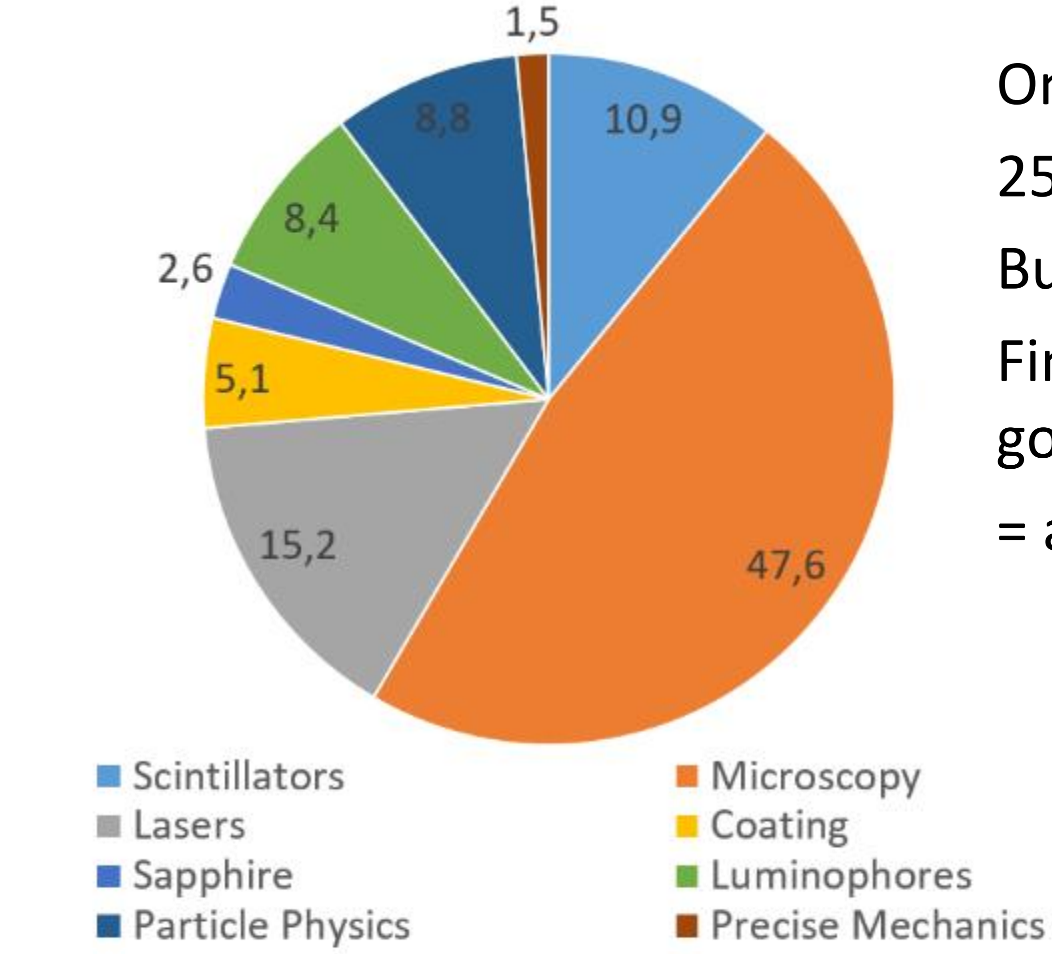
INTEGRATED OPTO-ELECTRONIC SOLUTIONS

Business Areas



One big customer -

25% share in 2020

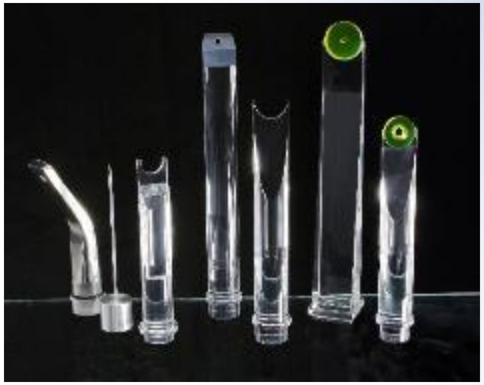
But no other customer over 10%

Final users - ca 50% academia and government paid organisations

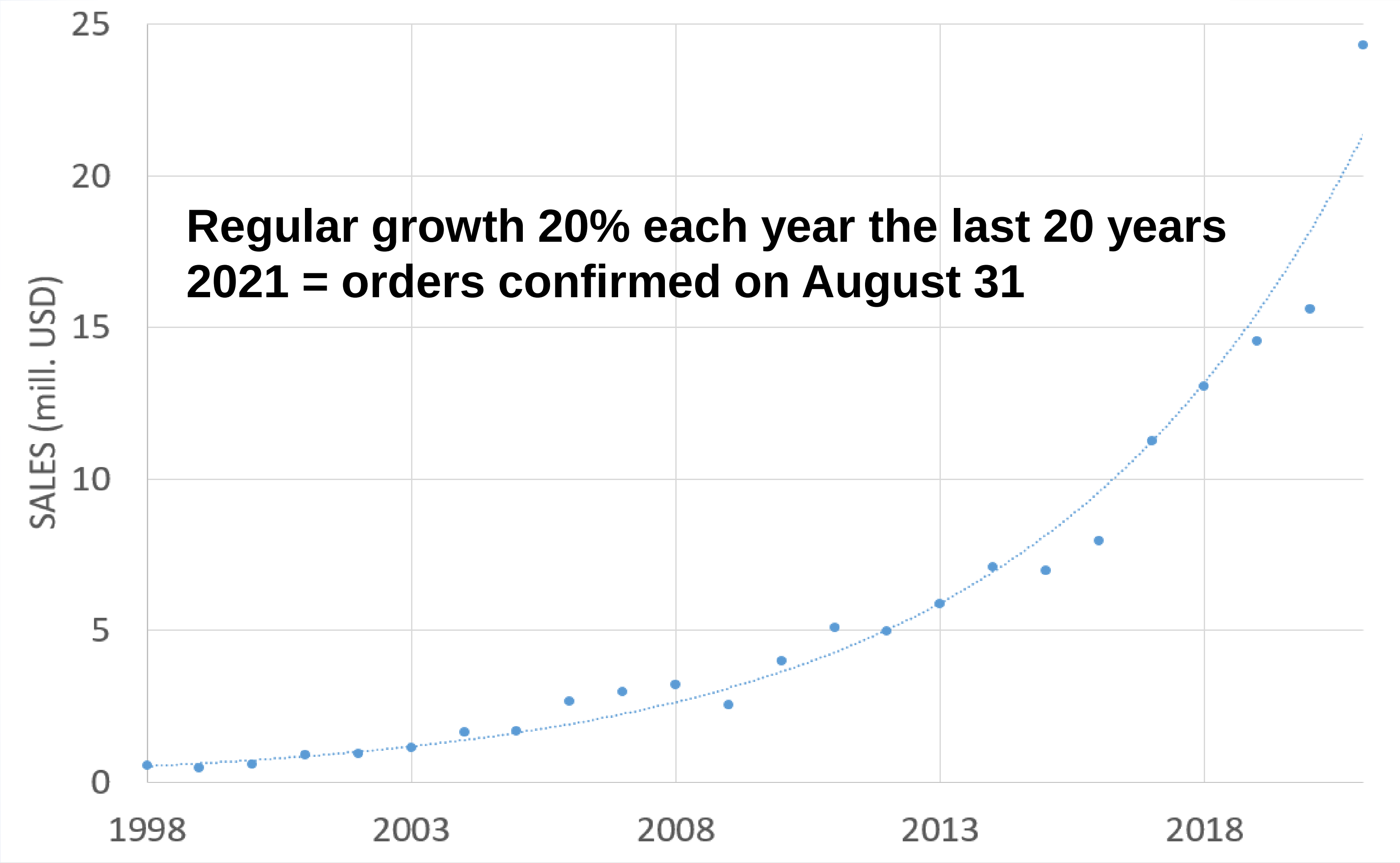
= anticyclic business model

PRODUCTION PORTFOLIO

- Global No. 1 supplier of detection units for electron microscopy
- The largest European manufacturer of laser rods
- Leader in single-crystal phosphors for high power LED/LD
- Very strong in radiation detectors



Sales


Regular growth 20% each year the last 20 years
2021 = orders confirmed on August 31
SALES (mill. USD)
0
5
10
15
20
25
1998
2003
2008
2013
2018

MANUFACTURING

MANUFACTURING

MANUFACTURING

CRYTUR IN-HOUSE SEM

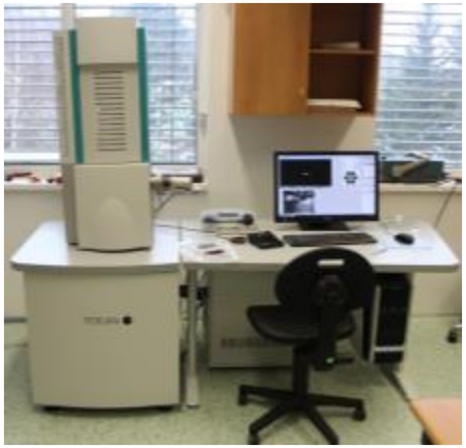
2009
Tesla/Tescan Proxima

W-filament

Production vacuum test chamber

SE, CL, BSE

2012
Tescan Vega

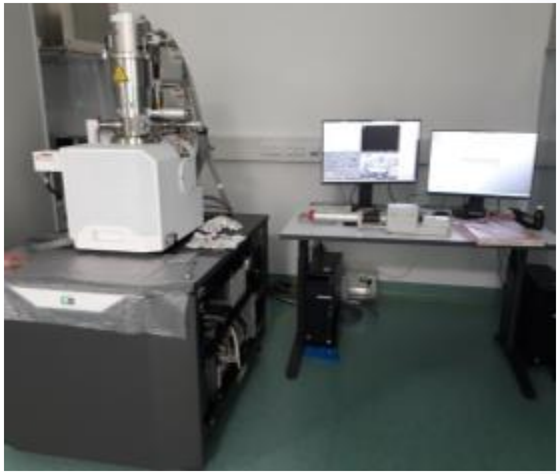


W-filament

Production testing SEM

SE, CL, BSE, EDS

2019
TFS Quattro



FEG

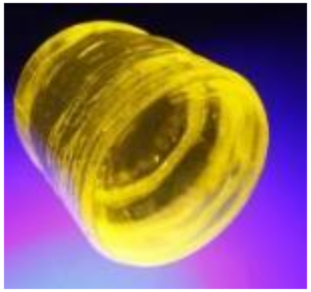
R&D+Production SEM
Low-vac, Beam deceleration

