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$Cs_2LiCeCl_6$: An intrinsic scintillator for dual gamma and neutron detector applications

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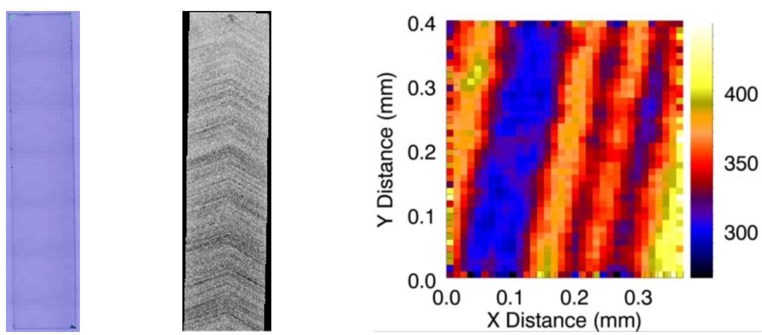
Introduction

Why are intrinsic materials preferred ?

Most of the scintillators are activated by foreign dopants
e.g.; NaI:Tl, $LaBr_3$:Ce and SrI_2:Eu

Disadvantages: i) Segregation of dopants
ii) Growth striations

The segregation and striations can severely degrade the uniformity and energy resolution of large-volume devices.



a b c

a) Optical transmission picture of a LSO:Ce sample of dimensions ~20x6x6 mm^3, b) X-ray response map, and (c) high magnification fluorescence map of Ce atoms (dopant).

Advantage of intrinsic scintillators:

Intrinsic compounds will ensure homogeneity of the material throughout the grown ingot, and thus a uniform detector response can be achieved at substantially lower cost for a large volume detector. The energy resolution is expected to be independent of detector volume.

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Motivation

Cs_2LiYCl_6:Ce (CLYC) is the most well known dual gamma-neutron- detector material. In our present study $Cs_2LiCeCl_6$ (*CLCC*) was chosen as the intrinsic scintillator as a potential replacement for CLYC.

This material is from the Elpasolite family; it has a cubic crystal structure and a density of ~3.4 gm/cc.

Advantage of $Cs_2LiCeCl_6$:

Intrinsic material; energy resolution is expected to be independent of the volume of the detector.

Growth of $Cs_2LiCeCl_6$

Crystals were grown by the vertical Bridgman technique.

