

DE LA RECHERCHE À L'INDUSTRIE



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# AMPLIFICATION OF THE LUMINESCENCE RESPONSE IN ORGANIC MATERIALS EXPOSED TO IONIZING RADIATIONS

***A NEW METHOD FOR  
IONIZING RADIATION  
DETECTION***

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*2012 IEEE Nuclear Science Symposium and Medical Imaging*



**digiteo**

**list**

**INTRODUCTION**

**EXPERIMENTAL SETUP**

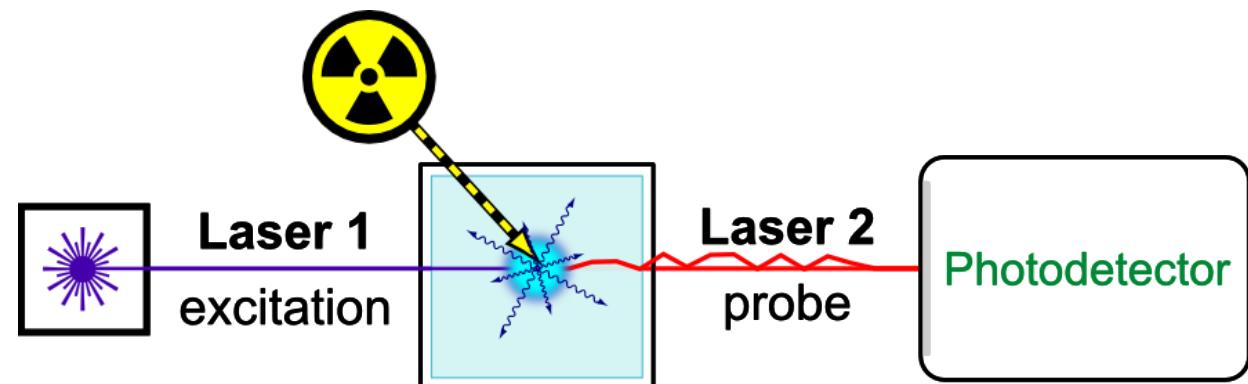
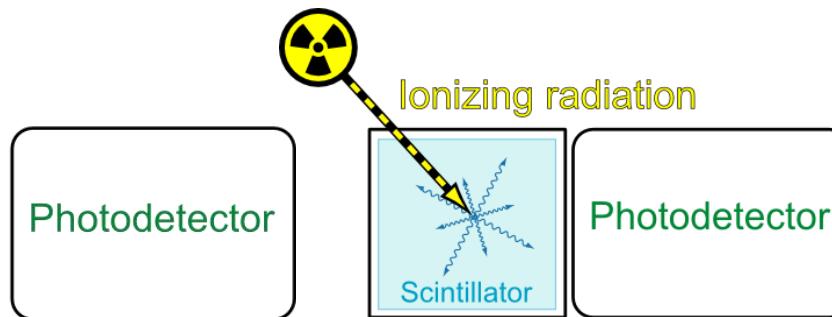
**RESULTS**

**CONCLUSION**

# WHY ARE WE WORKING ON THIS?

## Organic Scintillators today

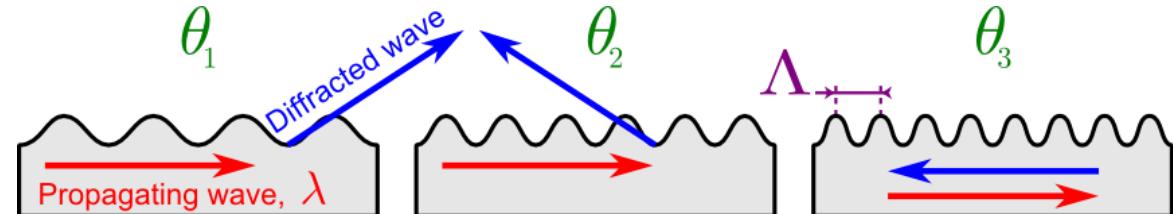
Liquids  
Plastics & Monocrystals



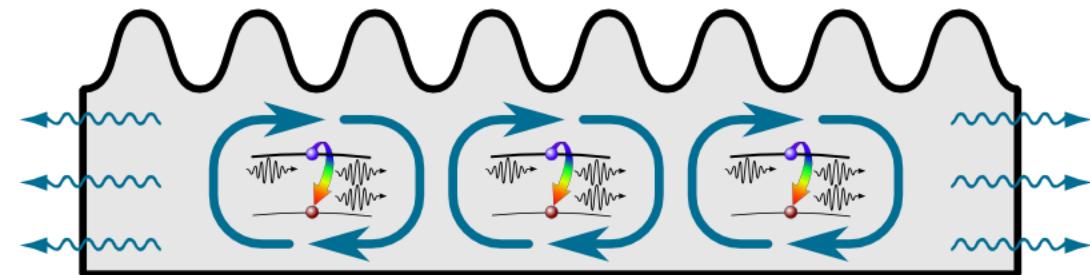
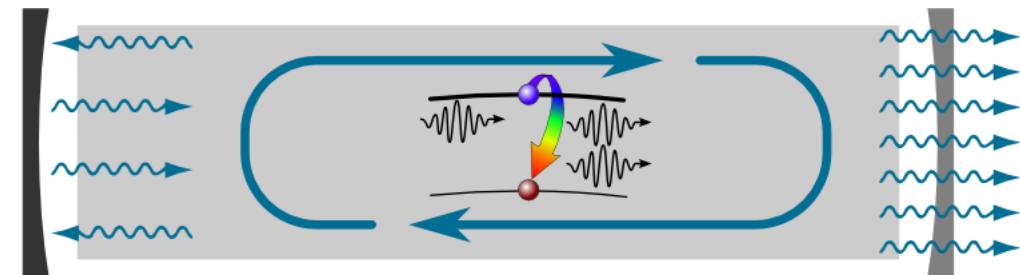
# WHERE ARE WE STARTING FROM?

## Distributed Optical Feedback

+ Gain



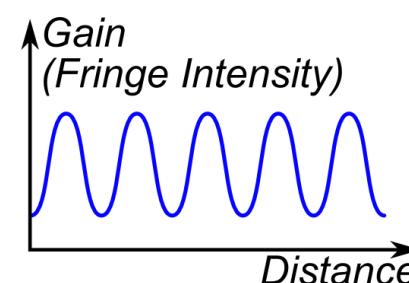
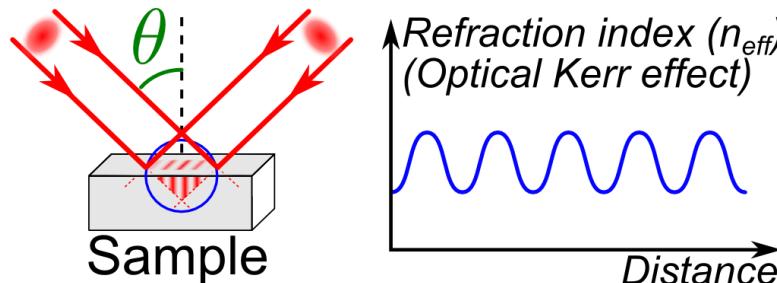
= Distributed Feedback Lasing



