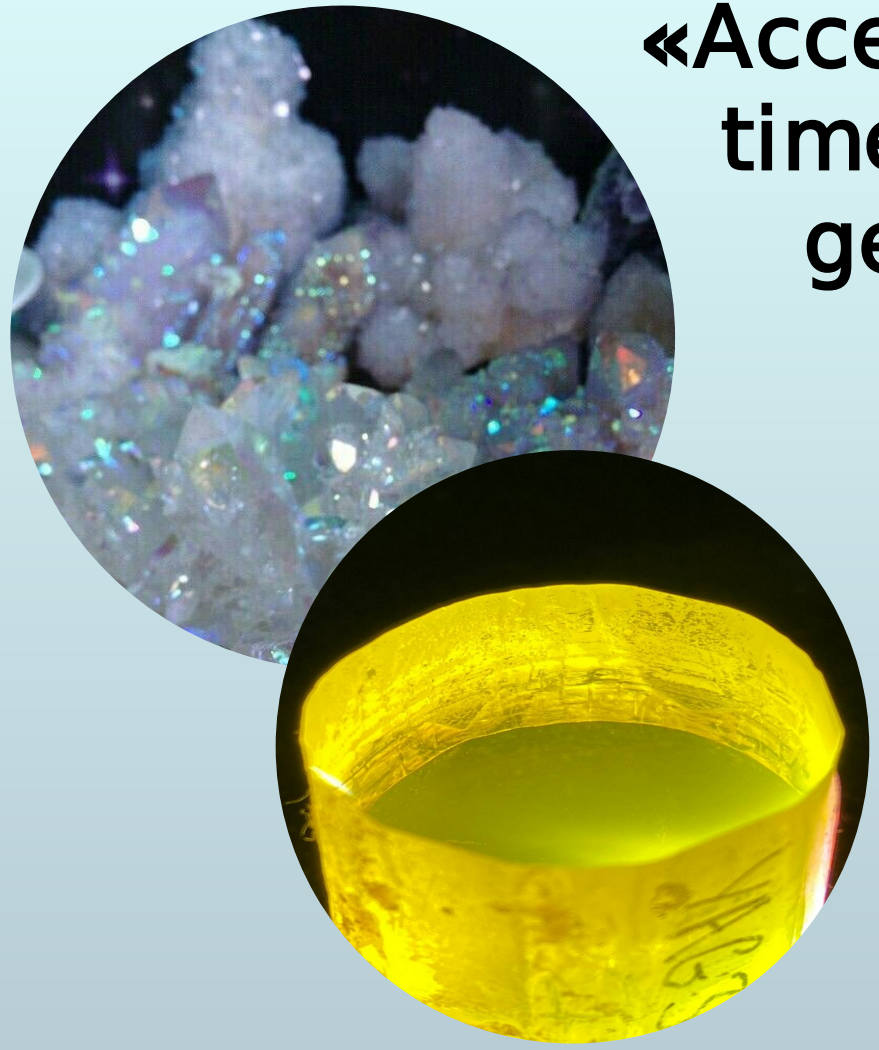

# «Acceleration of YAG:Ce decay time for application in new generation of colliders»

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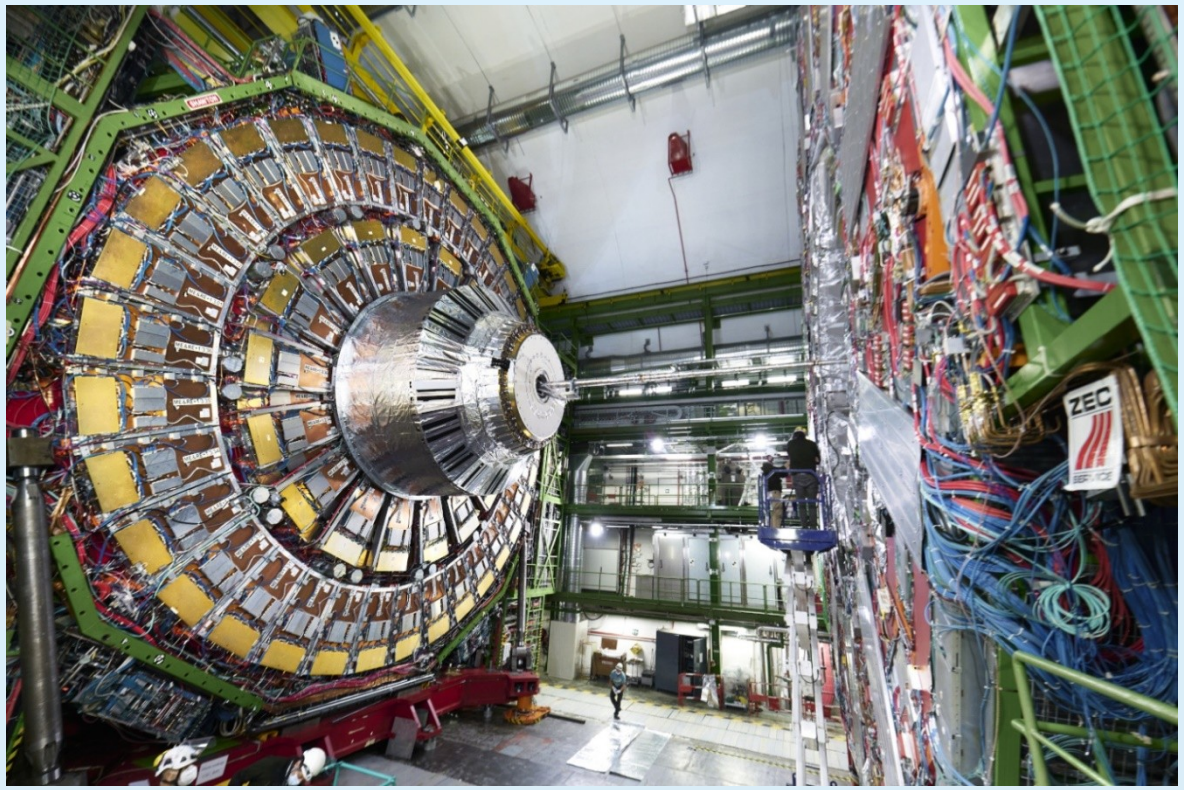
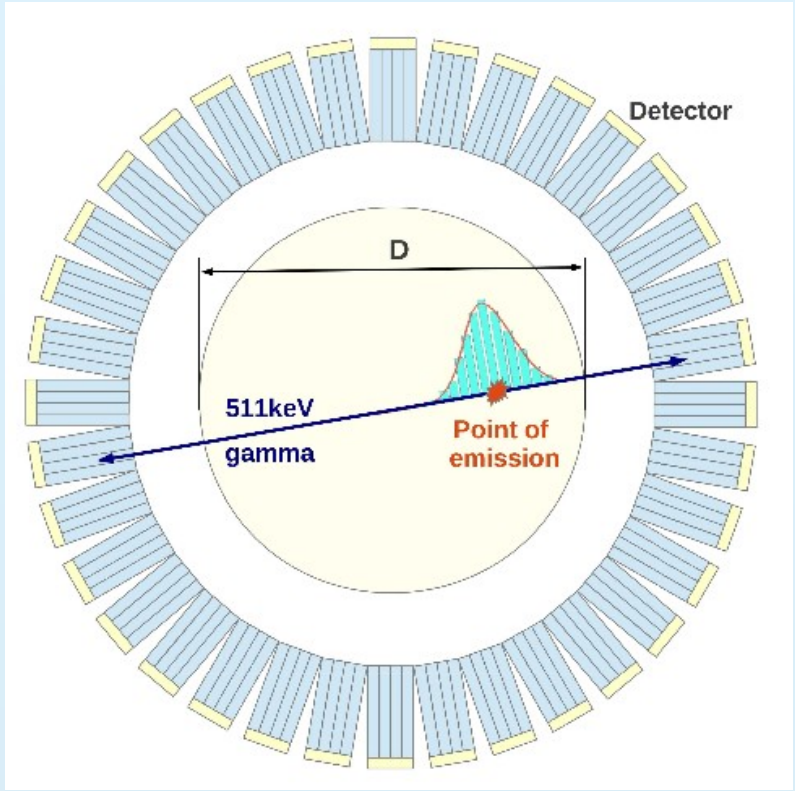
*11-20 July 2024*


The work was made in the frame of Horizon Europe Project No. 101078960 “TWISMA” and Crystal Clear Collaboration in CERN and supported by CERN EPR&D

# The scintillation materials are required for high energy physics and medicine



CMS in Large Hadron Collider
https://home.cern/science/experiments/cms




Positron emission tomograph

IEEE Transactions on Nuclear Science ( Volume: 65, Issue: 8, August 2018)

