Trap centers in molybdates

D.A. Spassky[a,b]*, V. Nagirnyi[a], V.V. Mikhailin[b], A.E. Savon[b], A.N. Belsky[c], V.V. Laguta[d], M. Buryi[d], E.N. Galashev[e], V.N. Shlegel[e], L.I. Ivleva[f], B.I. Zadneprovski[g]

[a]*Institute of Physics, University of Tartu, Estonia*
[b]*Skobeltsyn Institute of Nuclear Physics, Moscow, Russia*
[c]*Institute of Light and Matter, CNRS, University Lyon1, France*
[d]*Institute of Physics AS CR, Prague, Czech Republic*
[e]*Nikolaev Institute of Inorganic Chemistry SB RAS, Novosibirsk, Russia*
[f]*A.M. Prokhorov General Physics Institute of RAS, Moscow, Russia*
[g]*Central Research and Development Institute of Chemistry and Mechanics, Moscow, Russia*

***e-mail: dmitry.spasskiy@ut.ee**

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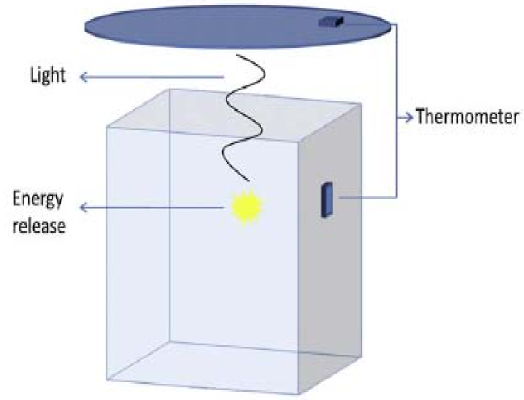
Motivation

- **Application**: high-sensitivity cryogenic phonon–scintillating detector for registration of rare events.
- ^{100}Mo **->** ^{100}Ru **+ 2e +** $Q_{\beta\beta}$, where $Q_{\beta\beta}$ = 3034 keV
- Most promising crystals are:

  well-known $CaMoO_4$ and new $ZnMoO_4$.
- **$CaMoO_4$:** AMoR Experiment is in preparation.

  [H. Bhang, et al., J.Phys.: Conf. Series 375 (2012) 042023]



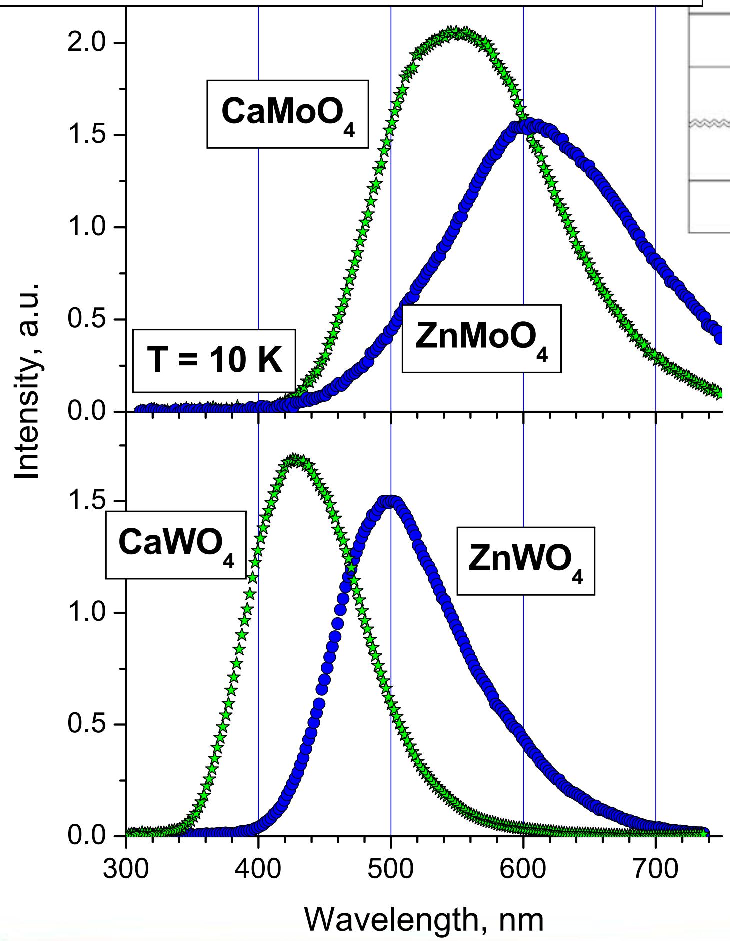
[*L. Gironi NIM A 617 (2010) 478*]