**Kogelnik, H. & Shank, C. V. (1971)**  
 'Stimulated emission in a periodic structure', *Applied Physics Letters*

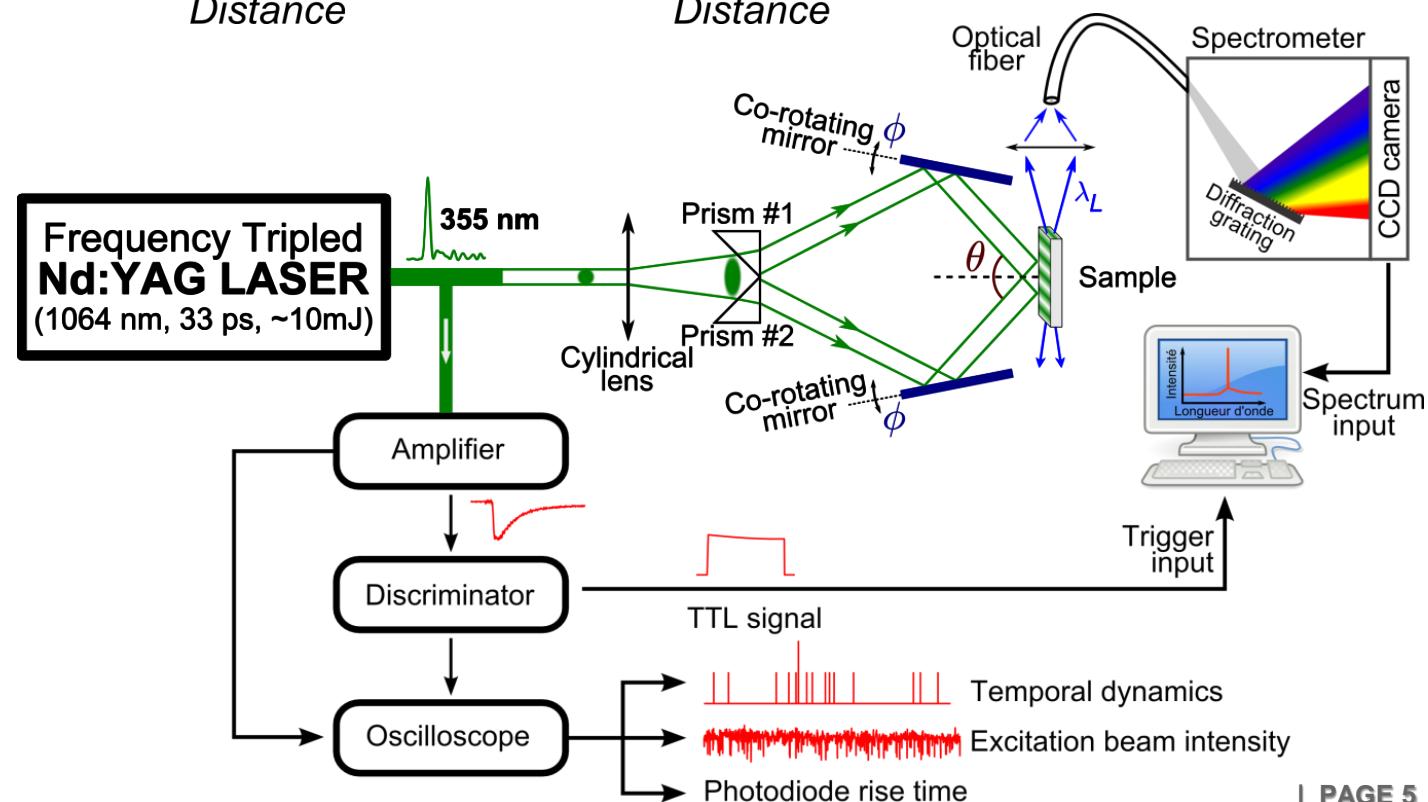
# EXPERIMENTAL SETUP

## Transient grating formation

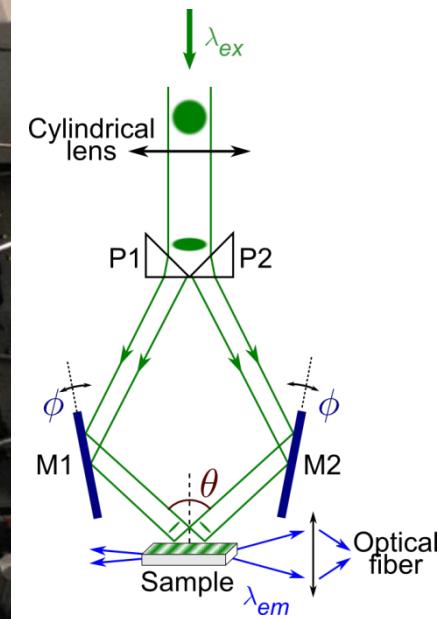
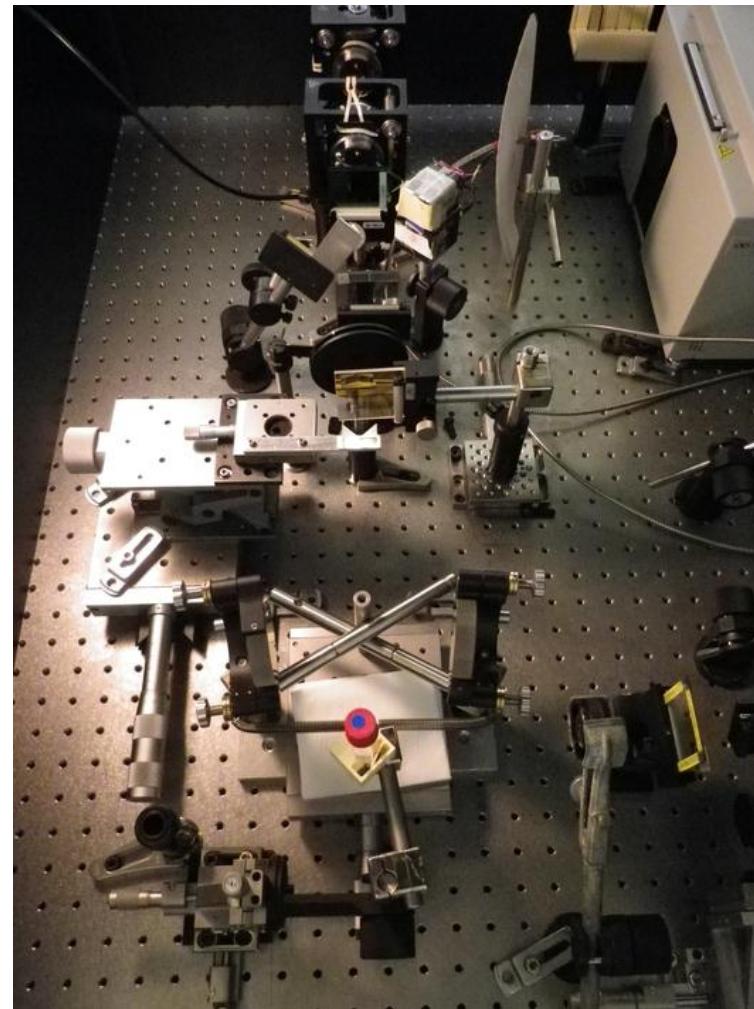
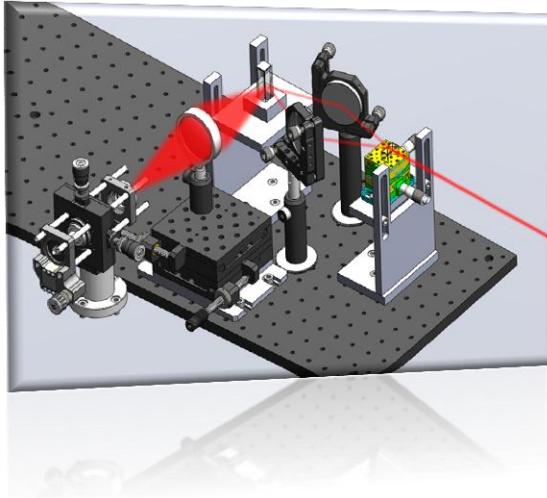