# YAG:Ce single crystals

## Candidate crystals for use in new HEP and medicine applications

| | GAGG:Ce* | LYSO:Ce** | YAG:Ce*** |
|---|---|---|---|
| light output, ph./MeV | 25000 | 25000 | 30000 |
| luminescence decay time, ns | 40 | 45 | 70-100 |
| luminescence wavelength, nm | 520 | 410 | 550 |
| density, g/(cm^3) | 6,7 | 7,15 | 4,57 |
| melting point,℃ | 1850 | 2100 | 1970 |
| cost price | $$$ | $$$ | $ |

*https://www.c-and-a.jp/assets/img/products/102210514_GFAG.pdf

**https://advatech-uk.co.uk/lyso_ce.html

***https://www.crytur.com/materials/yagce/

**** IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 70, NO. 7, JULY 2023

SCINTILLATION DECAY TIMES (NS) AND CONTRIBUTIONS OF DECAY COMPONENTS (%) IN YAG:CE,C,$A^{2+}$ UNDER IRRADIATION BY $\gamma$-RAYS ($^{137}$CS, 662 KEV)

| | As-grown | | | Annealed | | |
|---|---|---|---|---|---|---|
| | τ1 | τ2 | τ3 | τ1 | τ2 | τ3 |
| Mg | 58 (14%) | 230 (55%) | 819 (31%) | 78 (37%) | 368 (52%) | 1260 (11%) |
| Ca | 40 (19%) | 131 (43%) | 805 (38%) | 55 (77%) | 282 (23%) | |
| Sr | 74 (34%) | 286 (49%) | 1698 (17%) | 73 (33%) | 327 (37%) | 25862 (30%) |
| Ba | 118 (49%) | 465 (51%) | | 111 (30%) | 367 (48%) | 6668 (22%) |
| YAG: Ce,C | | | | 101 (19%) | 359 (60%) | 2260 (21%) |

IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 70, NO. 7, JULY 2023

# Purpose of my work

➡ Determination of the impact of Mg and Ca co-doping and high temperature treatment on luminescence decay time of yttrium aluminum garnet crystal, activated with cerium.

➡ Single crystal YAG:Ce,Ca,Mg was grown; samples were produced; experiments on annealing samples were conducted, measured optical and scintillation characteristics

Induction heating furnace "OXIDE'

