Progress on Single Crystals for Detection of High-Energy Particles

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Crytur is one of the world leading companies in synthetic crystal manufacturing with history reaching back to 1943. Crytur operates a modern 4500 sqm facility where it uses sophisticated proprietary crystal growing and machining technologies.

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CRYTUR
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Experienced supplier

- 125 employees
- Turnover 5,7 mil. EUR in 2014
- ISO 9001:2009 certified
- Advanced customer audits
- SME status
SCINTILLATORS

- Heavy scintillators (LuAG:Ce, LuAP:Ce, LuAG:Pr, PWO)
- „Radiation hard“ scintillator (YAG:Ce)
- High temperature scintillators (YAP:Ce, LuAG:Pr)
- Other scintillators (CRY18, CRY19, silicates, etc.)
- Scintillation probes and detectors, including housing and electronics
- Single photon counting detectors, based on Timepix
PANDA calorimeters

Calorimeters:
all endcap crystals produced
TDR approved
Lead Tungstate

• All end cup crystals produced, but ca 8000 crystals still missing
• BTCP plant closed in 2010
• CRYTUR decides to re-start product in May 2014, with support of Giessen University
• Proof-of-concept realized within one year
• Crytur approaches semi-production phase in August 2015.
Lead Tungstate
Fig. 7. Transversal and longitudinal optical transmittance spectra of 200 mm sample. For comparison the longitudinal transmittance of 200 mm PWO-II produced by BTCP according to PANDA EMC specification is presented.

Taken from SCINT: New Start of Lead Tungstate Crystal Production for High-Energy Physics Experiments - Andrei Borisevich, Valery Dormenev, Jindrich Houzvicka, Mikhail Korjik, Rainer W. Novotny
Proof-of-concept realized – parameters comparable to the BTCP production, the same Czochralski method, the same raw material (from Russia).

The next stage – test production of 150 pieces until 3/2016

4 growth stations
2 polishing machines
Lead Tungstate
Lead Tungstate

Production period: ?

Increase number of growing furnaces up to 20, grinding and polishing machines up to 4, single wire saw and annealing furnaces according the requirements from pre-production period

Depends on FAIR
YAG:Ce Fibres

Material for High Luminosity phase of the Large Hadron Collider at CERN

- Good radiation hardness
- High light yield

Measurement performed at Giessen
YAG:Ce Fibres
YAG:Ce/Tungsten Fibre Detector
Radiation Tolerance of LuAG:Ce and YAG:Ce Crystals under High Levels of Gamma- and Proton-Irradiation – SCINT publication

M. Lucchini, K. Pauwels, K. Blazek, S. Ochesanu and E. Auffray
CERN
Response of a sampling detector module to high energetic photons

- A single module and 2 x 2 array of modules have been tested
- Readout with bialkali photo-multiplier tubes (+ light guide)
- Tagged photon beam from 56 to 766 MeV @ MAMI (Mainz)
- Beam diameter: ~ 1.0 cm
Energy distributions for a single module

- 56 MeV
- 160 MeV
- 406 MeV
- 681 MeV

Counts vs. channel / a.u.
YAG:Ce Large Crystals
CRYTUR PROPRIETARY TECHNOLOGY

Parameters:

Sizes up to 6 inch, can be further up-scaled, just question of investment
Stress-free core, excellent material properties
Excellent process economics due to the size
YAG:Ce/Tungsten Fibre Detector

New Detector for Large Hadron Collider at CERN

To produce 1 million fibers:
1 crystal ~ 5000 - 7000 fibers ~ 1 and ½ month
200 crystals
With 10 furnaces in work it takes ~2.5 years
1 year ~ 8X10 crystals X 5000 fiber = 400000 fibers/year

Technology well feasible
YAG:Ce/Tungsten Fibre Detector

- CRYTUR has in hands growing of good quality garnets and manufacturing of the square fibers
- **YAG:Ce** is the one of the best candidates for high energy physics applications
  - Good radiation hardness
  - High light output
  - Decreasing of time decay ongoing work

We are ready to grow YAG:Ce and to produce fibers
SCINTILLATORS

- Single crystals for high resolution imaging (1 micron) with ionising particles (electrons, protons, neutrons, X-ray, etc.)
- PET
- High-resolution imaging scintillation systems directly coupled to CCD
### SCINTILLATION MATERIALS

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**Screen quality**

YAG:Ce ($Y_3Al_5O_{12}$)
CONTRACTUAL RESEARCH COLLABORATION

LuAG:Ce

YAG:Ce

YAP:Ce

CRY-18
Fast Heavy Scintillator LuAP:Ce
NEW TECHNOLOGIES
Probably the world largest YAG stress-free crystals

Diameters up to 105 mm!
CRYSTAL HOMOGENEITY

Yb:YAG Disc
Diameter 80mm
Thickness 8mm

Wavefront deformation smaller than $\lambda=20$ in the central area of 70mm.
Different Shapes

- Free-Standng
- Dia 2 mm
- Dia 50 mm
- On Substrates
- In Frames
Grids for Beam Location

50 micrometers

30 micrometers

L = 1 mm
Imaging System CRYCAM/CRYPIX

Scintillators (CRYCAM) or Semiconductor (CRYPIX) Based Detectors
Ionizing Radiation Detectors
VUV-XUV Radiation Imaging
Beam Detection
X-Ray Radiography
The physical parameters of the imaging screen are crucial for the high resolution imaging system.

- Screen homogeneity, optical quality
- Quantum efficiency
- High light output (DQE, efficient light gathering)
High Resolution

YAG:Ce, LuAG:Ce Screens

- Transparent very thin single crystal plates
- Resolution limited by the optical system used
High Resolution

- Cotton Stick
- Polymer Fibers
- Carbon Ski Stick
- Plastic Foam
CRYPIX/CRYCAM APPLICATIONS
CRYPIX in Nuclear Safety

- Single particle (counting) pixel detectors
- Ionizing radiation creates charge which is compared with threshold and registered digitally in pixels
- Good spatial resolution
- High read-out speed
- No noise, no dark current
- Almost unlimited dynamic range

Particle recognition and detection

Characteristic track shapes recorded by the Timepix device in TOT mode for different particle types:

a) gamma rays (60 keV),
b) electrons from a 90Sr source,
c) 5.5MeV alpha particles,
d) 11MeV protons entering the detector at angle 85 degrees
X-ray fluorescence imaging

Sample

Characteristic radiation

Pin-hole collimator

Pixel detector

X-ray tube

Piece of PCB

One Euro coin

Courtesy of IEAP Prague
X-ray fluorescence imaging

Color coding:
**Cu** = Red, **Pb** = Green, **Sn** = Blue

Pure Pb
- Pb: 40%
- Sn: 60%

Cu: 75%
- Zn: 20%
- Ni: 5%

Color coding:
Zn content is displayed in Pink

Courtesy of IEAP Prague
Soft tissue organs well recognized

Bone structure nicely imaged

Very light objects resolved (hairs)

Strange textured noise

Not a noise:
We can resolve hair fibers through the full mouse body!

High contrast X-ray imaging:
Courtesy of IEAP Prague
Noise-Free Camera
Noise-Free Camera

Gamma Camera
Neutron Camera

Very high resolution
Real camera – image generated by Timepix detector
Sapphire capillaries for SAXS, WAXS, XRD, PDF, EPR, ... in situ measurements

Diameters OD/ID: Ø1.0/0.6 and Ø1.6/1.1

Sealed by sapphire cap on one end. Tested at 100-200 MPa

Supercritical condition (water: p = 21.8 MPa, T = 647.1 K)

High temperature

High pressure
Thank you for your attention