



Cavity Resonator Integrated Guided mode resonance Filter : Spectral & Modal Reflector

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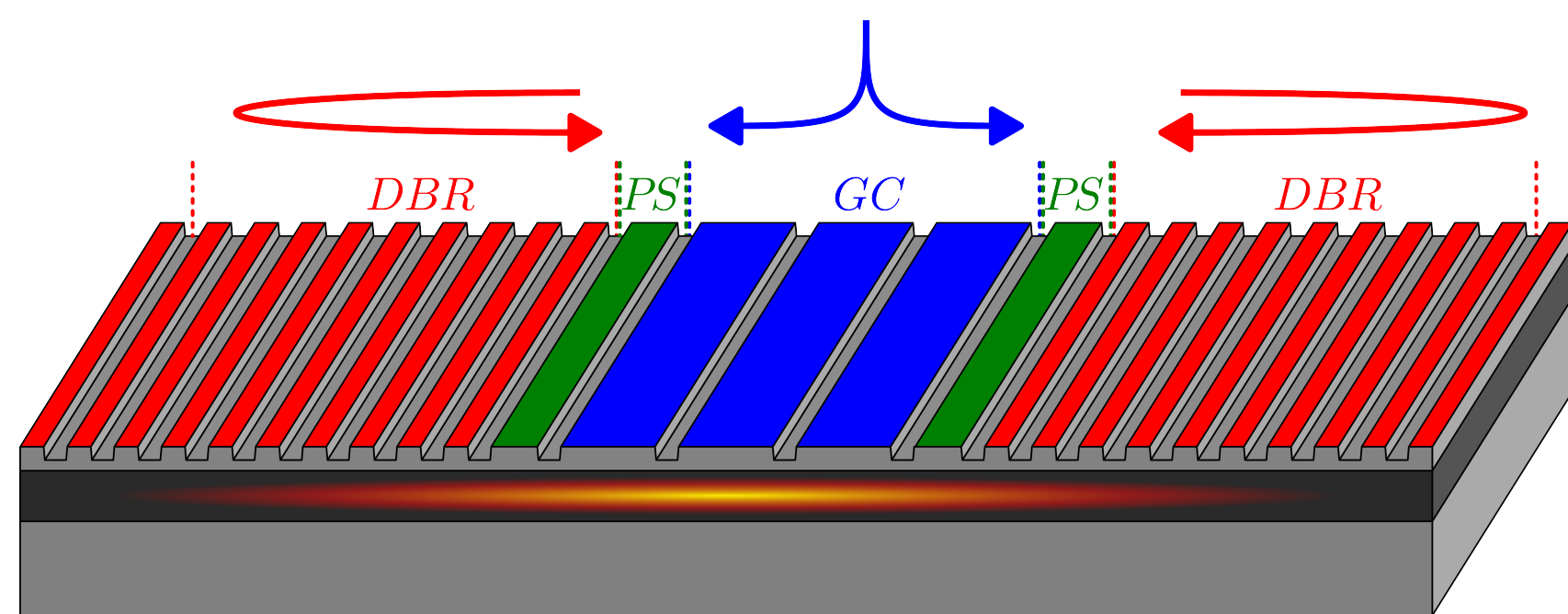
Cavity Resonator Integrated Guided mode resonance

Filter : Spectral & Modal Reflector

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CRIGF : What is it ?

CRIGF is a new generation of narrowband filter. It consists of subwavelength gratings nearby or upon a waveguide. At the center, a small **GMRF (Guided Mode Resonance Filter)** or **GC (Grating Coupler)** coupled radiated & guided mode, then, **DBR (Distributed Bragg Reflector)** at each side localise mode inside a horizontal Fabry-Pérot cavity. Two **PS (Phase sections)** are used to fine tune the Fabry-Pérot modes with the grating coupler.