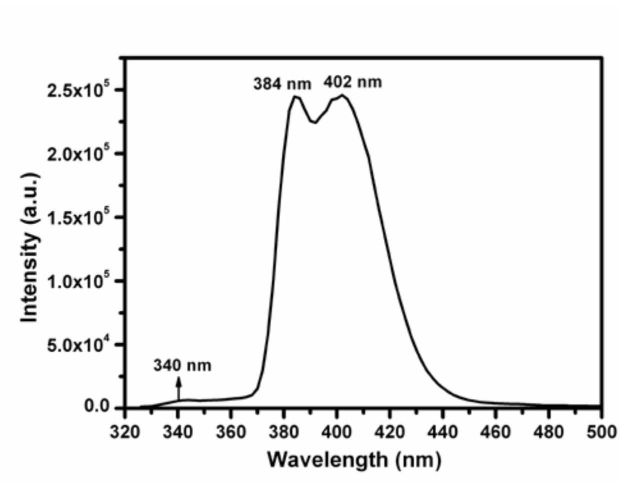
The compound was synthesized from

$$2CsCl + CeCl_3 + LiCl \longrightarrow Cs_2LiCeCl_6$$

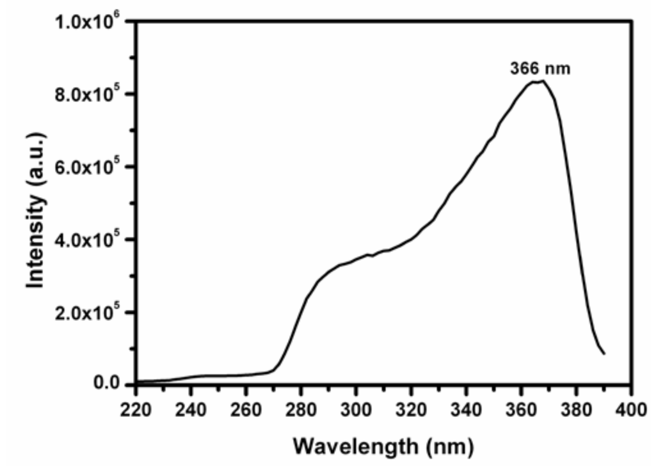
99.999% pure anhydrous CsCl
> 99.999% pure anhydrous $CeCl_3$
> 99% pure anhydrous LiCl

Same ampoule was used for synthesis and growth.
Loaded material in the quartz ampoule was heated to ~180 ^{0}C for 24 hrs under a dynamic vacuum.
The ampoule was sealed under dynamic vacuum of 2×10^{-6} torr.
Growth rate: ~1.4 cm/day.
Post growth cooling rate: 4 ^{0}C/hr.

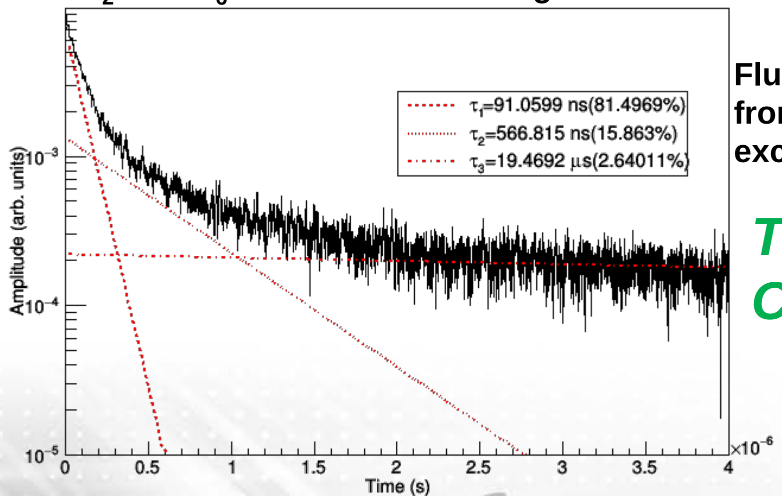
Emission and excitation spectra of $Cs_2LiCeCl_6$ and fluorescence decay



Optically pumped emission spectrum of $Cs_2LiCeCl_6$. Excitation wavelength: 280 nm



Excitation spectrum of $Cs_2LiCeCl_6$.



Fluorescence decay obtained from $Cs_2LiCeCl_6$ using 662-keV excitation from a ^{137}Cs source.

The response of CLCC is faster than CLYC.

