Development of $ZnMoO_4$ and Li_2MoO_4 crystal scintillators

Laboratory of Crystal Growth, Nikolaev Institute of Inorganic Chemistry, SB RAS, Novosibirsk 630090, Russiaa

Content

The Low Thermal Gradient Cz Technique (LTG Cz)

The General Features of the Conventional Cz Technique
The General Features of the LTG Cz Technique

Crystals Growth BGO, CWO, ZWO, ZMO und LMO

- **Crystal morphology**
- **Influence of growth rate on shaping**
- **Advantages of BGO, CWO, ZWO, ZMO und LMO Crystals Grown by the LTG Cz**

Collaboration with
Institute for Nuclear Research, Kyiv, Ukraine
was initiated by F. Danivich visit of the NIIC at the end 2005

CWO for neutrinoless 2β decay search

2006-2008:	**Evaluation of $CdWO_4$ crystals grown by the LTG Cz as detectors for high sensitivity double beta decay experiments was perfomed.** **CWO Ø 20x20 mm - Ø70x70 mm**

2009:	**Trial Growth of $^{106}CdWO_4$ crystals is performed** **Trail growth of $^{116}CdWO_4$ crystals is planned**

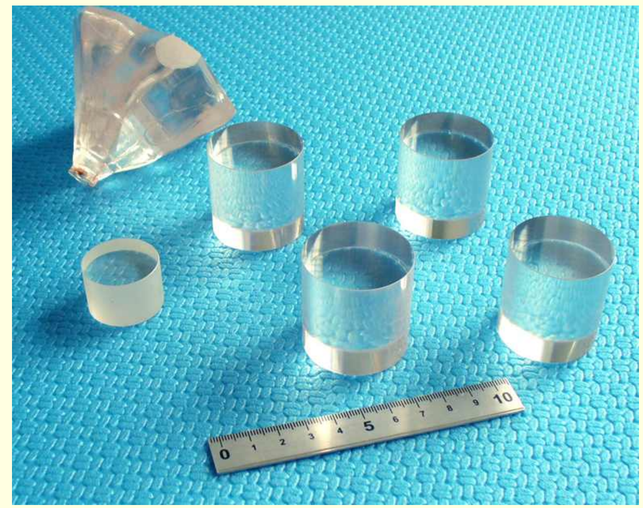
ZMO for neutrinoless 2β decay search

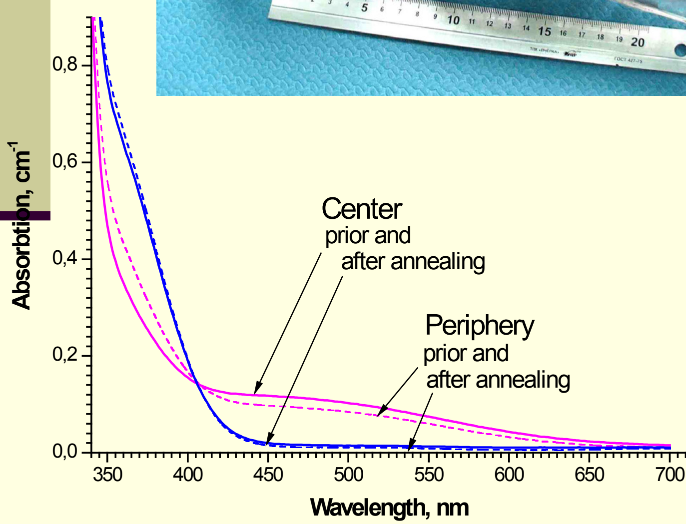
2012: Project LUMINEU (CNRS, France)

Luminescent **U**nderground **M**olybdenum **I**nvestigation for **NEU**trino mass and nature