$$\lambda_{\text{em}}(\Lambda) \quad \Lambda(\theta) \quad \theta(\Phi)$$

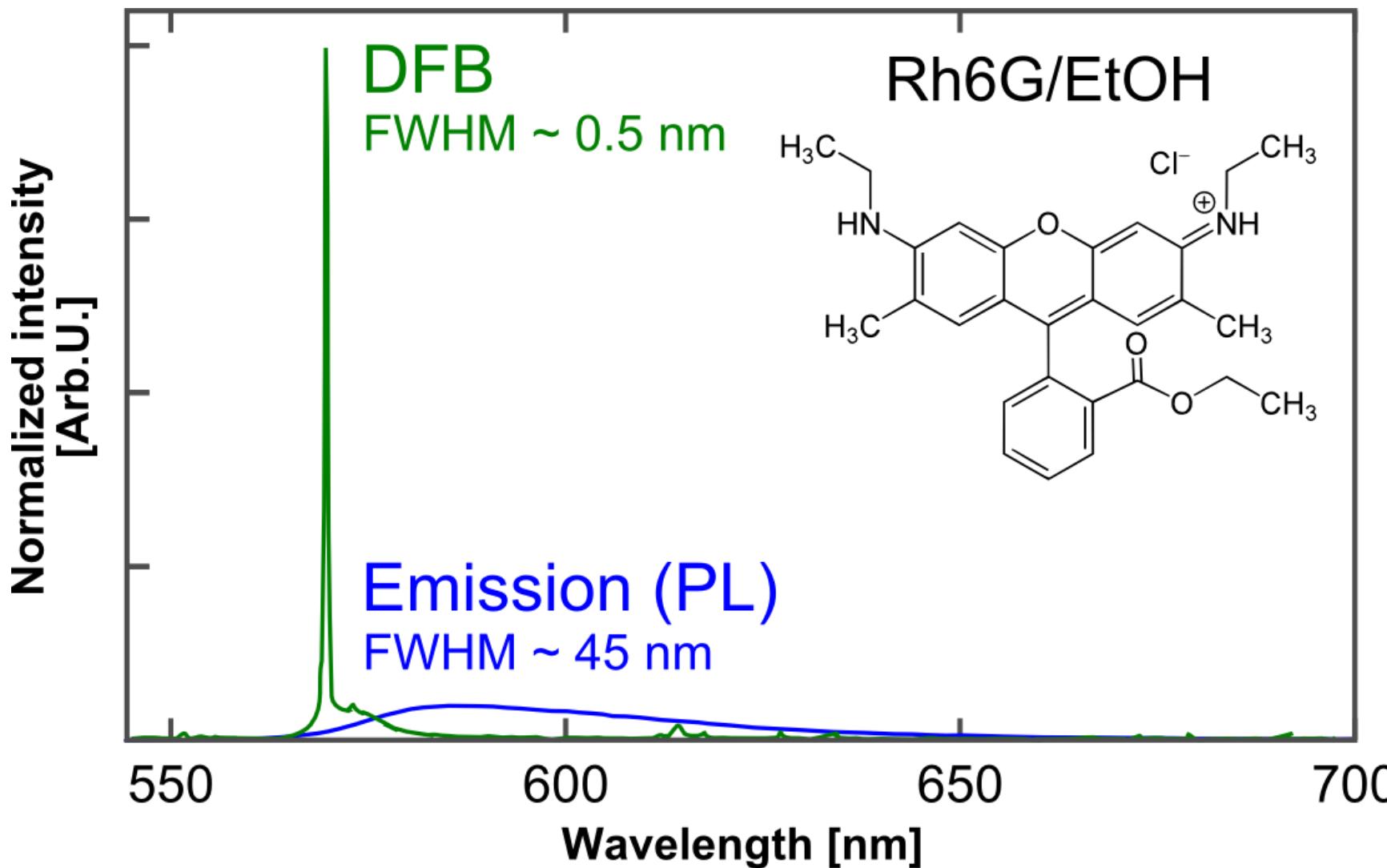
$$\Lambda = \frac{\lambda_{\text{exc}}}{2n \sin \theta}$$



# EXPERIMENTAL SETUP



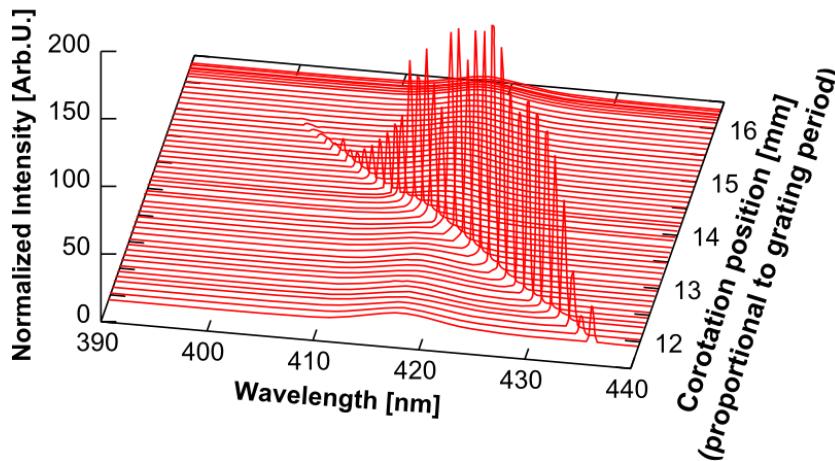
# DFB EMISSION OF A COMMON LASER DYE



# DFB TUNING OF COMMERCIAL SCINTILLATORS

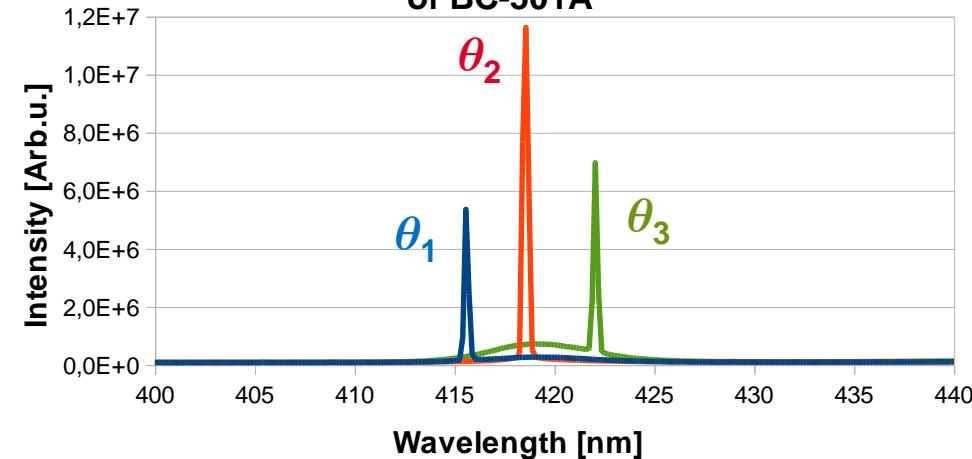
## Ultima Gold™ AB (Perkin-Elmer)

