Spectromètres compacts infrarouges: couplage entre guides et détecteurs

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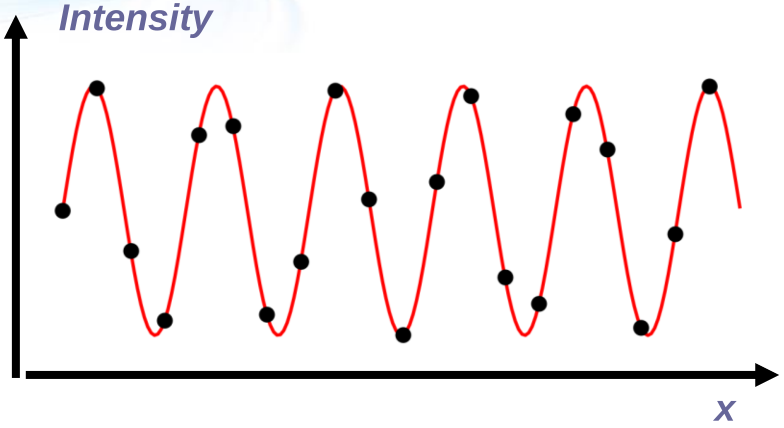
Outline

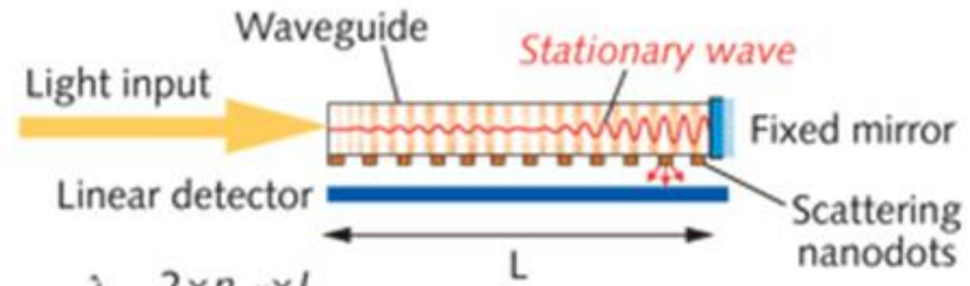
- SWIFTS principles
- Problems related to its transfer in NIR or MIR
- Directive antenna
- Few technologies used
  - Direct Laser Writing
  - Titane diffusion in Lithium Niobate
  - Ion exchanged in glass
- Lastest results using Lithium Niobate Technology
- Find and use the optimal detector
- Few projects in progress

SWIFTS Principles

- **Stationary wave**

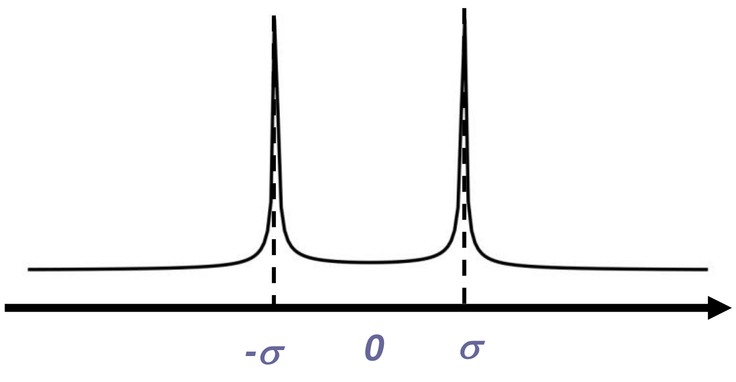


- **Integrated version principle**

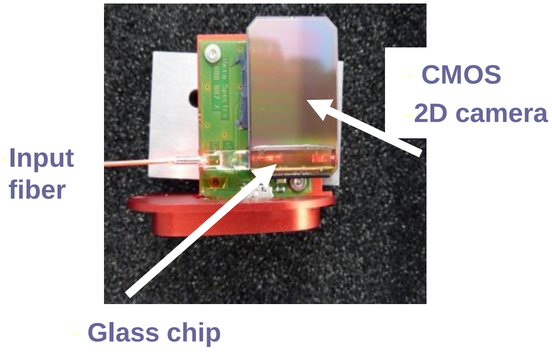


$$R = \frac{\lambda}{\Delta\lambda} = \frac{2 \times n_{eff} \times L}{\lambda}$$

- **After inverse Fourier Transform**

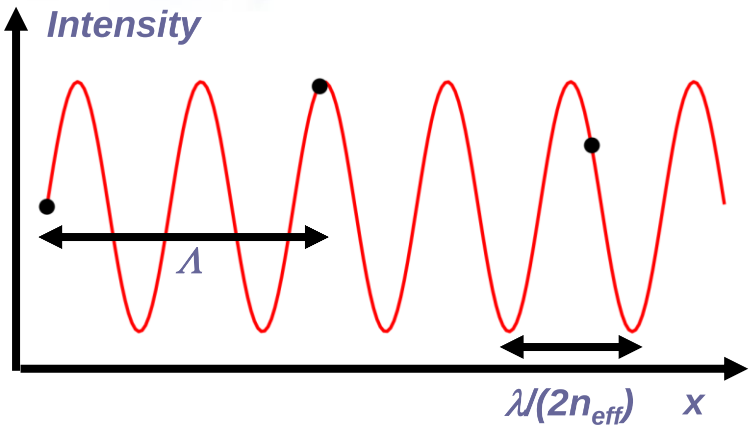


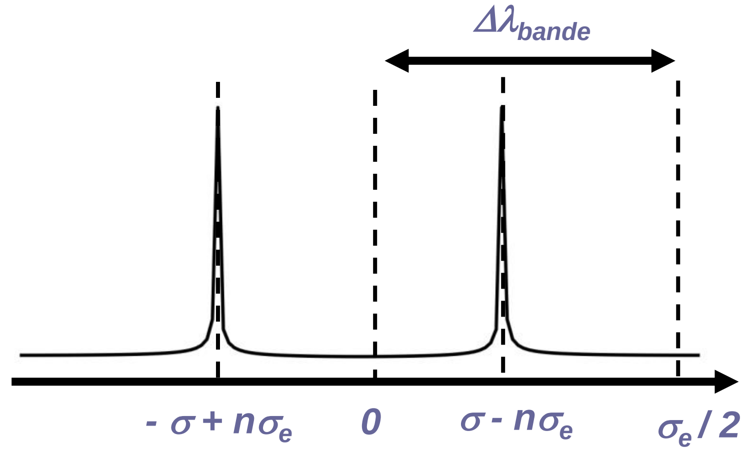
- **SWIFTS initially developed in 400-1000nm wavelength range**



Under sampling effect

- **Single waveguide ⇒ under sampling**
  - Pitch Λ >> Fringe period $\lambda/(2n_{eff})$

