HIGH RESOLUTION AND COHERENT SPECTROSCOPY OF EUROPIUM DOPED CRYSTALS AND CERAMICS.

Alban Ferrier, Biagio Tumino, Julien Lejay, Philippe Goldner

Solid state Chem. Lab.
Pierre et Marie Curie University, Chimie Paristech, CNRS
Paris, France

Chimie ParisTech
École nationale supérieure de chimie de Paris

OUTLINE

- **$Eu:Y_2SiO_5$ single crystal**
  - Introduction
  - Optical inhomogeneous linewidth
  - Ground state hyperfine ihnomogeneous and homogeneous linewidths

- **$Eu:Y_2O_3$ transparent ceramics**
  - Introduction
  - Optical inhomogeneous and homogeneous linewidths

Introduction

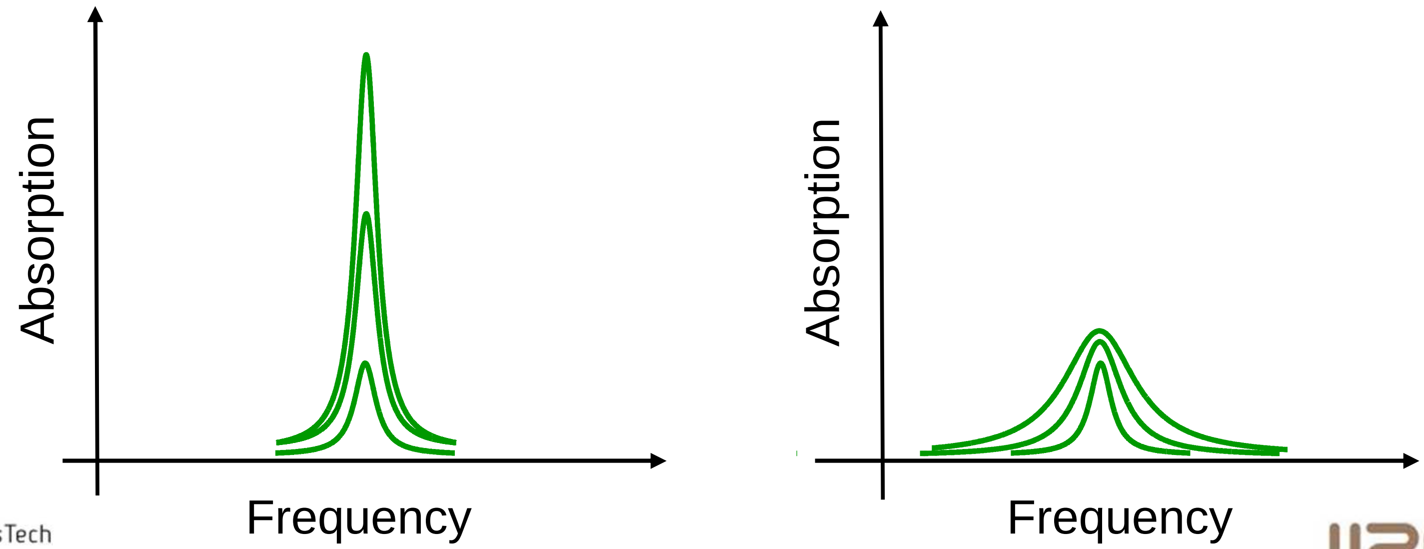
Why Eu:Y_2SiO_5 for quantum memories ?

Y_2SiO_5?

- Melt congruently but at high temperature (~2000°C)
- Doping possible by all rare earth ions
- Low nuclear spin

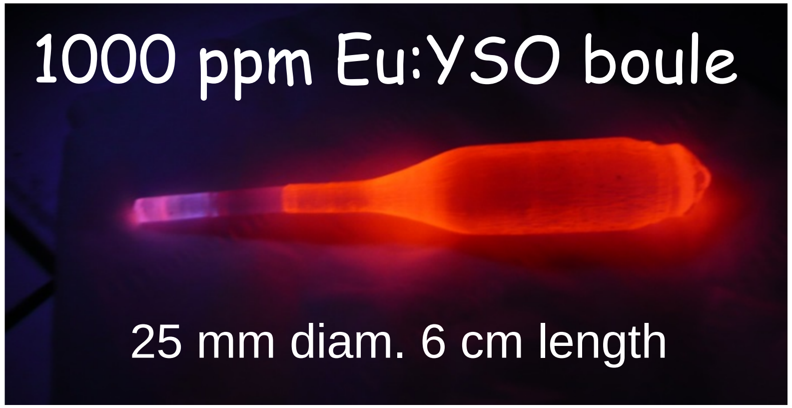
Eu ?

- Long optical coherence lifetime $^7F_0 \rightarrow {}^5D_0$
- Long ground state hyperfine coherent lifetime for ^{151}Eu
- Larger hyperfine splitting for ^{153}Eu
- Low oscillator strength → high dopind level required