- **$ZnMoO_4$** benefits in:
  - high energy resolution of the heat channel ≈800 eV FWHM,
  - the *α/β* rejection factor > 99.9% in the region of interest for double *β* decay (≈3 MeV),
  - Improved radiopurity.

  [Beeman et al J. Low Temp. Phys. 167 (2012) 1021]

The aim of study

emission of STE under direct excitation



	E_g, eV	Emission peak, nm	Light yield, ph/MeV (T ~ 10 K)
$CaMoO_4$	4.4	540	**15000**
$ZnMoO_4$	4.3	595	**500**
$CaWO_4$	4.9	420	**16000**
$ZnWO_4$	4.6	490	**19000**

$$N_{ph} = \frac{E}{\beta E_g} SQ$$

Q ($CaMoO_4$) ~ **Q**($ZnMoO_4$)
E_g ($CaMoO_4$) ~ **E_g** ($ZnMoO_4$)

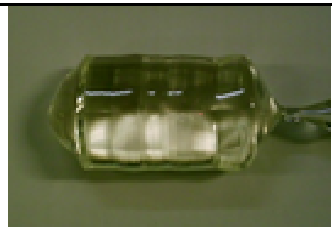
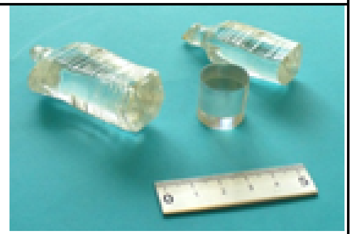
Energy losses occurs at the stage of migration of charge carriers to the emission centers?

S($CaMoO_4$) > **S**($ZnMoO_4$).

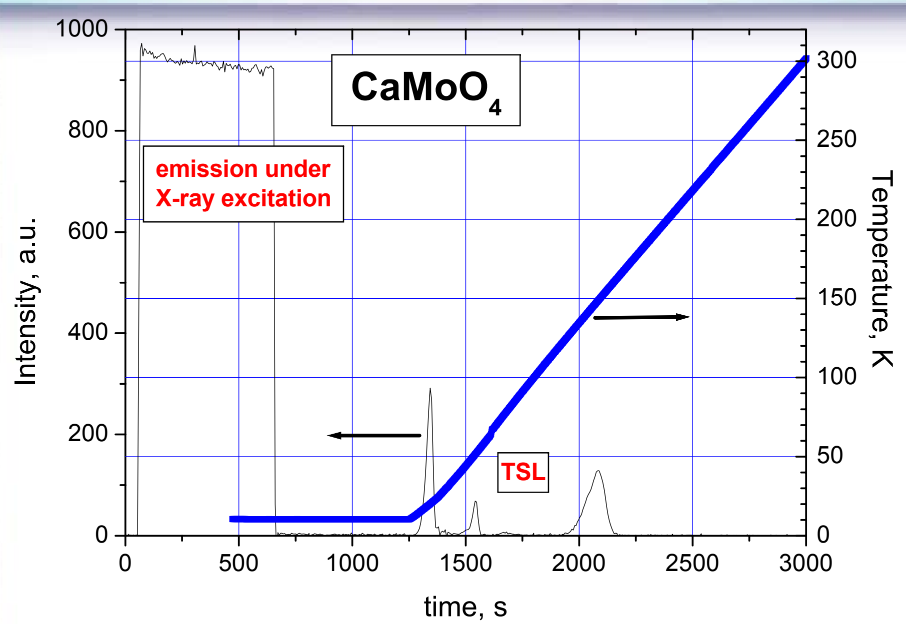
Subject of the presentation: Role of intrinsic traps in the energy transfer processes at low temperatures.

