SAINT-GOBAIN

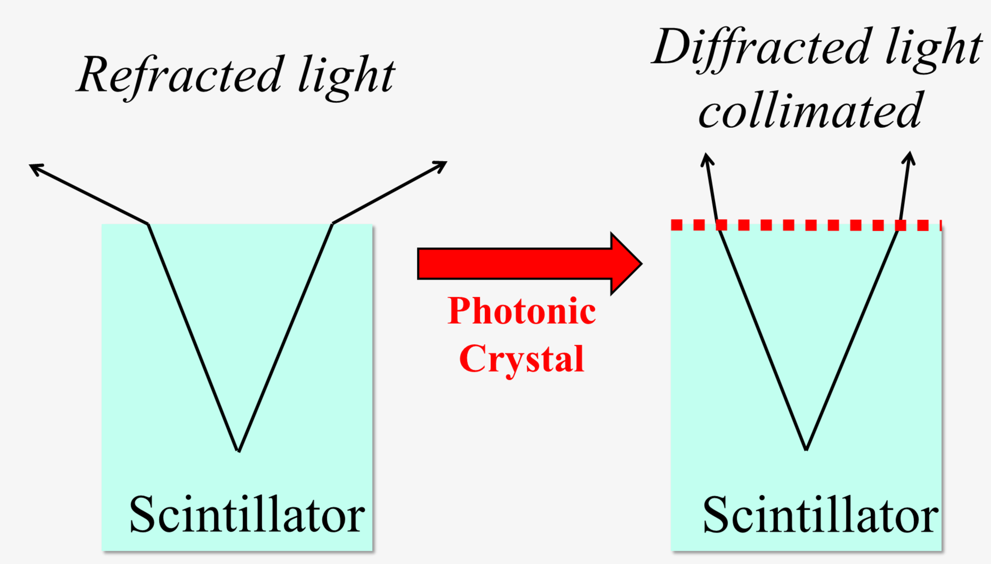
SAINT-GOBAIN RECHERCHE

D. Costantini, S. Chatel, S. Le Roy, P. Trinh

Improved light collimation for scintillators crystals using a photonic crystal

Why a photonic crystal (PhC) ?

We aim to collimate light extracted from a scintillator crystal, in order to improve coupling when standoff between the scintillator and the detector is required (eg. high energy radiography with an electron accelerator, IRM-PET, reactor core imaging and human PET imaging).



To change Fresnel law at the interface we propose a Photonic crystal, which is a 2D grating with period close to the extracted wavelength

Currently light extraction from scintillators reaches more than 80% thanks to:

- wrapping of high reflective Teflon film
- roughened surfaces in order to reflect light with nearly random angles

It's hard to further increase the quantity of the extracted light … however there is substantial room for improving angular distribution.