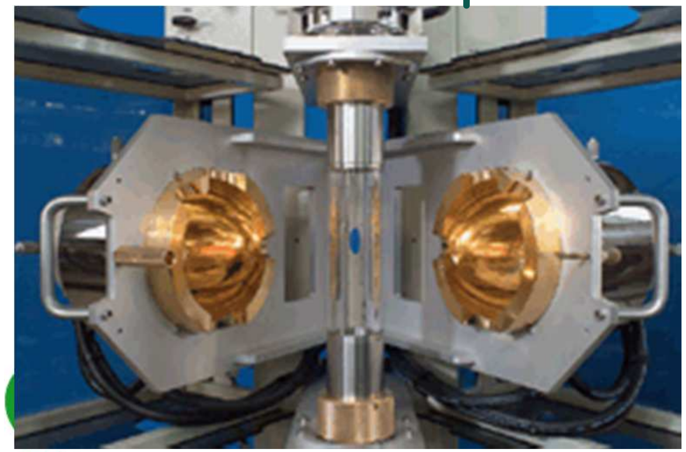
Cristal Growth facilities at Paris

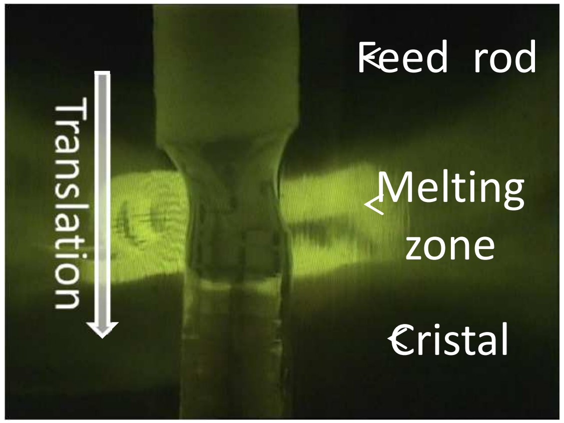
Czochralski



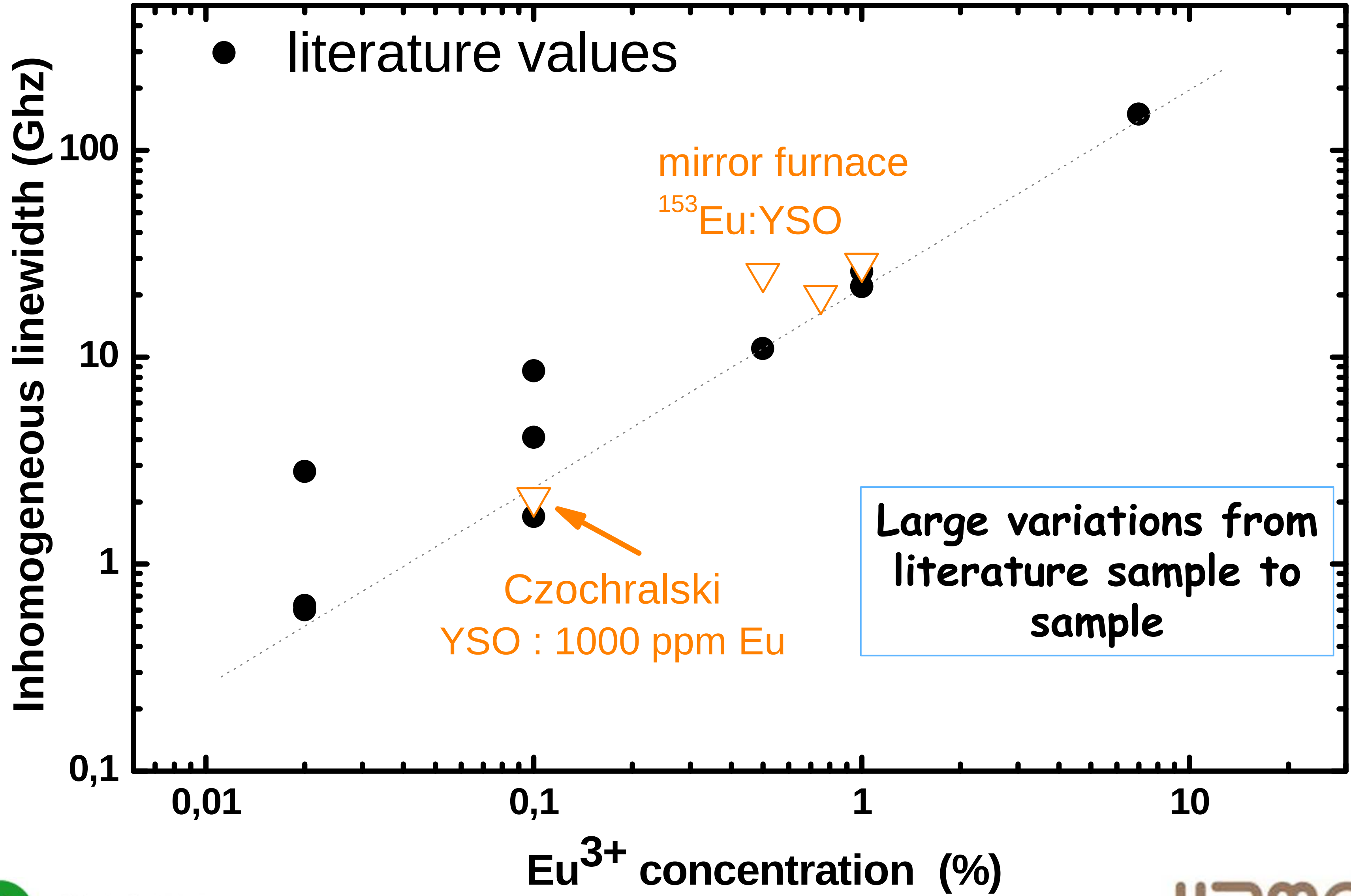
Mirror Furnace for ^{153}Eu:YSO

Cheaper – Faster ⇒ 3 mm diam. 5-10mm length



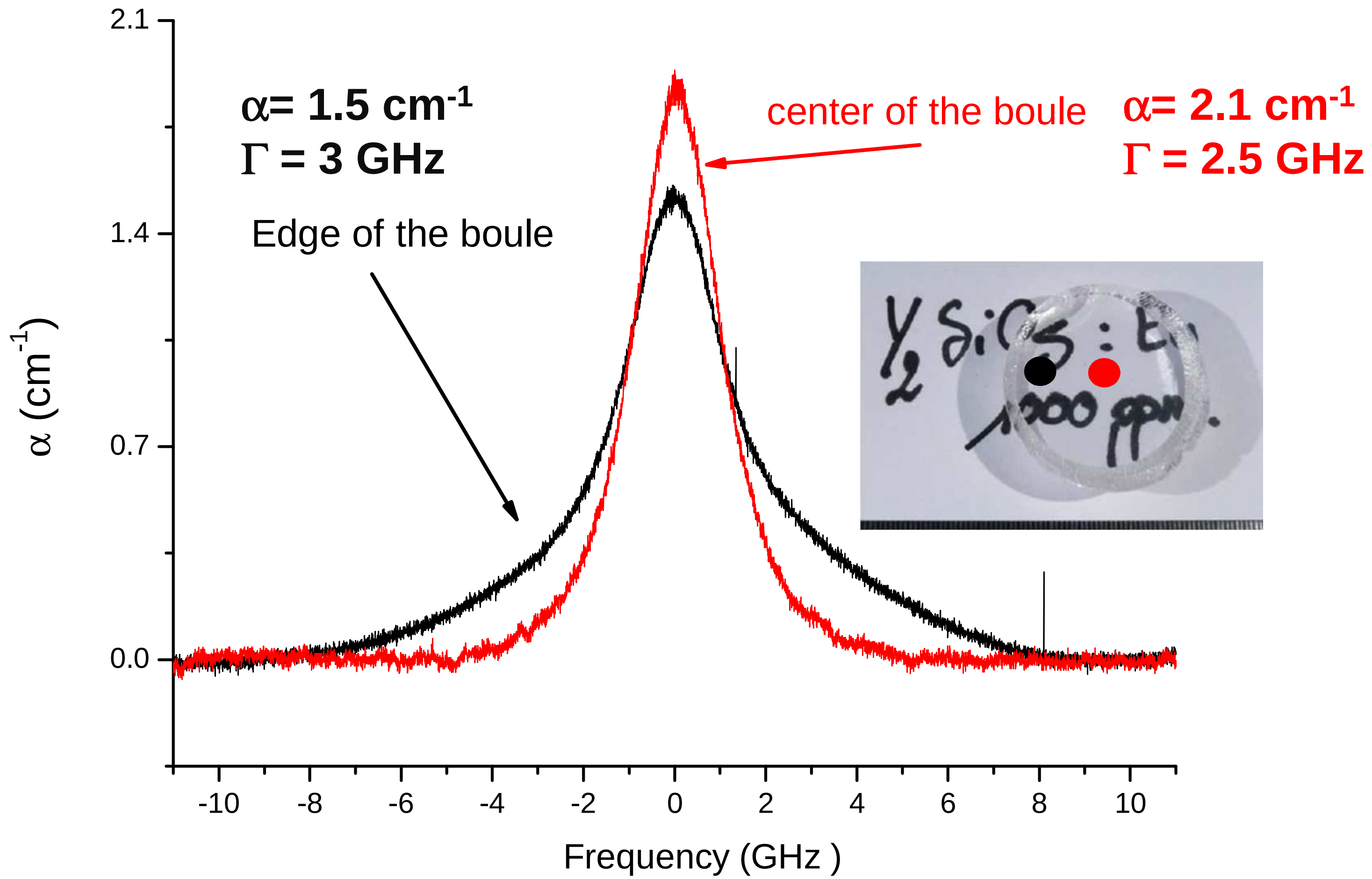


Inhomogeneous Linewidth I



Inhomogeneous Linewidth II

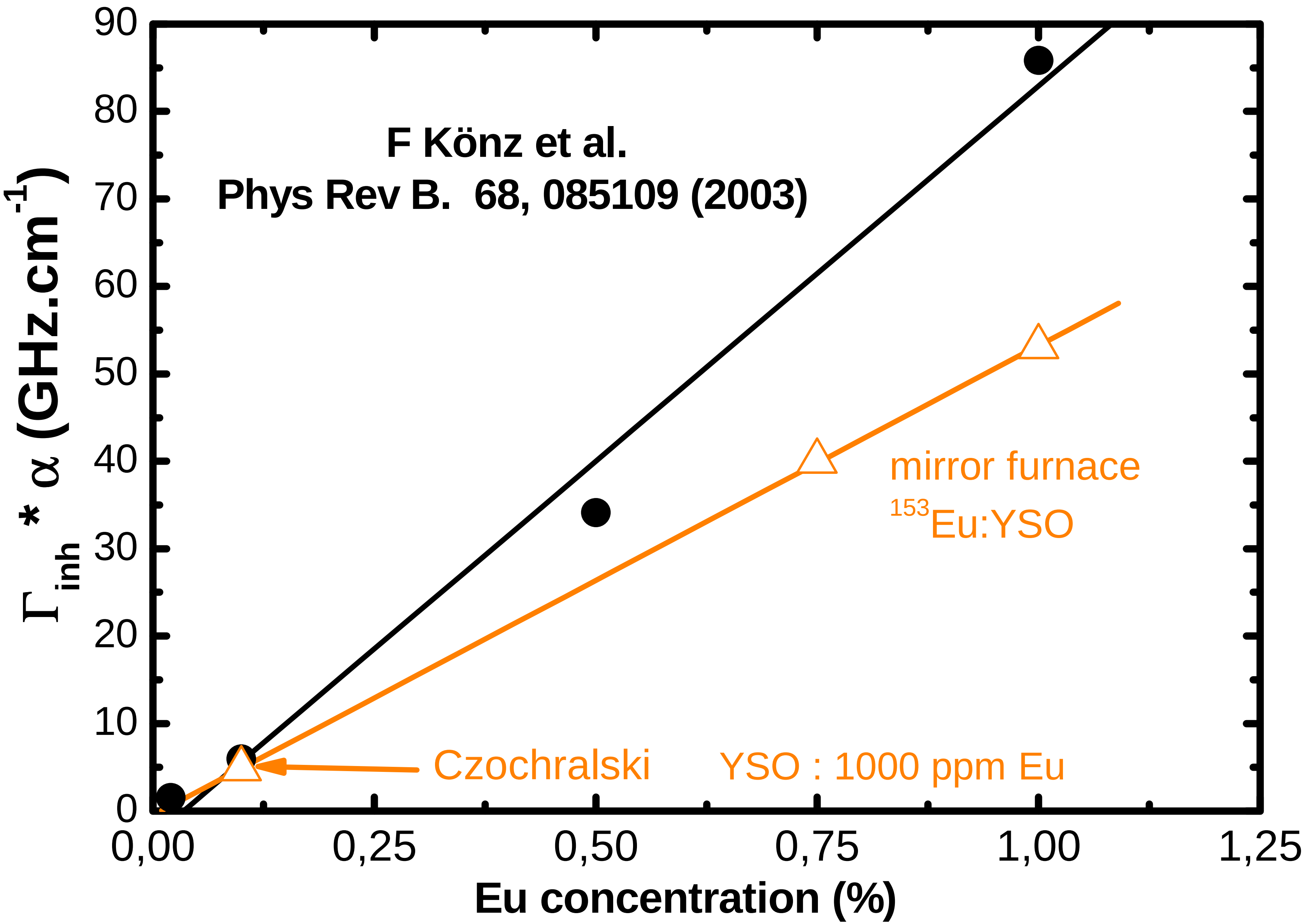
1000 ppm Eu:YSO (Czochralski)



