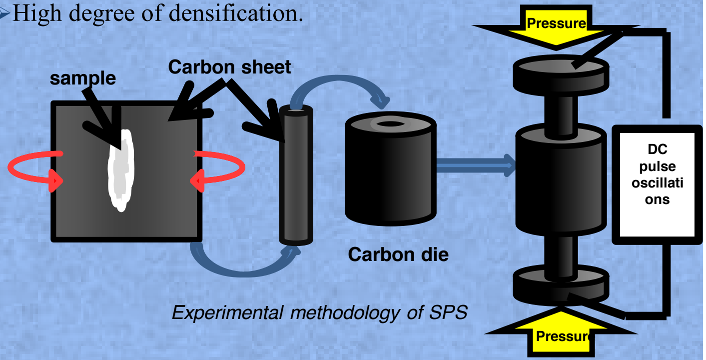


Antisite-defects absent in ceramics → submicrosecond components also expected to be absent

Spark plasma sintering(SPS), Collaboration with Goto lab, IMR

Advantages of SPS

- A rapid consolidation rate appropriate for densification of variety of ceramics.
- Highly reductive condition due to carbon die and punch and vacuum environment.
- High degree of densification.

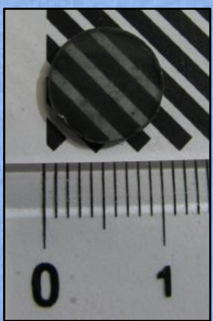


Experimental methodology of SPS

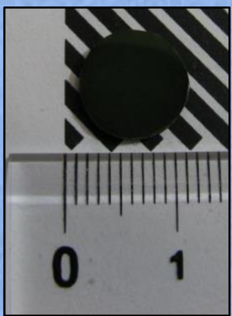
$Lu_3Al_5O_{12}$:Ce(LuAG:Ce) nanoceramics

LuAG:Ce Nanopowder prepared by unique radiation-induced precipitation 20-60 nm size, Ce concentration around 1.5 mol%
(see J. Barta, V. Cuba et al.: J. Mater. Chem., 2012, 22, 16590 for details)
Napowders sintered by SPS at 1700C at 100MPa pressure for 45 minutes.
Sintering temperature 1700C
Rapid pre-heating to 1000C in 4 min

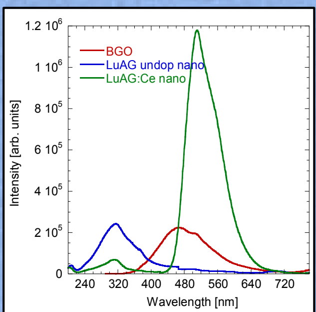
LuAG samples sintered by SPS method



LuAG undoped -transparent!



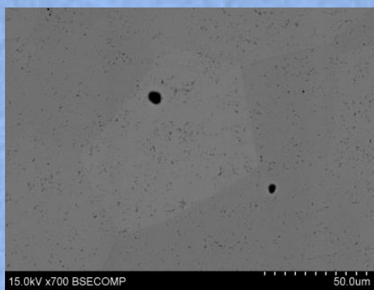
LuAG:Ce



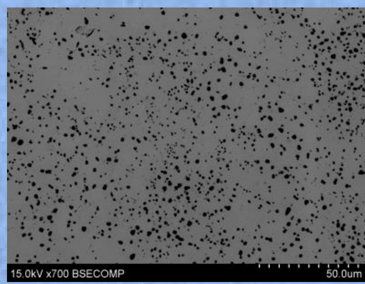
Radioluminescence intensity for the nanopowder ceramic 5 times higher of that of the $Bi_4Ge_3O_{12}$ standard scintillator!

Defect emission observed for both samples at 313 nm

Backscattered electron images (BSE)

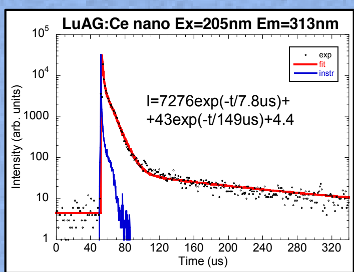


LuAG undoped – small amount of pores, large grains

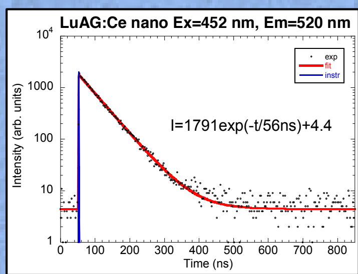


LuAG:Ce – large amount of pores, no grains apparent

Photoluminescence decay kinetics



313nm defect emission under band-to-band excitation (193nm) – slower components related to other complex defects



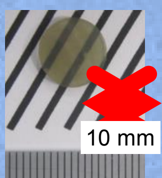
Ce^{3+} emission under direct excitation (452nm)

Samples from nanopowder sintered with rapid pre-heating:
Undoped sample clearly transparent, few pores, large grains
Ce-doped sample opaque, many pores, no grains distinguished
Different nature of defect luminescence when compared to samples prepared without rapid preheating

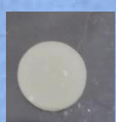
J. Pejchal et al., WGMSC1 2014, Shanghai, China

Ce:$SrHfO_3$

Hf : High Z, but high melting point.
Crystal growth impossible → Task for the SPS method.

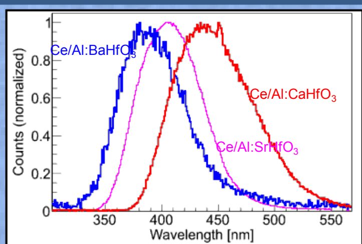


Sintered $SrHfO_3$:Ce



$SrHfO_3$:Ce after annealing

Annealed $SrHfO_3$:Ce Under UV excitation



Radioluminescence of other Ce-doped hafnate ceramics

Photodetectors

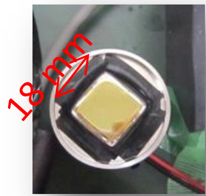
We investigate radiation response of our scintillators using a photomultiplier tube and semi-conductor in a specially designed temperature chamber.

1, Pulse-height Measurement System

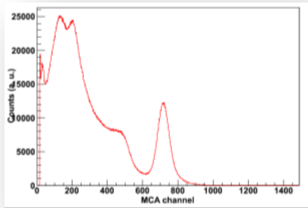
We use several photo-detectors for pulse height measurements.

PMT (Photo multiplier tube)

- ✓ Ultra and super –bialkali (UBA and SBA) PMTs for basic measurement and applications
- ✓ Ruggedized PMTs for oil well logging
- ✓ Multi-anode PMTs for medical imaging or other exciting fields

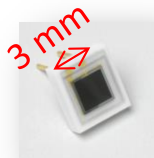


Ultra Bialkali (UBA)
R7600U-200

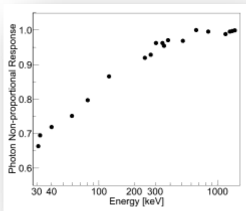


APD (avalanche photodiode)

- ✓ High quantum efficiency (up to ~80%)
- ✓ Wide sensitive range (ex: 320 -1000 nm for S8664 HPK)

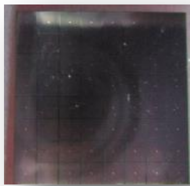


APD

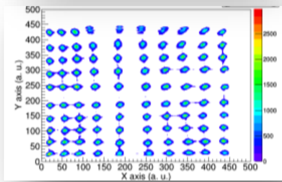


MPPC (Multi-Pixel Photon Counter)

- ✓ Photon counting
- ✓ multi-channel MPPC (MPPC array)

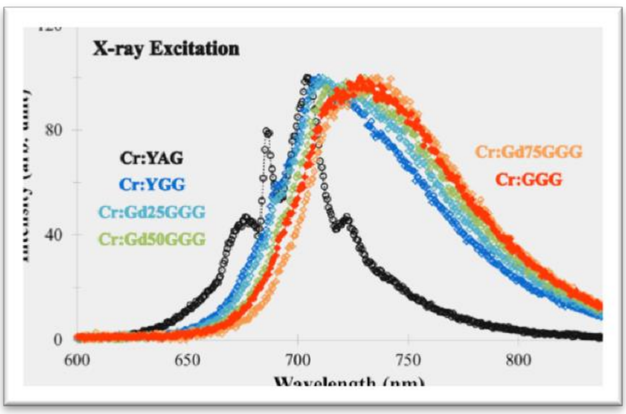


MPPC array



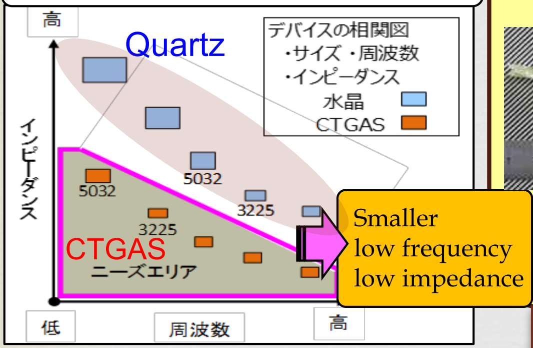
2, New Spectrometers

We have developed new spectrometers with a wavelength dynamic rage for emission spectra from VUV to near Infra-red

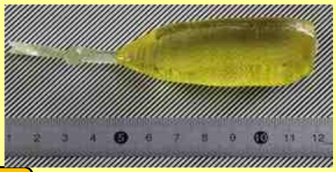


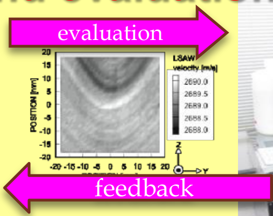
Piezoelectric Single Crystals

Target area of resonators



Development and evaluation of CTGAS



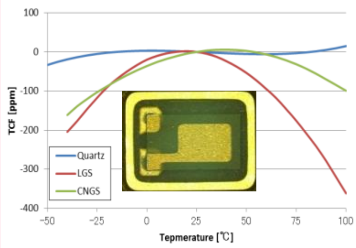


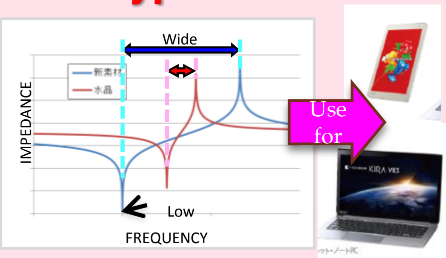
Ultrasonic Micro-Spectroscopy technology piezoelectric characteristic

application

application

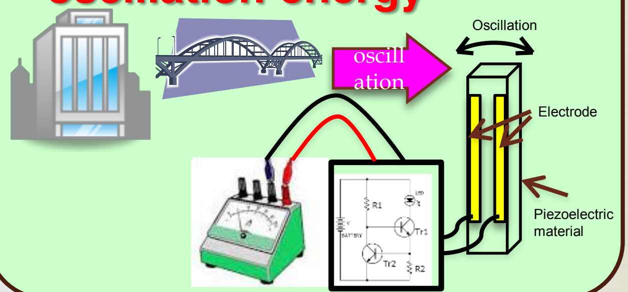
Development for new type resonator





Smaller, low-power consumption, rapid booting and high electro-mechanical coupling resonator

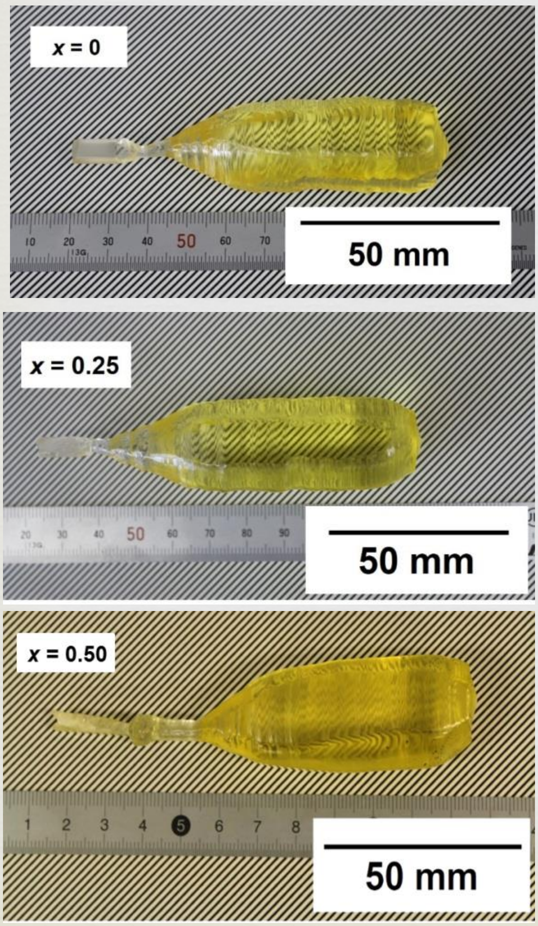
Energy harvester using oscillation energy



Clean energy harvester

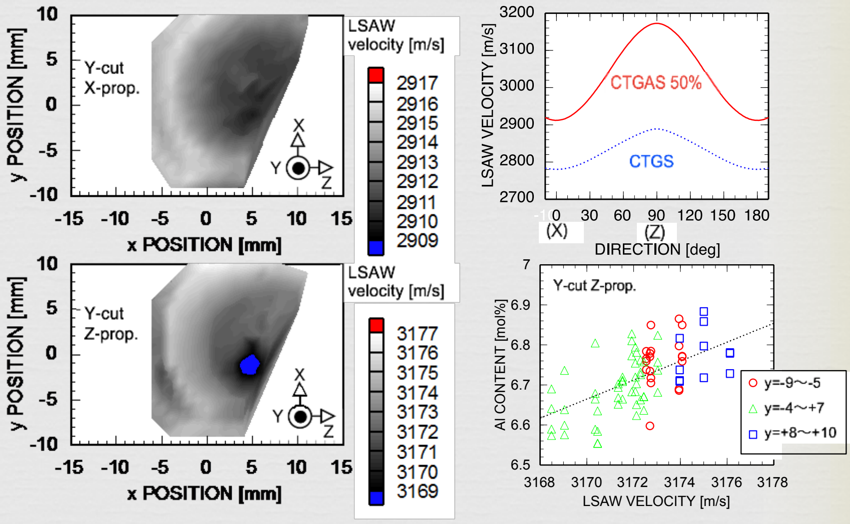
Crystal growth by Cz method

$Ca_3Ta(Ga_{1-x}Al_x)_3Si_2O_{14}$ crystals

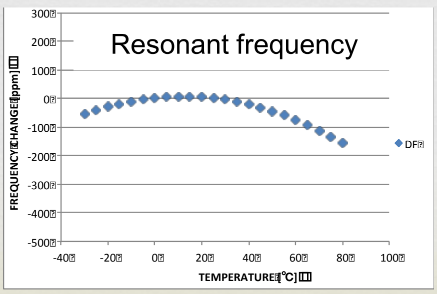


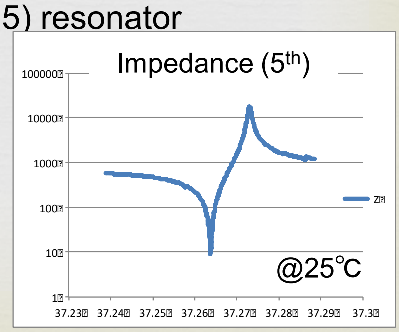
Characterization by the UMS technology

LSAW velocities measured for Y-cut CTGAS(x=0.50)



Temperature dependence of resonant frequency for rotated *Y*-cut CTGAS(x=0.25) resonator