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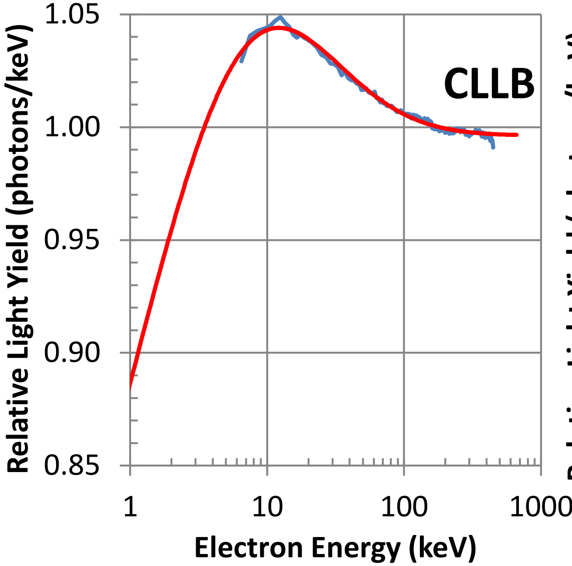
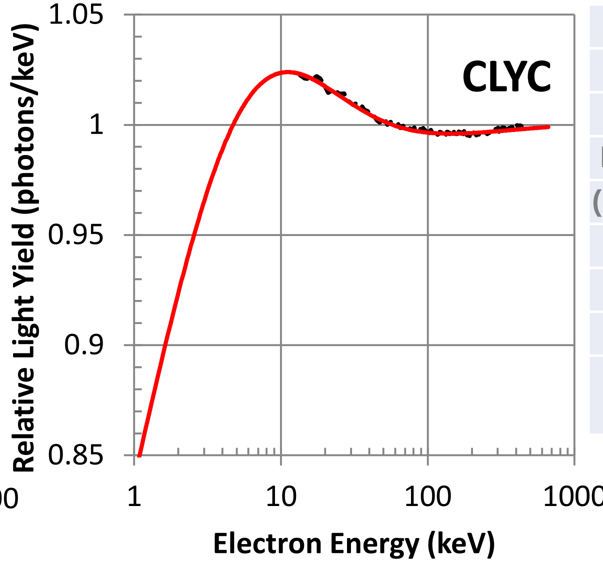
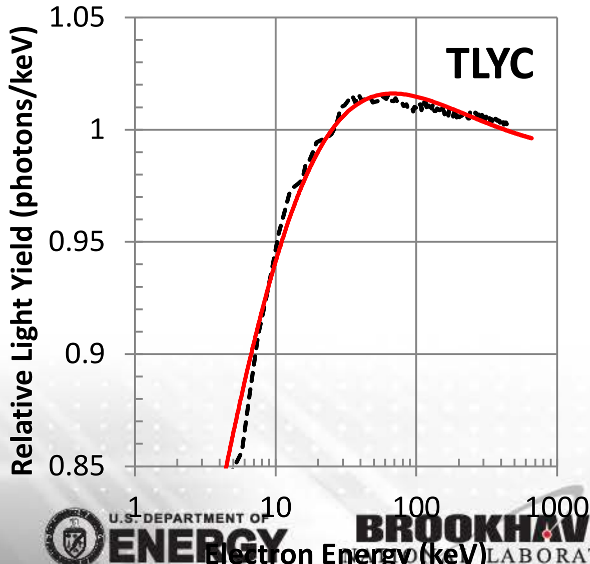
Non-proportionality of CLCC and other elpasolites (activated by cerium) for comparison

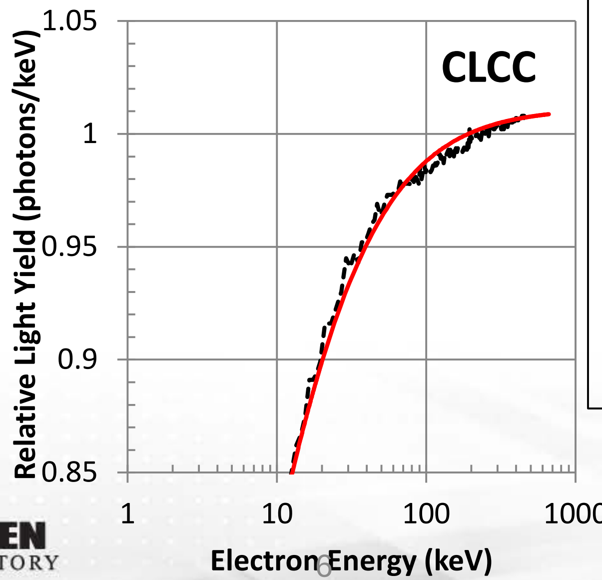




Parameter	Elpasolites			
	CLLB	CLYC	TLYC	CLCC
Density	4.2 g/cm³	3.3	4.5	3.52
Ioniz. Energy	0.45 keV	0.33	0.47	0.36
$(dE/dx)_{ONSAGER}$	36.4 MeV/cm	36.4	36.4	36.4
$(dE/dx)_{BIRKS}$	**730 MeV/cm**	**(520)**	**300**	**155**
$(dE/dx)_{TRAP}$	**30 Mev/cm**	**40**	**0**	**0**
e/h creation	**19%**	**22**	**25**	**23**
Calc'd Res. @ 662 keV	**1.53%**	**(1.7?)**	**2.90**	**3.46**

