First manufactured diamond AGPM vector vortex for the L- and N-bands: metrology and expected performances

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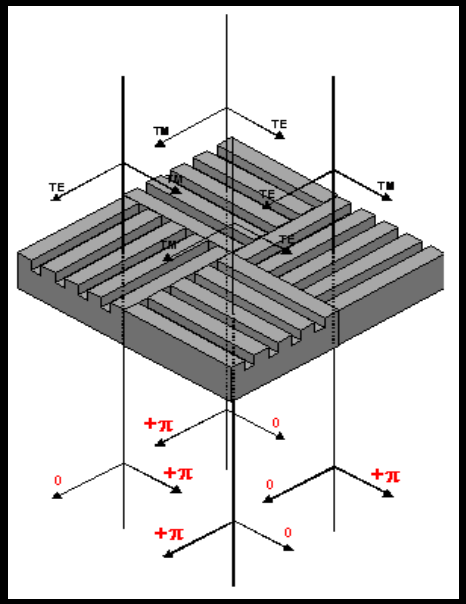
In the Spirit of Lyot, 28/10/2010

HOLOLAB – Optics laboratory

University of Liège

The Annular Groove Phase Mask (AGPM)

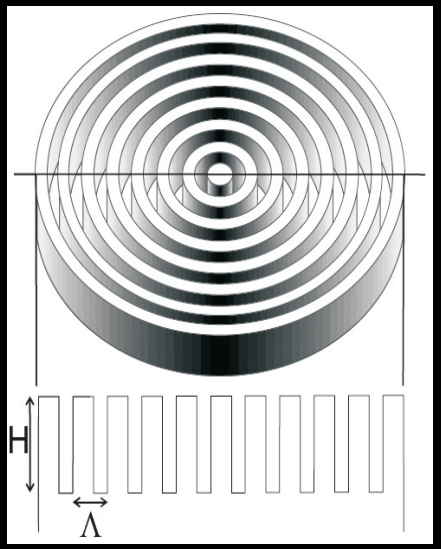
- Proposed by Mawet et al. 2005
- Zeroth Order (sublambda => period < λ/n) Grating (ZOG)
- Form birefringence → $\Delta\Phi_{TE\text{-}TM} = \pi$ → phase retarders
- Achromatic on wide spectral bands (in the visible or IR)

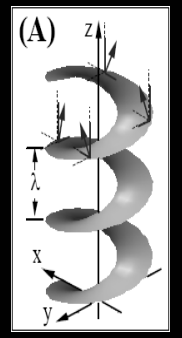


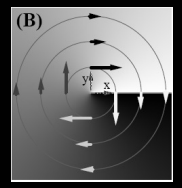
FQPM *(Four Quadrant Phase Mask)*

Vector Vortex Coronagraph (VVC)

360° discovery space







AGPM *(Annular Groove Phase Mask)*

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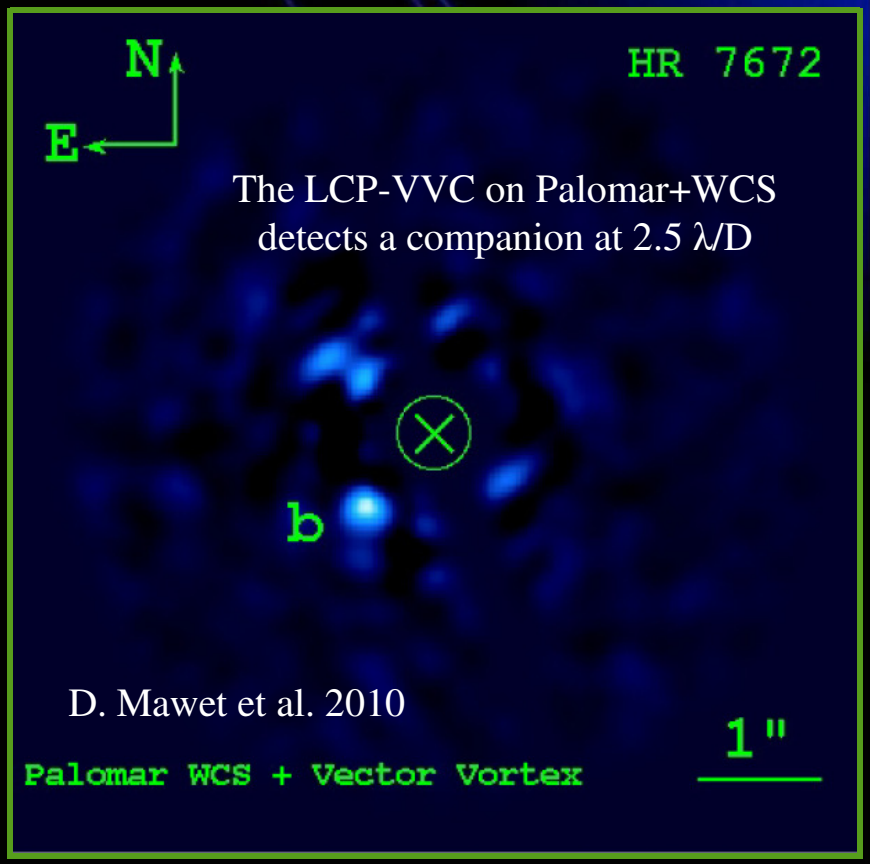
Which spectral band ?

