Polarisation reflection measurements

Preliminary Report, May 2021

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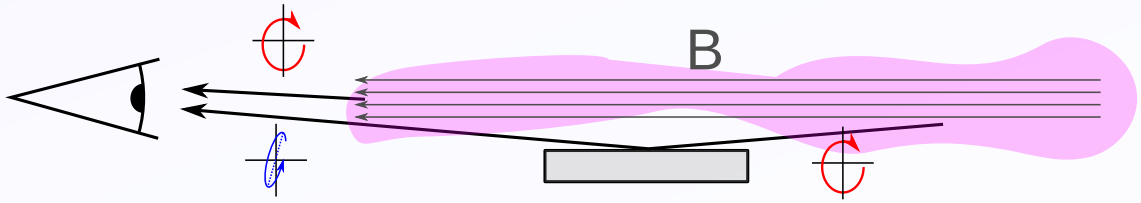
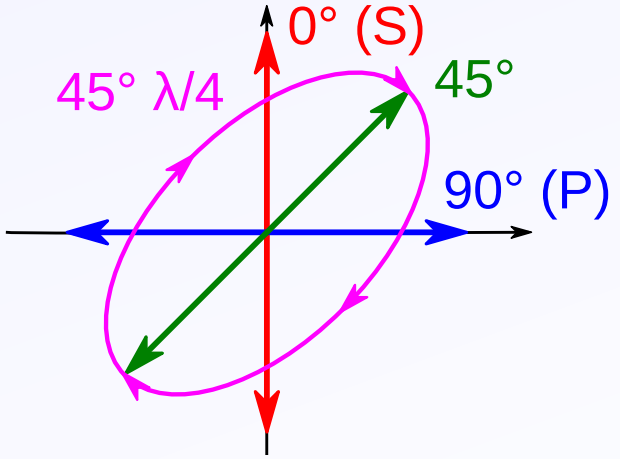
- ITER Flow monitor includes principle of isolating reflections from direct emission with polarisation change:



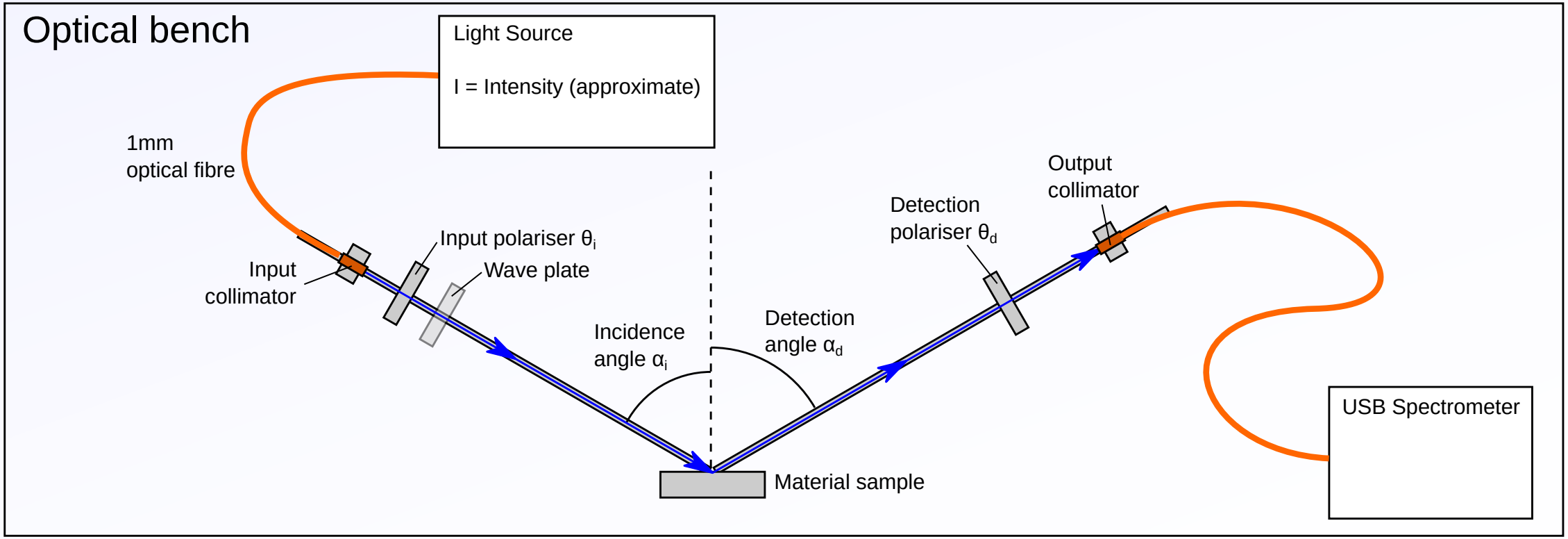
- Measurement of polarisation effect of reflection for relevant material surfaces to assess principle and inform the design