Special attention is paid to $ZnMoO_4$!

Objects of the study

	$CaMoO_4$	$SrMoO_4$	$PbMoO_4$	$ZnMoO_4$
Space group	C_{4h}^{6}($I4_1/a$), tetragonal			P-1, triclinic
Photo of the bulk crystal			No photo	
Contaminating impurities	Ba (100 ppm), Sr (60 ppm), Na (30 ppm), Ag (10 ppm), W (10 ppm)	Si (70 ppm), Ca (20 ppm), Cl (15 ppm), W (10 ppm), Ba (10 ppm)	W (300 ppm), Ca (40 ppm), S (10 ppm), Bi (4 ppm), K (4 ppm)	W (200 ppm), Si (40 ppm), Cd (4 ppm)
Intrinsic trap centers	Hole center O^-	Hole center O^-	Electron center MoO_4^{3-}	?
Release temperature, K	150 [Z.Physik(B) 35 (1979) 1]	200 [J.Lumin. 22 (1981) 419]	140 [PSS b 89 (1978) 375] 40 [J.Lumin. 33(1985) 315]	?

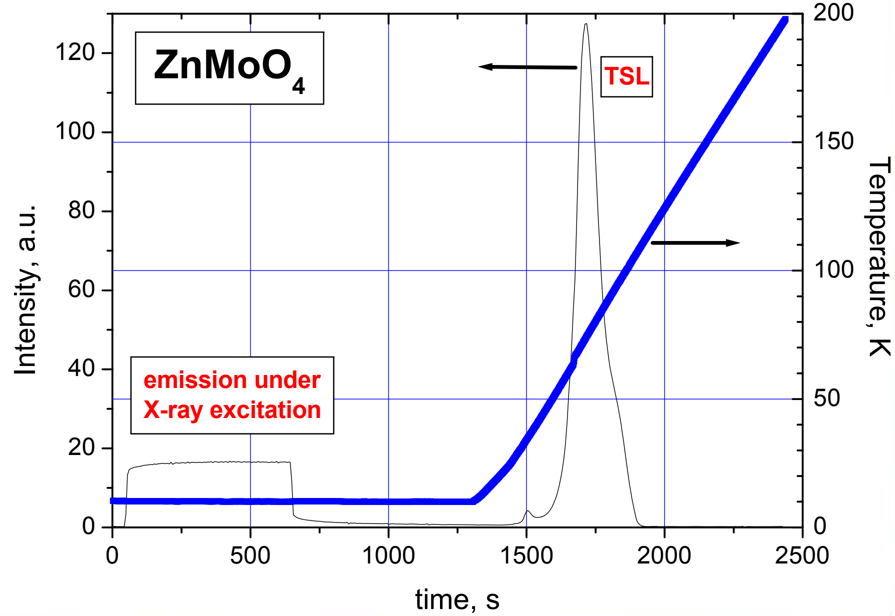
Efficiency of trap centers



Integrated intensity of TSL relatively to the integrated intensity of emission under X-ray excitation:

$CaMoO_4$ – 5% **$SrMoO_4$** – 3%

$PbMoO_4$ – 20% **$ZnMoO_4$ – 150%**



Traps prevents energy transfer to the emission centers in **$ZnMoO_4$**. Can we avoid the negative influence from the traps?