2010 : Growth of large size radiopure $ZnWO_4$ crystals

RHR ~10% at gammas 662 keV
for Ø40x40 mm cylinders

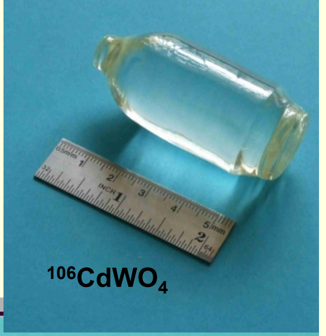


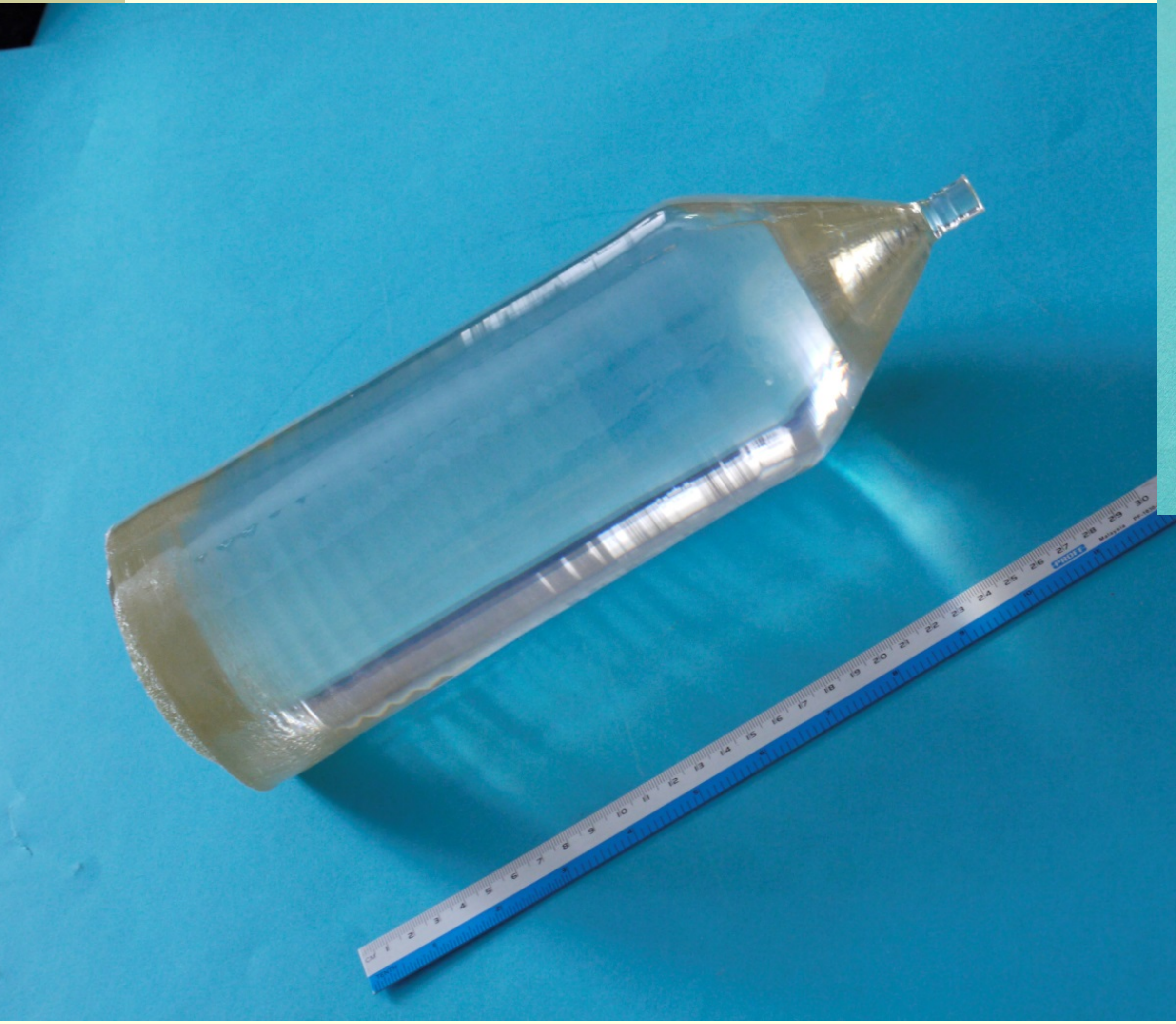


Collaboration with

- ***Institute for Nuclear Res., Kyev***
- ***Max Plank Institute (Germany)***
- ***INFN (Italy)***

