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Stray light in the LISA instrument characterization and modelling of the coherent perturbation of a homodyne interference

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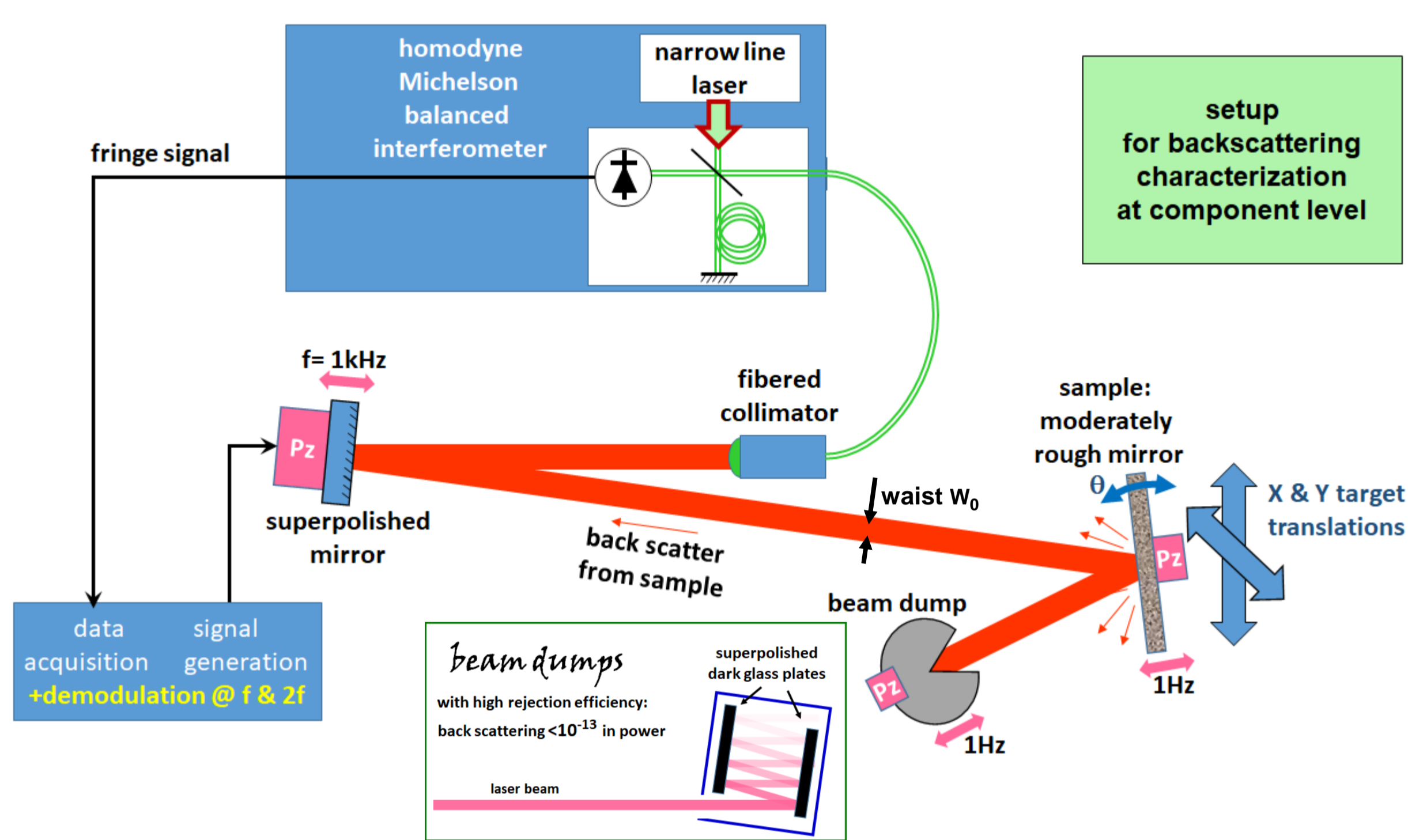
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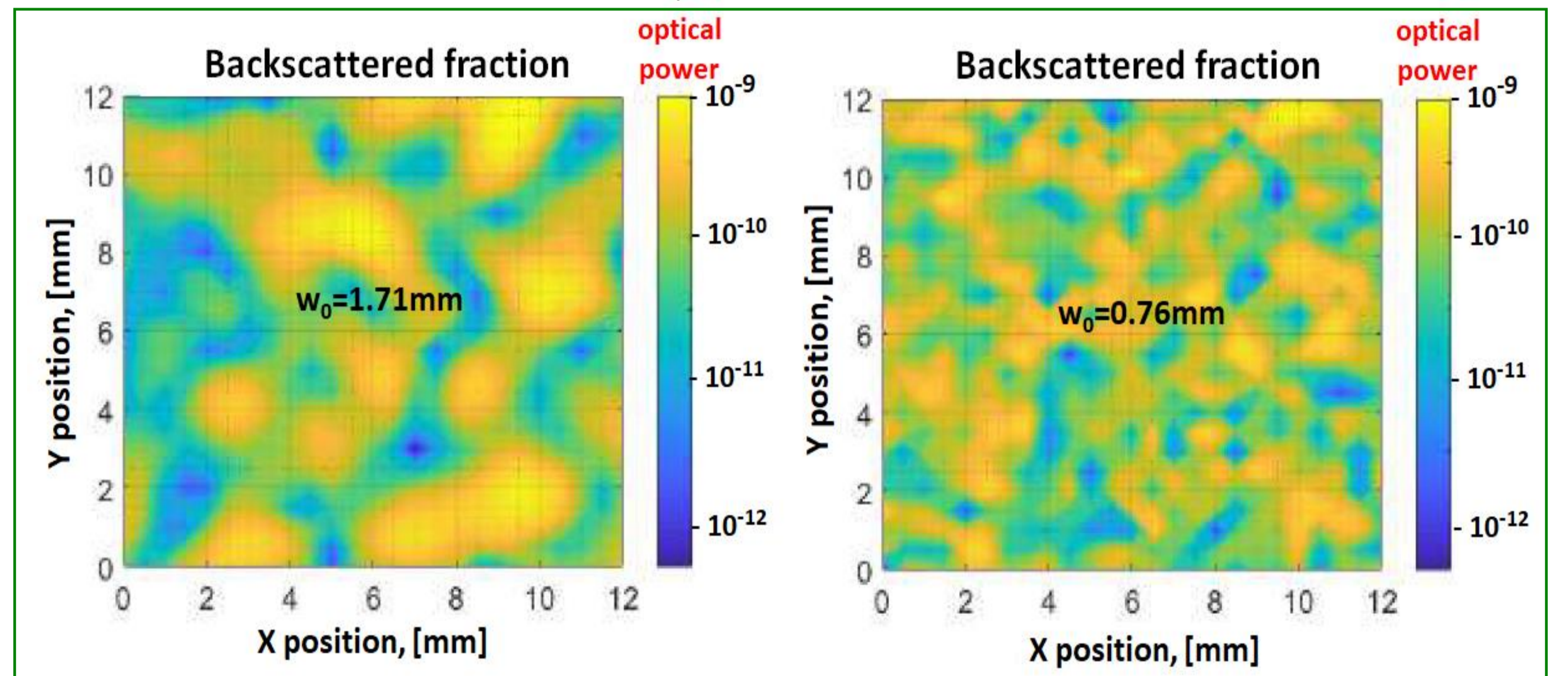
Goals of this study