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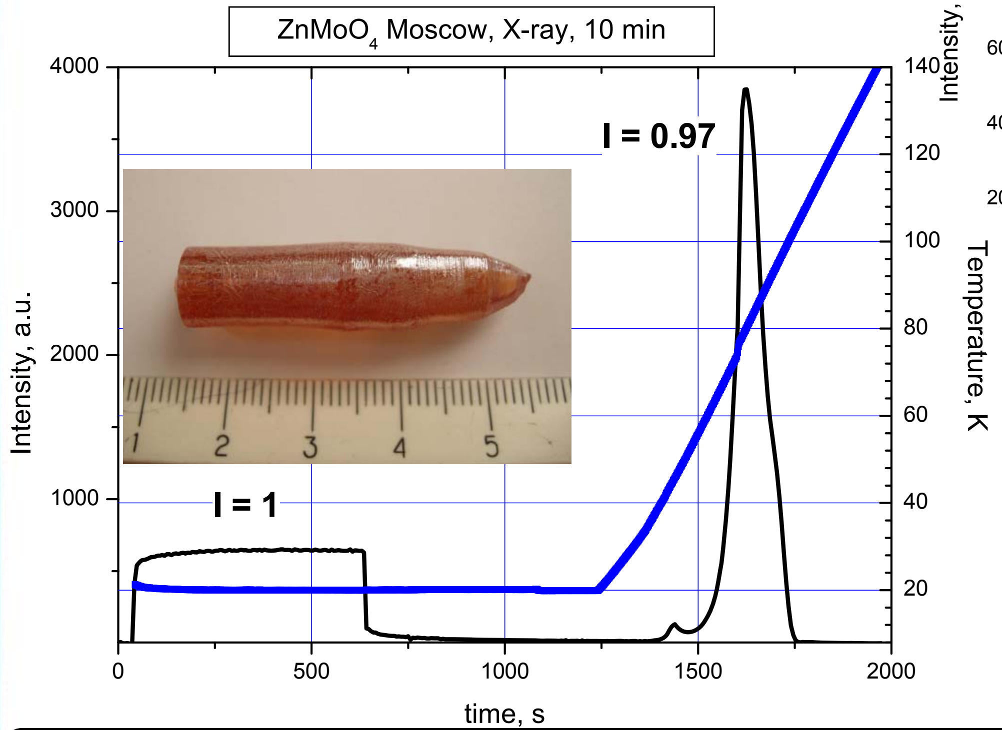
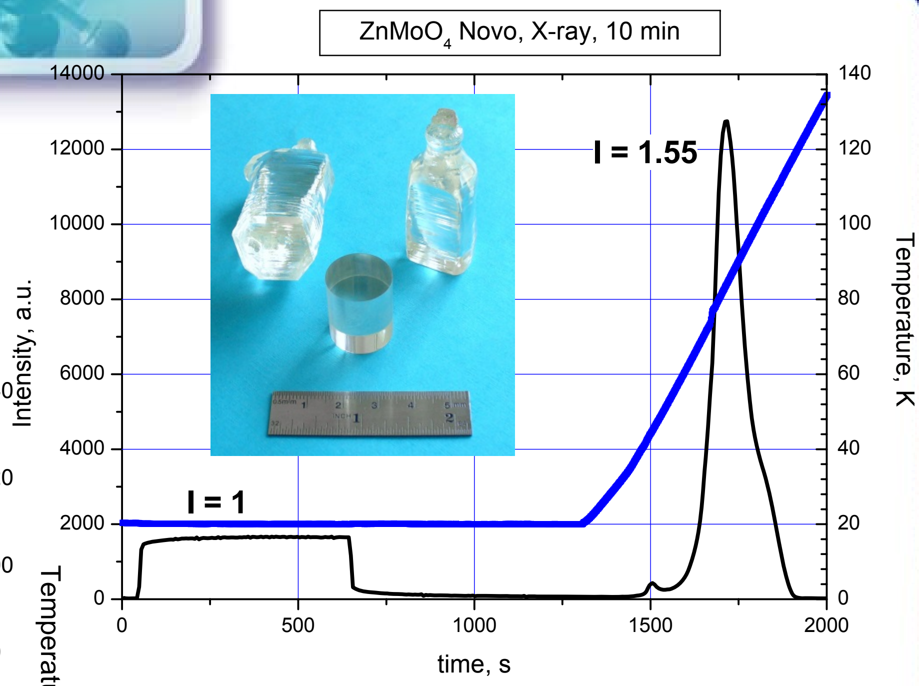
TSL in $ZnMoO_4$