Measurement set up

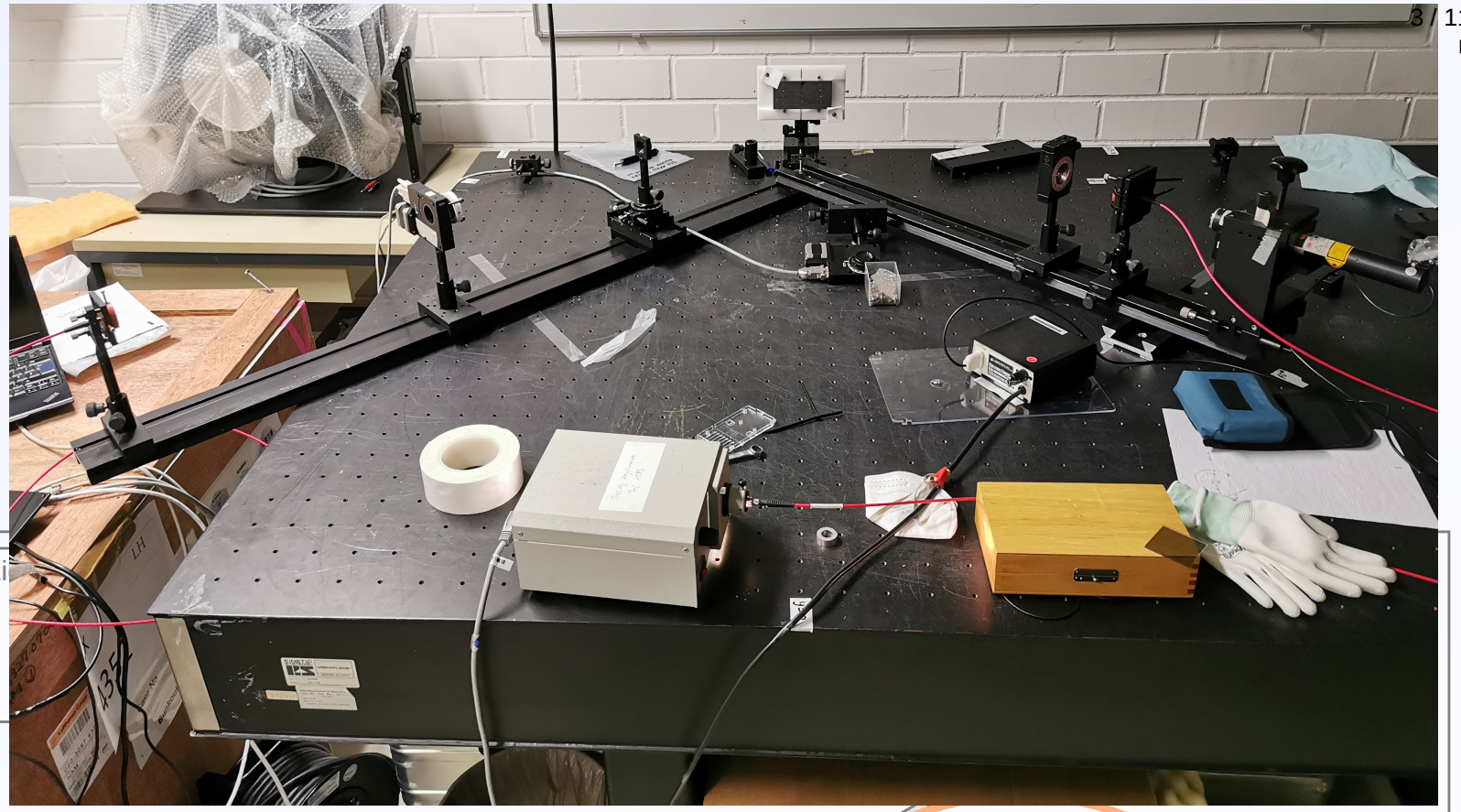
- Narrow beam projected reflected from mirror/material sample.
- 4 input polarisation states.
- Scan of output of polarisation.
- Measurement of:
  - Specular and diffuse reflection.
  - All visible wavelengths.
  - Absolute attenuation, full polarisation change and depolarisation.



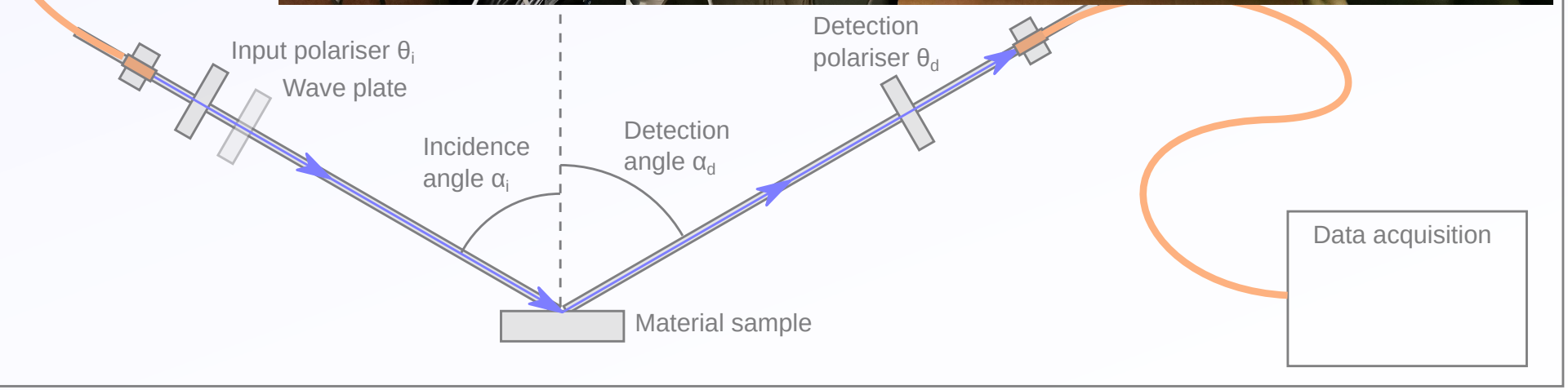
Optical bench



Real life is somewhat messier:

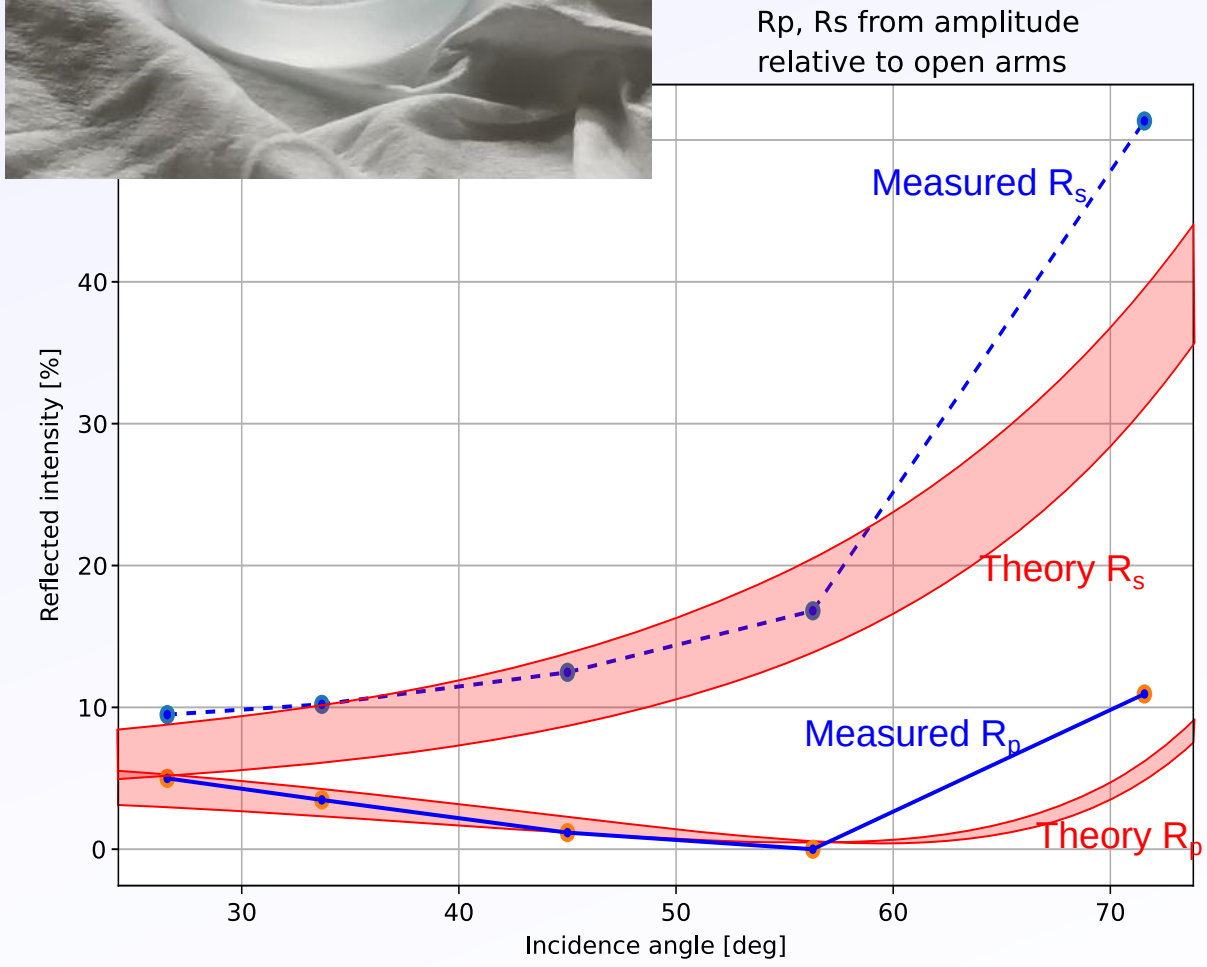


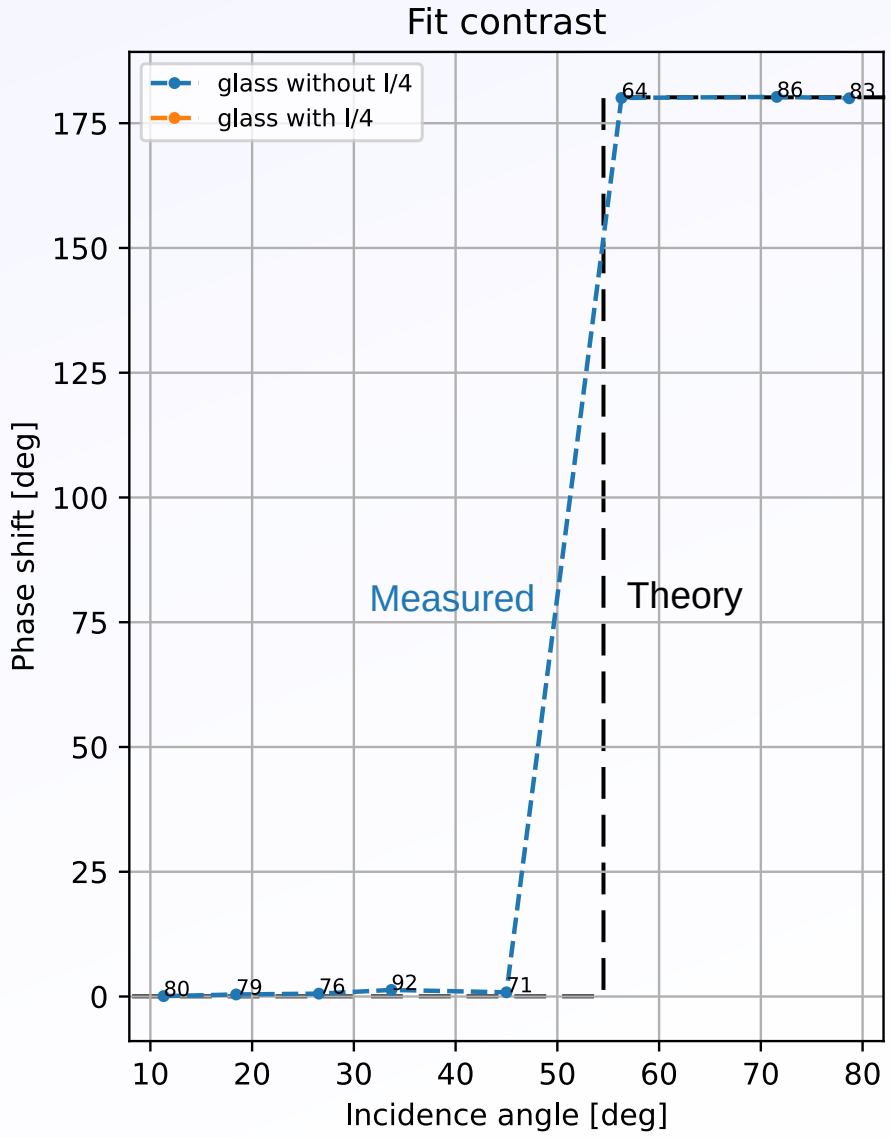
Optical bench



Glass

Reflection from glass surface as benchmark case:
simple known physics from Fresnel coefficients.