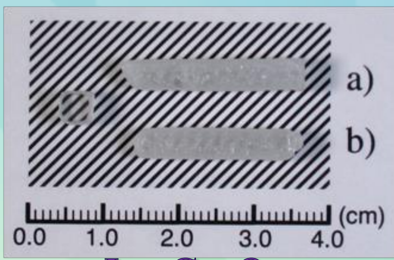
CRYSTAL GALLERY

OXIDE

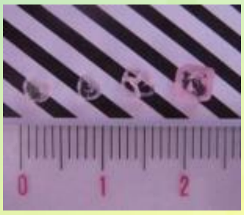
< Garnet type >

$Y_3Al_5O_{12}$

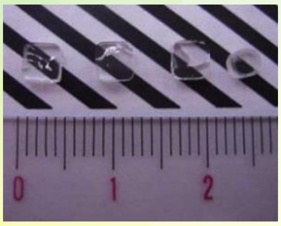
$Yb:Y_3Al_5O_{12}$



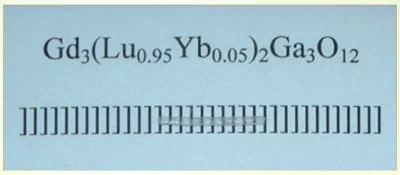
$Lu_3Ga_5O_{12}$



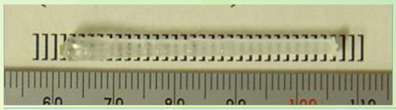
$Ho:Lu_3Al_5O_{12}$



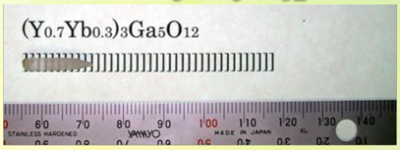
$Tm:Lu_3Al_5O_{12}$



$Gd_3Lu_2Ga_3O_{12}$

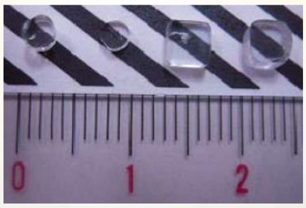


$Lu_3Al_5O_{12}$



$Y_3Ga_5O_{12}$

$Ce:Lu_3Al_5O_{12}$

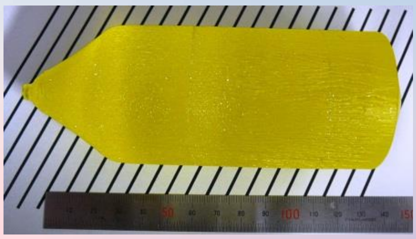


$Nd:Lu_3Al_5O_{12}$

$Pr:Lu_3Al_5O_{12}$

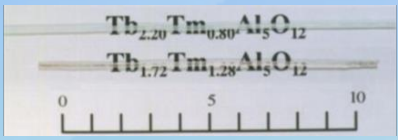
$Gd_3Ga_5O_{12}$

$Gd_3Al_2Ga_3O_{12}$

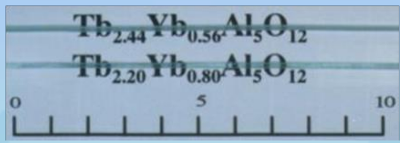


$Ce:Gd_3Al_2Ga_3O_{12}$

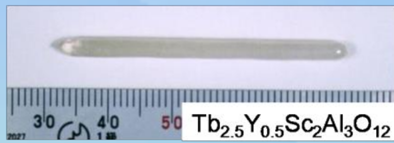
< *Garnet type* >



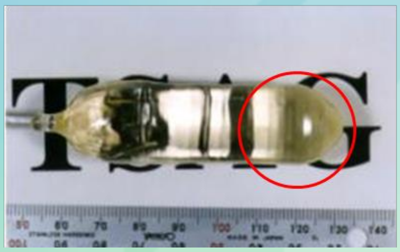
$Tb_{3-x}Tm_xAl_5O_{12}$



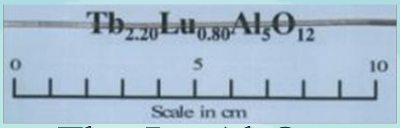
$Tb_{3-x}Yb_xAl_5O_{12}$



$Tb_{2.5}Yb_{0.5}Sc_2Al_3O_{12}$



$Tb_{2.2}Sc_{2.8}Al_3O_{12}$



$Tb_{3-x}Lu_xAl_5O_{12}$

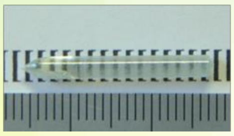
$Tb_{3-x}Sc_{2+x}Al_3O_{12}$

< *Ilmenite type* >

$LiNbO_3$

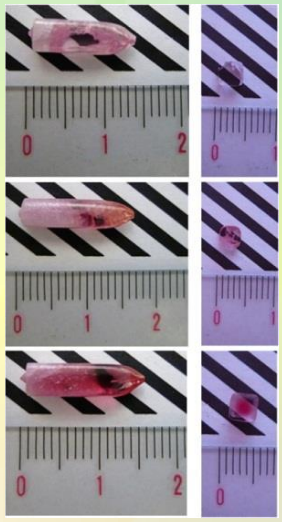
< *Perovskite type* >

$YAlO_3$

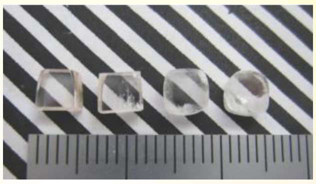


$(Lu, Y)AlO_3$

$KNbO_3$



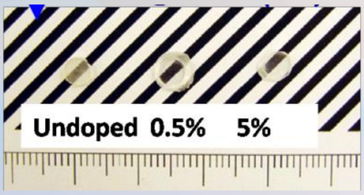
$TbAlO_3$



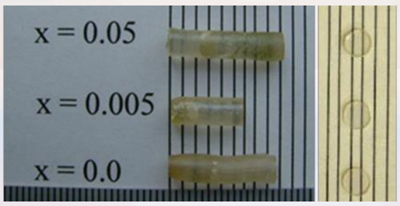
$Tm{:}YAlO_3$

$Cr{:}YAlO_3$

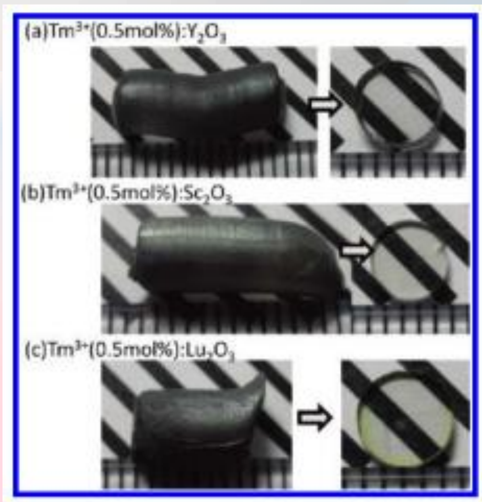
< *Sesquioxide type* >

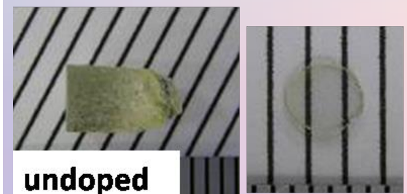


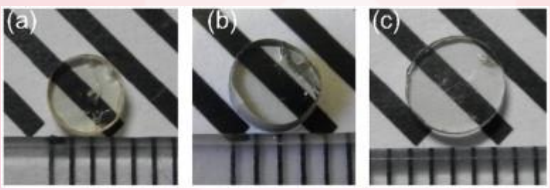
Sc_2O_3



Y_2O_3





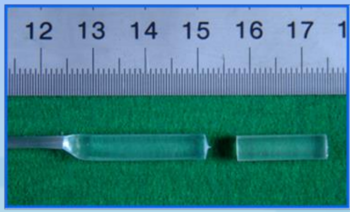


Lu_2O_3

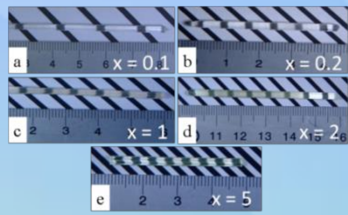
< Apatite type >

$Ca_8La_2(PO_4)_6O_2$

< Spinel type >

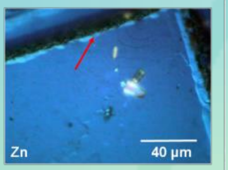


$Ti{:}MgAl_2O_4$



$Mn{:}MgAl_2O_4$

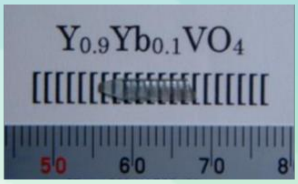
< ZnO type >

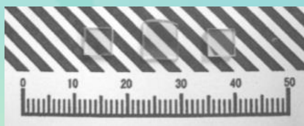


LPE ZnO Single Crystalline film

ZnO Single Crystal

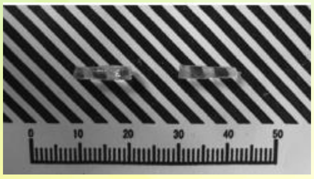
< Vanadate type >





YVO_4,(Y,Lu)Vo_4,$LuVO_4$

< Aluminate type >



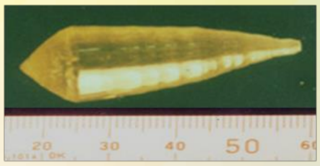
$LiAlO_2$

< Corundum type >

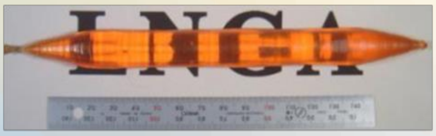
Al_2O_3

$Cr{:}Al_2O_3$

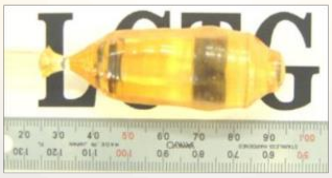
< Langasite type >



$Sr_3TaGa_3Si_2O_{14}$

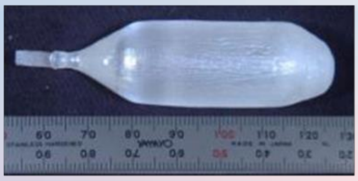


$La_3Nb_{0.5}Ga_{5.3}Al_{0.2}O_{14}$

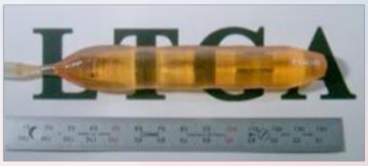


$La_{2.95}Ca_{0.05}Ta_{0.525}Ga_{5.475}O_{14}$

$La_{2.95}Ba_{0.05}Ta_{0.525}Ga_{5.475}O_{14}$

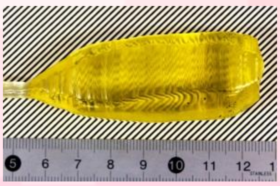


$La_3Ga_{5.3}Al_{0.2}SiO_{14}$



$La_3Ta_{0.5}Ga_{5.3}Al_{0.2}O_{14}$

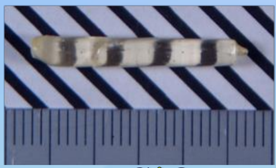
$Ca_3TaGa_{1.5}Al_{1.5}Si_2O_{14}$



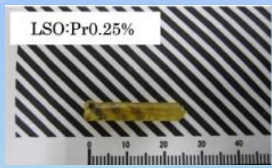
$Ca_3TaGa_3Si_2O_{14}$

$Ca_3NbGa_3Si_2O_{14}$

< Silicate type >

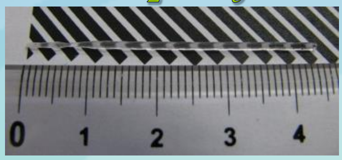


Lu_2SiO_5



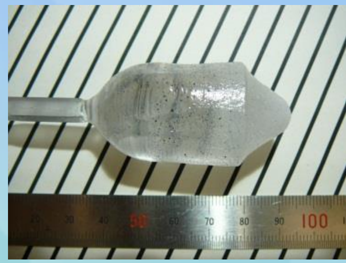
$Pr:Lu_2SiO_5$

$Pr:Y_2SiO_5$



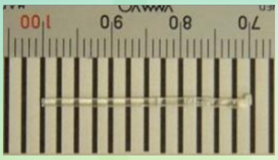
Li_4SiO_4

$Ce:Gd_2SiO_5$

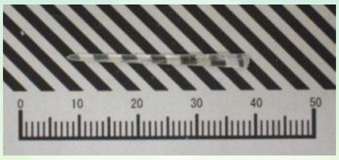


$Ce:(GdLa_xSi_{1-x})2O_7$

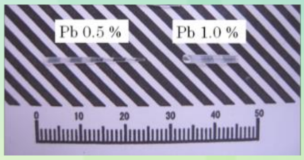
< Borate type >



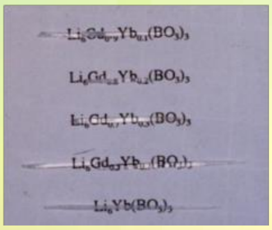
$Li_6Y(BO_3)_3$



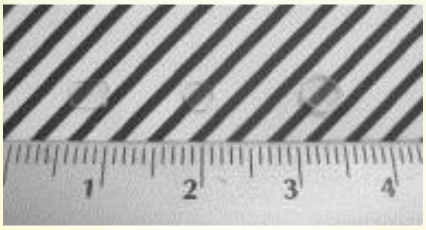
$YCa_4O(BO_3)_3$,



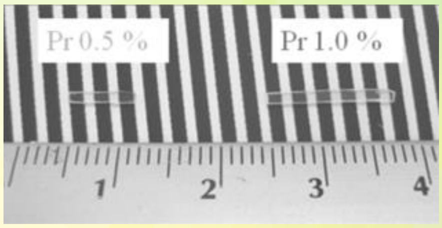
$Pb:YCa_4O(BO_3)_3$



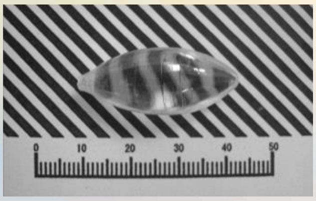
$Li_6Yb(BO_3)_3$,
$Li_6Gd(BO_3)_3$



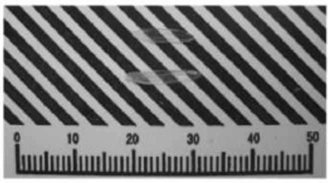
$Tm:Ca_3(BO_3)_2$



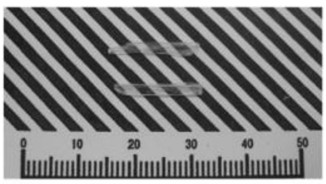
$Pr:Ca_3(BO_3)_2$



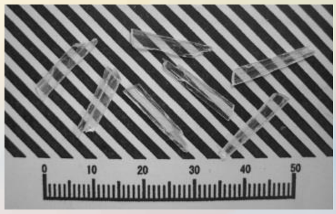
$Ce:Ca_3(BO_3)_2$



SrB_2O_4

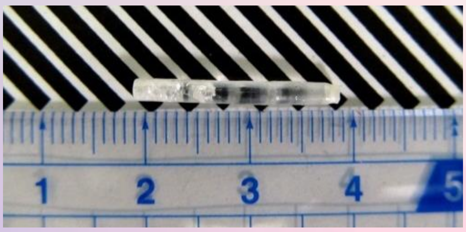


$Ce:SrB_2O_4$

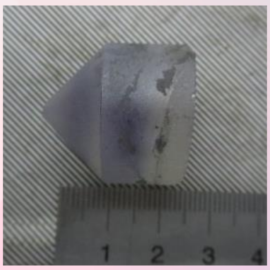


CaB_2O_4

Halide

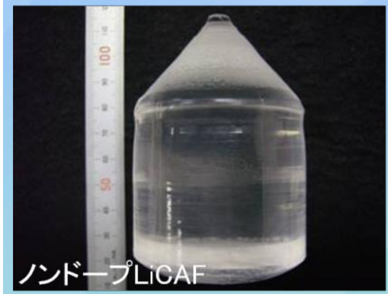


$Yb:RbPdCl_5$

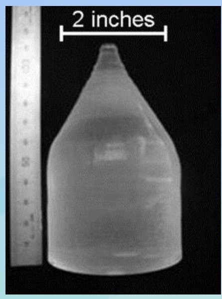


$Eu:SrI_2$

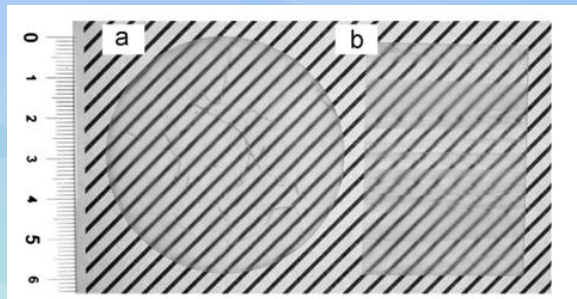
Fluoride



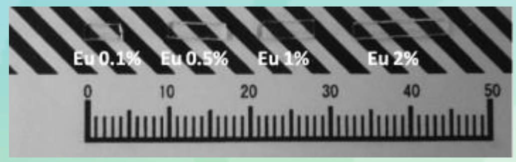
$LiCaAlF_6$



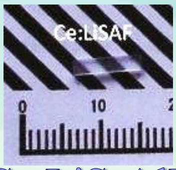