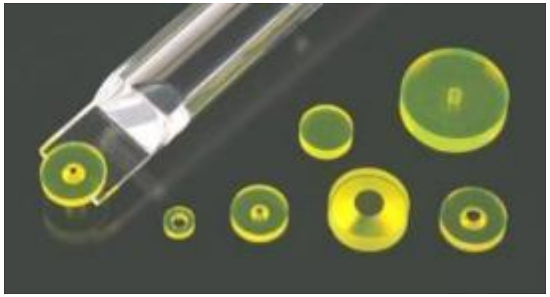
SE, CL, BSE, EDS,
+ low-vac, ESEM detectors

CRYTUR KEY COMPETENCE

INTEGRATED TECHNOLOGIES UNDER ONE ROOF

CRYSTAL GROWTH	BROAD COMPONENT MANUFACTURING	COATING	CLEAN-ROOM ASSEMBLY	SOPHISTICATED CHARACTERISATION TECHNIQUES





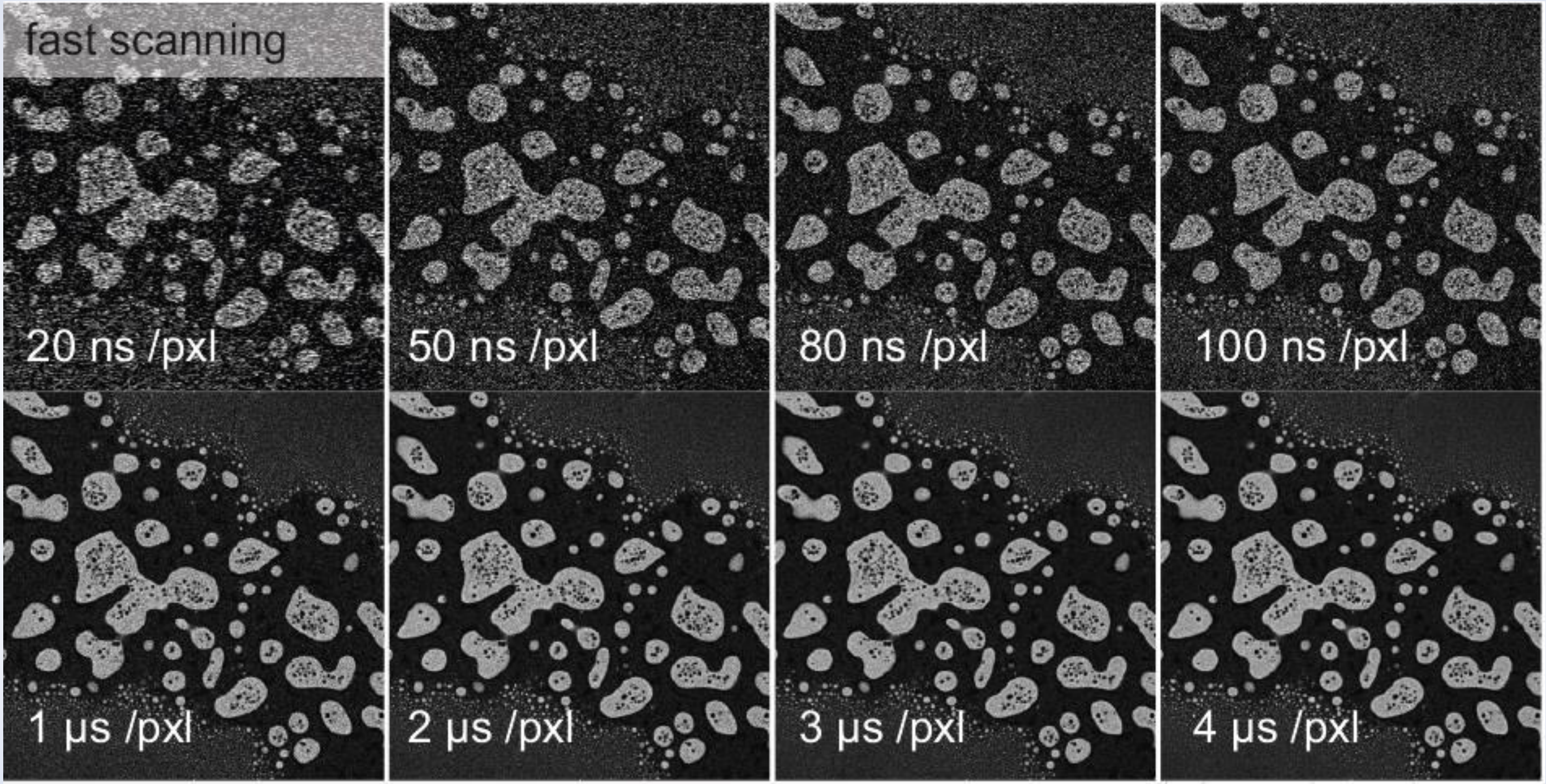
SINGLE CRYSTAL SCINTILLATOR

YAG:Ce BSE scintillators

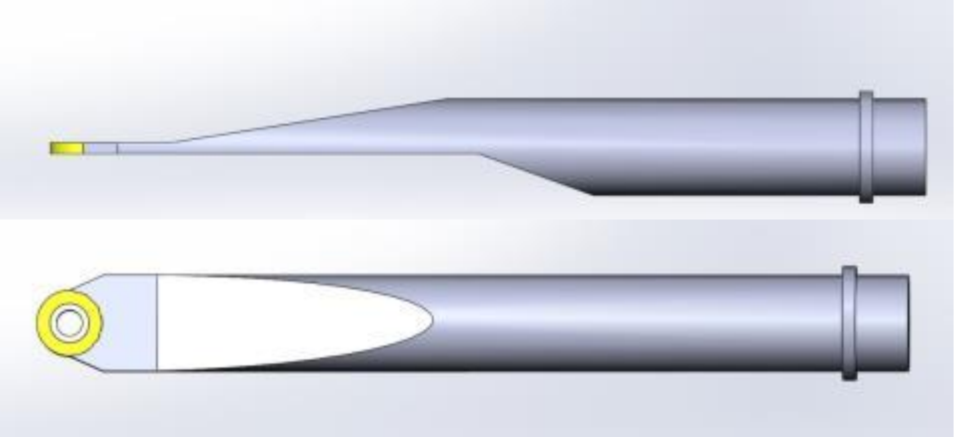
$YAlO_3:Ce$ $Y_3Al_5O_{12}:Ce$

	YAG:Ce	YAP:Ce	CRY18
Density (g/cm³)	4.57	5.37	4.50
Hardness (Mho)	8.5	8.6	5.8
Crystal structure	cubic	rhombic	monoclinic
Hygroscopic	no	no	no
Refraction index	1.82	1.95	1.79
Wavelength maximum (nm)	550	370	425
Decay time (ns)	70	25	40
Photon yield (photons/keV)	35	25	30
Spectral matching to bialcali PMT – integral quantum efficiency (%)	6	20	21