literature
α= 3.5 cm-1
Γ = 1.7 cm-1

Significant variation along the same crystal boule

Inhomogeneous Linewidth III



Chimie ParisTech
École nationale supérieure de chimie de Paris

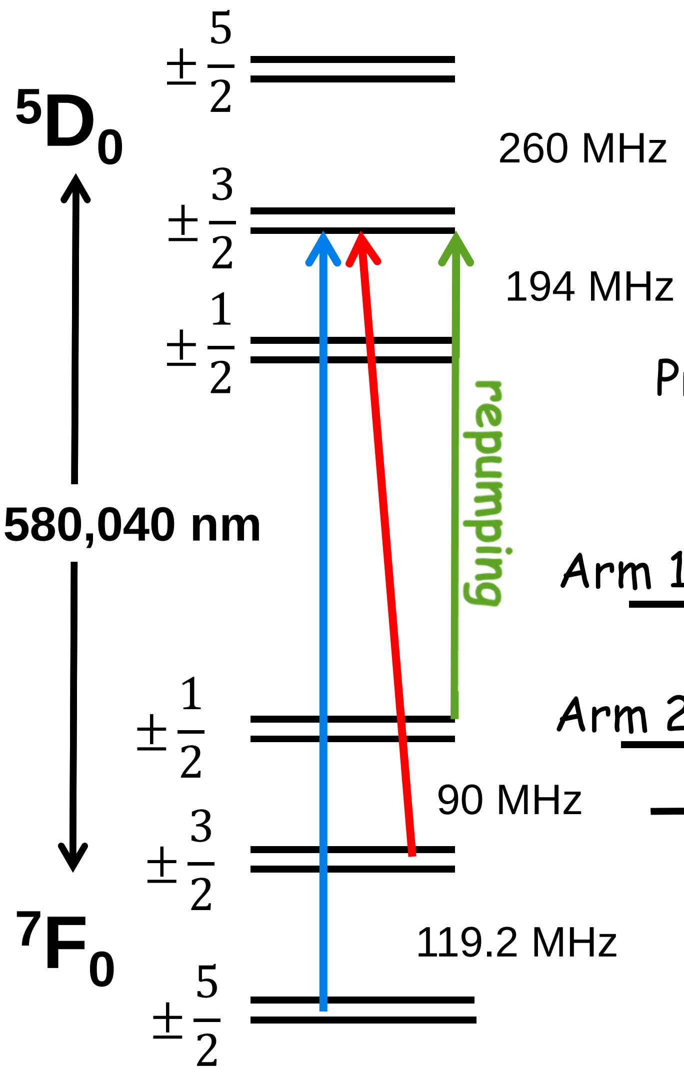
OUTLINE

- **Eu:Y_2SiO_5 single crystal**
  - Introduction
  - Optical inhomogeneous linewidth
  - ➡ Ground state hyperfine inhomogeneous and homogeneous linewidths

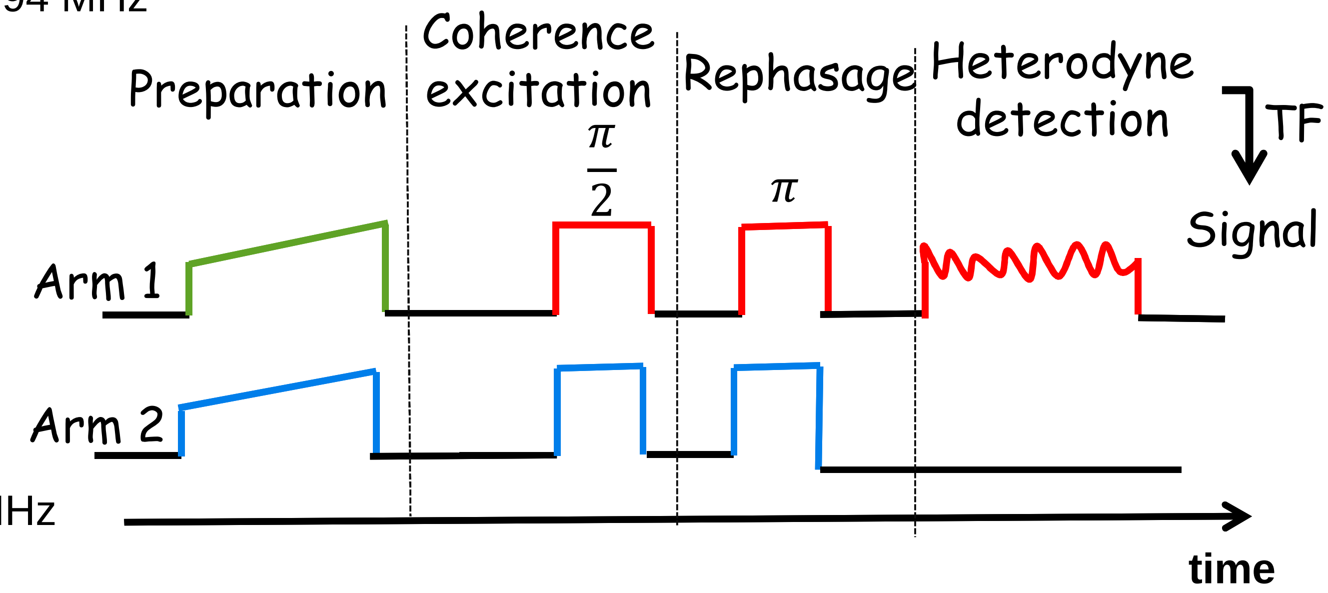
- **Eu:Y_2O_3 transparent ceramics**
  - Introduction
  - Optical inhomogeneous and homogeneous linewidths