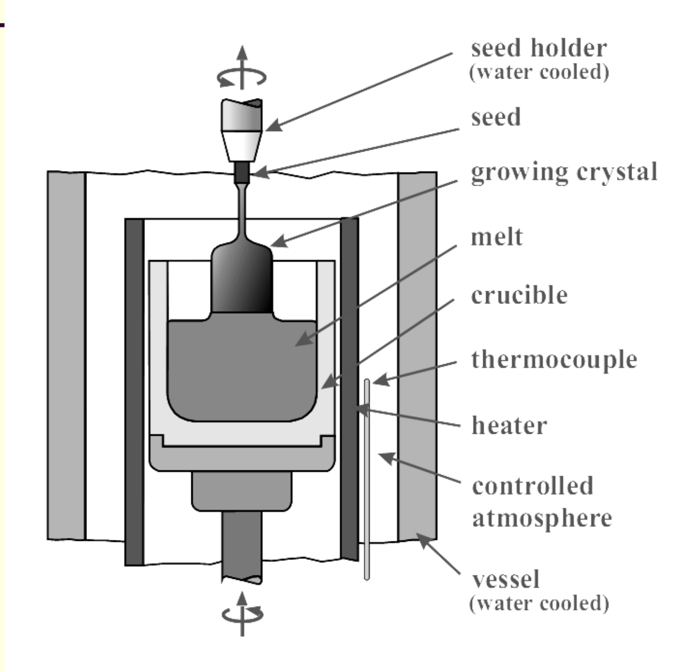
Big size CWO und ZWO crystals

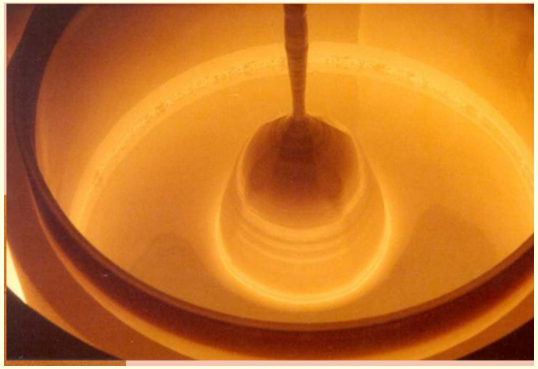


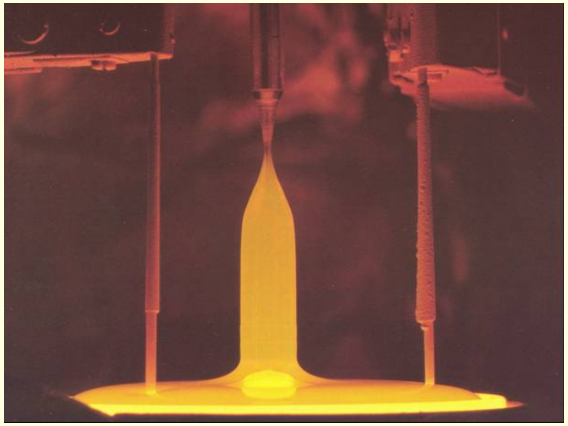


Traditional Czochralski Technique

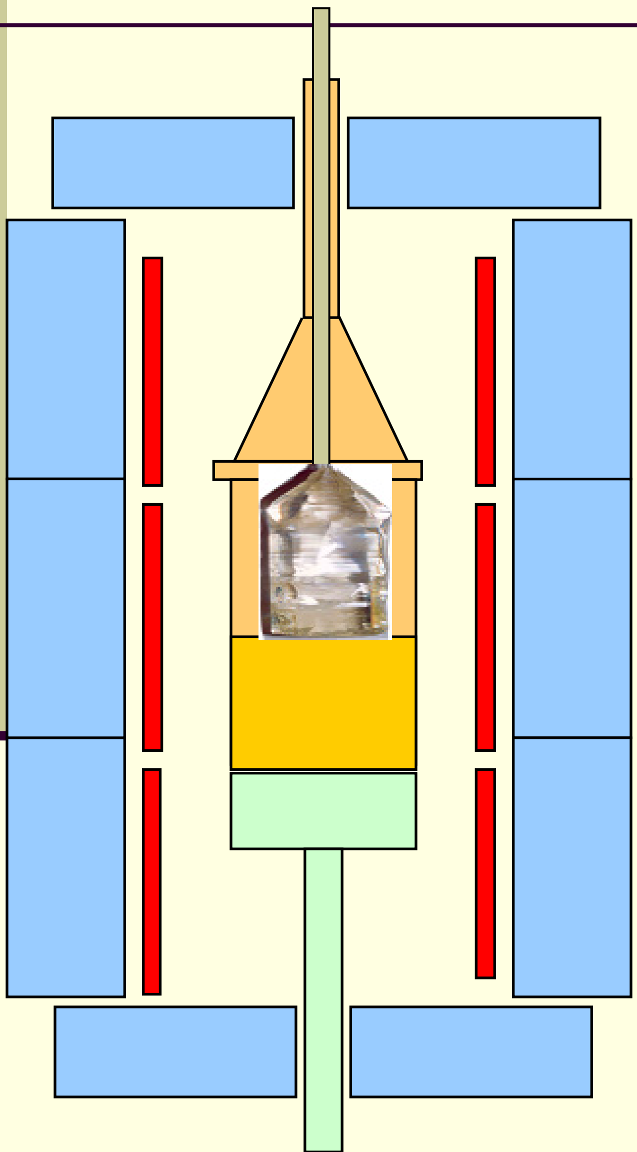
- High temperature gradient ***(10-100 K/cm)***
- Perfect cleavage of CWO
  thermoelastic stress destroy crystal
- High local superheating of melt up to ***200 K***
- Evaporation and decomposition of CWO melt





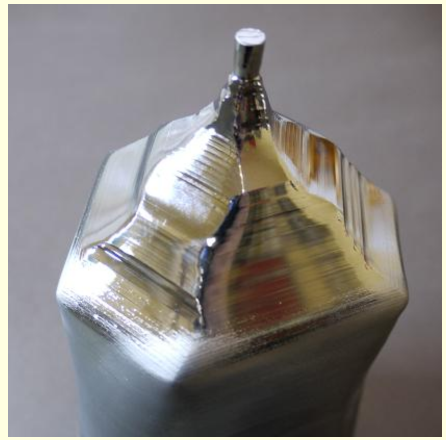


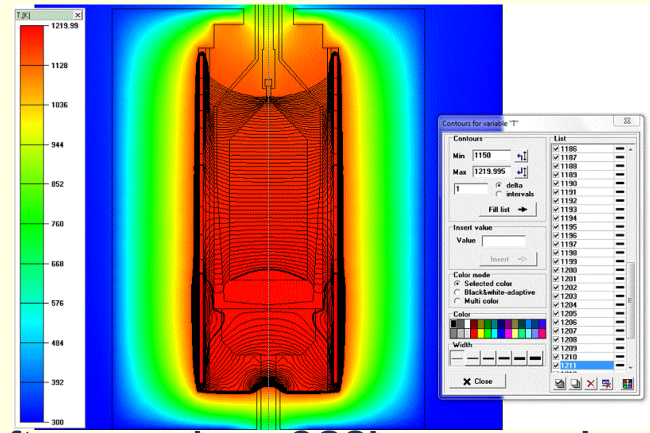
The General Features of the LTG Cz Technique



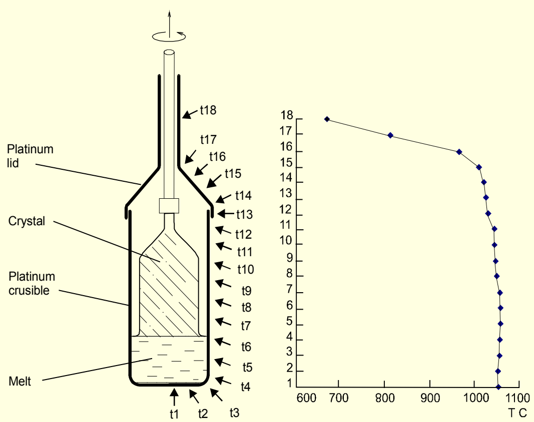
- The grown crystal inside the crucible
- Weighing control at all the stages of the process
- Temperature gradients less ***1.0 deg/cm***.
- Temperature fluctuations in the melt are practically not developed
- Evaporation and decomposition processes are suppressed by the pipe socket, which works as a diffusion barrier
- The faceted interface develops and layered growth mechanism prevails

Experimental and the simulated values of temperature fields



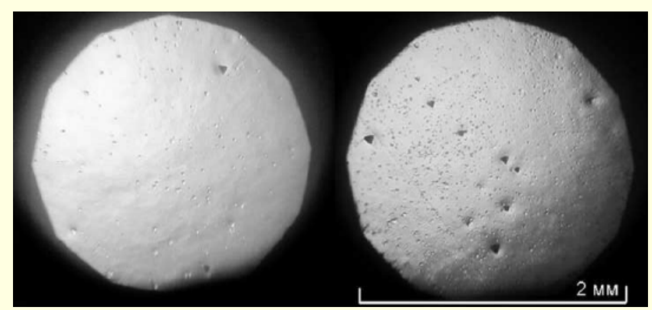


Software package CGSim was used for mathematical modeling of heat transfer in the growth furnace.