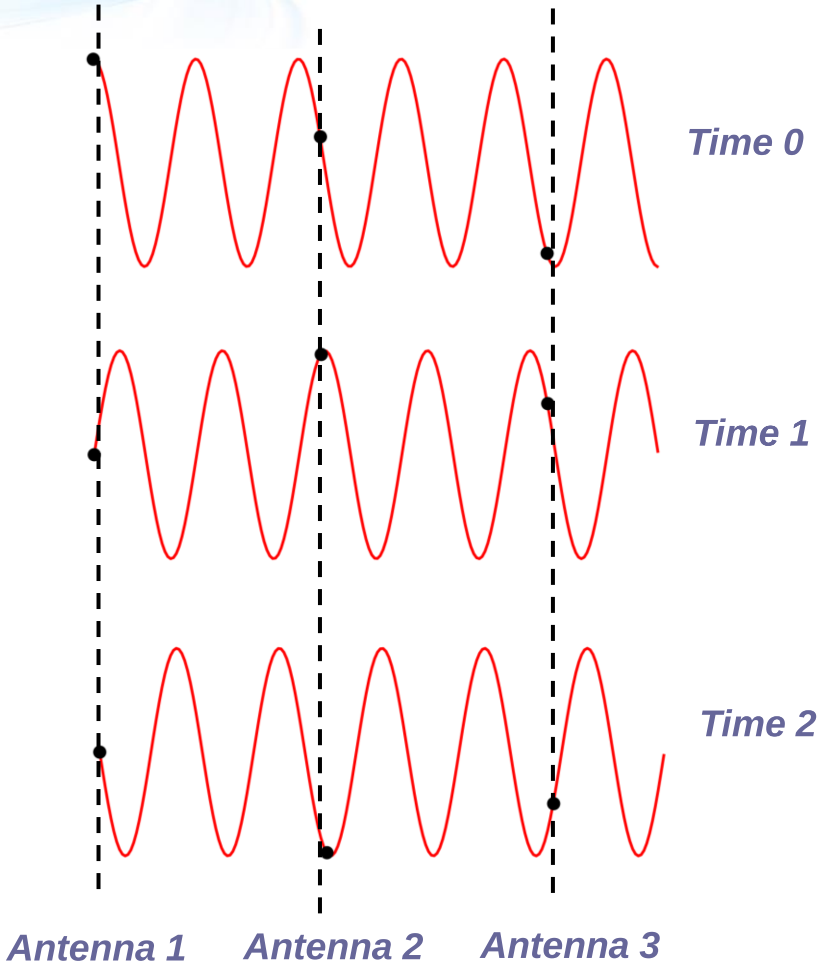




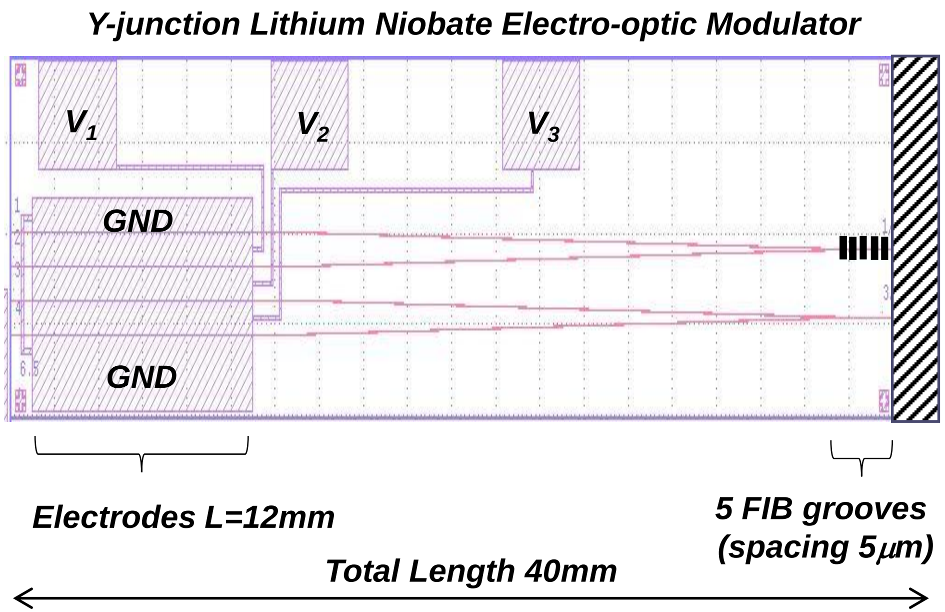
- **Typical values:**
  - Fringe period: $\lambda/(2n_{eff})$ = 0,4µm in LiNbO3
  - Camera pitch: Λ = 20µm or σ_e = 0,05µm^{-1}
  - Waveguide length: L = 10mm
  - Resolution: $R = (2n_{eff} L)/\lambda$ = 28000 or $\Delta\lambda$ = 60pm
  - Spectral band: $\Delta\lambda_{bande} = \lambda^2/(4\, n_{eff}\, \Lambda)$ = 14nm