FAST BSE SCANNING



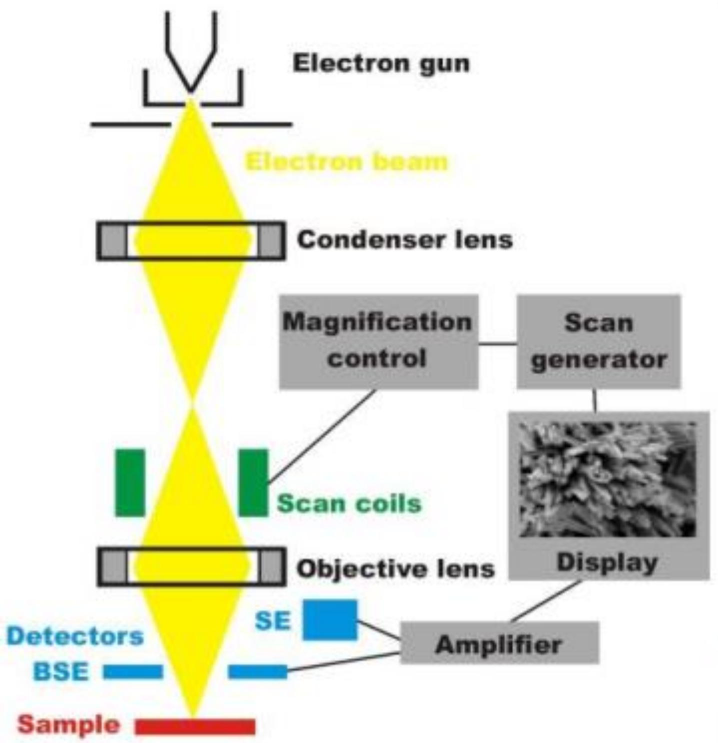
HISTORY



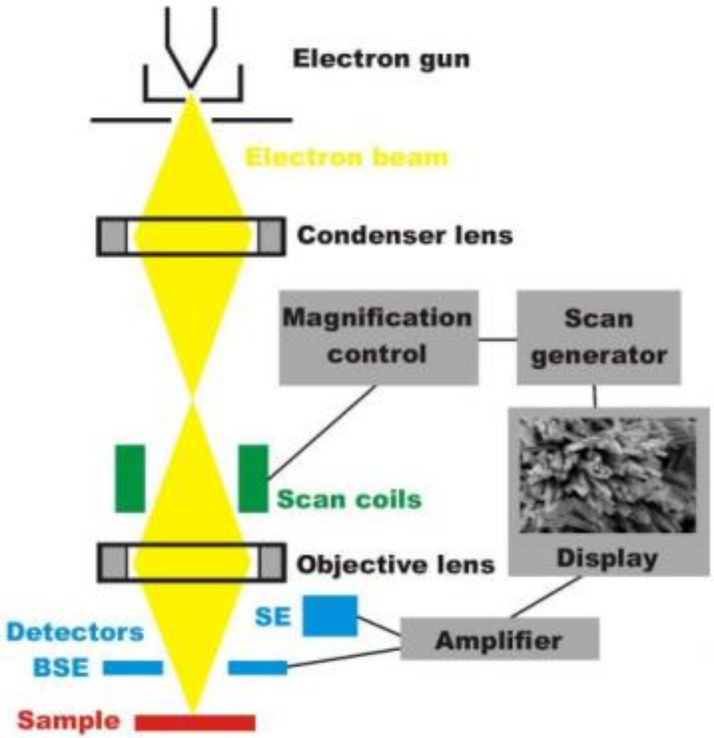
Rudolf Autrata (*1933 - +2006)
- inventor of the Autrata YAG detector of backscattered electrons
- key person of the Institute of Scientific Instruments of the Academy of Sciences of the Czech Rep. in Brno, where he worked his whole life

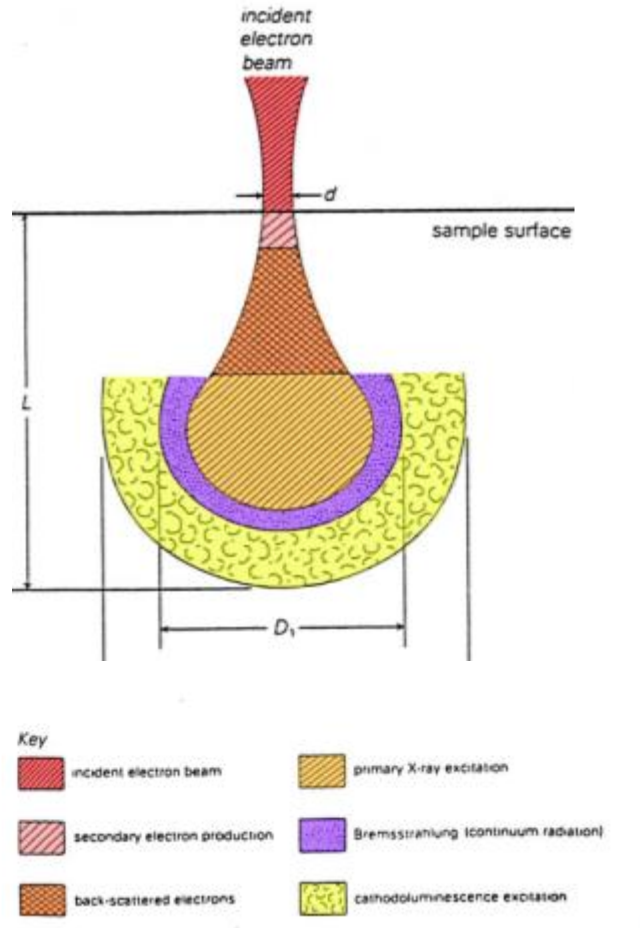
R. Autrata, P. Schauer, Jo. Kvapil and Ji. Kvapil,
***A single crystal of YAG – new fast scintillator in SEM*, J. Phys. E, 11, 707-708, (1978)**

ELECTRON MICROSCOPY - SCINTILLATION DETECTORS



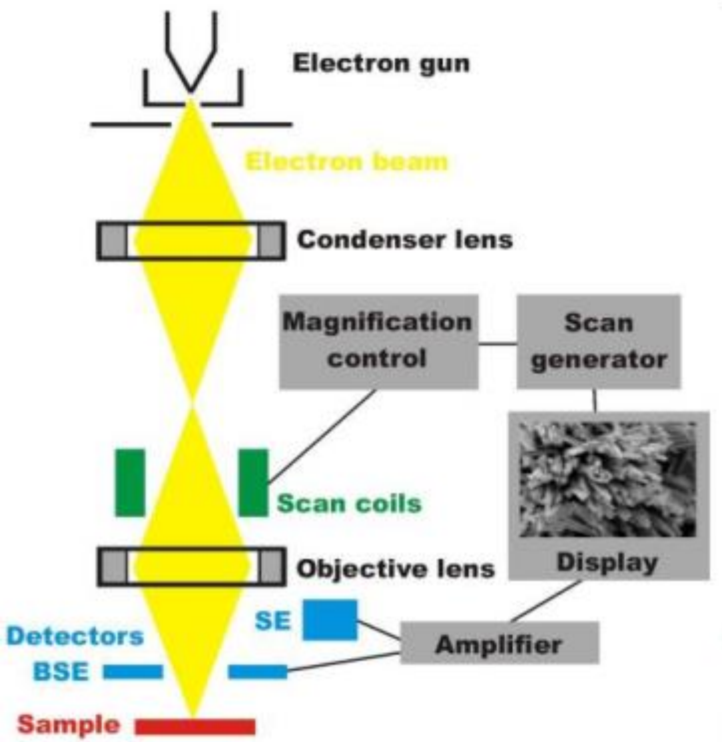
ELECTRON MICROSCOPY - SCINTILLATION DETECTORS

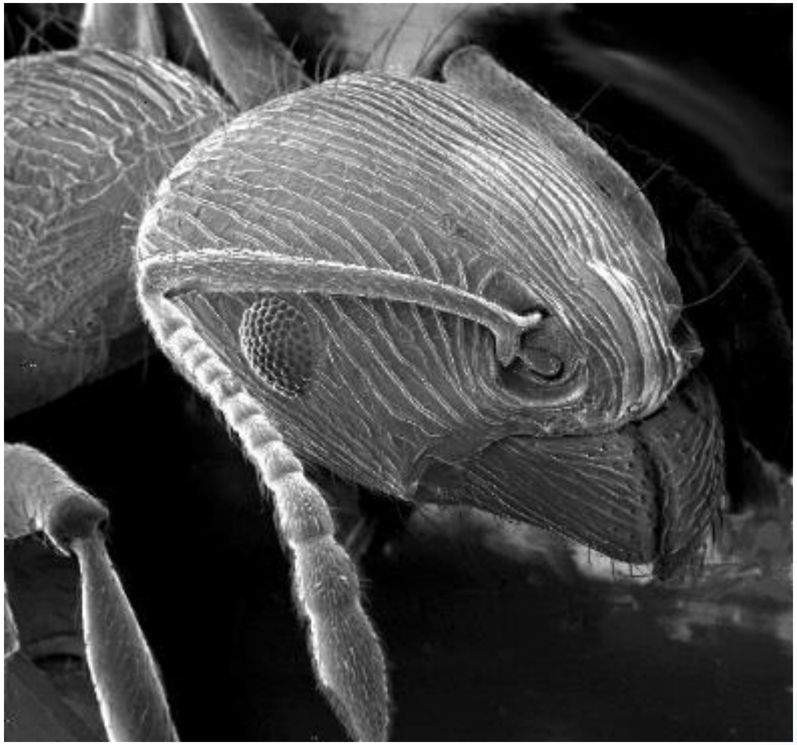




Source: wikipedia

ELECTRON MICROSCOPY - SCINTILLATION DETECTORS





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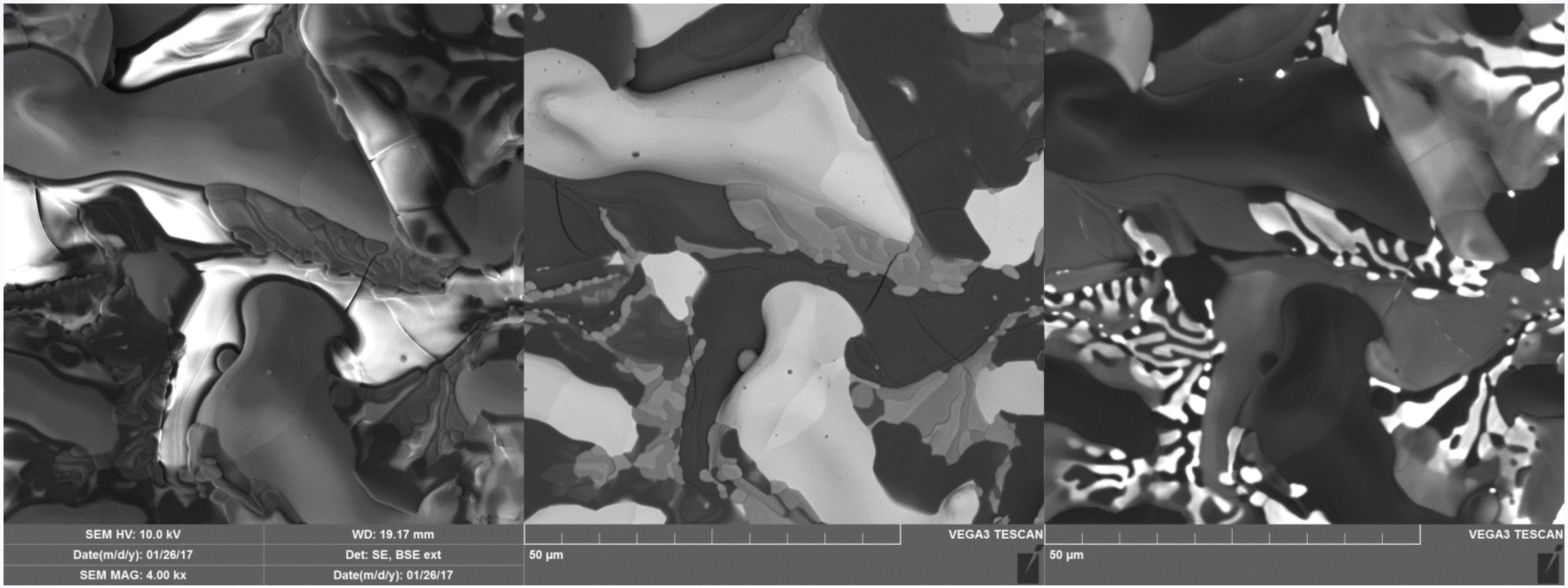