^{153}Eu Raman echo measurments

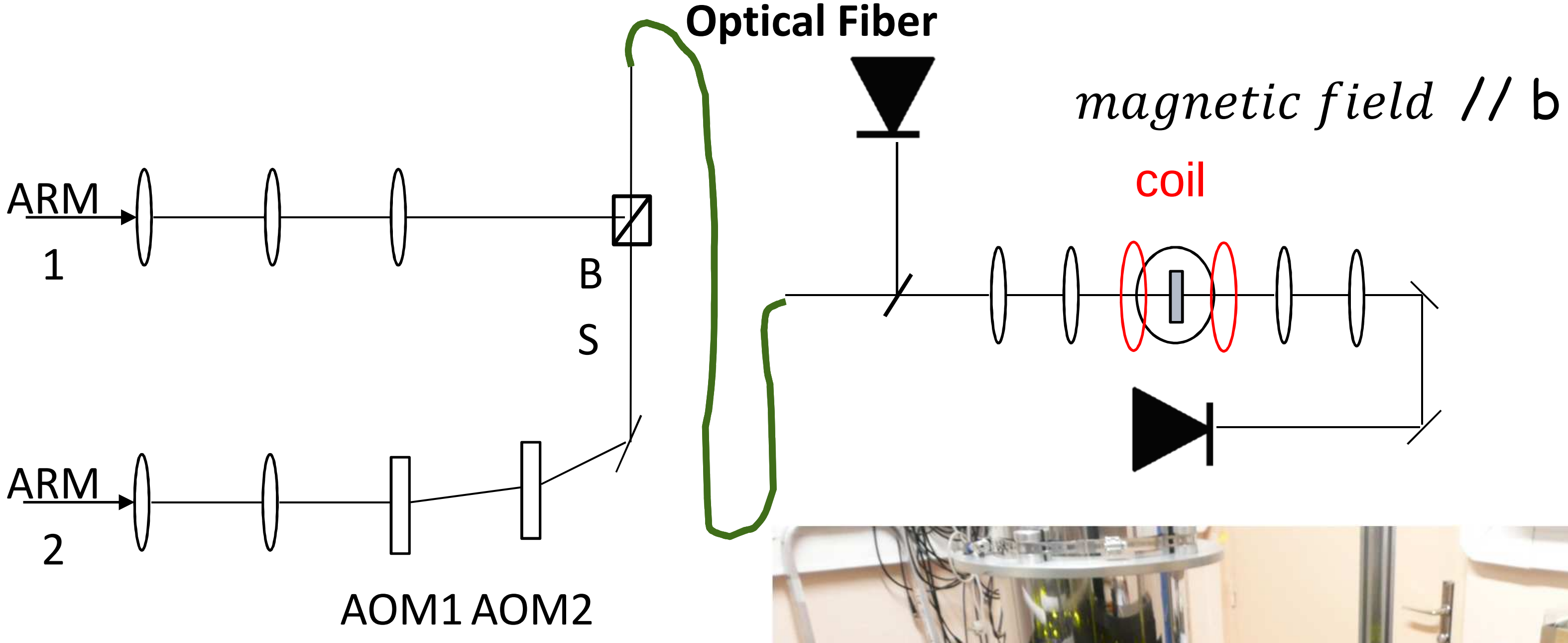
Collaboration : Stefan Kröll

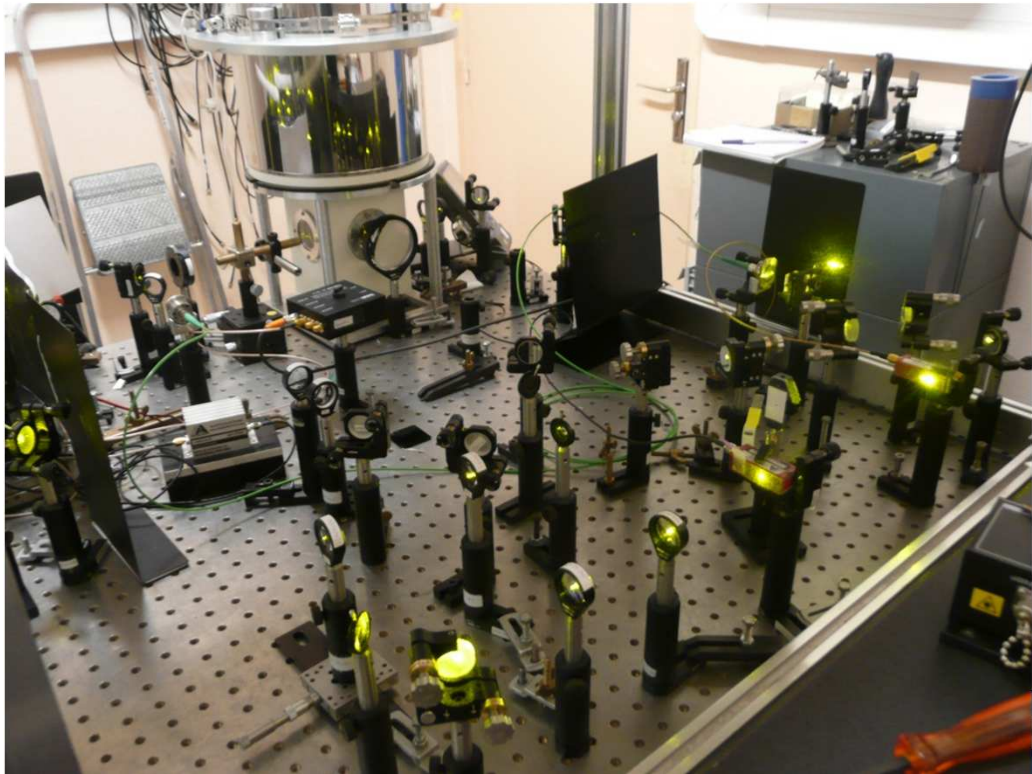


Pulse sequence for Raman Echo

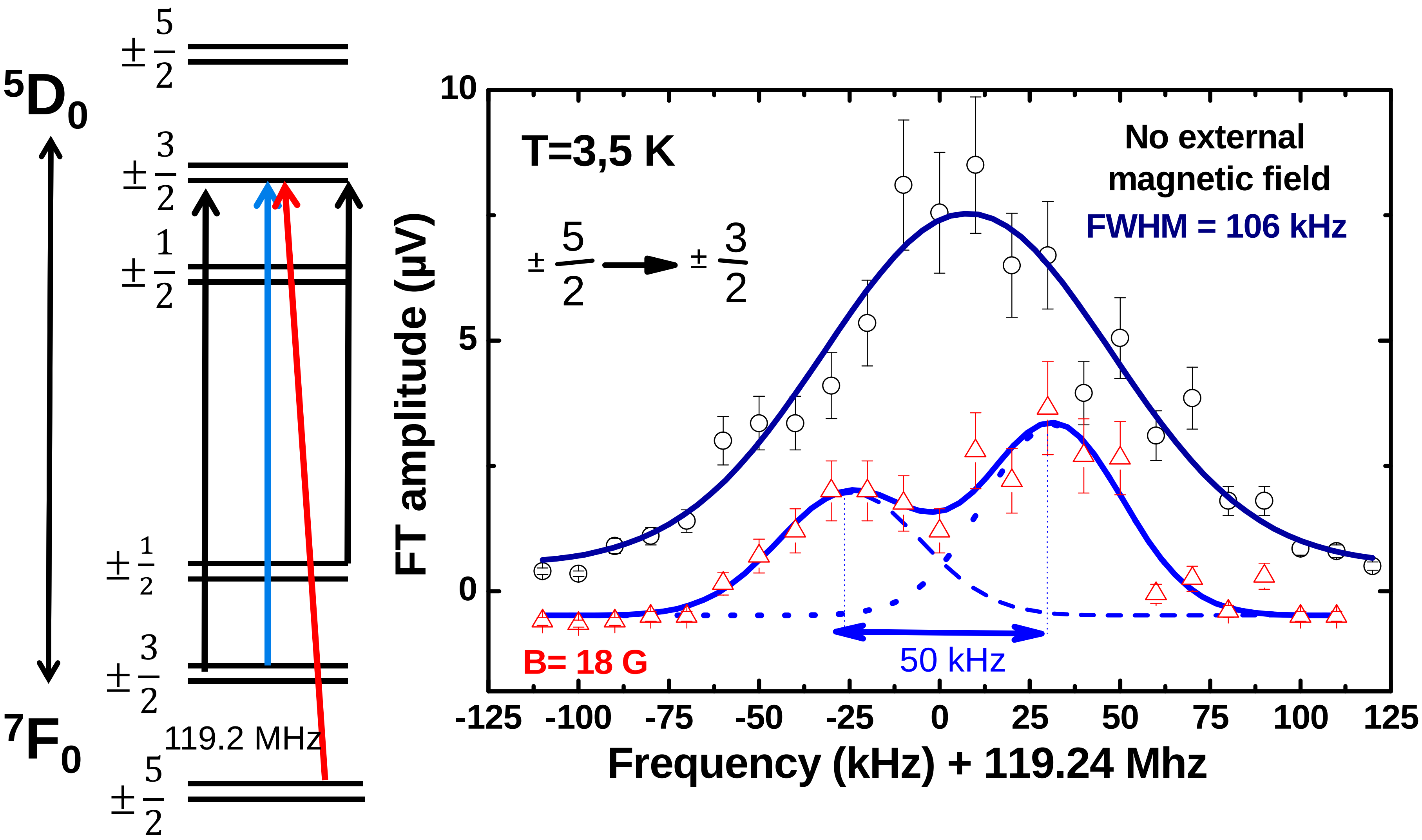


Experimental setup

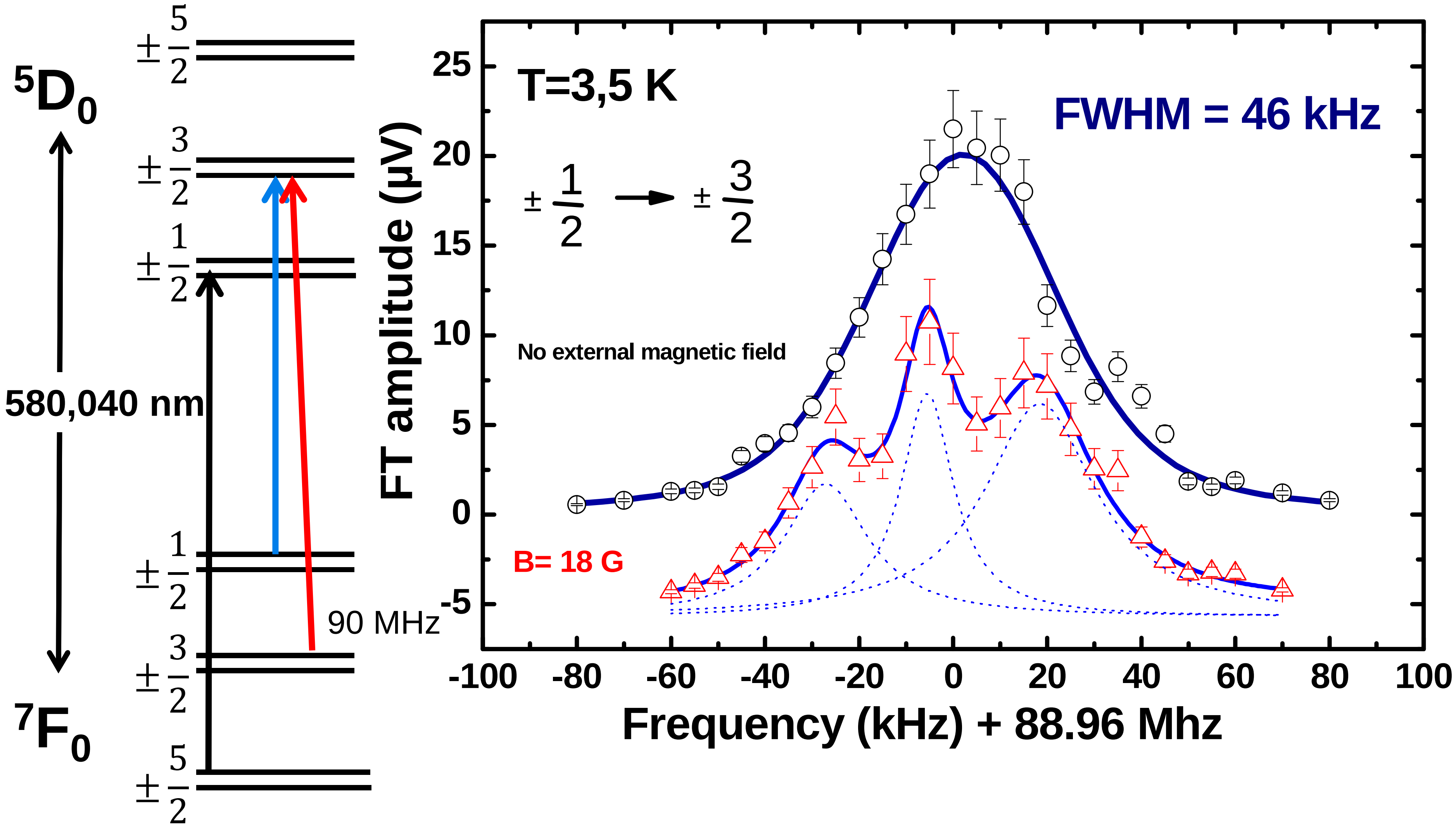




Inhomogeneous linewidth I

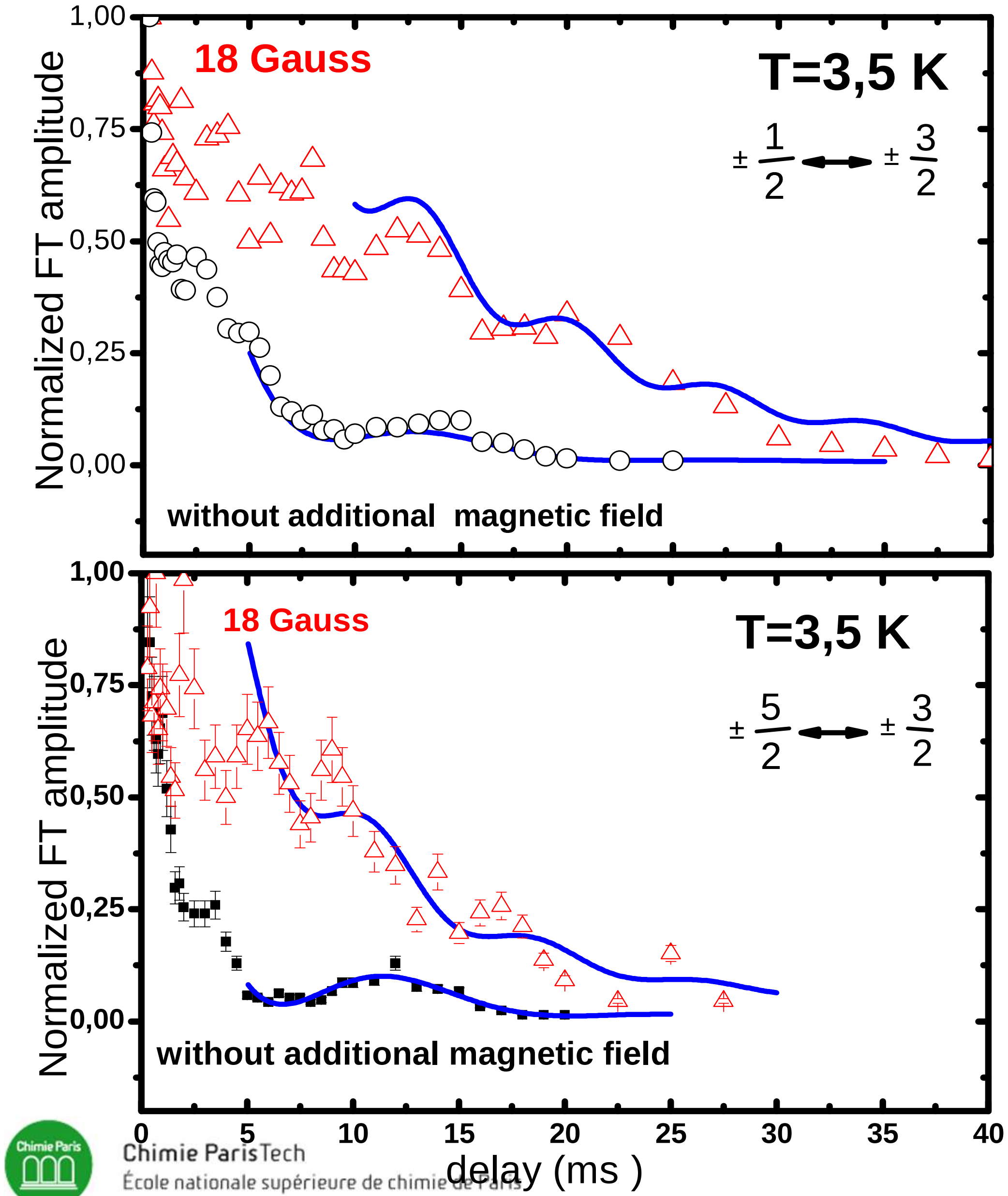


Inhomogeneous linewidth II



Chimie ParisTech
École nationale supérieure de chimie de Paris
UPMC SORBONNE UNIVERSITÉS
cnrs

Raman decay



T_2 (No ext B) = 9.9 ms

T_2 (18G) = 23,6 ms

