LABORATORY OF SPECTROSCOPY

LATVIJAS UNIVERSITĀTES
CIETVIELU FIZIKAS INSTITŪTS
INSTITUTE OF SOLID STATE PHYSICS
UNIVERSITY OF LATVIA

Dr. phys. Anatolijs Šarakovskis

KEY NUMBERS OF LABORATORY

- **Staff - 38 people**
  - 19 Dr., including 2 postdocs
  - 17 students, including 7 PhD students

- **Ongoing projects - 19**
  - 4 national research grants,
  - 1 ERA-NET,
  - 4 European Research & Development Fund,
  - EUROfusion,
  - National Research Programme “Collaboration with CERN”

LABORATORY VISION

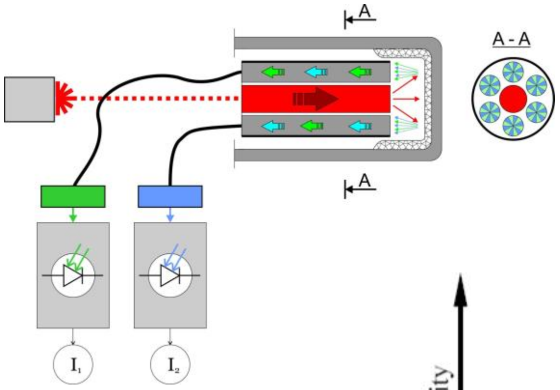
To become an internationally significant partner for collaboration with scientists and industry

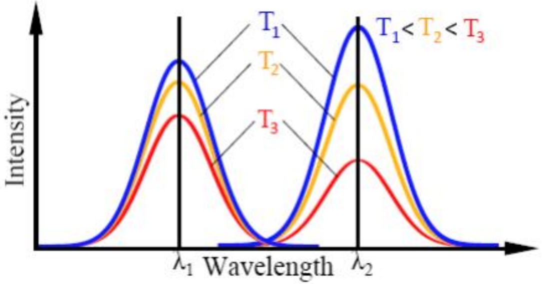
The laboratory is involved in research projects and provides service in spectroscopy research for other laboratories, academic institutions and industry

Few examples of the research projects:

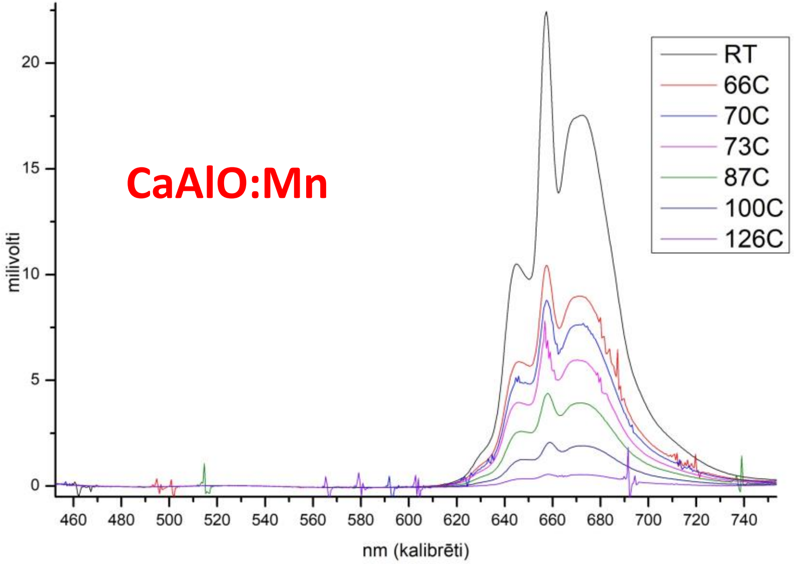
- All-optical temperature sensors
- Scintillators
- Persistent luminophors
- Upconversion luminescence

ALL OPTICAL TEMPERATURE SENSOR





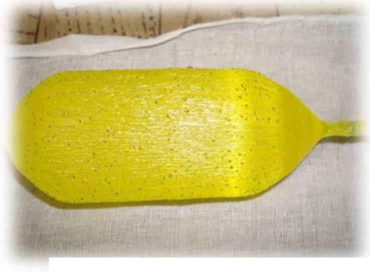
CaAlO:Mn

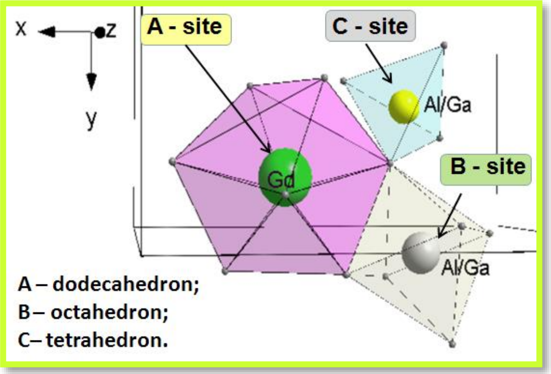


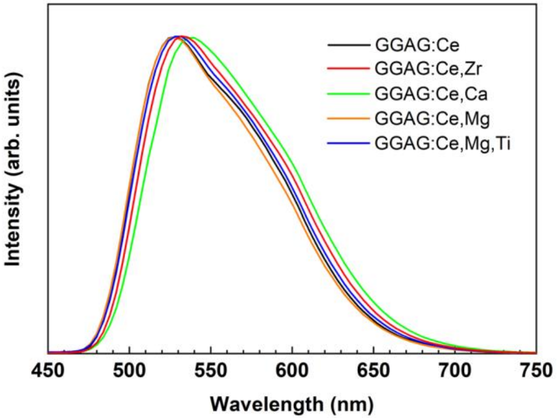
Collaboration with local optical fibers producer LightGuide

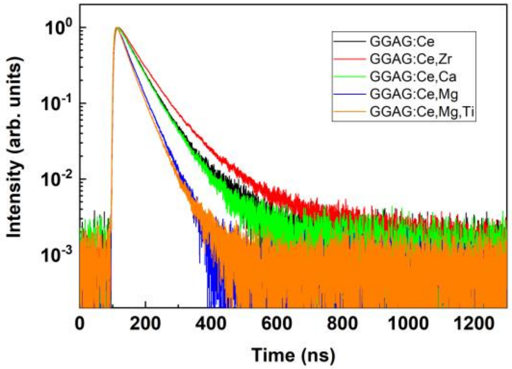
https://www.lightguide.com/about/

CERIUM DOPED GGAG UNDER SYNCHROTRON RADIATION







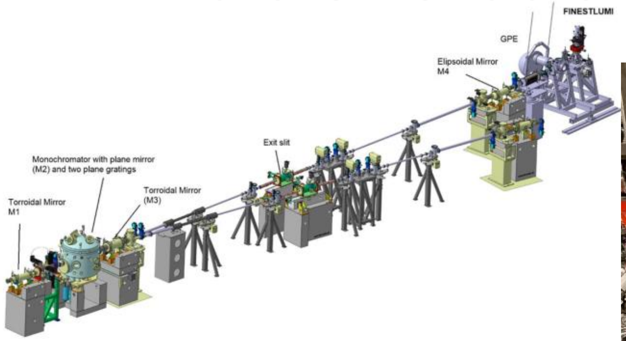


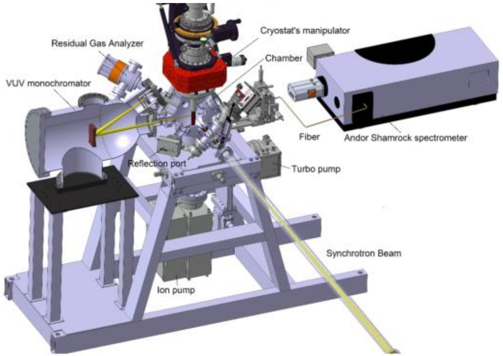
- The role of intrinsic defects on the luminescence and scintillation performance of codoped GGAG:Ce^{3+} single crystals has been elucidated.
- The fundamental mechanisms of energy transfer processes in codoped GGAG:Ce^{3+} single crystals have been elucidated.