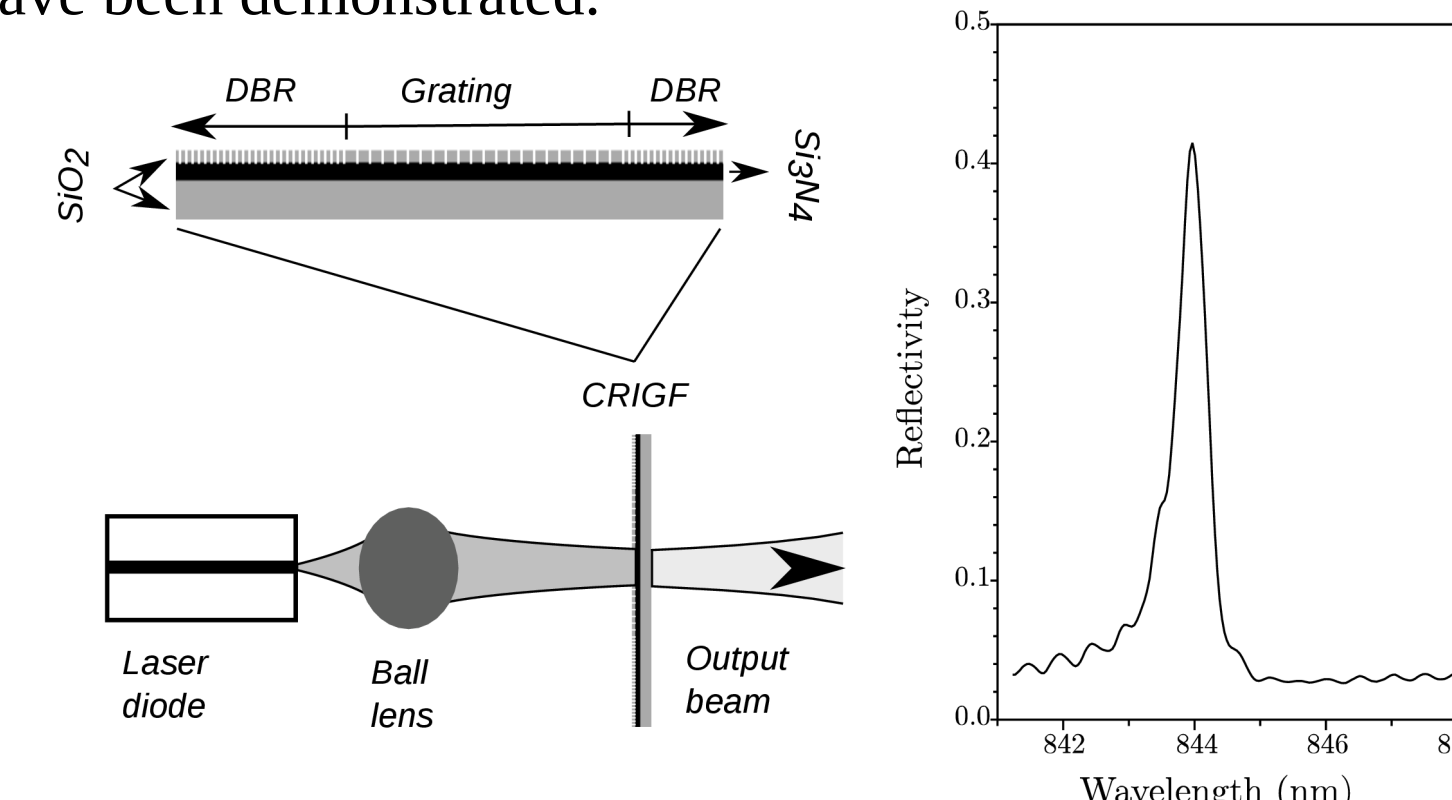


GRMF	CRIGF
Plane waves	Focused Beams
High Q reflector, filter $\Delta\theta < 1^\circ$	High Q reflector, filter $\Delta\theta \sim 8.5^\circ$
Large scale (cm^2)	Small aperture (μm^2)

Kenji Kintaka, Tatsuya Majima, Junichi Inoue, Koji Hatanaka, Junji Nishii, and Shogo Ura, "Cavity-Resonator-Integrated Guided-mode Resonance Filter for aperture miniaturization," Opt. Express **20**, 1444-1449 (2012)

CRIGF : What is it for?

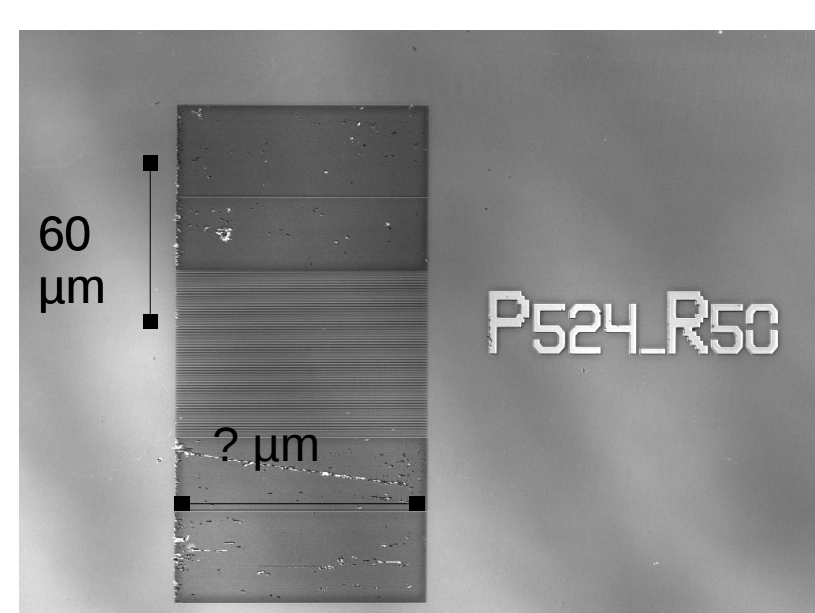
Extended Cavity Diode Lasers (where a laser diode is inserted in an optical cavity with a spectrally selective element) can benefit from CRIGFs high angular acceptance. Wavelength stabilization in small and robust cat's eye cavity have been demonstrated.



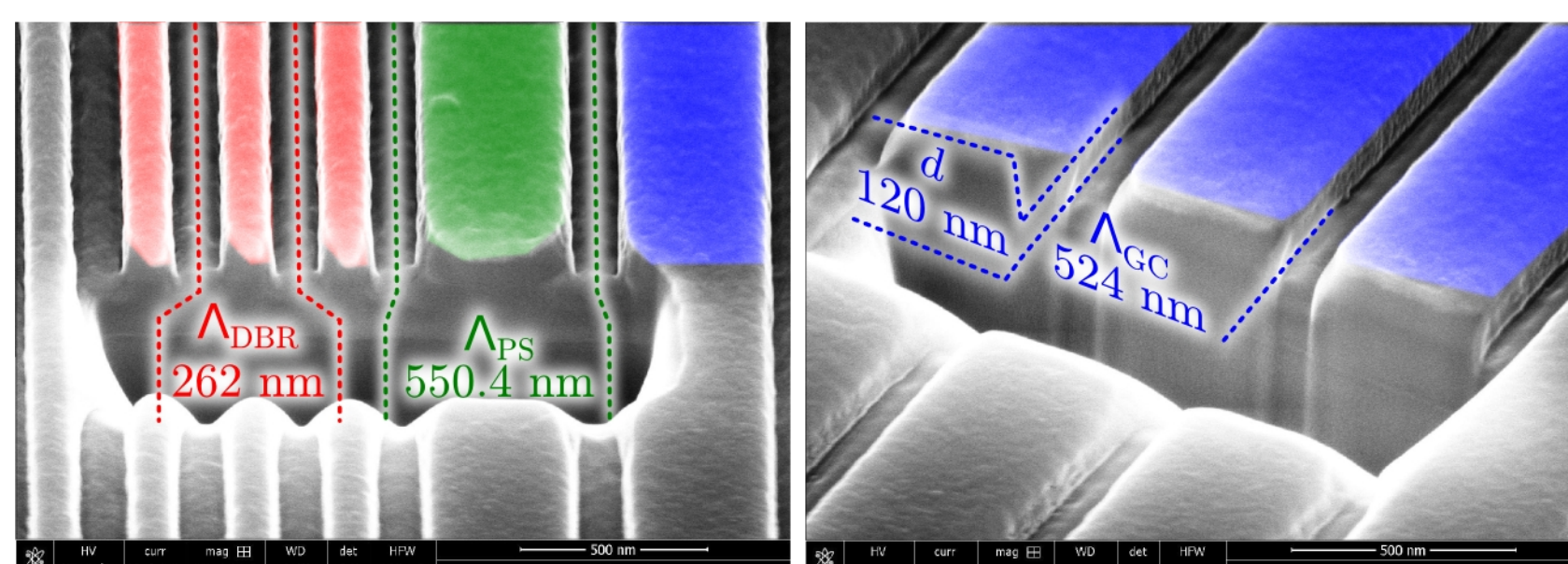
Buet, X.; Guelmami, A.; Monmayrant, A.; Calvez, S.; Tourte, C.; Lozes-Dupuy, F.; Gauthier-Lafaye, O., "Wavelength-stabilised external-cavity laser diode using cavity resonator integrated guided mode filter", Electronics Letters, vol.48, no.25, 1619-1621, 2012