Conventional Czochralski method
GPI RAS (Moscow) 2008

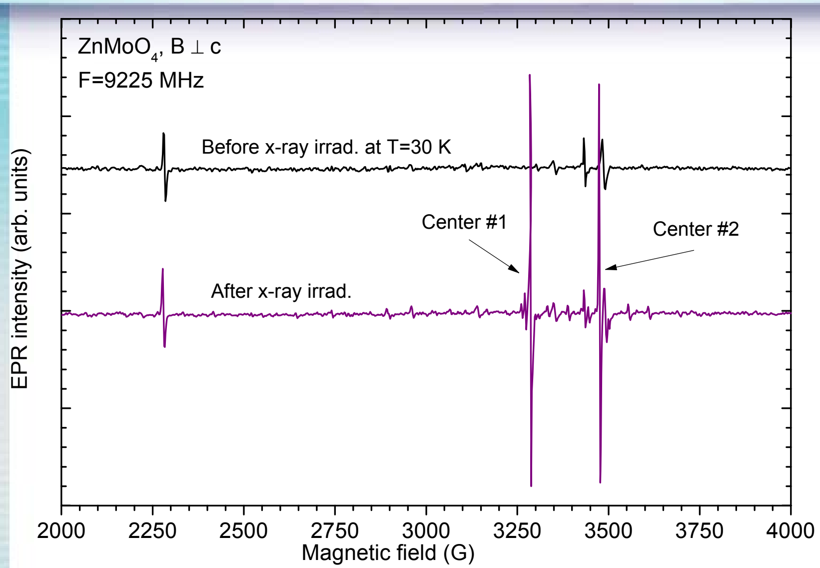




Low gradient Czochralski method
NIIC SRAS (Novosibirsk) 2011

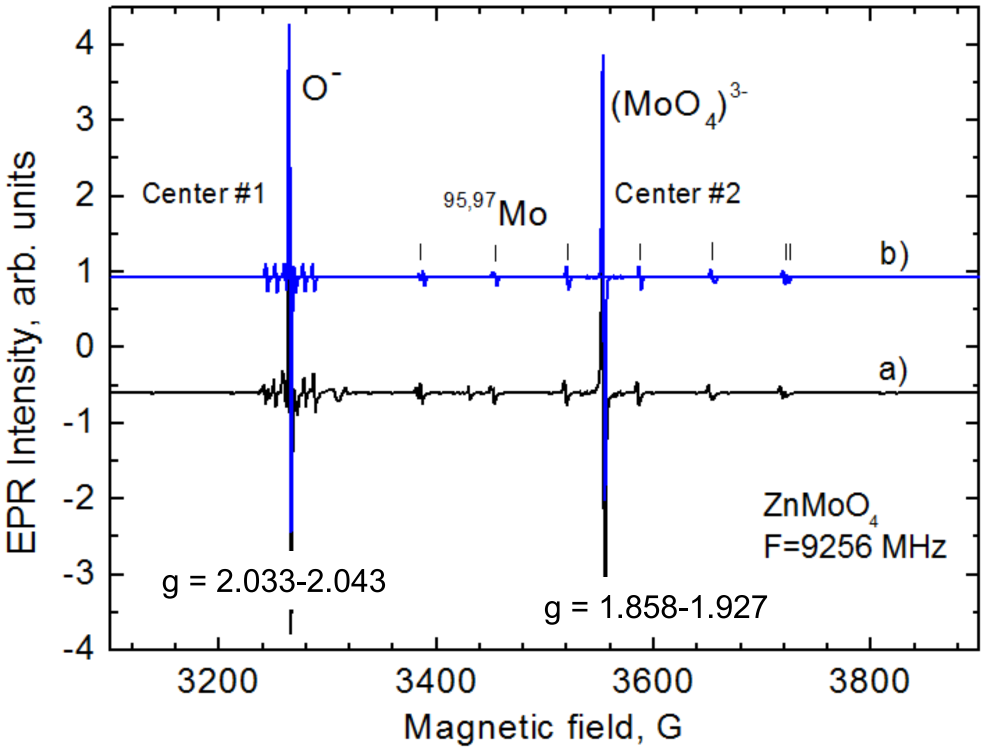
Improvement of optical quality of **$ZnMoO_4$** does not results in suppression of traps concentration!