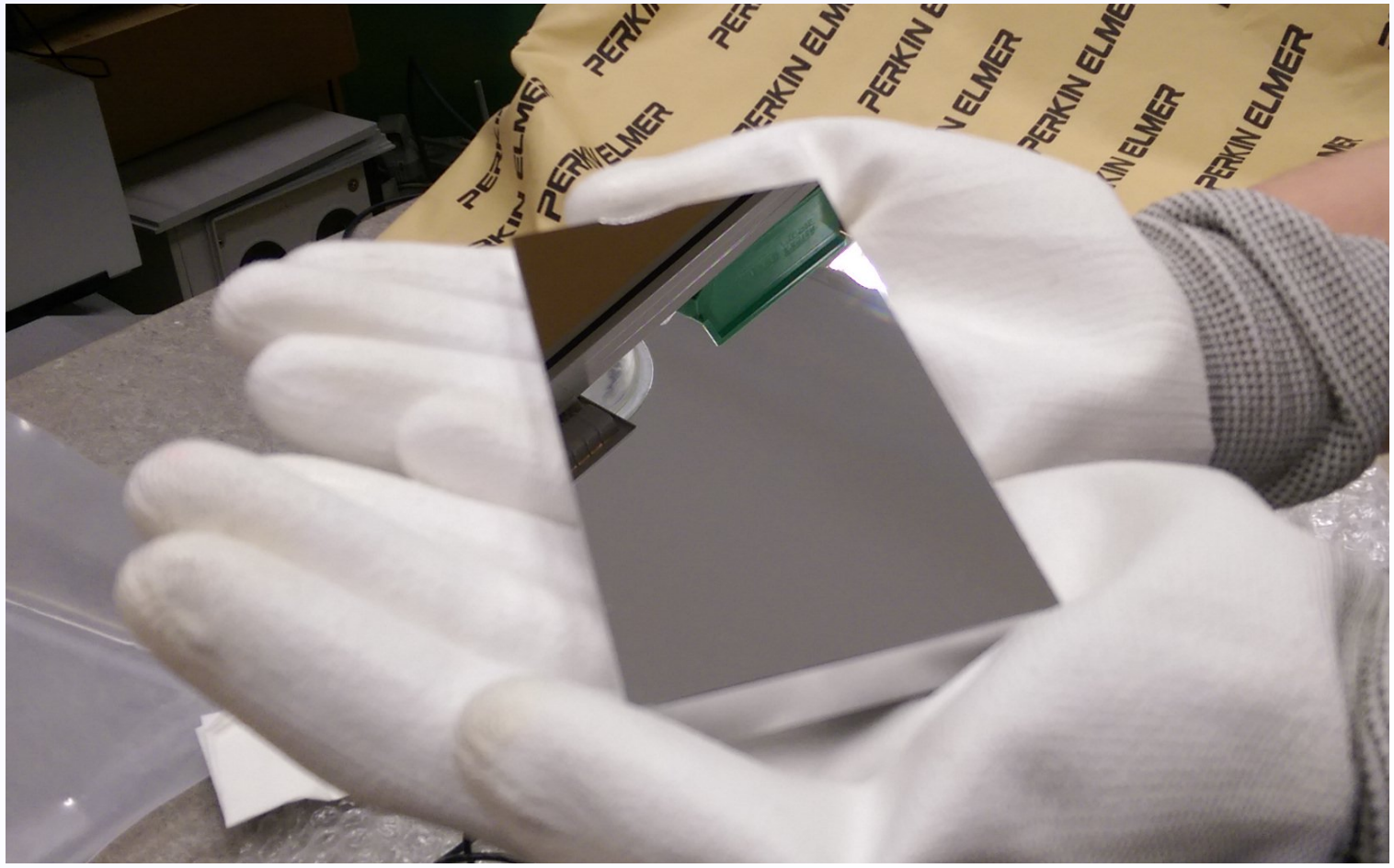




Aluminium (specular)

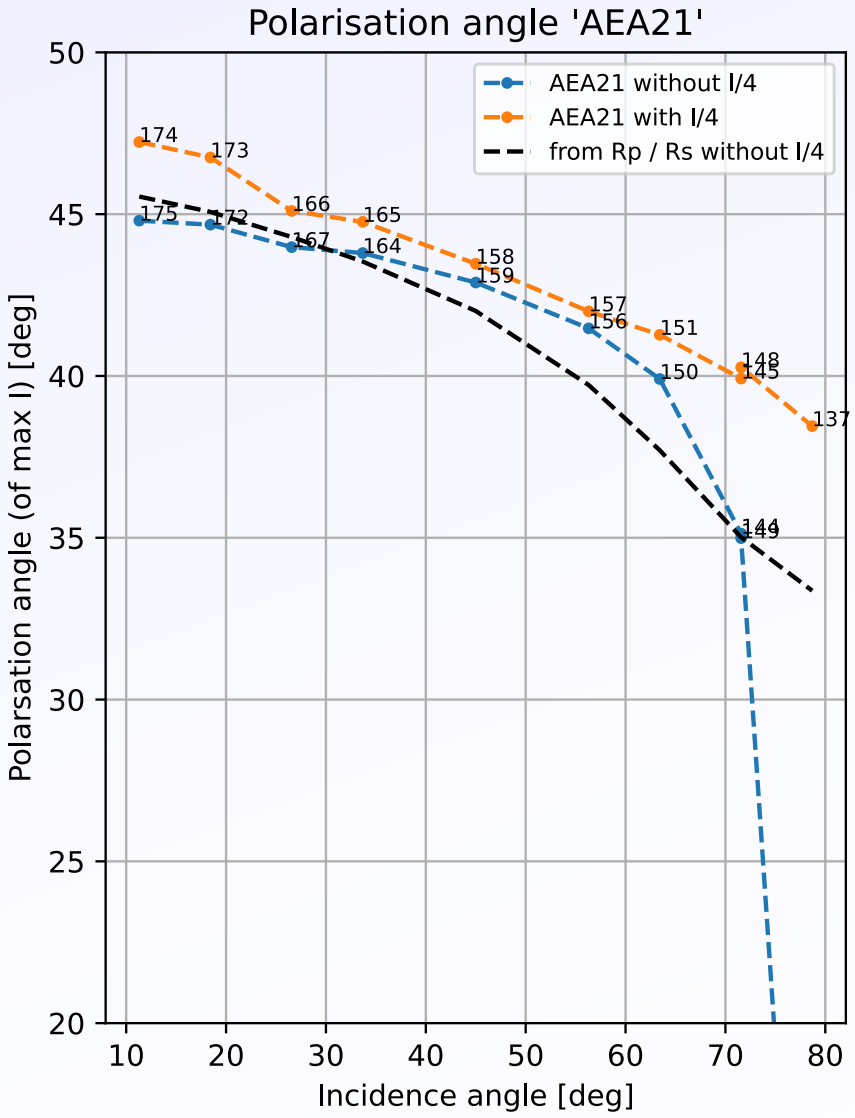
Fine milled aluminium alloy RSA-905 (W7-X beam emission spectroscopy mirrors):

