Infrared transparent detectors

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Aligment in trackers

- Alignment of any (Silicon) tracker is crucial to obtain spatial resolutions comparable to the mechanical stability of the structures O(1-10 um)
- Offline software alignment (using tracks) needs reliable starting values, as provided by hardware alignment systems
- Laser system and:
  - Optical fiducials
  - Fully transparent detectors (amorphous silicon)
  - Silicon detector and IR laser (λ>1000nm)

Fully transparent detectors

- **Proposed in 1995 by W. Blum, H. Kroha, P. Widmann from MPI, Munich**
  - **Implemented in 2001**
  - **Used in many experiments (TESLA, CMS, ALIC, ATLAS, HERA-B, LHCb, ZEUS, ...)**
  - **Up to ten layers**
  - **Geometrical correlation with particle detectors**

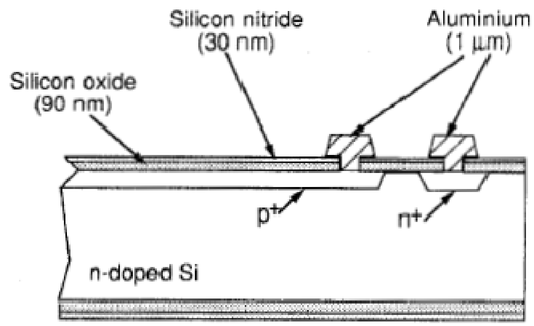


Fig. 3 Cross section of transparent crystalline silicon strip photodiodes (parallel to the p^+ strips).

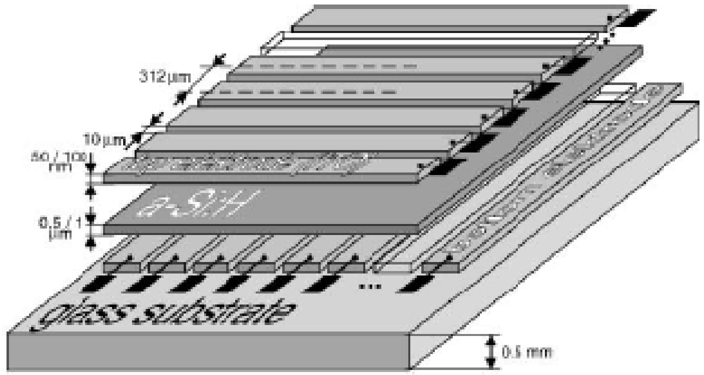


Fig. 1. Structure of ALMY sensors.

Silicon detector and IR laser

- Proposed in 1995 by W. Blum, H. Kroha, P. Widmann from MPI, Munich (in the same paper)
- Not implemented at that time (they used amorphous silicon)
- Claimed up to 71% transmission light
- Recently implemented in AMS and CMS
- Advantage: no geometrical errors, same detectors as particles.
- Problem: silicon not enough transparent