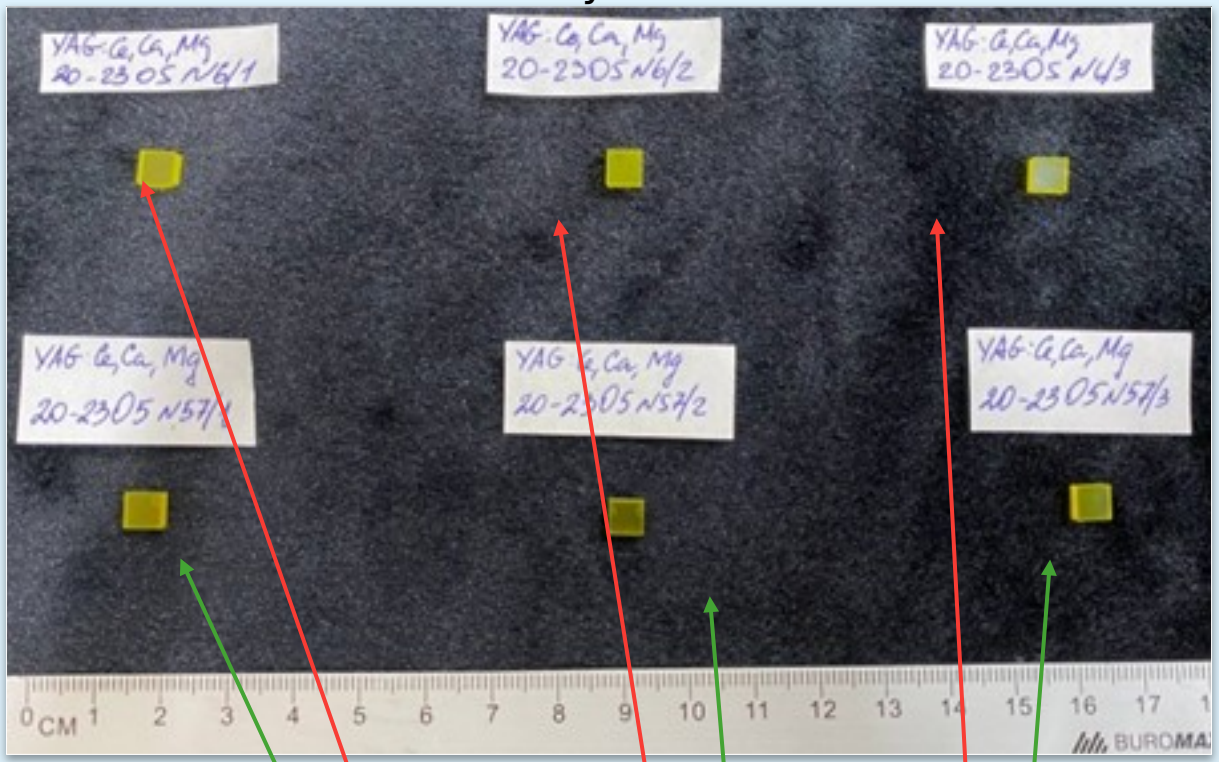
Tungsten crucible


YAG:1%Ce,0.75%Ca,0.25%Mg single crystal

# Annealing

Samples for testing

from the top (№ 6) and bottom (№ 57) parts of a crystal




| | 1500 °C 60 hours | 1300 °C 60 hours | 1100 °C 60 hours |
|---|---|---|---|
| top №6 | 6/1 | 6/2 | 6/3 |
| bottom №57 | 57/1 | 57/2 | 57/3 |