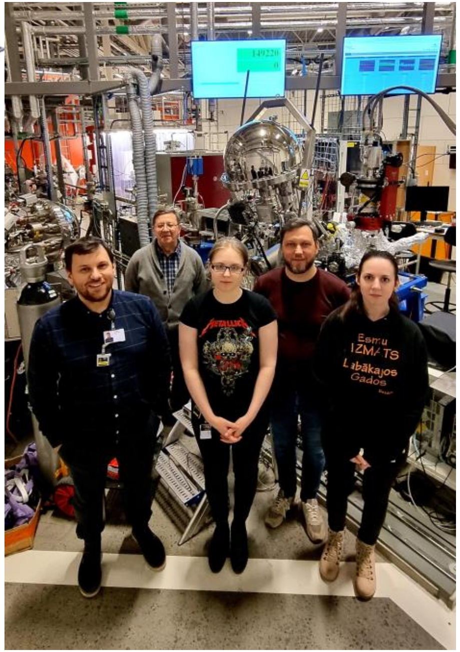
V. Pankratova, et. al., ***Scientific Reports*** **10 (2020) 20388**

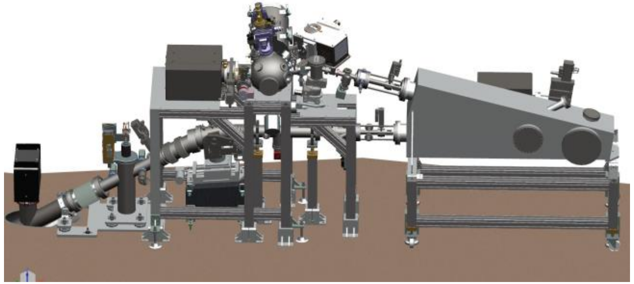
A.P. Kozlova, ..., **V. Pankratov,** ***Results in Physics*** **16 (2020) 103002**

CERIUM DOPED GGAG UNDER SYNCHROTRON RADIATION









PERSISTENT LUMINESCENCE

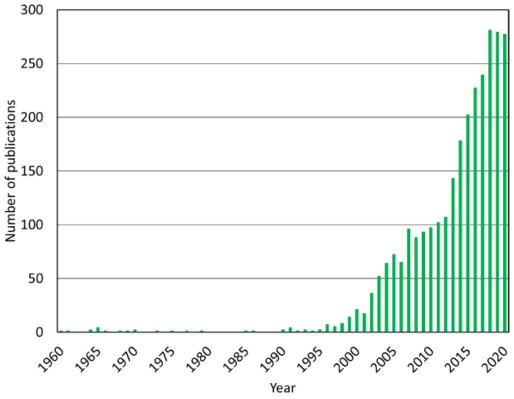
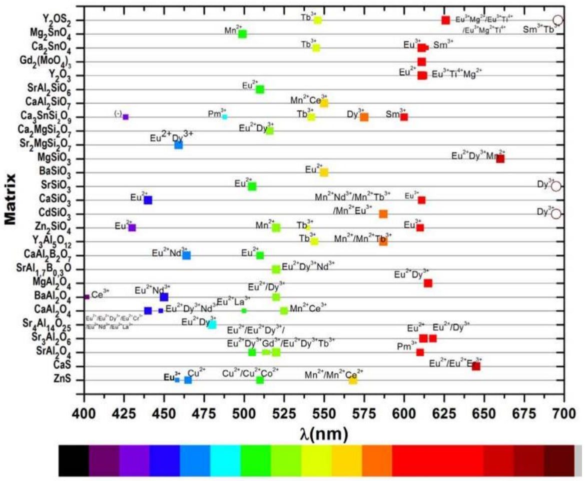
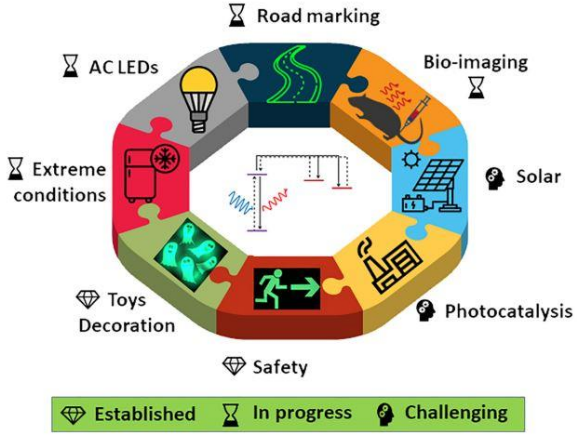


FIG. 2. Number of publications on persistent luminescence in the Web of Science (all databases); search string: **TS =** ("persistent luminescen*") *OR* **TS =** ("long after-glow") *OR* **TS =** ("long-lasting phosphorescen*") *OR* **TS =** ("persistent phosphor*") (accessed Nov 12, 2020).

Increasing interest



Most of the well established materials emitting VIS, especially green

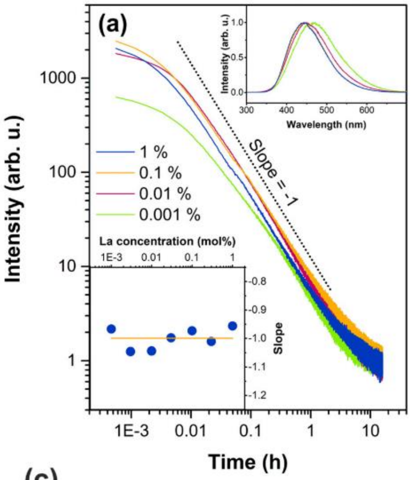


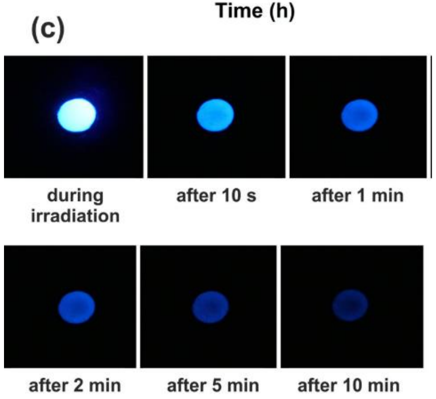
Wide variety of applications

T. Lécuyer *et al.*, "Chemically engineered persistent luminescence nanoprobes for bioimaging," *Theranostics*, vol. 6, no. 13, pp. 2488–2523, 2016.
R. E. Rojas-Hernandez, *et al*. *Renew. Sustain. Energy Rev.*, vol. 81, no. June 2017, pp. 2759–2770, 2018.
D. Poelman, *et al.* Persistent phosphors for the future: Fit for the right application. *J. Appl. Phys.* **128**, 240903 (2020).