$Ce:LiCaAlF_6$



$Eu:LiF/CaF_2$

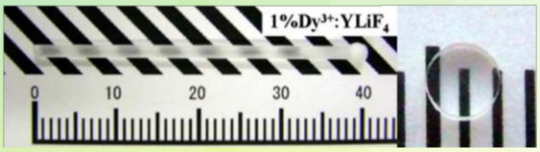


$Eu:LiCaAlF_6$

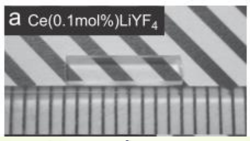


$Ce:LiSrAlF_6$


$Eu:LiSrAlF_6$



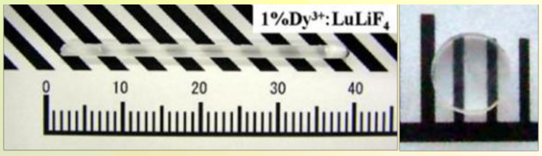
$Dy:LiYF_4$



$Ce:LiYF_4$

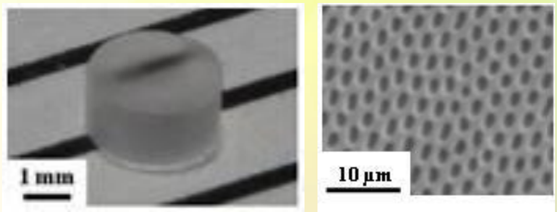

$SrMgF_4$


$Ba_{0.2}Sr_{0.8}MgF_4$

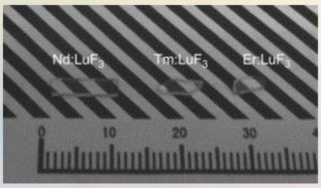


$Dy:LuYF_4$

$BaMgF_4$



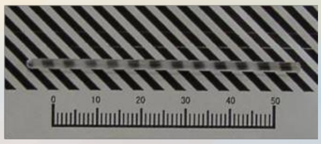
$LiGdF_4$-LiF_4 Eutectic

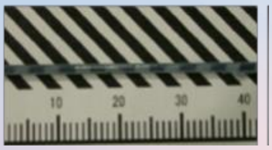


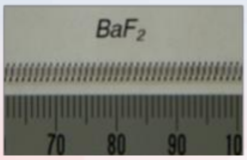
$Nd:Tm:Er:LuF_3$


$Tm:Nd:BaYLuF_8$

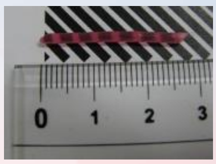

$Ce:PrF_3$

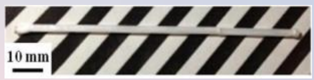

$K(Y_{0.99}Pr_{0.01})_3F_{10}$


$NdFF_3$

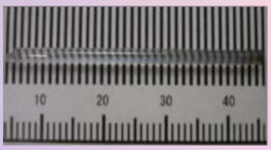


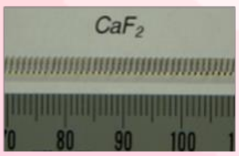
BaF_2


EuF_3

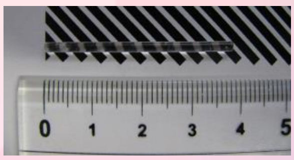


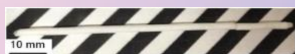
$LiGdF_4$-LiF


CeF_3



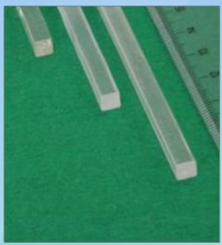
CaF_2

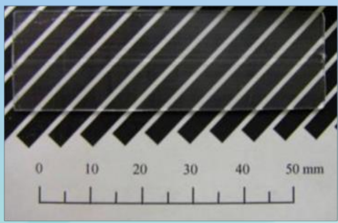

KYF_4

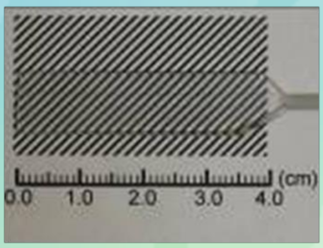


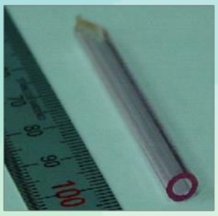
$LiAlF_6$-CaF_2

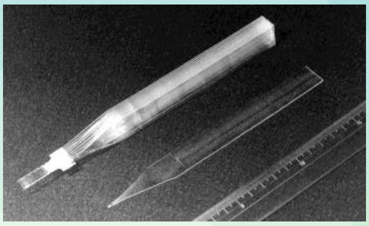
Shaped Crystal

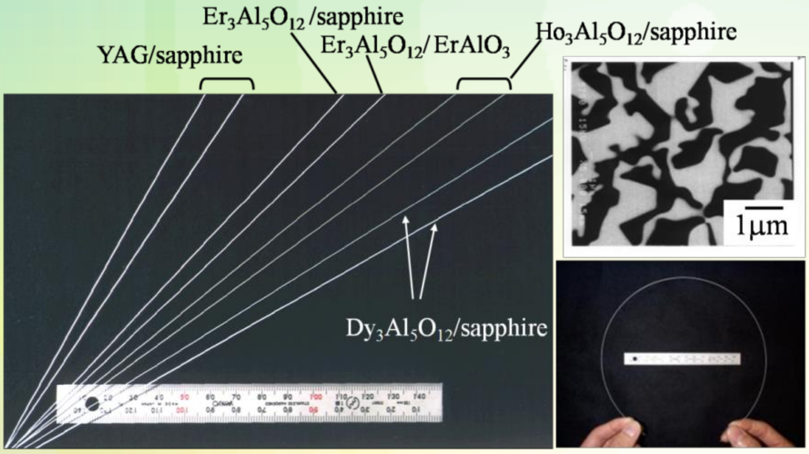


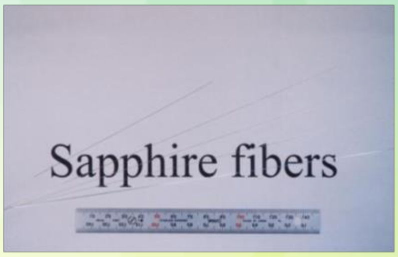




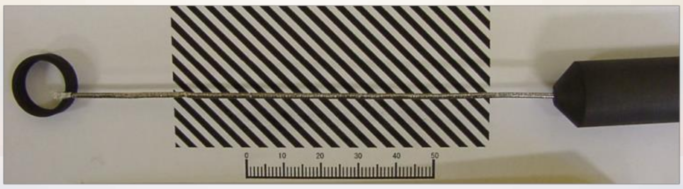




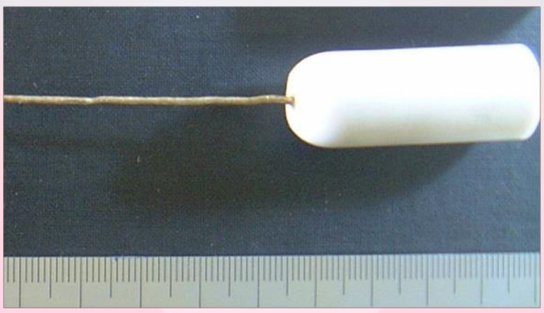




Others



Fe-Ni-Ga alloy fiber produced from carbon crucible (right) with conically shaped bottom (Scale in mm)



$Cu_{72}Al_{17}Mn_{11}$ alloy fiber produced from Al_2O_3 ceramic crucible (right) with spherically shaped bottom (Scale in mm)

Instruments in 2014

Growth Equipment (μ-PD Method)

Fluorides (RF-Heated μ-PD System)

TDK, MPD-HT
Anti-vibration system
Temperature: ~ 2500ºC
Atmosphere: Ar, N_2, H_2, CF_4, O_2

TDK, MPD-HT
Anti-vibration system
Temperature: ~ 2500ºC
Atmosphere: Ar, N_2, H_2, CF_4, O_2

Halides (RF Heated μ-PD System)

Toei scientific industrial co., ltd.
Temperature: ~ 1200ºC
Atmosphere: Ar, N_2, H_2, CF_4, O_2

Oxides (RF Heated μ-PD System)

SAPOIN,
CNMPD
Anti-vibration system
Atmosphere: Ar,N_2,H_2,O_2

TACHIBANA RIKO,
SCF-600M
Anti-vibration system
Temperature: ~ 2000°C
Atmosphere: Ar,N_2,H_2,O_2

TDK, M-PD2-A
Anti-vibration system
Temperature: ~ 2500°C
Atmosphere: Ar,N_2,H_2,O_2

Sapoin 2
Anti-vibration system
Atmosphere: Ar,N_2,H_2,O_2

Growth Equipments (Cz Method)

Fluorides (RF Heated Cz System)

Nisshin Giken
Temperature: ~ 1600°C
Atmosphere: Ar, N_2, H_2, CF_4, O_2

Oxides (RF Heated Cz System)

CYBERSTAR,
OXYPULLER 05-03
Heating system: RF
Vacuum: 30Pa
Atmosphere: Air, Ar, N_2, O_2
Temperature: ~2200°C

30kW-Cz
Heating system: RF
Atmosphere: Air, Ar, N_2, O_2
Temperature: ~ 2000°C

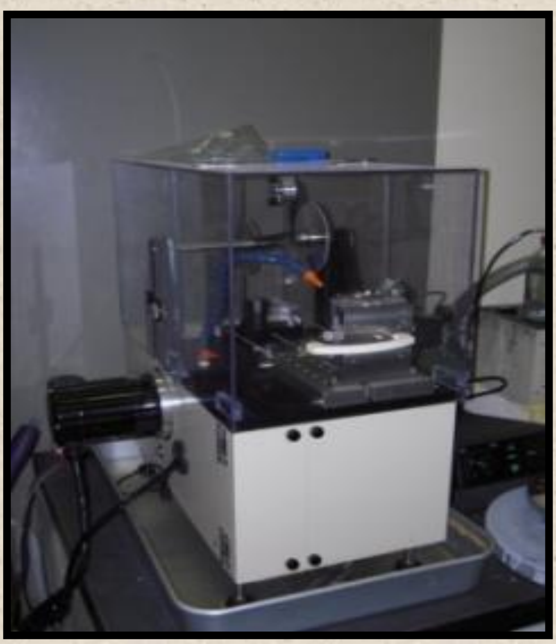
Sample Preparation

Fine cutting machine
HeiwaTechnica, HS-25A

Glove box

Automatic lapping
polishing machine

Electric balance
Shimadzu



Diamond Wire Cutting Machine
New Metals & Chemical corporation

Measurement & Analysis Equipment

Nomarski-Type Differential Interference Contrast Microscope

NIKON, Eclipse ME600,TYPE 120
Light Source: White light
DIC Microscope System
Magnification: ×1000

Polarized microscope

NIKON, Eclipse, E600POL
Light Source: White Light
DIC Microscope System
Magnification: ×500

NIKON, SMZ-U
Light Source: Halogen lamp

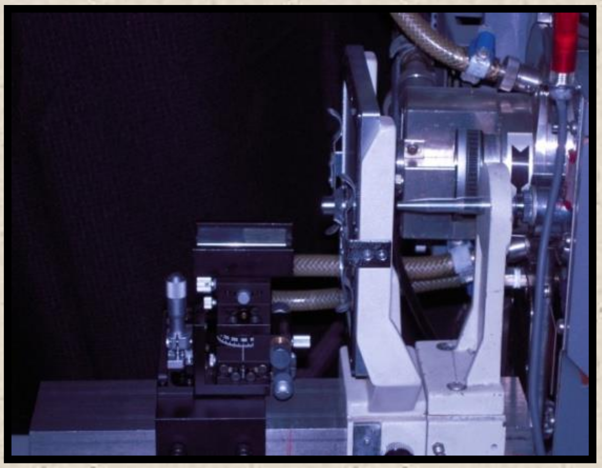
Horiba, EDX, EMAX X-act
Analyzer & Mapping & Point and ID & Broad Area Automatic Analysis

SEM, Hitachi S-3400N

Thin Film HRXRD
RIGAKU

Powder XRD
RIGAKU

Rotary Type XRD
RIGAKU



Laue Camera
Rigaku
R-AXIS DS3

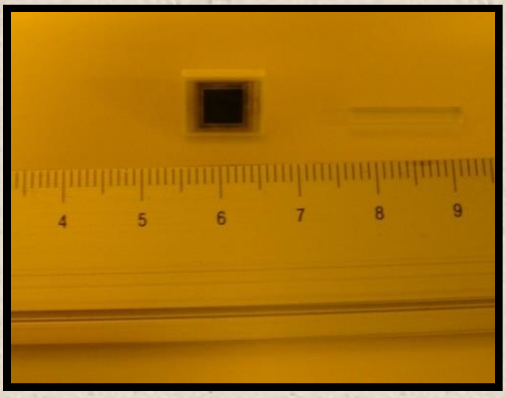
TG-DTA
SETARAM

Piezoelectric Constant
Measurement System

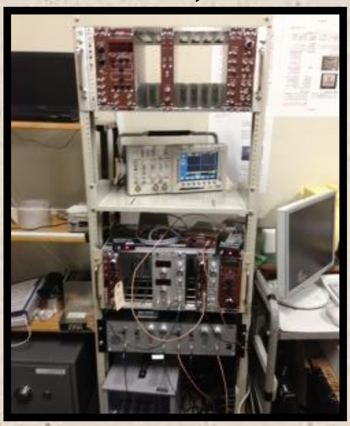
IP Reader
Rigaku R-AXIS DS3C

Absorption and fluorescence spectrometer

UV-VIS spectrophotometer
Shimadzu,UV-2550



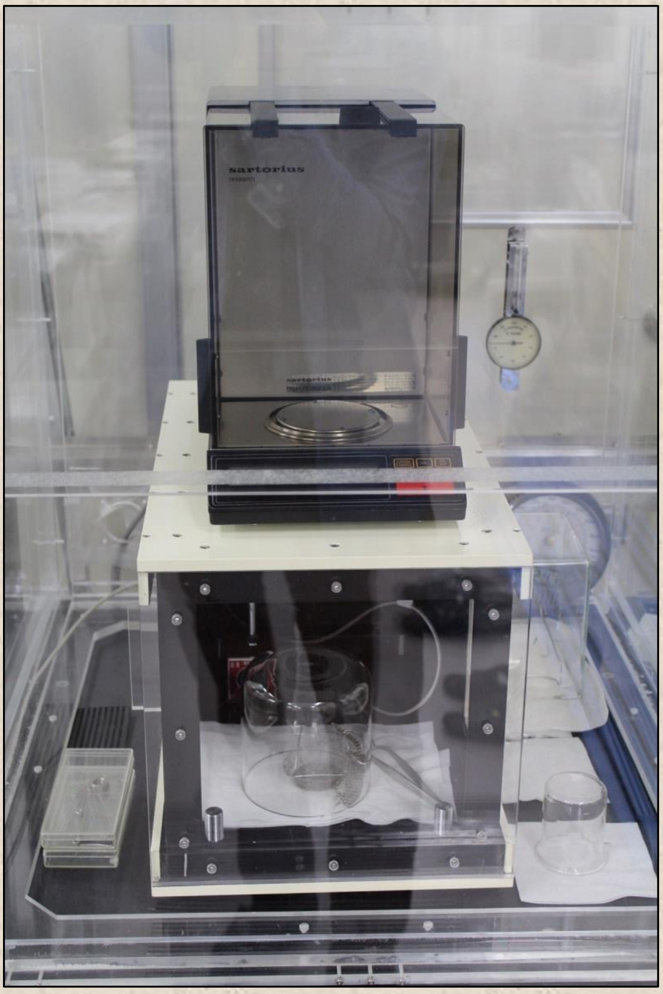
Si Avalanche Photodiode



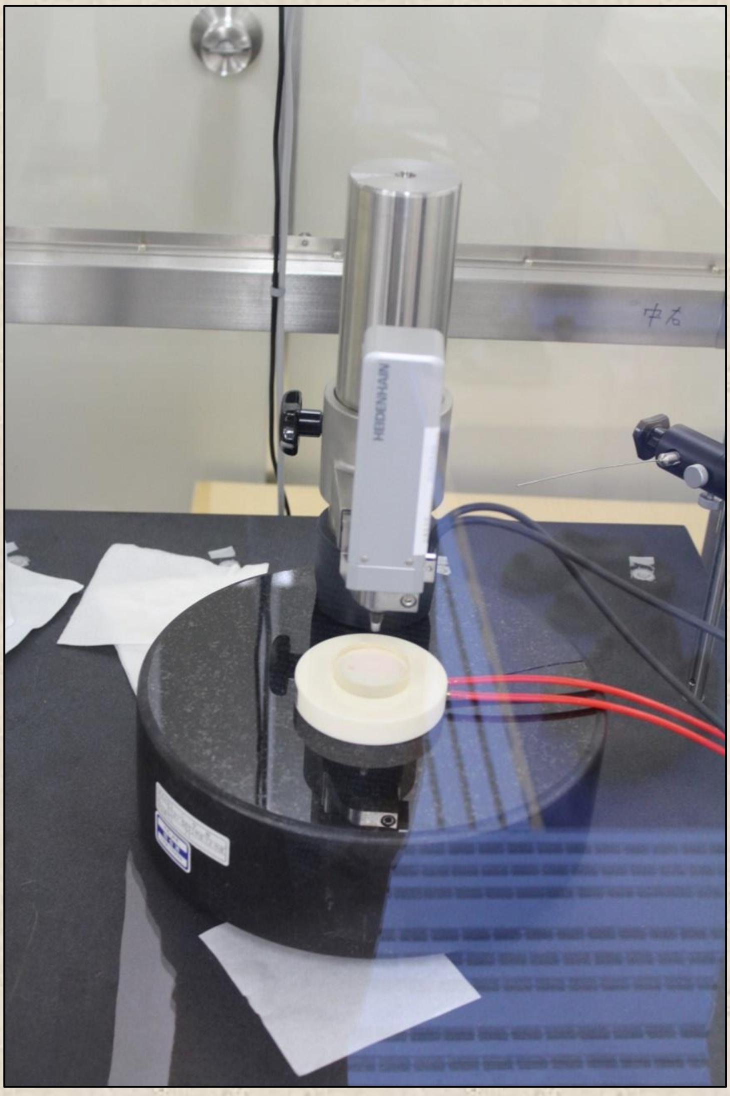
Radiation measurement modules
(Light yield, Scintillation decay time)

