Robust computer-vision algorithm for shadowgraph images of tin pancake targets

UCSB Senior Year Capstone Project with ASML

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August, 2020

Project description: Design, implement, and test a robust computer vision (CV) algorithm to determine the key metrics of Sn (tin) “pancake” targets that are used in ASML’s Laser Produced Plasma EUV Sources. Develop an optical transmission model to relate the measured shadow contrast to the density-depth on tin targets. Additionally, extend the algorithm to execute in real time during high speed operation.

Background: ASML San Diego, CA develops EUV (Extreme Ultraviolet, 13.6 nm radiation) lithography light sources using LPP (Laser Produced Plasma) technology. EUV production takes place inside a large vacuum chamber by first shaping a ~30 micron tin (Sn) droplet with a laser pre-pulse and then vaporizing the resulting tin disk (pancake) using a more powerful (tens of kW) CO2 laser pulse to produce plasma and EUV light. This operation occurs at a rate of 50 kHz.

The EUV Source relies on a plasma target recipe (algorithm) to ensure maximum conversion efficiency for each set of laser pulses (pre-pulse and main pulse) to achieve maximum EUV power output. This plasma recipe has many key parameters, including the tin pancake target metrics (length (T) and angle (O) – see Figure 1). These metrics are derived from shadowgraph measurements of tin targets with two droplet formation cameras (DFC). In the EUV source vessel the cameras are located at 90 degrees with respect to each other and 90 degrees to the CO2 laser beam. DFCs are back-illuminated by the near infrared (NIR) back light modules (BLM). Achieving the tin target metrics with required accuracy is challenging in practice due to limitations of detection optics and assumptions of the CV algorithms. Further, there is a desire to generate these target measurements in real-time and high speed to enable feedback control.

Problem Statement: The measurement of the tin pancake target length as determined by the current CV algorithm is consistently less than the measurement a human would make based on the shadowgraph images. The Target Formation Monitor (TFM) is a CV processing module in the EUV source that schedules and captures shadowgraph images. The current CV includes the following main steps: 1) Pre-processing, 2) Thresholding, 3) Binarization, 4) Ellipse Fit, 5) Measurements. The algorithm executes at a rate of 25-40 Hz. These measurements are currently mainly used for research, diagnostics and root cause analysis.

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The goal of this project includes the following tasks:

- build an optical transmission model that, based on the measured shadow contrasts, allows estimating the distribution of tin density extended (integrated) along the shadowgraph direction
- design an improved computer vision algorithm that delivers accurate measurements of target metrics. Areas of improvement include improved thresholding and shape fitting techniques. Machine Learning might also be considered if the (limited) training and validation data can be mitigated.
- Introduce additional metrics providing more extensive description of tin-target shape and morphology. Fusion of metrics from stereoscopic images can be considered.
- Validate and optimize the optical model as well as improved computer-vision algorithm on the measurements from ASLM's EUV source.
- further, there is a desire to run this algorithm at higher speed (1 kHz to 50 kHz) and in real-time to deliver a measurement for use in high bandwidth feedback control. This will involve implementing the algorithm on an FPGA-based computing platform.

Further information:

https://en.wikipedia.org/wiki/Extreme_ultraviolet_lithography

https://www.asml.com/en/technology#lithography

https://www.youtube.com/watch?v=NHSR6AHNiDs

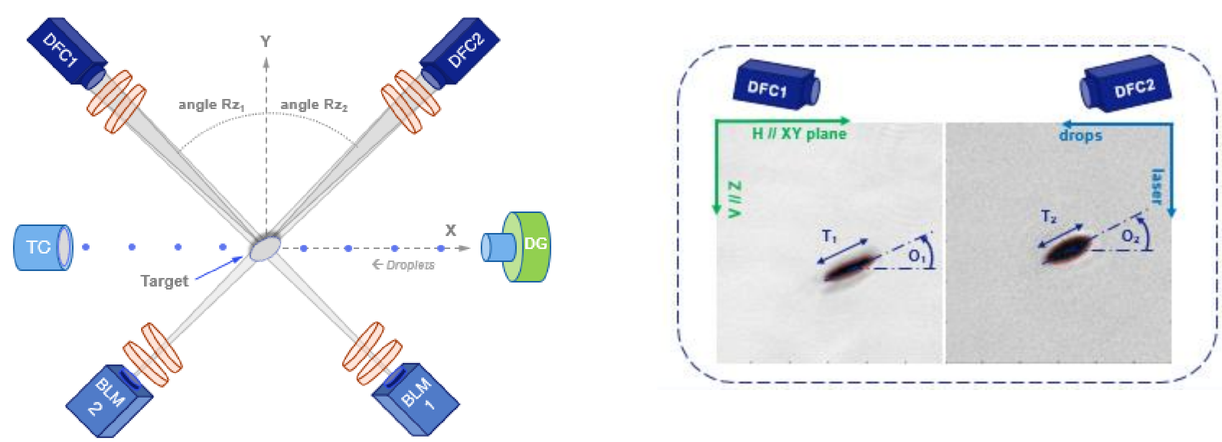

Figure 1: Layout of shadowgraph metrology (left); example of stereoscopic shadowgraph (right)

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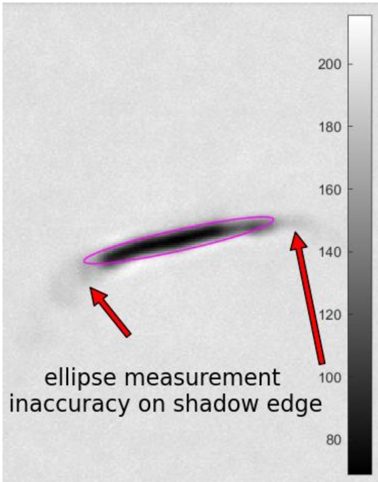

Figure 2: Example of Tin Target Shadowgraph (pancake) including ellipse fit from current algorithm

Figure 3: EUV Source