Other techniques for VVCs exist, e.g.
- liquid-crystal polymers (LCP), Mawet et al.
- photonic crystals, Murakami et al. (cf. poster 8.7)

☺ lab demos in the visible and near-IR
☺ LCP used on Palomar in the H- and K-bands
☹ technically limited to the visible/near-IR

In fact, these are limited to the visible and near-IR whereas the AGPM is suitable for any spectral band, from the visible to the thermal IR



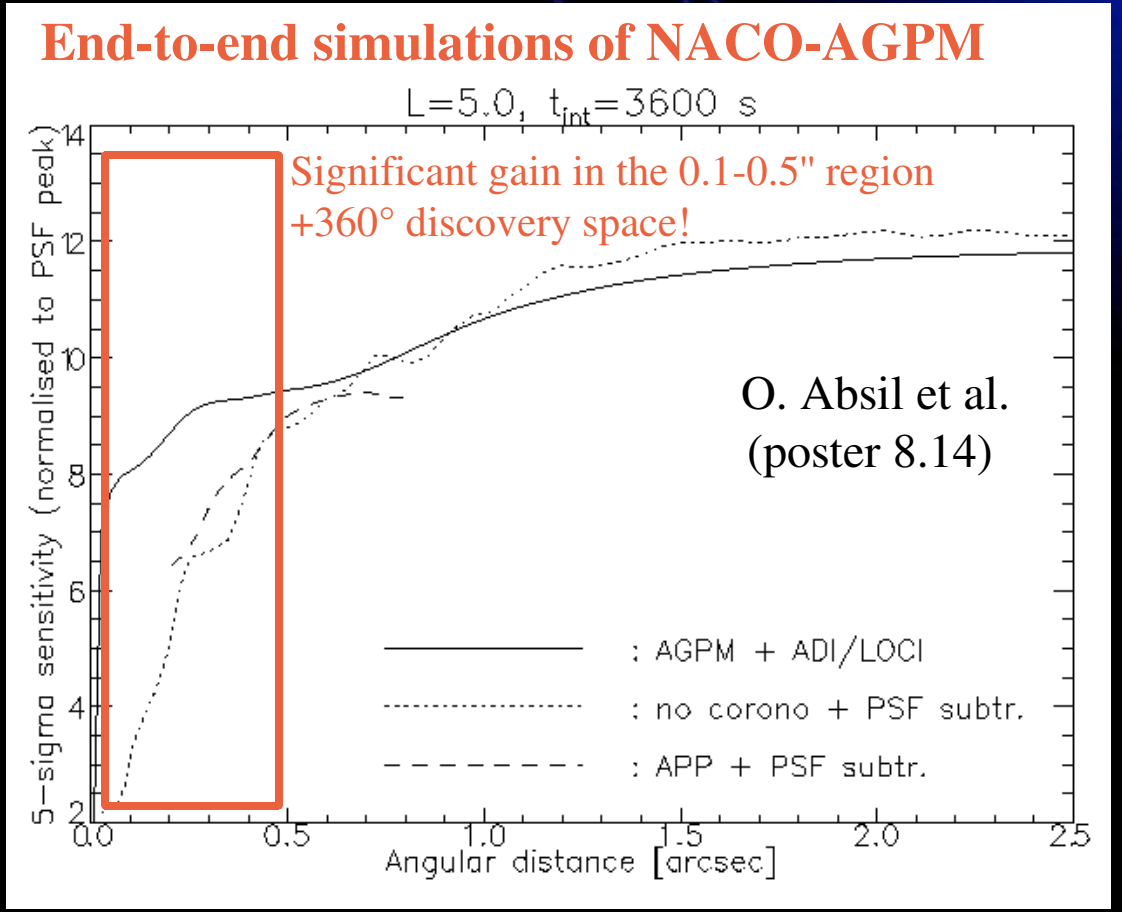
Which spectral band ?

