Measuring the modulus of the spatial coherence function using an error tolerant phase shifting algorithm and a continuous lateral shearing interferometer

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Measuring principle

The modulus of the spatial degree of coherence can be derived from the contrast of interference patterns by scanning the lateral shift between the interfering waves. Here we are using temporal phase shifting interferometry (PSI) which enables the quantitative measurement of the complex degree of coherence, i.e. modulus and phase on a pixel-oriented basis but which suffers from instabilities and drifts which is the background for the derivation of an error immune algorithm. This algorithm will use five $\pi/2$-steps of the reference phase for the calculation of the contrast similar to the calculation of the object phase [1].

Here a lateral shearing interferometer exploiting a diffractive grating wedge providing a linearly progressive shear is used as a model experiment to measure the spatial degree of coherence for a set of selected binary light source distributions.

Error compensating algorithm

PSI: Single intensity frame $I_r = I_0\,[1 + V\cos(\Phi - \psi_r)]$ $\rightarrow$ Phase $\Phi = \arctan(\frac{N}{D})$ and visibility $V = \frac{\sqrt{N^2+D^2}}{I_0}$ (N sin-dependent terms, D cos-dependent terms)

5-step (phase closure): $N_5 = (I_2 - I_4)$, $D_5 = \frac{I_1+I_5}{2} - I_3$, $I_0 = \frac{I_1+I_5}{2} + I_3$

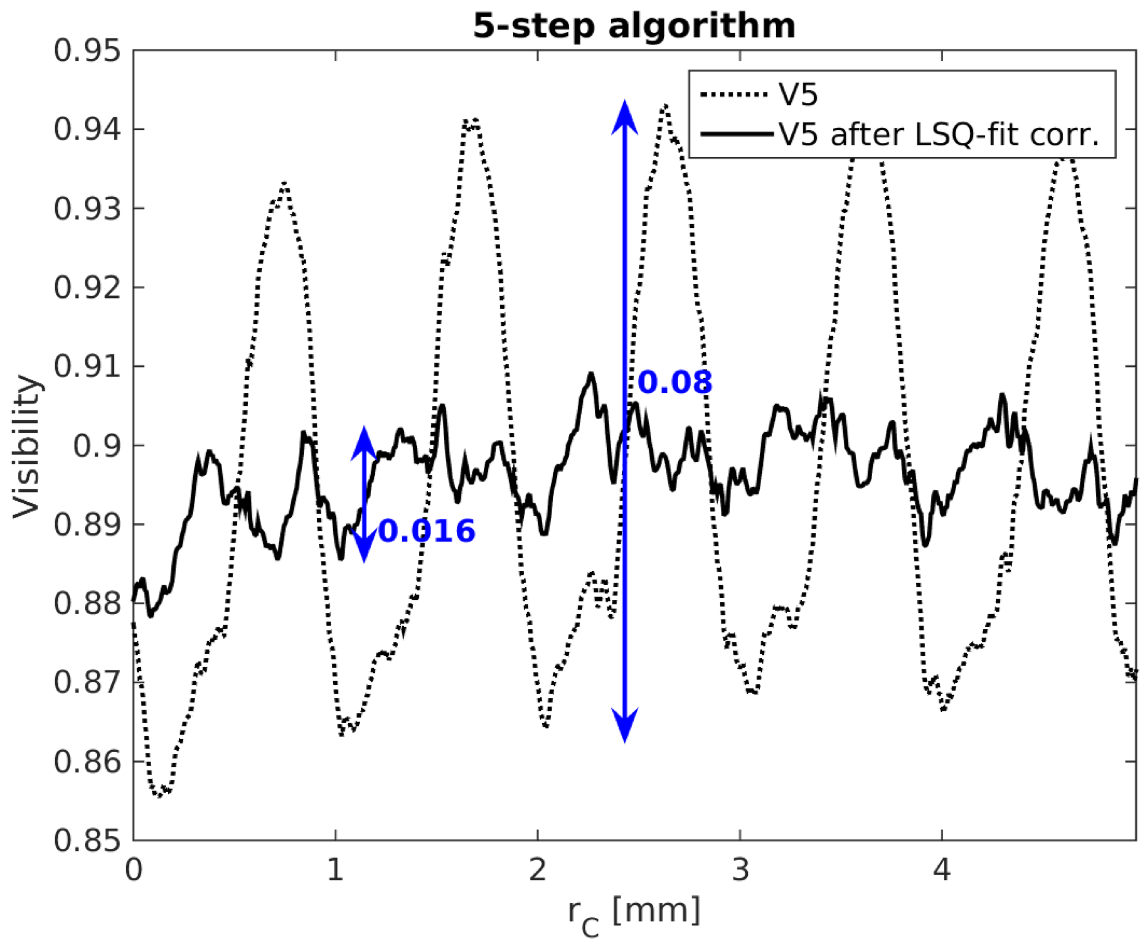
Reference phase error [2]:

- Error phase $\Delta\Phi_5 \approx \arctan(\frac{\bar{\epsilon}^2}{4}\sin(2\Phi) - 2\bar{\epsilon}) + O(\bar{\epsilon}^3\ and\ higher)$
- Visibiltity $V_5 \approx V(1 - \frac{3\bar{\epsilon}^2}{4} + \bar{\epsilon}^2(V\cos(\Phi) - \frac{1}{4}\cos(2\Phi))) + O(\bar{\epsilon}^3\ and\ higher)$

4-step: $N_4 = (I_2 - I_4)$, $D_4 = I_1 - I_3$, $I_0 = I_1 + I_3$

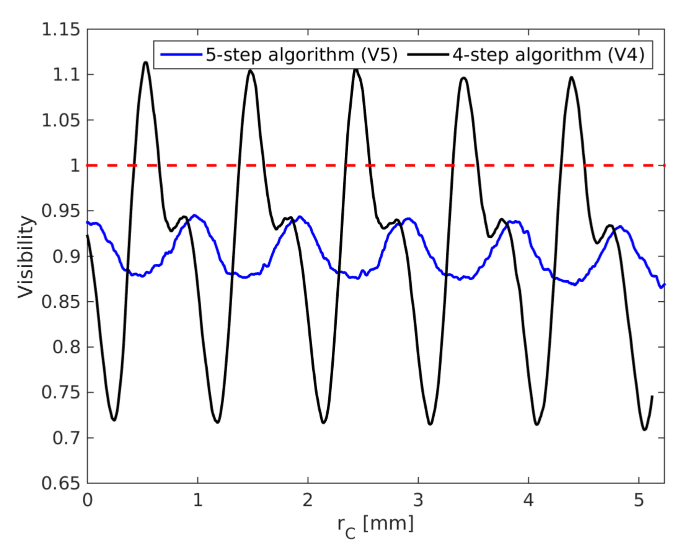
Reference phase error [1]:

- Error phase $\Delta\Phi_4 \approx -\arctan(\frac{\bar{\epsilon}}{2}(3 + \cos(2\Phi)) + 2\bar{\epsilon}^2\sin(2\Phi)) + O(\bar{\epsilon}^3\ and\ higher)$
- Visibiltity $V_4 \approx \frac{V}{\sqrt{(1-\bar{\epsilon}^2)}}[1 - \bar{\epsilon}^2 - \bar{\epsilon}(\frac{1}{2}\sin(2\Phi) - V\sin(\Phi))$ $+\bar{\epsilon}^2(\frac{3}{2}\cos(2\Phi) - V\cos(\Phi) - \frac{V}{2}\sin(\Phi)\sin(2\Phi))] + O(\bar{\epsilon}^3\ and\ higher)$