PERSISTENT LUMINESCENCE

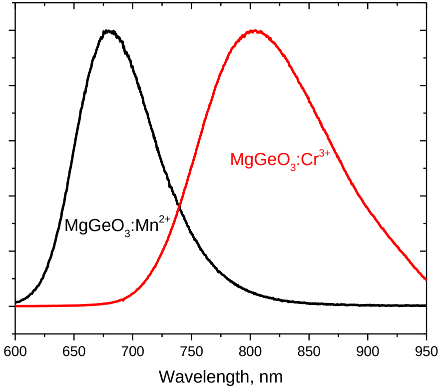
$Ca_2SnO_4:La^{3+}$

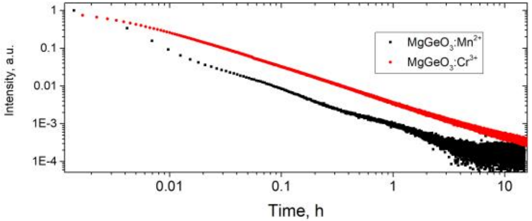


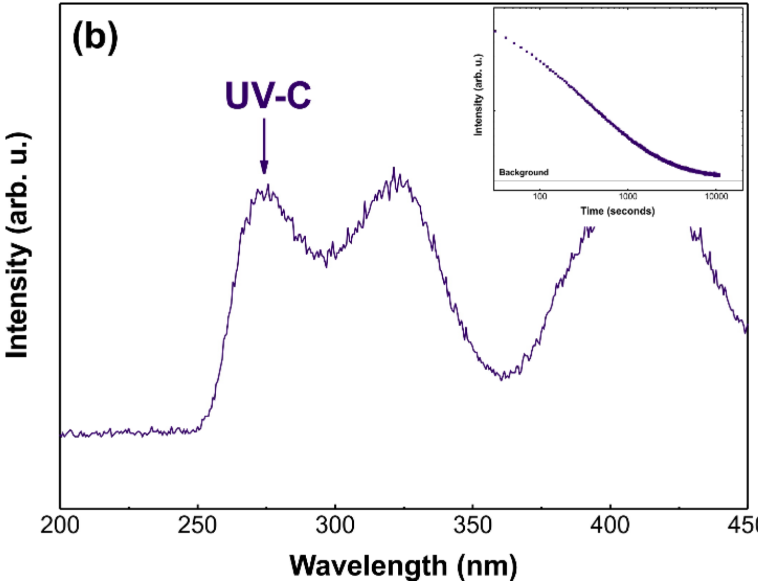


Latvian Council of Science grants:

- Novel persistent luminescent material – red light emitter
- Defect engineering of novel UV-C persistent phosphor materials

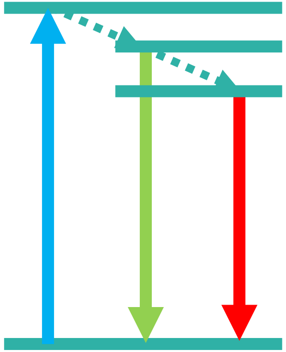






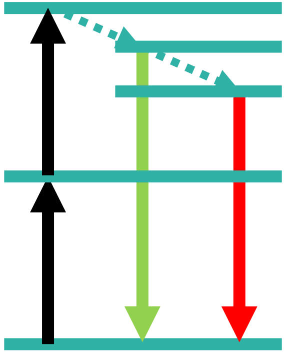
$Ca_2Al_2SiO_7:Pr^{3+}$ - UV phosphor

UPCONVERSION LUMINESCENCE



Traditional photoluminescence

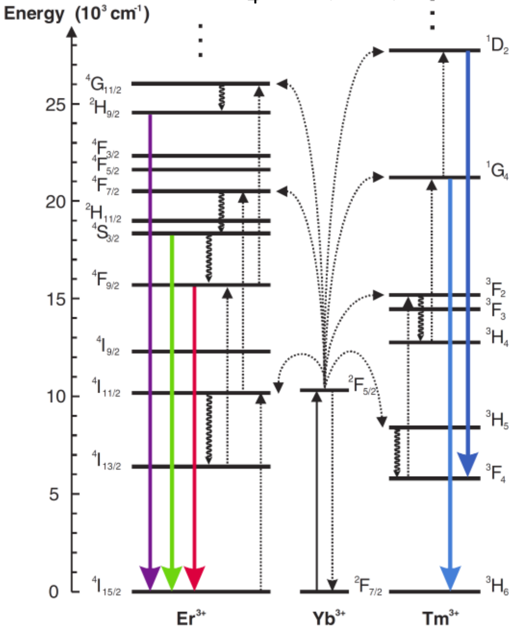
Visible luminescence excited by blue or ultraviolet radiation



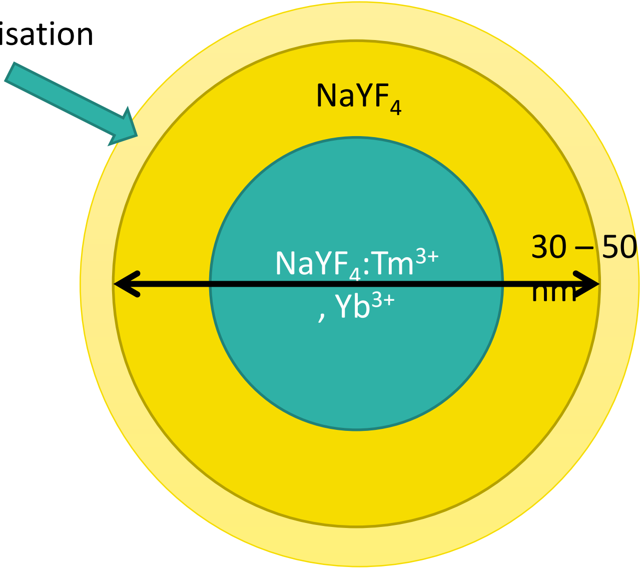
Upconversion luminescence

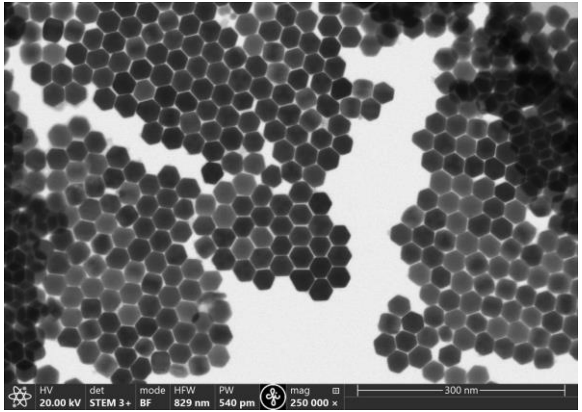
Visible luminescence excited by red or infrared radiation