L-band (3.5 – 4.1 µm)

- recent success with NAOS-CONICA (Lagrange et al. 2010)
- significant gain in the 0.1-0.5" region, compared to APP+PSF substraction, Absil et al. (cf. poster 8.14)

N-band (8 – 13 µm)

- the AGPM is foreseen for the upgrade of VISIR, and candidate for METIS on the future E-ELT
- subwavelength gratings are one of the only solutions at this wavelength



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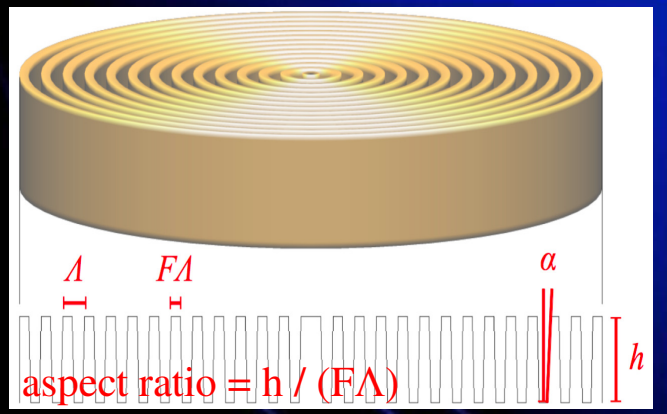
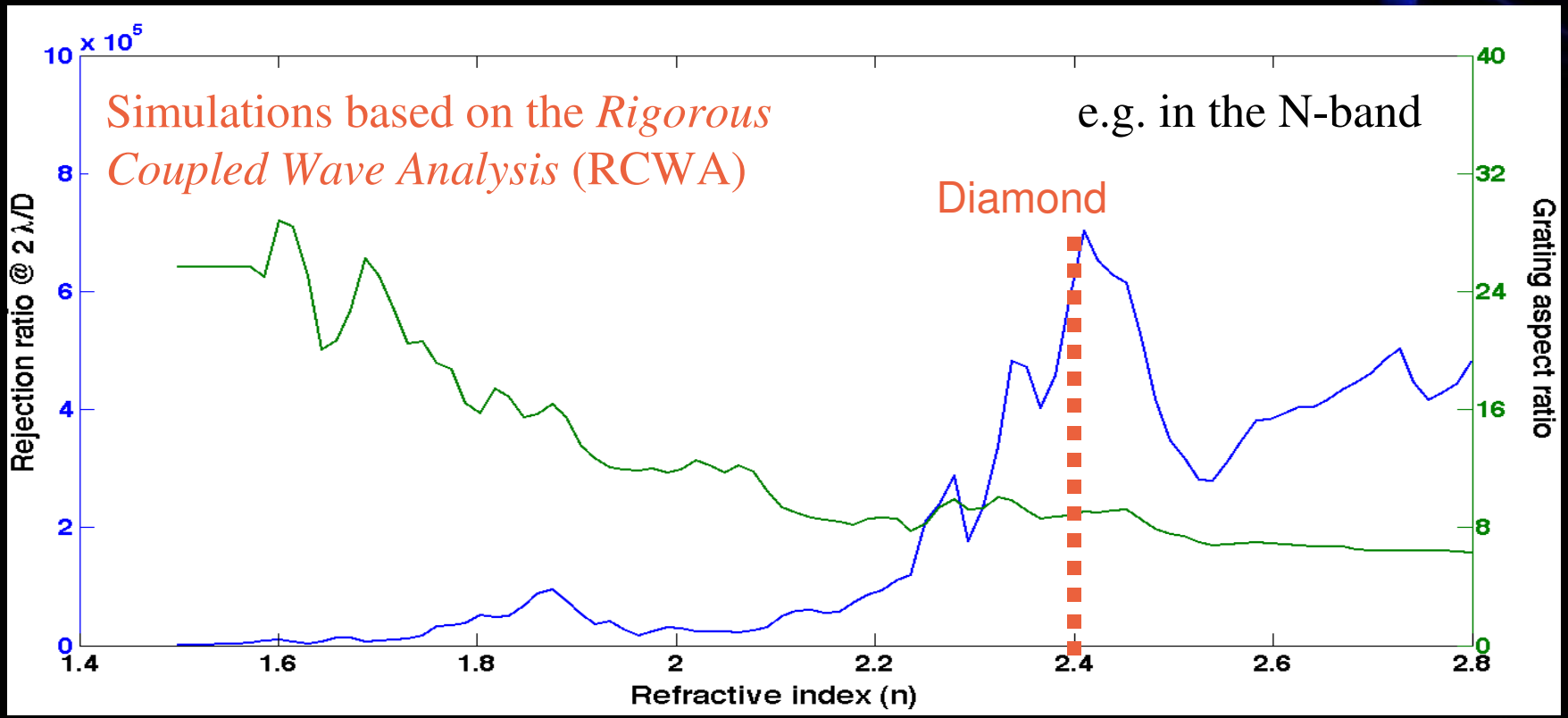
Which substrate material ?