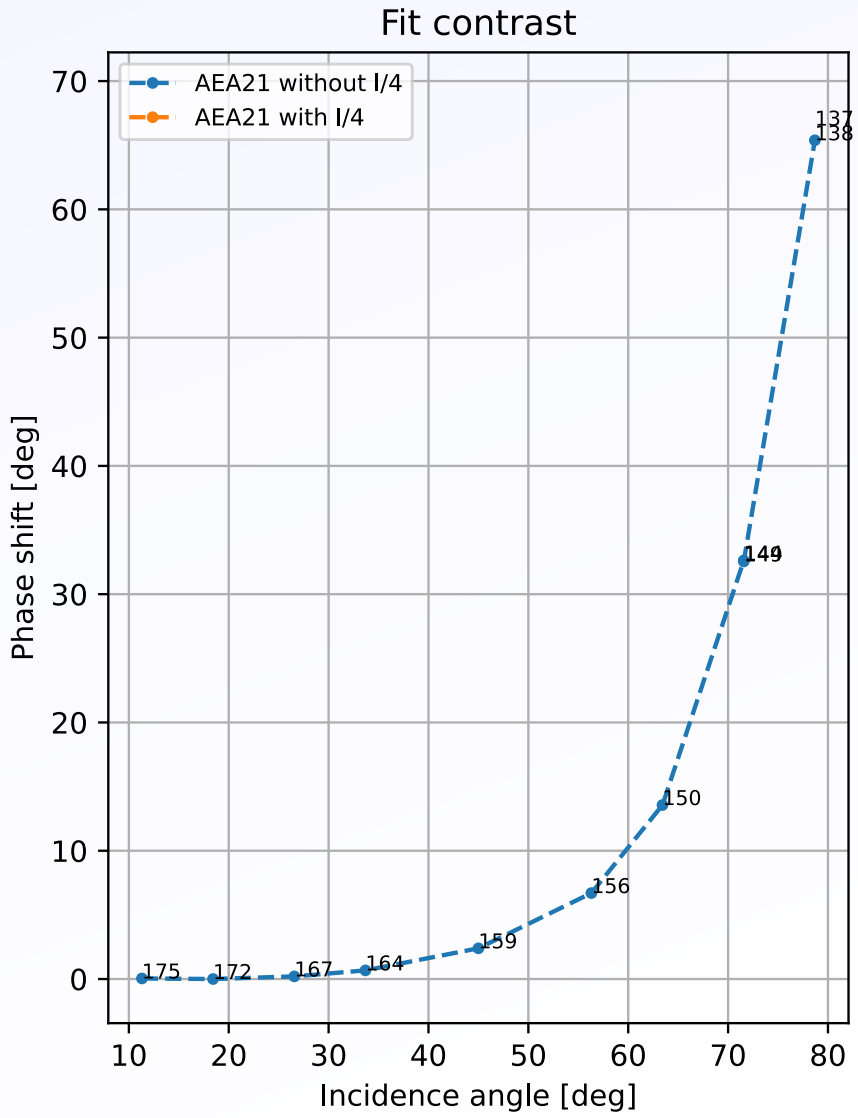
Benchmark for RaySect ray tracing software for pure specular reflection from ideal surface.



Aluminium

Near 'ideal' specular reflection
Normal incidence up to ~45° --> Almost **no effect on polarisation** except reference frame reversal
From 45° to oblique angles --> Small polarisation rotation due to P attenuation, **strong phase shift** between S and P.