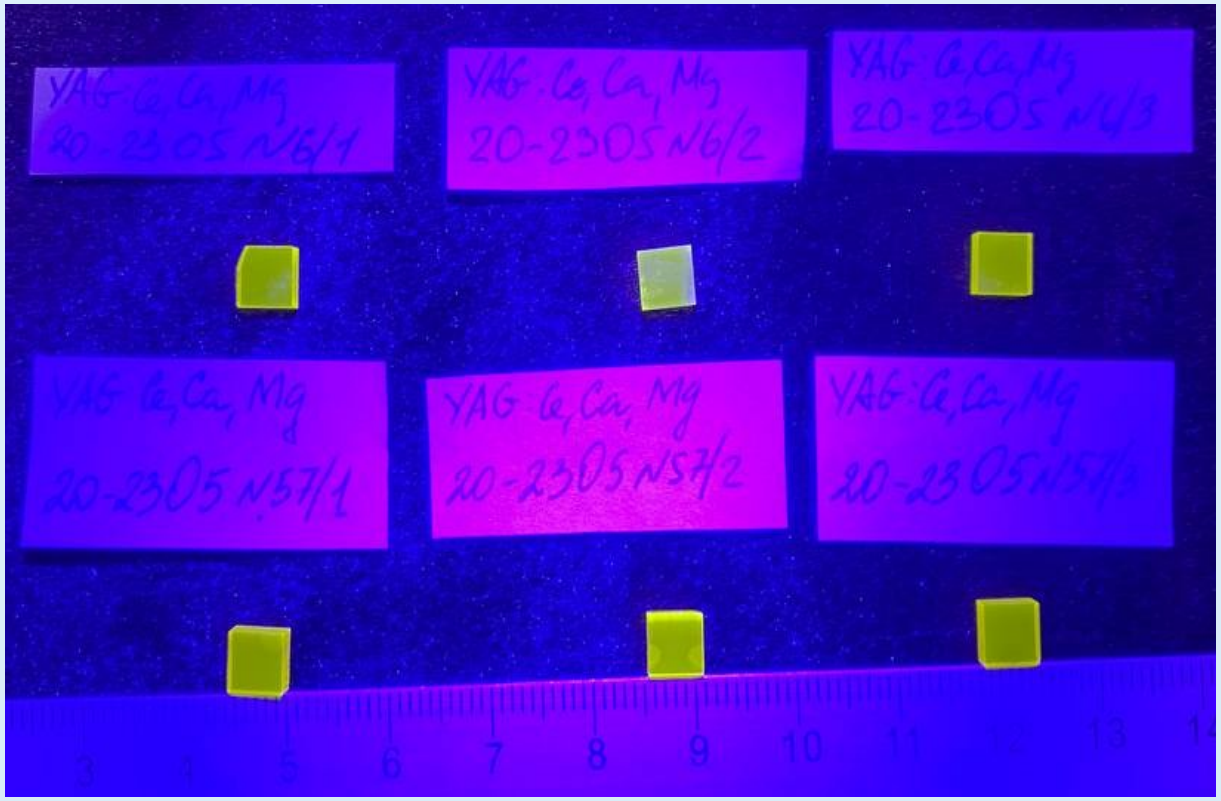
High temperature oven

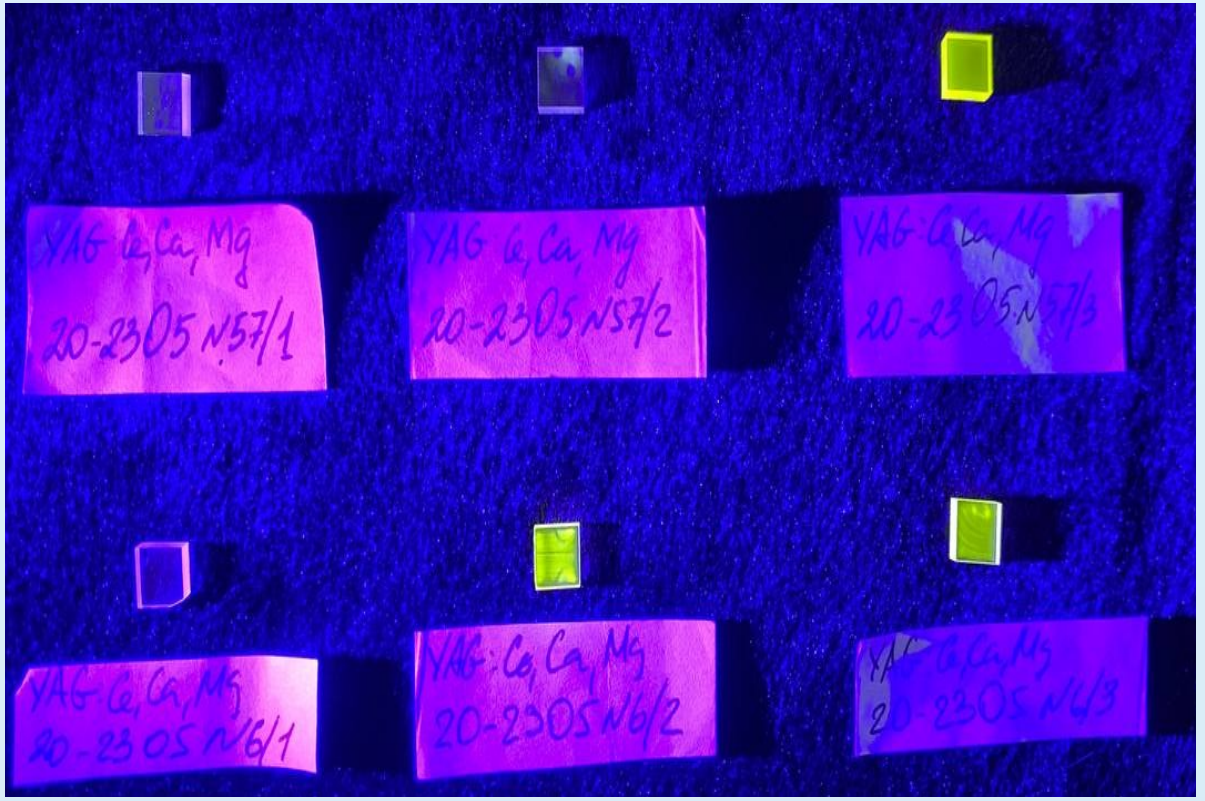
YAG:Ce,Ca,Mg