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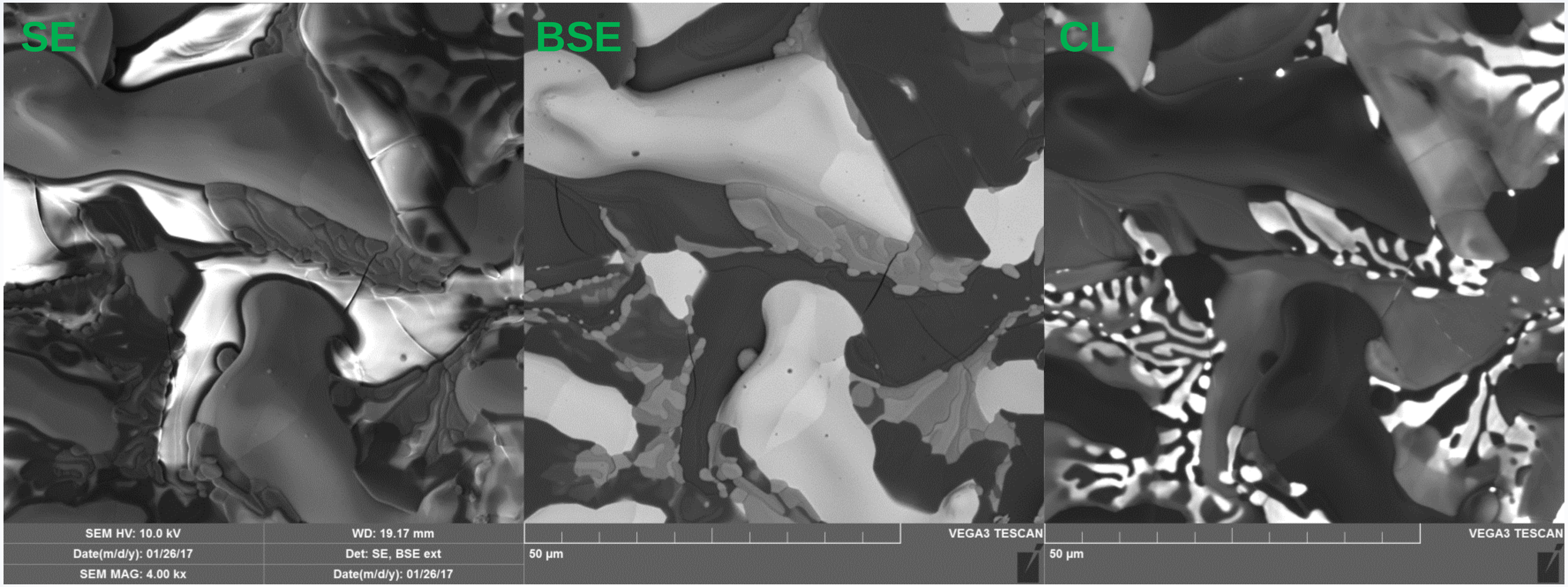
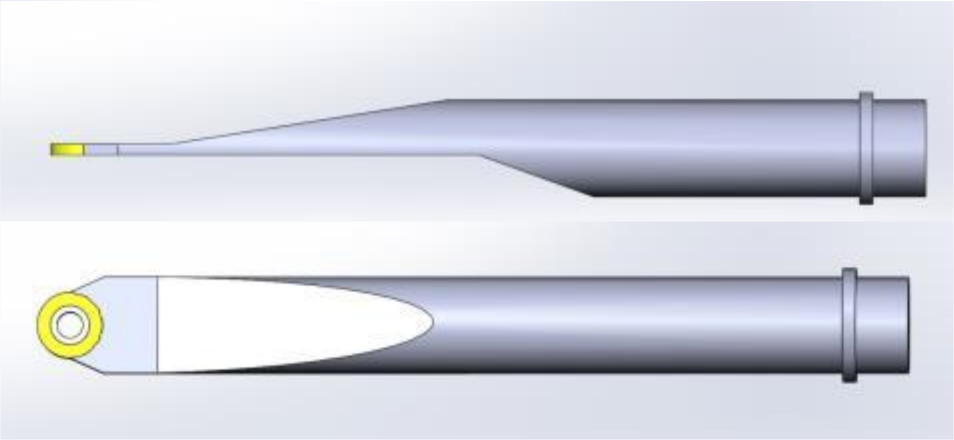


ELECTRON MICROSCOPY - SCINTILLATION DETECTORS

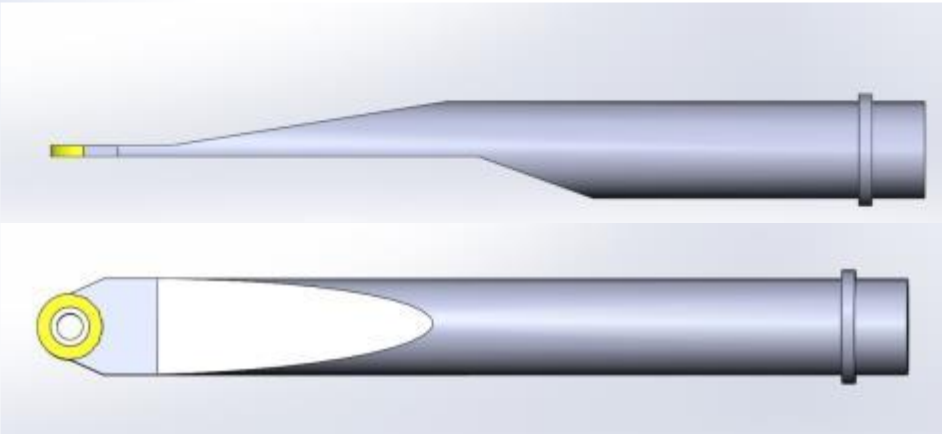


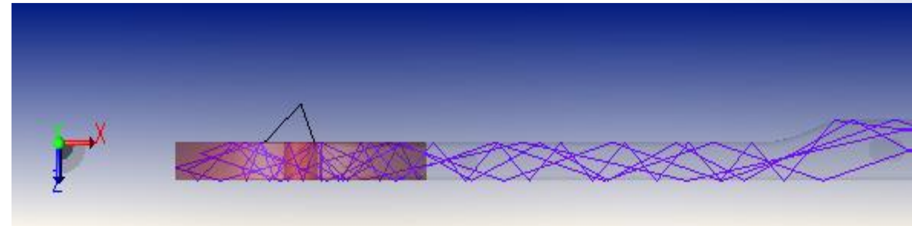
Ligth-guide: PMMA or Quartz glass

Annular Scintillator

- Conventional **BSE** collection geometry: **concentric**

ELECTRON MICROSCOPY - SCINTILLATION DETECTORS





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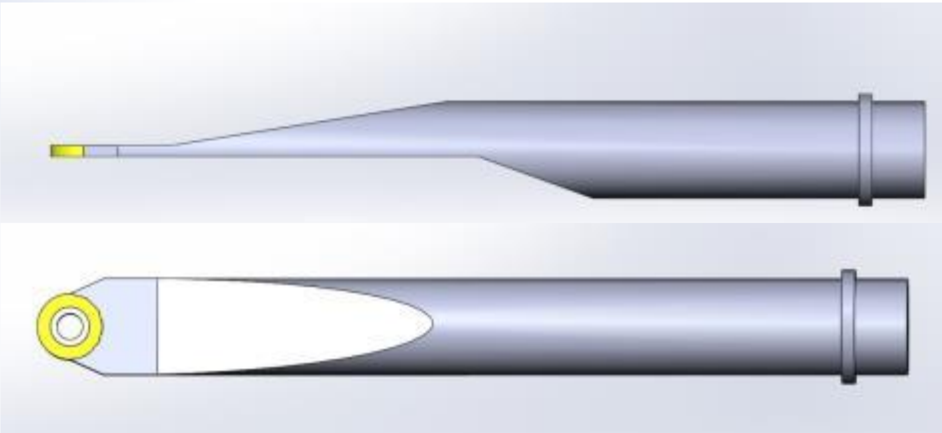
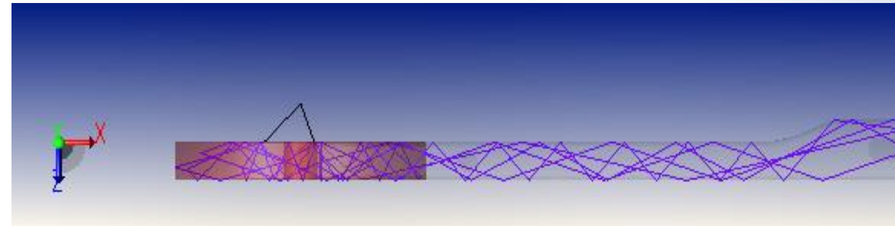
ELECTRON MICROSCOPY - SCINTILLATION DETECTORS