Fabrication

A stack is defined by PECVD deposit :
 SiO_2 (111nm, $n=1.46$)-
 Si_3N_4 (165nm, $n=1.97$)-
 SiO_2 (substrate, $n=1.50$).
Then, several CRIGFs are obtained using e-beam, then ICP etching,

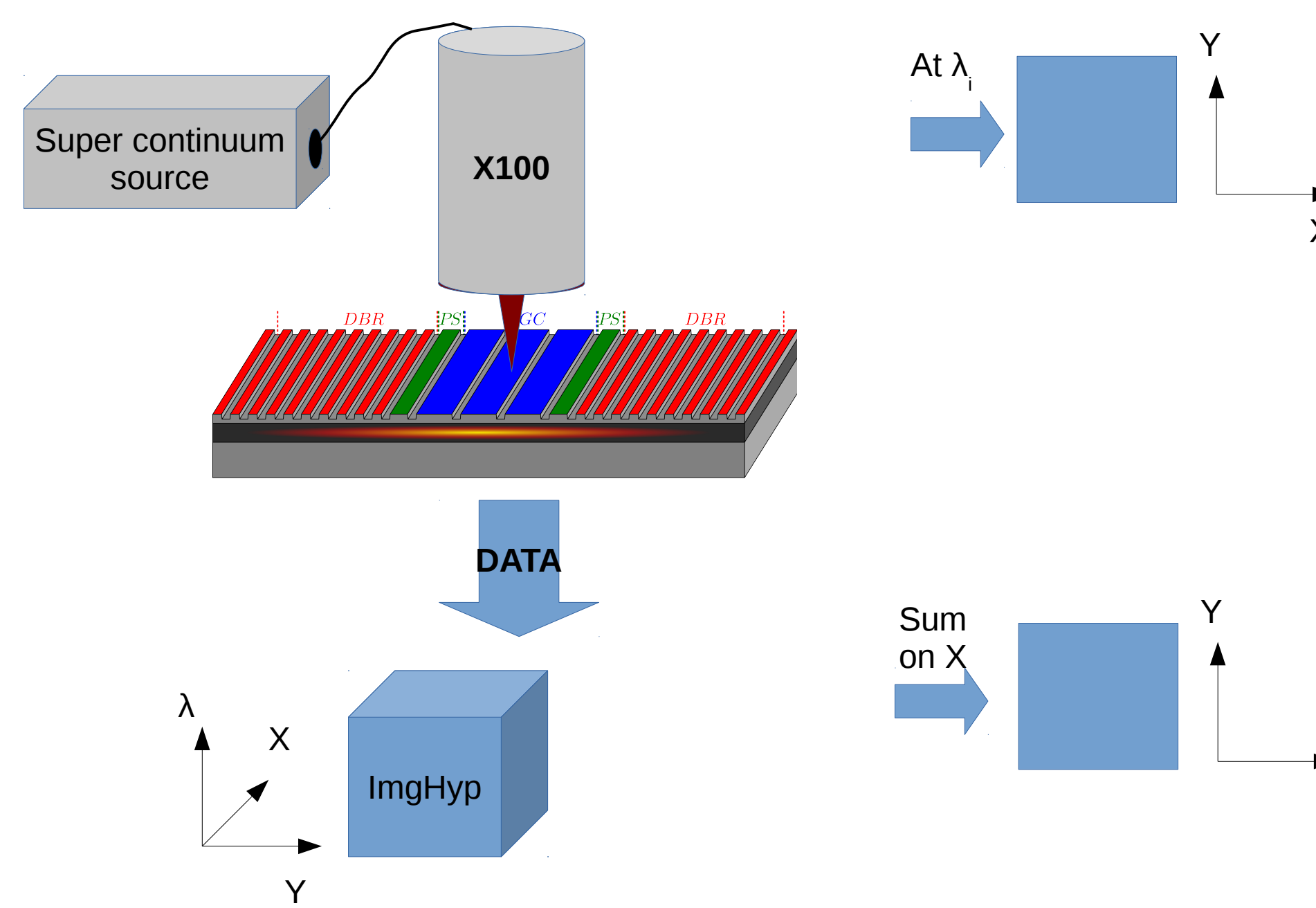


Confocal image of a 1D CRIGF



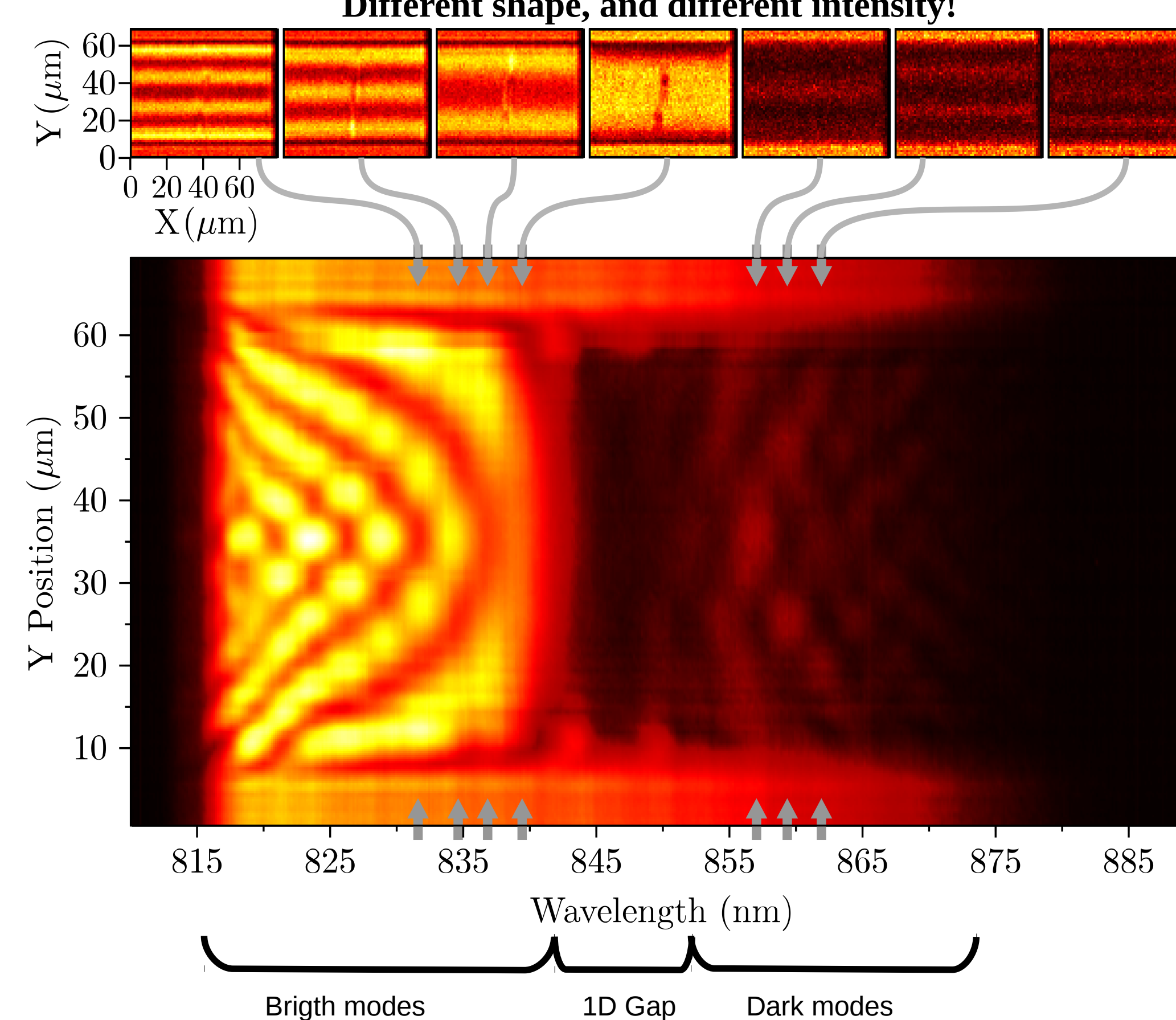
FIB cut and observations have been realised to inspect the length, the height and the profil of the gratings