CVD diamond

☺ large spectrum : from visible to thermal-IR (~ 20 µm)
☺ favorable mechanical and thermal properties
☺ high refractive index = shallow etching





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First manufactured diamond AGPM

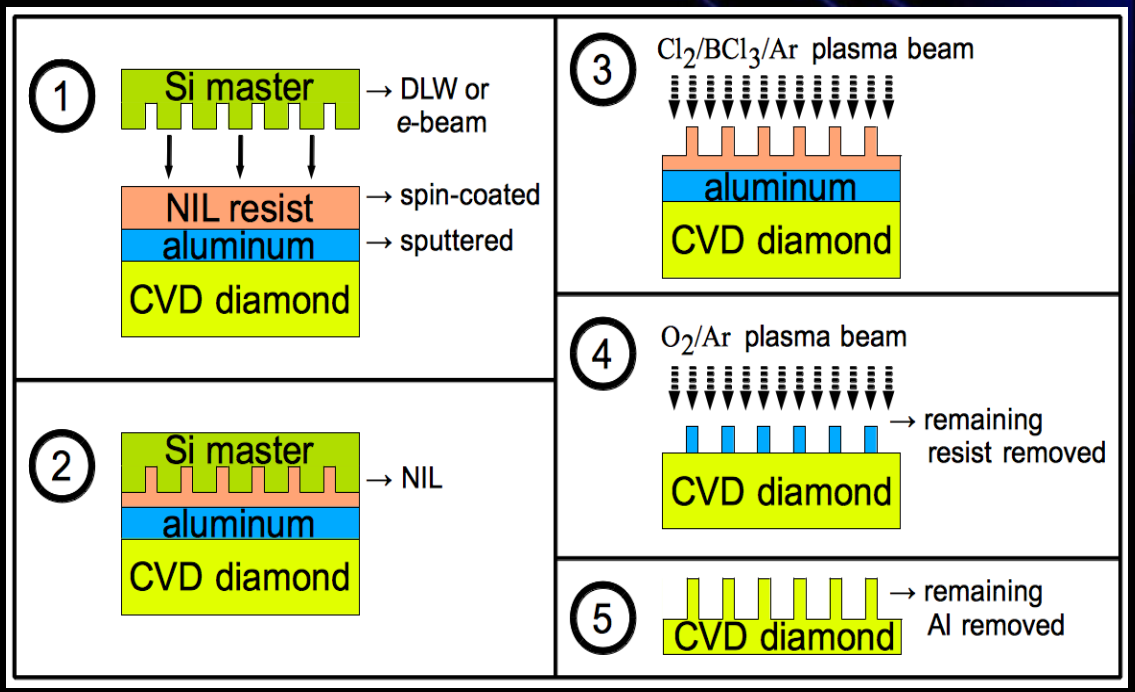
Manufacturing process

Inter-University collaboration:

- e-beam mask, University of Joensuu, Finland (Pr. M. Kuittinen)

- Nano-Imprint Lithography (NIL) and Reactive Ion Etching (RIE), University of Uppsala, Sweden (Pr. M. Karlsson)

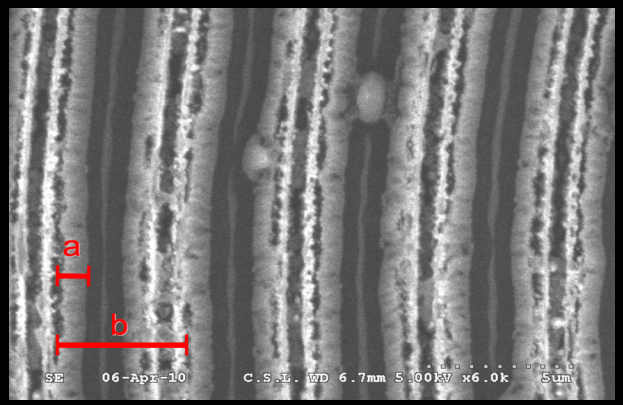
- Metrology and optical testing, University of Liège, Belgium (Pr. S. Habraken)