Time multiplexing

- Time multiplexing

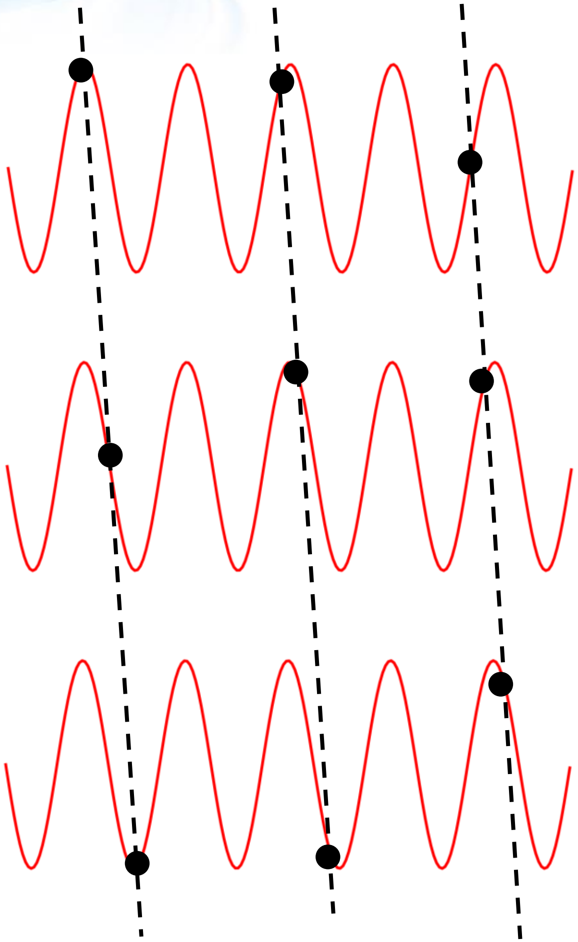


- Integrated solution

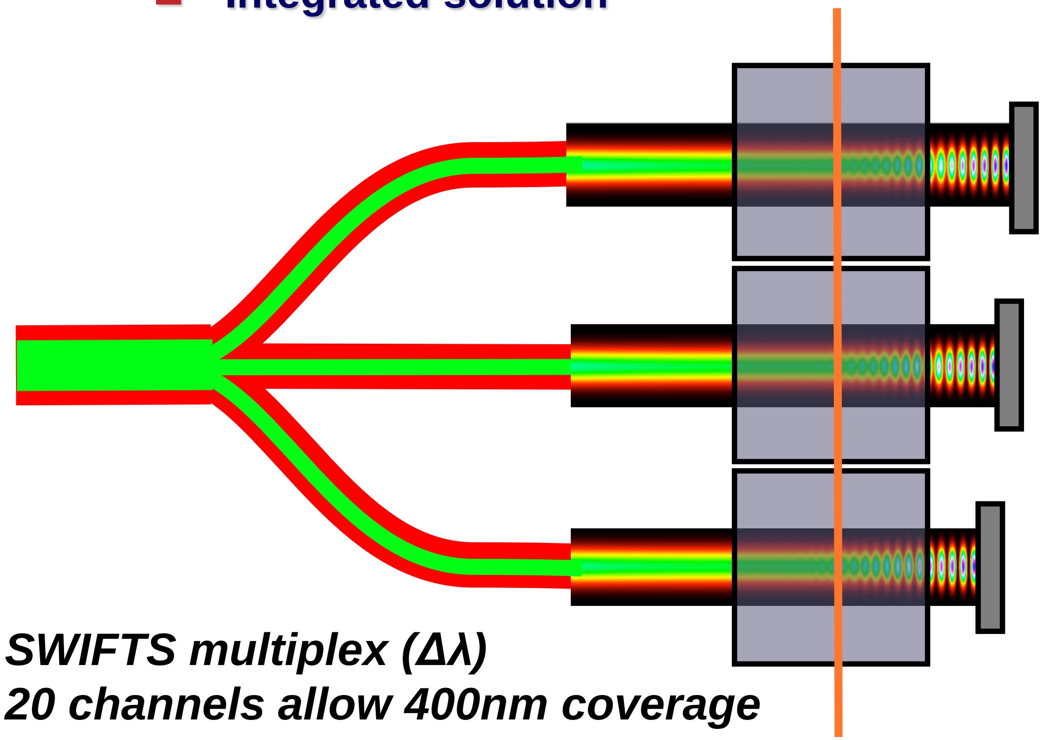


Spatial multiplexing

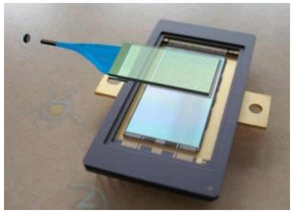
- Spatial multiplexing



- Integrated solution

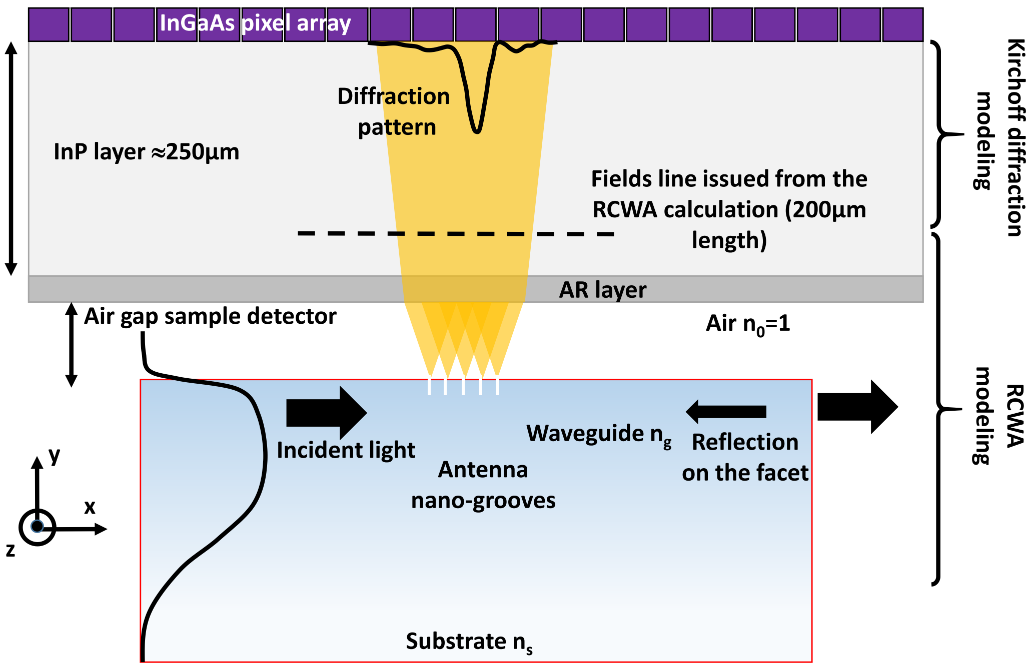


SWIFTS multiplex (Δλ)
20 channels allow 400nm coverage
Splitting the Etendue at the entrance