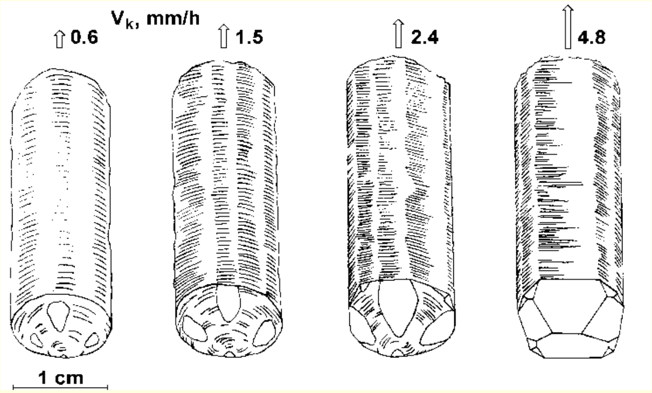


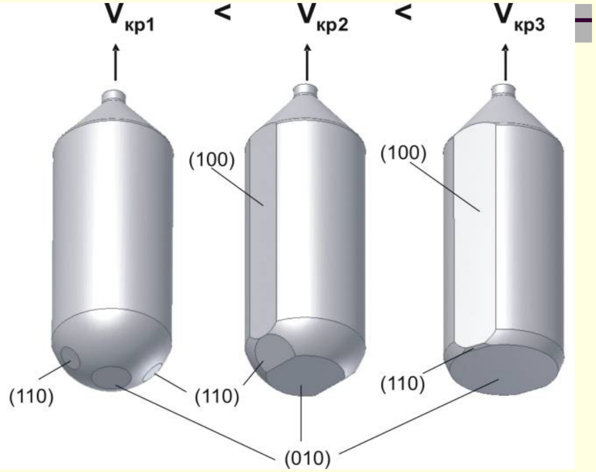
Heat conditions *can be characterized experimentally by the curves of temperature distribution along the crucible*