EPR data on $ZnMoO_4$



- The center #1 is of hole-type, created as a result of a hole trapping at lattice oxygen ion.
- The center #2 is of electron – type, and is created by trapping of an electron by $(MoO_4)^{2-}$ complex.

- Two paramagnetic centers are created under X-ray irradiation at T = 30 K.



Thermal stability of paramagnetic centers in $ZnMoO_4$

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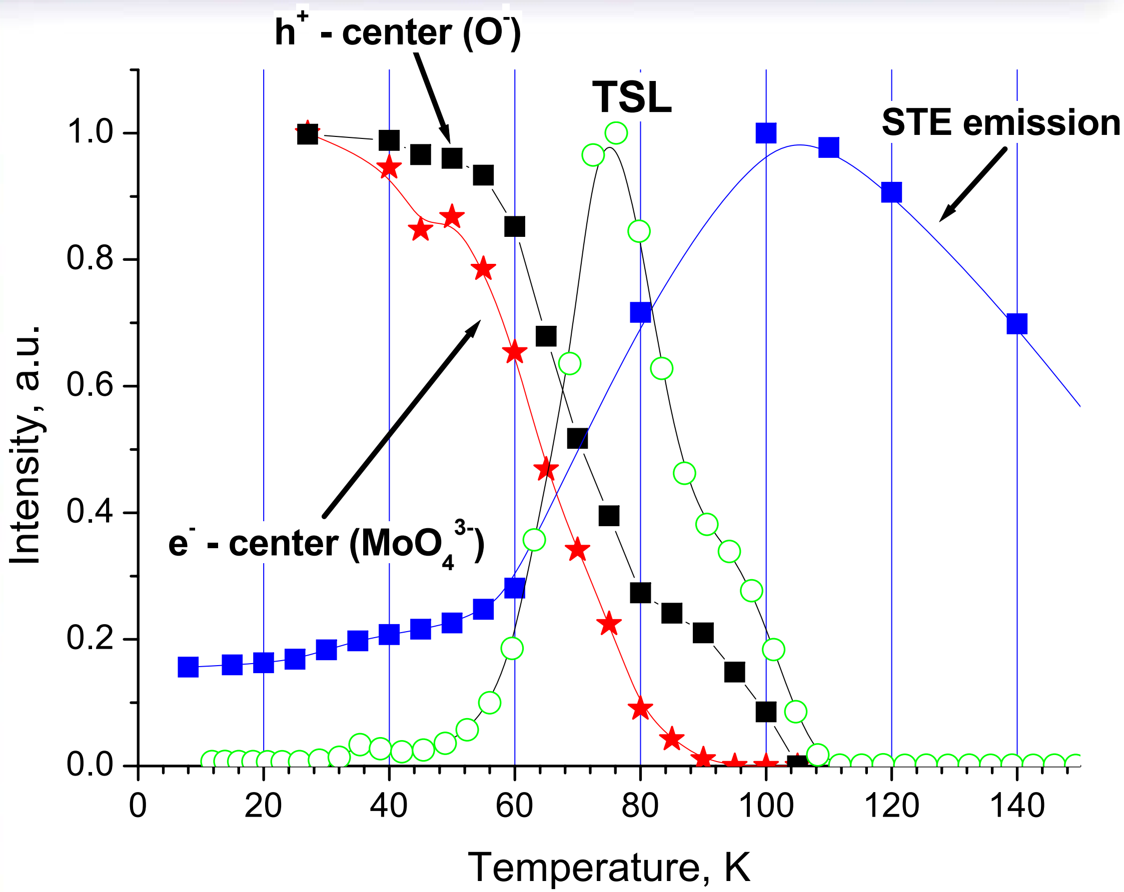
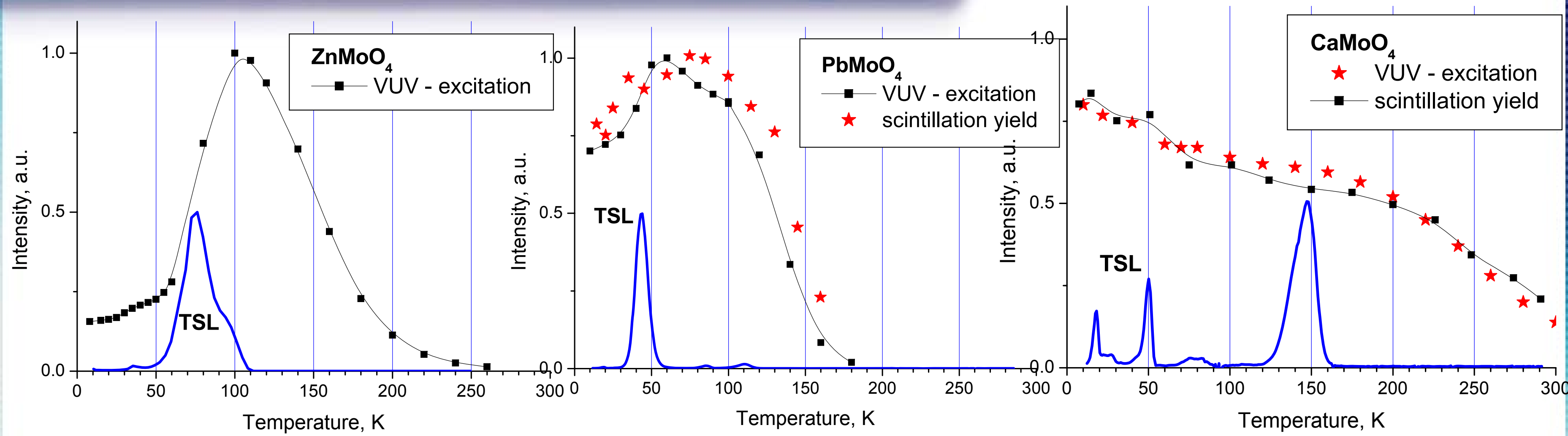


- Both types of charge carriers are immobile at the low temperatures.
- It may be the main reason for low scintillation yield of $ZnMoO_4$ at low temperatures.

Scintillation yield



data on scintillation light yield of $PbMoO_4$ were obtained in [Danevich et al NIM. A 622 (2010) 608]
data on scintillation light yield of $CaMoO_4$ were obtained in [Mikhailik et al PSS (b) 247 (2010) 1583]

	$CaMoO_4$	$SrMoO_4$	$PbMoO_4$	$ZnMoO_4$	
Space group	C_{4h}^6(I4_1/a), tetragonal			P-1, triclinic	
Intrinsic trap centers	O^-	O^-	MoO_4^{3-}	MoO_4^{3-}	O^-
Release temperature, K	150	200	40	76	97

Conclusion

Intrinsic trapping centers for electrons and holes exist in $ZnMoO_4$. The immobility of charge carriers at T < 50 K results in the substantial decrease of the probability of STE creation with consequent worsening of the luminescent properties at low temperatures and in the unusually low scintillation light yield of $ZnMoO_4$.

Acknowledgements

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Thank you for your attention!