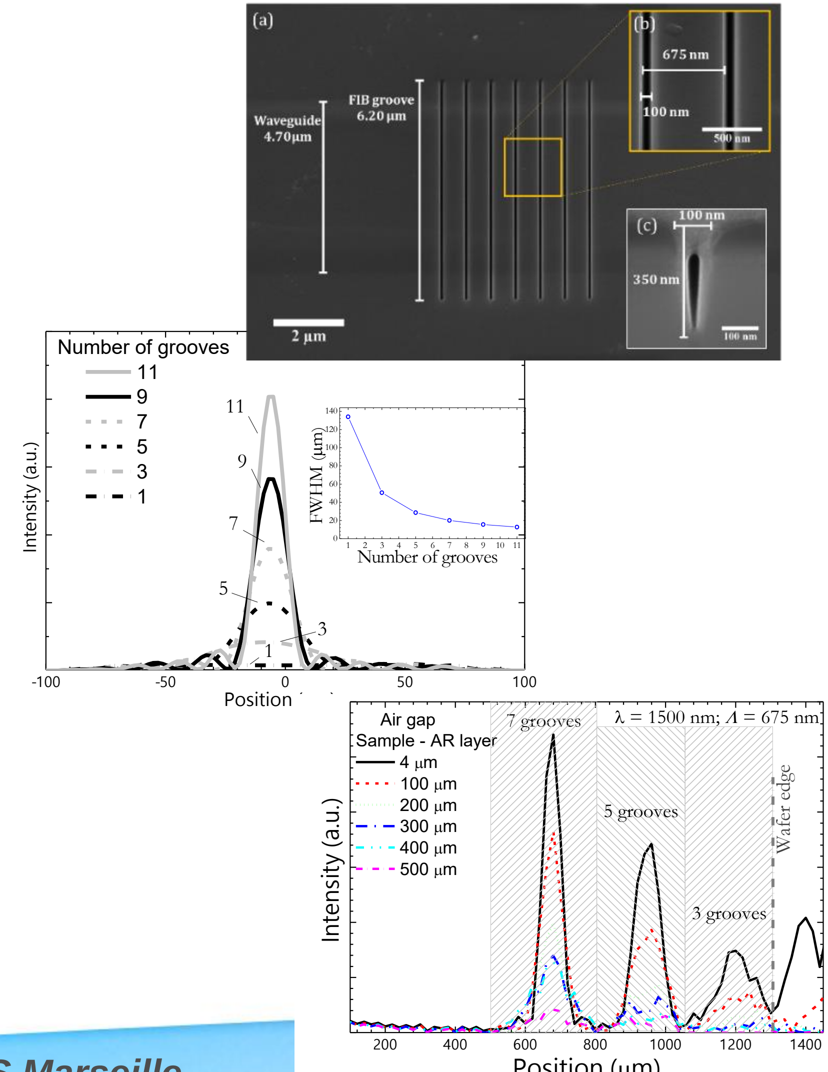


Directive scattering need

- **InGaAs camera:**
  - active zone under the surface (few hundred microns)



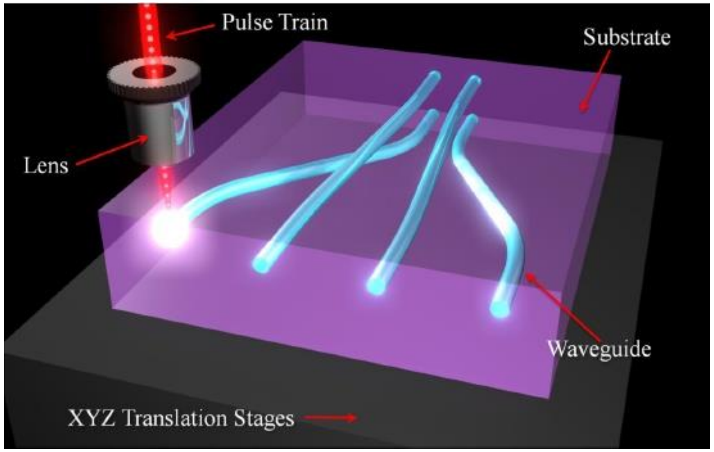
- **Micro Bragg antenna**

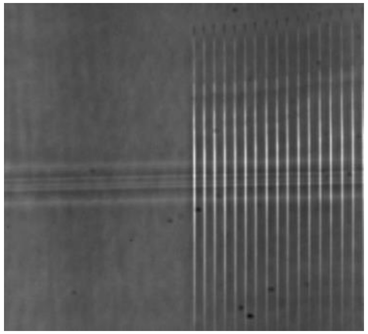


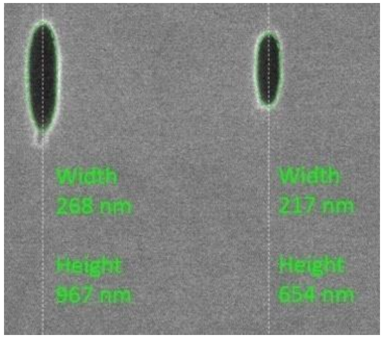
Few technologies can be used

- **DLW in glass**

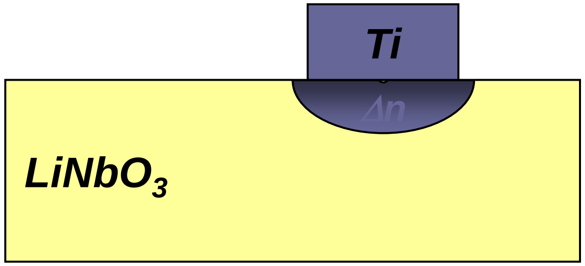
3D method
Long waveguide (few cm)
Control of the hole shape