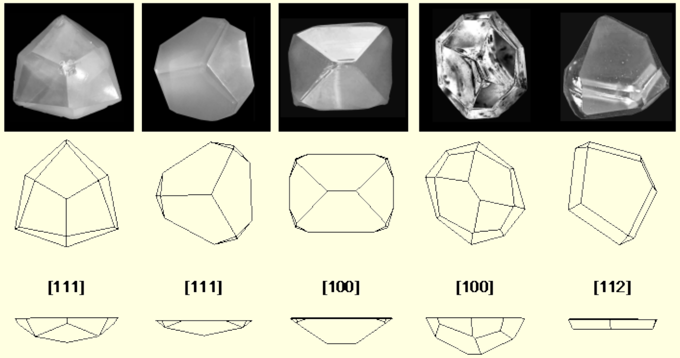
Dislocation density $10^2/cm^2$

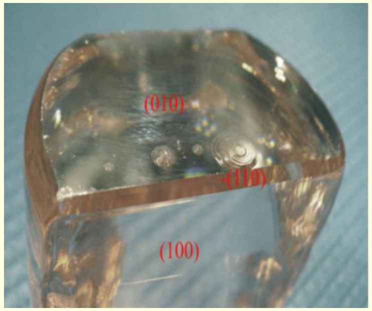


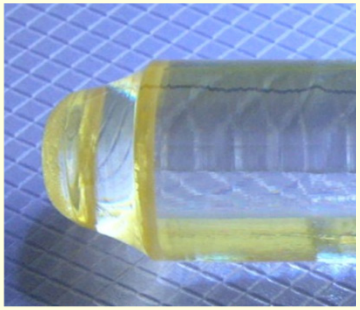
Crystal morphology LTG CZ

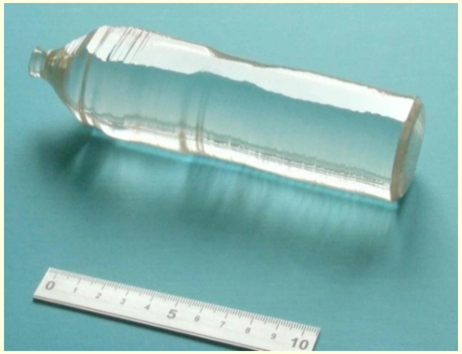




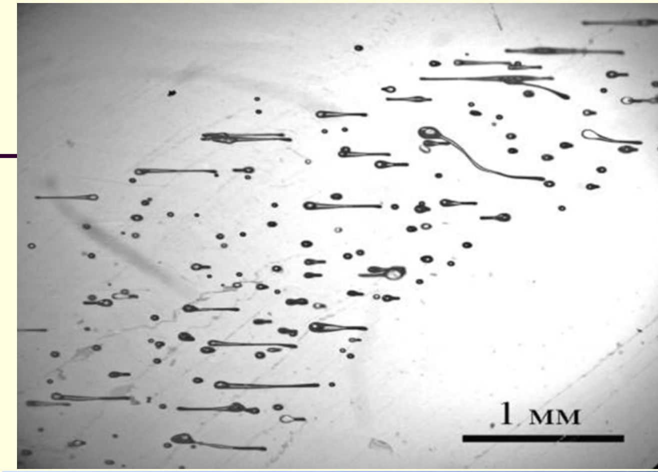


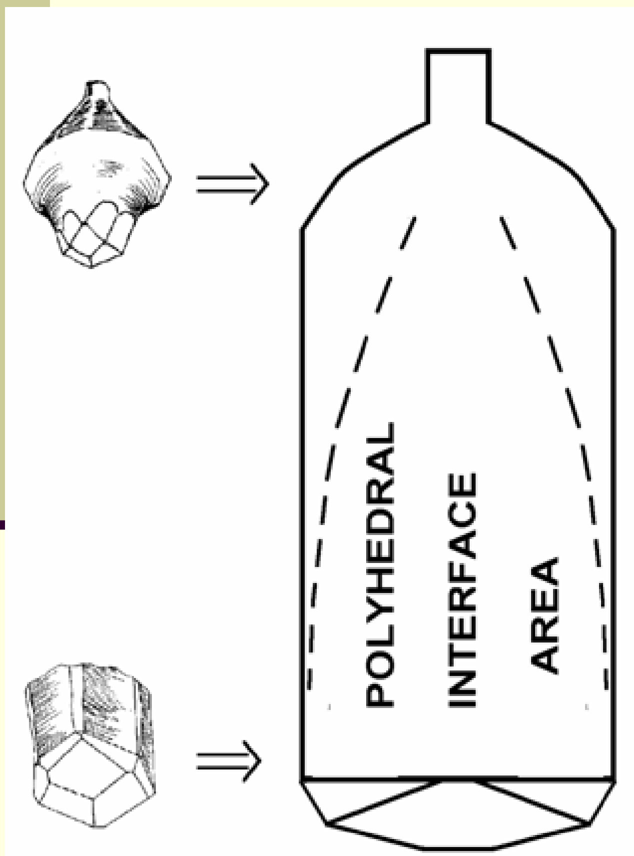


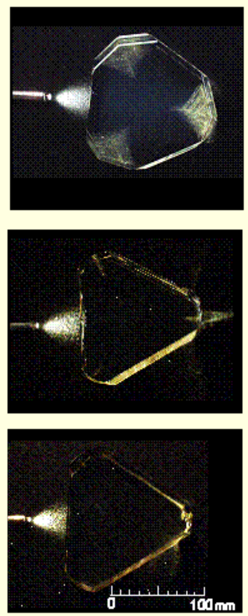


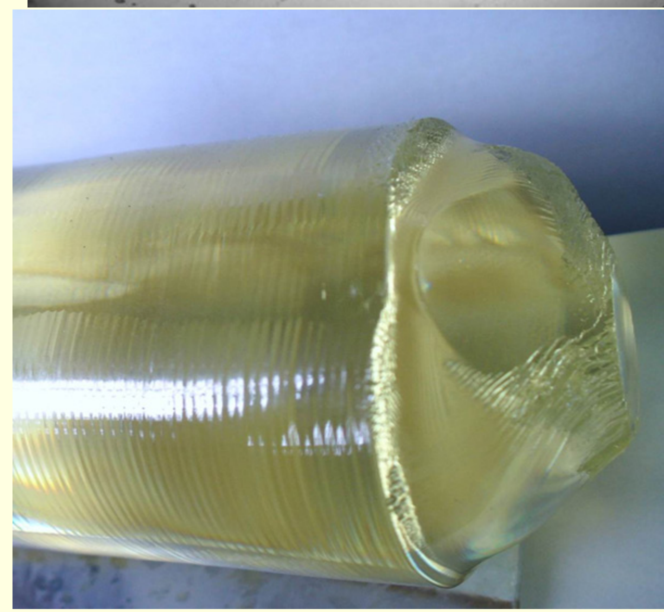


Co-existing two mechanism of growth

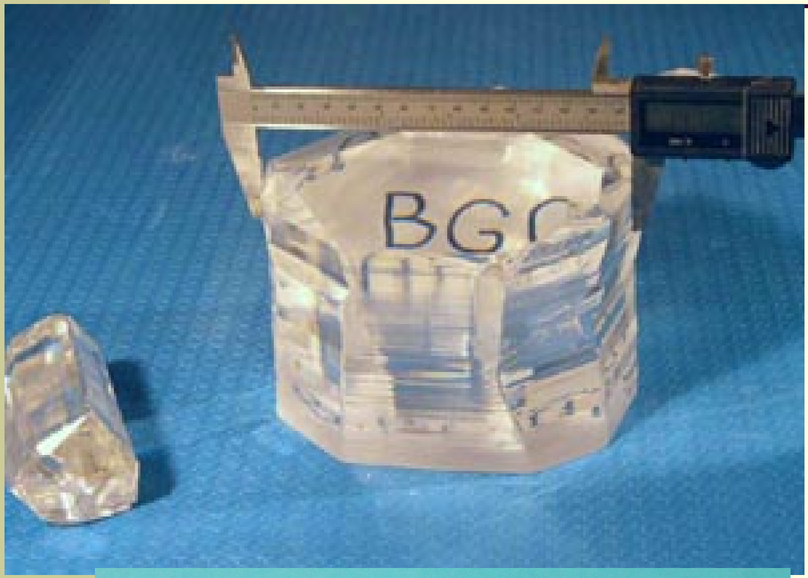


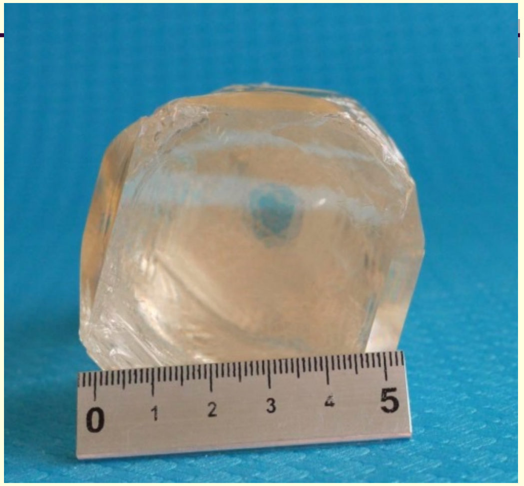




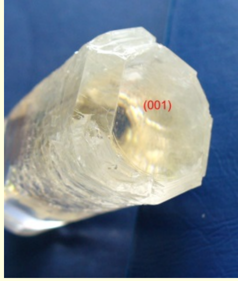


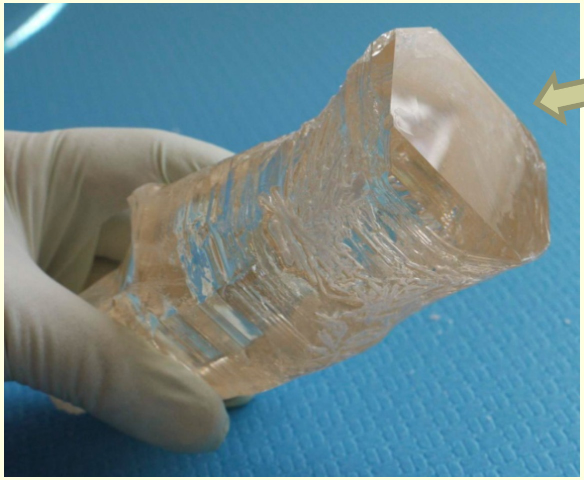
Layer-by-layer growth mechanism





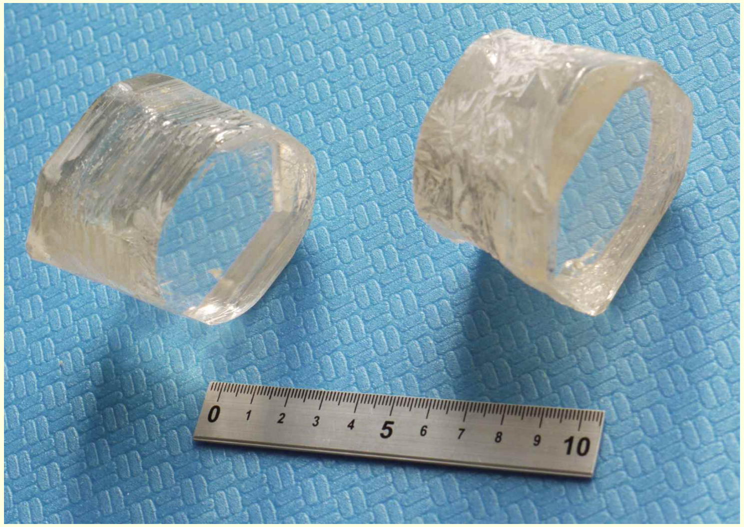
$ZnMO_4$ crystals grown along [001] direction