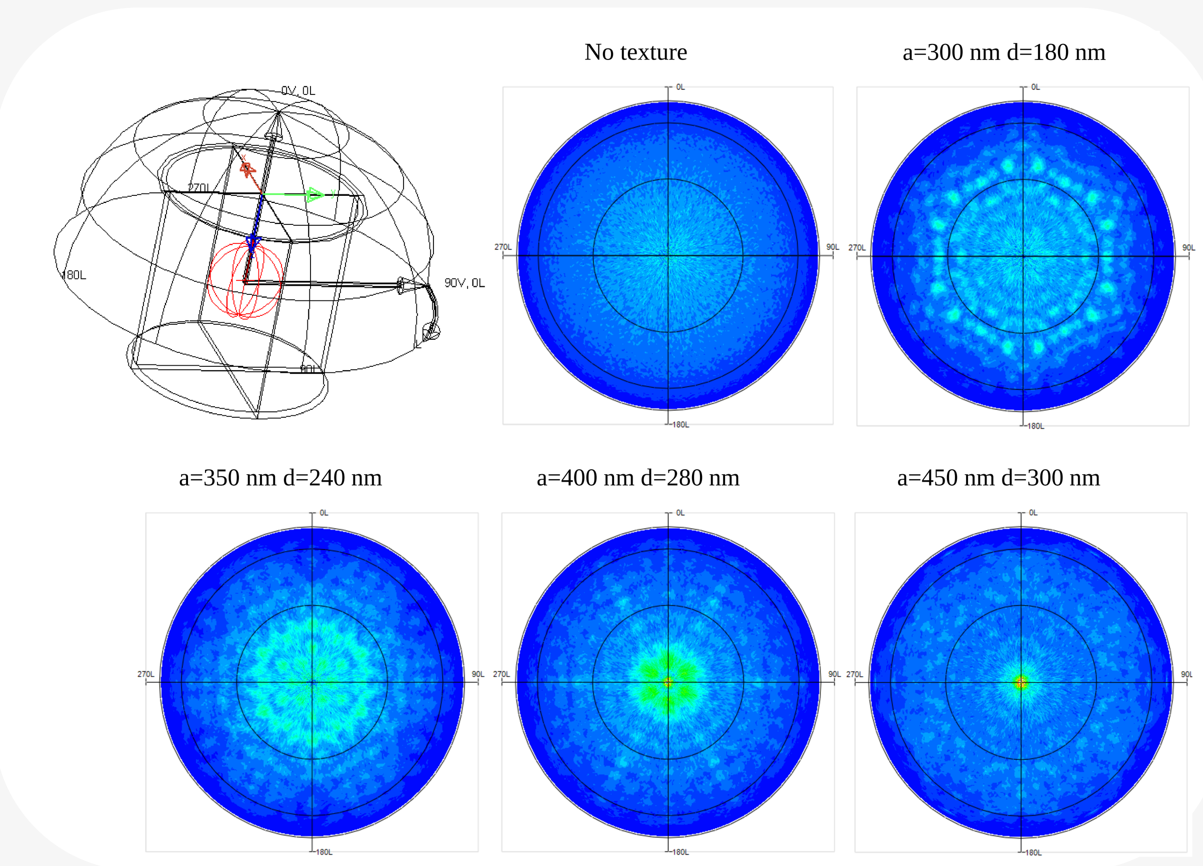
PhC effect - Numerical calculations

We consider a cylindrical scintillator crystal of diameter 50 mm, height 50 mm and optical index n=1,85. Using the ray tracing software, LighTools, we calculated the extracted power from one of the circular faces of the scintillator collected by a far-field detector

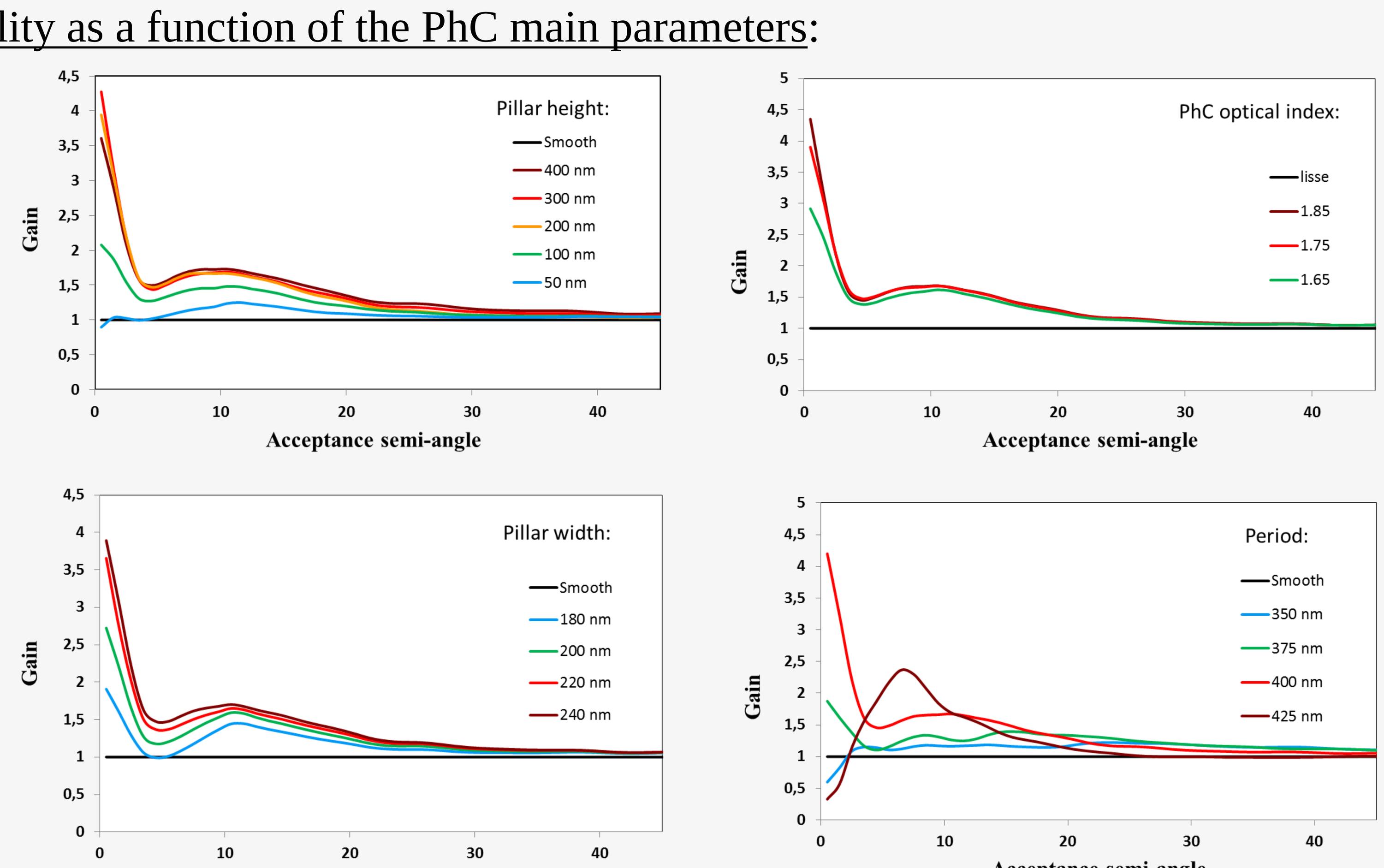
PhC were simulated with a Rigorous Couple Wave Analysis (RCWA) method