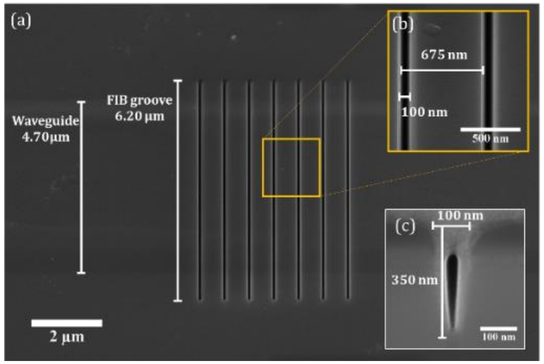




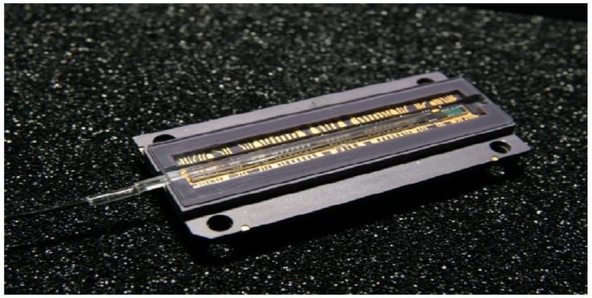


- **Lithium niobate**



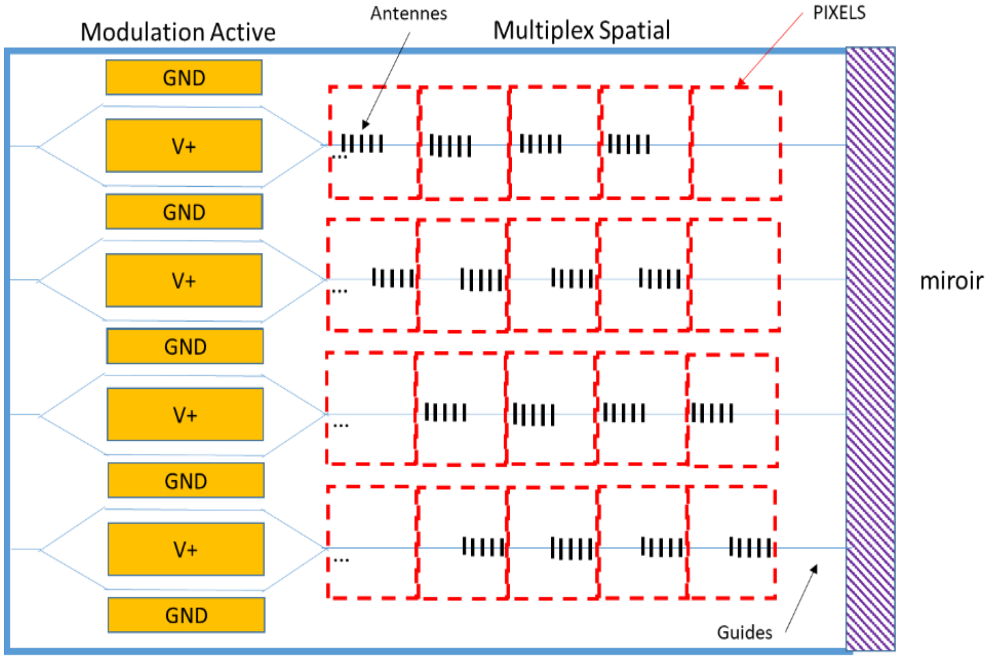


- **Ion exchanged in glass**

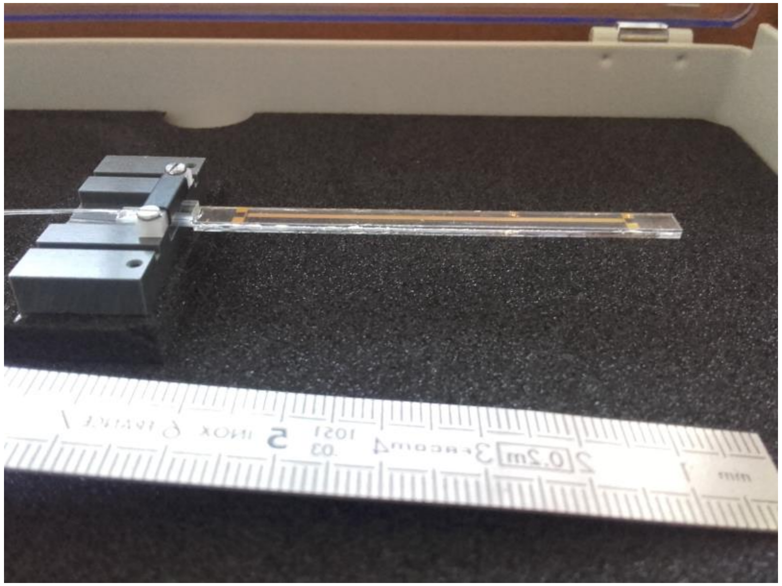


Time and spatial multiplexing

- **SIWFTS in LiNbO3**
  - Time multiplexing (EO modulator)
  - Spatial multilplexing (4 parallel waveguides with shifted antennas)



- **Chip without mirror pigtailed with 5 PM fibers**



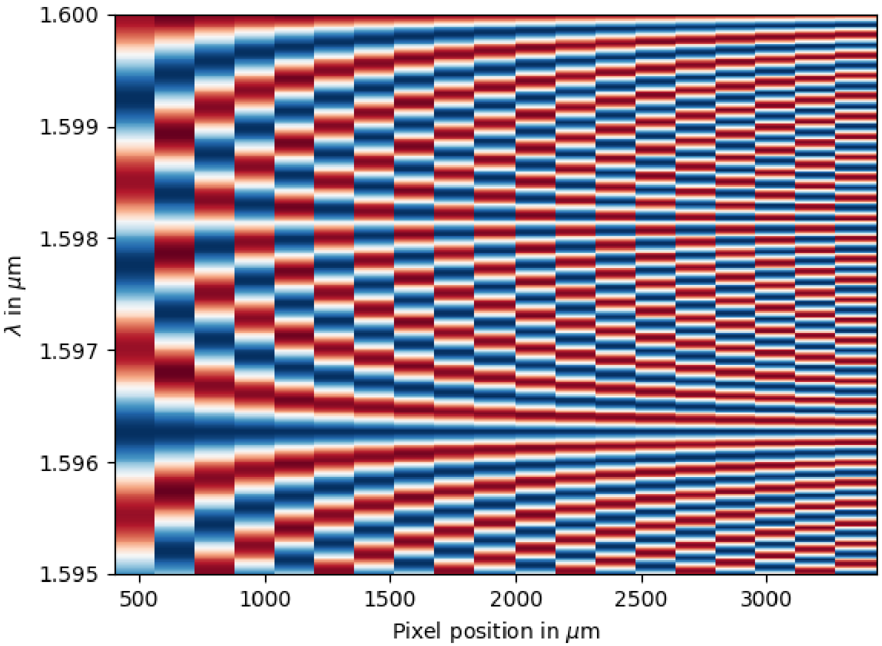
Modelization

- **Intensity evolution**

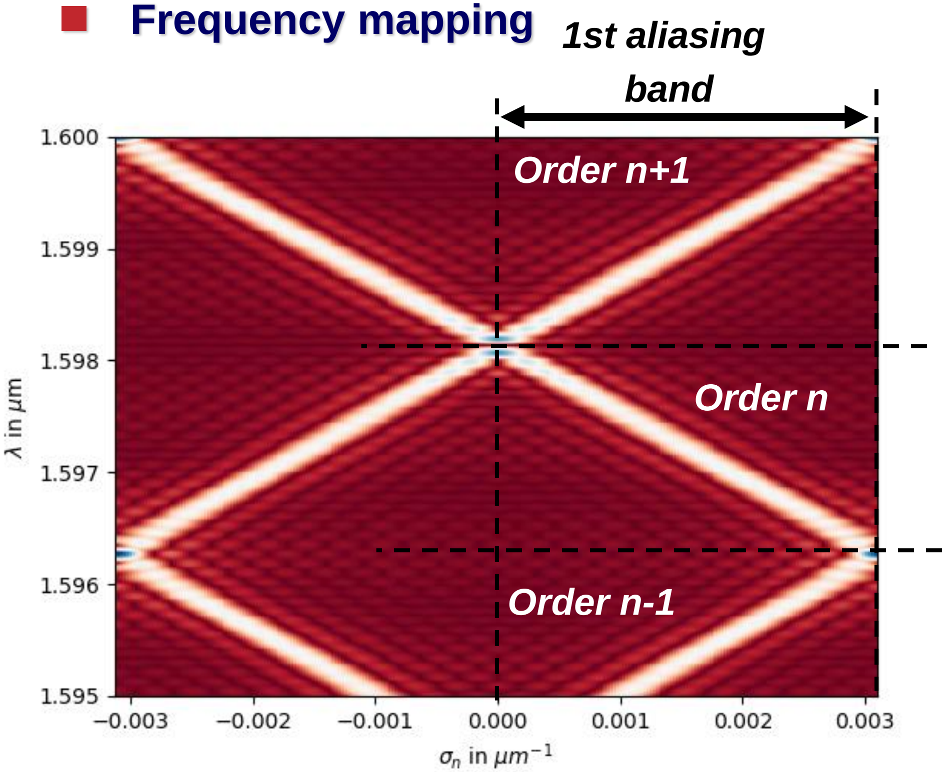
$$I(\lambda_0, z) = \left[1 + R - 2\sqrt{R}\cos\left[\frac{2\pi}{\lambda_0} n_{eff}(\lambda_0) 2 \cdot \underbrace{\Delta z \cdot N_b}_{position}\right]\right]$$