$NaYF_4:Yb^{3+},Er^{3+}, Tm^{3+}$



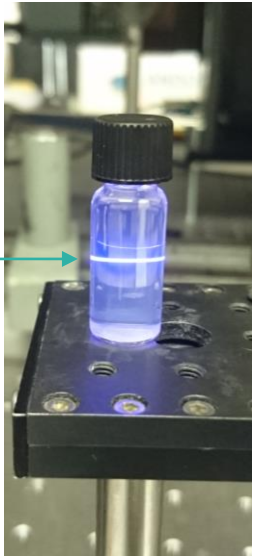
UPCONVERSION LUMINESCENCE





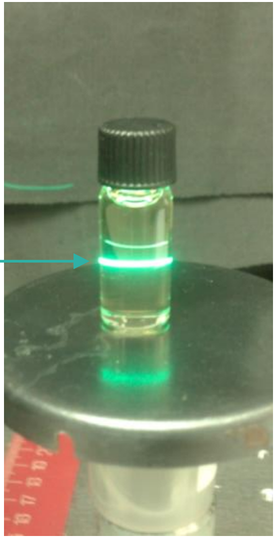
UPCONVERSION LUMINESCENCE

980 nm

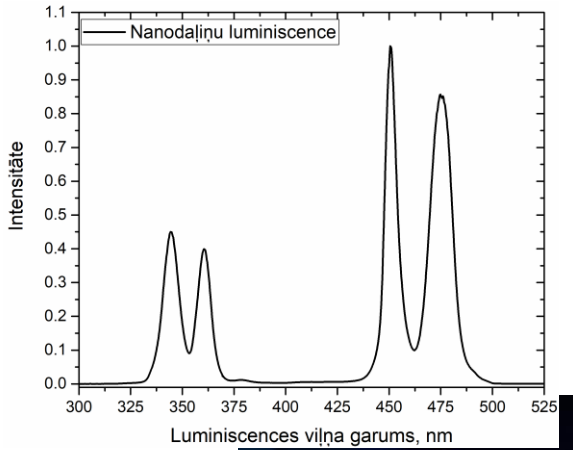


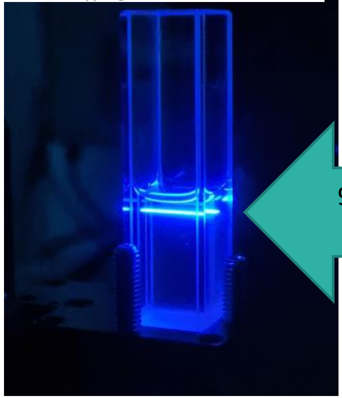
$NaYF_4:Yb^{3+}, Tm^{3+}$

980 nm



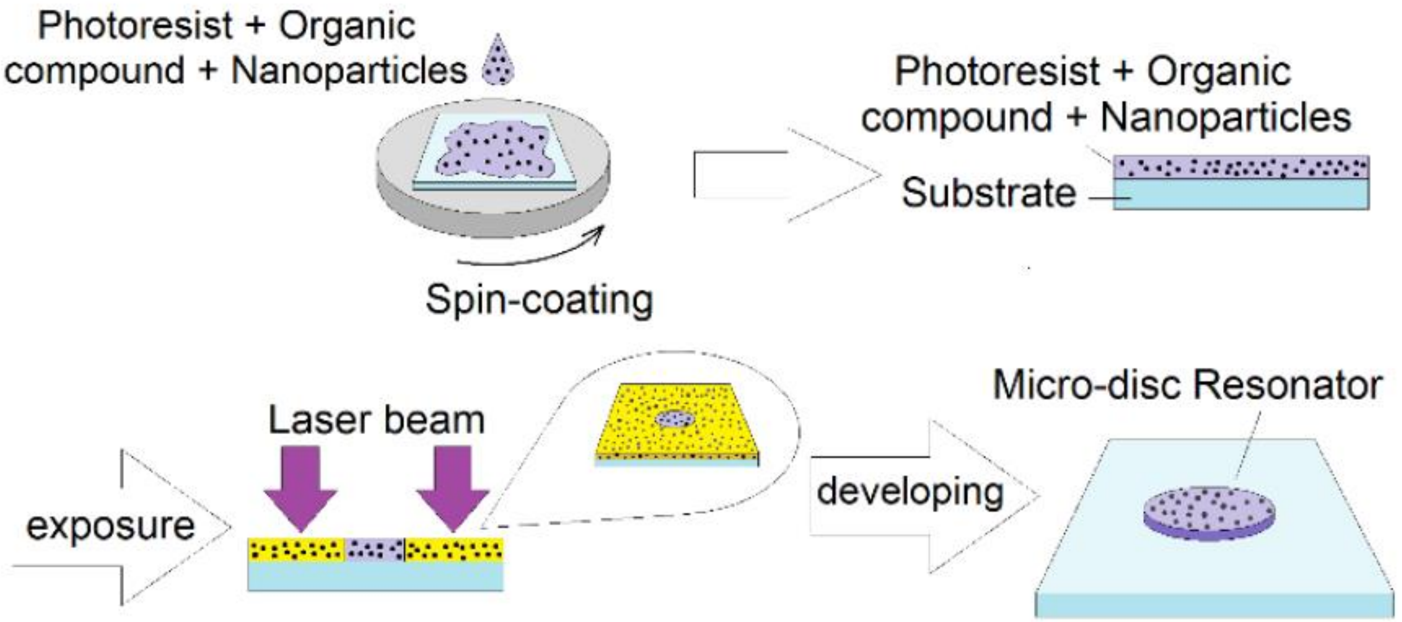
$NaYF_4:Yb^{3+}, Er^{3+}$





976 nm (infrared radiation)

UPCONVERSION LUMINESCENCE

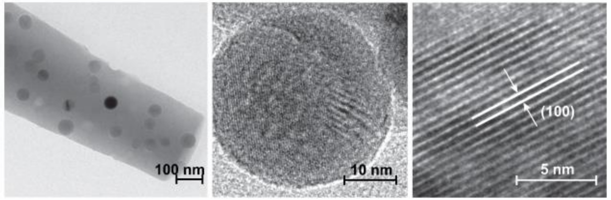


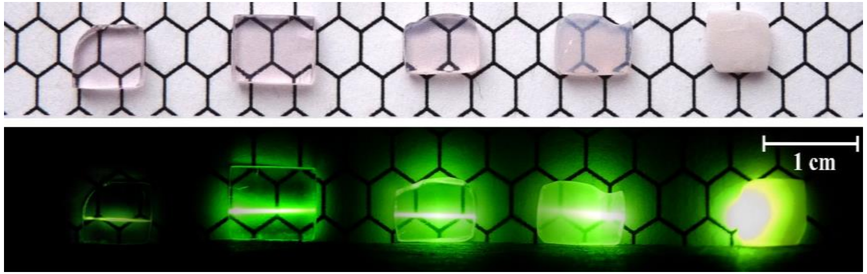
UPCONVERSION LUMINESCENCE

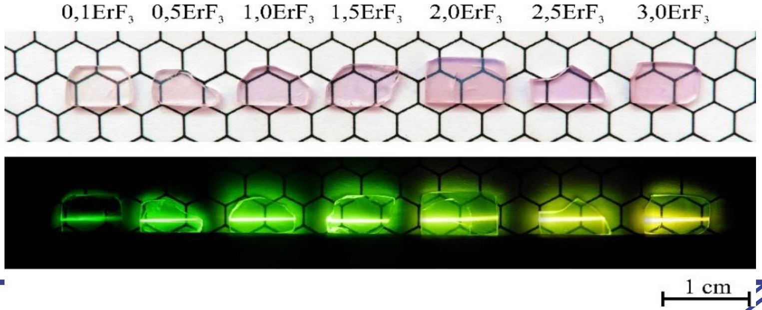
Synthesis and optical properties of oxyfluoride glass ceramics

- Broad range of fluoride microcrystals and nanocrystals doped with transition and rare-earth ions: CaF_2 – BaF_2, LaF_3, YF_3, $NaREF_4$ and others.

- Oxyfluoride glass ceramics: SiO_2 matrix with nanocrystallites (fluorides) for lighting applications







KEYFACTS ABOUT THE LABORATORY – COMPETENCES

- Generation and transformation of defects including radiation defects in solids
- Complex oxides for scintillator applications
- Upconversion luminescence in different materials
- Materials for all-optical temperature sensors
- Broad variety of different experimental tools for spectroscopic characterization of materials