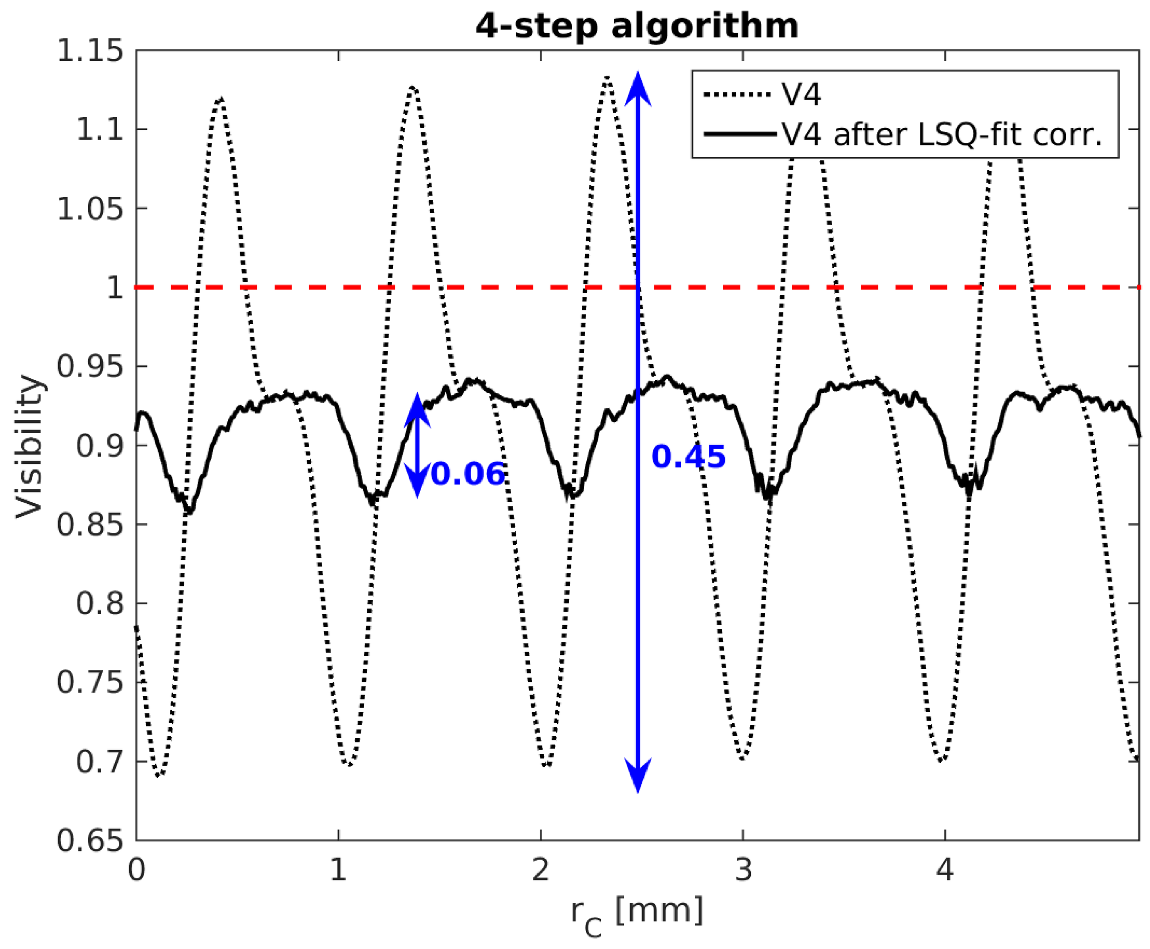
A posteriori error elimination [4]: Fit Φ and 2Φ functionals

4-step [3] vs. 5-step (phase closure) algorithm:



Constant visibility (with linear object phase $\Phi \propto r_c$)

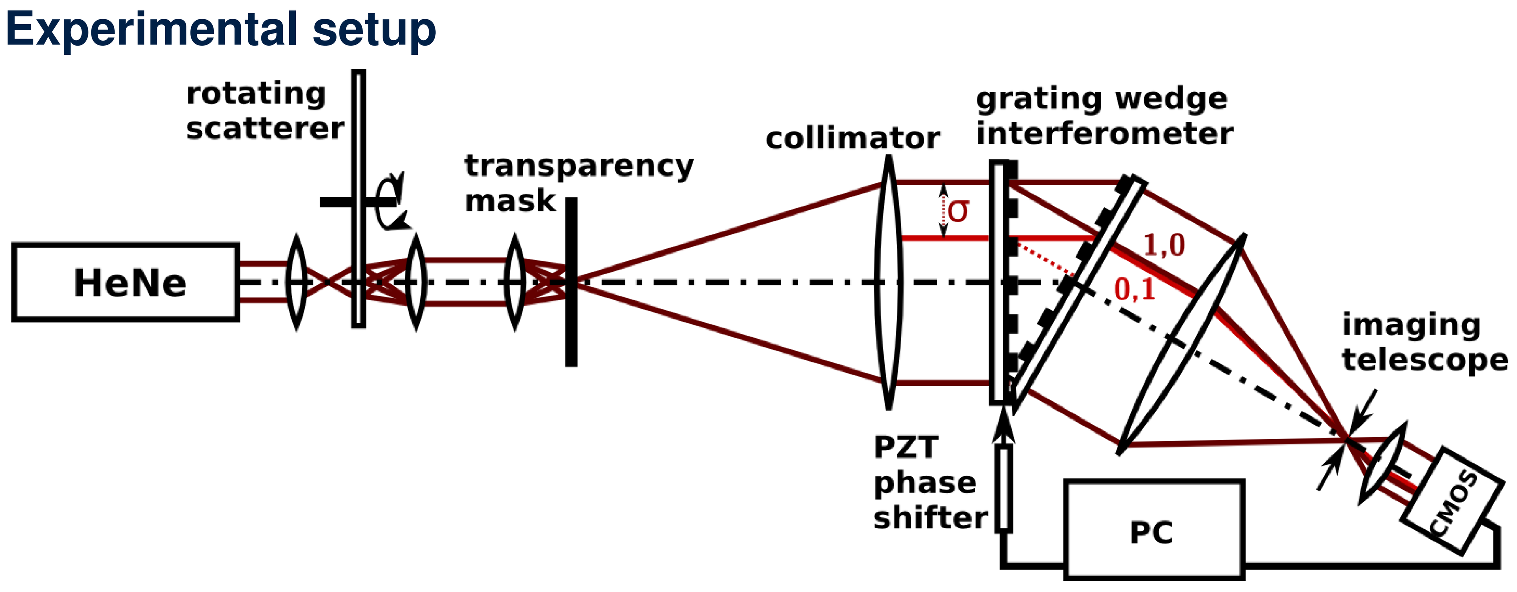
$\rightarrow$ Modulation due to reference phase error reduced with 5-step algorithm, no values > 1