Experimental Observations



The pattern of the shape modes, the symmetry between bright & dark modes suggest standing wave confinement, like quantum system but with a $60 \mu\text{m} \times ? \mu\text{m}$ element !

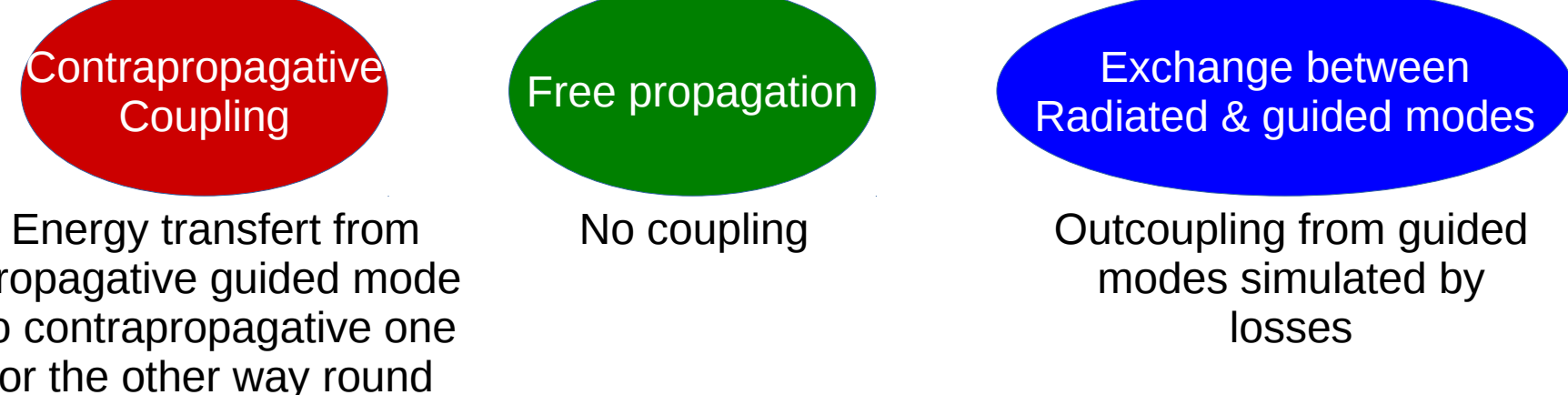
High order reflected modes observed ! Different shape, and different intensity!