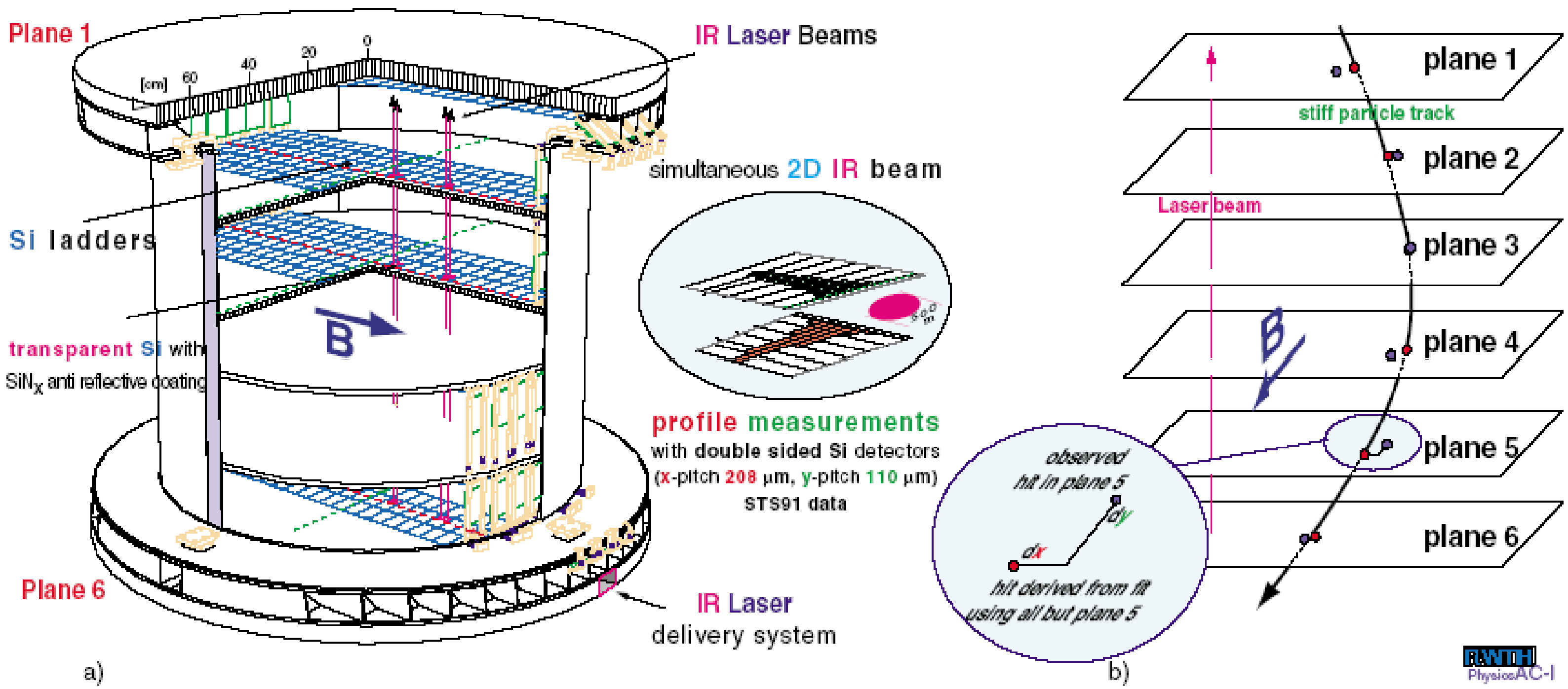
AMS alignment

- AMS novel Silicon alignment design used laser beams as straight tracks.
  - InfraRed Laser beams propagate through several Silicon modules
  - Silicon modules are made partially transparent to IR laser by removing (locally) the aluminum back metalization.
  - The modules need to be modified already at production time.
- The alignment of the CMS tracker has followed the same strategy.

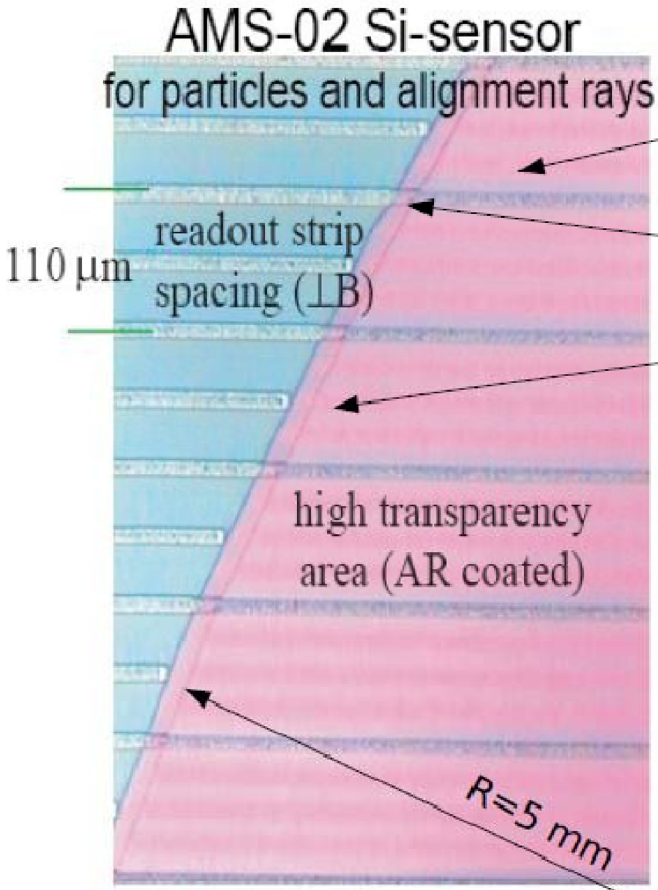
AMS alignment

- **Resolution better than 2 microns achieved**

AMS Laser & Cosmics alignment



AMS alignment



Features:

- Aluminum back electrode is removed locally near alignment passages
- RO strips thinned (12 µm→10µm) to increase Al-free area.
- Remaining strip (unbonded) implants have no Al
- Anireflection coating+(SiO_2,Si_3N_4) thickness tuned to reduce destructive interference of laser in the sensor multilayer structure, thus improving transmittance (%T)

