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


In the Spirit of Lyot, 28/10/2010
The Annular Groove Phase Mask (AGPM)

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

FQPM (Four Quadrant Phase Mask)

Vector Vortex Coronagraph (VVC)
360° discovery space
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 subtraction, 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

End-to-end simulations of NACO-AGPM

Significant gain in the 0.1-0.5'' region +360° discovery space!

O. Absil et al.
(poster 8.14)
Which substrate material?

CVD diamond

- Large spectrum: from visible to thermal-IR (~ 20 µm)
- Favorable mechanical and thermal properties
- High refractive index = shallow etching

Simulations based on the *Rigorous Coupled Wave Analysis* (RCWA)

Diamond

E.g. in the N-band
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)

Christian Delacroix
28 october 2010
First manufactured diamond AGPM

- optimised for $[10.5 \mu m - 12.25 \mu m]$

- performances simulated with RCWA, mean Null Depth @ $2\lambda/D$
  - 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

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

Christian Delacroix
28 October 2010
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:

Diamond AGPM: L-band

Diamond AGPM: N-band

Components currently being manufactured

Christian Delacroix
28 October 2010
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 currently being manufactured with expected performances $\mu < 10^{-5} @ 2\lambda/D$

We focus on the L-band for NACO where the AGPM is very promising
Thank you for your attention!