$R = 0{,}13$
$n_{eff} = 2{,}14$
$\Delta z = 160 \mu m$
$N_b = 20$

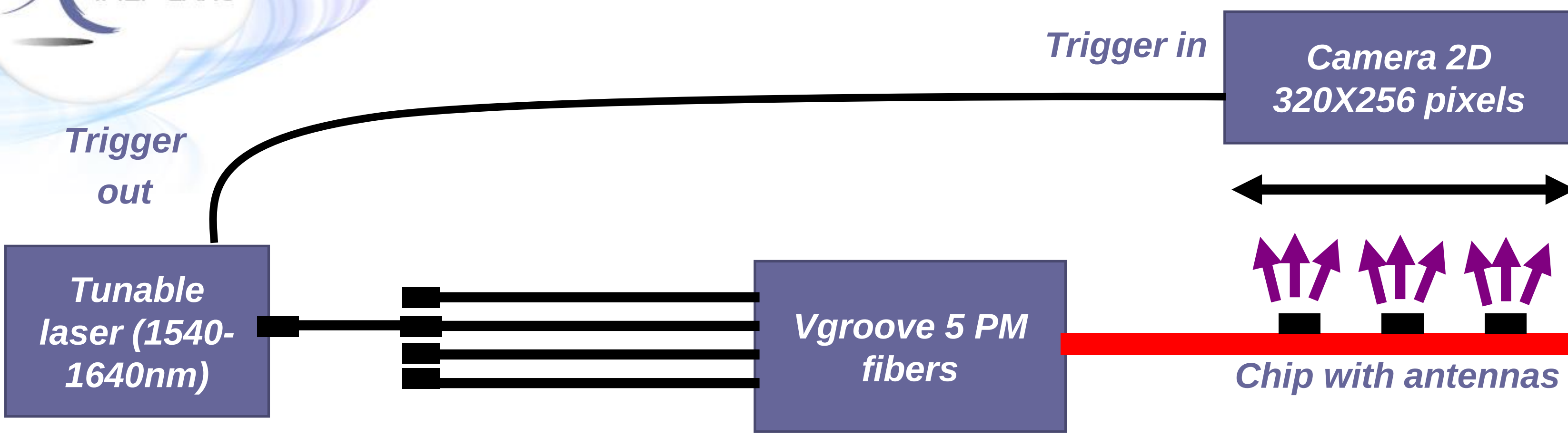
- **Spatial mapping**



- **Frequency mapping**

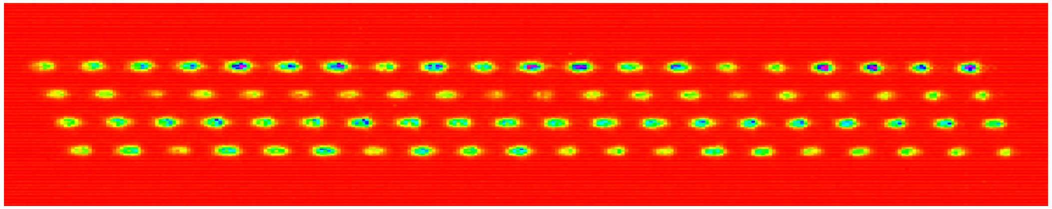


Measurement

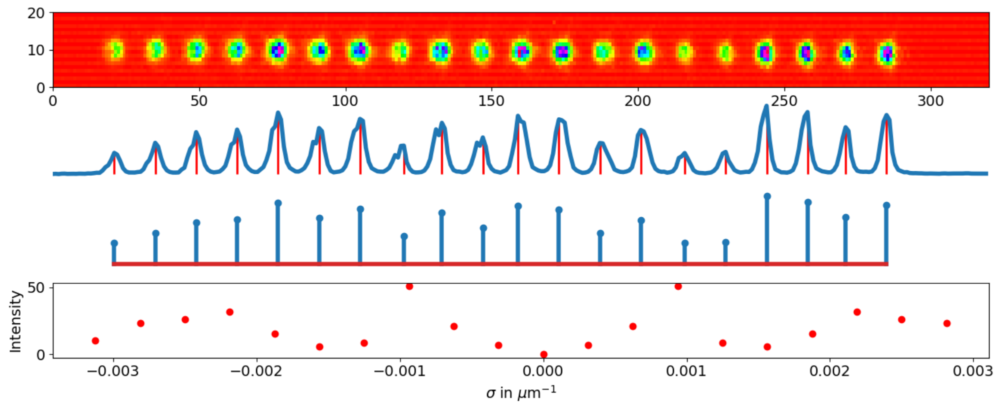


- **Image in the visible on one waveguide**

- **Image in the SWIR of the 4 waveguides**

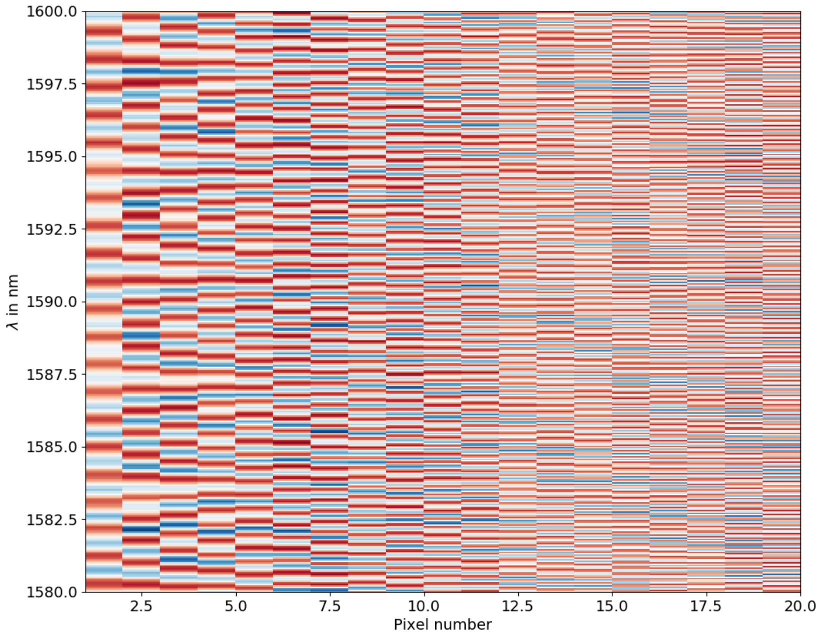


- **Data analysis**

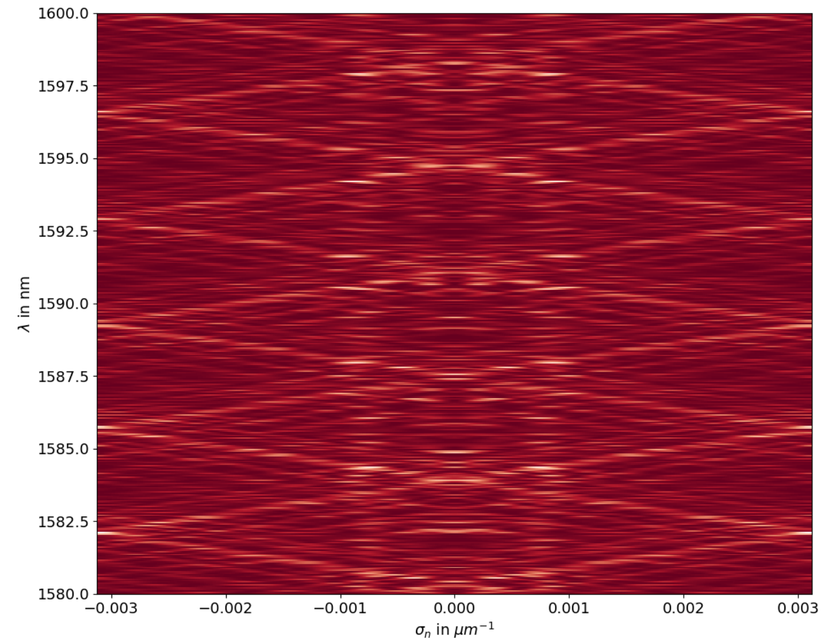


Results

- Spatial mapping over 20nm



- Frequency mapping over 20nm



- Low input power (~ - 10dBm) to avoid saturation
- Time step for the scan 0,1s

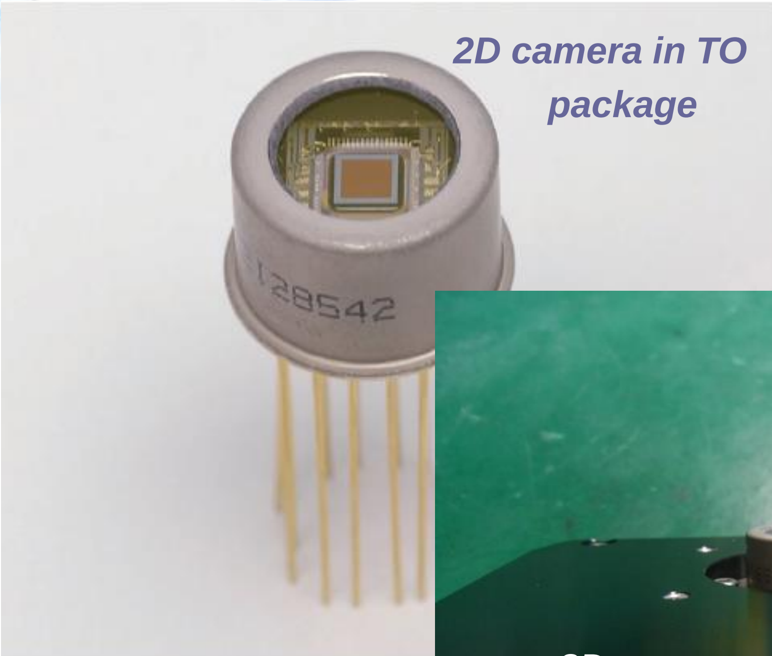