Growth interface

2012: Project LUMINEU (CNRS, France)
Luminescent **U**nderground **M**olybdenum **I**nvestigation for **NEU**trino mass and nature



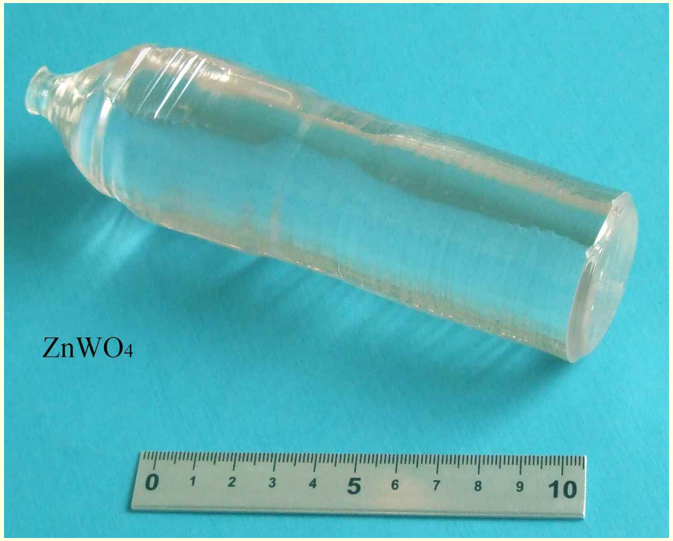
ZMO crystal grown with the charge utilization factor ~80%

Two different ways are possible to grow high quality oxide crystals by Czochralski technique.

- **Conventional Czochralski technique is based on the use of high temperature gradients to suppress the face formation and achieve the fully rounded solidification front.**

- **By the contrast in The Low Thermal Gradient Czochralski Technique (LTG Cz) the growth conditions are selected in such a way that the temperature gradients become small and the solidification front becomes fully faceted** *.*