PhC parameters are:

- Period (a)
- Pillar width (d)
- Pillar height (h)



We calculated the fraction of extracted optical power in the solid angle as a function of vertex semi-angle ϴ with respect to a flat surface (gain). We studied the gain stability as a function of the PhC main parameters:



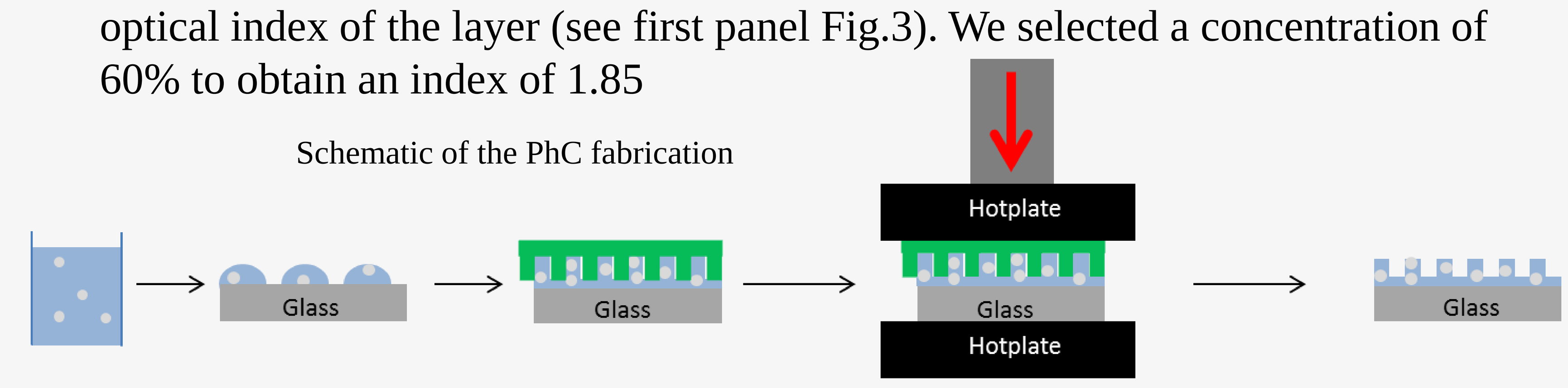
A PhC with index 1.85, a=400, d=200 nm, h=200nm can increase small angle light extraction up to 50%.