The samples **before** annealing under ultraviolet radiation

t°C

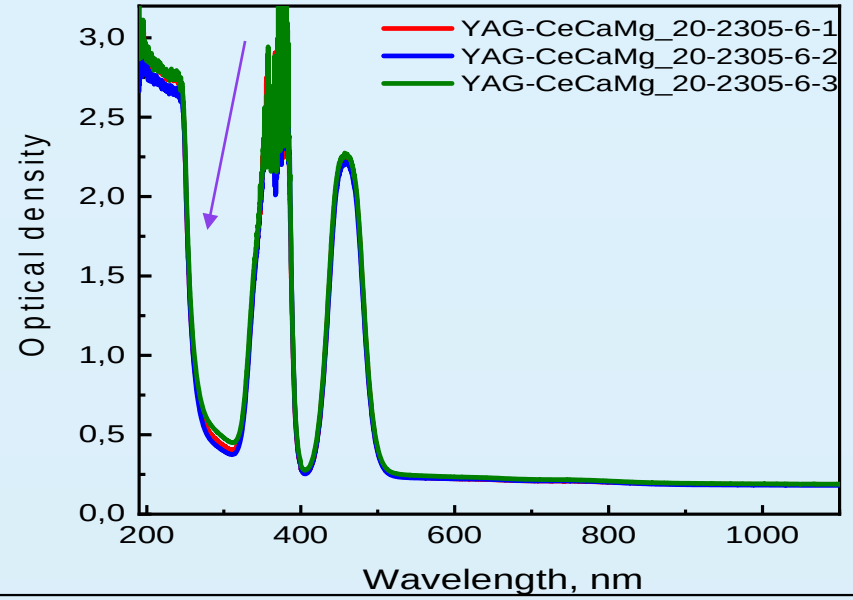
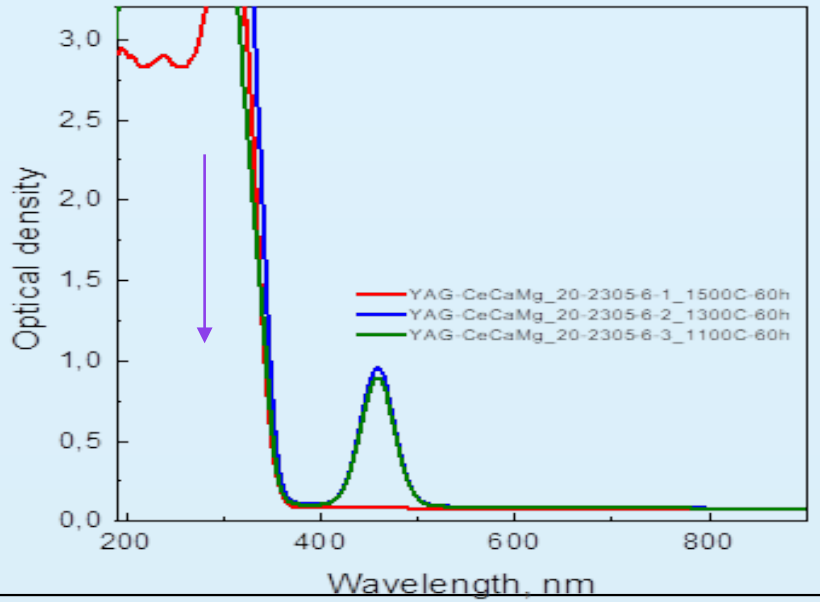