DFB signal evolution with incident angle of Ultima Gold AB



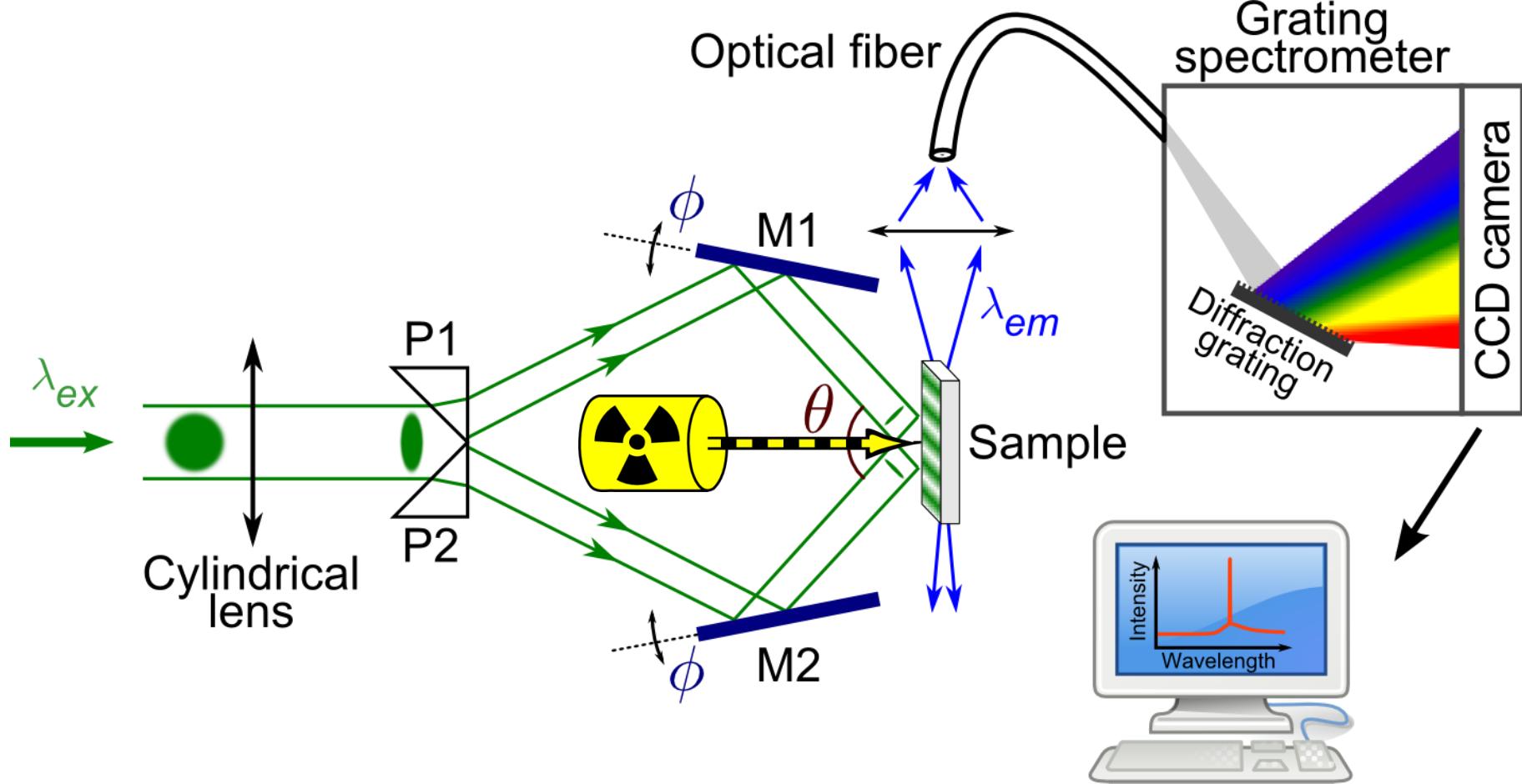
## BC-501A (Saint-Gobain)

DFB signal evolution with incident angle of BC-501A



## OPTICAL AMPLIFICATION

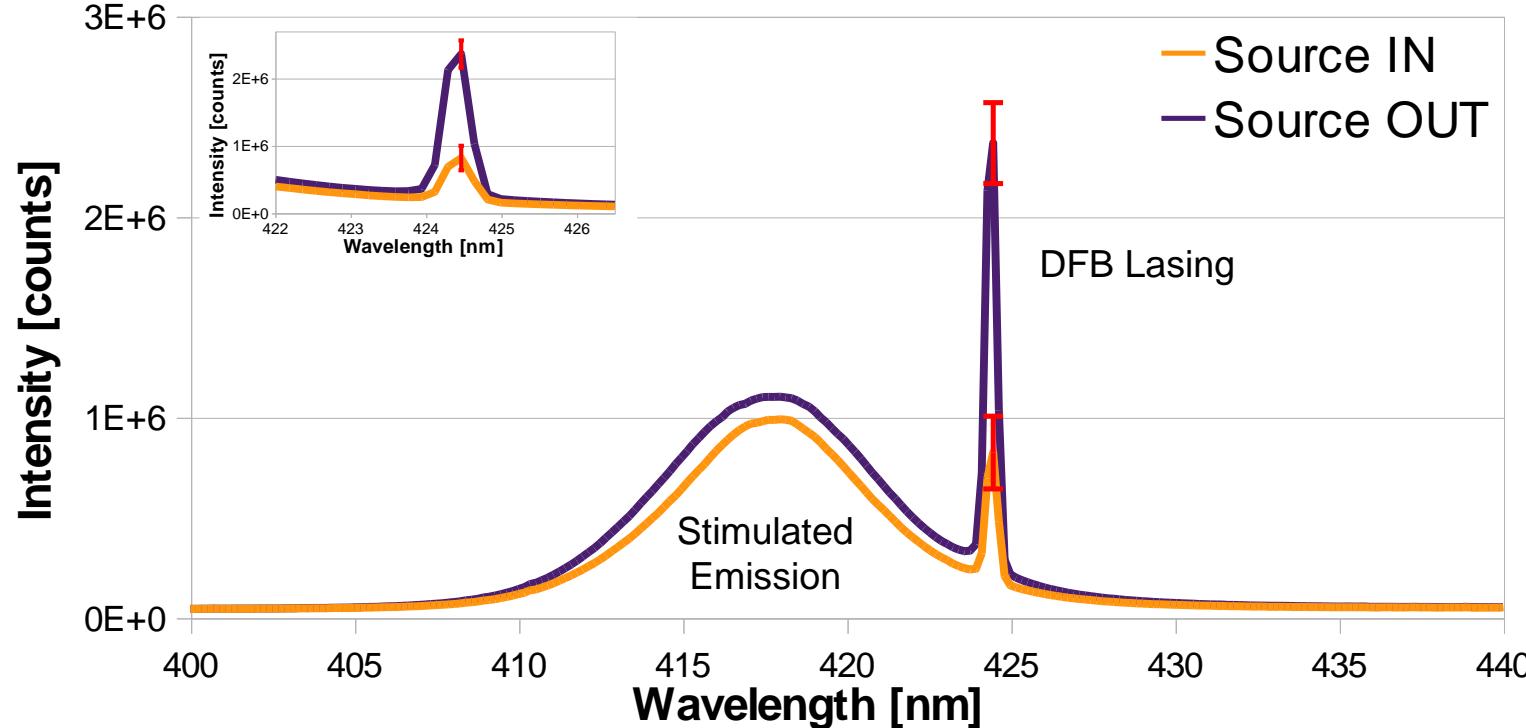
# $\beta$ EMITTER ( $^{90}\text{Sr}/^{90}\text{Y}$ )



# PRELIMINARY RESULTS: $\beta$ emitter ( $^{90}\text{Sr}/^{90}\text{Y}$ )

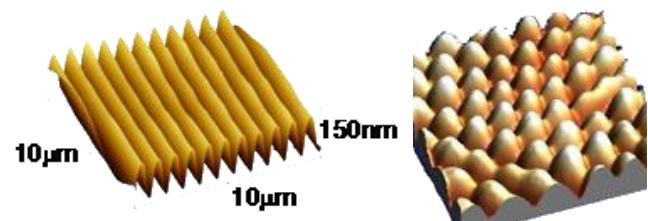
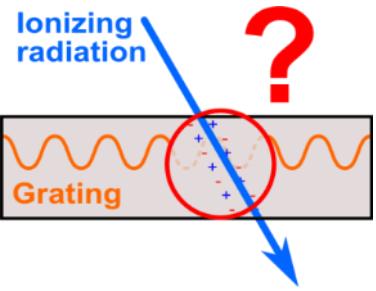
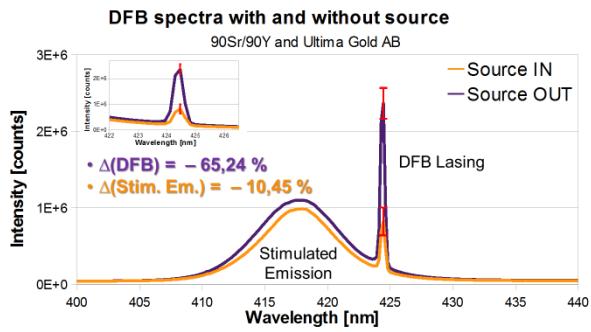
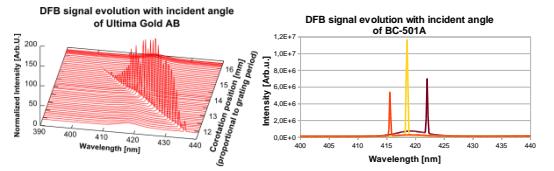
## DFB spectra with and without source