- achieve coherent detection of light back-scattered by a mirror
- characterize dependence with spot position, and incidence angle
- test cross-polarization scattering
- develop an accurate modelling of this coherent perturbation (electromagnetic optics formalism)
- provide scattering requirements at component level

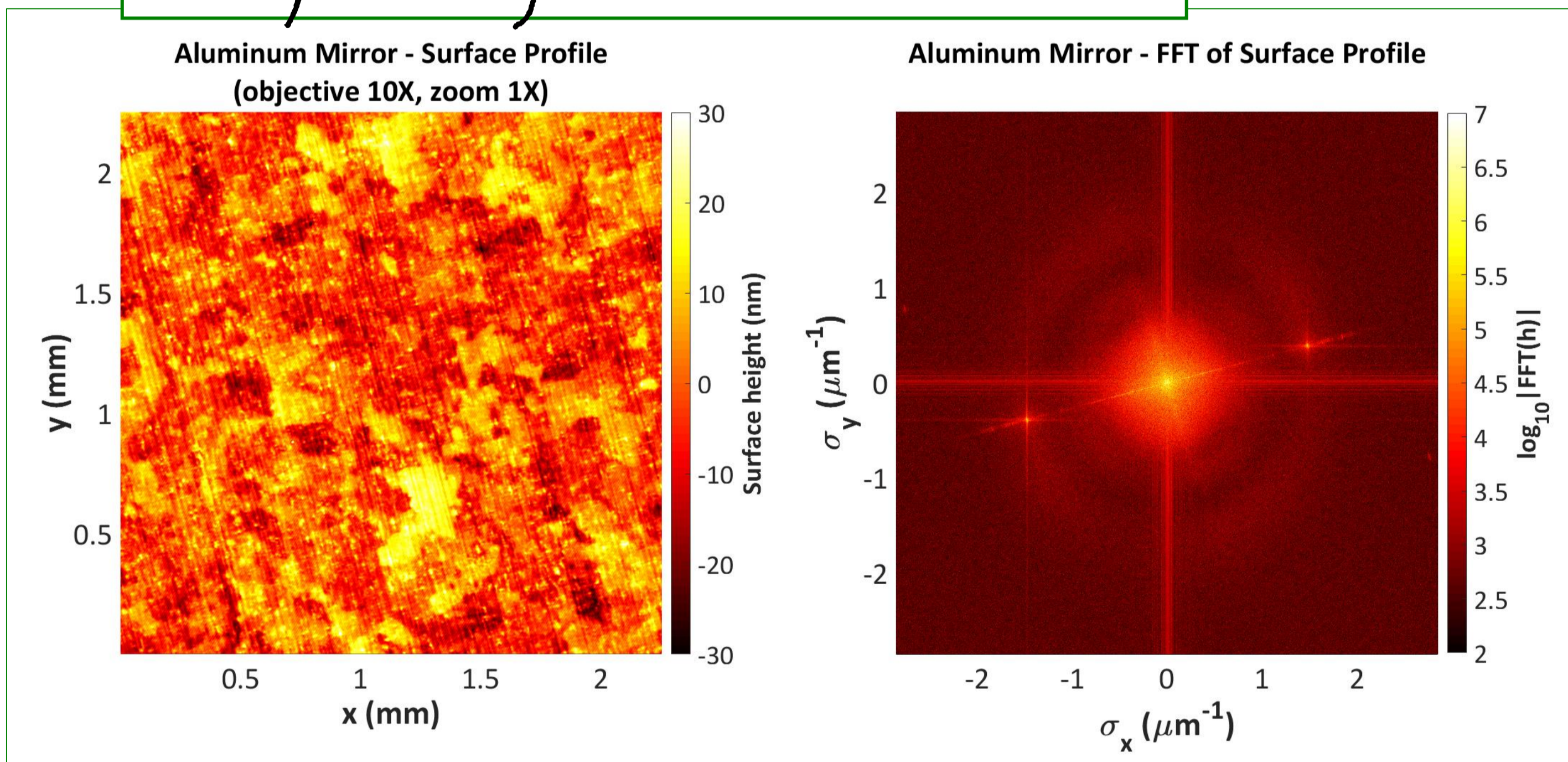
Experimental activities



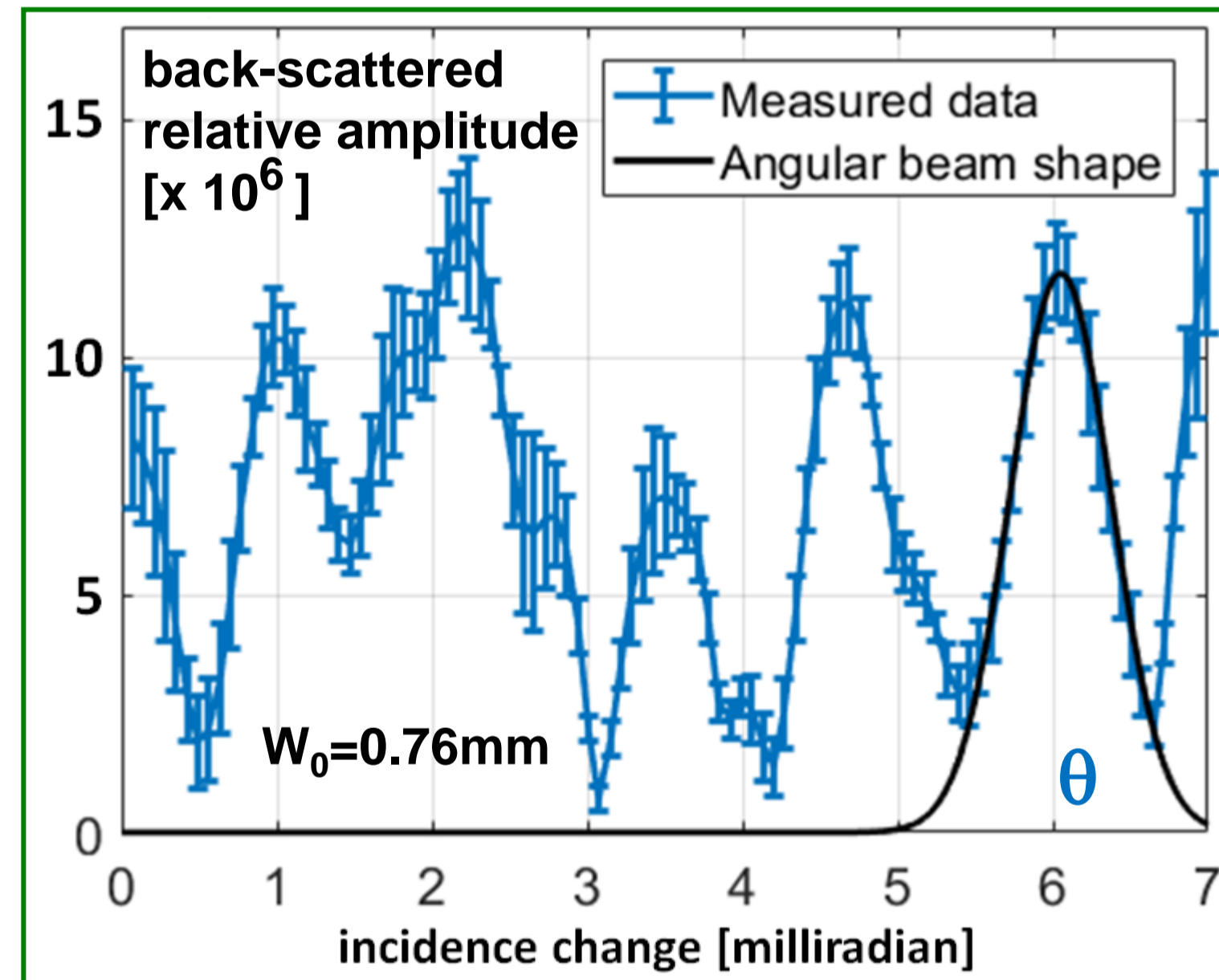
X-Y scan of the beam spot



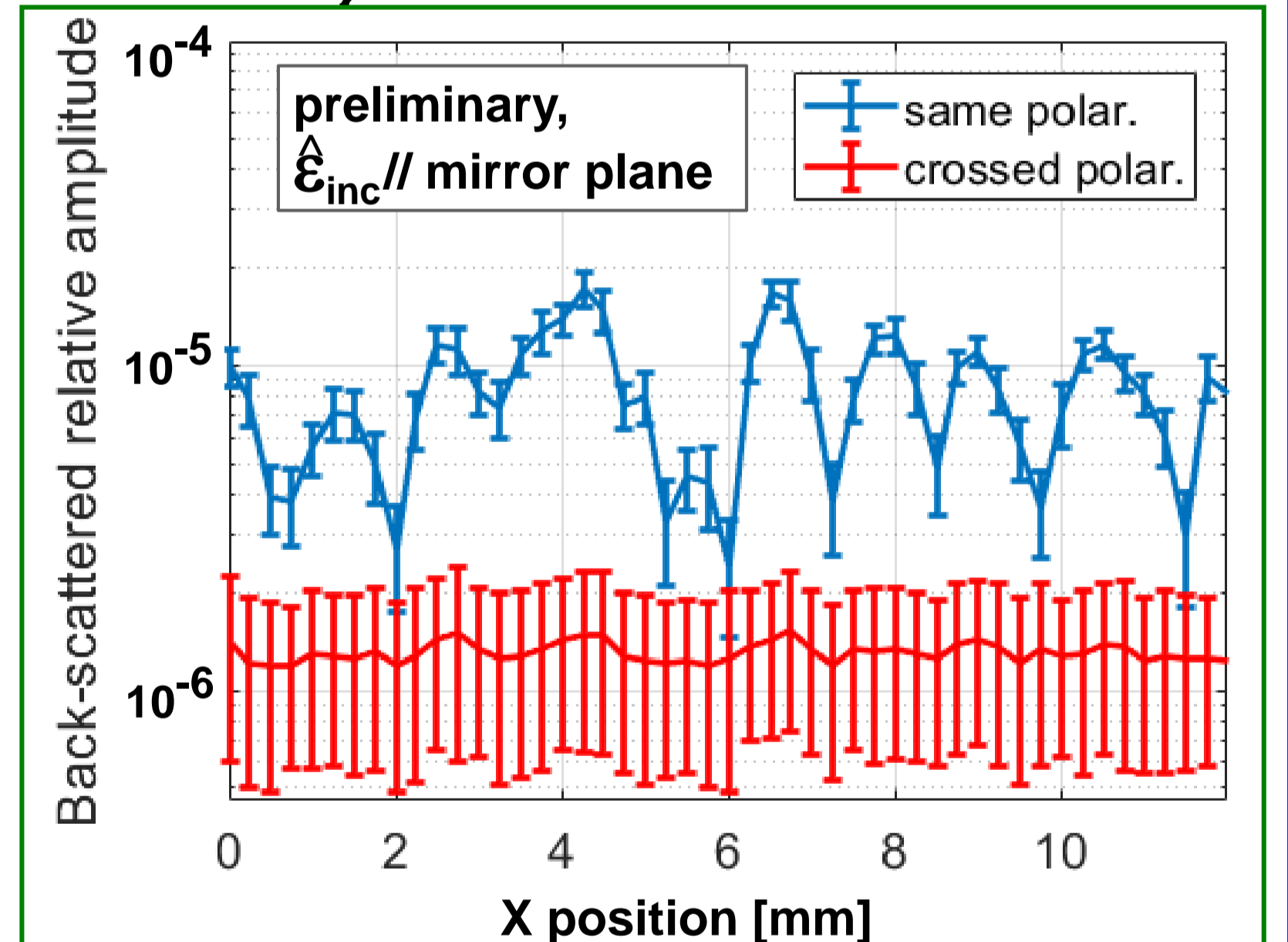
Sample roughness measurement



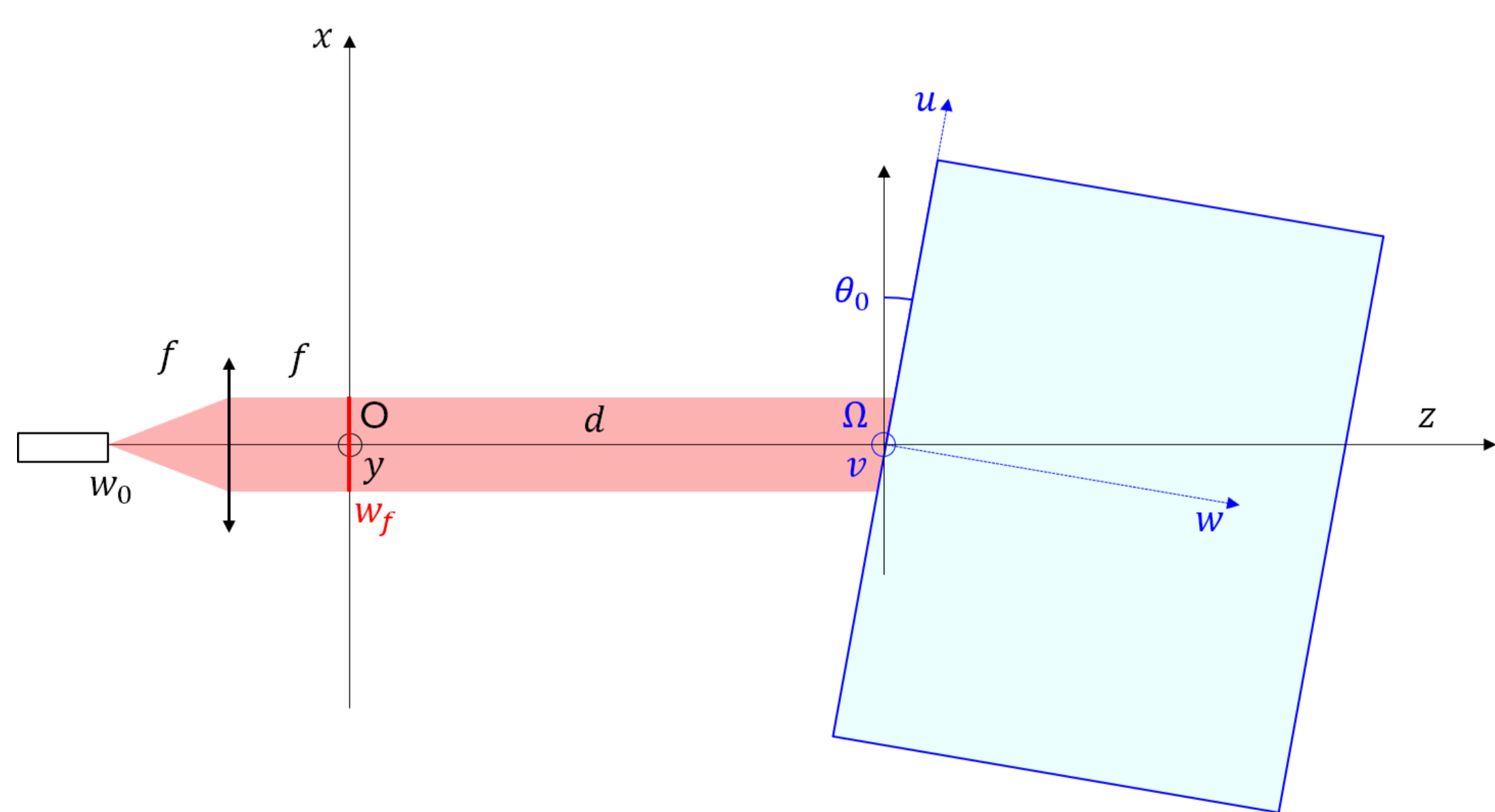
incidence scan near 14°



crossed polarization



Theoretical modelling