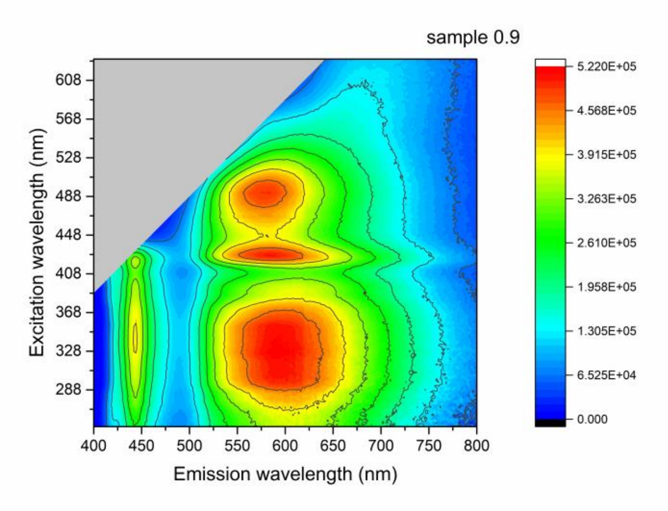
KEYFACTS ABOUT THE LABORATORY – SERVICE

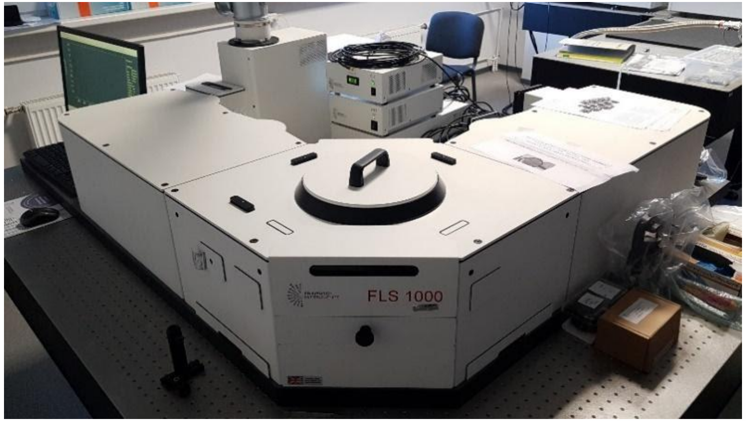
KEYFACTS ABOUT THE LABORATORY – SERVICE

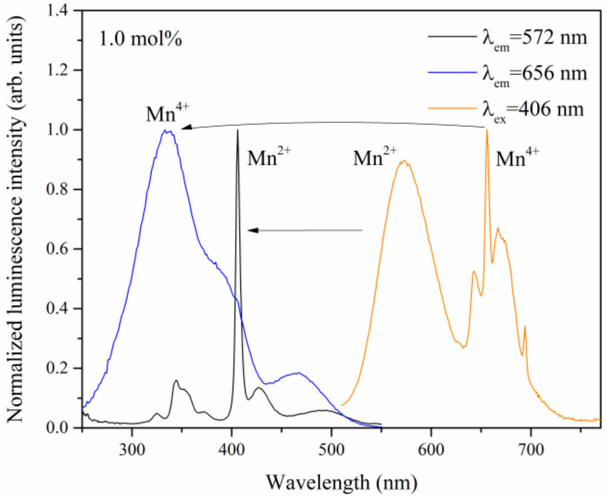
EXPERIMENTAL TECHNIQUES

- UV-VIS-IR optical spectroscopy

Edinburgh Instruments spectrometer





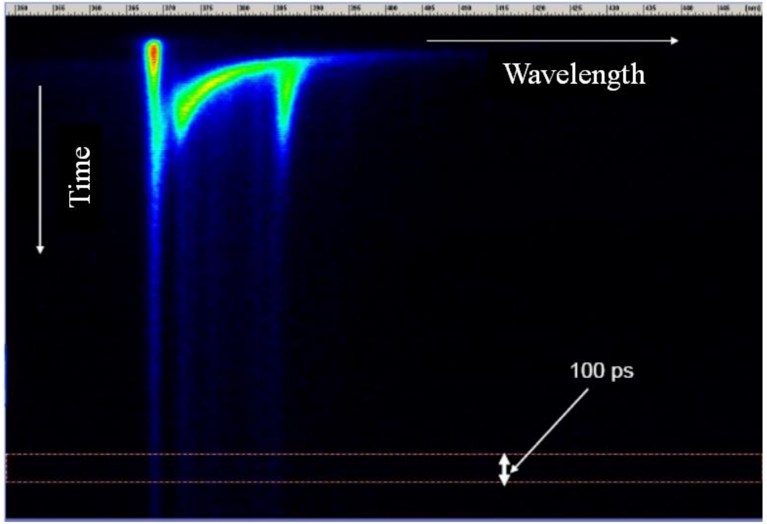


- Excitation range: 200 nm – 1000 nm
- Detection range: 200 nm – 870 nm
- Quantum yield measurements

EXPERIMENTAL TECHNIQUES

- UV-VIS-IR optical spectroscopy

Tunable nanosecond, picosecond and femtosecond laser systems

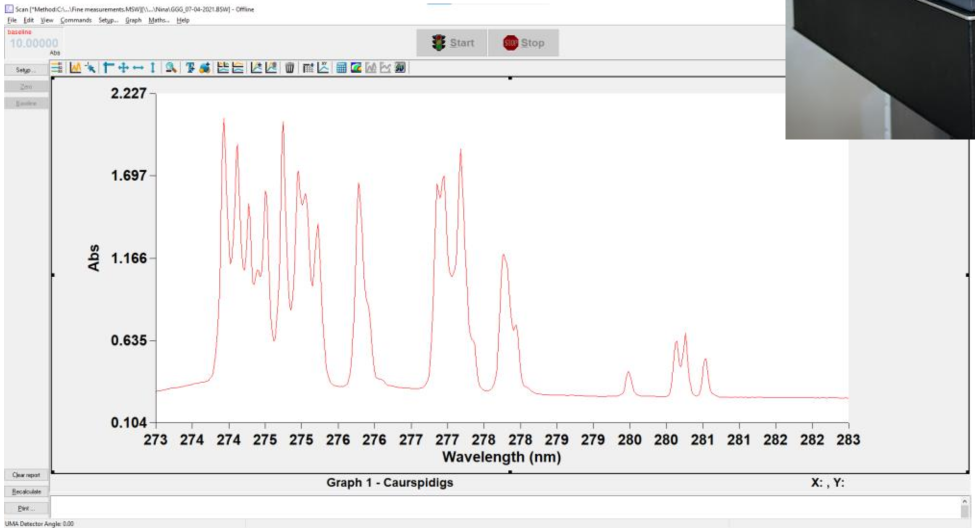


- Excitation range: 210 nm – 2600 nm
- Detection range: 200 nm – 850 nm
- Pulse duration/frequency: 5ns/10Hz, 27 ps/1kHz, 190 fs/1MHz
- Temporal resolution: up to 20 ps. Streak-camera, TCSPCs
- Temperature range: 5 K – 330 K

EXPERIMENTAL TECHNIQUES

- UV-VIS-IR optical spectroscopy

Cary 7000 spectrophotometer

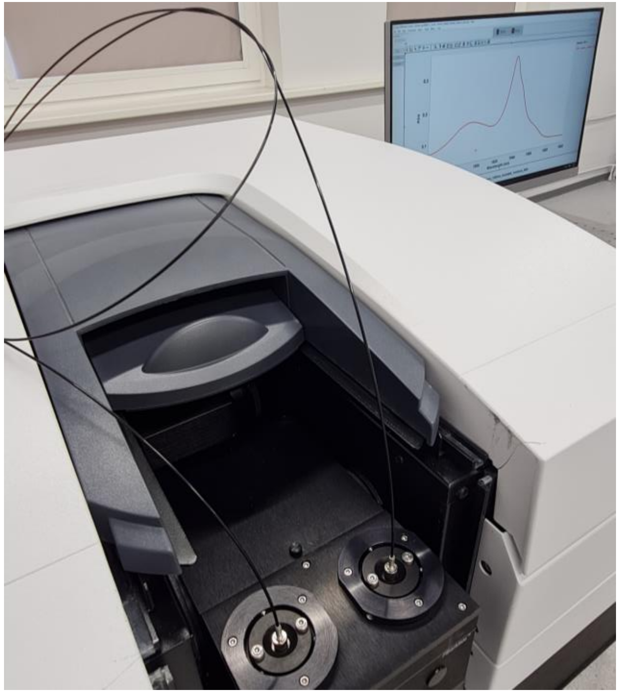


- Wavelength range: 190 nm – 3300 nm
- Detection range: up to 10 ABS
- Reflection, absorption, diffuse scattering
- Direct coupling to optical fibers possible

EXPERIMENTAL TECHNIQUES

- UV-VIS-IR optical spectroscopy

Cary 7000 spectrophotometer



- Wavelength range: 190 nm – 3300 nm
- Detection range: up to 10 ABS
- Reflection, absorption, diffuse scattering
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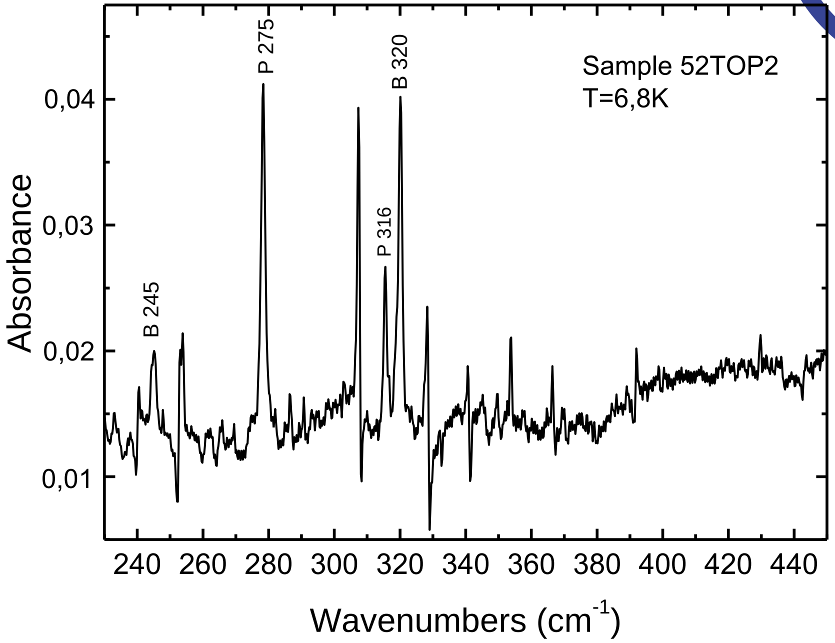
EXPERIMENTAL TECHNIQUES