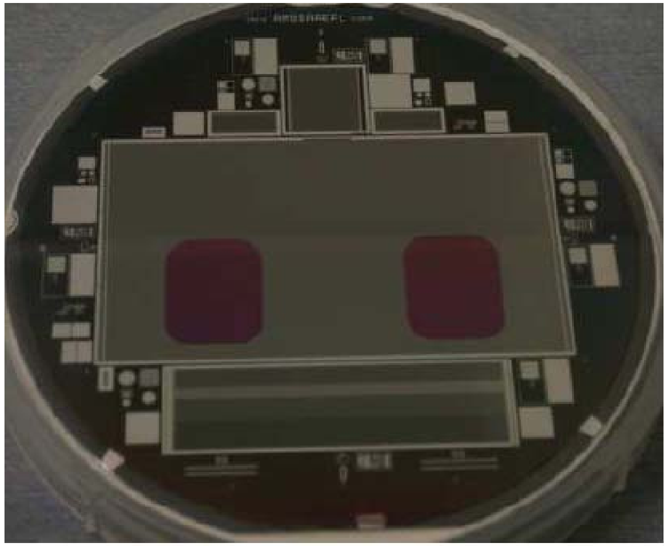
λ=1082 nm

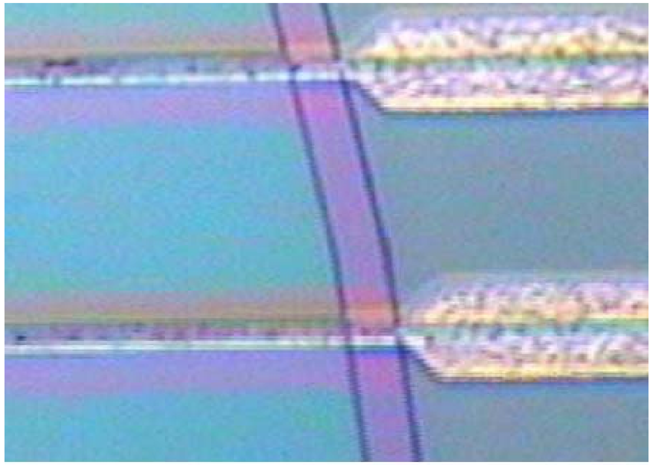
Transmittance≤ 50%
(Sensor was opaque with Al)

AMS alignment description:

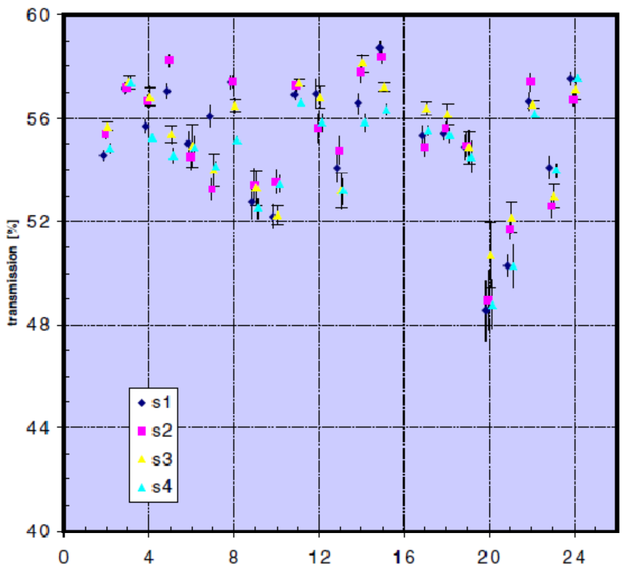
7th International Conference on Advanced Technology and Particle Physics, (ICATPP-7), Villa Olmo Como Italy 2001, M. Barone et al. (Eds.), World Scientific, Singapore 2002, ISBN 981-238-180-5. pp. 149-153

AMS alignment

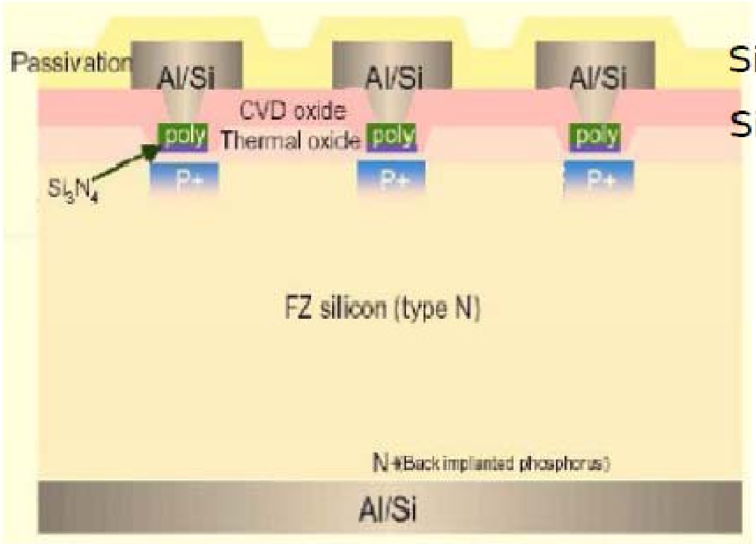




- Backside metal apertures
- Top side metal narrowing
- Transmittance distribution for a sensor batch (50-60%)