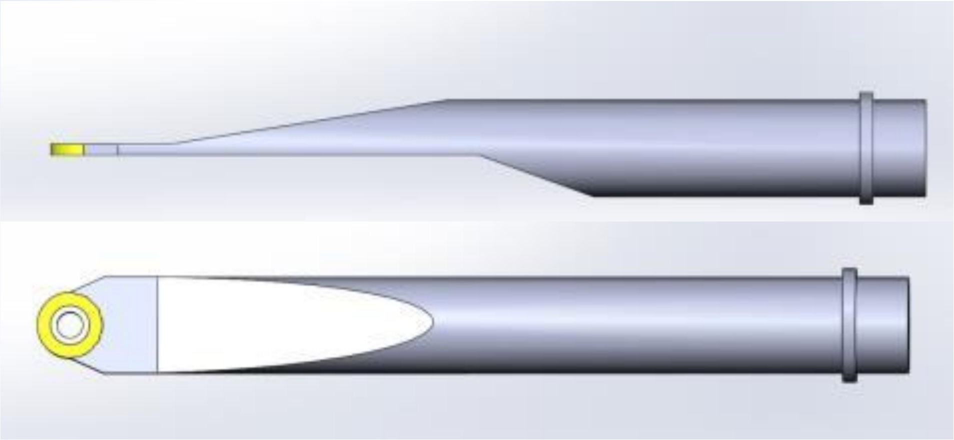




25-35% photons reach PMT

- Conventional **BSE** collection geometry: **concentric**
- Quest for maximazing photon transport from the Scintillator towards the PMT

ELECTRON MICROSCOPY - SCINTILLATION DETECTORS

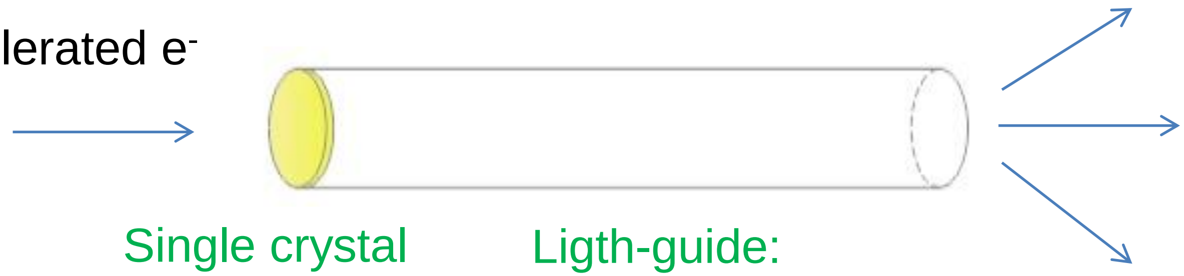


30-40% photons reach PMT

- **Concentric scintillation detector**
- Quest for maximazing photon transport from Scintillator towards the PMT
- Quest to drill and polish perfect circular hole and to evaporate a conductive coating into it
- Quest for circularity/perpendicularity in case of beam deceleration

Hole diameter of 300µm

ELECTRON MICROSCOPY - SCINTILLATION DETECTORS



- Conventional **SE** collection geometry: **side** geometry, but concentric also with more complex e-beam
- Powder scintillator more efficient (P47) for **side** geometry

WHY SCINTILLATION DETECTORS?

- Why not a direct detection by some form of p-n junction and amplifier?

WHY SCINTILLATION DETECTORS?

Photon yield of YAG:Ce, YAP:Ce, CRY18 vary around 20-30photons/keV

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- Energy conversion of e^- to photons in scintillator only approx 5%!

Ionisation, diffusion, trapping, luminescence

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- Why not a direct detection by some form of p-n junction and amplifier?
- Energy conversion of e^- to photons in scintillator only approx 5%!
- Optical losses: most of photons get lost on their way to the PMT
- **Far less than 1% of absorbed energy gets amplified by the PMT!**

Ionisation, diffusion, trapping, luminescence

Reflection, absortion, scattering

PMT photocathode efficiency

WHY SCINTILLATION DETECTORS?

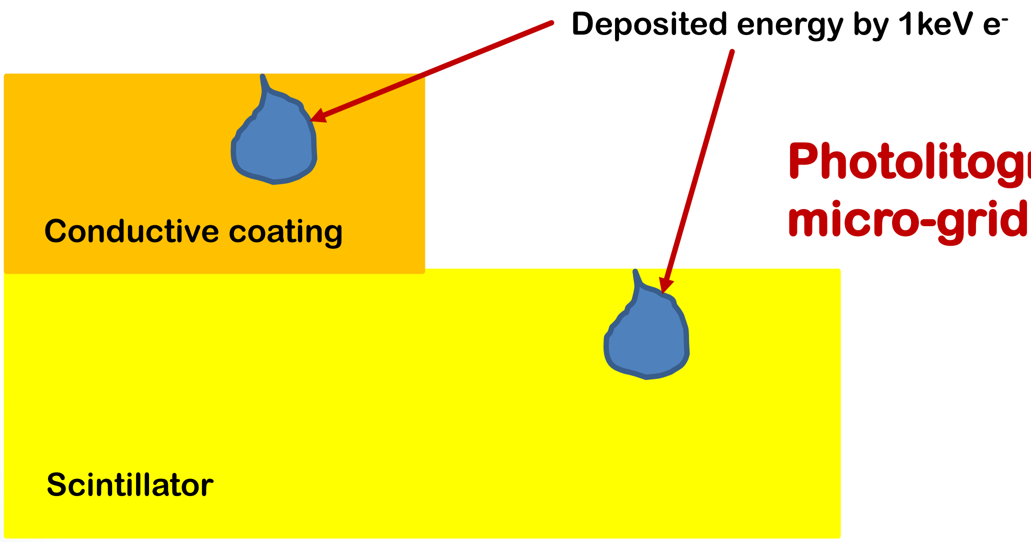
- Why not a direct detection by some form of p-n junction and amplifier?

- Fortunately for CRYTUR, the decisive arguments are
  - For Poisson statistics matters whether each e^- is detected
  - S/N at all scanning speeds (thanks to PMT)
  - life-time of crystal itself (YAG vs Silicon)
  - optical decoupling from el-mag fields

1pA x 1kev
30nA x 30keV
10^6 x change of
detector gain required

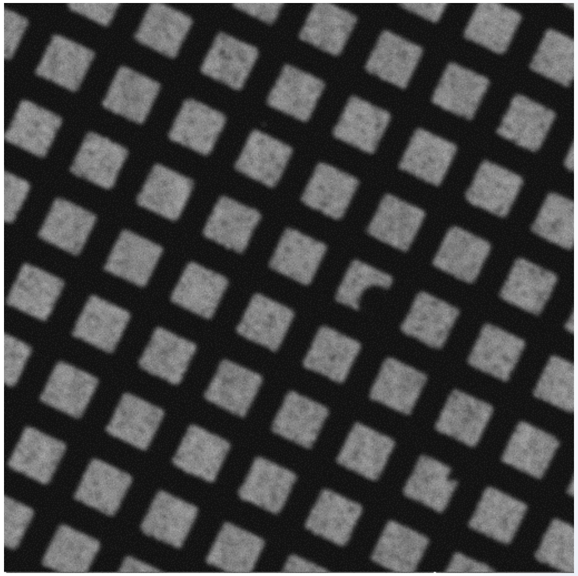
ELECTRON MICROSCOPY - SCINTILLATION DETECTORS

- **CRYTUR low-energy coating®** sensitive down to **200eV**
- Penetration depths down to units of nm