- Vibrational spectroscopy

FTIR Vertex 80v



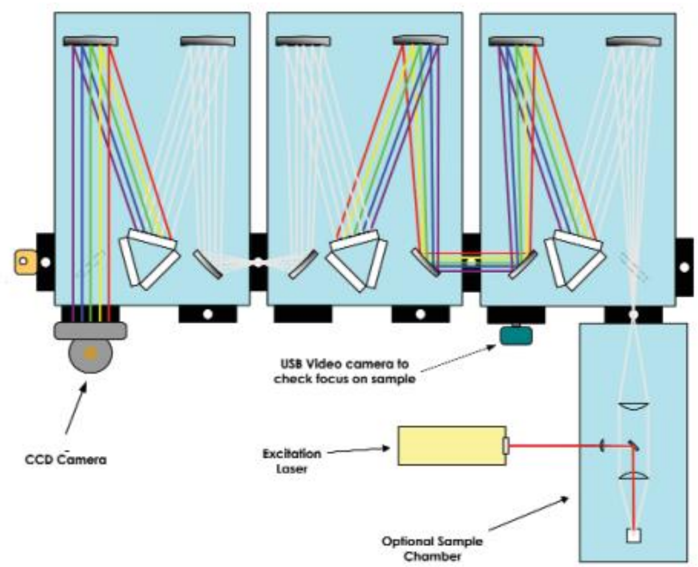
- Spectral range: 10 000 cm^{-1} – 5 cm^{-1}
- Spectral resolution: < 0.1 cm^{-1}
- Microscope spatial resolution: 20 μm

Ultrasmall concentrations of contaminants (in the range of ppt (10^{-12}) in silicon can be measured

EXPERIMENTAL TECHNIQUES

- Vibrational spectroscopy

Raman spectrometer TriVista CRS

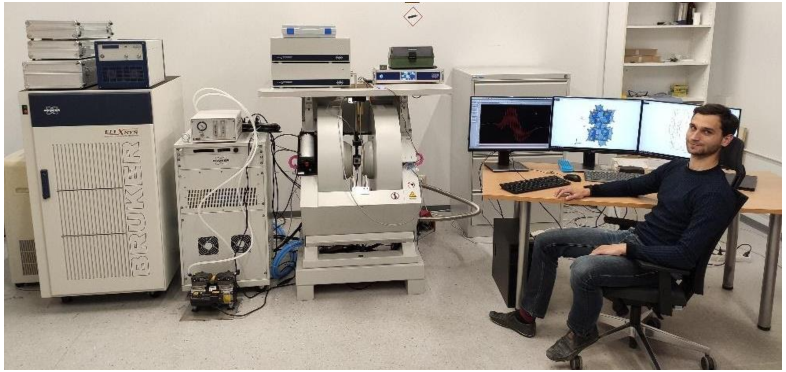


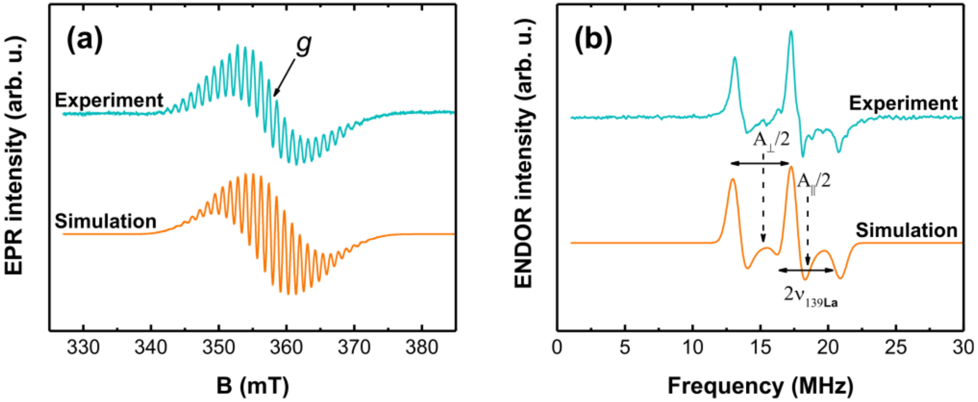
- Lasers: 1064 nm, 785 nm, 632.8 nm, 532 nm
- Detection: triple monochromator with CCD camera
- Spectral resolution: < 0.15 cm^{-1}
- Microscope: confocal microscope with submicron resolution

EXPERIMENTAL TECHNIQUES

- Magnetic spectroscopy

EPR spectrometer Elexsys-II E500 CW





- Magnetic field range: 0 – 1.7 T
- Temperature: 4 K – 300 K
- X-band: 9.2 GHz – 9.9 GHz; 200 mW
- Q-band: 33.85 GHz – 34.15 GHz, 80 mW
- ENDOR option

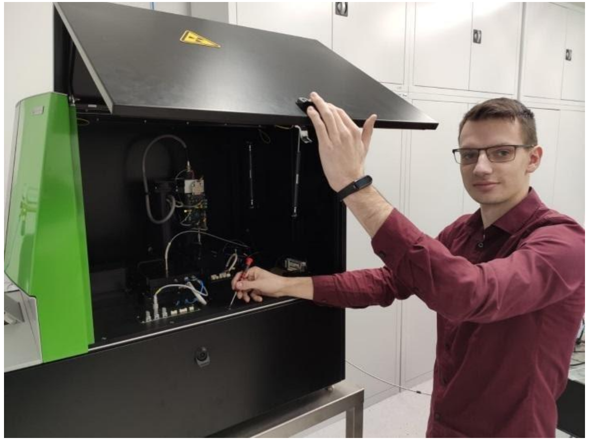
(a) EPR and **(b)** ENDOR spectra confirming hyperfine interaction between Cr^{5+} and La nuclei in LaOCl: Cr

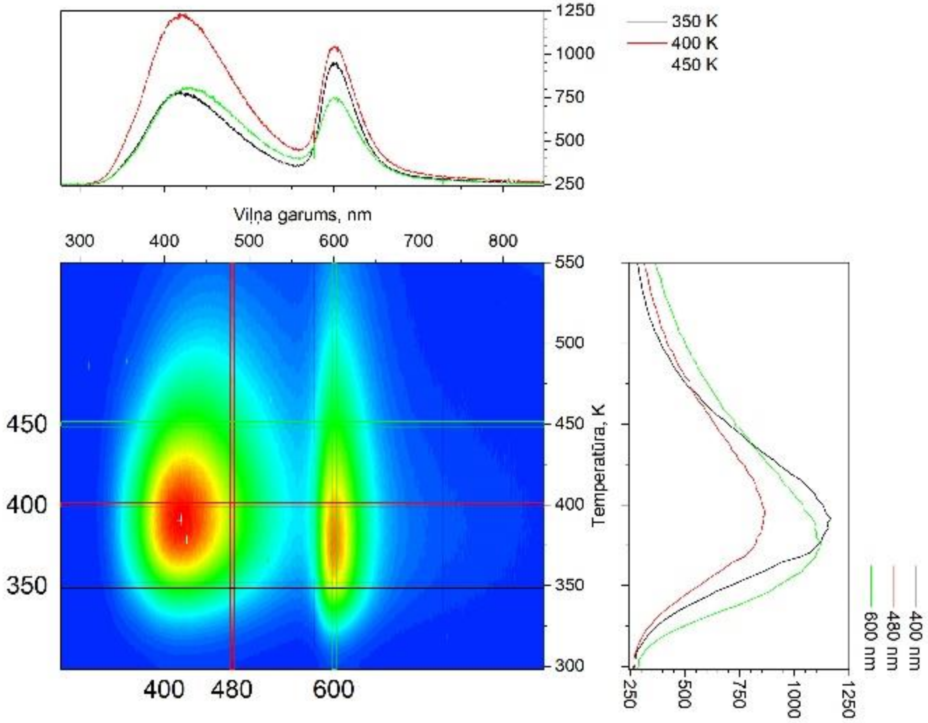
A. Antuzevics, G. Krieke, H. Ozols, A. Fedotovs, A. Sarakovskis, A. Kuzmin Materials **14** (2021)