CMS alignment

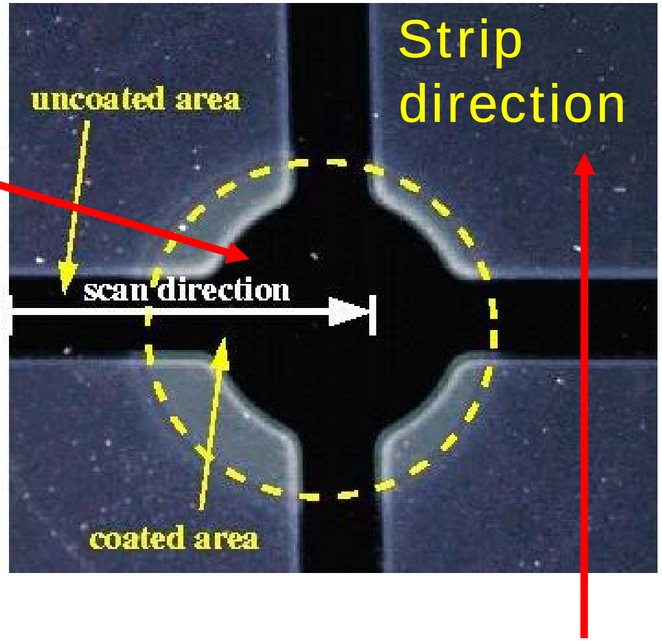


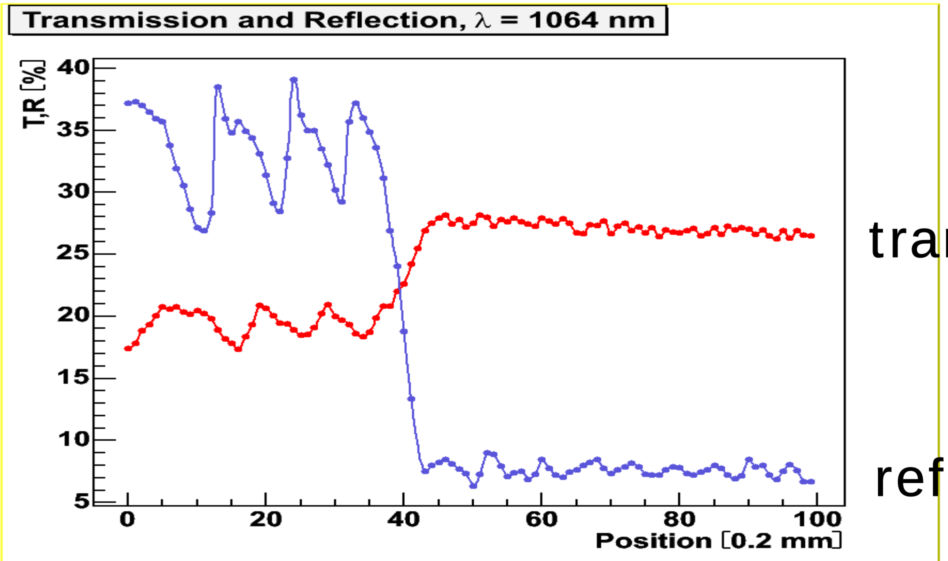
- Silicon alignment concept changed during the project.
- AMS scheme adopted:

- **Post-processing**
  - backside Al removal
  - backside ARC coating
  - Front side ARC reduced interstrip resistance ⇒ rejected Using a passivation (Si3N4) layer on top
- **Sensor design is proprietary information.**
  - CVD oxide: Probably SiO2 + Si3N4 passivation
- **Transmittance 14-20%**
  - (Sensor was opaque with Al)
  - λ=1075 nm
- **Reflectivity <= 6%**

CMS alignment

- **10 mm hole in aluminum backside coating**





R&D Goals

- **Optimize sensor layout and technology design to achieve maximum transmitance**
  - **Reflectance should be close to zero**
  - **Some absorbance is needed to have signal**
  - **Target: T = 70%**

Layout optimization

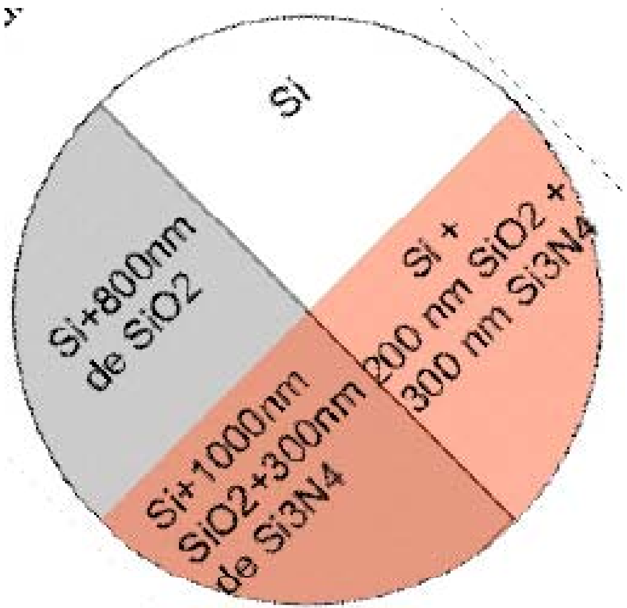
- **Reduce surface covered by metal (aluminum)**
- **Options:**
  - **Use semi-transparent coatings**
  - **Use ITO (or similar) transparent coatings**
  - **Use semitransparent doped polysilicon**