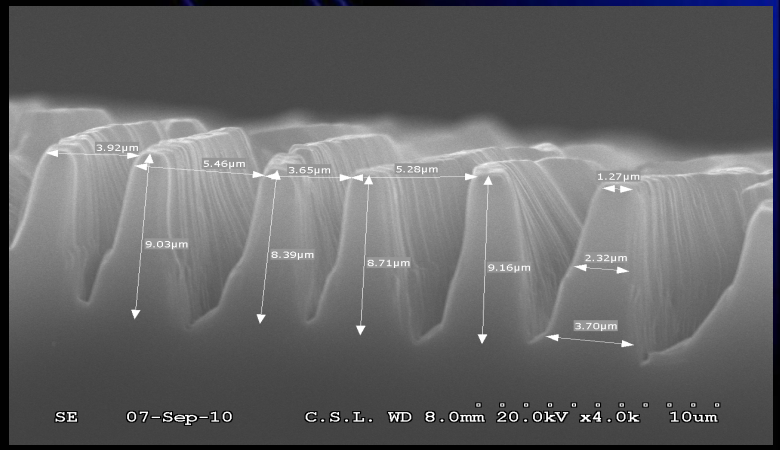


First manufactured diamond AGPM

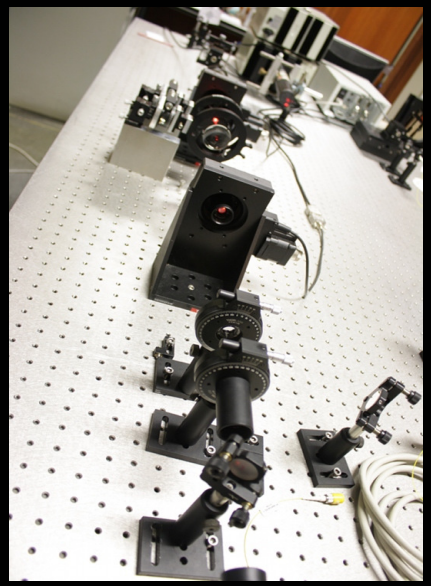
Classical metrology + moulding

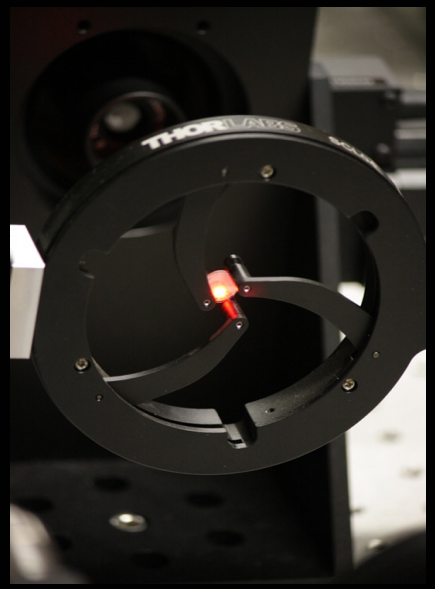
- interferometry
- SEM, AFM
- PDMS moulding
- profile metrology

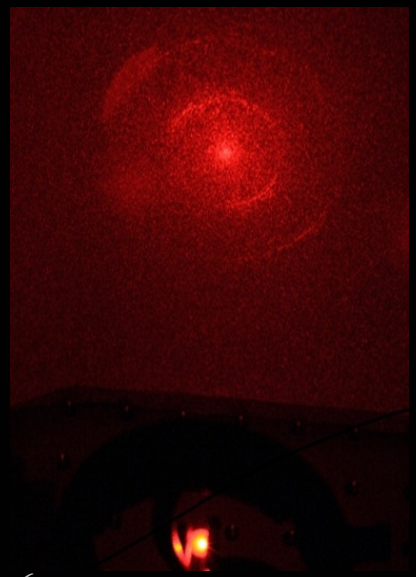




Diffractometry + scattering measurements







- optical bench
- HeNe laser (632.82 nm)
- 5 orders
- total integrated scattering (TIS) = < 0.4% (N-band) < 2.3% (L-band)