90Sr/90Y and Ultima Gold AB



$$\Delta I(\text{DFB}) = -65 \%$$

$$\Delta I(\text{Stim. Em.}) = -10 \%$$



- Commercial scintillators
- First effect of ionizing radiations on transient DFB Laser emission

- Understanding
- Optimizing

- Solid gratings
- GEANT4

**THANK YOU FOR YOUR ATTENTION**

# WHAT ABOUT THE OTHERS?

Zhou *et al.*

Gamma-ray irradiation effects on distributed-feedback laser diodes

*Journal of Russian Laser Research, Springer New York, 2009, 30, 164-171*

DFB Laser diodes irradiated by  $^{60}\text{Co}$ :  $10^2$  Gy and  $8 \cdot 10^3$  Gy (0.5 Gy/s)

(LD 50/30 = 400–450 rem (4 – 5 Sv) flash. If dose >30 Gy, patient dead within 2 days.)

G. N. Patel

Monitoring devices and processes based on transformation, destruction and conversion of nanostructures

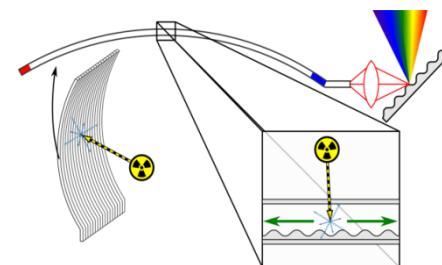
US Patent 2011/0003279 A1, 2010

Nanostructure damaging by chemical pollutants → signal lowering

S. Popescu

Waveguide-based detector module for X-radiation or gamma radiation.

US Patent 7,493,001 B2, 2009

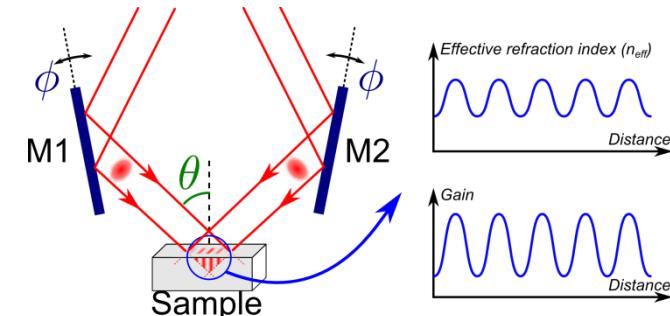


# GRATING STRUCTURATION

## Optical periodic structuration of samples

Refractive index and gain grating,  
with tunable period ( $\Lambda$ )

$$\Lambda = \frac{\lambda_P}{2n \sin \theta}$$

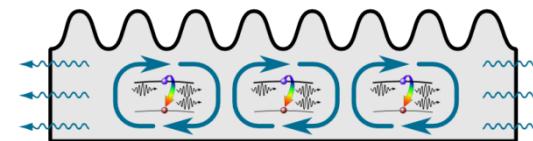
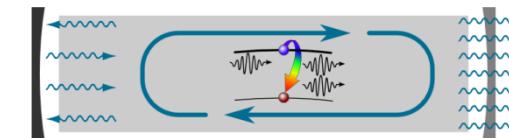


## Coupled wave theory

Wavelength-selective diffraction by grating

grating  $\Leftrightarrow$  optical cavity

$$\lambda_L = \frac{2n\Lambda}{p} = \frac{\lambda_P}{p \sin \theta}$$



## Emission mode selection

By changing interfering angle  $\theta$  of Laser beams, grating period is changed.

# OPTICAL KERR EFFECT

**Dielectric susceptibility** change with electric field,  $E$ , intensity

↔ variation of refraction index  $n$

↔ variation of effective refraction index  $n_{eff}$

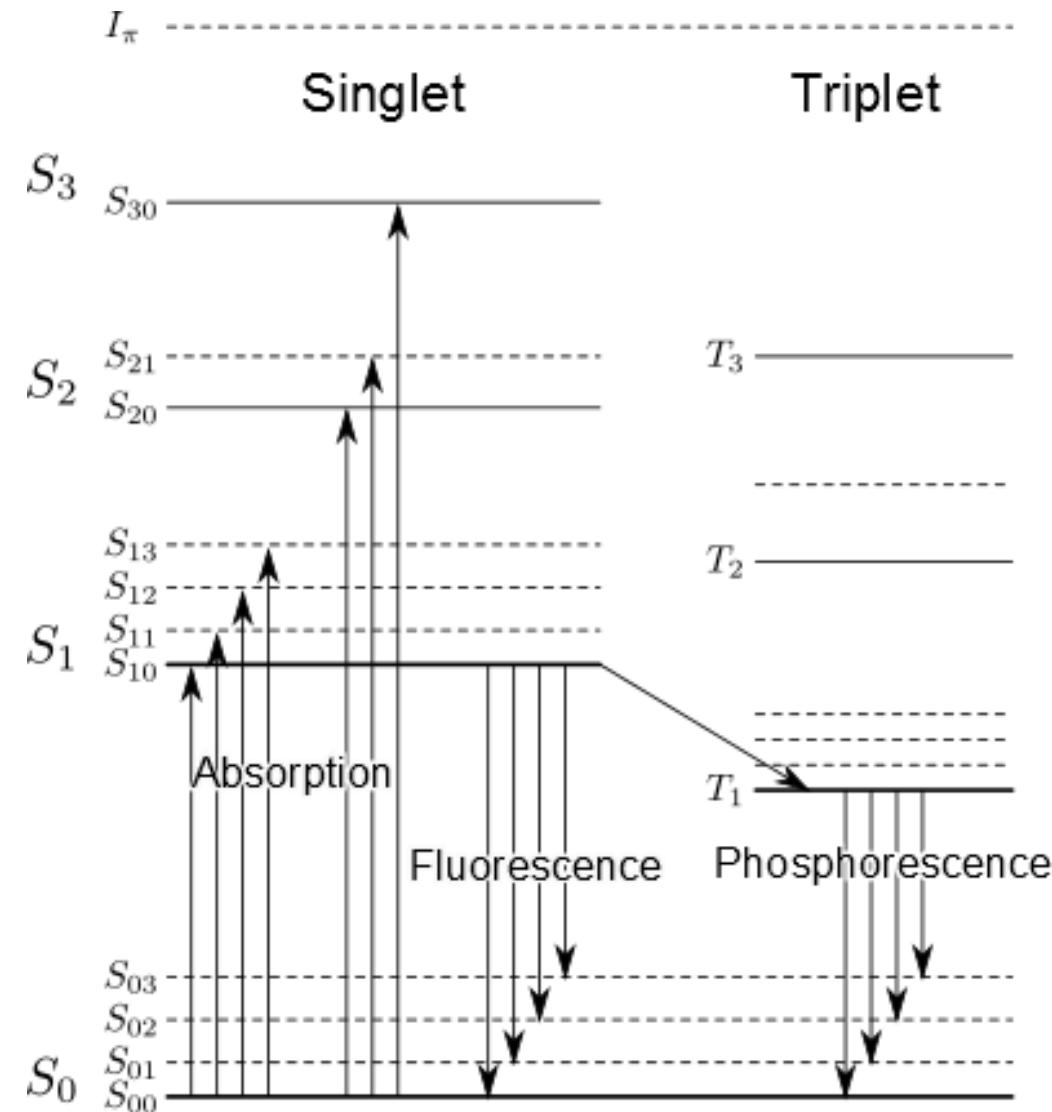
➔ birefringence

Refraction index varies as  $KE^2$ , with K the Kerr constant.