EXPERIMENTAL TECHNIQUES

- Dosimetric properties

TL-OSL reader Lexsyg research





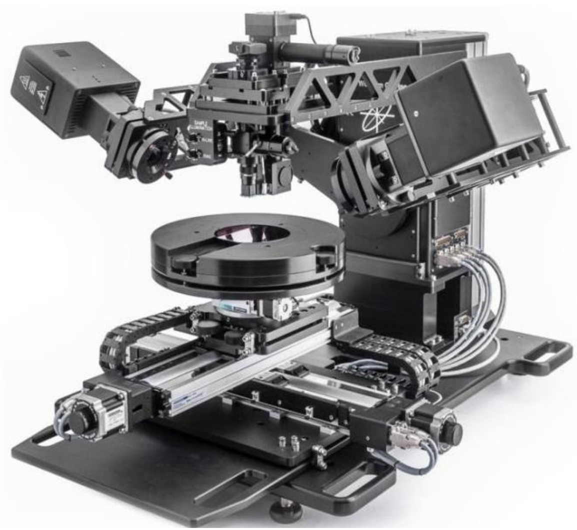
- Irradiation source: x-ray or beta
- Heating range: RT - 700 ^{0}C
- Heating rate: 0.1-20 ^{0}C/s
- Maximum number of samples: 80

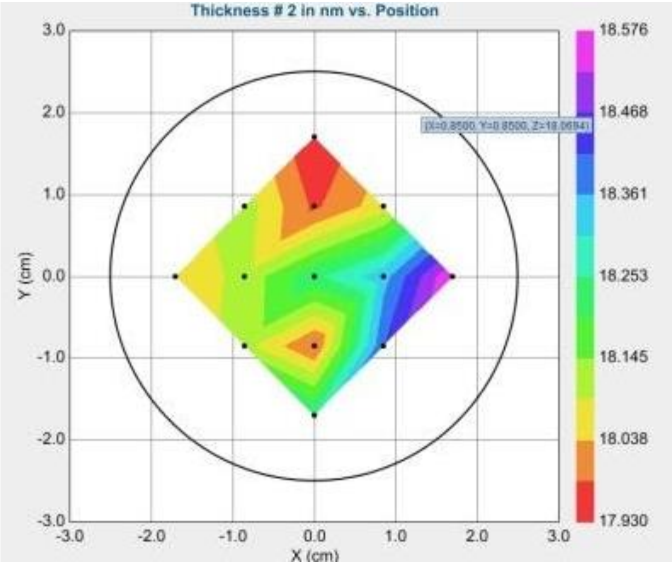
EXPERIMENTAL TECHNIQUES

- Ellipsometry

Spectroscopic ellipsometer RC2-XI (Woollam)

- *Wavelength range: 210 nm-1690 nm*
- *Angles of incidence:* 45°-90°
- *Beam size: 120 µm*
- *Temperature range: -50^{0}C-150^{0}C*





A light beam with known polarisation is reflected from the sample, and the output polarisation is measured. Ellipsometry measures the change in amplitude and phase of a reflected polarised light.

One of the features of our spectroscopic ellipsometer is a possibility to perform a sample mapping: a specific measurement will be repeated at several points of the sample. This is a fast and efficient way to control, e.g., the uniformity of the film thickness.

This figure describes the variations of thickness of HfO_2 thin film obtained by 13-point mapping of optical constants of the sample.

EXPERIMENTAL TECHNIQUES

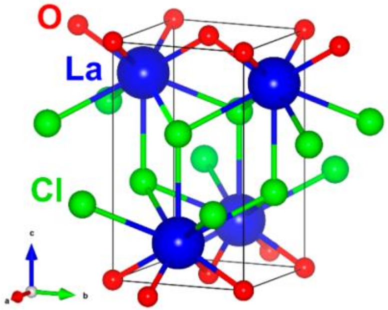
- Electron spectroscopy

XPS/UPS system

- Identification and quantification of individual chemical states
- Depth profiling by Ar ion etching
- Spatial resolution: <1 µm
- UPS
- REELS
- ISS

- Electron spectroscopy

XPS/UPS system



Citation: Antuzevics, A.; Krieke, G.; Ozols, H.; Fedotovs, A.; Sarakovskis, A.; Kuzmin, A. Oxidation State and Local Structure of Chromium Ions in LaOCl. *Materials* **2021**, *14*, 3539. https://doi.org/10.3390/ma14133539

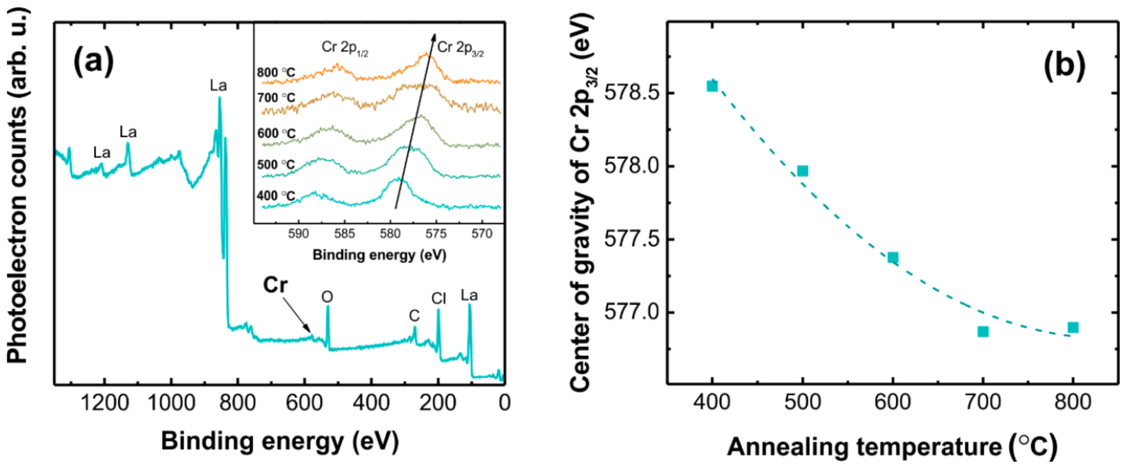
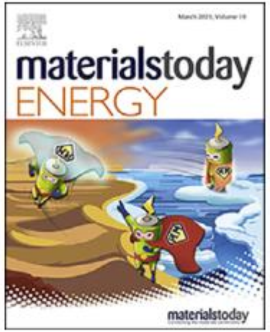


Figure 6. (**a**) XPS spectrum of the 5% Cr LaOCl sample prior annealing in a reducing atmosphere; inset: background corrected XPS spectra in Cr 2p peak range of 5% Cr LaOCl samples annealed at different temperatures in H_2/Ar atmosphere and (**b**) binding energy of Cr $2p_{3/2}$ to the annealing temperature of the samples.