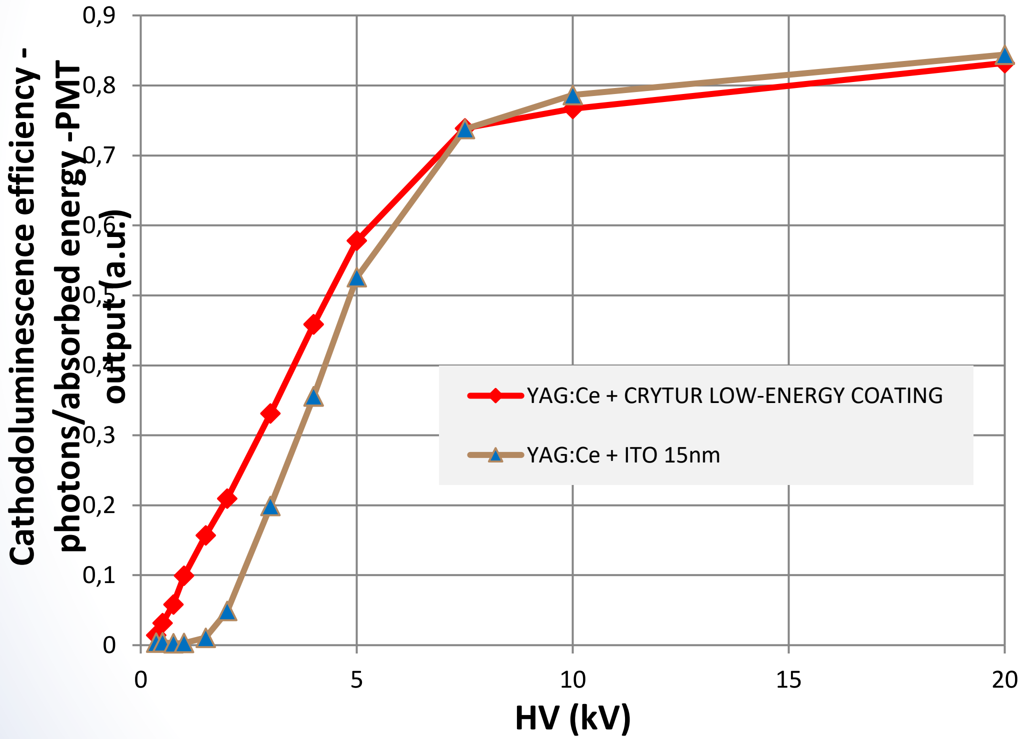
Side view

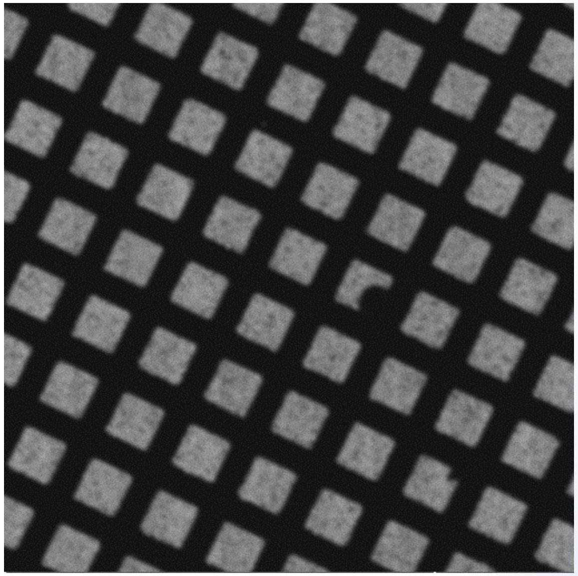
Photolitography micro-grid



Cathodoluminescence @0.2keV

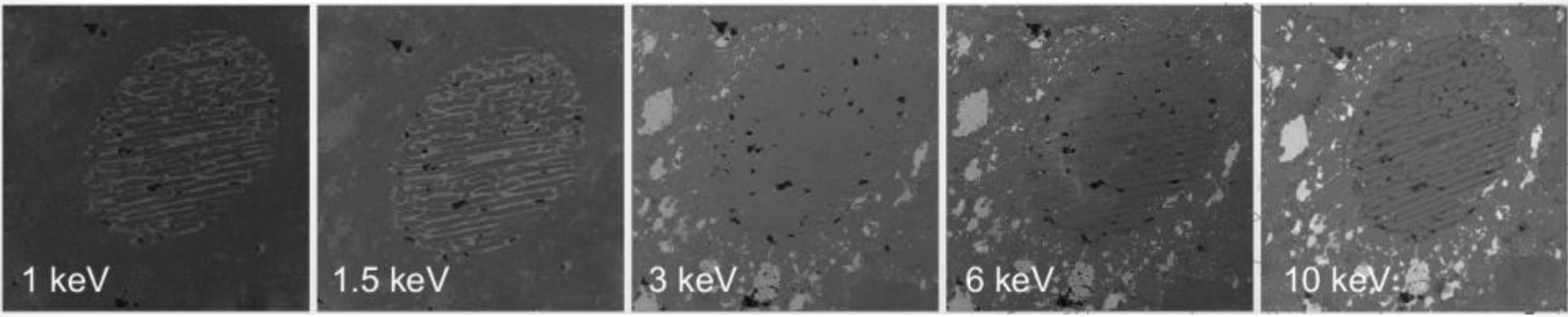
ELECTRON MICROSCOPY - SCINTILLATION DETECTORS





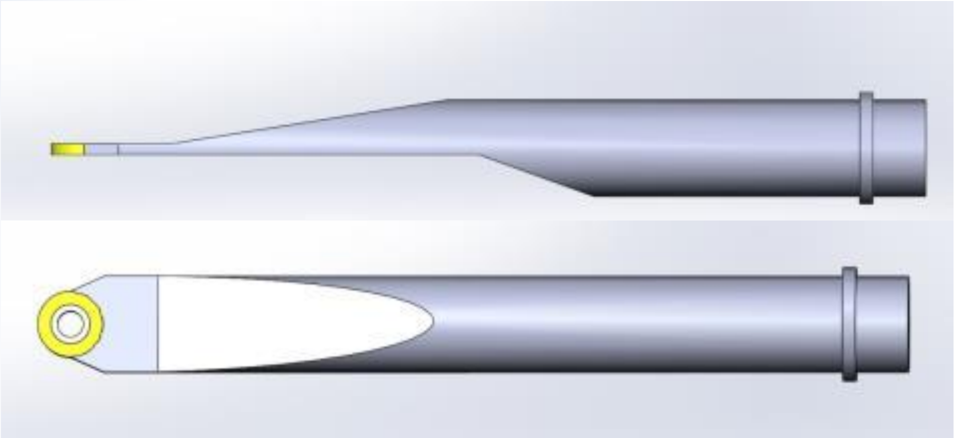
Cathodoluminescence @0.2keV

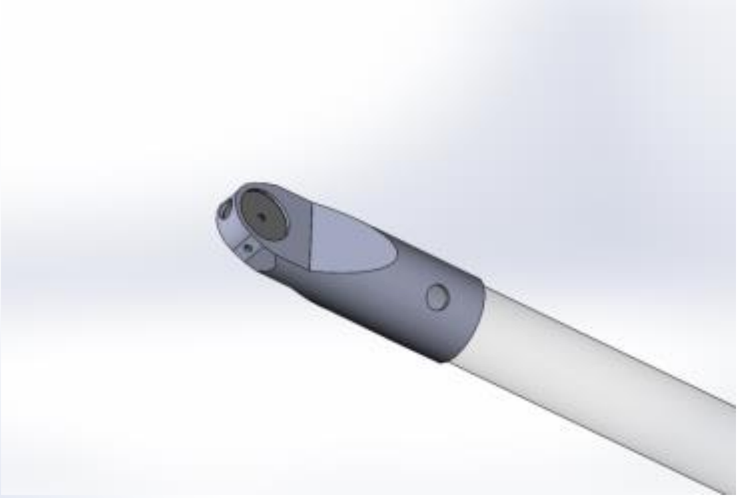
LOW-ENERGY BSE



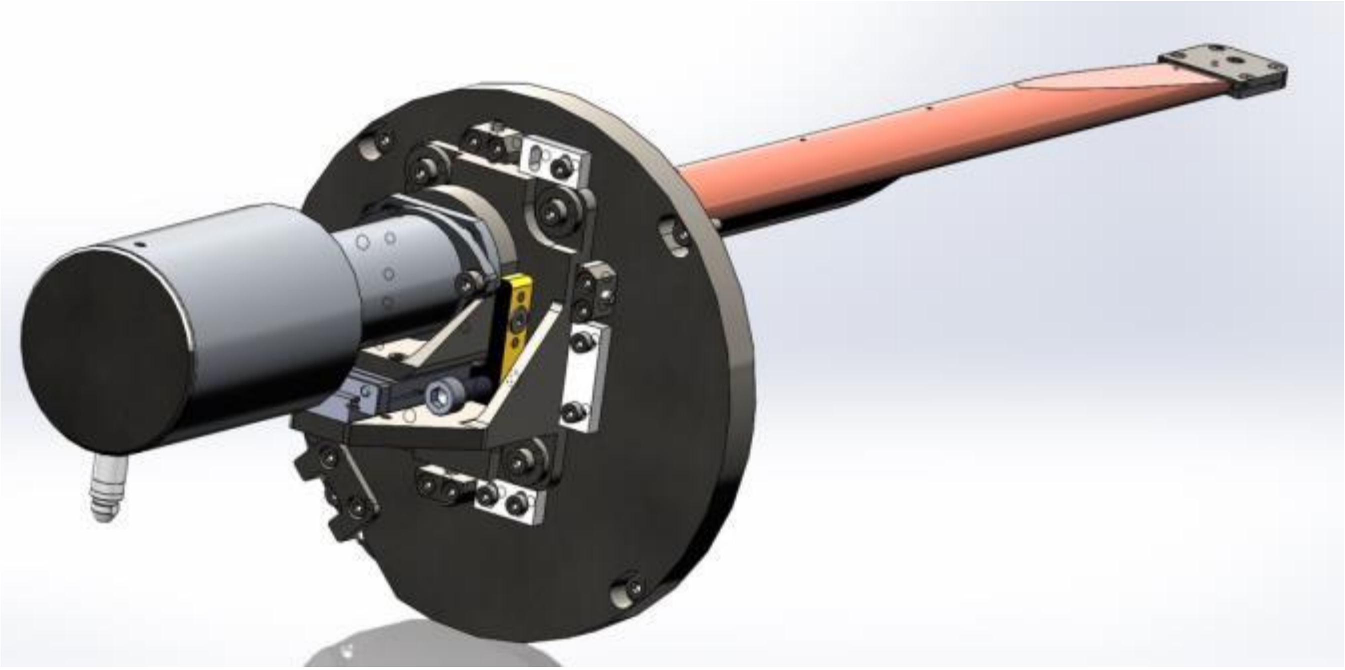
Evolution of BSE contrast with increasing landing energy.
Sample: **Chondrules and metal flakes in Ghubara Meteorite,** *provided by Institute of Geology CAS*