T_2 (No ext B) = 10.4 ms

T_2 (18G) = 15,1 ms

^{151}Eu: YSO

Alexander et al. JOSA B Vol 24 n 9 p2479

$\pm\frac{1}{2} \longrightarrow \pm\frac{3}{2}$ Γ_{ihn} = 60 kHz

T_2 (no field) = 15.5 ± 2 ms

T_2 (100 G) = 36± 4 ms

OUTLINE

High resolution and coherent spectroscopy of Eu doped low nuclear spin materials

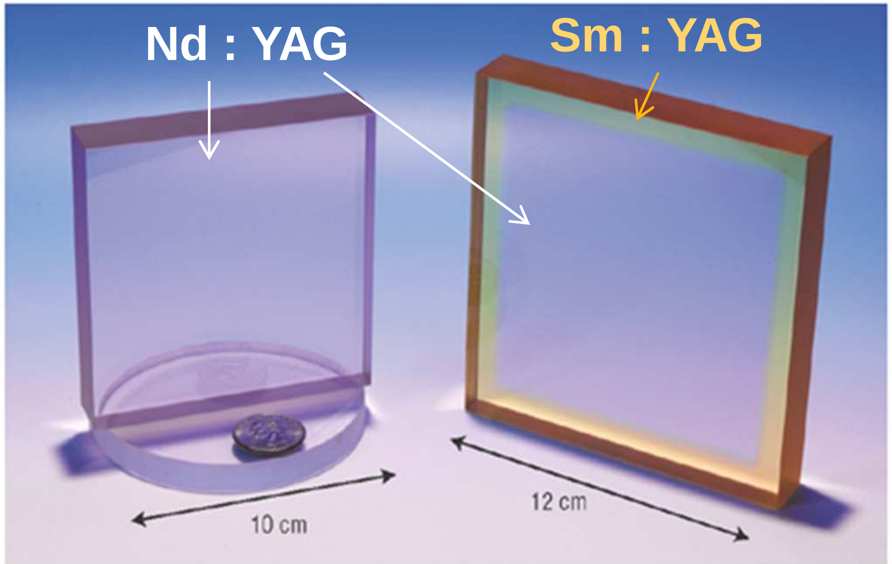
- Eu : Y_2SiO_5 single crystal
  - Introduction
  - Optical Ihnomogeneous linewith
  - Ground state hyperfine ihnomogeneous linewith
  - Hyperfine homogeneous lifetime