PhC fabrication

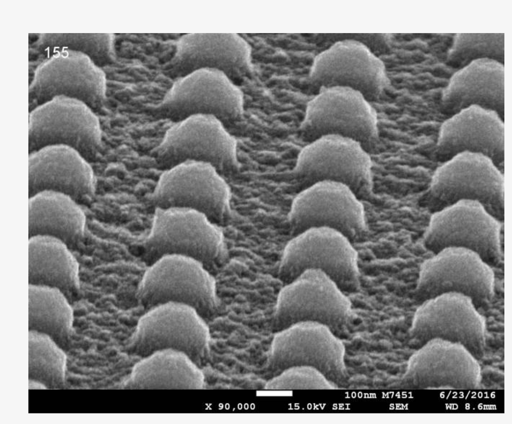
The proposed fabrication technique to realize high index photonic crystals is based on embossing a SiO_2 matrix doped with TiO_2 nanoparticles. Embossing is a relatively fast and low-cost process compared to electron beam lithography and this technique paves the way to large scale fabrication..

By changing the concentration of the TiO_2 nanoparticles we can finely tune the optical index of the layer (see first panel Fig.3). We selected a concentration of 60% to obtain an index of 1.85

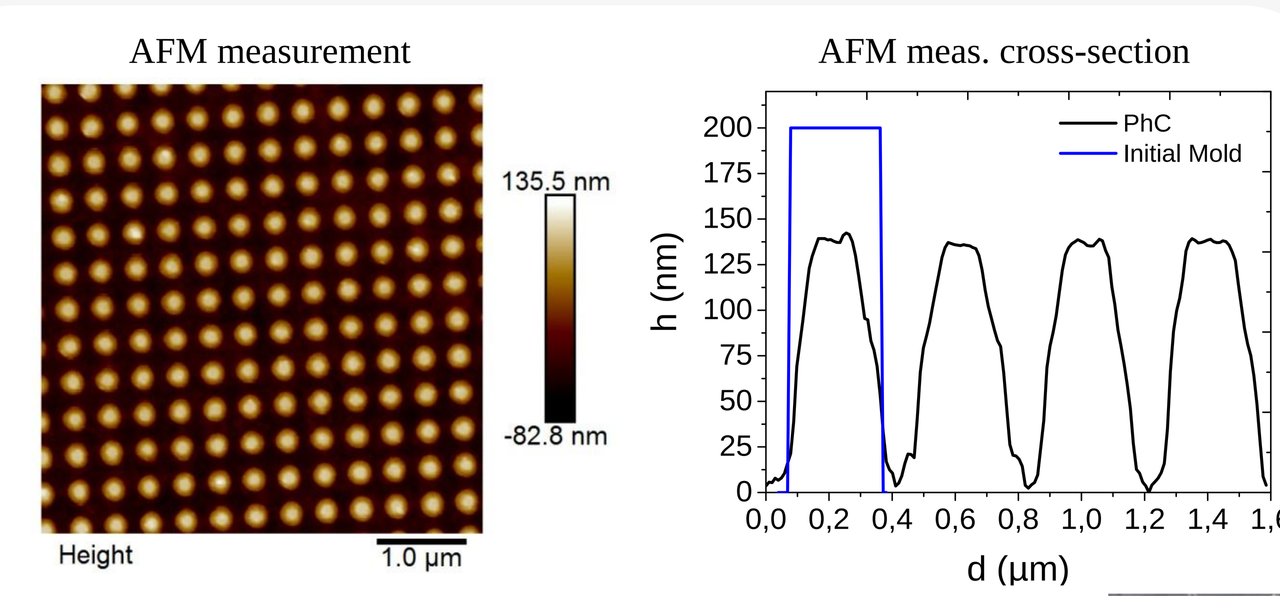
Schematic of the PhC fabrication



SEM image of the PhC

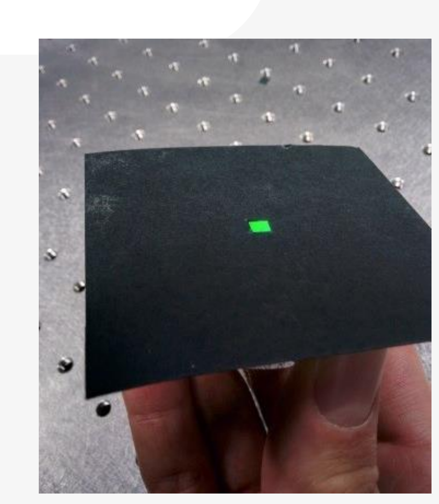


We demonstrated the experimental fabrication of a high index photonic crystal by embossing a solgel containing TiO2 nanoparticles