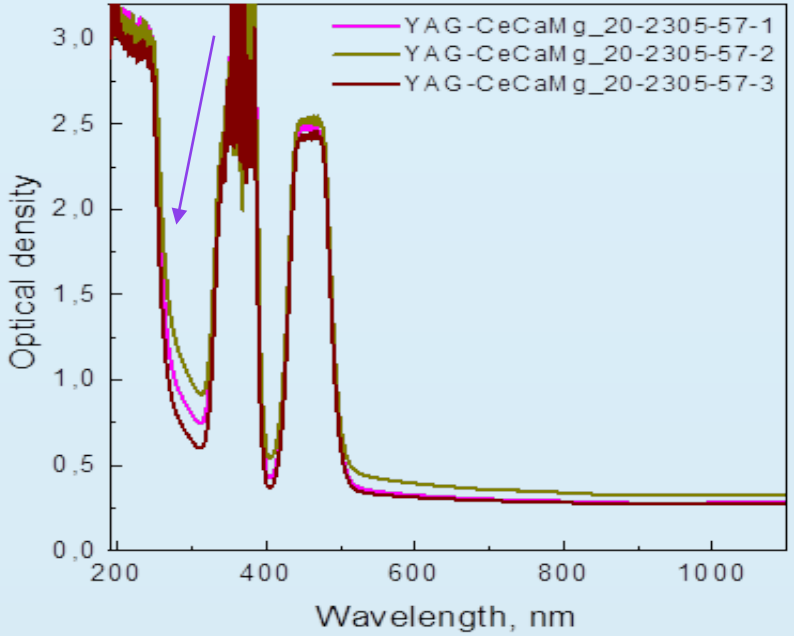
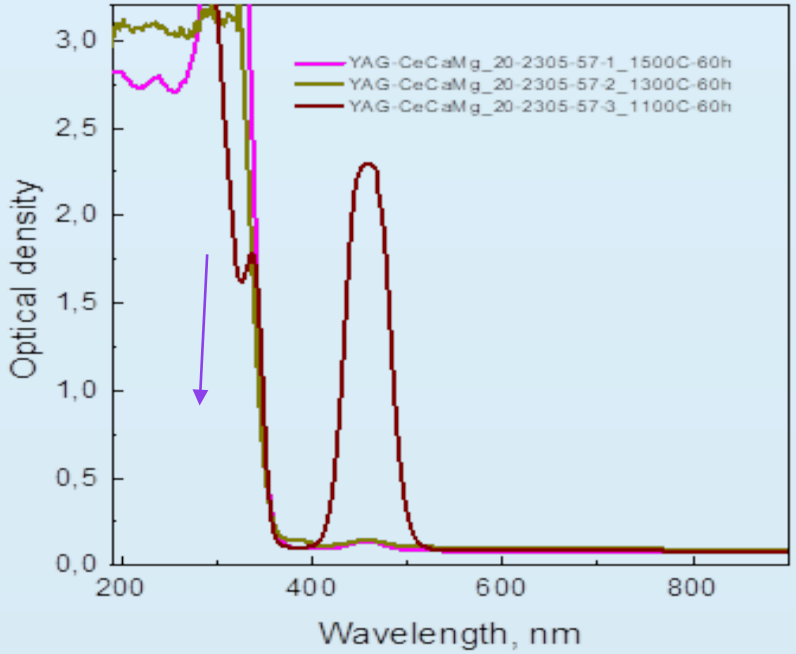
The samples **after** annealing under ultraviolet radiation




