Documentation

Dataset for Manuscript "Ultrafast imaging of laser-induced modifications in planar targets via single-shot in-line holography"

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1 General Information

Dataset title:	Dataset for Manuscript "Ultrafast imaging of laser-induced modifications in planar targets via single-shot in-line holography"
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2 Description

This document provides supplementary information for the data belonging to the publication [1].

3 File Format

The data is provided in the form of ".mat"-files (MATLAB workspace). It is most easily accessed by using MATLAB but can also be loaded with Python via the "loadmat" command (SciPy library). There are seven .mat files in total. Each file contains the data of one figure from the publication [1] as a set of MATLAB variables. The file name indicates the figure to which the data corresponds.

4 Archive Structure

- `Fig1__example_reconstruction.mat`

variable name	**data type**	**description**
dx_diff	double	spatial resolution of diffraction image [m]
diffraction_image	2160x2560 double	measured diffraction image
dx_rec	double	spatial resolution of transmission reconstruction [m]
transmission_reconstruction	1024x1024 complex double	2D complex transmission map as reconstructed from the diffraction image

Along with the example reconstruction of the 2D complex transmission map from a single-shot diffraction image (diffraction intensity), the spatial resolution of the diffraction image and the reconstructed image are provided.

- `Fig3__r_factor_reconstruction_algorithm.mat`

variable name	**data type**	**description**
dx_diff	double	spatial resolution of diffraction image [m]
diffraction_image	2048x2048 double	simulated diffraction image
dx_rec	double	spatial resolution of exit field reconstructions [m]
reconstruction_amplitude_*N*iterations	512x512 double	exit field reconstruction amplitude after N phase retrieval iterations
r_factor	1x500 double	evolution of the far field error (R-factor) over reconstruction iteration

To illustrate the reconstruction process over 500 phase retrieval iterations, the exit field reconstruction amplitudes are given for seven different iterations N. The R-factor reflects the accuracy of the reconstruction for each iteration.

- `Fig5__zfoil_quality_analysis.mat`

variable name	data type	description
dx_diff	double	spatial resolution of diffraction images [m]
target_positions	1x38 double	position of the target along the beam axis relative to the focal plane
diffraction_images	38x2160x2560 double	measured diffraction images at each target position
dx_rec	double	spatial resolution of exit field reconstructions [m]
exit_field_reconstructions	10x38x256x256 complex double	10 exit field reconstructions for each diffraction image
transmission_reconstructions	10x38x256x256 complex double	2D complex transmission reconstructions calculated from the exit field reconstructions
r_factors	10x38 double	R-factors (far field errors) of the 10 reconstructions at each of the 38 target positions
t_factors	10x38 double	T-factors (transmission map errors) of the 10 reconstructions at each of the 38 target positions

This data set is the result of an analysis of the accuracy and robustness of the 2D transmission map reconstruction with varying target positions relative to the focal plane of the imaging beam. Single-shot diffraction images were measured at 38 different target positions. From each image, 10 exit field reconstructions were performed, each resulting in a complex transmission map reconstruction. The R-factor and T-factor reflect the accuracy for each of these reconstructions in the far field and in the object plane, respectively.

- `Fig6__divergence_quality_analysis.mat`

variable name	data type	description
dx_diff	double	spatial resolution of diffraction images [m]
beam_waists	1x10 double	imaging beam waists for simulated diffraction images
diffraction_images	10x2048x2048 double	simulated diffraction image for each of the 10 beam waists
dx_rec	double	spatial resolution of exit field reconstructions [m]
exit_field_reconstructions	10x10x512x512 complex double	10 exit field reconstructions for each diffraction image
transmission_reconstructions	10x10x512x512 complex double	2D complex transmission reconstructions calculated from the exit field reconstructions
r_factors	10x10 double	R-factors (far field errors) of the 10 reconstructions at each of the 10 target positions
t_factors	10x10 double	T-factors (transmission map errors) of the 10 reconstructions at each of the 10 target positions

For practical reasons, the analysis of reconstruction accuracy and robustness with varying focal beam waist w_0 was performed on simulated diffraction data [1]. Diffraction images were simulated for 10 different w_0. From each image, 10 exit field reconstructions were performed, each resulting in a complex transmission map reconstruction. The R-factor and T-factor reflect the accuracy for each of these reconstructions in the far field and in the object plane, respectively.

- `Fig7__reproducibility_analysis.mat`

variable name	data type	description
dx_diff	double	spatial resolution of diffraction images [m]
diffraction_images	15x2160x2560 double	15 measured diffraction images at constant experimental conditions
dx_rec	double	spatial resolution of exit field reconstructions [m]
transmission_reconstructions	15x1024x1024 complex double	reconstructed 2D transmission maps from the 15 diffraction images
mean_amplitude	1024x1024 double	average transmission reconstruction amplitude map from the 15 reconstructions
rms_amplitude	1024x1024 double	RMS amplitude variation across the 15 reconstructed transmission amplitudes
mean_phase	1024x1024 double	average transmission reconstruction phase map from the 15 reconstructions
rms_phase	1024x1024 double	RMS phase variation across the 15 reconstructed transmission amplitudes

In order to analyze the reproducibility of transmission maps from different single-shot diffraction images, 15 diffraction images were recorded under constant experimental conditions. From the 15 associated reconstructed complex transmission maps, the average amplitude and phase map as well as the RMS veriation of the amplitude and phase maps were computed.