Edinburg Instruments Spectrometer: Photoluminescence & Decay time

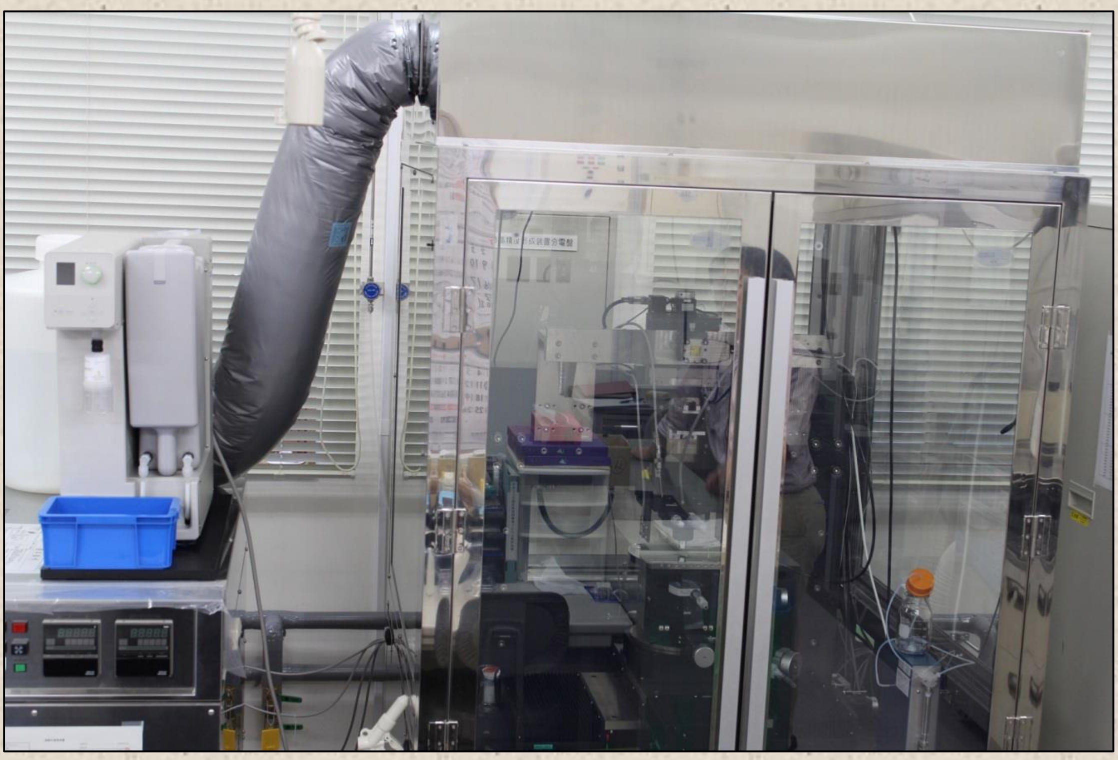
Measurements & Analysis Equipment for Piezo-electrical Materials



Density Measurement System

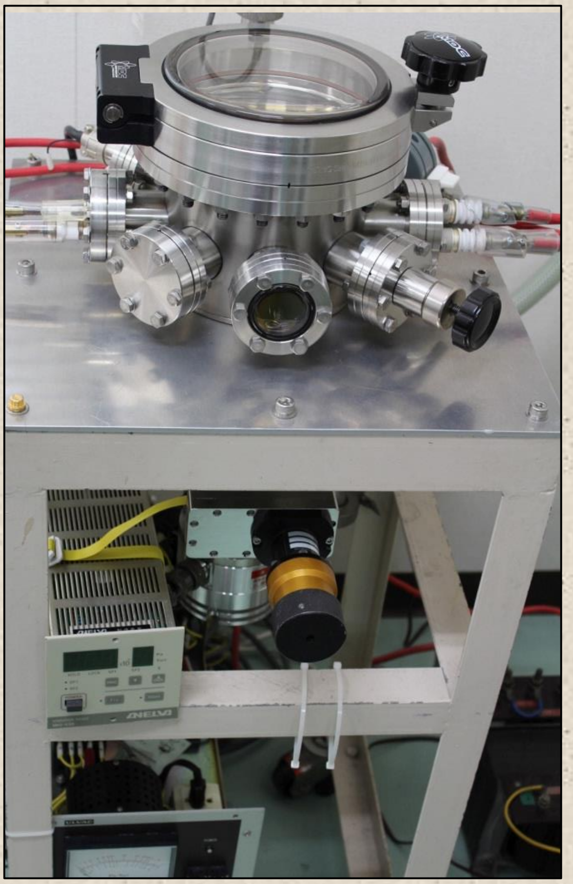


Thickness Measurement System



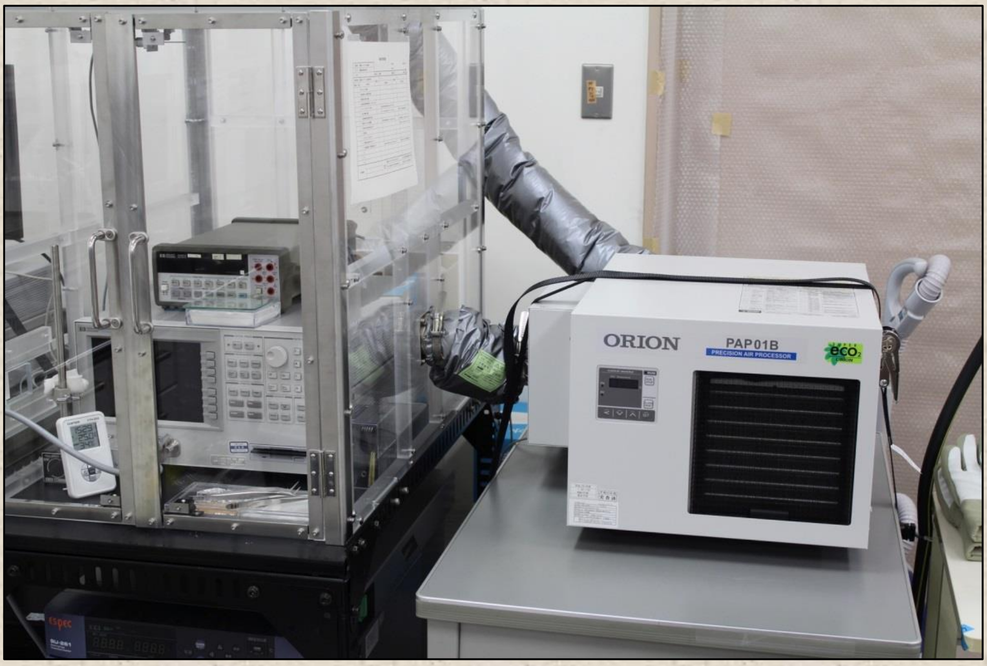
Ultrasonic Material Characterization System for Practical Use (Ver. 5)

Ultrasonic Material Characterization System for General Use (Ver. 6)



Vacuum Evaporation System

Dilatometer



Dielectric and Impedance Measurements System

Furnaces & Ovens

Drying oven

AS ONE, DO-450-V

Temperature: 100º C

YAMATO, FO200

DENKEN, KDF007F

Temperature: 1100℃

Anneal furnace

Nisshin-giken,

Temperature: ~1600℃

SiC furnace

Motoyama Super-C

Max temperature: ~1450ºC

High Temperature Furnace

V&H Technology

Muffle Furnaces

ISUZU, STR-12K

Tube Furnace

ALPHA

Messages from foreign visitors

Message for 2015 annual report from Robert Kral (Institute of Physics, Czech Academy of Sciences, Prague, Czech Republic)

I have been visiting Prof. Yoshikawa's laboratory, Institute for Materials Research (IMR), Tohoku University, Sendai, Japan, continuously for short term stays since 2009 during a long and very successful collaborative researcher of Prof. Akira Yoshikawa and Dr. Martin Nikl, Institute of Physics, Czech Academy of Sciences, Prague, Czech Republic. However, in 2014, I was awarded by Japan Society for the Promotion of Science (JSPS) by a fellowship "FY2014 JSPS Postdoctoral Fellowship for Foreign Researchers, P14040" to conduct research in Japan under the leadership of Prof. Yoshikawa for a period of 12 consecutive months from April 2014 to May 2015.

During this stay, our research was focused mostly on preparation, growth, and study of hygroscopic halide materials to investigate and to improve their luminescence and scintillation properties. Preparation of strontium iodide single crystals doped with ns^2 (Sn^{2+} and In^+) or Eu^{2+} ions as well as of ternary halides ($RbPb_2Cl_5$ and KPb_2Cl_5) was performed using modified micro-pulling-down method. In total, more than 60 experiments of both the preparation of starting materials as well as their crystal growth were conducted. Furthermore, prepared single crystals were characterized by methods available in IMR (XRD, ICP, light yield) and in the Institute of Physics (absorption, radioluminescence, photoluminescence, decay kinetics).

My wife, Kristyna Kralova, joined me in Sendai in July 2014 and stayed here until April 2015. It was her first visit in Japan, so, her fascination of Japan reminded me my feelings and impressions when I visited Japan for the first time. Together, we visited new places around Sendai or other parts of Japan. Moreover, I am deeply grateful to Prof. Yoshikawa that he gave a permission to my wife allowing her to access IMR to continue in her PhD studies here Japan. Beside that we are very thankful to Kawaguchi-san, who helped us very much with organizing all necessities related to arranging a moving of me and my wife to a new apartment at the end of August 2014.

During my stay I presented results by oral or poster contributions at following conferences: 6-IWCGT (June 15-19, 2014, Berlin, Germany, poster: "Growth and luminescence properties of pure and RE-doped $RbPb_2Cl_5$ crystals prepared by vertical Bridgman method"), 5-ISFM Summer symposium (August 7-11, 2014, Rizzan Seapark Hotel Tancha-bay, Okinawa, oral: "Study of vertical Bridgman growth of halide materials"), 75-JSAP Automn meeting (September 17-20, 2014, Sapporo, Japan, oral: "Crystal growth of pure and Sn-doped SrI_2 by atmosphere-controlled micro-pulling-down method and its luminescence and scintillation properties"), 44-NCCG (November 6-8, 2014, Tokyo, Japan, poster: "Crystal growth of SrI_2-based scintillators and characterization of luminescence properties"), 6-ISFM Winter symposium (March 5-7, 2015, Hakodate, Japan, oral: "Preparation, crystal growth, and luminescence properties of SrI_2 single crystals doped with In(I) and Sn(II) ions grown by modified micro-pulling-down method"), and 62-JSAP (March 11-14, 2015, Tokai University, Kanagawa, Japan, oral: "Luminescence properties of SrI_2 single crystals doped with s^2-group ions grown by modified micro-pulling-down method").

Hereby, I would like to express my acknowledgement to Ito(T)-san, Murakami-san, and Nagura-san for perfect organization of 5-ISFM Summer symposium, August 7-11, 2014, Rizzan Seapark Hotel Tancha-bay, Okinawa and of the secondary program. It was my first visit to Okinawa as well as for my wife, who accompanied me, and beside of very interesting lectures at the symposium, we enjoyed our stay at Okinawa very much. Due to colorful program we could visit Okinawa Churaumi Aquarium, taste famous Okinawa pork ribs ramen, and visit traditional Okinawa restaurants. Moreover, I would like to thank very much to Prof. Yokota, who was during the stay our excellent guide and always watched over us.

Similarly, we experienced memorable moments when attending the 6-ISFM Winter symposium (March 5-7, 2015, Hakodate, Japan), where we travelled by shinkansen and had a brief stop for a lunch at Hachinohe fish market. There, we could taste fresh fish and seashells served either raw (as sashimi or sushi) or prepared by ourselves on a grill. After arriving to Hakodate, we visited watchtower on the Mount Hakodate, where we had wonderful night view on the Hakodate bay with bright full Moon rising on the horizon.

Furthermore, I was very glad that we could be with my wife in Sendai during a Hanami festival (Cherry Blossoms Festival) in April 2015. I have already been in Sendai during Hanami Festival once, however, I always enjoy this festival very much. I must admit that I cannot get tired of watching the beautiful scenes of Cherry trees in full blossom looking like never ending white sea.

I am very grateful for the opportunity to stay in Prof. Yoshikawa’s laboratory for one year, it was an unforgettable experience. I had full support from all the lab members whenever I needed help and I was honored to participate and continue in our collaborative research. I would like to give a special thanks to Dr. Pejchal for all his help and support. Moreover, I was amazed how rapidly Prof. Yoshikawa’s laboratory developed on the level of equipment used for growth of various single crystals as well as on the level of characterization techniques used for evaluation of material, optical, luminescence, and scintillation properties of prepared single crystals. This stay helped me to develop and extended my skills in crystal growth by micro-pulling-down method and in the characterization of prepared single crystals. I hope our cooperation will successfully continue and I am already looking forward for the next visit in Prof. Yoshikawa’s laboratory.

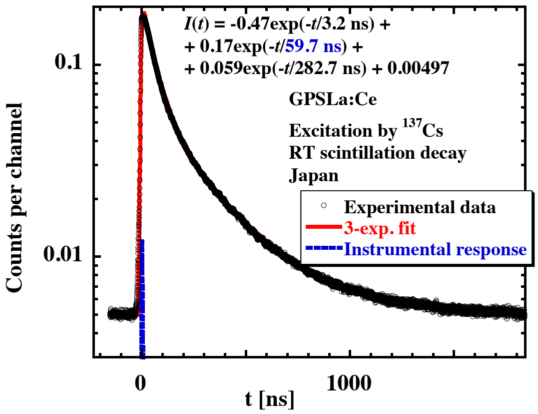
Message for 2015 annual report from Vitezslav Jary (Institute of Physics, Czech Academy of Sciences in Prague, Czech republic)

I have been a member of Dr. Martin Nikl´s team from Institute of Physics, Czech Academy of Sciences in Prague, Czech republic, since 2008 and thanks to his fruitful collaboration with Prof. Yoshikawa group I received an invitation to visit his laboratory at Tohoku University in Sendai for joint experiments on characterization of the Ce^{3+}-doped gadolinium pyrosilicate crystal grown by the μ-PD method. Furthermore I was kindly ask to participate and give a lecture at **5th International Symposium on Functional Materials 2015** which was held 5th – 7th March 2015 in Hakodate, Japan. The lecture was called **Ce^{3+}-doped silicate-based scintillators** and was followed by an interesting discussion.

Almost immediately after the invitation, I started preparations for the visit with great assistance of Hiroshi Uemura-san, who made excellent job to complete all the formalities in time and booking BelAir hotel in Sendai. Hereby I would also like to express my thanks to Jan Pejchal-san and Robert Kral-san whose help was also deeply appreciated.

I departed from Prague on February 28th and after 30-hours of stop-over in Dubai I arrived to Haneda-airport in Tokyo. I took the first shinkanzen train to get to Sendai on 3rd March early morning. The first colleague I met in Sendai was Dr. Robert Kral, who escorted me to the lab. I was very happy to meet with the members of the laboratory and to be introduced to their research. During my stay in IMR, I was also lucky to participate at the research meeting of Yoshikawa Lab and to discuss there various aspects of the laboratory activities, including luminescent properties and fabrication of novel functional materials.

During the rest of my stay, I was shown all the experimental equipment of IMR and also participated in the optical experiments when, together with Kurosawa-san and Murakami-san we measured scintillation light yield and scintillation decay curves on selected Ce^{3+}-doped GPSLa crystals grown at IMR by μ-PD techique. Those measurements were followed by a detailed discussion concerning software evaluation of the measured data and possible differences in the experimental data obtained in IMR and those obtained in Prague.



From my point of view, the great success of the Yoshikawa Lab is based on high professionalism of its leader, a great friendly team of highly qualified enthusiasts, and excellent growth and characterization equipment. As a result, fundamental and practical achievements of this research group are well recognized by the world scientific community.

Before leaving Sendai, I found some time to discover couple of cities around worth visiting, like Matsushima or Yamadera. After departure from Haned airport 14th March, I enjoyed view of beautiful night Tokyo from the window of the airplane.

Travel to Japan and visit the Yoshikawa Laboratory gave me the great opportunity to meet new people and new culture. That was an unforgettable experience.