1500°C 1300°C 1100°C

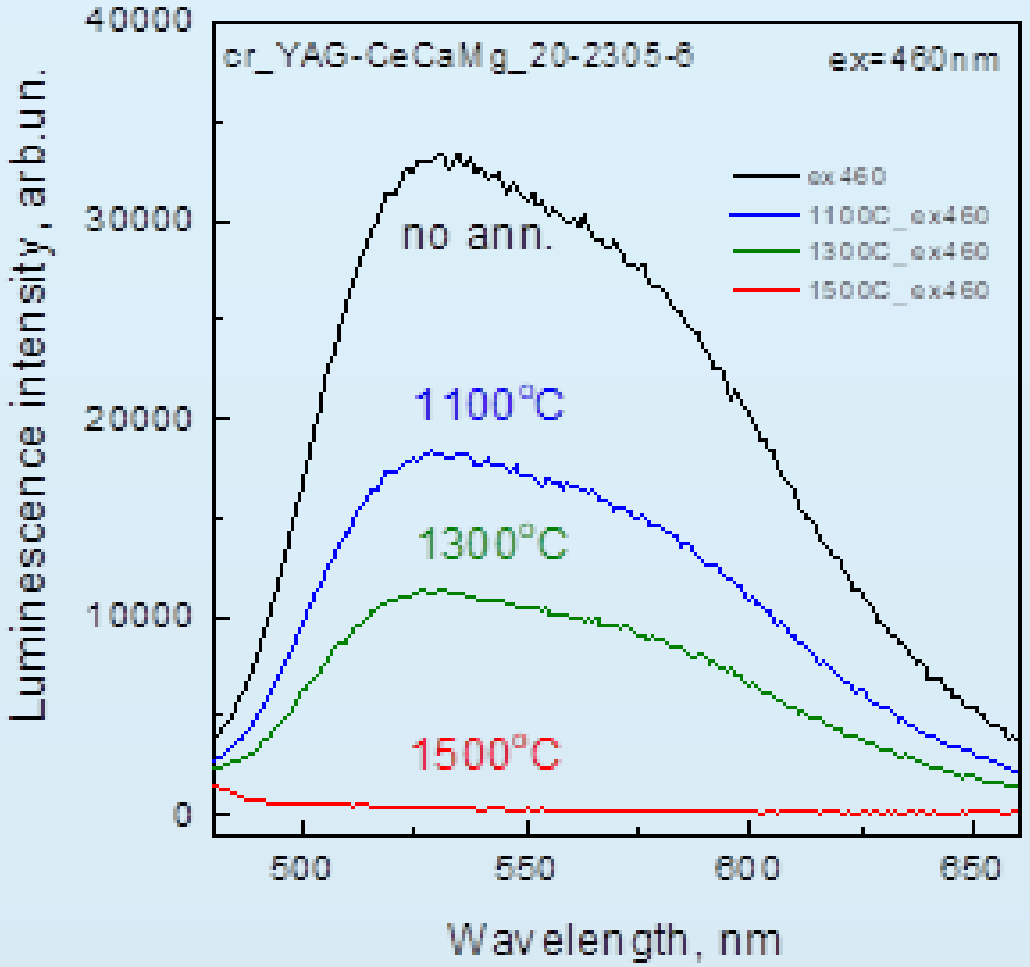
# Optical properties

| | Before annealing | After annealing |
|---|---|---|
| Top of the crystal |  |  |
| Bottom of the crystal |  |  |