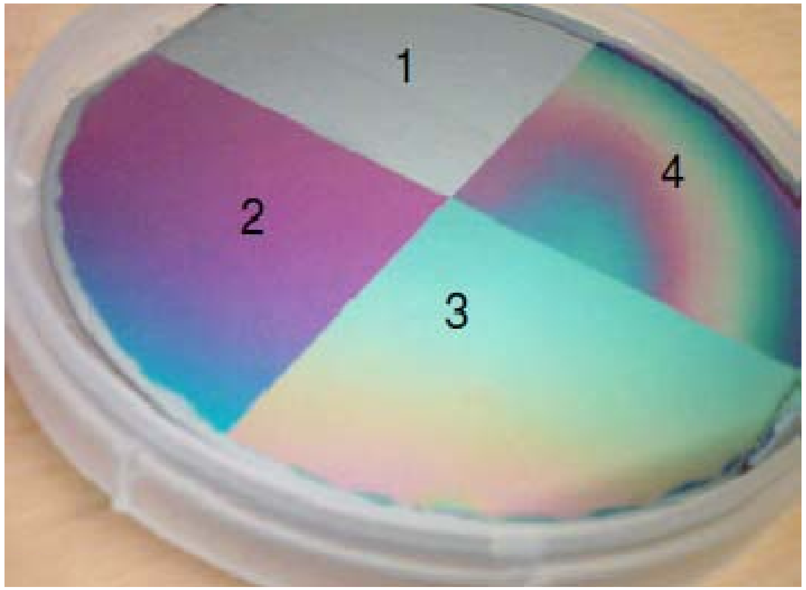
- **We have selected**
  - **Just geometry: reduce metal area**
  - **Apertures in the back**
  - **Narrow metal (3 μm) in the strips**

  - **We have simulated the effect of metal narrowing in electric field ⇒ no problem**

Technology optimization

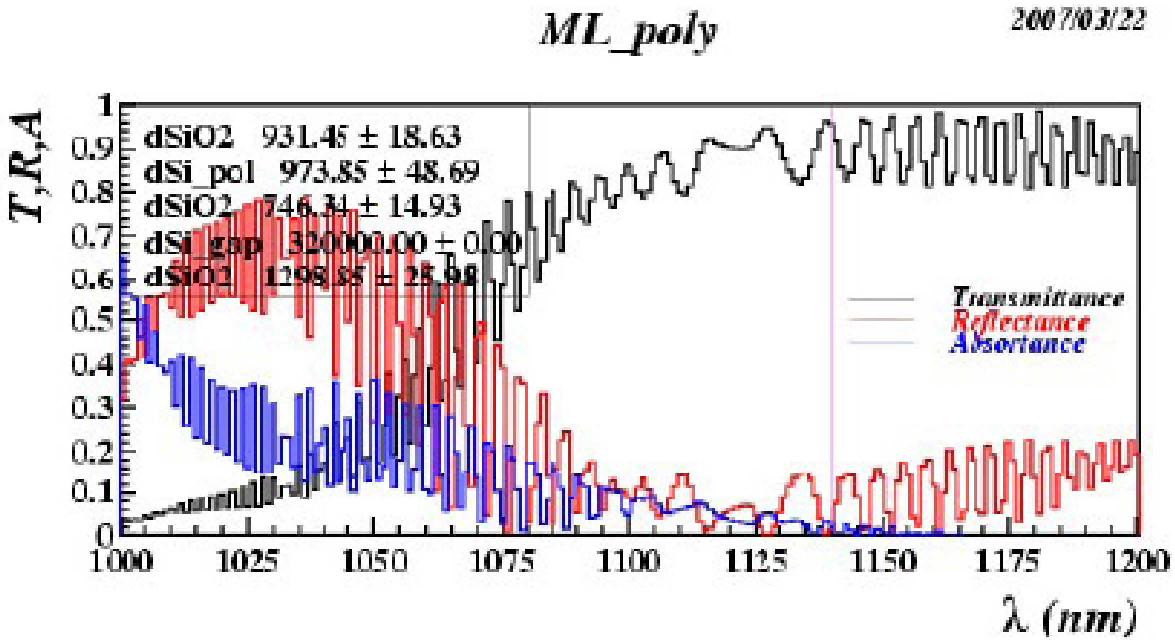
- **Optical simulation of microelectronic layers at IR wavelengths**
- **Proposed laser λ = 1140 nm**
- **No data published for Si at that wavelength**
  - **Intensive characterization with test samples**