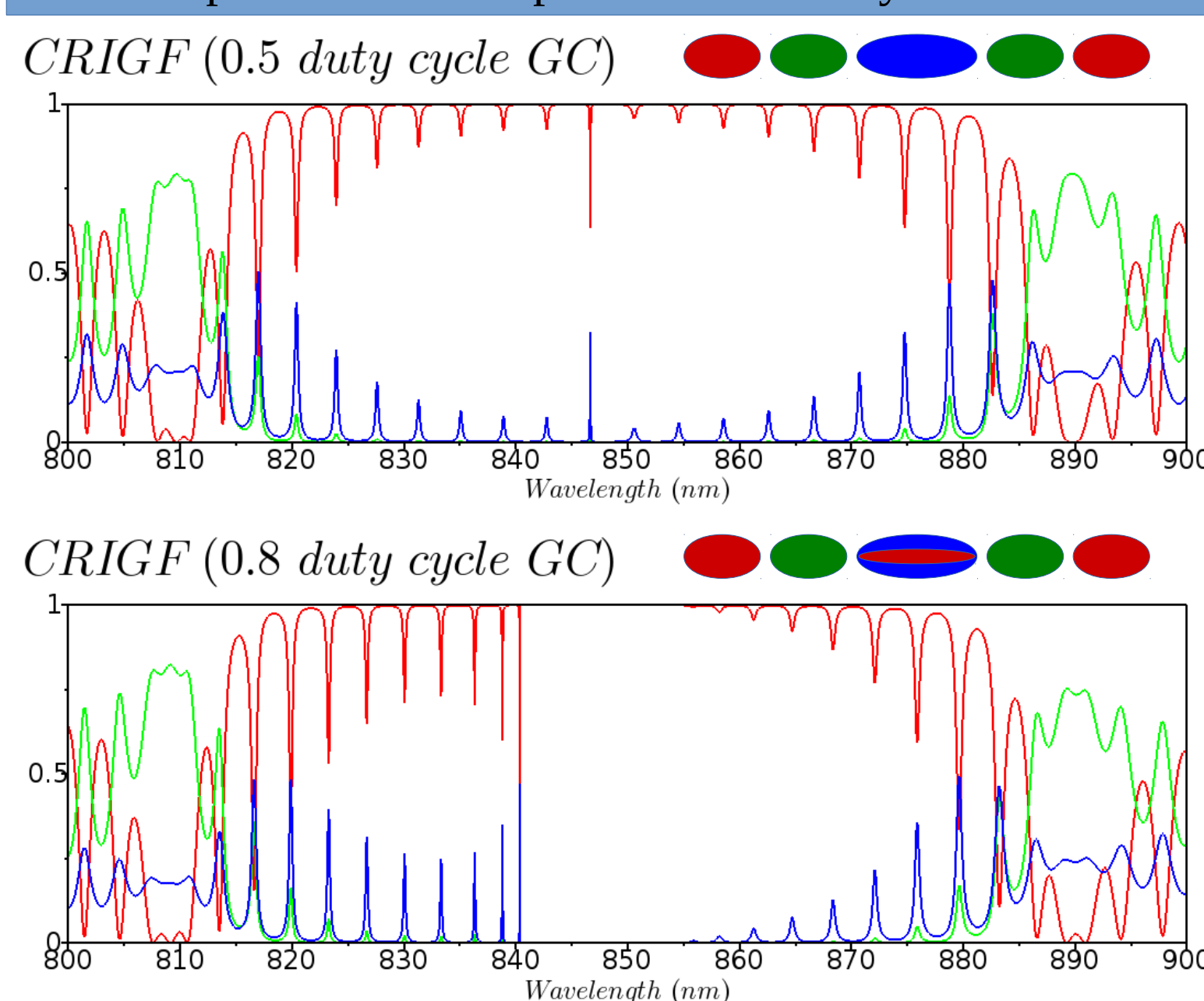
CRIGF Modelling

Several long periodic elements of finite length:
No RCWA
No FDTD
Coupling, resonator, modes :
Theory of coupled modes

Based on "Design of resonance grating coupler," Opt. Express **16**, 12207-12213 (2008) : Each block is a 1D effective medium where specific coupling occurs. All the coupling impact the guided mode. So we focus only on them, with the coupler point of view.