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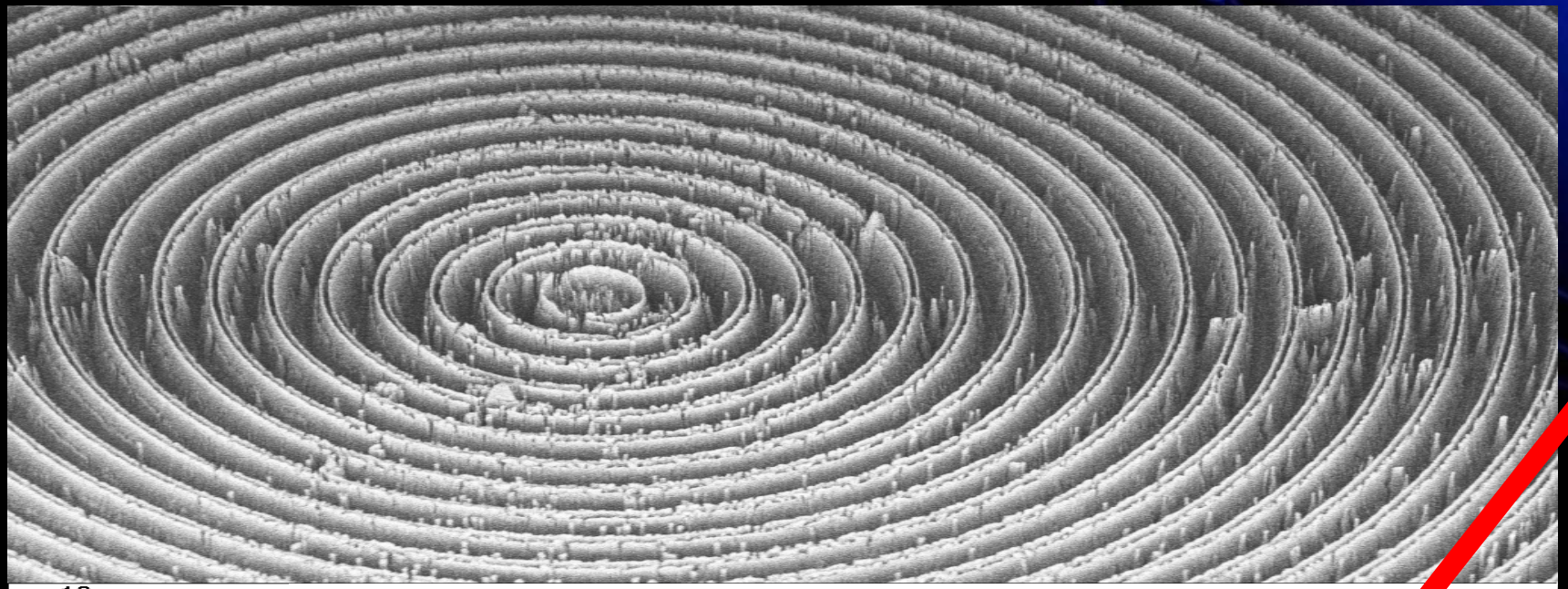
First manufactured diamond AGPM



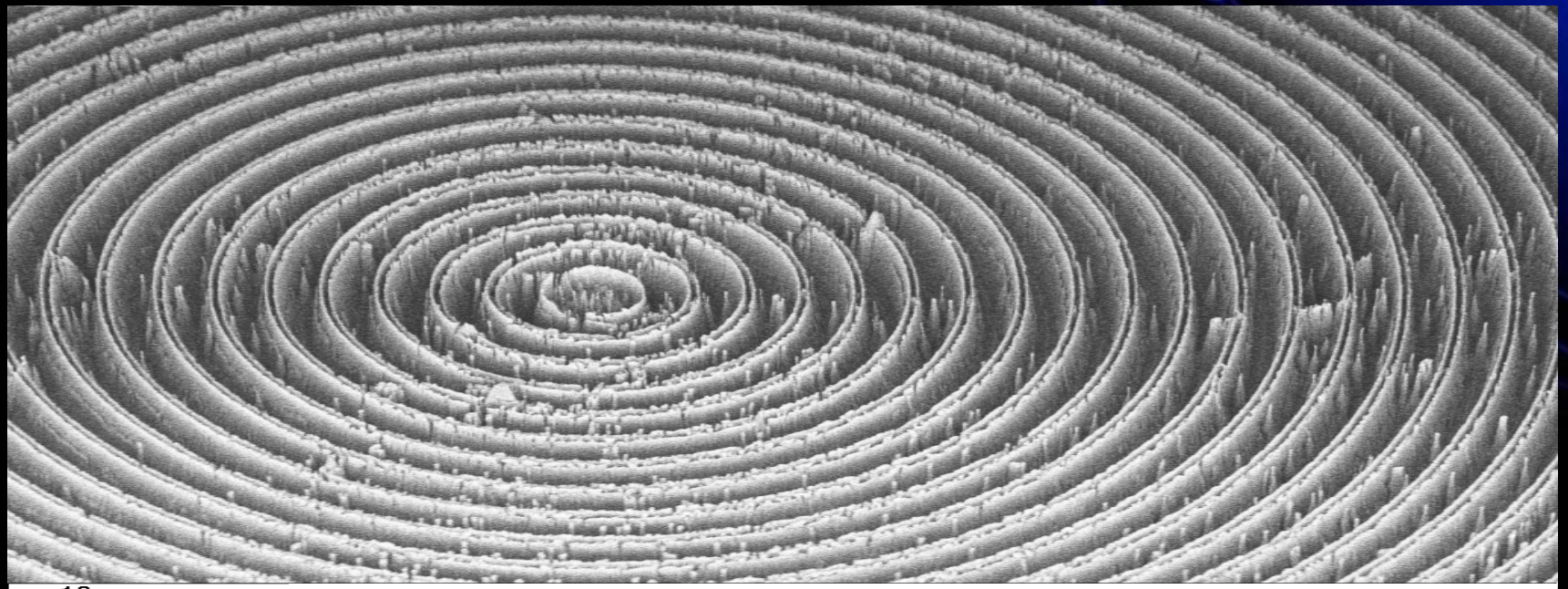
First N-band prototype (SEM picture)

