Optimization of IR heater shapes for mirror temperature control in wafer scanners

*Citation for published version (APA):*

*Document status and date:*
Published: 22/10/2019

*Document Version:*
Accepted manuscript including changes made at the peer-review stage

*Please check the document version of this publication:*

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher’s website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

*General rights*
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain.
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the “Taverne” license above, please follow below link for the End User Agreement:

www.tue.nl/taverne

*Take down policy*
If you believe that this document breaches copyright please contact us at:
openaccess@tue.nl
providing details and we will investigate your claim.

Download date: 17. Jan. 2020
Optimization of IR heater shapes for mirror temperature control in wafer scanners

D.W.M. Veldman¹, S.A.N. Nouwens¹, R.H.B. Fey¹, H.J. Zwart¹,², M.M.J. van de Wal³, J.D.B.J. van den Boom³, H. Nijmeijer¹

¹ Eindhoven University of Technology, Dynamics & Control
² University of Twente, Applied mathematics
³ ASML

Application: ASML’s wafer scanners

ASML’s wafer scanners, crucial machines for the production of computer chips, project a pattern of electronic connections on a silicon substrate with tolerances approaching the subnanometer range. The latest generation wafer scanners uses Extreme Ultraviolet (EUV) light, which is projected through a sequence of mirrors onto the silicon substrate. Every mirror absorbs about 30% of the EUV light it receives.

Problem: the mirrors heat up and expand, which deteriorates the imaging quality.

Solution approach: additional Infrared (IR) heating to flatten temperature distribution

Finite Element model

\[ 0 = AT_{ss,i} + E_{top}(B_{d,i}d_i + B_u u_i), \quad (1) \]

for \( i = 1, 2, ..., N_d \). EUV illumination patterns lead to a large set of \( N_d \) disturbances \( B_{d,i} \) with \( d_i \in \mathbb{R} \). To flatten the steady-state temperature increase \( T_{ss,i} \), an actuation IR heat load \( B_u u_i \) with \( u_i \in \mathbb{R}^{N_u} \) is applied. Matrix \( E_{top} \) assures the heat loads are only applied at the top surface.

Biconvex optimization problem

\[ \min_{B_u, u_1, u_2, ..., u_{N_d}} \sum_{i=1}^{N_d} u_i^T B_u^T W B_u u_i, \quad (2) \]

such that for all disturbances \( i = 1, 2, ..., N_d \)

\[ T_{min} \leq (T_{ss,j})_i \leq T_{max}, \quad (3) \]

for all nodes \( j \) in the OFP. Furthermore, the actuation heat load shape \( B_u \) and the intensities \( u_i \) must be nonnegative.

Design question:

Design shape \( B_u \) and intensities \( u_i \) to counteract all disturbances \( B_{d,i} \).

Result: IR heat load shapes

7 disturbances \( B_{d,i} \)

Example:

for \( N_d = 7 \) disturbances, keep OFP-temperature increase between \( T_{min} = 8K \) and \( T_{max} = 12K \) with \( N_u = 2 \) heater shapes.

Resulting shapes \( B_u \)

Resulting intensities \( u_i \)

Outlook: deformation based control

Extend the approach to a (nonlinear) thermomechanical model with constraints on deformation in the OFP.