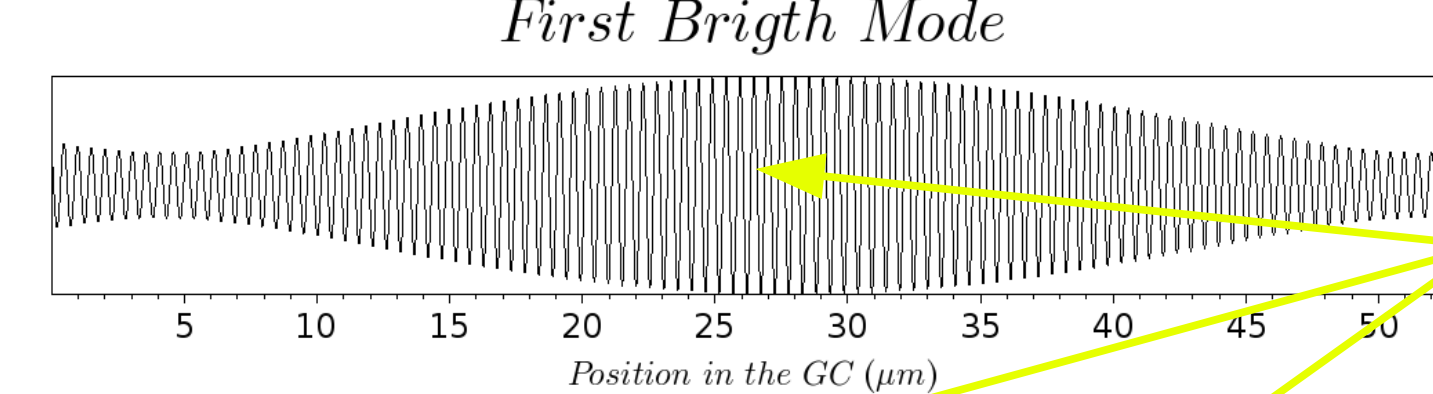


Spectra from Coupled Mode Theory Model



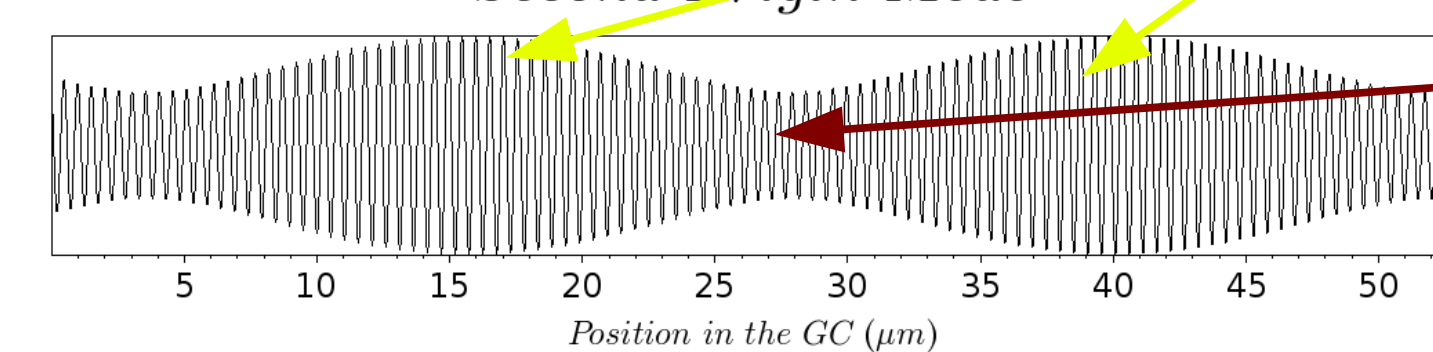
Guided Mode Field Profile in GC from Coupled Mode Theory Model

First Bright Mode



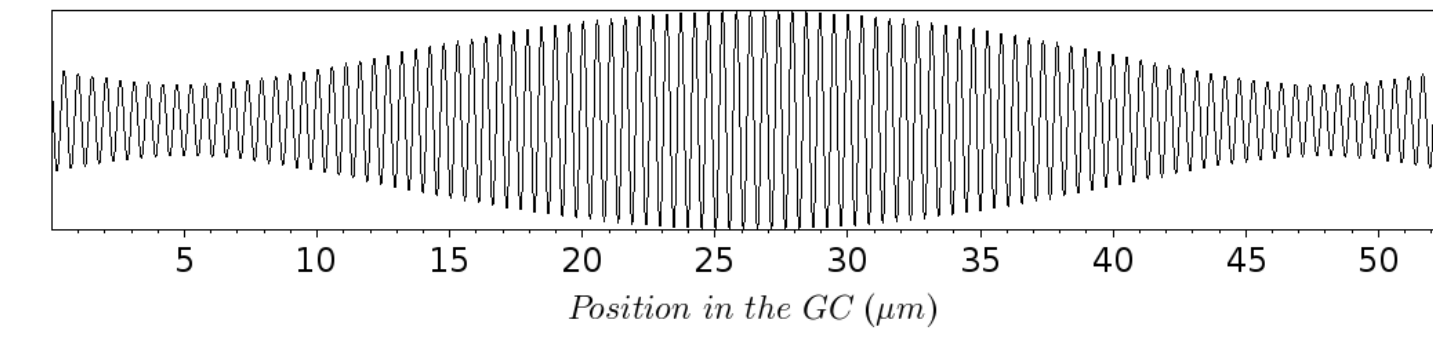
Extremums OK !