- **Eu : Y_2O_3 transparent ceramics**
  - Introduction about transparent ceramics
  - Optical Ihnomogeneous linewith
  - optical homogeneous lifetime

Low nuclear spin transparent Ceramics

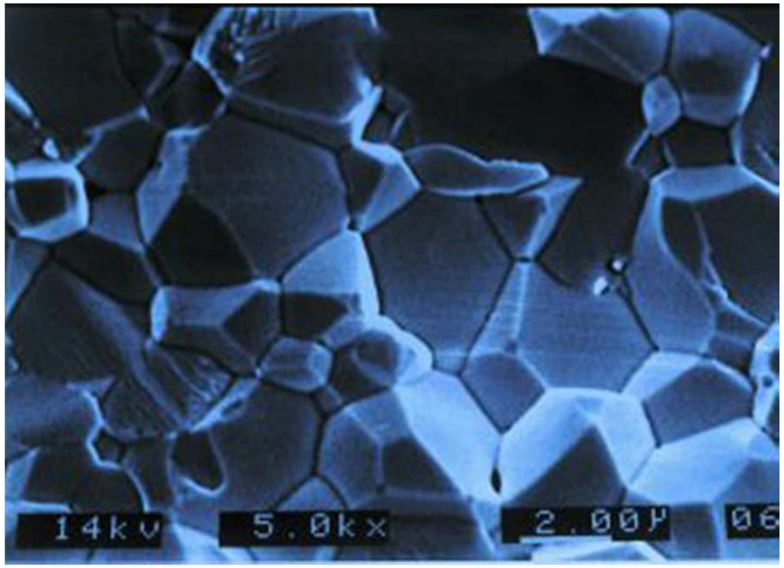
Konoshima Chemical Corp

Akio Ikesue & Yan Lin Aung Nature Photonics 2, 721 - 727 (2008)



Large scale

Composite materials



Density > 99,9%

Cubic materials → $Eu{:}Y_2O_3$ with and without additive

Are ceramics useful materials for some applications :