- Low frequency signal not expected

Results

- **Spectral resolution at 1,5 – 1,6µm:**
  - 0,180nm (0,173nm)
- **Bandwidth (First aliasing band):**
  - 1,80nm (1,73nm)
- **Reproductibility**
  - 1 of the 5 waveguides not efficient

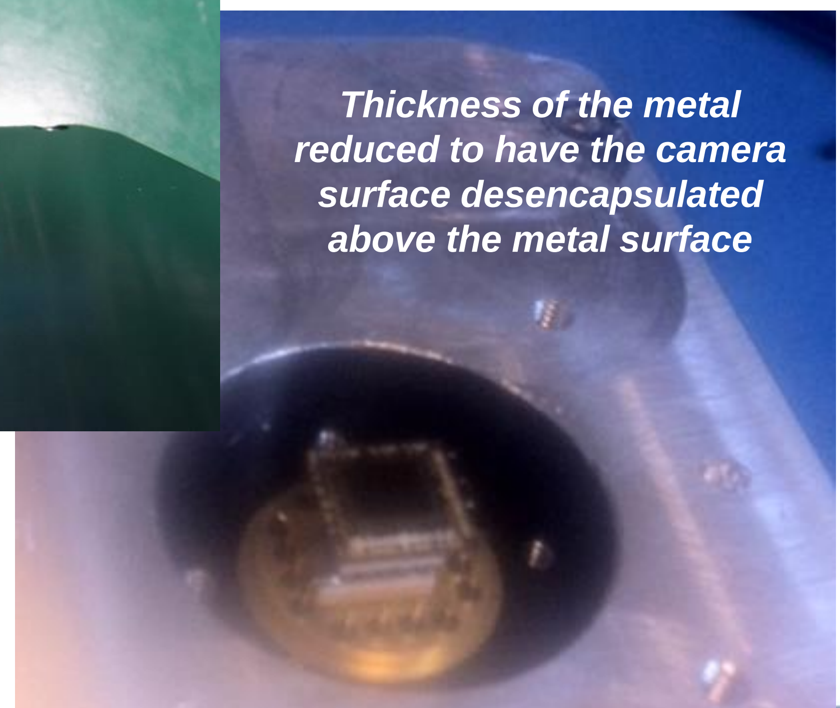
- **To do:**
  - Mirror deposition for a better contrast
  - Improved the numerical treatment
    - The real position of the antenna
    - The real efficiency of each antenna
  - Concatenation of the scattering of each waveguide (Spatial multiplexing)
  - Associated the chip with a desencapsulated camera
  - Test the electro optic effect (Time multiplexing)

