EUV Sensor Fusion and Energy Control

UCSB Senior Year Capstone Project with ASML

Andrew Liu, Vivian Wang,
Sam Crisafulli, and David Brandt

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Project description: Design a real-time, sensor-fusion algorithm which combines high-sample-rate, inaccurate measurements of EUV energy with longer-latency, down-sampled, more accurate measurements. Integrate the algorithm with the Energy Control feedback loop and demonstrate realization of the tighter performance requirements of future lithography platforms.

Background: ASML San Diego, CA develops EUV (Extreme Ultraviolet, 13.5 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 converting the resulting tin disk (pancake) using a more powerful (tens of kW) main laser pulse to produce plasma and EUV light. This operation occurs at a rate of 50 kHz.

A key goal is to generate EUV light at a constant power level. During production, the EUV energy per droplet is measured within the vessel where plasma is generated (typically known as the internal EUV sensors), and, after passing through multiple optical elements, at the reticle through which light exposes the wafer (the external or scanner sensor). In current systems, the energy measured at the reticle is directly used as feedback for the Energy Control subsystem, which modulates the lasers in order to regulate the intensity of the generated plasma (Figure 1: Energy Measurement and Control). Due to signal processing and transmission delays, the EUV measured at the reticle is only available to Energy Control on the sample after it is measured, though the impact on performance in today's systems is manageable.

Problem Statement: In order to continue scaling power, future platforms will require Energy Control to run at increasing rep rates; these higher rates magnify the effect of latency of the reticle EUV sensor. E.g., rather than being transmitted to Energy Control with a delay of a single sample period, the measurement may be delayed by two or more sample periods.

The goal of this project is to design modifications to the Energy Control subsystem which continue to achieve the required level of suppression of variation in EUV as the rep rate of Energy Control increases, and, thus, the sampling delay of the reticle sensor increases. This may include the following:

- Develop candidate sensor fusion algorithms which combine the low-latency, high-rate internal EUV sensors with the higher latency, potentially down-sampled external EUV measurement at the reticle.
    - This may require modeling dynamics in the transmission of EUV from source to scanner.

    - Algorithms should be sufficiently flexible to reject measurements flagged as valid and to yield good EUV estimates even in the presence of missing measurements.
    - Algorithms should account for sensor characteristics and behaviors (accuracy, precision, invalid or missing measurements).
    - A Kalman filter may be a good choice of algorithm for the above sensor fusion objectives.
- Analyze how latency affects Energy Control behaviors such as its transient responses to disturbances and settling time. Determine the achievable performance of Energy Control with and without sensor fusion.
    - For a provided Energy Control algorithm, tune gains for each scenario.
    - Optionally consider alternative feedback loop designs, such as Linear Quadratic Gaussian control.
- Validate the performance of the algorithm by integrating it with provided simulations of the Energy Control subsystem and quantifying the closed-loop EUV variability.
    - The objective is to design the sensor fusion algorithm to be "plug-and-play"; that is, regardless of whether the algorithm is enabled or disabled, no modifications to the connected Energy Control subsystem is needed.
- Define the calibration procedure for determining the parametrization of the sensor fusion algorithm in order to correct for slow deviations of the internal and external sensors and/or system-to-system variation.
- Generate C++ and/or VHDL code of the developed algorithm, which can be used on the EUV source real-time control system.

Further information:

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

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

Laser and tin in the light source - Inside the TWINSCAN NXE:3400 EUV lithography machine | ASML - YouTube

The full EUV optical light path - Inside the TWINSCAN NXE:3400 EUV lithography machine | ASML - YouTube

The reticle and reticle stage - Inside the TWINSCAN NXE:3400 EUV lithography machine | ASML - YouTube

How An EUV Light Source Works - YouTube

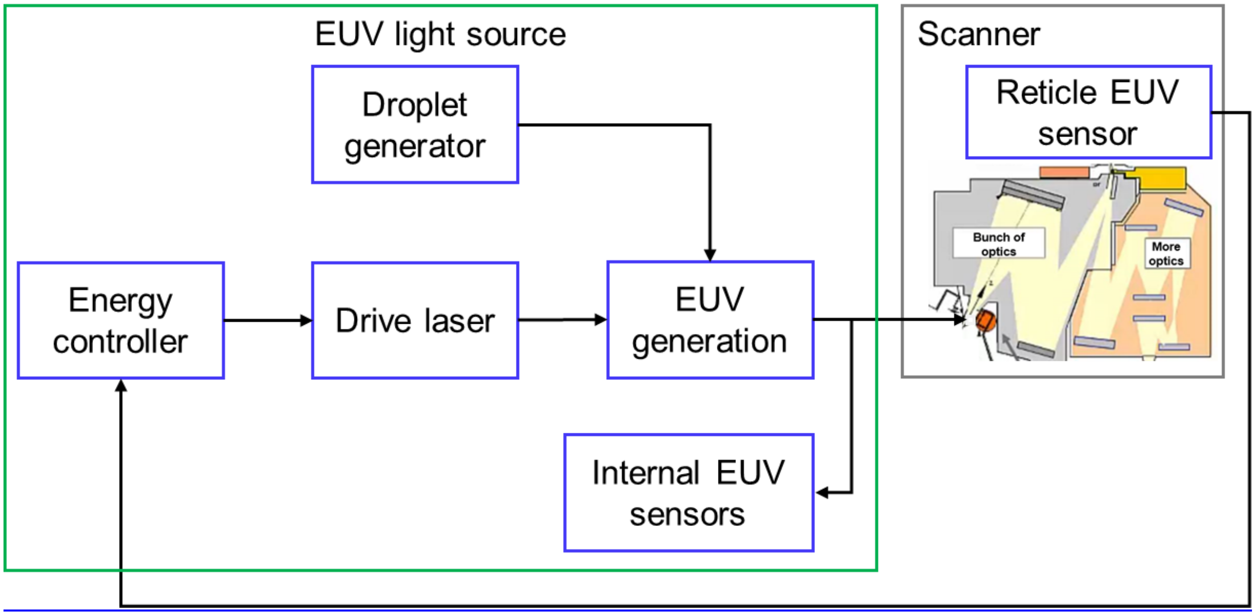

Figure 1: Energy Measurement and Control