→Spectral hole burning filtering

Chimie ParisTech
École nationale supérieure de chimie de Paris

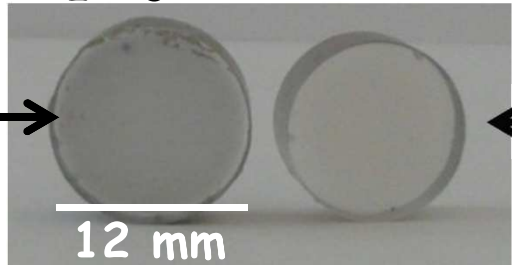
UPMC SORBONNE UNIVERSITÉS

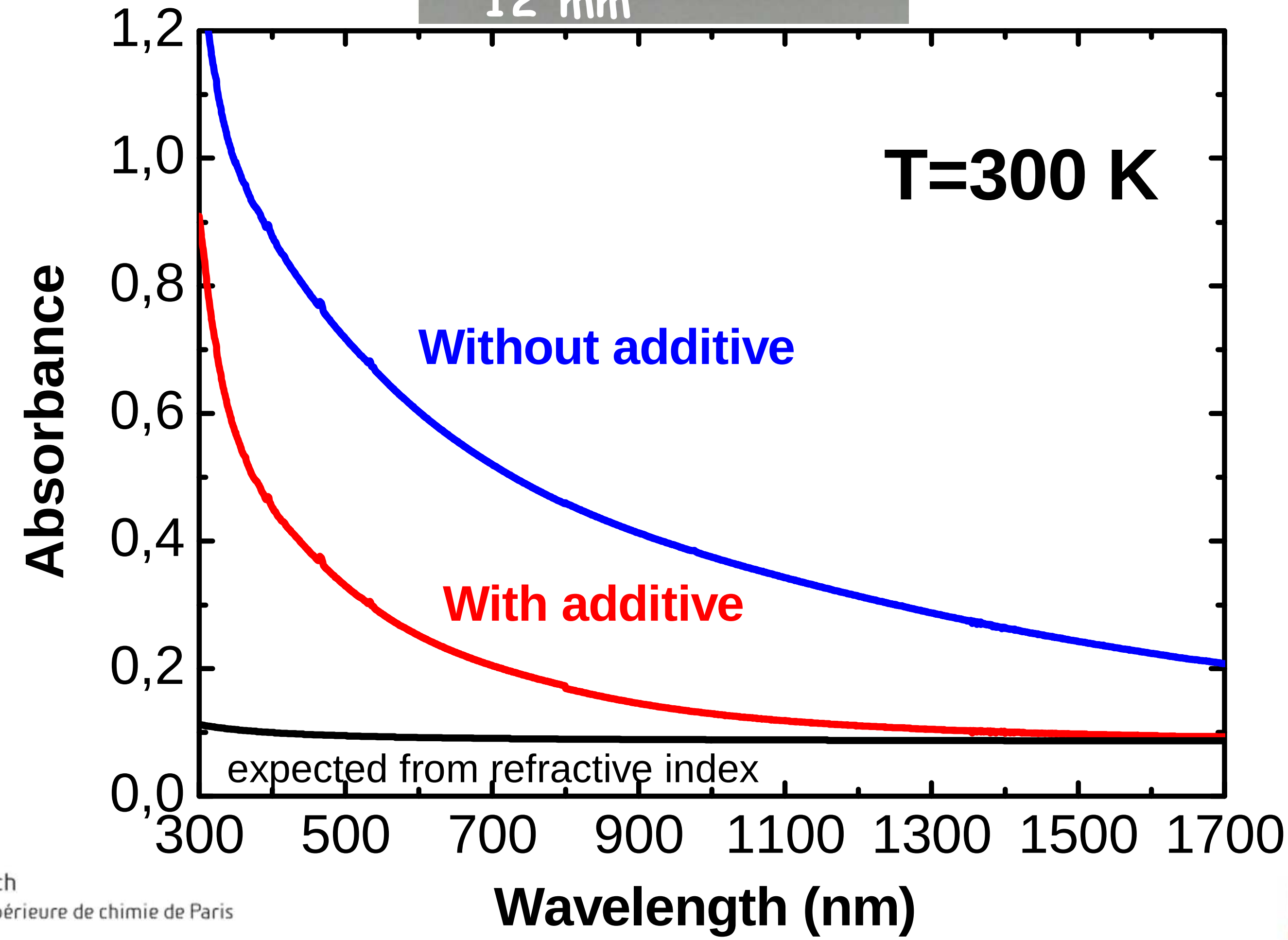
cnrs

Low nuclear spin transparent ceramics

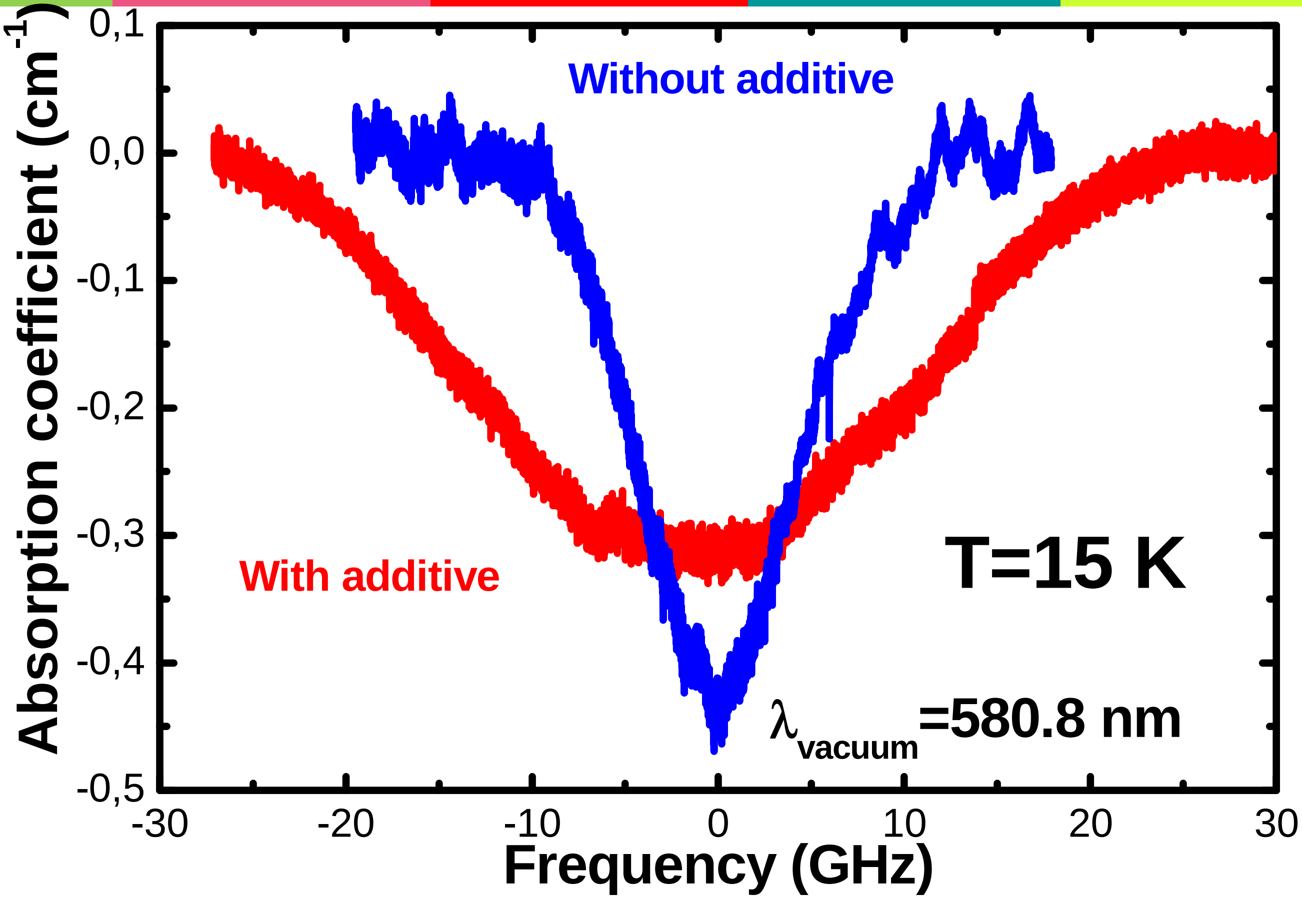
Y_2O_3:0.1% Eu   From Japan A. Ikesue

Without additive → ← With additive





High resolution Low temperature transmission measurments



Same central frequency as in single crystals

Without additive Γ_{inh}=8.6 GHz

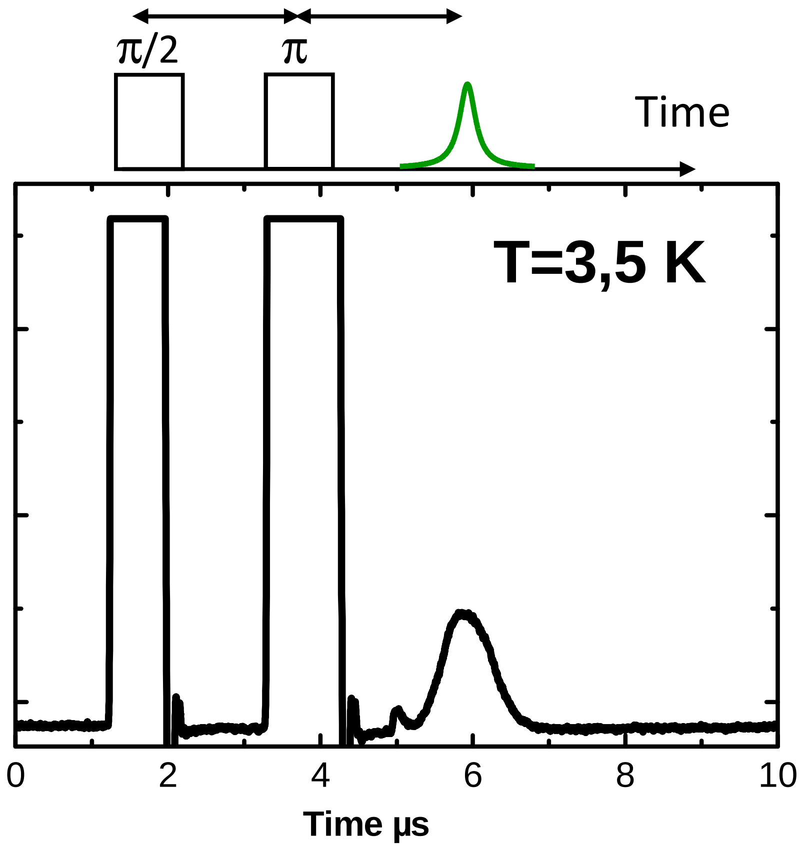
With additive Γ_{inh}= 22.7 GHz

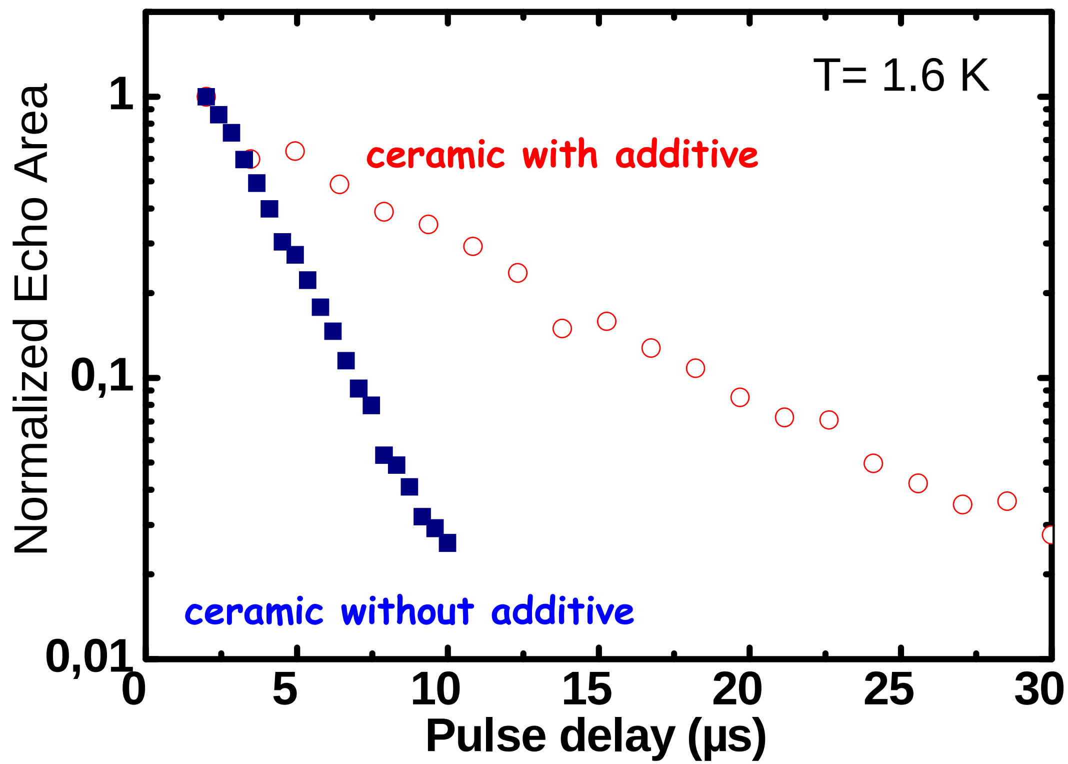
Bulk crystal 0.1% : Eu Y_2O_3

Γ_{inh}=7 - 90 GHz

G.P. Flinn Phys rev B Vol 49 p5821 1994

Homogeneous linewidth





Ceramics: Eu : Y_2O_3

Without additive T_2 = 6 μs

With additive T_2 = 30 μs

↔

Bulk crystal : Eu Y_2O_3

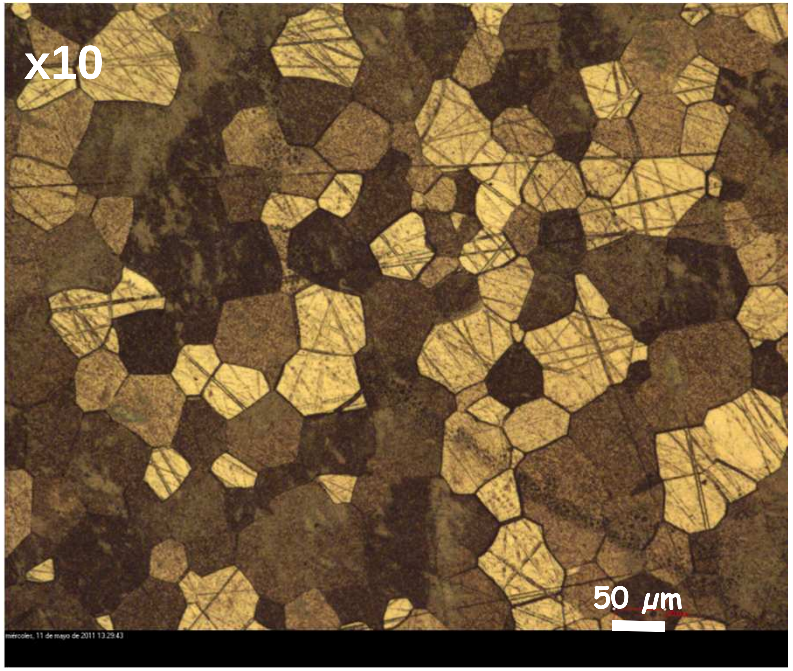
T_2 = 130 μs ↔ Flame fusion

G.P. Flinn Phys rev B Vol 49 p5821 1994