- optimised for [10.5µm – 12.25 µm]

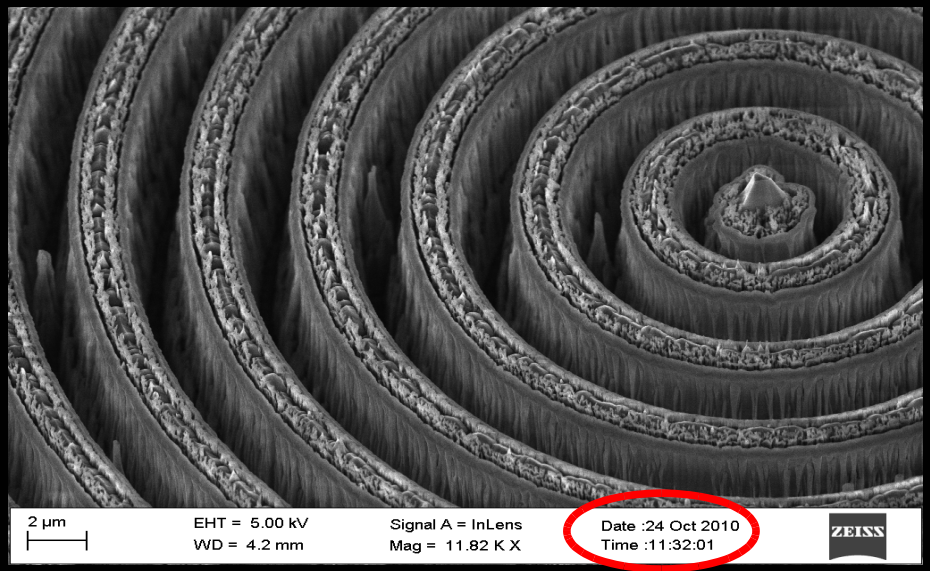
- performances simulated with RCWA, mean Null Depth @ 2λ/D
  - near the center: $\mu \approx 10^{-5}$
  - away from the center: $\mu \approx 10^{-3}$

- poor optical quality in the area away from the center
- inhomogeneous depth
- NIL hard to masterize on small substrates (1cm diameter)

First manufactured diamond AGPM



First N-band prototype (SEM picture)



→ NIL process improved
→ walls completely filled
→ better roughness
→ homogeneous on the whole substrate
→ next : bigger substrates (2cm diam)

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Components currently being manufactured