Looking forward to further cooperation,
Vitezslav Jary

Members

2014年度　吉川研究室
Members (2014 academic year)

4. 1. 2014

Professor		**教授**	
Dr.	Akira Yoshikawa	吉川　彰	NICHe 兼任
Associate Professor		**准教授**	
Dr.	Yuui Yokota	横田　有為	NICHe
Dr.	Kei Kamada	鎌田　圭	NICHe
Research Assistant Professor		**助教**	
Dr.	Shunsuke Kurosawa	黒澤　俊介	
Dr.	Yuji Ohashi	大橋　雄二	
Dr.	Jan Pejchal	ヤン　ペジャール	NICHe
Adviser		**顧問**	
Prof	Masae Kikuchi	菊地　昌枝	
Prof	Touetsu Shishido	宍戸　統悦	
Technical Counsellor		**技術参事**	
	Hiroshi Uemura	上村　博	
Assistant		**技術補佐研究員**	
	Keiko Toguchi	戸口　景子	
	Megumi Sasaki	佐々木　愛美	
	Chouichi Takyu	田久　長一	

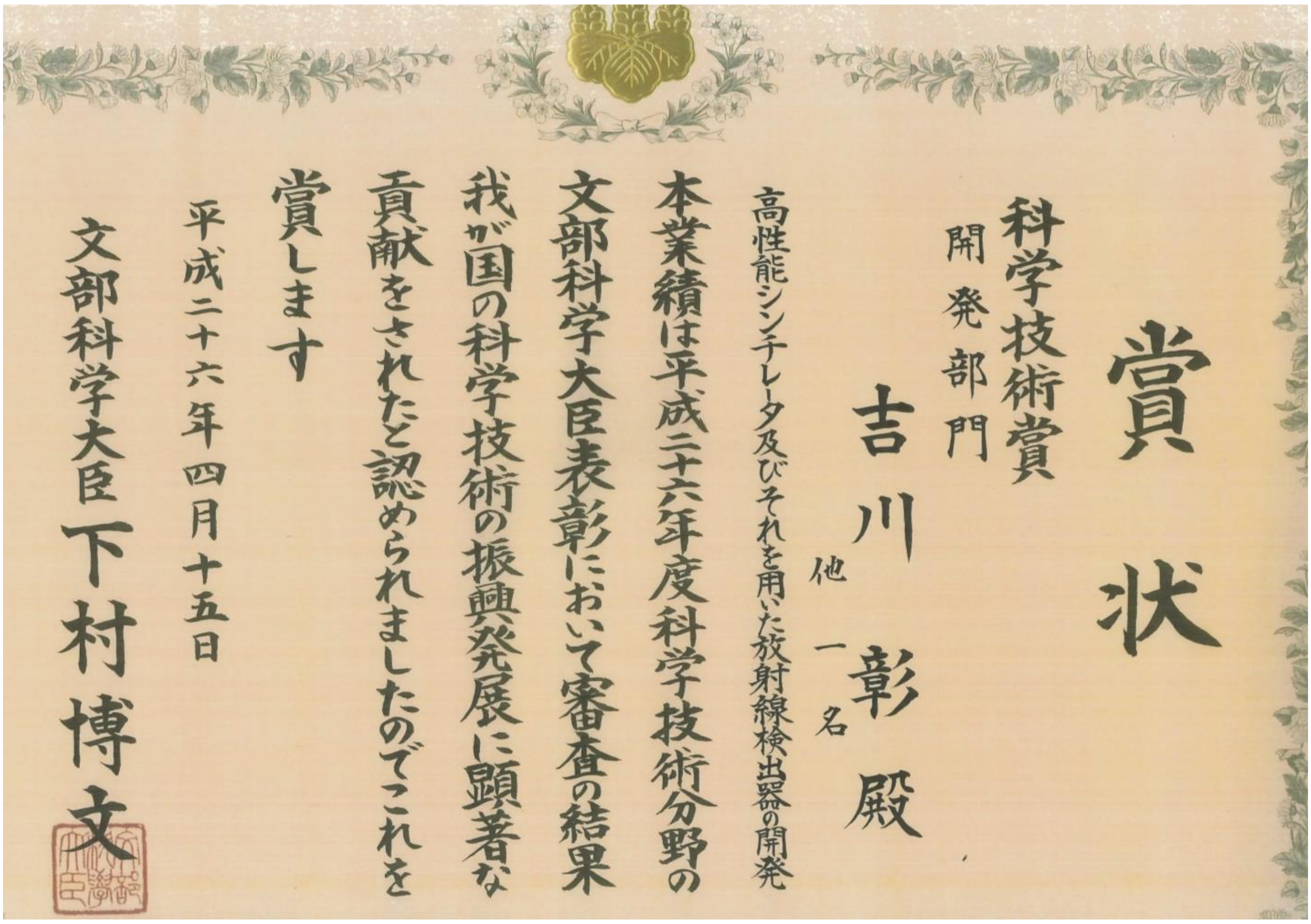
Secretaries	**秘書**	
Yuka Takeda	武田　悠佳	
Kuniko Kawaguchi	川口　邦子	
Researcher	**研究員**	
Yasuhiro Shoji	庄子　育宏	
Takuya Sato	佐藤　拓也	
Masatoshi Ito	伊藤　正敏	
Toshio Sannomiya	三野宮　利男	
Robert Kral	ロバート　クラル	外国人特別研究員
Graduate Students	**大学院生**	
Akihiro Yamaj	山路　晃広	D3
Tetsuo Kudo	工藤　哲男	M2
Kousuke Hishinuma	菱沼　康介	M2
Tomoki Ito	伊藤　友樹	M1
Rikito Murakami	村上　力輝斗	M1
Aya Nagura	名倉　亜耶	M1
Researchers	**民間等共同研究員**	
Masato Sato	佐藤　真人	TDK 株式会社 TDK Co., Ltd.　～2014.8 月
Takayuki Nihei	二瓶　貴之	TDK 株式会社 TDK Co., Ltd.　～2014.8 月
Nobuhiro Yasui	安居　伸浩	キヤノン株式会社／ Canon Co., Ltd.

	Tatsuya Iwasaki	岩崎　達哉	キヤノン株式会社／ Canon Co., Ltd.
	Ryota Ohashi	大橋　良太	キヤノン株式会社／ Canon Co., Ltd.
	Osamu Eguchi	江口　治	株式会社 C & A／ C&A Co., Ltd.
	Hisakazu Nagato	長門　久和	株式会社 C & A／ C&A Co., Ltd.
	Syouki Hayasaka	早坂　将輝	株式会社 C & A／ C&A Co., Ltd.
	Idzumi Chida	千田　いづみ	株式会社 C & A／ C&A Co., Ltd.
	Satoshi Suzuki	鈴木　智司	(株)ASE ジャパン
	Tsuneyoshi Miki	三木　常義	由利工業(株)

Visiting Professors/Researchers		**客員教授**	
Prof.	Georges Boulon	ジョージ　ブーロン	France
Prof.	Martin Nikl	マーチン　ニクル	Czech Republic
Dr.	Vladimir V.Kochurikhin	ヴラディミール カチューリッヒン	Russia

Visiting Researchers		**客員研究員**	
Dr.	TCHANI Valery	チャニ　ワレリー	Canada
Dr.	Andrey Medvedev	アンドレ　メドベージェフ	Russia

Prizes and awards



賞状

科学技術賞
開発部門

吉川彰 殿
他一名

高性能シンチレータ及びそれを用いた放射線検出器の開発

本業績は平成二十六年度科学技術分野の
文部科学大臣表彰において審査の結果
我が国の科学技術の振興発展に顕著な
貢献をされたと認められましたのでこれを
賞します

平成二十六年四月十五日

文部科学大臣 下村博文

贈呈状

一般研究助成

研究テーマ名
「非侵襲血中RI濃度測定を実現するサブミリ分解能PET検出器の開発」

東北大学　金属材料研究所

吉川　彰殿

あなたの研究は当財団の目的であるライフサイエンス発展に対し貢献が期待されることから助成の対象に相応しいものとして選考されましたので頭書の通り平成２５年度の助成金を贈呈いたします

平成26年3月18日

公益財団法人 テルモ科学技術振興財団

理事長　中尾　浩治

List of research collaborations

Visits by International Collaborator 2014

Affiliation	Researcher	Research Theme
General Physics Institute (Russia)	Dr. V. Kochurikhin	Growth of bulk single crystals and automatic diameter control in Czochralski growth
Fomos Materials (Russia)	Dr. A. Medvedev	Langasite-type piezoelectric single crystals and their piezoelectric properties
LPCML, CB Lyon1 Univ. (France)	Pr. G. Boulon	Ceramic laser materials with a nonpress vacuum sintering method
Svetcha (Canada)	Dr. V. Chani	Growth of bulk oxide single crystals
Institute of Physics CAS (Czech Republic)	Dr. M. Nikl	Characterization of various scintillator materials
Institute of Physics CAS (Czech Republic)	Dr. R. Kral	Growth of bulk halide scintillator crystals
Institute of Physics CAS (Czech Republic)	Dr. V. Jary	Growth of bulk halide scintillator crystals

Seminar at Yoshikawa Laboratory 2014

Date	Affiliation	Speaker	Title of speech
August 8-10	Institute of Physics CAS (Czech Republic)	Dr. R.Kral	Study of vertical Bridgman growth of halide materials
March 5-7	Institute of Physics CAS (Czech Republic)	Dr. V. Jary	Preparation, crystal growth, and luminescence properties of SrI2 single crystals

Visits to International Collaborator 2014

Affiliation	Researcher	Period of stay
The Pennsylvania State University (USA)	Pr. Yoshikawa Assoc. Pr. Yokota Mr. Kudo	May 12-16
University of Michigan (USA)	Assist. Pr. Kurosawa	June 10-12
Institute of Physics CAS (Czech Republic)	Assist. Pr. Pejchal Assoc. Pr. Kamada Mr. Shoji	June 9-14
Leibniz-Institut für Kristallzüchtung (German)	Pr. Yoshikawa Assoc. Pr. Yokota Assoc. Pr. Kamada Assist. Pr. Pejchal Mr. Shoji, Mr. Kudo	June 15-20
University of Wroclaw (Poland)	Pr. Yoshikawa Assist. Pr. Kurosawa	July 14-18
Leeds University (UK)	Pr. Yoshikawa Assoc. Pr. Kamada	July 28-29
The University of Tennessee (USA)	Assoc. Pr. Yokota Assist. Pr. Kurosawa Mr. Ito Mr. Murakami	November 17-18
University of Wroclaw (Poland)	Pr. Yoshikawa	December 1-3
CERN (Switzerland)	Pr. Yoshikawa Assist. Pr. Kurosawa	March 10-11

Research funds

平成 26 年度　研究資金
Research funds (2014 fiscal year)

【経済産業省－東北経済産業局】

Tohoku Bureau of Economy, Trade and Industry
The Ministry of Economy, Trade and Industry

1. 戦略的基盤技術高度化支援事業（サポイン）
Funding Program for Strategic Supporting Industry, 2014
株式会社インテリジェント・コスモス研究機構からの再委託研究
Truster: Intelligent Cosmos Research Institute, Miyagi pref.
「Ce:GAGGシンチレータ結晶の量産化における大型結晶製造プロセスの低コスト化」
“ Cost reduction of the mass-production of large-sized Ce:GAGG scintillator crystals”
期間　Term:　2014.10 - 2017.3
本年度 Total:　12,110,000 yen for our team, 2014.10 - 2015.3

2. 中小企業による技術シーズの事業化・実用化事業のうち橋渡し研究支援事業
Funding Program for small business innovation research, 2014
株式会社東栄科学産業からの再委託研究
Truster: Toei Kagaku Co.Ltd
「量産型マイクロＰＤ装置の開発」
“Development of mass-production of micro-pulling-down apparatus”
期間　Term:　2014.11 - 2015.3
本年度 Total:　6,480,000 yen for our team, 2014.11 - 2015.3

3. 先端技術実証･評価設備整備費等補助金
（企業等の実証･評価等設備の開発）
Funding Program for small business in promoting innovation, 2013
株式会社ジー･イー・エスからの再委託研究
Truster: GES Co.Ltd
「無坩堝で高融点酸化物シンチレータ結晶の製造を実現するスカルメルト法溶解技術の開発」

"Development of Skull Melt method to produce oxide scintillator crystals of high melting point without using crucible"
期間　Term:　2014.3 - 2015.3
本年度 Total:　15,000,000 yen for our team, 2014.4 - 2015.3

【JST プロジェクト】

Japan Science and Technology Agency

1. JST研究成果展開事業　【先端計測分析技術・機器開発】
Development of Systems and Technology for Advanced Measurement and Analysis Technology, 2012
「無人ヘリ搭載用散乱エネルギー認識型高位置分解能ガンマカメラの実用化開発」
"Research and development of scattered energy recognition type and high positional resolution gamma camera for unmanned helicopter survey"
古河機械金属株式会社からの再委託研究
Truster: Furukawa Co. Ltd.
期間　Term:　2012.4 - 2015.3
本年度 Total:　13,000,000 yen for our team, 2014.4 - 2015.3

2. JST研究成果最適展開支援プログラム　(A-STEP) シーズ育成タイプ
Adaptable and seamless technology transfer program through targetdrive R&D, 2012
「核物質セキュリティ用3He 代替中性子計測装置の開発」
"Development of neutron scanning apparatus for homeland security using scintillator instead of 3He gas detector "
期間　Term:　2012.10 – 2015.3
本年度 Total:　9,420,000 yen for our team, 2014.4 - 2015.3

3. JST研究成果展開事業　【先端計測分析技術・機器開発】
Development of Systems and Technology for Advanced Measurement and Analysis Technology, 2013
「高エネルギー分解能・高スループットの国産放射測定検査装置」
"Development of radiometry tester having high energy resolution and high efficiency"
株式会社千代田テクノルからの再委託研究
Truster: Chiyoda Technol Corporation

期間　 Term:　2013.10 - 2016.3
本年度 Total:　18,200,000 yen for our team, 2014.4 - 2015.3

4. JST研究成果展開事業
研究成果最適展開支援プログラム（A-STEP）
実用化挑戦ステージ実用化挑戦タイプ　（中小・ベンチャー開発）
Foundation for Small and Medium Enterprise Promotion, 2013
(Supporting small and medium-sized and the venture company of the research and development.)
「高温域で劣化しない資源探査用シンチレーター」
“Scintillator for Resources Exploration Equipment having high performance at high temperature”
株式会社Ｃ＆Ａからの再委託研究
Truster: C&A Corporarion
期間　 Term:　2013.12 - 2017.3
本年度 Total:　20,000,000 yen for our team, 2014.4 - 2015.3

5. JST研究成果展開事業
研究成果最適展開支援プログラム（A-STEP）
ハイリスク挑戦タイプ
Foundation for High-risk challenging, 2014
「Ｘ線位相イメージングを飛躍させる超高解像度、高感度Ｘ線検出器の実用化開発」
“Development of ultra-high resolution and highly sensitive X-ray detector for innovative X-ray phase imaging”
キヤノン株式会社からの再委託研究
Truster: Canon Inc.
期間　 Term:　2014.12 - 2015.3
本年度 Total:　11,590,000 yen for our team, 2014.12 - 2015.3

6. JST研究成果展開事業
FS 探索タイプ
FS stage

「新規ランガサイト型圧電単結晶を用いた高安定・広帯域弾性波デバイスの開発」

大橋　雄二 (Yuji Ohashi)

"Development of highly stable and broadband SAW device using a new Langasite type piezoelectric single crystal"

期間　Term:　2014.4 - 2016.3

本年度 Total:　400,000 yen for our team, 2014.4 - 2015.3

「共晶体構造を応用した、超高分解能、高感度中性子イメージング装置の開発」

鎌田　圭 (Kei Kamada)

"Development of ultra-high resolution and highly sensitive neutron imaging apparatus using a eutectic structure"

期間　Term:　2014.4 - 2016.3

本年度 Total:　710,000 yen for our team, 2014.4 - 2015.3

「ナノ秒以下の高速応答を示す放射線素子の開発と医療への応用」

ペジャール　ヤン (Jan Pejchal)

"Development of scintillator crystal having a high-speed response of nanoseconds, and its medical applications"

期間　Term:　2014.4 - 2016.3

本年度 Total:　1,500,000 yen for our team, 2014.4 - 2015.3

【NEDO プロジェクト】

New Energy and Industrial Technology Development Organization

1. 平成２５年度課題設定型産業技術開発費助成金
（希少金属代替・低減技術実用化開発助成事業）
Rare Metal Substitute Materials Development Project, 2013
ＴＤＫ株式会社からの再委託研究
Truster: TDK Corporation
期間　Term: 2013.10 - 2015.2
本年度 Total: 25,000,000 yen for our team, 2014.4 - 2015.2

2. 平成２６年度戦略的省エネルギー技術革新プログラム・実用化開発
Strategic energy-saving innovation programs, 2014
東芝照明プレシジョン株式会社からの再委託研究

Truster: Toshiba Shomei Precision Corporation
期間　 Term: 2015.2 – 2016.6
本年度 Total: 15,000,000 yen for our team, 2015.2 – 2015.3