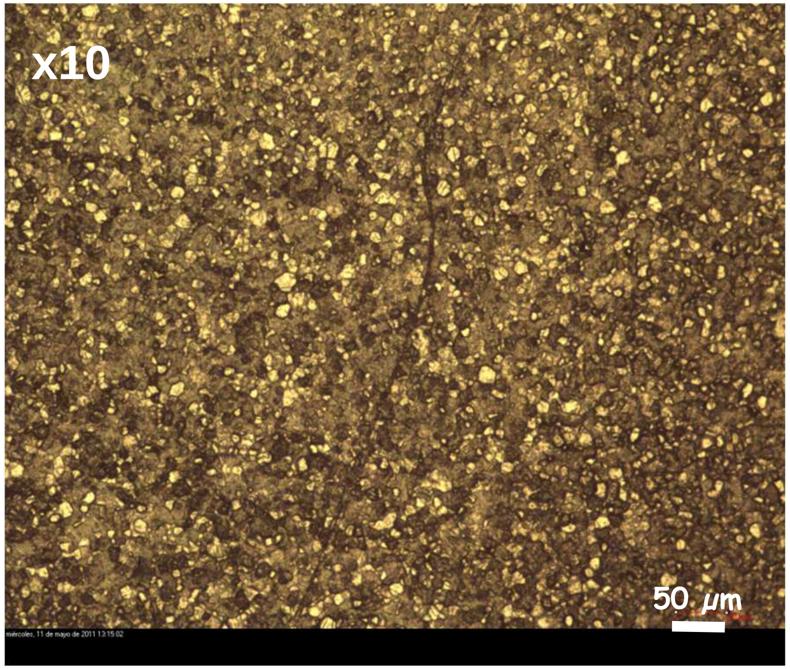
microstructure

**Luisa Bausa and Mariola Ramirez
from Universidad autonoma de Madrid**

Ceramic without additive



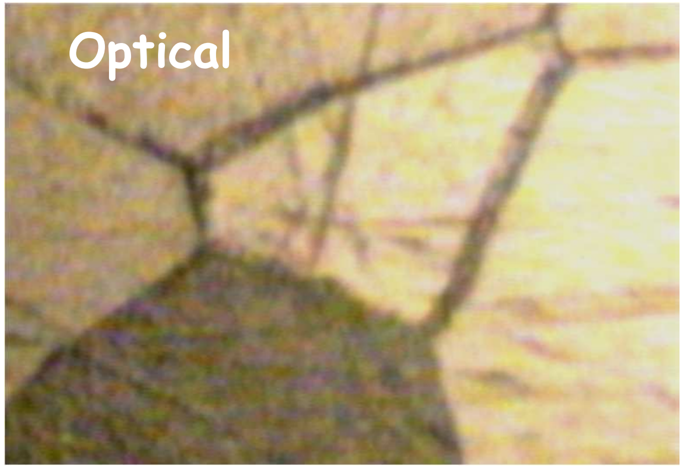
Ceramic with additive

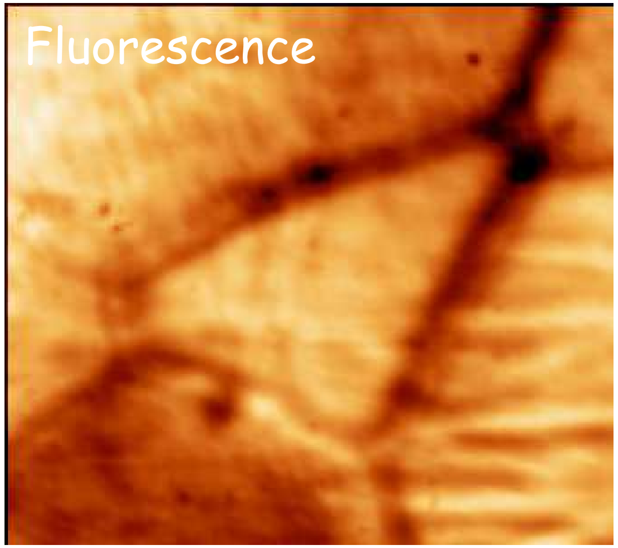


Very different grain size

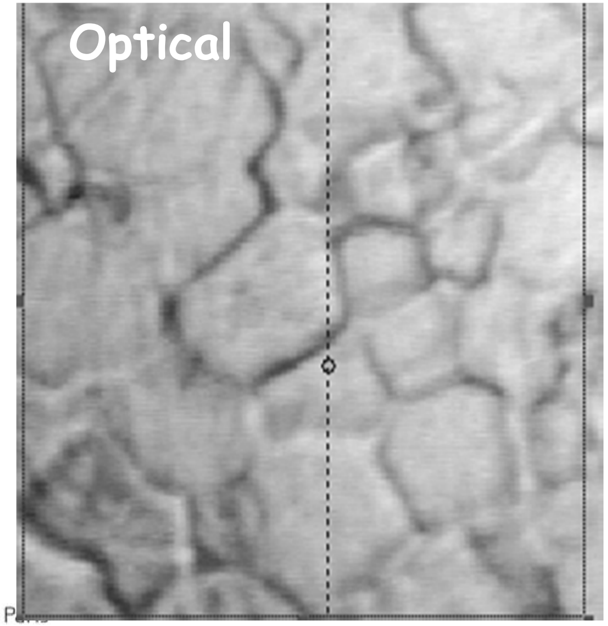
Segregation ?

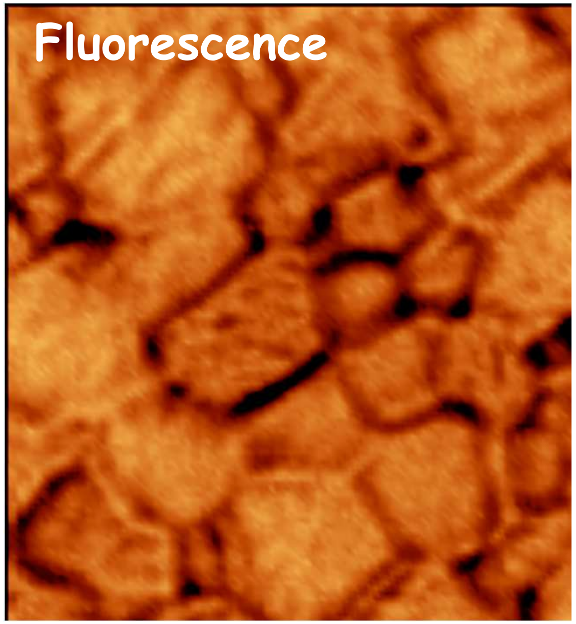
Without ADDITIVE





With ADDITIVE





Conclusion

Eu:Y_2SiO_5

- Improved crystal growth process
- Γ_{ihn} of the 2 hyp transition are differents

$\pm\frac{1}{2} \leftrightarrow \pm\frac{3}{2} \Rightarrow 46kHz$ whereas $\pm\frac{3}{2} \leftrightarrow \pm\frac{5}{2} \Rightarrow 106kHz$

- T_2 hyp is long similar to the value observed for ^{151}Eu
- Small magnetic field increases the T_2 hyp

Eu:Y_2O_3

- Γ_{ihn} additive > Γ_{ihn} without additive
- T_2 additive < T_2 without additive
- Very different microstructure
- No segregation