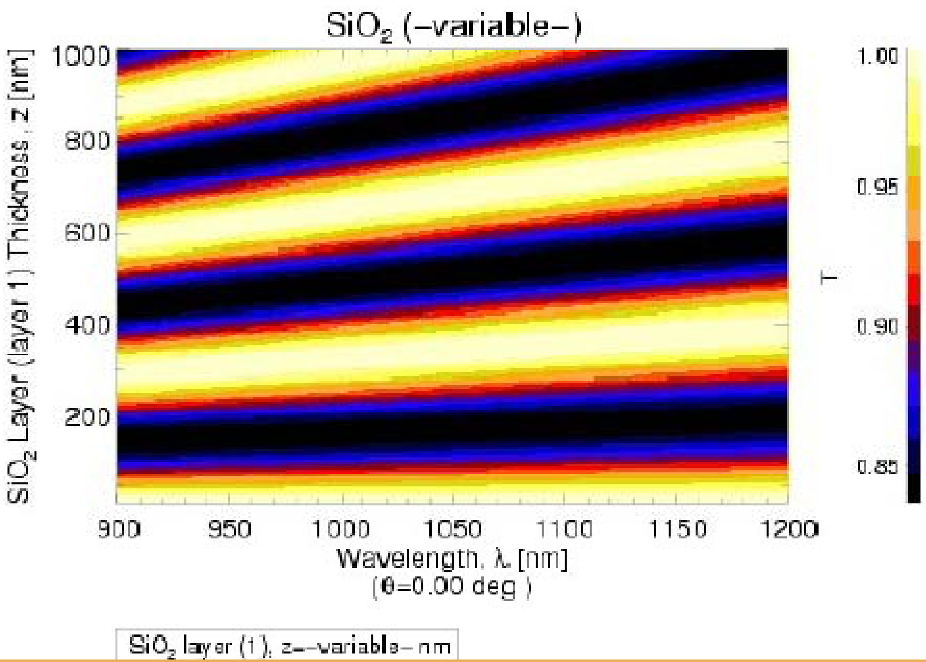
Optical optimization

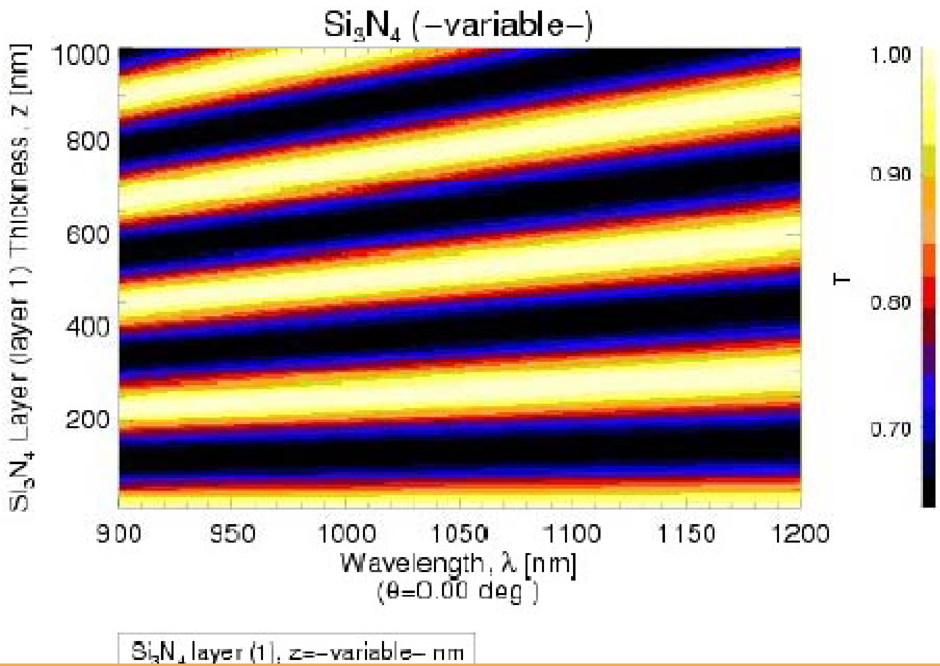
- **Microstrip module as a multilayer media**
- **Optical characterization: elipsometry, reflectivity, transmitted beam reflection.**
- **Compare results with very detailed sensor optical simulation.**
- **Optimize sensor structure and coating for laser detection.**



Optical optimization: process variations

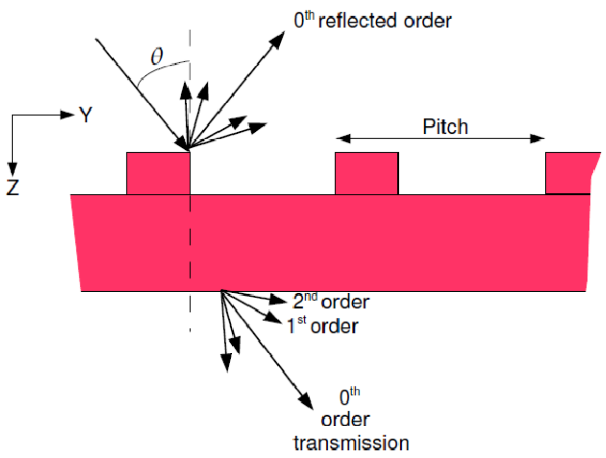
- **Effect of process thickness variations**
  - **Up to 20%**
- **Goal: robust design**
  - **Not the maximum transmittance, but constant intra- and between wafers**