ZWO scintillation crystals

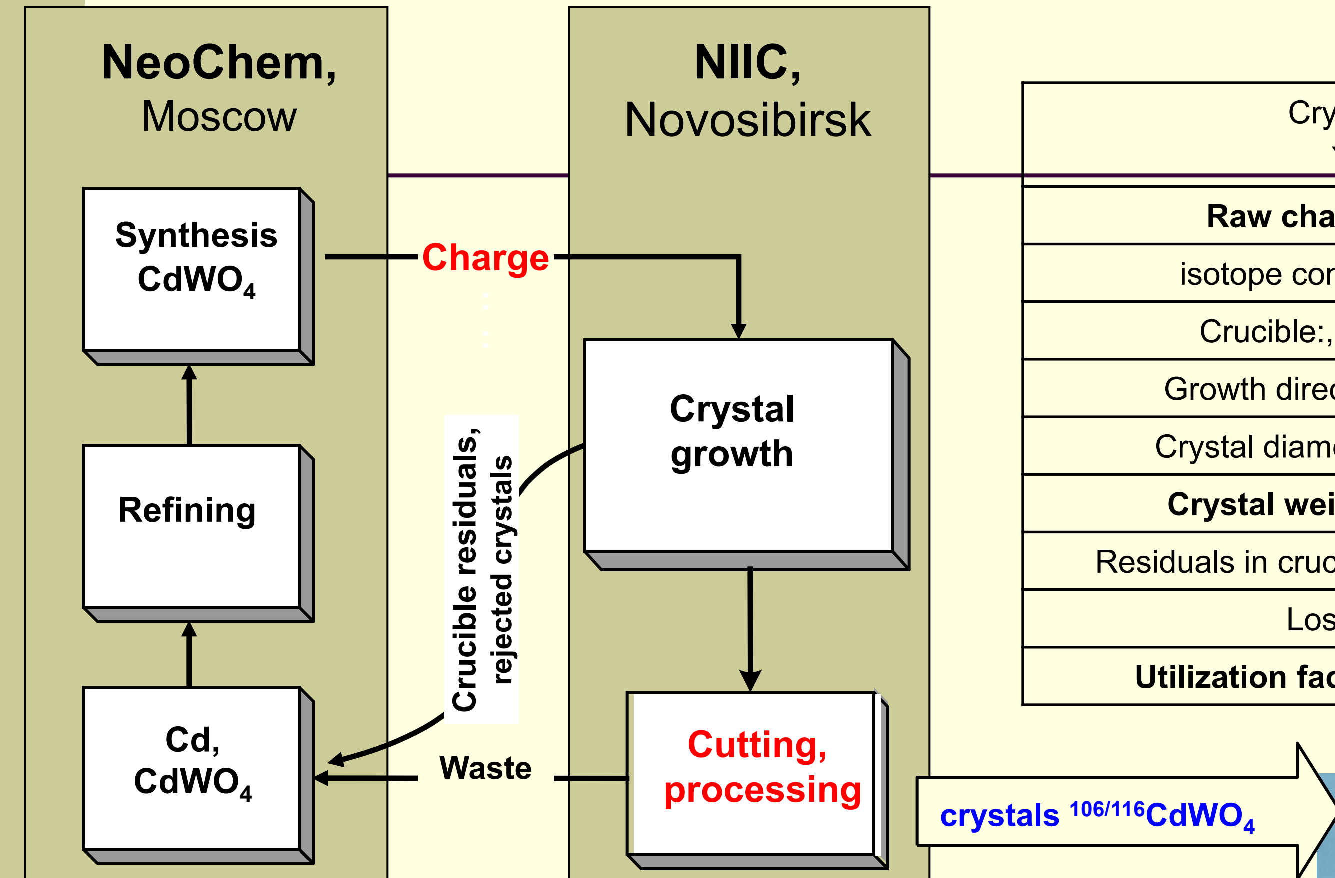


Growth direction [010]

Crucible dimensions:
Ø 70 mm; H 150-200 mm

Initials:
HP ZnO from Umicore (Belgium);
HP WO3 NIIC

Growth of isotopically enriched $^{106}CdWO_4$ and $^{116}CdWO_4$

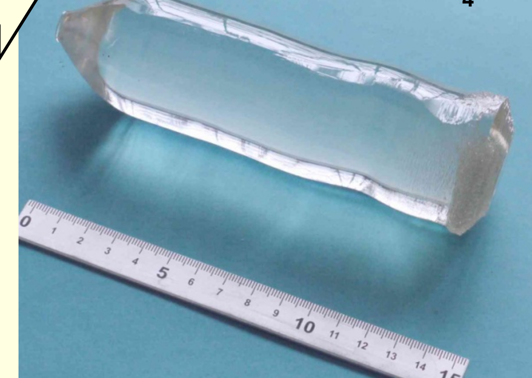


raw material $^{106/116}Cd$

Crystal, Year	$^{106}CdWO_4$ 2009	$^{116}CdWO_4$ 2010
Raw charge:	**265 g**	**2140 g**
isotope content	66,4 %	82 %
Crucible:, mm	Ø40x100	Ø70x150
Growth direction	[100]	[100]
Crystal diameter:	~27 mm	~45 mm
Crystal weight:	**230,5 g**	**1868 г**
Residuals in crucible:	33,7 g	267,7 g
Losses:	0,79 g	2,8 g
Utilization factor:	**87 %**	**87,3 %**

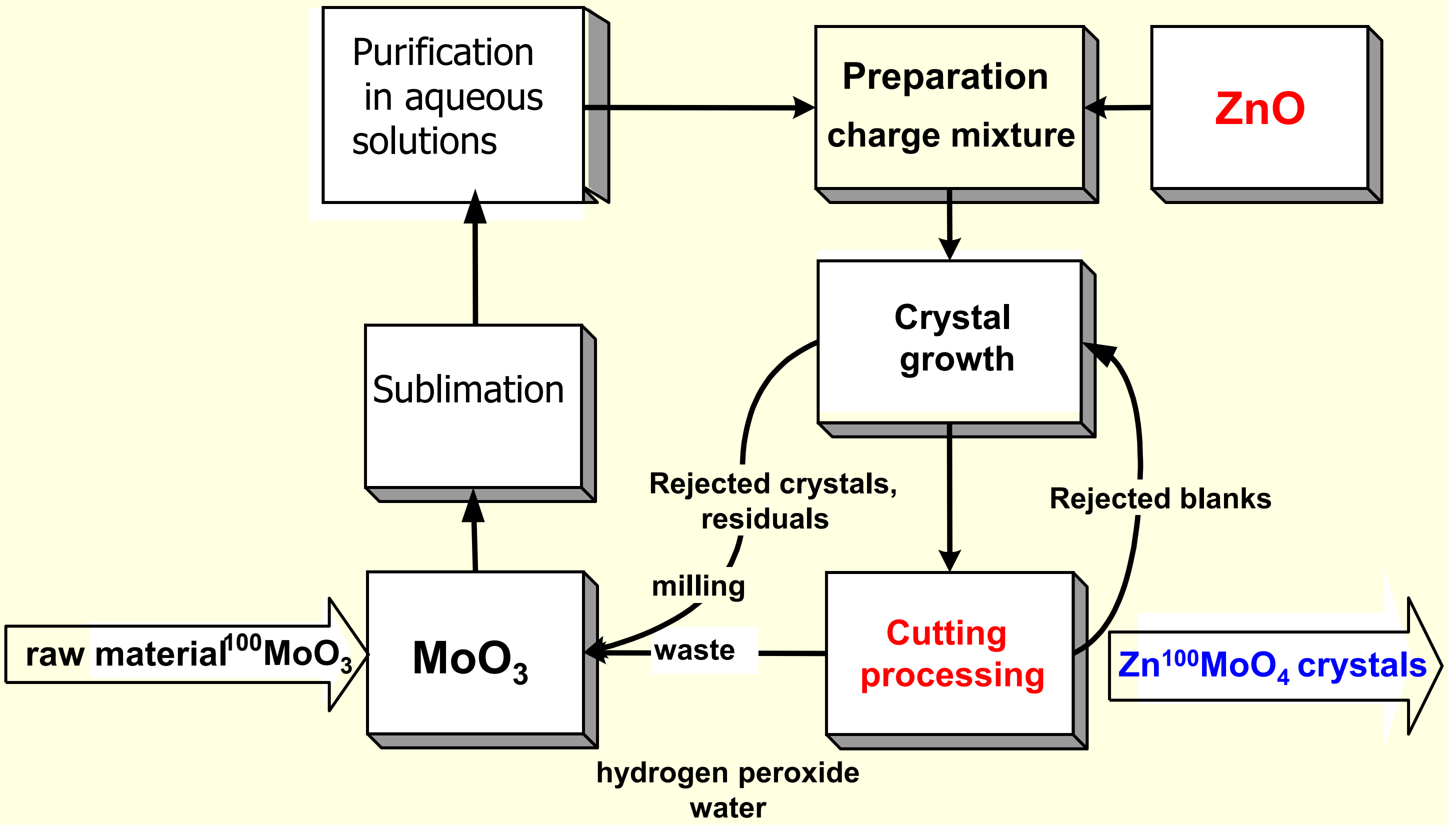
Technology of growing crystals CWO by LTG Cz allows to solve the problem of obtaining crystals for the next stage of a possible experiment with detectors $^{116}CdWO_4$