A posteriori error elimination [4]: Fit Φ and 2Φ functionals

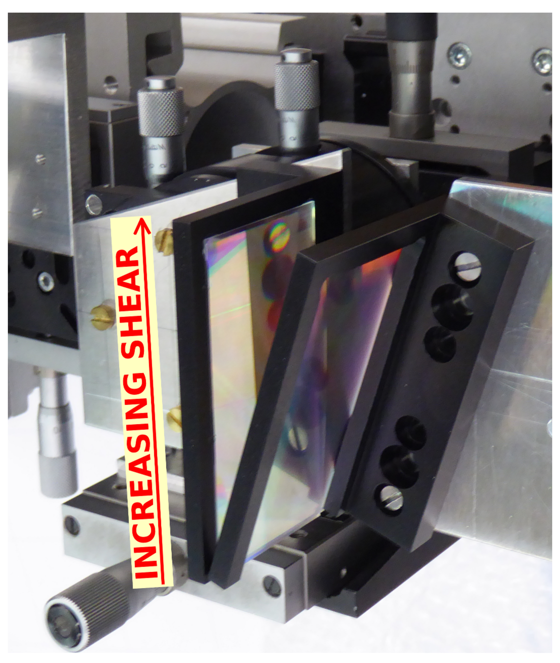
Model experiment

Experimental setup

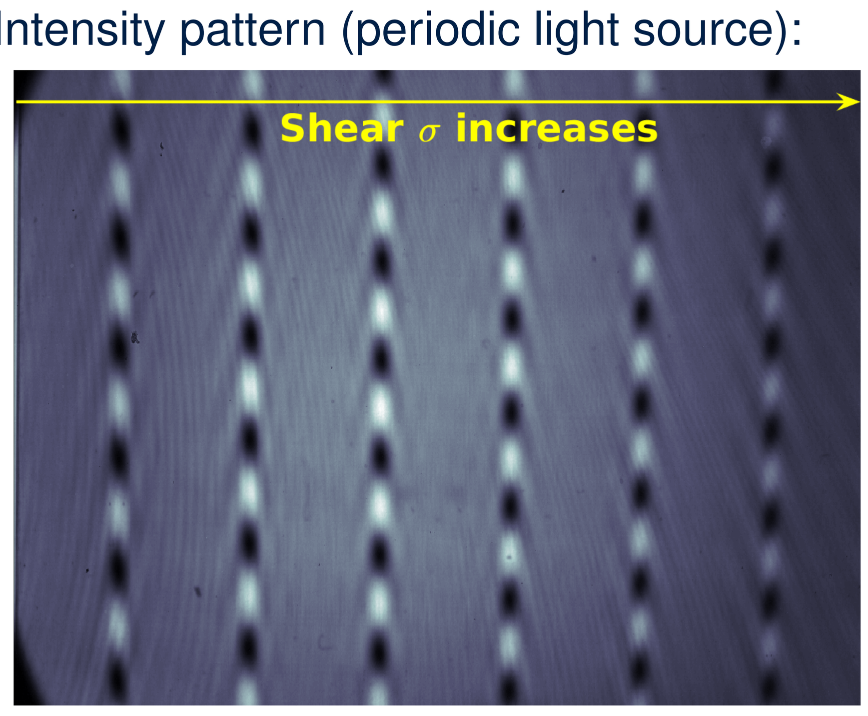


Continuous lateral shearing interferometer based on 2 binary tilted gratings [5]: The extended light source is defined by the transparency of the mask. The phase shift is introduced by moving the first grating perpendicular to the grating lines. The angle between the gratings is equal to the angle of the first diffraction order.