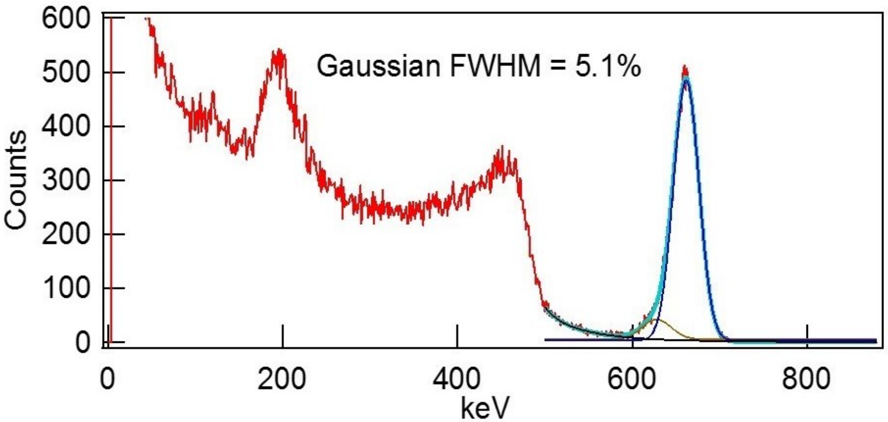
- **All scintillators have similar percent of free electrons/holes created**
- **Bromide (CLLB) has least Birks exciton annihilation and best predicted resolution, CLCC has the most**
- **CLYC & CLLB have large amount of trapping**
- **TLYC & CLCC have little trapping, perhaps because Tl^{+} and Ce^{3+} (respectively) reduce the bandgap and circumvent impact of native shallow traps**





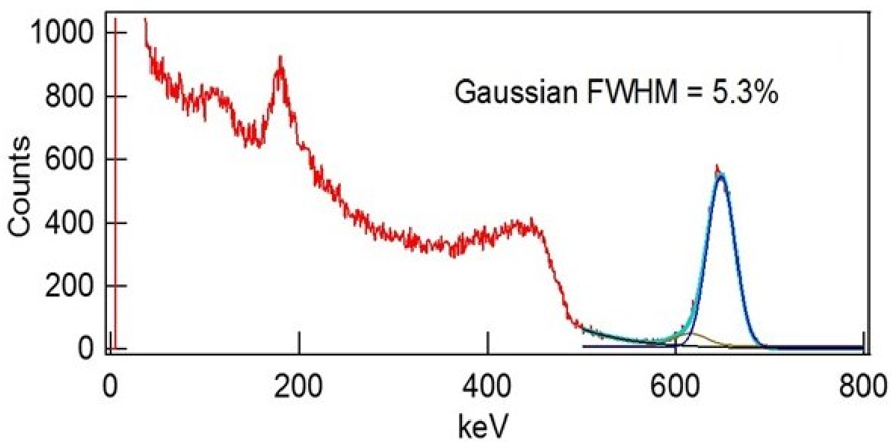
CLLB, CLYC and TLYC crystals courtesy of RMD