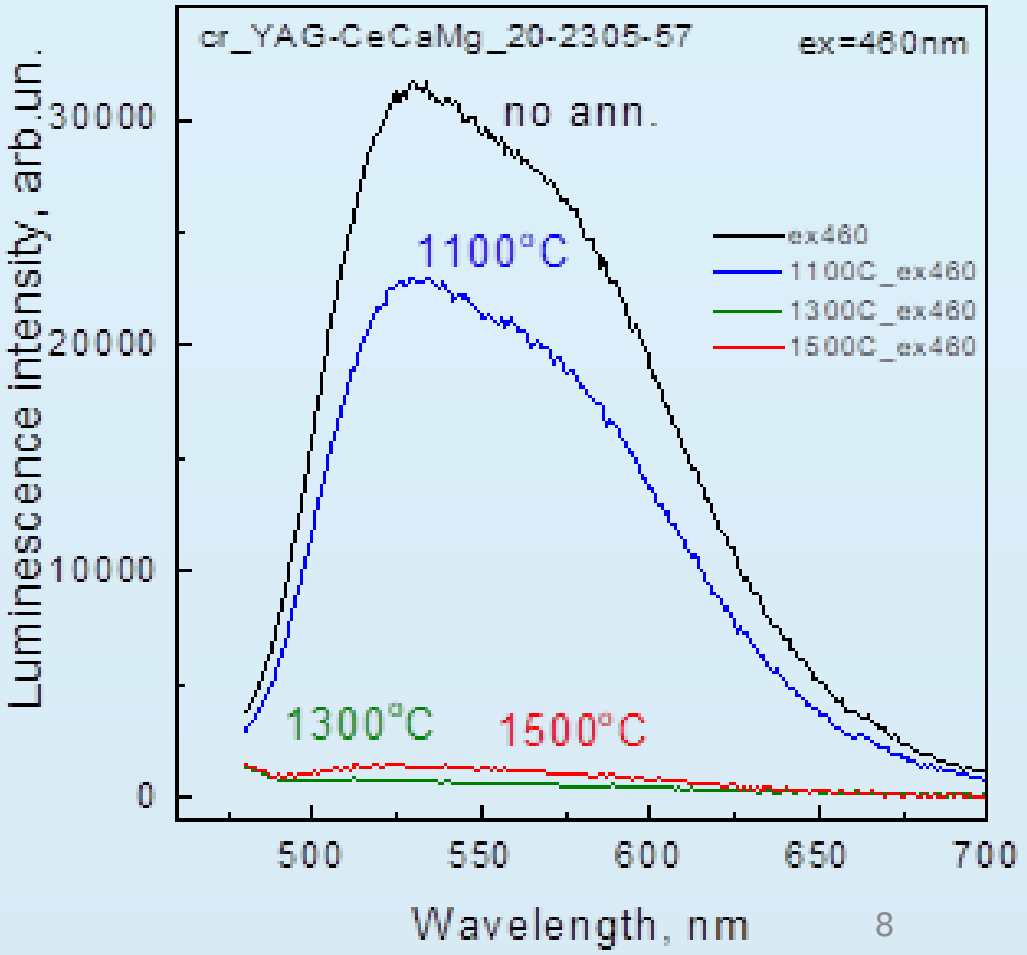
# Photoluminescence spectra

After annealing photoluminescence spectra disappear already at 1300°C and 1500°C

**Top** of the crystal




**Bottom** of the crystal



# Scintillation properties

| | Top of the crystal YAG:Ce,Ca,Mg | | | Bottom of the crystal YAG:Ce,Ca,Mg | | |
|---|---|---|---|---|---|---|
| | **6/1** | **6/2** | **6/3** | **57/1** | **57/2** | **57/3** |
| **Light output before annealing, ph./MeV** | 4200 | 4200 | 4200 | 3200 | 3300 | 3800 |
| **Light output after annealing, ph./MeV** | 23900 (1500°C) | 21850 (1300 °C) | 24900 (1100 °C) | 22380 (1500°C) | 23650 (1300 °C) | 23100 (1100 °C) |
| **Extinction time before annealing, ns** | 73 | - | - | 70 | - | - |
| **Extinction time after annealing, ns** | 34,01 | 29,31 | 36,82 | 27,78 | 34,50 | 33,83 |

After annealing the light output is increased

After annealing,a reduction in the luminescence decay times is observed

## Conclusions

- For the first time, a single crystal of YAG:Ce,Mg,Ca was grown by the Czochralsky method in a reducing atmosphere using a tungsten crucible
- A positive effect of annealing on the scintillation characteristics of this single crystal was found. **After annealing, the light output increases by 5-6 times,** regardless of the annealing temperature (1100°C -1500°C). **The value of the scintillation decay time is reduced by about 50 % under the influence of oxidative annealing**
- No strict correlation between the annealing temperature and the values of scintillation parameters has been determined .