Core of the interferometer:

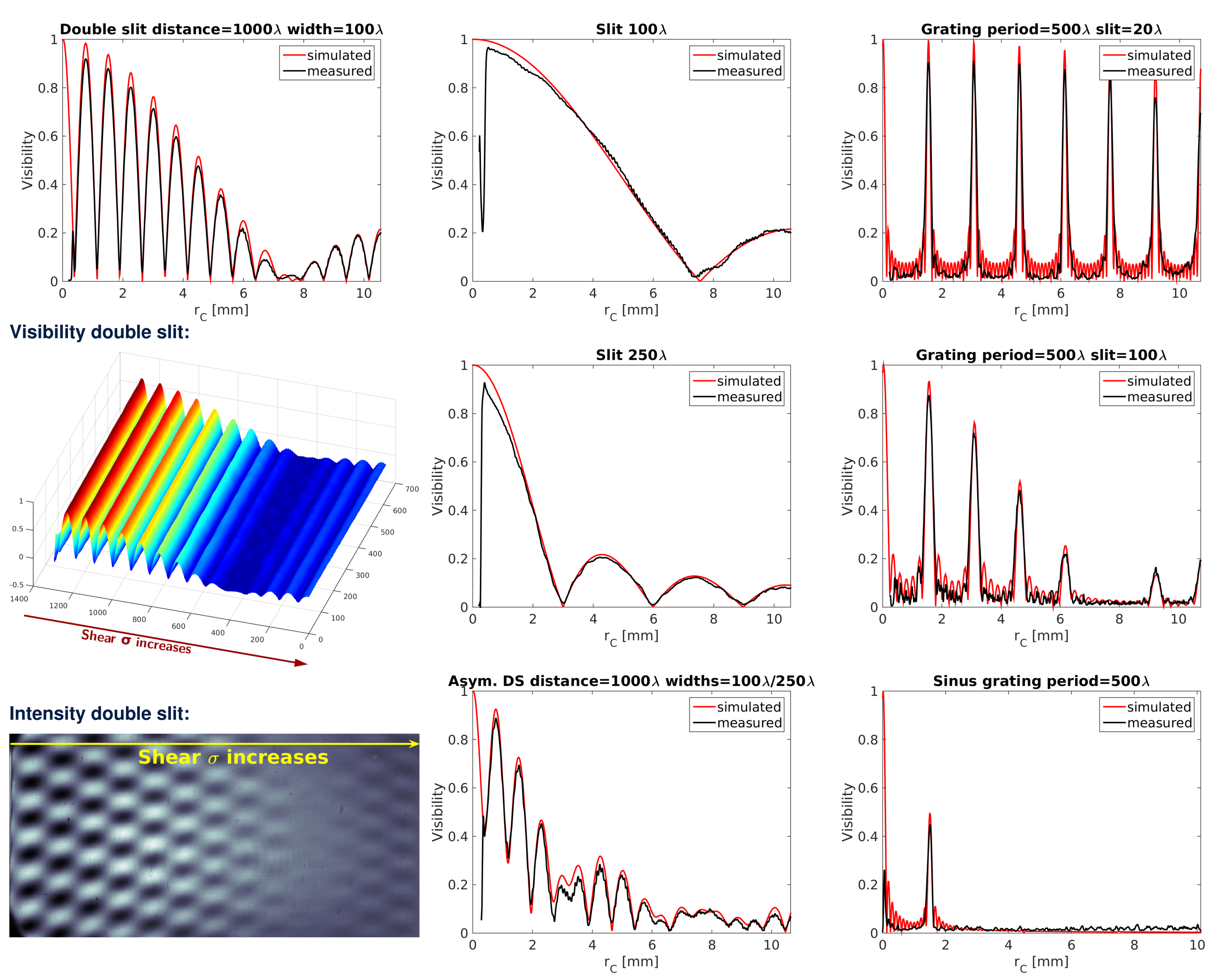


Intensity pattern (periodic light source):



Experimental results

Visibilities of different light sources:



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