EXPERIMENTAL TECHNIQUES

- Electron spectroscopy

XPS/UPS system



Thickness-dependent properties of ultrathin bismuth and antimony chalcogenide films formed by physical vapor deposition and their application in thermoelectric generators

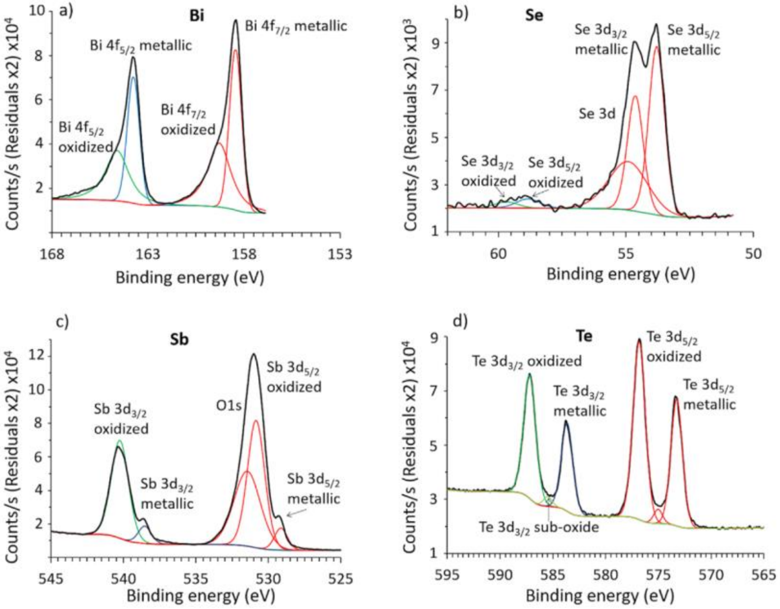


Fig. 2. Representative deconvoluted XPS spectra of a-b) 6 nm thin Bi_2Se_3 film and c-d) 5 nm thin Sb_2Te_3 film deposited on mica substrates. XPS, X-ray photoelectron spectroscopy.

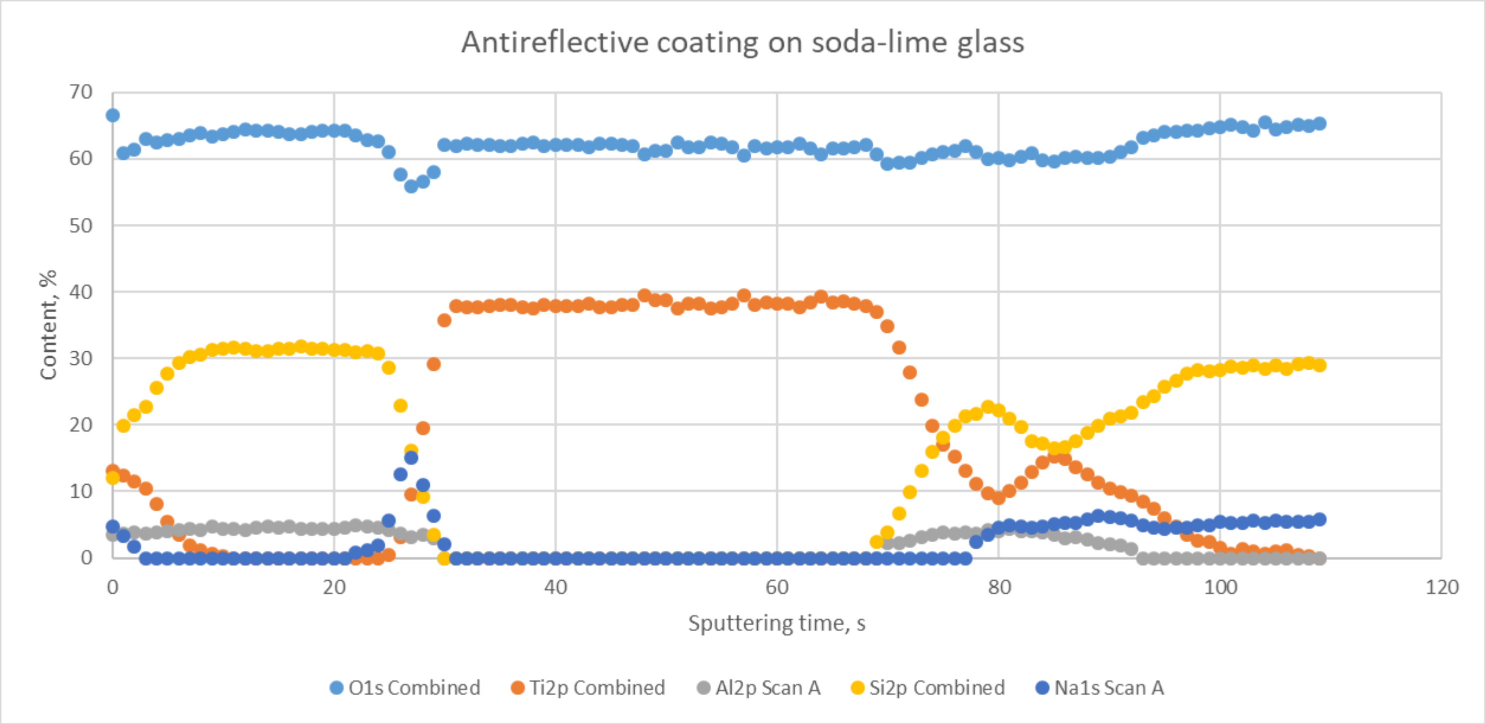
Table 1
Comparison of the chemical compositions of the Bi_2Se_3 and Sb_2Te_3 source materials and ultrathin films deposited on mica substrates revealed by the XPS measurements.

Chemical element	Bi_2Se_3 source material	Bi_2Se_3 6 nm thin film on mica	Chemical element	Sb_2Te_3 source material	Sb_2Te_3 5 nm thin film
	at %	at %		at %	at %
Bi	37.1	36.7	Sb	41.6	44.9
Se	62.9	63.3	Te	58.4	55.1

EXPERIMENTAL TECHNIQUES

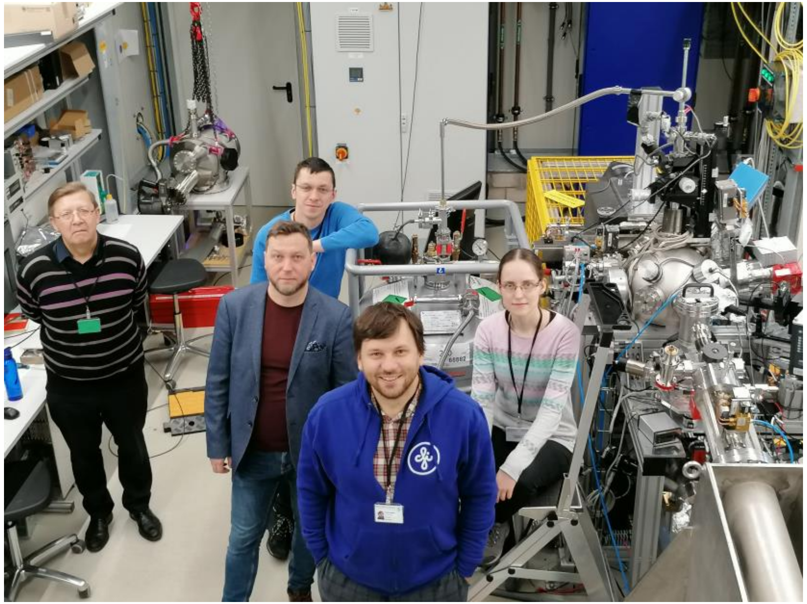
- Electron spectroscopy

XPS/UPS system



EXPERIMENTAL TECHNIQUES

- Large Scale Facilities – synchrotrons [DESY (Hamburg), MAX IV (Lund)] – excitation in vacuum ultraviolet region



DESY

MAX IV

LOOKING FORWARD TO POSSIBLE COLLABORATION

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