3. 平成２６年度新エネルギーベンチャー技術革新事業
Grand renewable energy innovation programs, 2014
株式会社Ｃ＆Ａからの再委託研究
Truster: C&A Corporation
期間　 Term: 2014.12 – 2015.9
本年度 Total: 1,040,000 yen for our team, 2014.12 - 2015.3

【復興庁】 Reconstruction Agency

1. 平成２４年度地域イノベーション戦略支援プログラム
Funding Program for "Invest Japan" promotion for reconstruction, 2012
宮城県インテリジェントコスモス研究機構からの再委託プログラム
Truster: Intelligent Cosmos Research Institute, Miyagi pref.
「次世代自動車のための人材育成プログラム」
"Manpower training program for innovation in automotive industry"
期間　 Term: 2012.4 - 2017.3
本年度 Total: 10,600,000 yen for our team, 2014.4 - 2015.3

【厚生労働省科学研究費補助金】

Ministry of Health, Labour and Welfare
平成２５年度科学研究費助成　Health Science Research Grants, 2013
東京大学からの再委託研究
Truster: Tokyo University
「非侵襲血中 RI 濃度測定を可能にするウエアラブル・サブミリ解像度 PET 装置の開発」
"Development of wearable and sub-millimeter resolution type PET apparatus that enables non-invasive measurement of RI concentration in blood"
期間　 Term: 2013.4 - 2016.3
本年度 Total: 20,000,000 yen, 2014.4 - 2015.3

【文部科学省科学研究費補助金】

Ministry of Education, Culture, Sports, Science and Technology
日本学術振興会　Japan Society for the Promotion of Science
科学研究費助成　Grants-in-Aid for Scientific Research

1. 特別研究員奨励費　Fellowship
   吉川　彰　(Akira Yoshikawa)、ロバート クラル(Robert Kral)
   1,2000,000 yen,　2014.4-2015.3
2. 萌芽　Grants-in-Aid for young scientists(Sprout)
   吉川　彰　(Akira Yoshikawa)
   1,200,000 yen,　2014.4-2015.3
3. 萌芽　Grants-in-Aid for young scientists(Sprout)
   鎌田　圭　(Kei Kamada)
   1,500,000 yen,　2014.4-2015.3
4. 基盤研究（C）　Grants-in-Aid for young scientists(Scientific Research (C))
   大橋　雄二　(Yuji Ohashi)
   1,000,000 yen,　2014.4-2015.3
5. 基盤研究（C）　Grants-in-Aid for young scientists(Scientific Research (C))
   黒澤　俊介　(Shunsuke Kurosawa)
   1,000,000 yen,　2014.4-2015.3
6. 特別研究員　Fellowship
   山路　晃広　(Akihiro Yamaji)
   1,000,000 yen,　2014.4-2015.3

【国立大学法人　事業化推進事業型研究】

事業化推進型研究補助金
Foundation for Business Incubation Program
期間　Term:　2014.2 - 2015.3
本年度 Total:　50,000,000 yen,　2014.2 - 2015.3

【企業・財団・個人からの受託・共同研究，寄付金および小型プロジェクト】

Funds from industry, foundations, personal donation and small project

1.	株式会社トクヤマ	Tokuyama Corporation
2.	TDK 株式会社	TDK Corporation
3.	古河機械金属株式会社	Furukawa Co. Ltd.
4.	株式会社千代田テクノル	Chiyoda Technol Corporation
5.	キヤノン株式会社	Canon Inc.
6.	株式会社Ｃ＆Ａ	C&A Corporation
7.	東芝照明プレシジョン株式会社	Toshiba Shomei Precision Corporation
8.	由利工業株式会社	Yurikogyo Co. Ltd
9.	株式会社ジー･イー・エス	GES Co. Ltd
10.	株式会社東栄科学産業	Toei Kagaku Co. Ltd
11.	浜松ホトニクス株式会社	Hamamatsu Photonics K.K
12.	TANAKA ホールディングス株式会社	Tanaka Holdings Co. Ltd.
13.	日立金属株式会社	Hitachi Metals, Ltd

14. 大阪大学レーザーエネルギー学研究センター　共同研究
Collaboration program with Institute of Laser Engineering, Osaka Univ.
「真空紫外域に発光する新規発光結晶の開発」

平成２６年度申請特許

List of patents

1. 発光体及び放射線検出器

   鎌田　圭、吉川　彰、黒澤　俊介、横田　有為、庄子　育宏
   (Kei Kamada, Akira Yoshikawa, Shunsuke Kurosawa, Yuui Yokota, Yasuhiro Shoji)

2. 圧電振動子

   吉川　彰、大橋　雄二、横田　有為、鎌田　圭、天野　宏之、
   江口　治
   (Akira Yoshikawa, Yuji Ohashi, Yuui Yokota, Kei Kamada, Hiroyuki Amano,
   Osamu Eguchi)

3. シンチレータおよび放射線検出器

   鎌田　圭、吉川　彰、横田　有為、黒澤　俊介、菱沼　康介、山路　晃広
   (Kei Kamada, Akira Yoshikawa, Yuui Yokota, Shunsuke Kurosawa, Kosuke Hishinuma,
   Akihiro Yamaji)

他　国内出願　２　件

List of abstracts

JOURNAL OF CRYSTAL GROWTH 393, 134, Published: MAY 2014

Czochralski growth of $Gd_3(Al_{5-x}Ga_x)O_{12}$ (GAGG) single crystals and their scintillation properties

S. Kurosawa[1,2], Y. Shoji[1], Y. Yokota[2], K. Kamada[2,3], V. I. Chani[1], A. Yoshikawa[1,2,3]

1. Institute for Materials Research, Tohoku University, 2-1-1 Katahira, Aoba-ku, Sendai, Miyagi 980-8577, Japan
2. New Industry Creation Hatchery Center, 6-6-10 Aoba, Aramaki, Aoba-ku, Sendai, Miyagi 980-8579, Japan
3. C&A Corporation, 6-6-40 Aoba, Aramaki, Aoba-ku, Sendai, Miyagi 980-8577, Japan

Abstract:
Ce:$Gd_3(Al_xGa_{1-x})_5O_{12}$ (x=2.5/5 and 3/5, Ce:GAGG-2.5 and Ce:GAGG-3) crystals were grown by the Czochralski process in order to reduce cost of the starting materials as compared with conventional Ce:$Gd_3Al_2Ga_3O_{12}$ (Ce:GAGG-2) crystal which have high light output. Although perovskite phase was detected in Ce:GAGG-3, Ce:GAGG-2.5 had single-phase garnet structure. Solidification fraction for the Ce:GAGG-2.5 growth was 0.52. Optical properties including transmittance, emission, and excitation spectra of 30 samples cut from the Ce:GAGG-2.5 bulk ingot did not depend on their original position along the growth axis. These samples had light outputs of approximately 58,000±3000 photons/MeV. However, scintillation decay times varied from 140 to 200 ns and depended on the position clearly.

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http://www.sciencedirect.com/science/article/pii/S0022024813007410

JOURNAL OF CRYSTAL GROWTH 393, 163, Published: MAY2014

Optical properties of a Nd-doped $SrBr_2$ crystal grown by the Bridgman technique

S. Kurosawa[1,2], Y. Yokota[2], Y. Yanagida[3], J. Pejchal[1,4], A. Yamaji[1], Y. Shoji[1], K. Kamada[2,5], A. Yoshikawa[1,2,5]

1. Institute for Materials Research, Tohoku University, 2-1-1 Katahira, Aoba-ku, Sendai, Miyagi 980-8577, Japan
2. New Industry Creation Hatchery Center, 6-6-10 Aoba, Aramaki, Aoba-ku, Sendai, Miyagi 980-8579, Japan
3. World Engineering System, 122 Oyakesekishocho, Yamashina-ku, Kyoto 607-8188, Japan
4. Institute of Physics AS CR, Cukrovarnicka 10, Prague 6, 16200, Czech Republic
5. C&A Corporation, 6-6-40 Aoba, Aramaki, Aoba-ku, Sendai, Miyagi 980-8577, Japan

Abstract:
We have investigated the optical properties of 1 mol% Nd-doped $SrBr_2$ crystal grown by the Bridgman technique for an X-ray scintillator application. We succeeded in obtaining a transparent crystal, whose X-ray diffraction was measured under dry condition because of its hygroscopic nature. Roughly, we estimated that 90% of this crystal dissolved within 300 min. under 25°C and 65‑70% humidity. Under excitation by 270 and 400 nm photons several emission peaks originating from $^4F_{3/2}$ or $^4G_{i1}\rightarrow{}^4I_{i2}$ (i1=5/2 and 7/2 and i2=13/2, 11/2, and 9/2) transitions of Nd3+ were observed. 1 mol% Nd:$SrBr_2$ had a maximum quantum yield of approximately 45%. Additional emission peaks were observed under X-ray excitation.

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http://www.sciencedirect.com/science/article/pii/S0022024813008361

JOURNAL OF CRYSTAL GROWTH 393, 138, Published: MAY2014

Crystal growth of $CaYAlO_4$ single crystals grown by the micro-pulling down method and their luminescent properties

A. Yamaji[1], A. Suzuki[1], Y. Shoji[1], S. Kurosawa[1,2], J. Pejchal[1], K. Kamada[2], Y. Yokota[2], Akira Yoshikawa[1,2]

1. IMR, Tohoku University, 2-1-1 Katahira, Aoba-ku, Sendai 980-8577, Japan
2. NICHe, Tohoku University, 6-6-10 Aoba, Aramaki, Aoba-ku, Sendai 980-8579, Japan

Abstract:
Nd and Yb doped $CaYAlO_4$ crystals have been grown by the micro-pulling down method. The segregation coefficient along the growth direction and the radial dopant distribution were measured by using electron probe micro-analysis (EPMA). The X-ray induced luminescence spectra in the spectral range from 300 to 1500 nm were measured: Nd and Yb doped $CaYAlO_4$ showed intense peaks at 990 and 1045 nm, respectively. These crystals would be promising materials for near infrared emission scintillators.

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http://www.sciencedirect.com/science/article/pii/S0022024813008439

JOURNAL OF CRYSTAL GROWTH 393, 142, Published: MAY2014

Crystal growth and optical properties of $Ce:(La,Gd)_2Ge_2O_7$ grown by the floating zone method

S. Kurosawa[1,2], T. Shishido[1], T. Sugawara[1], K. Yubuta[1], J. Pejchal[1,3], A. Suzuki[1], Y. Yokota[2], Y. Shoji[1], K. Kamada[2,4], A. Yoshikawa[1,2,4]

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Abstract:
Some pyrosilicate scintillators such as $Ce:Gd_2Si_2O_7$ and $Ce:Lu_2Si_2O_7$ have a good light output, and especially $Ce:(Gd,La)_2Si_2O_7$ has an excellent light output of over 36,000 ph/MeV. In order to search novel scintilators, we have developed a pyrogermanate-based scintillation material $(Ce_{0.01},Gd_{0.90},La_{0.09})_2Ge_2O_7$ using the floating zone method. Although the light output was decreased due to quenching, 5d–4f transition of Ce^{3+} was observed around 480 nm in photo- and radio-luminescence spectra. This emission wavelength was longer than that of $(Ce_{0.01},Gd_{0.90},La_{0.09})_2Si_2O_7$ with an emission wavelength of 390 nm.

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Crystal growth and scintillation properties of selected fluoride crystals for VUV scintillators

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Abstract:
Single crystals of orthorhombic and monoclinic $BaLu_2F_8$ doped with Nd and Tm were grown by micro-pulling-down method. The monoclinic (low temperature modification) was grown using LiF flux, while the orthorhombic (high temperature modification) was grown with special hot-zone with shallow gradient and employing quenching process. Reasonable scintillation efficiency was achieved for the crystals of the former modification, while no rare-earth ion emission was observed in the latter due to preferential energy transfer to defects. The orthorhombic (low temperature) modification of ErF_3 was grown using LiF flux and hot zone with steep gradient. Quite low scintillation efficiency was found for the Nd-doped sample due to energy migration over the Er^{3+} levels. Possibility of using pure ErF_3 as an infra-red scintillator is discussed.

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Growth and luminescent properties of Ce-doped LiF/$LiLuF_4$ eutectic fibers grown by micro-pulling-down method

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Abstract:
The undoped and Ce-doped LiF/$LiLuF_4$ eutectic fibers with various ratios of LuF_3 to LiF were grown by the micro-pulling-down method for their application as neutron scintillators with light guiding structure. The differential thermal analysis (DTA) of undoped eutectic materials indicated that the eutectic point of LiF/$LiLuF_4$ was positioned around LiF 80 mol%–LuF_3 20 mol% composition. Some of the as-produced eutectic solids had rod-like regular array structures. This was observed using SEM images of cross-sectional and parallel cuts of the grown solids. In the range of $x \geq 0.28$, the dendrites appeared between the eutectic areas. Ce doped LiF/$LiLuF_4$ eutectic fibers demonstrated two emission peaks around 310 and 326 nm in the photoluminescence spectrum, and the decay time of the emission at 326 nm was 32.3 ns.

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Performance of Ce-doped (La, Gd)$_2$Si$_2$O$_7$ scintillator with an avalanche photodiode

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Abstract:
Scintillation properties of Ce-doped (La, Gd)$_2$Si$_2$O$_7$ (Ce:La-GPS) crystal were measured with Si avalanche photodiode (APD, Hamamatsu S8664-55). Since Ce:La-GPS is a novel scintillator, its scintillation properties have been evaluated using the APD for the first time. This crystal grown by floating zone method had a good light output of 41,000±1000 photons/MeV and FWHM energy resolution at 662 keV was 4.4±0.1% at 23.0±0.2 °C. The photon non-proportional response (PNR) of Ce:La-GPS was approximately 65% at 32 keV, where light output at 662 keV was normalized to 100%. Moreover, the temperature dependence of the light outputs was determined to be approximately 0.15%/°C from −10 to 30 °C.

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Studies of light yield as a function of temperature and low temperature thermoluminescence of $Gd_3Al_2Ga_3O_{12}$:Ce scintillator crystals

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Abstract:
In this paper we report the measurements of pulse height spectra, radioluminescence spectra at various temperatures between 10 and 325 K, and low temperature thermoluminescence glow curves of $Gd_3Al_2Ga_3O_{12}$:Ce. It is shown that the scintillation yield of the studied material correlates with the concentration of cerium and anti-correlates with the thermoluminescence intensity. However, regardless of the cerium content, the yield at room temperature is almost twice lower than below 180 K.

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Radiation imaging with a new scintillator and a CMOS camera

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Abstract:
A new imaging system consisting of a high-sensitivity complementary metal-oxide semiconductor (CMOS) sensor, a microscope and a new scintillator, Ce-doped $Gd_3(Al,Ga)_5O_{12}$ (Ce:GAGG) grown by the Czochralski process, has been developed. The noise, the dark current and the sensitivity of the CMOS camera (ORCA-Flash4.0, Hamamatsu) was revised and compared to a conventional CMOS, whose sensitivity is at the same level as that of a charge coupled device (CCD) camera. Without the scintillator, this system had a good position resolution of 2.1 ± 0.4 μm and we succeeded in obtaining the alpha-ray images using 1-mm thick Ce:GAGG crystal. This system can be applied for example to high energy X-ray beam profile monitor, etc.

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Development of a 30 cm-cube Electron-Tracking Compton Camera for the SMILE-II Experiment

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Abstract:
To explore the sub-MeV/MeV gamma-ray window for astronomy, we have developed the Electron-Tracking Compton Camera (ETCC), and carried out the first performance test in laboratory conditions using several gamma-ray sources in the sub-MeV energy band. Using a simple track analysis for a quick first test of the performance, the gamma-ray imaging capability was demonstrated with clear images and 5.3 degrees of angular resolution measure (ARM) measured at 662 keV. As the greatest impact of this work, a gamma-ray detection efficiency on the order of 10^{-4} was achieved at the sub-MeV gamma-ray band, which is one order of magnitude higher than our previous experiment. This angular resolution and detection efficiency enables us to detect the Crab Nebula at the 5σ level with several hours observation at balloon altitude in middle latitude. Furthermore, good consistency of efficiencies between this performance test and simulation including only physical processes is very important; it means we achieve nearly 100% detection of Compton recoil electrons and means that our predictions of performance enhancement resulting from future upgrades are more realistic. We are planning to confirm the imaging capability of the ETCC by observation of celestial objects in the SMILE-II (Sub-MeV gamma ray Imaging Loaded-on-balloon Experiment II). The SMILE-II and following SMILE-III project will be an important key of sub-MeV/MeV gamma-ray astronomy.