Second Bright Mode



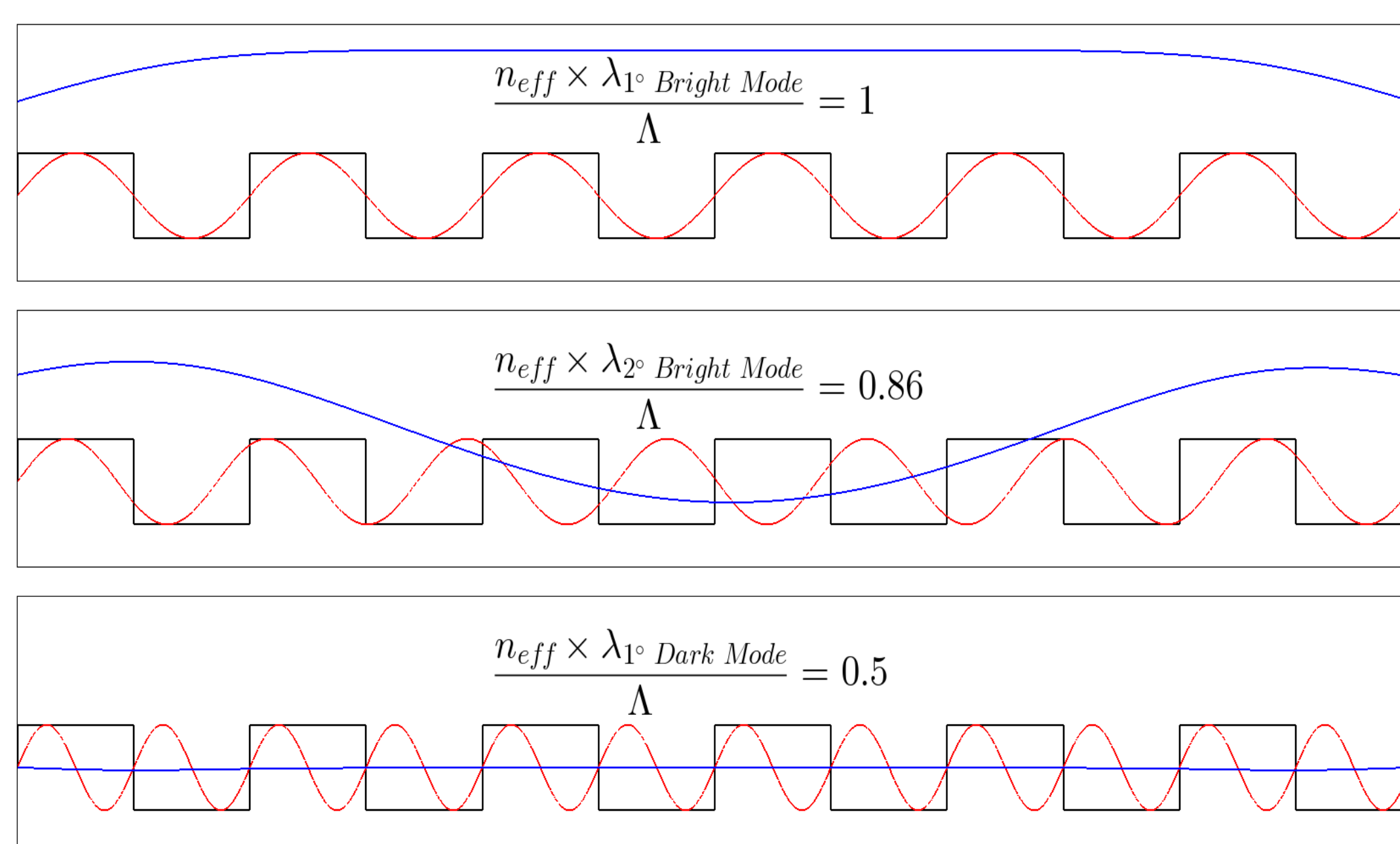
Nodes ?

First Dark Mode



Bright vs Dark ?

Illustrations of Moiré Effect

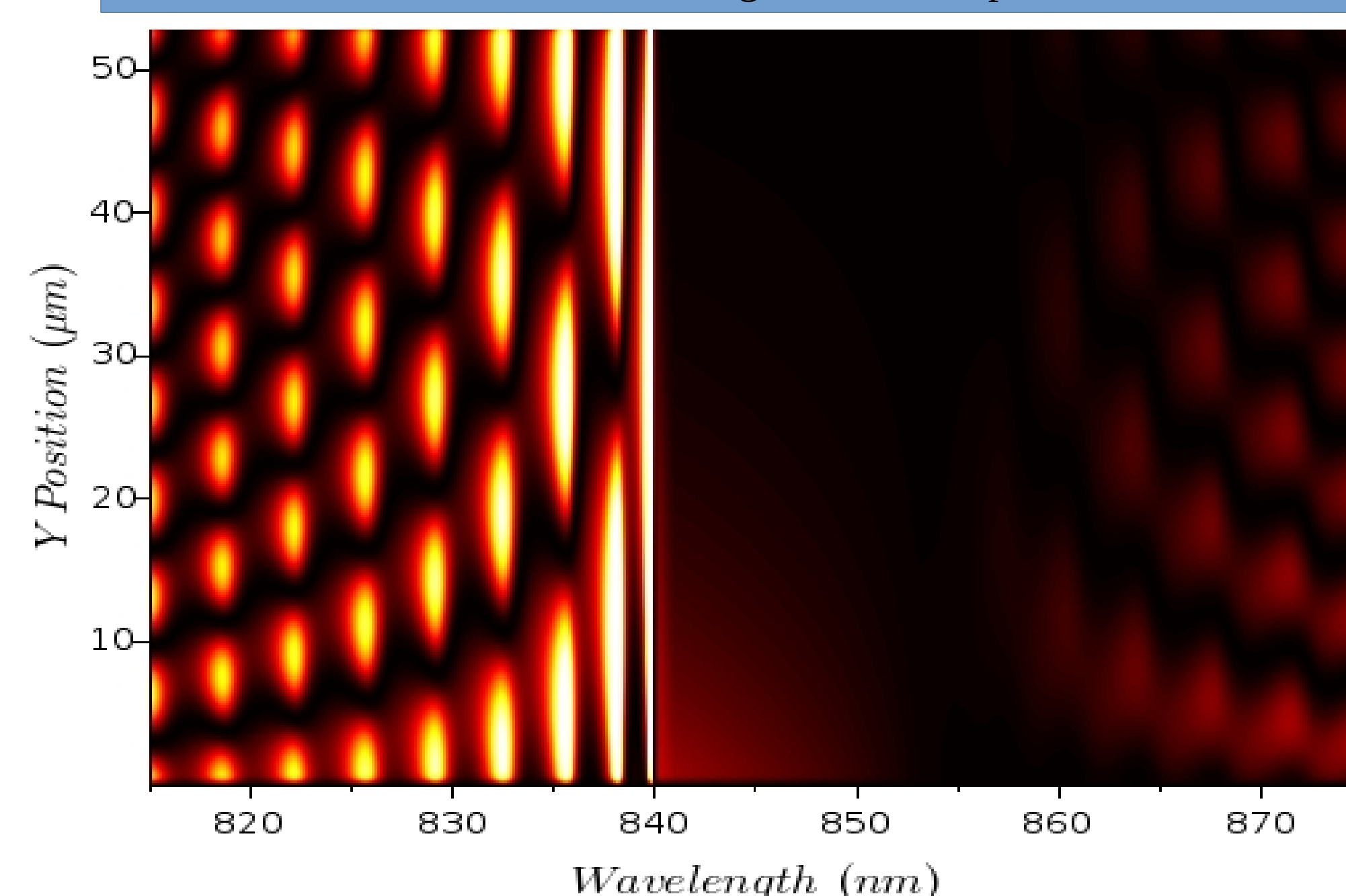


Usually, GMRF + guided mode
=> infinity grating + propagative wave
No Phasing

Black curves = GC profil
Red curves = standing wave for the FP mode
Blue curves = Moiré