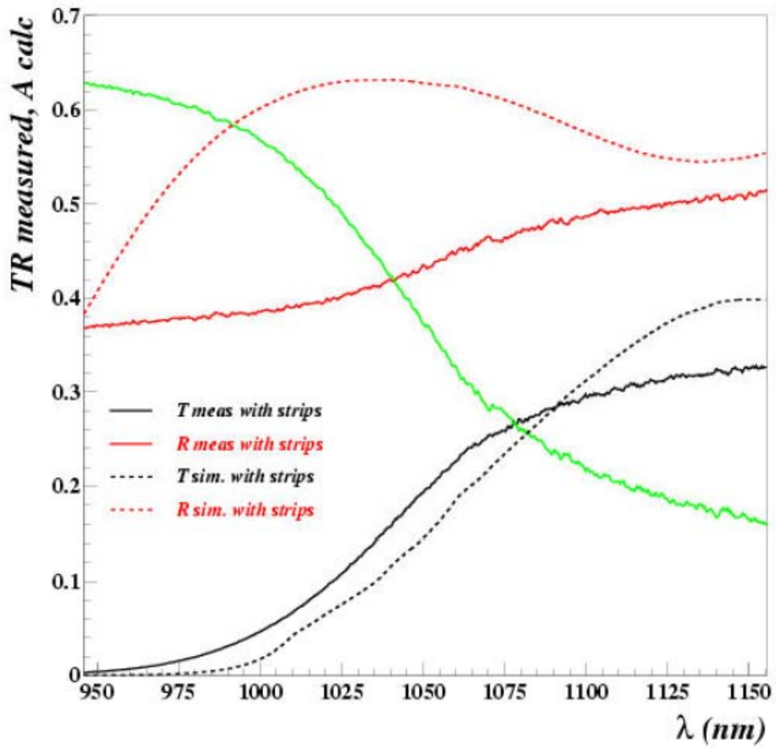




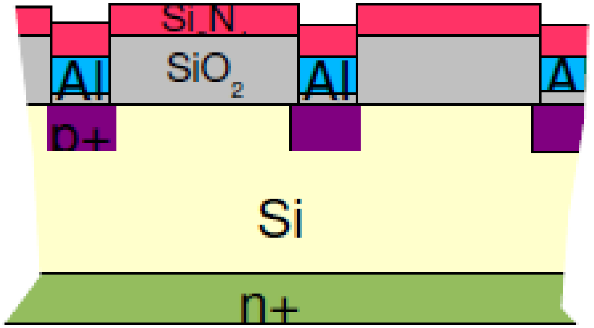
Optical optimization: 2D structure

- **Effect of diffraction in metal strips**
  - **2D optical simulators**
- **Very difficult simulation**