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Crystal Growth and Luminescence Properties of Yb-doped $Gd_3Al_2Ga_3O_{12}$ Infra-red Scintillator

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Abstract:
1-mol%-Yb-doped $Gd_3Al_2Ga_3O_{12}$ infra-red scintillator crystal has been studied as a novel implantable radiation monitor in radiation therapy. Powder X-ray diffraction measurement and chemical analysis with a field emission scanning microscope and wavelength dispersive spectrometer determined its garnet structure and average chemical composition of $Yb_{0.03\pm0.01}Gd_{2.99\pm0.07}Al_{2.21\pm0.08}Ga_{2.64\pm0.09}O_{12.10\pm0.09}$. Transmittance measurements reached high values of approximately 70% in the human body transparency region between 650 to 1200 nm. Photoluminescence peaks were detected around 970 and 1030 nm under the 940 nm excitation with a Xe lamp. Infra-red scintillation emissions were clearly observed around 970 and 1030 nm due to Yb^{3+} 4f-4f transitions under X-ray excitation. Therefore, these results suggest that Yb-doped $Gd_3Al_2Ga_3O_{12}$ might be used as an infra-red scintillator material.

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Luminescent properties of Cr-doped $(Gd_X, Y_{1-X})_3Al_5O_{12}$ infra-red scintillator crystals

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Abstract:
Cr-doped $(Gd_X Y_{1-X})_3Al_5O_{12}$ ($X = 0$, 0.25, 0.50) crystals prepared by the micro-pulling down method were investigated to develop a infra-red scintillator for implantable patient dosimeter in radiation therapy. In order to evaluate their optical and scintillation performance, the following properties were measured: (i) transmittance between ultra-violet and near-infra red region, (ii) photoluminescence spectra under Xe-lamp excitation, and (iii) X-ray excited radio-luminescence spectra. Cr:$Y_3Al_5O_{12}$ and Cr:$(Gd_{0.25}Y_{0.75})_3Al_5O_{12}$ crystals showed increased transmittance of 80%, while Cr:$(Gd_{0.50} Y_{0.50})_3Al_5O_{12}$ had a lower transmittance of 40% due to its polycrystalline structure. In addition, all the Cr:$(Gd_X Y_{1-X})_3Al_5O_{12}$ crystals showed sharp scintillation luminescence peaks ascribed to Cr^{3+} d‐d transitions. Therefore, these results suggested that Cr:$Y_3Al_5O_{12}$ and Cr:$(Gd_{0.25} Y_{0.75})_3Al_5O_{12}$ crystals can be candidate materials for the dosimeter use.

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CRYSTAL GROWTH AND DESIGN, 14, 3327, Published: MAY2014

Structural Investigations of Lu_2O_3 as Single Crystal and Polycrystalline Transparent Ceramic

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Abstract:
The X-ray single crystal structure determination of Lu_2O_3 sesquioxide and of polycrystalline transparent ceramic fabricated by the unconventional spark plasma sintering (SPS) method is presented for the first time. High quality single crystals of Lu_2O_3 samples were obtained by using both the micropulling-down (μ-PD) method and the laser heated pedestal growth (LHPG) technique. The SPS method is promising for obtaining high-density ceramics with fine grains at a relatively low temperature within a short holding time. The structural characterizations helped to complete information about the cubic structure of Lu_2O_3 sesquioxide, not clear until now in the literature from only polycrystalline samples and has raised doubts among many researchers.

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Effects of Eu concentration control on crystal growth and scintillation properties for Eu:LiSrAlF_6 crystals

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Abstract:
Eu doped LiSrAlF_6 (Eu:LiSAF) crystals with various Eu concentrations were grown by a micro-pulling-down (μ-PD) method and the effects of Eu concentration control on crystal growth and scintillation properties for Eu:LiSAF crystals were investigated as a neutron scintillator. As-grown Eu0.3%:LiSAF crystal had no visible inclusion while milky parts were observed in the crystals with higher Eu contents. The secondary phases with the chemical composition of EuF_2 or EuF_3 in the Eu:LiSAF matrix were observed for the crystals with high Eu contents while the secondary phase couldn’t be observed in the powder XRD patterns. In the radioluminescence spectra of Eu:LiSAF crystals under α-ray irradiation, emission peaks around 375 nm originated from 5d-4f transition of Eu^{2+} ion were observed. The light yields systematically increased with an increase of actual Eu contents in the crystals and the decay times were 1490-1620 ns.

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Studies of low temperature thermoluminescence of GAGG:Ce and LuAG:Pr scintillator crystals using the *Tmax-Tstop* method

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Abstract:
Low temperature thermoluminescence of GAGG:Ce and LuAG:Pr scintillator crystals has been studied by means of the *Tmax-Tstop* method. It is shown that the glow curves of both materials are superpositions of discrete glow peaks and broad bands due to quasi-continuous Gaussian distributions of trapping levels. A model function has been built and trap parameters have been evaluated.

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Orientation relationships of unidirectionally aligned $GdAlO_3/Al_2O_3$eutectic fibers

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Abstract:
Unidirectionally solidified rare-earth activated $GdAlO_3$(GAP)/Al_2O_3 eutectic crystal with well-aligned fibrous structure exhibits excellent light guiding property and can be used as a scintillator plate for high-resolution X-ray imaging. In this paper, the microstructures and orientation relationships of the GAP/Al_2O_3eutectic fibers were investigated. The regular GAP single crystal fibers with a hexagonally close-packed arrangement grew straight in the same direction along the solidification direction, and were embedded in a*c*-axis oriented Al_2O_3 single crystal matrix. The majority of GAP fibers had the orientation relationships of [0 1 0]GAP//[0 0 0 1]Al_2O_3 to the growth direction and (100)GAP//(1120(Al_2O_3) to the interface plane, while slight misorientation angle of both [0 1 0]GAP axis and (1 0 0)GAP plane were observed. In the GAP/Al_2O_3 interface boundary, the lattice misfit between the two phases was relieved by insertion of extra half-planes on the Al_2O_3 side.

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COMPUTERS & MATHEMATICS WITH APPLICATIONS, 68, 1107, Published: NOV2014

An alternative lattice Boltzmann model for three-dimensional incompressible flow

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Abstract:
In this work, an alternative lattice Boltzmann (LB) model for three-dimensional (3D) incompressible flow is proposed. The equilibrium distribution function (EDF) of the present model is directly derived in accordance with the incompressibility conditions by applying the Hermite expansion. Moreover, an alternative formula for pressure computation is designed from the second order moment of the distribution function. The present 3D LB model inherits the advantageous features of Guo’s LB model: the density is a constant, the fluid pressure is independent of density and the Navier‐Stokes (N‐S) equations for incompressible flow can be derived. Two benchmark tests, flow over a backward-facing step and the lid-driven cavity flow, are applied to validate the present model. Accurate results for these tests are obtained with the present model, and further comparisons with the previous LB models (the standard LB model, the He‐Luo model and Guo’s LB model) demonstrate that the present model provides better accuracy in the region of high deviatoric stress and such advantage is further enhanced by using the D3Q27 lattice.

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NUCLEAR INSTRUMENTS AND METHODS IN PHYSICS RESEARCH A, 767, 289, Published: DEC2014

Development of GAGG depth-of-interaction (DOI) block detectors based on pulse shape analysis

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Abstract:
A depth-of-interaction (DOI) detector is required for developing a high resolution and high sensitivity PET system. Ce-doped $Gd_3Al_2Ga_3O_{12}$ (GAGG fast: GAGG-F) is a promising scintillator for PET applications with high light output, no natural radioisotope and suitable light emission wavelength for semiconductor based photodetectors. However, no DOI detector based on pulse shape analysis with GAGG-F has been developed to date, due to the lack of appropriate scintillators of pairing. Recently a new variation of this scintillator with different Al/Ga ratios−Ce-doped $Gd_3Al_{2.6}Ga_{2.4}O_{12}$ (GAGG slow: GAGG-S), which has slower decay time was developed. The combination of GAGG-F and GAGG-S may allow us to realize high resolution DOI detectors based on pulse shape analysis. We developed and tested two GAGG phoswich DOI block detectors comprised of pixelated GAGG-F and GAGG-S scintillation crystals. One phoswich block detector comprised of 2×2×5 mm pixel that were assembled into a 5×5 matrix. The DOI block was optically coupled to a silicon photomultiplier (Si-PM) array (Hamamatsu MPPC S11064-050P) with a 2-mm thick light guide. The other phoswich block detector comprised of 0.5×0.5×5 mm (GAGG-F) and 0.5×0.5×6 mm^3 (GAGG-S) pixels that were assembled into a 20×20 matrix. The DOI block was also optically coupled to the same Si-PM array with a 2-mm thick light guide. In the block detector of 2-mm crystal pixels (5×5 matrix), the 2-dimensional histogram revealed excellent separation with an average energy resolution of 14.1% for 662-keV gamma photons. The pulse shape spectrum displayed good separation with a peak-to-valley ratio of 8.7. In the block detector that used 0.5-mm crystal pixels (20×20 matrix), the 2-dimensional histogram also showed good separation with energy resolution of 27.5% for the 662-keV gamma photons. The pulse shape spectrum displayed good separation with a peak-to-valley ratio of 6.5. These results indicate that phoswich DOI detectors with the two types of GAGGs are promising for developing a high resolution PET system.

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NUCLEAR INSTRUMENTS AND METHODS IN PHYSICS RESEARCH A, 753, 84, Published: JUL2014

Development of a prototype of time-over-threshold based small animal PET scanner

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Abstract:
A time-over-threshold (ToT)-based positron emission tomography (TODPET) scanner was designed and fabricated. The PET scanner consisted of eight block detectors, each of which is composed of a 12×12 array of 2×2×10 mm^3 Pr:LuAG crystals individually coupled with a 12×12 UV-enhanced avalanche photodiode (APD) array. The APDs were individually read out using a custom-designed time-over-threshold application-specific integrated circuit (ASIC) and field-programmable gate array (FPGA) readout system. The PET scanner has an energy resolution of 10% and a time resolution of 4.2 ns. A spatial resolution of 1.17 mm (FWHM) was demonstrated in the initial results.

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CRYSTAL GROWTH AND DESIGN, 14, 4827, Published: SEP2014

Defect Engineering in Ce-Doped Aluminum Garnet Single Crystal Scintillators

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Abstract:
Mg^{2+} codoping in the cerium-doped $Lu_3Al_5O_{12}$ single crystal stabilizes a part of the cerium ions in the tetravalent charge state. Stable Ce^{4+} centers in aluminum garnet scintillators create an additional fast radiative recombination pathway in the scintillation mechanism which effectively diminishes the unwanted slow delayed recombination processes and transforms them into the fastest part of the scintillation response.

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Polycrystalline Yb^{3+}–Er^{3+}-co-doped YAG: Fabrication, TEM-EDX characterization, spectroscopic properties, and comparison with the single crystal

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Abstract:
Yttrium aluminum garnet (YAG)-based ceramics represent a valuable alternative to single crystals as active media in laser devices for specific applications. In this connection, the 1.5–1.65 μm emission channel of Er^{3+}-doped YAG is of particular importance for the realization of diode pumped solid state lasers operating in the so-called 'eye-safe' region. A well-known drawback of this material is related to its small absorption cross section in correspondence to the diode pumping radiation at 940–980 nm. However, its emission performance can be significantly improved through sensitization with Yb^{3+} ions that can efficiently absorb the excitation radiation and transfer it to the Er^{3+} ions. This work deals with the fabrication of polycrystalline YAG co-doped with Er^{3+} and Yb^{3+} ions from oxide powders via solid state sintering in high vacuum conditions and its microstructural analysis by transmission electron microscopy–energy-dispersive x-ray spectroscopy to determine the dopants distribution and to assess their influence on the sintering process and on the spectroscopic properties. For this purpose, the absorption and emission spectra of the prepared material have been measured and compared with those of a single crystal having the same composition, appositely prepared by the micro-pulling down method. Suitable calculations have been finally carried out to verify the effective perspectives of application of the investigated ceramics as active lasing medium.

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OPTICAL MATERIALS, 41, 3, Published: MAR2015

Nd^{3+}-doped Lu_2O_3 transparent sesquioxide ceramics elaborated by the Spark Plasma Sintering (SPS) method. Part 1: Structural, thermal conductivity and spectroscopic characterization

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Abstract:
We report the detailed analysis of both structural characterization by SEM, thermal conductivity of high value and high resolution spectroscopic properties of Nd^{3+}-doped Lu_2O_3 transparent ceramics fabricated by the non-conventional SPS method. The emission spectra of the main C_2 site shows two close $^4F_{3/2} \rightarrow {}^4I_{11/2}$ laser lines at 1076.3 and 1080.5 nm, respectively. The optical properties of the two C_2 and C_{3i} sites and of C_2-C_{3i} and C_2-C_2 Nd^{3+} pairs have especially been analyzed.

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Nd^{3+}-doped Lu_2O_3 transparent sesquioxide ceramics elaborated by the Spark Plasma Sintering (SPS) method. Part 2: First laser output results and comparison with Nd^{3+}-doped Lu_2O_3 and Nd^{3+}-Y_2O_3 ceramics elaborated by a conventional method

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Abstract:
We report the first demonstration of laser oscillation of two close IR emission lines at 1076.3 nm and 1080.5 nm using a 1% Nd^{3+}-doped Lu_2O_3 transparent ceramics fabricated by the non-conventional Spark Plasma Sintering (SPS) method. A comparison is made with Nd^{3+}-doped Lu_2O_3 and Nd^{3+}-doped Y_2O_3ceramics elaborated by HIP conventional method.

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NUCLEAR INSTRUMENTS AND METHODS IN PHYSICS RESEARCH A, 772, 72, Published: FEB2014

Scintillation properties of $Ce:(La,Gd)_2Si_2O_7$ at high temperatures

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Abstract:
Temperature dependence of scintillation properties was investigated for $(Ce_{0.01}, Gd_{0.90}, La_{0.09})_2Si_2O_7$ grown by floating zone method. The light output over 35,000 photons/MeV was found constant in the temperature range from 0 °C to 150 °C. In addition, FWHM energy resolution of Ce:La-GPS (roughly 7–8%) at 662 keV remained constant up to 100 °C. Thus, this crystal can be applied to oil well logging or other radiation detection application at high temperature conditions.

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OPTICAL MATERIALS, 41, 58, Published: MAR2015

Luminescence and scintillation properties of rare-earth-doped LuF_3 scintillation crystals

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Abstract:
The Nd-doped and Er-doped LuF_3 single crystals were grown by the micro-pulling-down method to study their scintillation properties in the vacuum-ultraviolet (VUV) region. The doubly Nd‐Er codoped single crystal was grown to study possibility of scintillation performance improvement by energy transfer from Er^{3+} to Nd^{3+} ions. The LiF flux was to avoid phase transition below melting temperature. The 1%Nd-doped sample showed the highest overall scintillation efficiency under X-ray excitation which was 7 times as high as that of the LaF_3:Nd 8% standard. The leading Nd^{3+} 5d‐4f emission was situated at 176 nm, while the Er^{3+} 5d‐4f emission for Er-doped samples was observed at 163 nm, which better matches the sensitivity of some VUV-sensitive photodetectors. The optimum Er concentration was determined to be around 1‐3 mol%. No Er^{3+} 5d‐4f emission was observed for the doubly Er,Nd-codoped sample due to energy transfer from the Er^{3+} to Nd^{3+} ions. Slight improvement of the light yield was observed in the doubly-doped sample with respect to the Nd-only doped one.

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Czochralski growth of $Gd_3(Al_{5-x}Ga_x)O_{12}$ (GAGG) single crystals and their scintillation properties

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Abstract:
Ce:$Gd_3(Al_xGa_{1-x})_5O_{12}$ (x=2.5/5 and 3/5, Ce:GAGG-2.5 and Ce:GAGG-3) crystals were grown by the Czochralski process in order to reduce cost of the starting materials as compared with conventional Ce:$Gd_3Al_2Ga_3O_{12}$ (Ce:GAGG-2) crystal which have high light output. Although perovskite phase was detected in Ce:GAGG-3, Ce:GAGG-2.5 had single-phase garnet structure. Solidification fraction for the Ce:GAGG-2.5 growth was 0.52. Optical properties including transmittance, emission, and excitation spectra of 30 samples cut from the Ce:GAGG-2.5 bulk ingot did not depend on their original position along the growth axis. These samples had light outputs of approximately 58,000±3000 photons/MeV. However, scintillation decay times varied from 140 to 200 ns and depended on the position clearly.

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Alkali earth co-doping effects on luminescence and scintillation properties of Ce doped $Gd_3Al_2Ga_3O_{12}$ scintillator

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Abstract:
The Mg and Ca co-doped Ce:$Gd_3Al_2Ga_3O_{12}$ single crystals were prepared by micro pulling down method with a wide concentration range 0‐1000 ppm of the codopants. Absorption and luminescence spectra were measured together with several other scintillation characteristics, namely the scintillation decay and light yield to reveal the effect of Mg and Ca co-doping. The scintillation decays were accelerated by both Mg and Ca codopants. Comparing to Ca co-doping, the Mg co-doped samples showed much faster decay and comparatively smaller light output decrease with increasing Mg dopant concentration.