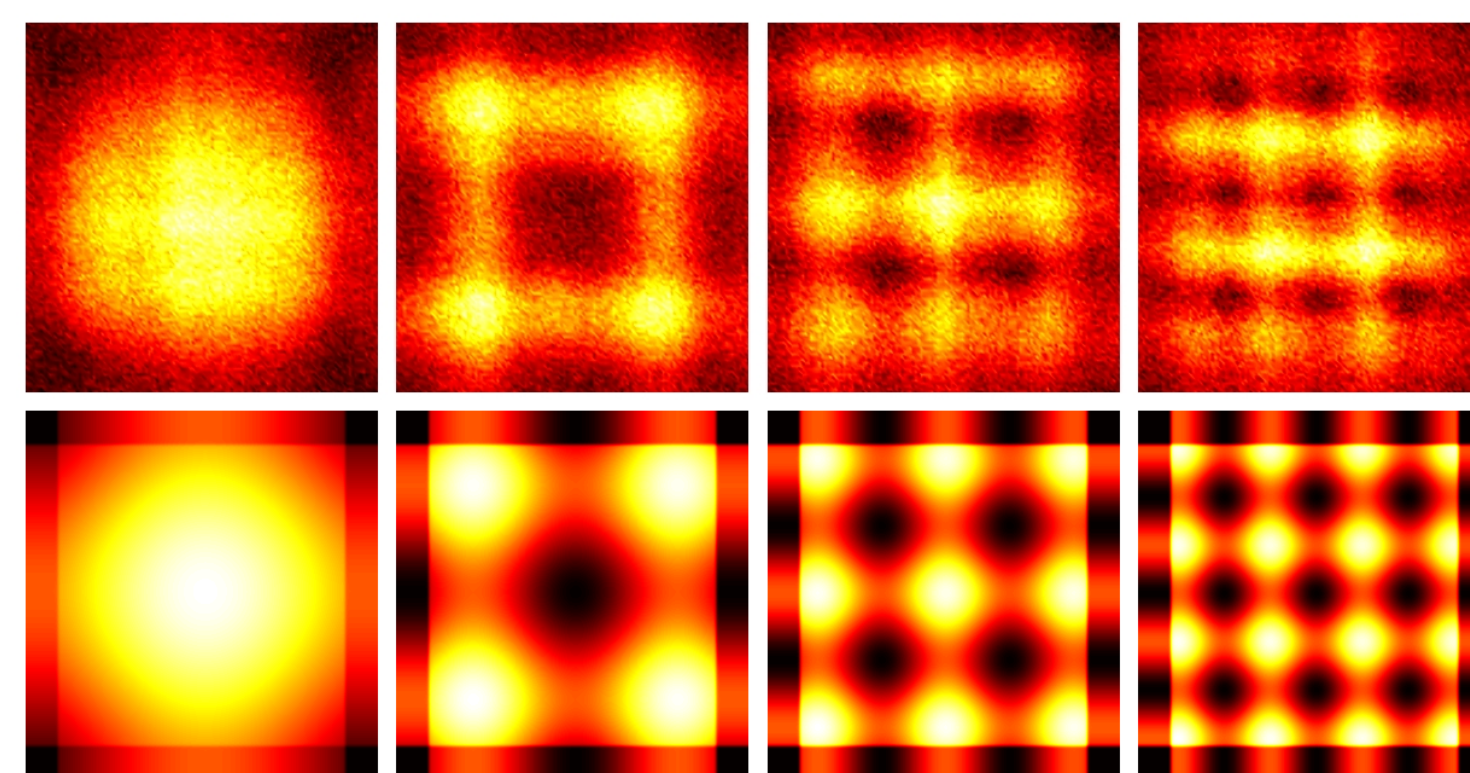
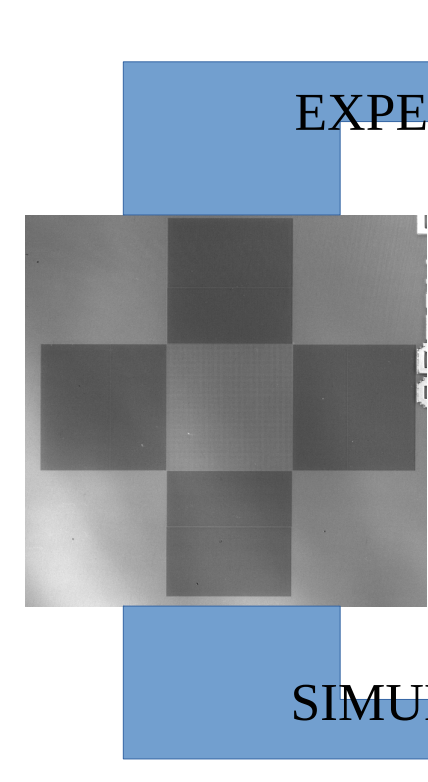
CRIGF
Short GMRF (GC) + Modes FP
=> Phasing between GC profile & standing wave
=> Moiré Effect

CRIGF + Moiré Modelling : simulation of the image from the experiment



What about 2D CRIGF?

=> both the cavity have the same resonance modes, and they don't interact since they are orthogonal.



-> Experimental demonstration of intricate spectral and modal filtering.
-> Modelling combining coupled modes and Moiré analysis to explain all observed features.
-> Simple and Fast model adapted to design of multimodal spectral and modal couplers/reflectors

CRIGFs are both spectral and modal reflectors where both complex modal and spectral properties can be tuned at will