Commercial 2D camera 128 x 128 pixels



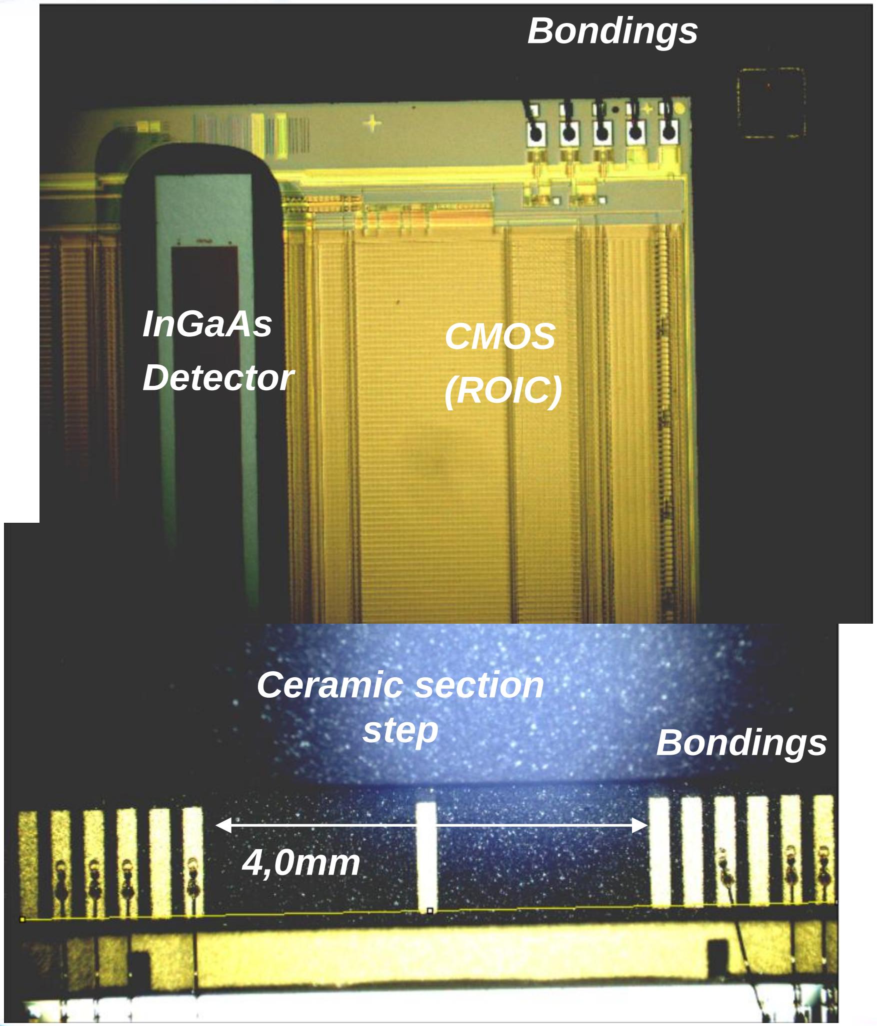
2D camera in TO package

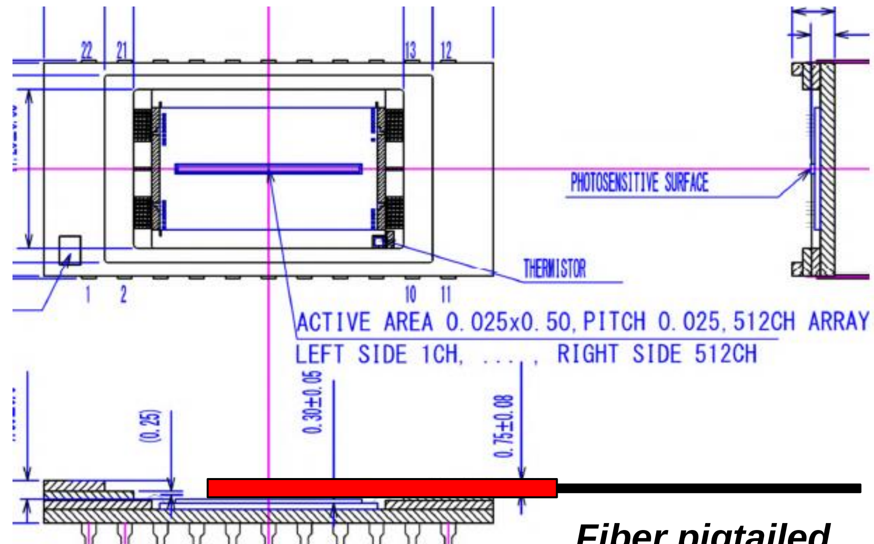
2D camera connected to the electronic module



Thickness of the metal reduced to have the camera surface desencapsulated above the metal surface

Linear detector 512 pixels

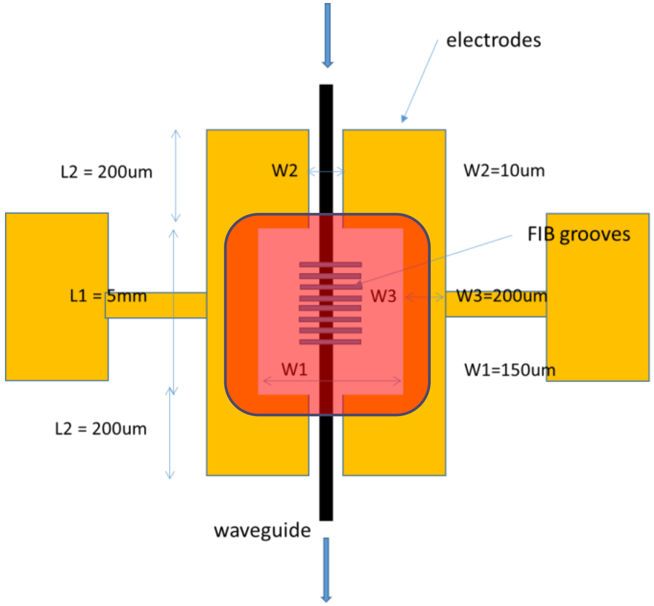


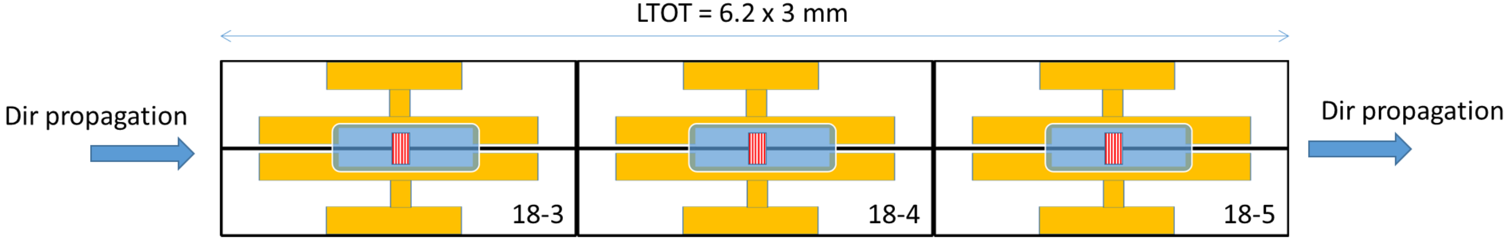


Fiber pigtailed to the chip set over the pixels

Realize the detector over the grating

- **Electrode connected to a PbSe detector principle**
- **Component realized in lithium niobate without the PbSe**





One detector by pixel

Project in progress

- **ED EEATS: PHD Myriam Bonduelle**
  - SWIFTS MIR in the wavelength range (3,4µm-4,1µm) in Chalcogenure glass or Lithium niobate
- **FOCUS support allowing techno runs and apprentice engineer**
- **External collaborations:**
  - FEMTO/ST in besançon (Lithium niobate Technolgoy)
  - LabHC in St-Etienne (DLW)
  - Salamanca university (DLW)
  - NIT(New Infrared Technology) in Madrid (PbSe detector)
- **Projet fund by the region (start in 01/22 for 4 years):**
  - With PHD funding: SWIFTS SWIR (ion exchange glass)
- **Recovery plan:**
  - 2 years post-doc (thermo optic effect on glass => time multiplexing)
- **Otpimized Antenna Geometry to enhance signal directivity and extracted power (Patent on going)**