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Characterization of GAGG:Ce scintillators with various Al-to-Ga ratio

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Abstract:
Temperature dependence of scintillation properties was investigated for $(Ce_{0.01}, Gd_{0.90}, La_{0.09})_2Si_2O_7$ grown by floating zone method. The light output over 35,000 photons/MeV was found constant in the temperature range from 0 °C to 150 °C. In addition, FWHM energy resolution of Ce:La-GPS (roughly 7–8%) at 662 keV remained constant up to 100 °C. Thus, this crystal can be applied to oil well logging or other radiation detection application at high temperature conditions.

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Luminescence and scintillation properties of Ce dope $SrHfO_3$ based eutectics

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Abstract:
Ce doped $SrHfO_3/SrAl_{12}O_{19}$ eutectics were grown by the micro pulling down (μ -PD) method and their directionally solidified eutectic system has been investigated. Investigations of obtained eutectic structure, luminescence and scintillation performances were also performed. Eutectics were grown at the speed of 0.60‐0.90 mm/min. In the eutectics, Ce^{3+} 4f‐5d emission was observed at 410 nm. The eutectics showed light yield of around 300 photon/5.5 meV alpha-ray by ^{241}Am excitation. Scintillation decay time was 26.4 ns (45%) with slower decay component of 263 ns (55%).

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Luminescence study on Eu or Tb doped lanthanum‑gadolinium pyrosilicate crystal

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Abstract:
$(Eu_{0.01}, Gd_{0.90}, La_{0.09})_2Si_2O_7$ (Eu:La‑GPS) and $(Tb_{0.01}, Gd_{0.90}, La_{0.09})_2Si_2O_7$ (Tb:La‑GPS) crystals were grown by the floating zone method, and their optical and scintillation properties were investigated. Gd^{3+}-to-Tb^{3+} or ‑Eu^{3+} energy transfer processes were found, and photo-luminescence and radio-luminescence emission spectra showed $^5D_0$‑^7F_i (i = 1‑4) Eu^{3+} transitions in Eu:La‑GPS, and $^5D_3$‑^7F_i (i = 3‑6) and $^5D_4$‑^7F_i (i = 3‑6) transitions in Tb:La‑GPS. Using these scintillators, alpha-ray imaging was possible with a CMOS camera. These materials can be used for X-ray detection as well.

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Performance of a new Electron-Tracking Compton Camera under intense radiations from a water target irradiated with a proton beam

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Abstract:
We have developed an electron-tracking Compton camera (ETCC) for use in next-generation MeV gamma ray telescopes. An ETCC consists of a gaseous time projection chamber (TPC) and pixel scintillator arrays (PSAs). Since the TPC measures the three dimensional tracks of Compton-recoil electrons, the ETCC can completely reconstruct the incident gamma rays. Moreover, the ETCC demonstrates efficient background rejection power in Compton-kinematics tests, identifies particle from the energy deposit rate (dE/dX) registered in the TPC, and provides high quality imaging by completely reconstructing the Compton scattering process. We are planning the ``Sub-MeV gamma ray Imaging Loaded-on-balloon Experiment" (SMILE) for our proposed all-sky survey satellite. Performance tests of a mid-sized (30 cm)^3 ETCC, constructed for observing the Crab nebula, are ongoing. However, observations at balloon altitudes or satellite orbits are obstructed by radiation background from the atmosphere and the detector itself [1]. The background rejection power was checked using proton accelerator experiments conducted at the Research Center for Nuclear Physics, Osaka University. To create the intense radiation fields encountered in space, which comprise gamma rays, neutrons, protons, and other energetic entities, we irradiated a water target with a 140 MeV proton beam and placed a SMILE-II ETCC near the target. In this situation, the counting rate was five times than that expected at the balloon altitude. Nonetheless, the ETCC stably operated and identified particles sufficiently to obtain a clear gamma ray image of the checking source. Here, we report the performance of our detector and demonstrate its effective background rejection based in electron tracking experiments.

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Photoluminescence studies on energy transfer processes in cerium-doped $Gd_3Al_2Ga_3O_{12}$ crystals

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Abstract:
We have measured photoluminescence properties of cerium-doped $Gd_3Al_2Ga_3O_{12}$ (Ce:GAGG) crystals at low temperatures with use of synchrotron radiation. Excitation spectra for the Ce^{3+} 5d-4f emission exhibit prominent peaks at Gd^{3+} intra-4f absorption bands. The Gd^{3+} intra-4f emission band is observed at 3.91 eV, but is not in resonance with the lowest energy Gd^{3+} intra-4f absorption band at 3.95 eV. The temperature dependence of the Gd^{3+} emission intensity is not correlated with that of the Ce^{3+} emission intensity. Decay curves of the Ce^{3+} emission were also measured at 9 K under excitation at various photon energies. The decay curve is remarkably changed, depending on the excitation photon energies. The present results give us hints to understand the whole of energy transfer processes in Ce:GAGG crystals.

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OPTICAL MATERIALS, 41, 32, Published: MAR2015

Growth of Nd doped $(Lu, Gd)_3(Ga, Al)_5O_{12}$ single crystal by the micro pulling down method and their scintillation properties

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Abstract:
Nd 1 mol% doped (Lu, Gd)3(Ga, Al)5O12 (LGGAG) single crystals were grown by the micro-pulling down (μ-PD) method. Luminescence and scintillation properties such as absorption, excitation and emission spectra, light yield and decay time were evaluated. Nd1%:Lu3Al5O12 showed the highest light output of around 8200 photons/MeV among the grown crystals. Scintillation decay time of Nd:Y3Al5O12 was 1.32 μs (36%) 2.02 μs (64%). Nd:Lu3Ga3Al2O12 was relatively high dense scintillator of 7.38 g/cm3 with good light yield of 6800 photons/MeV and scintillation decay time of 0.20 μs (5%) 2.60 μs (95%).

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JAPANESE JOURNAL OF APPLIED PHYSICS, 54, 04DH04, Published: FEB2015

$LiF/CaF_2/LiBaF_3$ ternary fluoride eutectic scintillator

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Abstract:
$LiF/CaF_2/LiBaF_3$ ternary eutectic scintillators were grown by the μ-PD method. In the solidified eutectic the phases were uniformly distributed in the transverse direction and aligned along the growth direction. For the Eu-doped samples, the expected emission peak observed at 425 nm was ascribed to Eu^{2+} 5d–4f transition from $Eu:CaF_2$ under X-ray excitation. The $LiF/CaF_2/LiBaF_3$ ternary eutectic scintillators showed a light yield around 7,000 photons/neutron and decay time of 260 ns (73.6%) and 50 ns (26.4%).

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Growth, Structural Considerations, and Characterization of Ce-Doped $(La,Gd)_2Si_2O_7$ Scintillating Crystals

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Abstract:
Ce-doped lantanium-gadolinium pyrosilicate $(La,Ce,Gd)_2Si_2O_7$ (Ce:La-GPS), crystals with various content of rare-earth elements were produced from the melt, and their optimal La/Gd ratio was examined. It was found that Ce:La-GPS single crystals of acceptable optical quality can be produced from the melts ranging from $La_{0.5}Gd_{1.5}Si_2O_7$ to $La_{1.0}Gd_{1.0}Si_2O_7$ and containing about 1 atom % Ce with respect to the host rare-earths of La and Gd. The crystal growth was performed by the micro-pulling-down and Czochralski methods. The crystals were chemically uniform along the growth axis, and their composition was equal to that of the melt, thus corresponding to vicinity of congruent melting composition. Spatial distribution of Ce in La-GPS was also inspected, and no variation of Ce content was detected as a result of its similarity to one of the host cations (La) regarding the size. Basic optical and scintillation properties of the Ce:La-GPS crystals are also reported, and it is demonstrated that partial substitution of Gd with La has no negative impact on crystal growth and physical performance of the crystals.

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Growth of Sc doped $RE_3Al_5O_{12}$ (RE = Y, Lu) single crystals by micro-pulling-down method and their scintillation properties

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Abstract:
Sc doped $Y_yLu_{3-y}Al_5O_{12}$ ($y = 0$–1) single crystals were grown by the μ-PD method. EPMA techniques were employed to check their chemical composition. Luminescence characteristics were measured. Anti-site defect-related host emission was observed within 280–360 nm wavelength. The light yield was increasing with Y concentration and with an optimum for Sc2% concentration. The Sc 2% doped $Y_3Al_5O_{12}$ showed the highest light yield value around 30,000 photon/MeV and 670 ns scintillation decay time using a photomultiplier detector (R7600U). Substitution effects of the Lu site and their influence on luminescence and scintillation properties were studied.

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Improvement of scintillation properties on Ce doped $Y_3Al_5O_{12}$scintillator by divalent cations co-doping

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Abstract:
The Mg co-doped $Y_3Al_5O_{12}$:Ce single crystal scintillators were prepared by micro pulling down method in a wide concentration range 0–3000 ppm of Mg co-dopant. Absorption and luminescence spectra were measured together with several other scintillation characteristics, namely the scintillation decay, light yield to reveal the effect of Mg co-doping. The scintillation decays were accelerated by Mg co-doping. The Mg co-doped samples showed much faster decay with increasing Mg.

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Copies of TV, journal and newspaper items

河北新報 2014 年 5 月 9 日（金）

放射線測定 安価な機器開発へ前進

るつぼ使わず 絶縁性酸化物 溶解

宮城・利府のGES 国内初の成功

宮城県利府町の電子部品製造装置メーカー、ジー・イー・エス（GES）が、高価な金属るつぼを使わずに絶縁性酸化物を溶解することに国内で初めて成功した。将来的には放射線測定器に使われるシンチレーター単結晶製造装置への応用を目指しており、実現すれば安価で高性能な測定器の生産が可能となる。

◇

GESが成功したのはスカルメルト法という溶解技術。高さ8センチの水冷式の銅管容器に、絶縁性酸化物のニオブ酸リチウムの粉末を入れて高周波電流を加えたところ、1260度で溶解した。同社によると、スカルメルト法による溶解はロシアで技術が確立しているものの、日本国内では成功例がなかったという。

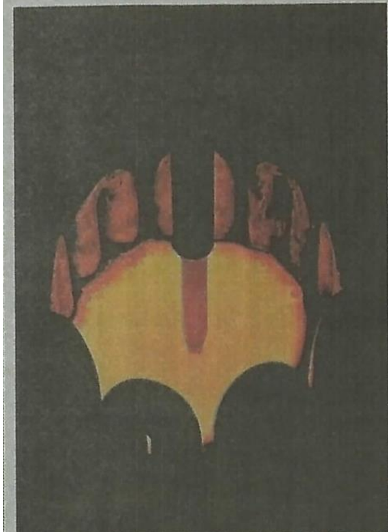
◇

放射性物質測定器に必要な高感度シンチレーターを生産するには、一度材料物質を溶かして単結晶をつくりださなければならない。日本国内ではこれまでスカルメルト法が成功していなかったため、高温で加熱する必要があり、高価なプラチナやイリジウムなど耐熱性の高い素材でできた容器のるつぼを使わなければならなかった。

数種あるシンチレーター材料の融点は最高約2000度。同社では今後、ニオブ酸リチウムより融点の高い物質でテストを進め、最終的にはシンチレーター材料での溶解を目指す。同時に高純度単結晶を作りだす実験も進めていく方針。

同社の鈴木正顕副社長は「ロシア製の放射線測定器は高価で精度が低いものも多い。国内で初めて溶解に成功したことで、国産の測定器を安価に生産することへ大きく前進した」と話している。

研究は国のイノベーション拠点立地推進事業の補助金を受け、GES社と東北大金属材料研究所、光学関連部品メーカーオキサイド（山梨県）が共同で進めている。



銅管の中で溶解するニオブ酸リチウム

実験に使われた銅管の容器（左）と溶解したニオブ酸リチウム

河北新報 2014 年 5 月 20 日（火）

井上氏ら10人に奨励賞

インコス財団 若手研究者を表彰

西澤理事長（右）から盾を受け取る受賞者

東北活性化への貢献が期待される自然科学分野の若手研究者を表彰する「インテリジェント・コスモス奨励賞」の授与式が19日、仙台市内であり、受賞した10人に記念の盾と研究助成費20万円が贈られた。

主催するインテリジェント・コスモス学術振興財団の西澤潤一理事長があいさつで「今後の研究の成長を期待する」と激励。受賞者を代表し、受精の膜融合メカニズム解明に取り組む井上直和福島県立医大生体情報伝達研究所准教授が「新しい命を育む技術の推進は東北の復興にも必要。礎となる研究をしていきたい」と決意を述べた。

13回目となる今回は、青森を除く東北5県と新潟から24人が応募。近年は生命科学分野の研究が増えているという。

ほかの受賞者は次の通り。

並河英紀山形大理学部物質生命化学科准教授▽林優一東北大大学院情報科学研究科准教授▽千場隆志山形大大学院理工学研究科准教授▽鈴木教郎東北大大学院医学系研究科講師▽鎌田圭東北大未来科学技術共同研究センター准教授▽生田和史福島県立医大医学部講師▽亀田知人東北大大学院工学研究科准教授▽西川尚宏岩手大工学部助教▽松八重一代東北大大学院工学研究科准教授

日刊工業新聞 2014 年 8 月 4 日（月）

福島民報 2014 年 9 月 6 日（土）

無人ヘリ用カメラ開発

日本原子力研究開発機構など
高度10メートルから高精度測定

日本原子力研究開発機構（JAEA）などは無人ヘリコプターに搭載できる軽量の高性能ガンマカメラを開発した。五日、県庁で発表した。

新たなガンマカメラはJAEAと古河機械金属、東京大が共同で開発を進めてきた。従来の航空機モニタリングは航空法に基づき高度三百メートルからの測定に限られるのに対し、無人ヘリにガンマカメラを搭載することで、高度十メートルから地形に合わせた詳細な放射性セシウムの分布を把握できる。

高度十メートルから、四十平方メートルを五分程度で測定できるほか、測定範囲以外からの放射線の影響を受けないため、より精度の高い測定が可能となった。

除染現場などでの活用に向け、平成二十七年度後半の実用化を目指す。

電気新聞 7 面 2014 年 9 月 8 日（月）

高精度でセシウム特定

原子力機構など ガンマカメラを改良

日本原子力研究開発機構、東京大学、東北大学などは5日、上空から放射線セシウムを可視化するガンマカメラについて、高性能化に成功したと発表した。従来製品に比べ、セシウムの位置を特定する精度が向上。実証実験では60㍍×60㍍の領域を飛行し、高精度に濃度・位置を計測できた。除染後の効果確認作業の効率化に貢献できるとしている。今年度内に実機1機を完成させ、来年度には実用化する考えだ。

マカメラは無人へリに搭載して活用する。従来は1つの検出器でセシウム濃度を特定してきたが、測定できるのは直径約100㍍の円内の平均値にとどまり、ホットスポットの正確な特定が困難な状態だった。

今回開発したガンマカメラは、直径約10㍍の円内のセシウム濃度を特定する。セシウム検出器に散乱体と吸収体の2つの検出部を設け、同時測定を可能にしたことにより、高精度な位置特定が実現した。

福島県浪江町で実証実験を実施しており、60㍍四方の範囲を20分飛行。高線量部分と低線量部分を確認することができたという。

今後は、計測回路の高集積化、検出素子の高精細化を図り、直径1㍍の円内におけるセシウム濃度を特定するなど、さらなる高性能化を図るとしている。

ガンマカメラは、科学技術振興機構（JST）先端計測分析技術・機器開発プログラムの開発課題として実施している。

河北新報 2014 年 9 月 20 日（土）

除染効果確認 効率的に

ガンマカメラを軽量化 原子力機構など

無人ヘリに搭載可能

日本原子力研究開発機構（原子力機構）は、放射性セシウムを可視化するガンマカメラを軽量化し、無人ヘリに搭載できる新型を東北大や東大、古河機械金属と共同で開発した。解像度を高め、来年度の実用化を目指す。福島第1原発事故で放射線量が局所的に高いホットスポットなどをヘリによる測定で正確に把握でき、除染効果を確認する作業の効率化などが期待される。

低空飛行が可能な無人ヘリは詳細なセシウムの測定に適するが、ガンマカメラの重量は50㌔ほどで、小型の無人ヘリには搭載できなかった。

有人ヘリは航空法により、飛行は高度300㍍以上と定められ、きめ細かい測定は困難だ。原子力機構などは今回、ガンマカメラを約10㌔まで軽量化し、無人ヘリに搭載できるようにした。

従来の測定方法では数十～数百㍍単位でしか線量状況を測定できなかったが、新型カメラを搭載した無人ヘリは約10㍍単位で測定できるという。今後、線量に応じて色分けした3Dマップの作成も計画している。

原子力機構は「試作品段階では測定地点の解像度は10㍍だった。今後、1㍍以内まで改善し、来年度には実用化したい」と話している。

試作のガンマカメラを搭載し、測定飛行する無人ヘリ＝福島県浪江町（原子力機構提供）

来年度の実用化 目指す

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