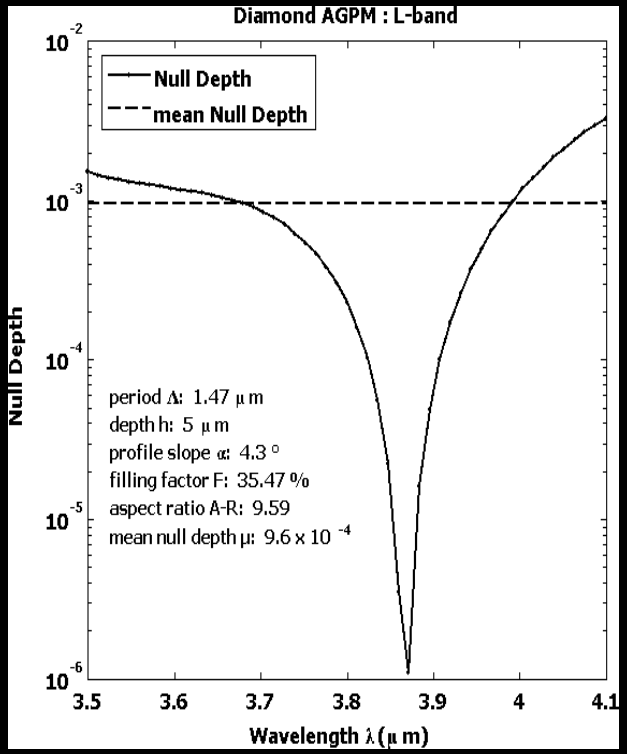
L-band

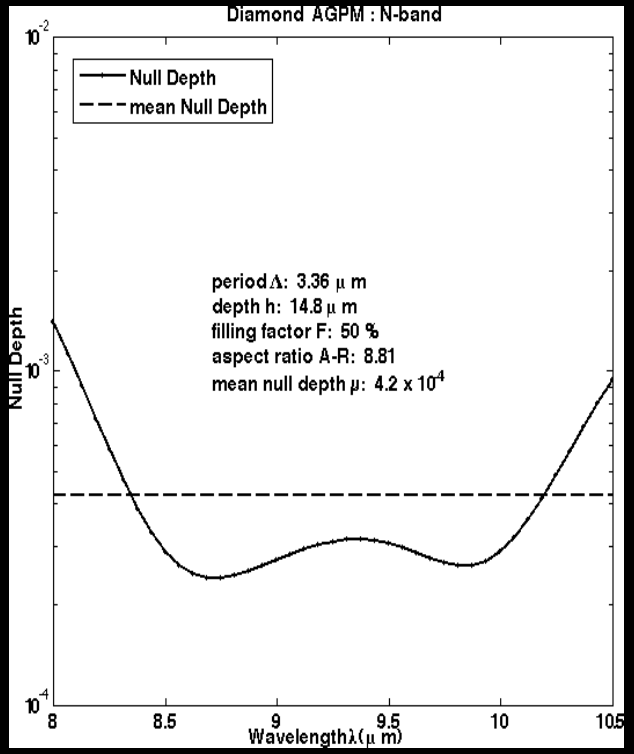
- [3.5 µm – 4.1 µm]: $\mu \approx 5 \times 10^{-6}$ @ $2\lambda/D$

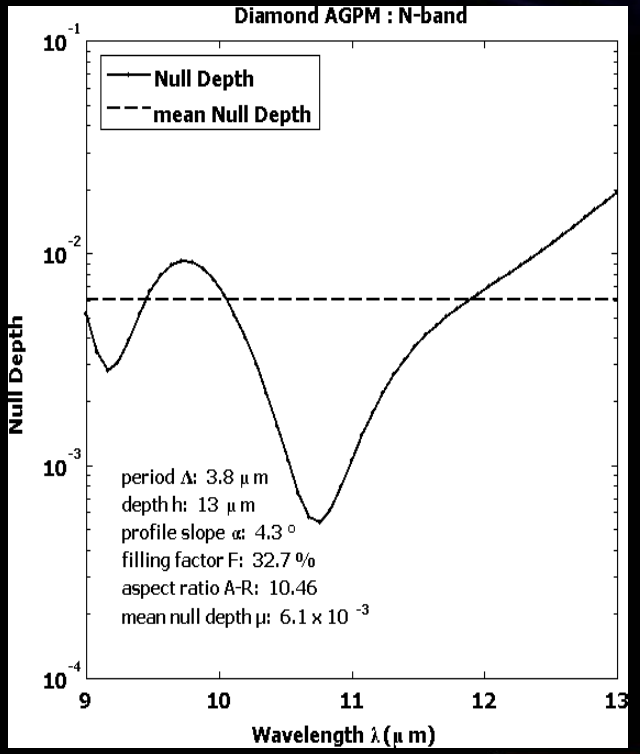
N-band : 2 components

- [8 µm – 10.5 µm]: $\mu \approx 2 \times 10^{-6}$ @ $2\lambda/D$
- [9 µm – 13 µm]: $\mu \approx 3 \times 10^{-5}$ @ $2\lambda/D$

→ RCWA simulations :







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Summary

- The first diamond prototype has been manufactured
- Good metrology → parameters well known
- Possible use on the sky with the future upgrade of VISIR at [10.5µm – 12.25 µm] with an expected $\mu \approx 10^{-5}$ @ $2\lambda/D$
- Lessons learned, microfabrication techniques improved
- Next components are curently being manufactured with expected performences $\mu < 10^{-5}$ @ $2\lambda/D$
- We focus on the L-band for NACO where the AGPM is very promising

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Thank you for your attention !