- Spatial distribution of the incident field (Gaussian mode)

$$\vec{E}(x, y, z) = \frac{w_0^2}{4\pi} \vec{E}_0 \iint e^{-\frac{w_0^2}{4}(\sigma_x^2 + \sigma_y^2)} e^{i(x\sigma_x + y\sigma_y + z\alpha_0, \sigma_x)} d\sigma_x d\sigma_y$$

- Spatial distribution of the back-scattered field in the $z = 0$ plane

$$\vec{E}_{0,s}^-(x, y, 0) = \frac{1}{(2\pi)^4} \int_{\sigma_x} \int_{\sigma_y} \vec{A}_{0,s}^-(\vec{\sigma}_s) e^{i[(x \cos \theta_0 - d \sin \theta_0) \sigma_{us} + y \sigma_{vs} + \alpha_{0,uv}(x \sin \theta_0 + d \cos \theta_0)]} d^2 \vec{\sigma}_s$$

$$\vec{A}_{0,s}^-(\vec{\sigma}_s) = -\frac{2i}{(\tilde{n}_0^+ + \tilde{n}_1^+)(\tilde{n}_0^- + \tilde{n}_1^-)} \hat{h}(\vec{\sigma}_s - \vec{\sigma}_i) \left\{ [\tilde{n}_0^+(\alpha_1^+ \tilde{n}_1^+ - \alpha_0^+ \tilde{n}_0^+) - \tilde{n}_1^+(\alpha_1^+ \tilde{n}_0^+ - \alpha_0^+ \tilde{n}_1^+)] \vec{A}_{0,i}^+(\vec{\sigma}_i) + (\vec{\sigma}_s - \vec{\sigma}_i) \frac{\tilde{\epsilon}_0 - \tilde{\epsilon}_1}{\tilde{\epsilon}_0} \frac{\tilde{n}_0^+ \tilde{n}_1^+}{\alpha_1^+} \vec{\sigma}_i \cdot \vec{A}_{0,i}^+(\vec{\sigma}_i) \right\}$$

FT of the surface height profile $h(x, y)$

- Coupling efficiency (overlapping integral)

$$\eta(d, \theta_0) = \frac{\left| \iint \vec{E}^+(x, y, 0) \cdot \vec{E}_{0,s}^-(x, y, 0) dx dy \right|^2}{\left| \iint |\vec{E}(x, y, 0)|^2 dx dy \right|^2}$$

Conclusions

- Study of coherent back-scattering from components
 - starting with metal mirror, roughness $\approx 100\text{\AA}$ RMS
- Backscattering speckle-type dependence with
 - spot position ($\sim 1/\text{beam waist}$)
 - incidence angle ($\sim 1/\text{beam divergence}$)
- Strong attenuation in crossed polarization scattering if $\hat{\epsilon}_{inc} // \text{surface}$
Other configurations not yet studied and may differ
- Electromagnetic modelling of the back-scattered field
=> numerical calculation under way
- Soon: monitoring of coherent backscattering by dust contamination

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