GENERIC BSE DESIGN

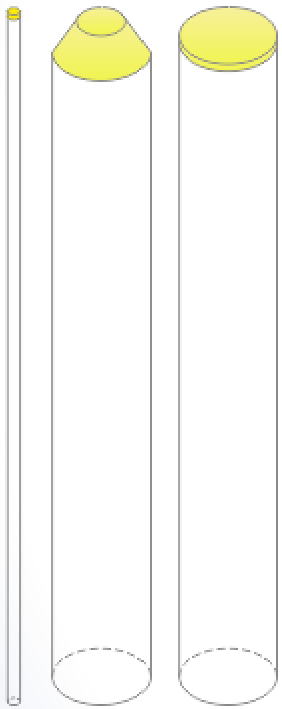




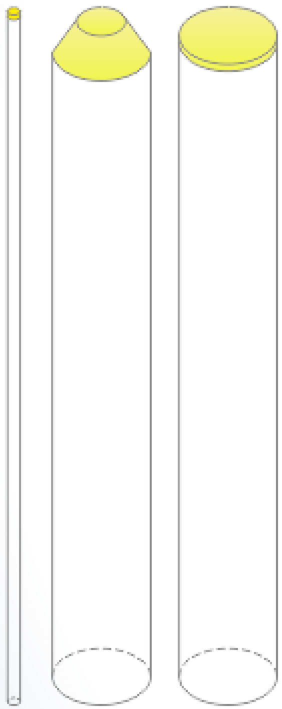
OEM BSE DESIGN

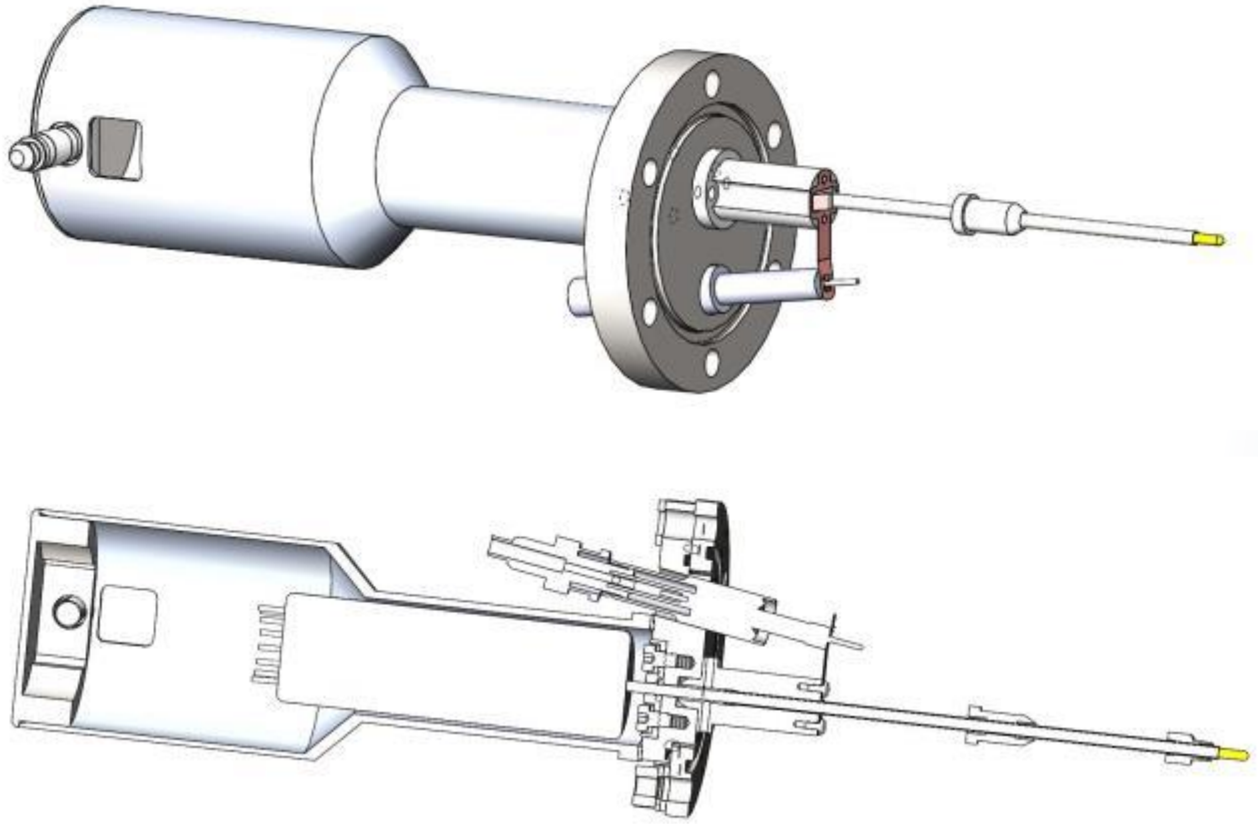


GENERIC SE DESIGN

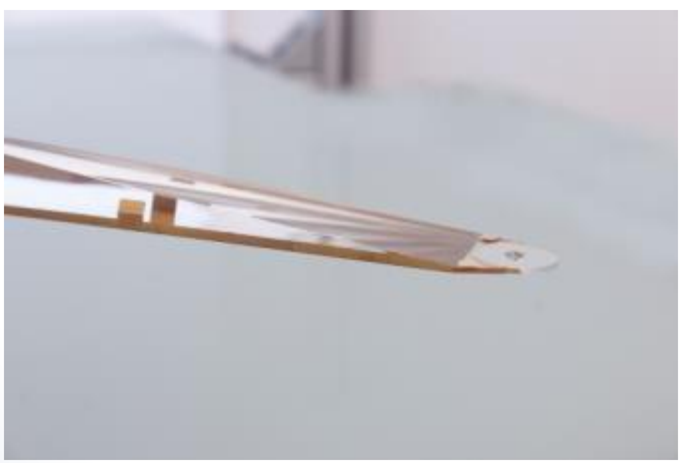


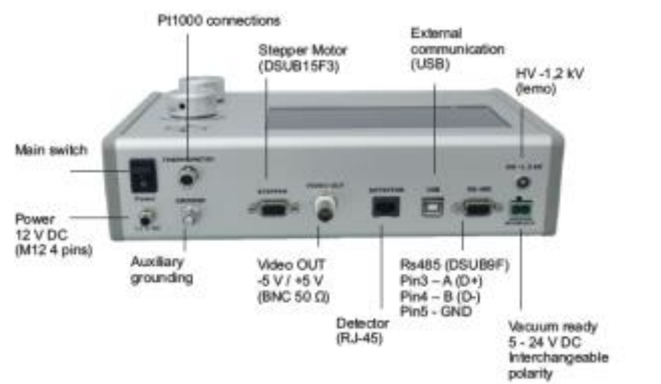
GENERIC SE DESIGN



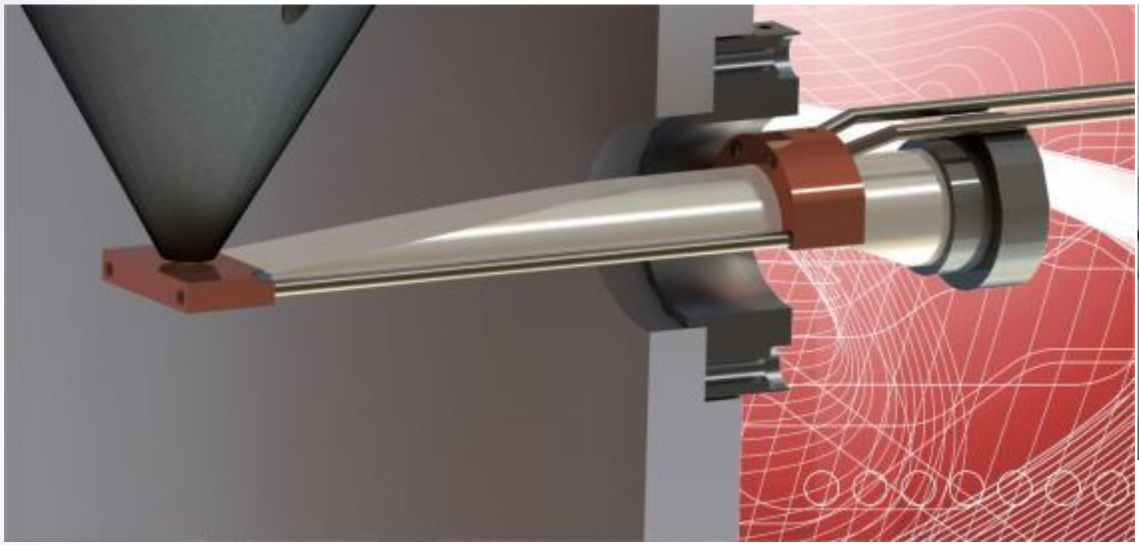


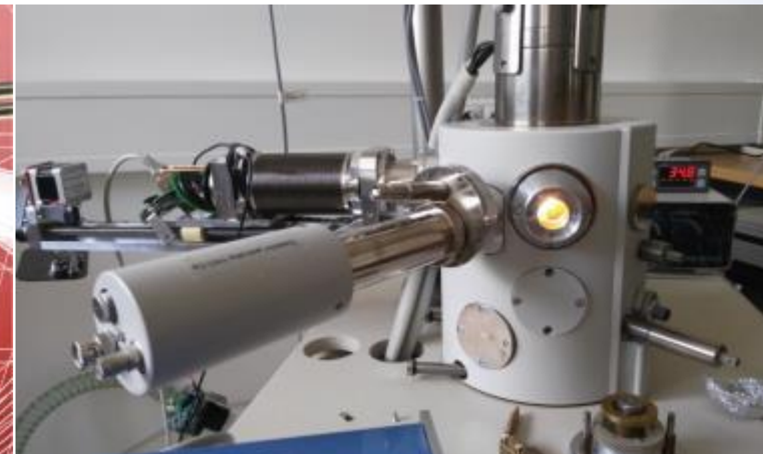
REBEKA BSE SYSTEM





KARMEN HOT-STAGE BSE





- Motorized scintillator BSE detector for ultimate S/N and ease of use
- Sample temperature up to 1000C
- Passive cooling using heat-sink and heat-pipes – robust and maintenance-free
- Unique optical shielding against IR and VIS light generated by black-body radiation
- Commercial availability since mid-2018

KARMEN HOT-STAGE BSE

Received: 6 April 2020 | Revised: 16 September 2020 | Accepted: 10 November 2020

DOI: 10.1111/jmi.12979

Journal of Microscopy RMS

ORIGINAL ARTICLE

Evaluation and application of a new scintillator-based heat-resistant back-scattered electron detector during heat treatment in the scanning electron microscope

R. Podor[1] | J. Mendonça[1,2] | J. Lautru[1] | H. P. Brau[1] | D. Nogues[2] | A. Candeias[2] | P. Horodysky[3] | A. Kolouch[3] | M. Barreau[4] | X. Carrier[4] | N. Ramenatte[5] | S. Mathieu[5] | M. Vilasi[5]

[1] ICSM, Univ Montpellier, CNRS, ENSCM, CEA, Bagnols sur Cèze, France
[2] NewTEC Scientific, Nimes, France
[3] CRYTUR, spol. s.r.o., Czech Republic
[4] Laboratoire de Réactivité de Surface, CNRS, Sorbonne Université, Paris, France
[5] CNRS, IJL, Université de Lorraine, Nancy, France