- `Fig8__fraunhofer_fresnel.mat`

variable name	data type	description
dx_diff	double	spatial resolution of diffraction images [m]
target_positions	1x500 double	target positions for the simulated diffraction images (horizontal axis of the detector intensity lineouts)
fraunhofer_scan / ext_fresnel_scan	2048x500 double	detector intensity lineouts for 500 different target positions in Fraunhofer / extended Fresnel approximation
fraunhofer_neg2mm / ext_fresnel_neg2mm	2048x2048 double	simulated detector intensity for a target position of -2 mm in Fraunhofer / extended Fresnel approximation
fraunhofer_2mm / ext_fresnel_2mm	2048x2048 double	simulated detector intensity for a target position of 2 mm in Fraunhofer / extended Fresnel approximation
reference_neg2mm / reference_2mm	2048x2048 double	simulated detector intensities for a target position of -2 mm / 2 mm with the angular spectrum method
dx_rec	double	spatial resolution of exit field reconstructions [m]

Here, diffraction images of a circular aperture (radius 15 μm) in a 30 nm gold film were simulated via the Fraunhofer approximation and the extended Fresnel approximation [1]. Cuts through the diffraction image are contained in the "scan"-variables for every one of the 500 target positions. At target positions -2 mm and 2 mm, the Fraunhofer and the extended Fresnel approximations are compared to an accurate reference obtained via the angular spectrum method.

- `Fig9__phase_retrieval_benchmark.mat`

variable name	data type	description
dx_diff	double	spatial resolution of diffraction images [m]
diffraction_image_noise0 / diffraction_image_noise1	2048x2048 double	simulated diffraction images with an rms noise level of 0 (*noise0) / 10^{-4} (*noise1)
dx_rec	double	spatial resolution of exit field reconstructions [m]
exit_field	512x512 double	simulated exit field amplitude of a characteristic aperture in a gold foil
relative_phase	512x512 double	simulated exit field phase with respect to a free propagating imaging beam
exit_field_reconstruction_noise0 / exit_field_reconstruction_noise1	512x512 double	reconstructed HIO-OO exit field amplitudes for diffraction image noise levels of 0 (*noise0) / 10^{-4} (*noise1)
relative_phase_reconstruction_noise0 / relative_phase_reconstruction_noise1	512x512 double	reconstructed HIO-OO exit field phase maps for diffraction image noise levels of 0 (*noise0) / 10^{-4} (*noise1)
exit_field_error_HIO_noise0 / exit_field_error_HIO_noise0p1 / exit_field_error_HIO_noise1	1x500 double	exit field errors of HIO reconstructions with noise levels 0 (*noise0) / 10^{-5} (*noise0p1) / 10^{-4} (*noise1)
exit_field_error_HIO_OO_noise0 / exit_field_error_HIO_OO_noise0p1 / exit_field_error_HIO_OO_noise1	1x500 double	exit field errors of HIO-OO reconstructions with noise levels 0 (*noise0) / 10^{-5} (*noise0p1) / 10^{-4} (*noise1)

variable name	data type	description
r_factor_HIO_noise0 / r_factor_HIO_noise0p1 / r_factor_HIO_noise1	1x500 double	R-factor evolutions of HIO reconstructions with noise levels 0 (*noise0) / 10^{-5} (*noise0p1) / 10^{-4} (*noise1)
r_factor_HIO_OO_noise0 / r_factor_HIO_OO_noise0p1 / r_factor_HIO_OO_noise1	1x500 double	R-factor evolutions of HIO-OO reconstructions with noise levels 0 (*noise0) / 10^{-5} (*noise0p1) / 10^{-4} (*noise1)

In [1], a combination of the well-known Hybrid Input-Output (HIO) and Output-Output (OO) phase retrieval algorithms are introduced. This dataset contains the simulated exit field of a characteristic aperture in a 30 nm gold film. From this, diffraction images with different noise levels were calculated and used for reconstructions with the HIO method and the combined HIO-OO method. The R-factor and the exit field error for 500 phase retrieval iterations are provided for each algorithm and noise level, showing that the HIO-OO method enables a more robust reconstruction procedure.

References

[1] Richard Altenkirch, Christian Peltz, Tom Böttcher, Stefan Lochbrunner, Franziska Fennel and Thomas Fennel, *Ultrafast imaging of laser-induced modifications in planar targets via single-shot in-line holography*, New Journal of Physics (submitted)