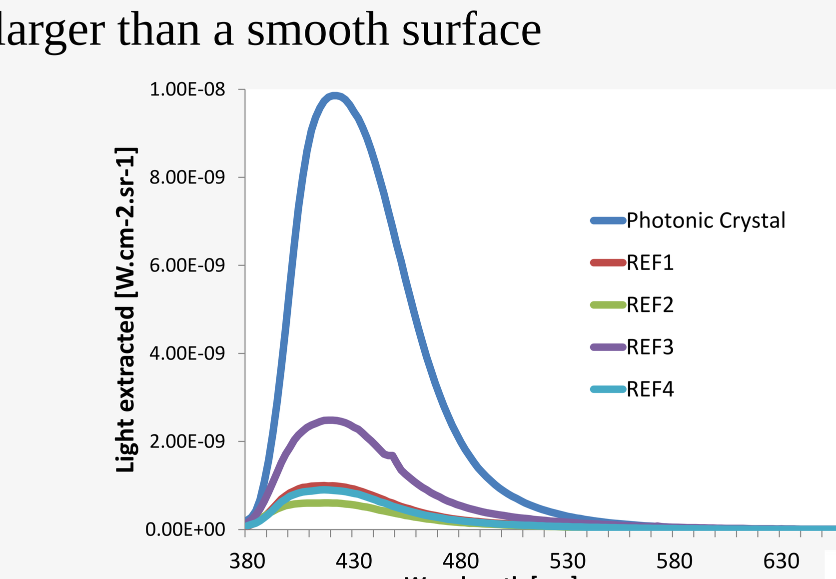
We measure a shrinkage of about 30% . This has to be taken into account during the mold design

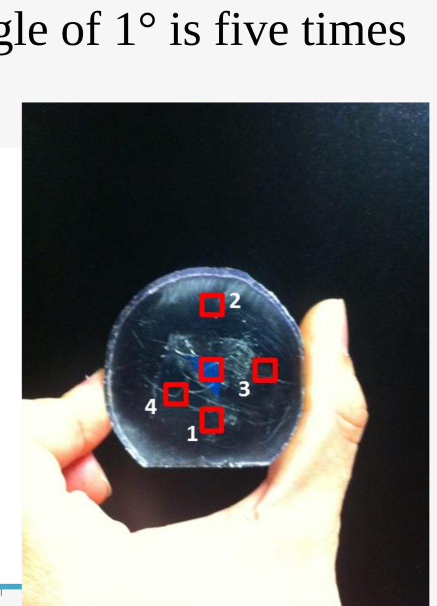
Picture of the PhC diffracting green light (The scintillator is covered with a black mask)



Preliminary measurement

Light extracted form the PhC in a solid angle of 1° is five times larger than a smooth surface





Conclusions and perspectives

We designed and fabricated a high index PhC on a LYSO scintillator crystal

- We will soon optically characterize our sample in order to verify simulations reliability by comparing them with experimental data and therefore experimentally demonstrate the collimation effect.
- In the future we aim at emboss a larger surface of many square centimeters

[1] M. Kronberger et al. "Improving Light Extraction from Heavy Inorganic Scintillators by Photonic Crystals", IEEE Transactions on Nuclear Science (Vol 57, Issue 5)
[2] A. Knapitsch "Photonic crystals: A novel approach to enhance the light output of scintillation based detectors" Nuclear Instruments and Methods in Phy. Res. A
[3] Pawel Modrzynski et al. "Light extraction from scintillating crystals enhanced by photonic crystal structures patterned by focused ion beam" IEEE transaction on nuclear science
[4] Patent WO2015197947 "Luminescent material with a textured photonic layer"