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Renaud Podor, ICSM, Univ Montpellier, CEA, CNRS, ENSCM, 5257 Site de Marcoule, Bâtiment 426 BP 17171, F-30207 Bagnols sur Cèze Cedex, France.
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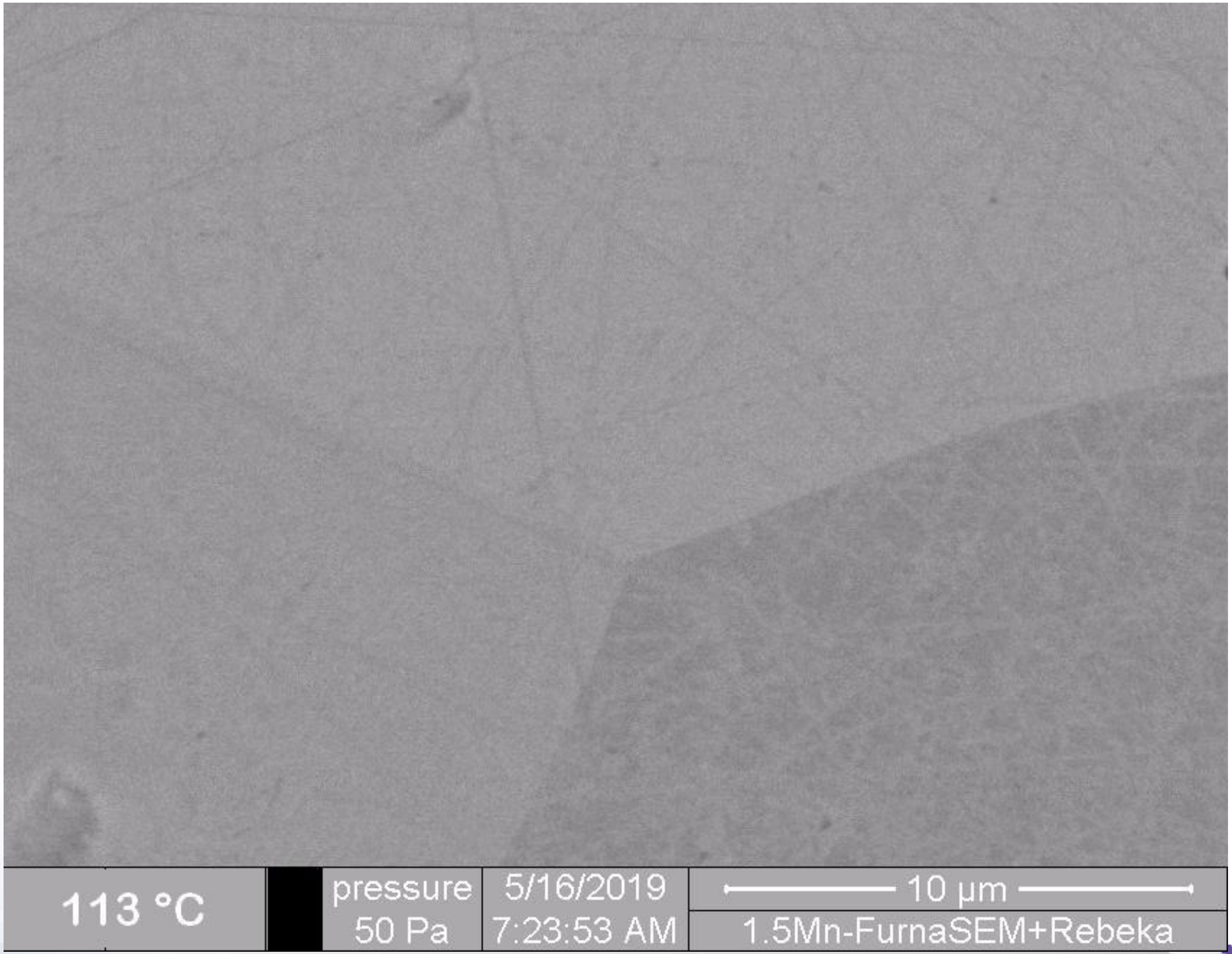
Région Occitanie, Grant/Award Number: Readynov Furna SEM Project

Abstract

A new high-temperature detector dedicated to the collection of backscattered electrons is used in combination with heating stages up to 1050°C, in high-vacuum and low-vacuum modes in order to evaluate its possibilities through signal-to-noise ration measurements and different applications. Four examples of material transformations occurring at high temperature are herein reported: grain growth during annealing of a rolled platinum foil, recrystallisation of a multiphased alloy, oxidation of a Ni-based alloy and complex phase transformations occurring during the annealing of an Al-Si coated boron steel. The detector could be potentially adapted to any type of SEM and it offers good opportunities to perform high-temperature experiments in various atmospheres.

KEYWORDS
backscattered electrons, high temperature, in situ, scanning electron microscopy, VP-SEM

KARMEN HOT-STAGE BSE



KARMEN HOT-STAGE BSE

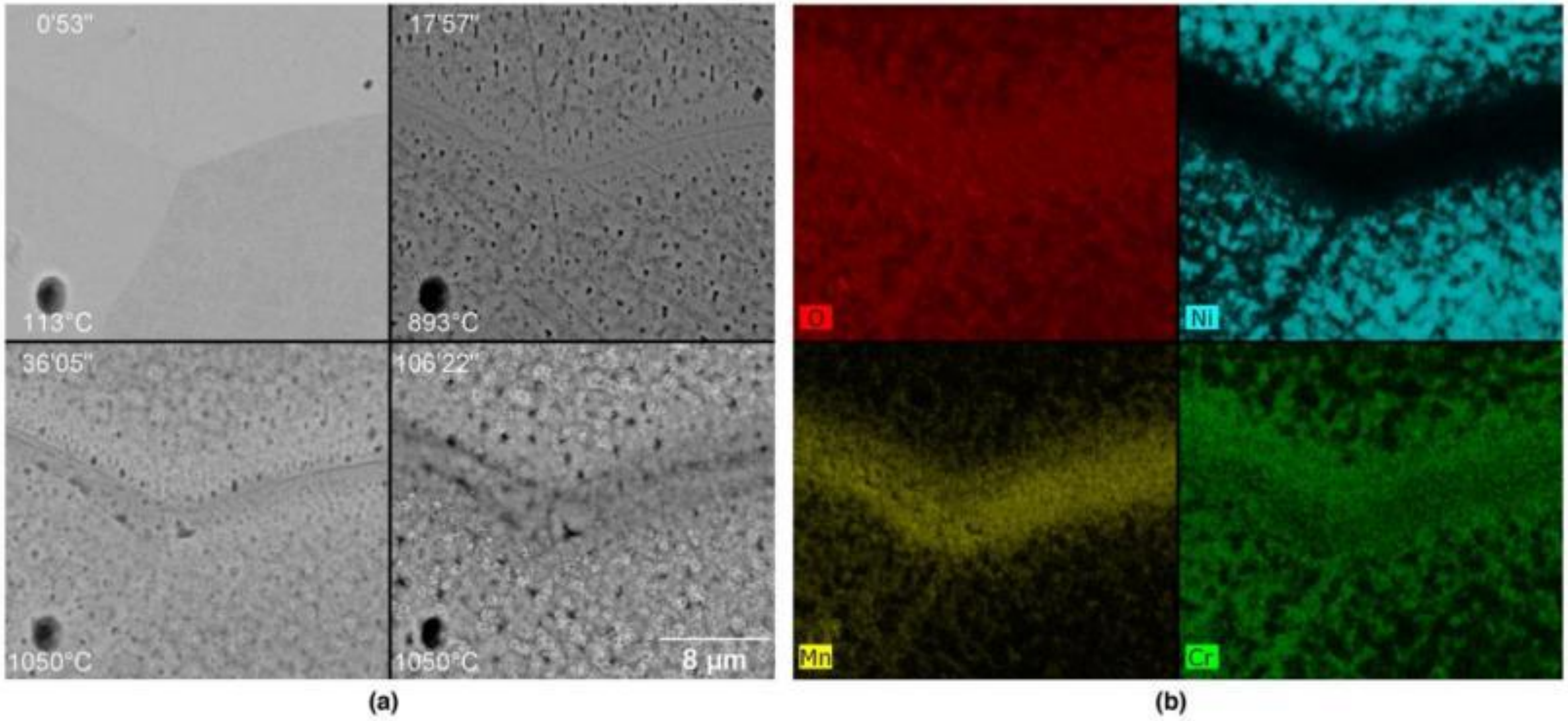


FIGURE 7 (a) High-magnification images of the oxidation of a Ni-25Cr-1.5Mn alloy in 50 Pa air up to 1050°C. (b) X-ray quantitative maps [Ni (Lα line), Mn (Lα line), Cr (Lα line) and O (Kα line)] recorded after sample cooling to room temperature on the region of interest observed at 1050°C, $t = 106'22''$, ($E_0 = 8$ kV)

Projects for Grant Agencies

- TA01010164 - *POKROČILÉ TECHNIKY DETEKCE IONIZUJÍCÍHO ZÁŘENÍ* (2011-2014, TA0/TA), CRYTUR+ FJFI ČVUT
- TE01020118 - *ELEKTRONOVÁ MIKROSKOPIE* (2012-2019, TA0/TE), 7 partnerů
- H2020-EU.2.1.1.7, ECSEL Joint Undertaking *TAKEMI5* (2017-2019), 26 partnerů
- FV30271 - *SCINTILAČNÍ DETEKTORY PRO SPECIÁLNÍ POUŽITÍ V SEM* (2018-2021, MPO/FV), CRYTUR+ÚPT AVČR
- TN01000008 - *CENTRUM ELEKTRONOVÉ A FOTONOVÉ OPTIKY* (2018-2022, TA0/TN), 13 partnerů

THANK YOU FOR YOUR ATTENTION