$^{106}CdWO_4$



$^{116}CdWO_4$

ZMO: Full production cycle at NIIC is developing



JACKSON criterion αL/kT

CWO			
Т пл	Q пл ккал/мол	Q пл дж/мол	
1543	33,3	133200	10,4

LMO			
Т пл	Q пл дж/г	Q пл дж/мол	
968	196	34068,72	4,2

ZWO			
Т пл	Q пл дж/г	Q пл дж/мол	
1475	356	111072	9,1

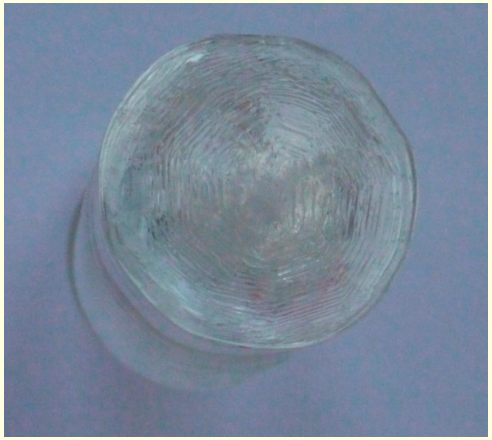
ZMO			
Т пл	Q пл дж/г	Q пл дж/мол	
1273	431	96975	9,2

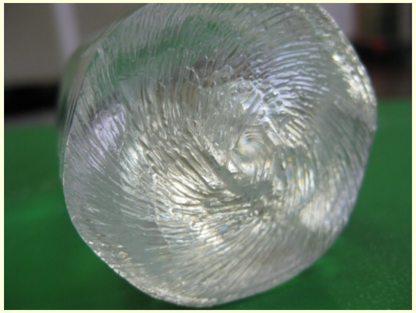
168

BGO			
Т пл	Q пл ккал/мол	Q пл дж/мол	
1308	44,6	178400	16,4

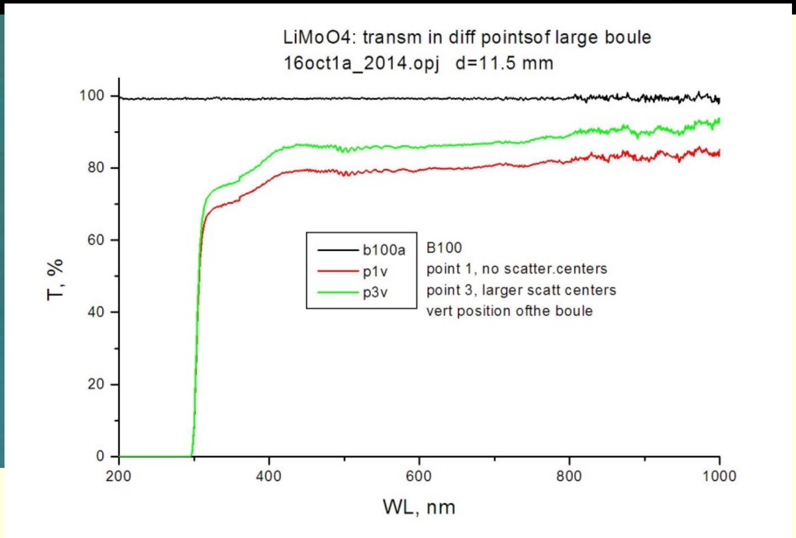
Morphology of LMO crystals, grown under low thermal gradient conditions

- V_{k1} < V_{k2} < V_{k3}





Results changing of crystallization rate in during growth process



The first crystallization and re-crystallization LMO crystals

- Diameter crystal 55mm
- Diameter crucible 68mm

Two different ways are possible to grow high quality oxide crystals by Low Thermal Gradient Czochralski technique.

- The Low Thermal Gradient Czochralski Technique are allowed to achieve the fully rounded solidification front und good quality LMO crystal.

- By the contrast in The Low Thermal Gradient Czochralski Technique (LTG Cz) the growth conditions are selected in such a way that the temperature gradients become small and the solidification front becomes fully faceted .

CONCLUSIONS

- *LTG CZ technique good variant for growing ZMO und LMO crystals high quality:*
  - *ZMO layer-by-layer mechanism of growth*
  - *LMO normal mechanism of growth*
- *The grown bouls ZMO und LMO high quality is more 80% of the mass of initial powder it is real fact*

- **LTG Cz technique with resistance-type heater is an effective method to grow oxide scintillation crystals. The grown crystals is more 80% of the mass of initial powder. The growth process and equipment are the most advanced parts of proceeding to mass scale production.**