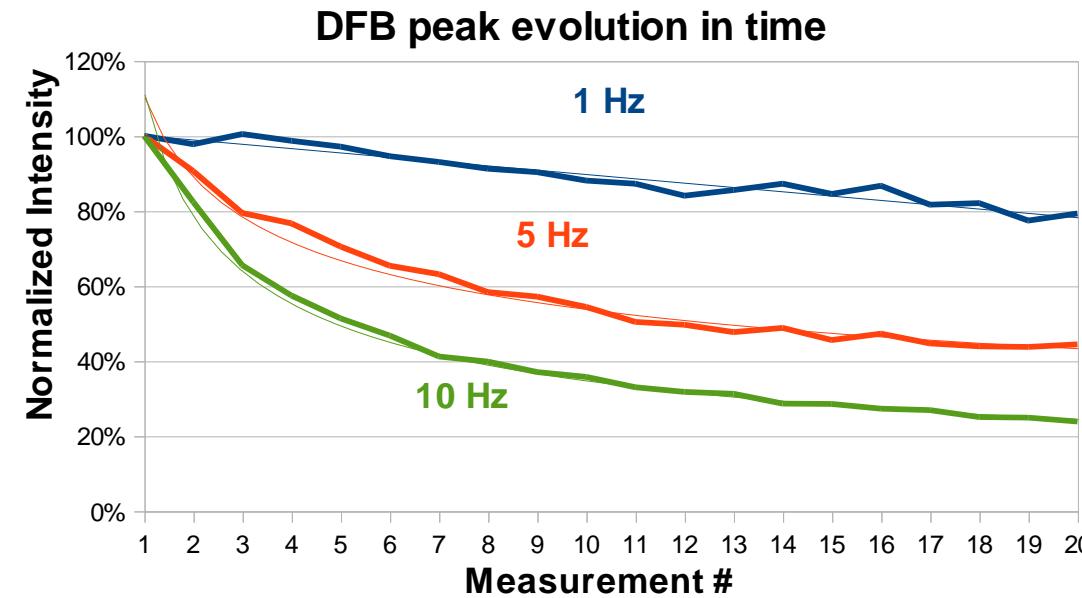
**Optical Kerr effect** because electric field variation is induced by light itself.

Kerr, J. (1875),

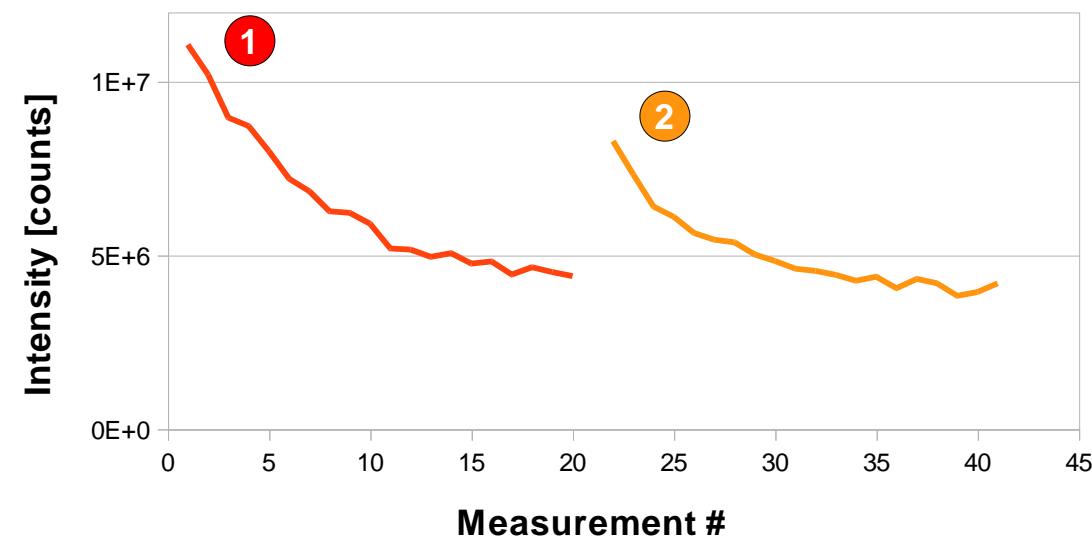
'A new relation between electricity and light: Dielectrified media birefringent',  
*Philosophical Magazine and Journal of Science 50*.