Detector response of $Cs_2LiCeCl_6$ for gamma radiation



After polishing, before packaging

- **LY = 34,000 Ph/MeV**
- **R(662 kev) = 5.1%**

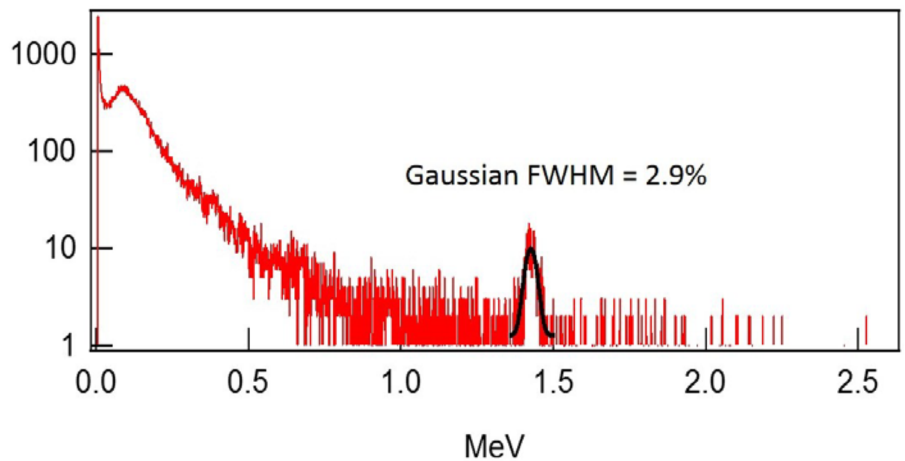


Crystal after packaging

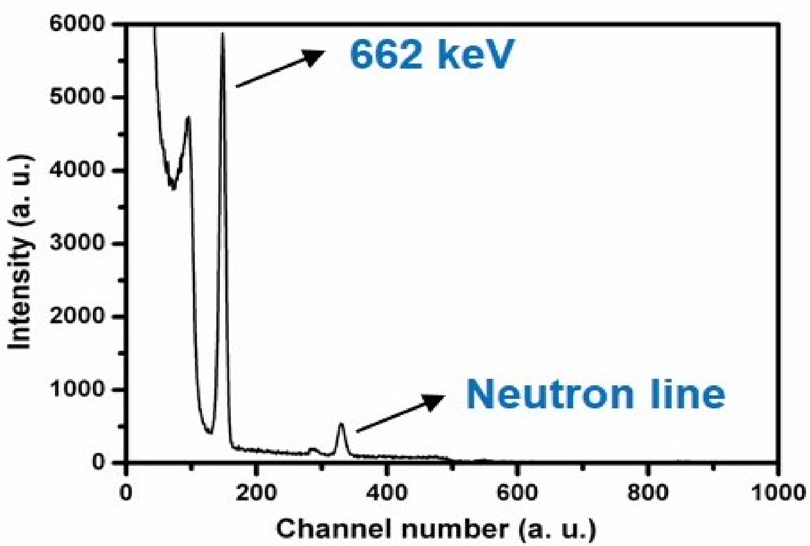
- **LY = 30,000 Ph/MeV**
- **R(662 kev) = 5.3%**

CLCC is brighter than CLYC. Light output of CLCC is ~34,000 ph/MeV, CLYC is ~22,000 ph/MeV

Detector response of $Cs_2LiCeCl_6$ to thermal neutron & gamma radiation



Neutron capture peak at 1.4 MeVee



Pulse height spectrum of Am-Be thermal-neutron and ^{137}Cs gamma source, measured at BNL. ***Resolution ~4%.***

Neutron capture peak at 1.48 MeVee

Summary

- *CLCC crystals can be grown in large volumes due to its cubic structure.*
- *CLCC is perhaps the only intrinsic scintillator capable of dual gamma- and neutron-detection.*
- *Because of intrinsic nature, the energy resolution of CLCC is expected to be independent of detector volume.*
- **CLCC has less trapping, and is capable of detecting lower-energy gamma rays compared to CLYC.**
- *CLCC is faster than CLYC.*
- *CLCC: brighter than CLYC.*

CLCC appears to be very promising and has tremendous potential to compete with CLYC, especially for large-volume detectors.

There is enough room for further improvement of energy resolution after successive purification by zone refining of the starting material.

Acknowledgement

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Thank you all for your kind attention