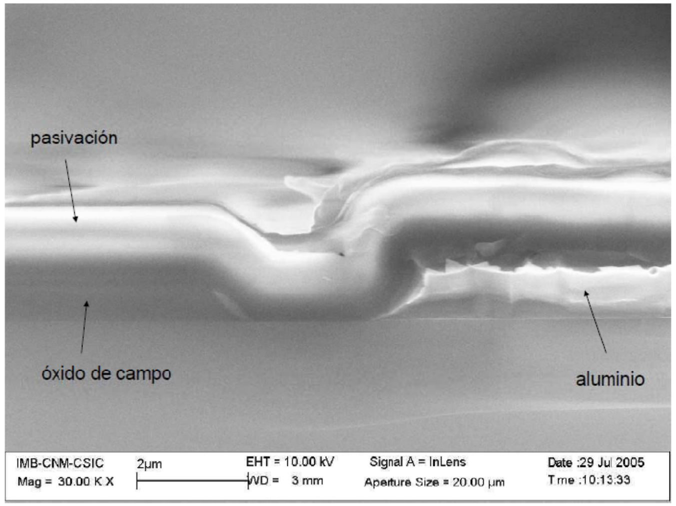




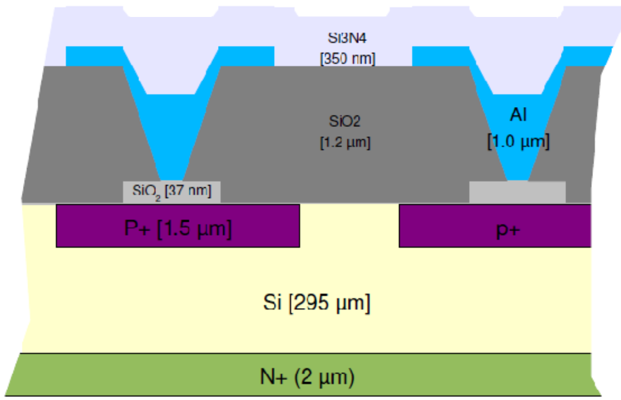
Accurate optical modeling



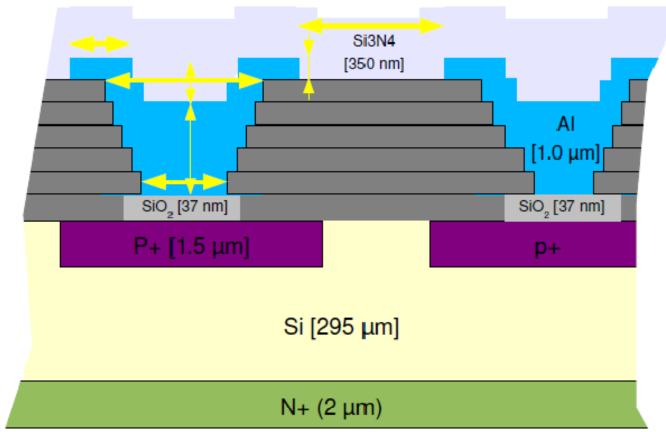
Simplified model



Actual profiles

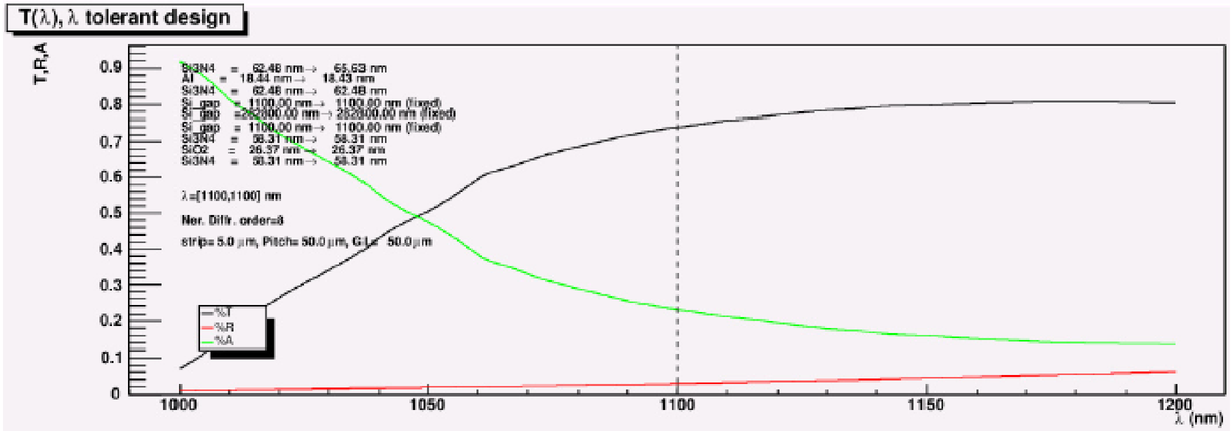


Profile approximation



Profiles for optical simulator

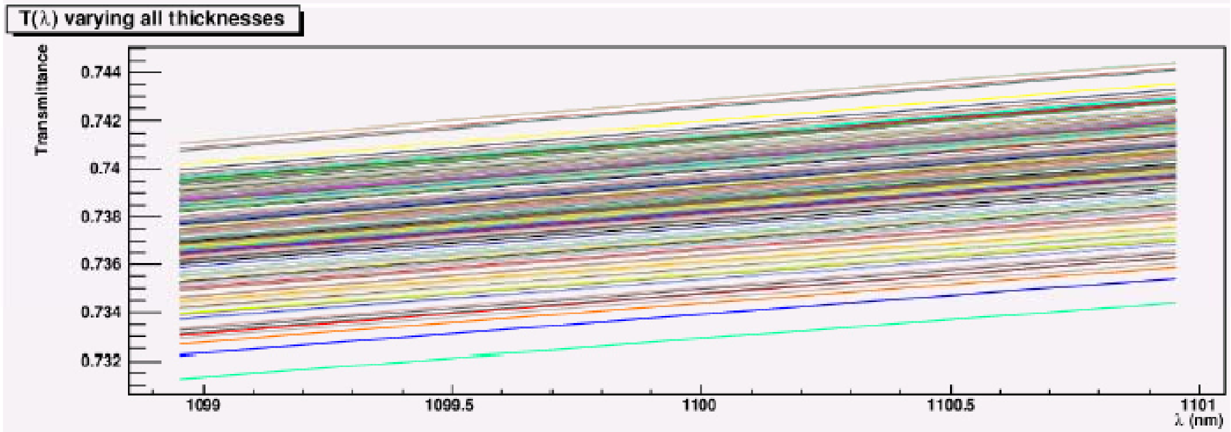
First (optimistic) results



Transmittance

Absorptance

Reflectance



%T for configurations where all thicknesses but Silicon have been randomly varied by 2%

$d \rightarrow d \pm \sigma_d$

Robust configuration: $\Delta T/T = 1.4\%$ if $\Delta d/d = 2(\%)$

In other words, ΔT does not go below 0.7

Only simulated 0^{th} diffraction mode. Actual %T is even higher!!

Conclusions

- With the Physics Institute in Santander, Spain (IFCA-CSIC) we are developing strip detectors as transparent to IR light as possible for direct alignment.
- The design is both geometrical and technological
- It is based in very accurate optical simulations
- We are experiencing many difficulties:
  - Optical properties not published for the materials used
  - 2D optical simulators hard to use
  - We have to cope with normal fabrication tolerances (up to 10-20%)
- First optimistic results achieved
- Target: T>70%, R<5%
- New mask design started
- Samples processed next year