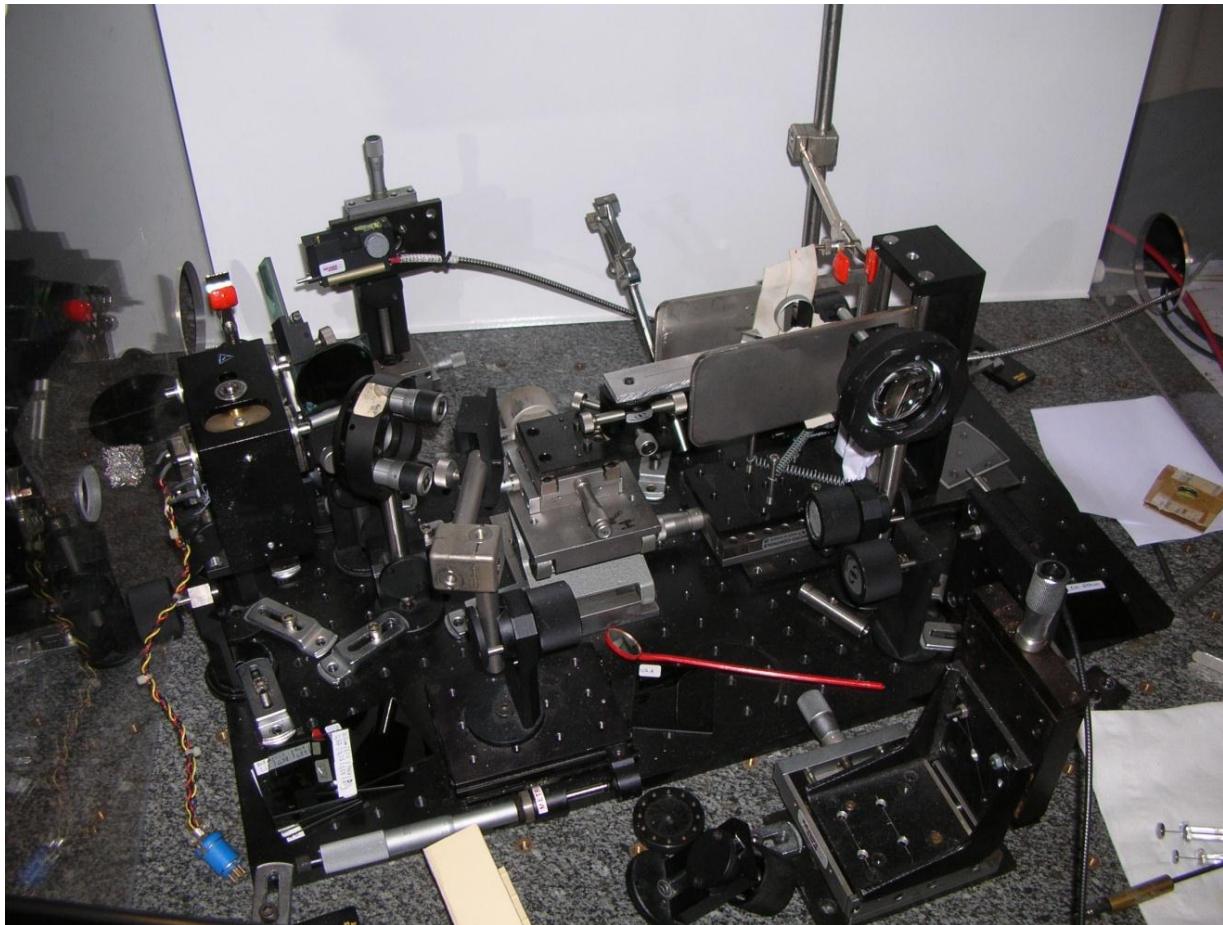


# SAMPLE REGENERATION

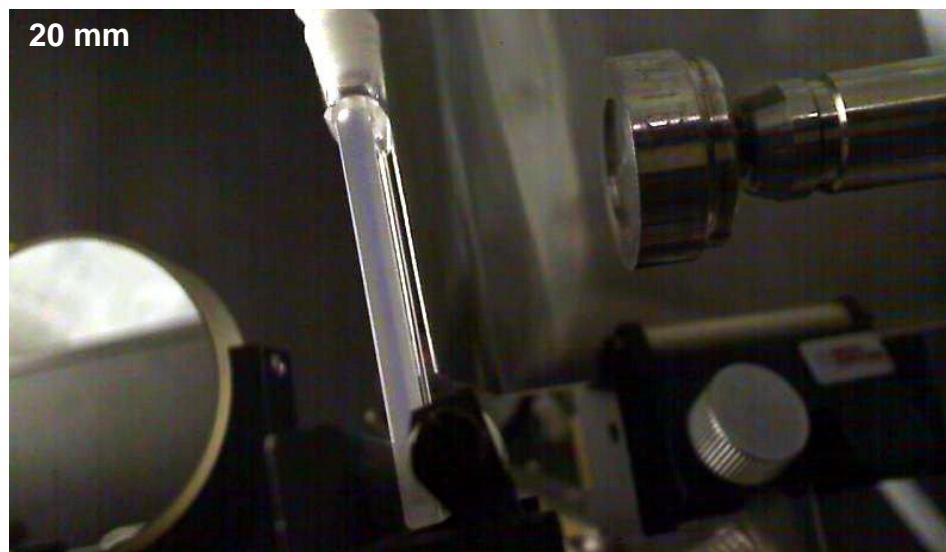
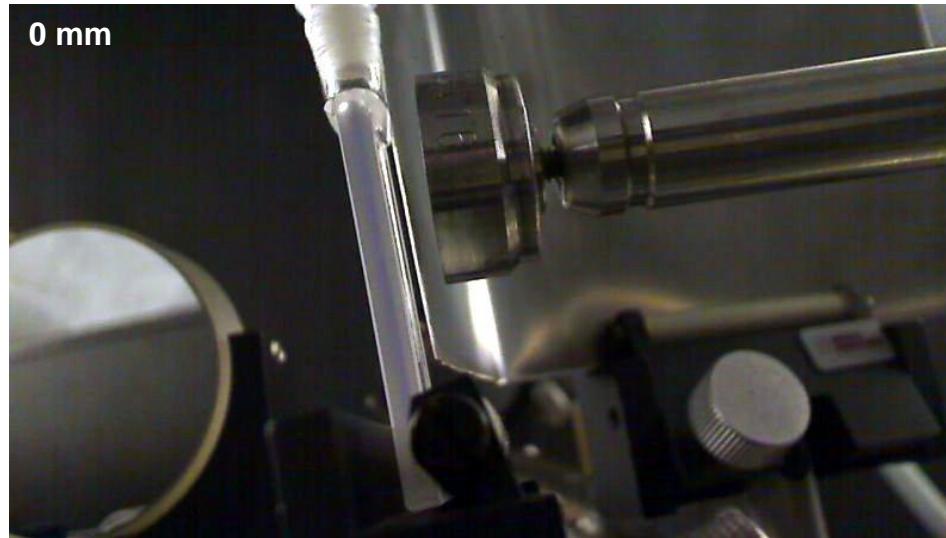


Sample regeneration ?