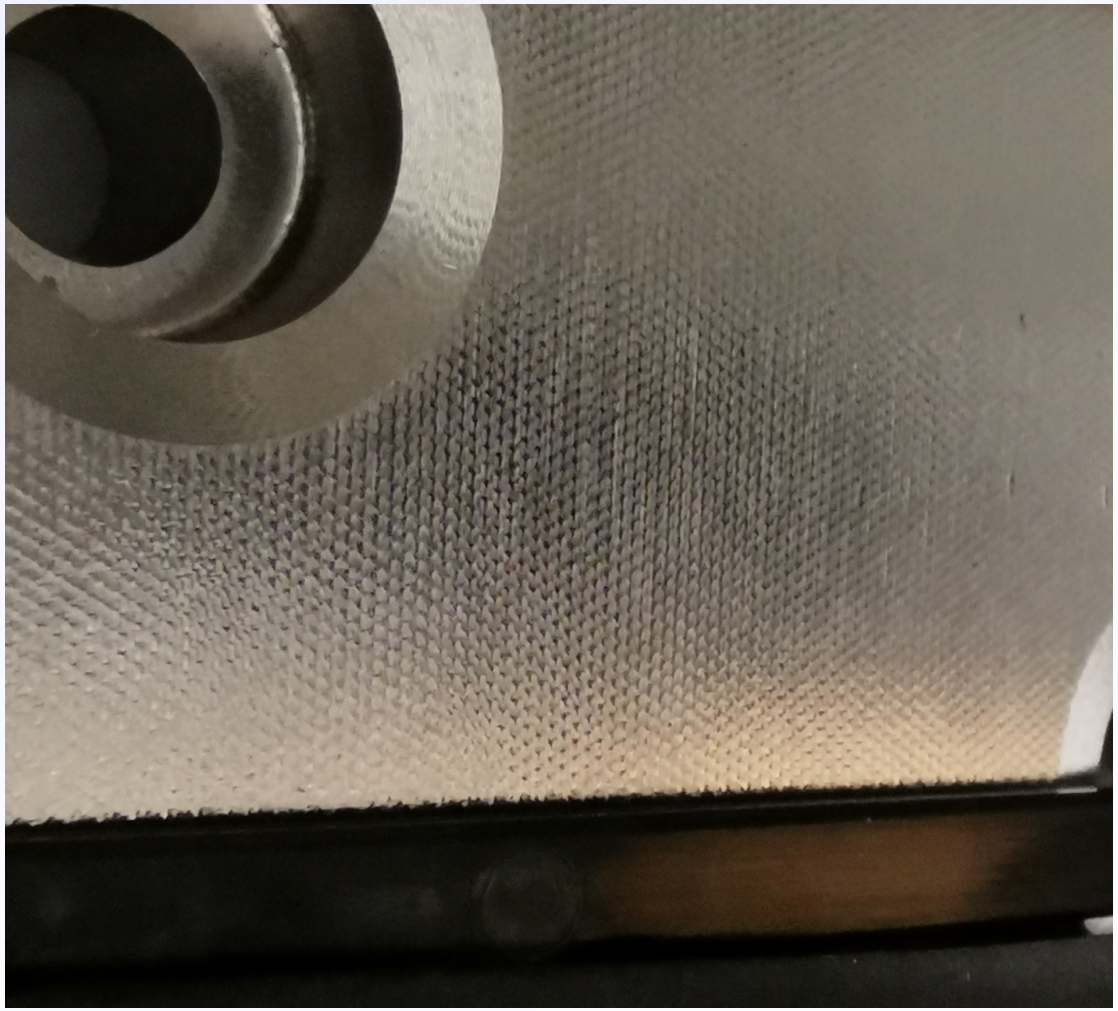


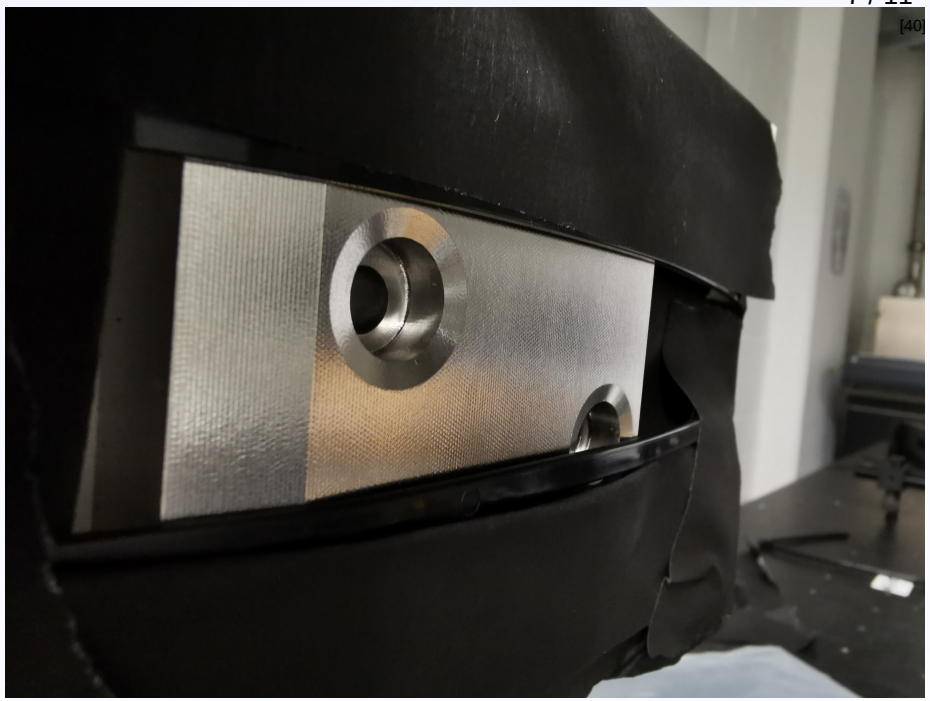


Tungsten

Tungsten alloy: W 97%, Fe 1%, Ni 2%
Wall tile from ASDEX Upgrade (not plasma exposed).

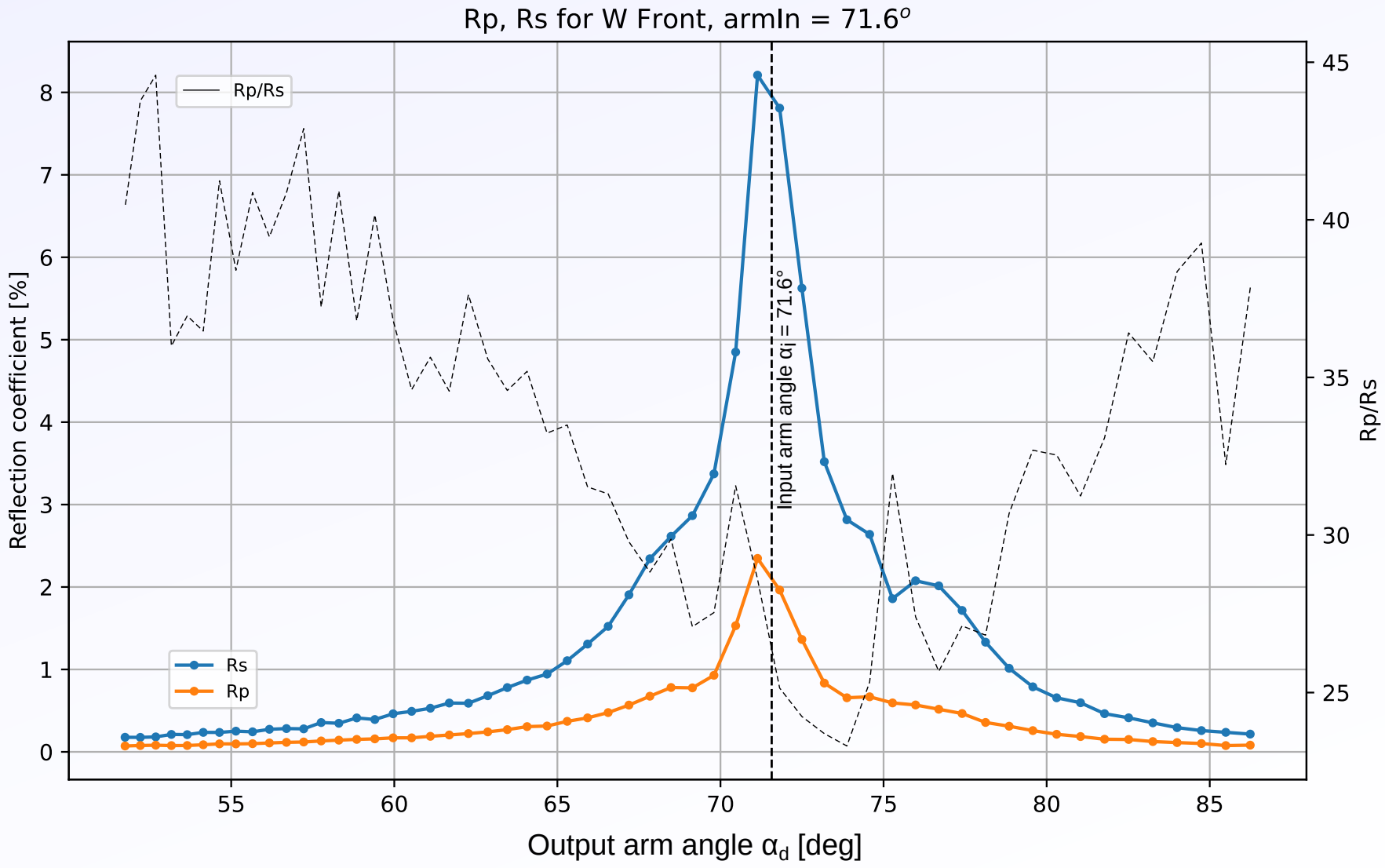
Visible surface structure without clear mirror effect:





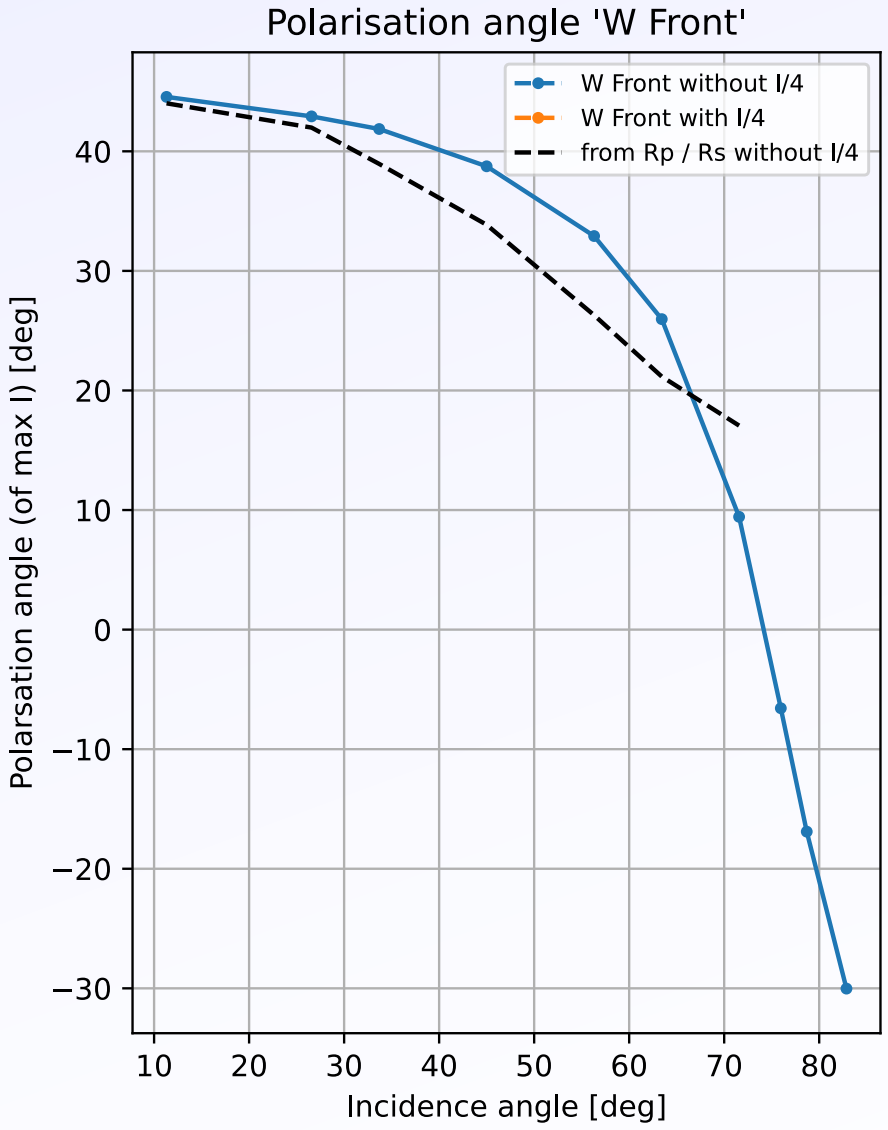
Tungsten

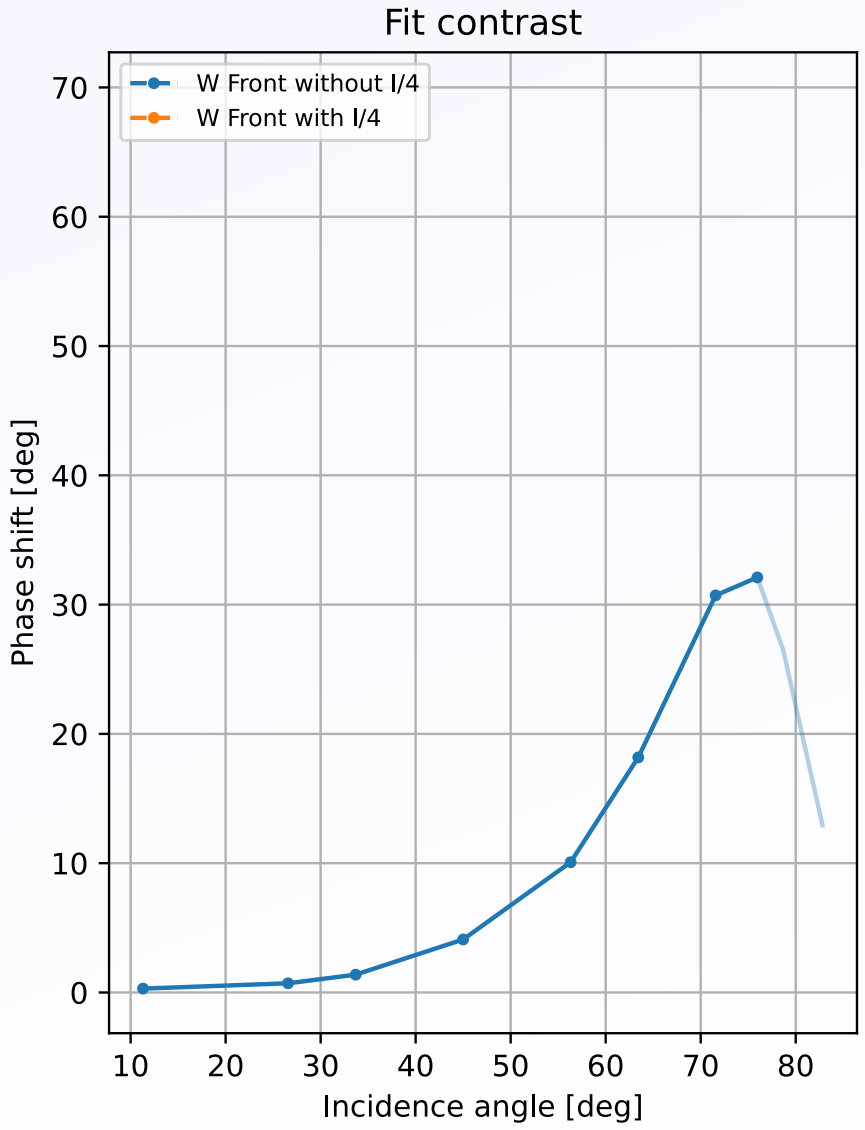
- Very significant diffuse reflection > ~1% up to ±10°
- Weak specular reflection ~ 5%
- Strong attenuation of P relative to S in both cases --> **tends toward linear polarisation**.



Tungsten

- Strong rotation toward S polarisation at oblique angles
- Similar phase shift to specular reflection.

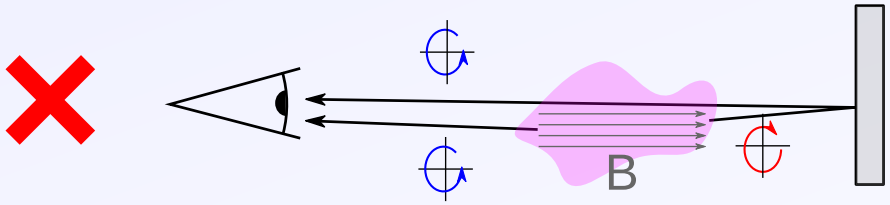




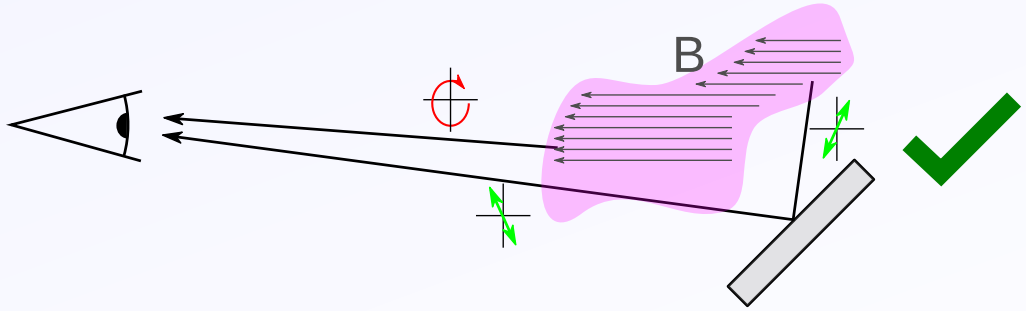
Simple cases

We can consider some simple relevant cases:

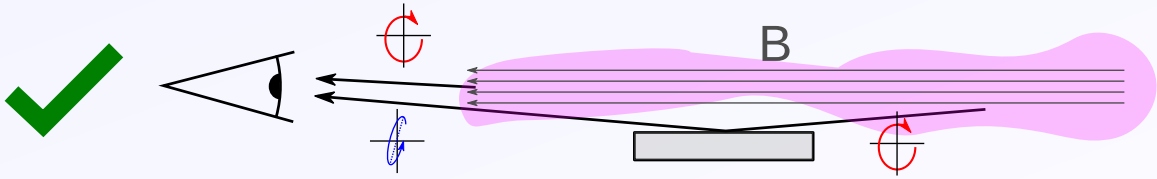
1) Specular reflector behind emitter



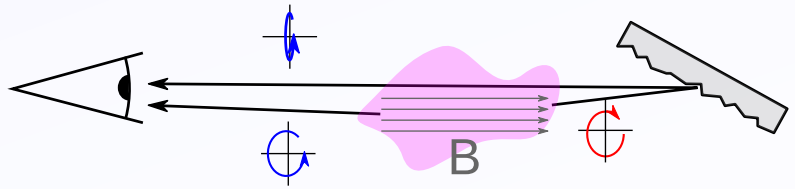
2) Mid range specular reflection



3) Oblique specular reflection



4) Diffuse reflection behind emitter



- Situation is complex - depends on precise geometry, emission and relfection properties.
- Many cases will be seperable, some not.
- In most cases, disturbance from reflections will be possible to identify.

Summary

Main indications so far:

- Preliminary measurements completed and validated with glass reflection (Brewster angle)

- Reflection properties strongly dependant on material surface (machining, coating, finish etc)
  --> We should measure an actual ITER wall tile if possible.

- No simple behaviour (e.g. *"Reflections tend to give linear polarisation"*)
  --> Assumption not *generally* valid (chit #12).

- Strong phase shift and R_p attenuation at oblique angles, $\Delta\varphi=180°$ at small angles.
  --> Significant transform of polarisation on reflection.

- **Should be possible to at least detect and avoid reflection contamination** using polarisation change.

- Isolate possible in some cases but this will require the Luffy simulation to tell us where it can trusted.

Future work:

- Use data set to validate Luffy reflection model for measured samples:
  1) Basic model for polarisation and phase change for ideal specular reflection.
  2) More realistic model for an arbitrary rough surface. Is this like the measured tungesten tile?

- Repeat measurements with more relevant materials - ITER wall tungsten tile?