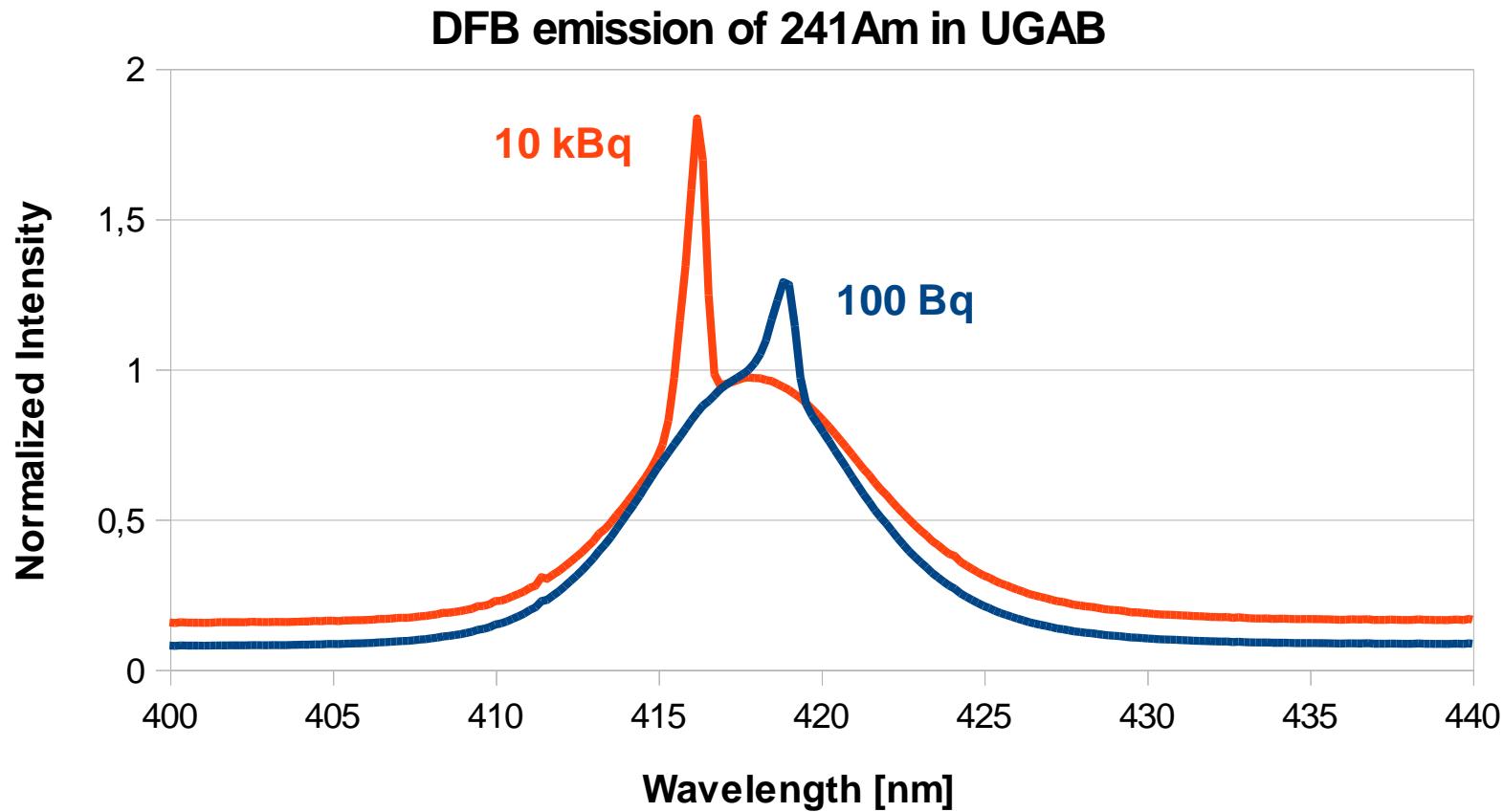




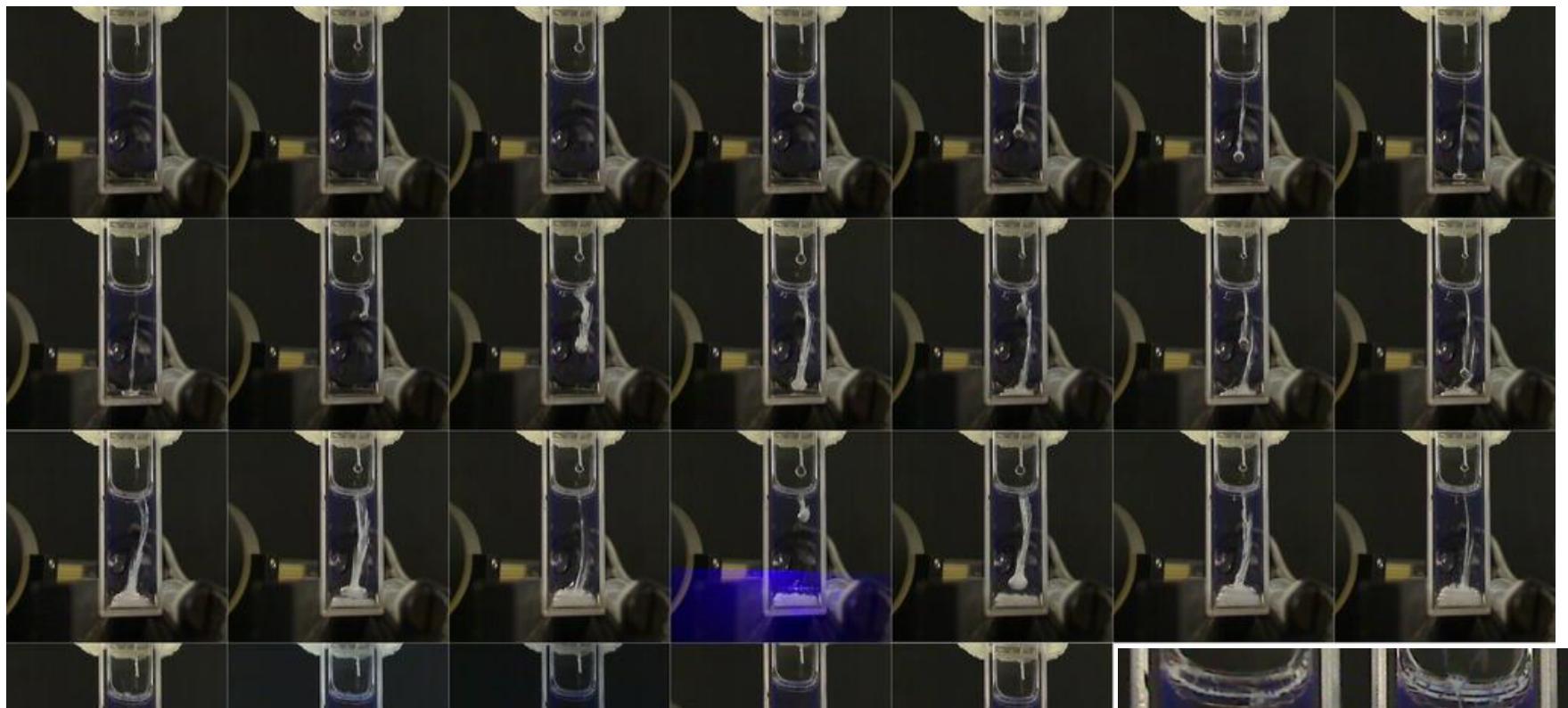
# $\beta$ EMITTER ( $^{90}\text{Sr}/^{90}\text{Y}$ , 22.7 MBq): SOURCE POSITIONING

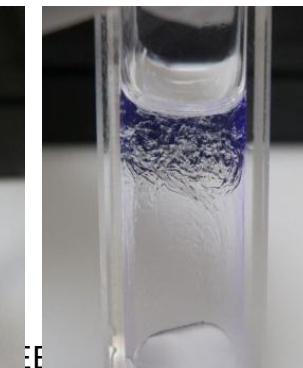
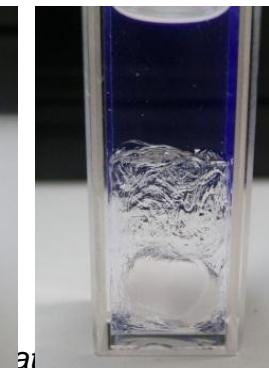
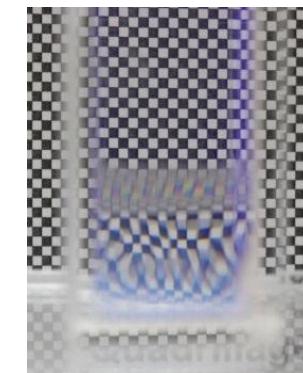
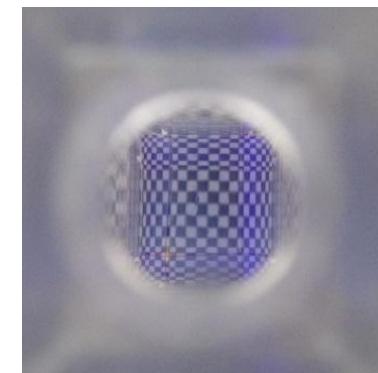
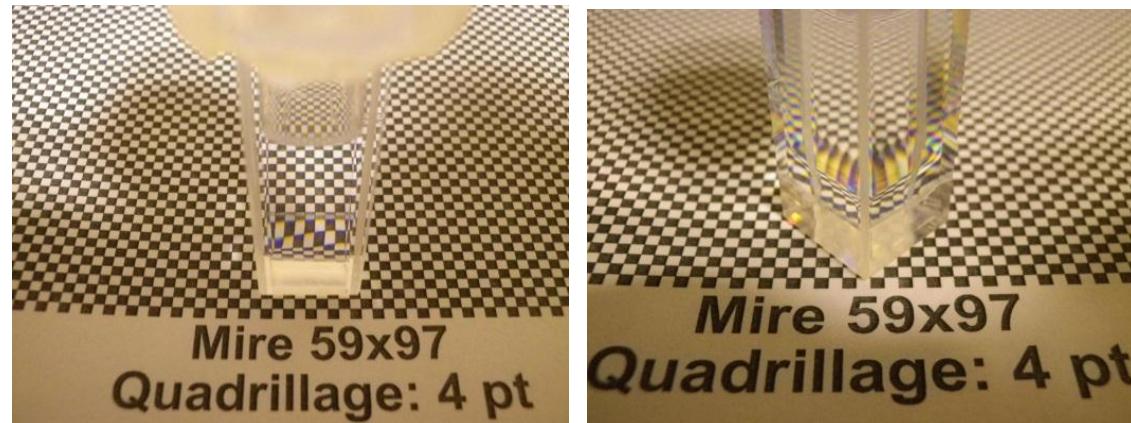


# ULTIMA GOLD™ AB WITH 241AM



# ULTIMA GOLD™ AB QUENCHING (250 µL WATER)





# MIRROR ALIGNMENT

