2nd EUVL Symposium

Throughput Model Consideration and Impact of Throughput Improvement Request on Exposure Tool

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Nikon

OUTLINE

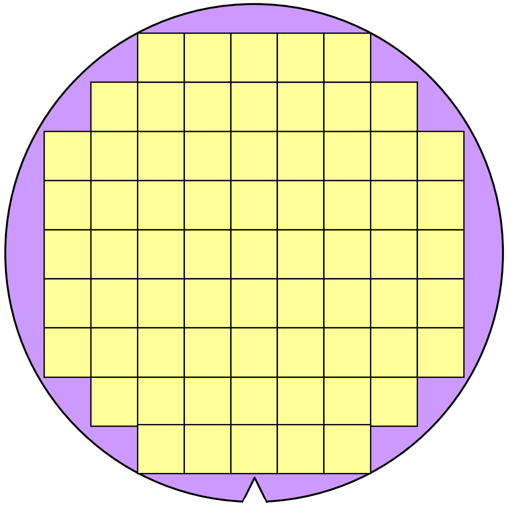
- To introduce a wafer throughput model.
  - Simple and easy to understand.
- To balance each parameter.
  - Source output power, stage acceleration, others.
- To examine the impact of the throughput improvement request.
  - Impact on each element.

Decomposition of wafer exposure process

- $T = T_{exp} + T_{oh}$
  - T: *total time for a wafer*
  - T_{oh}: *overhead time (wafer exchange, wafer alignment, …)*
  - T_{exp}: *wafer exposure time*

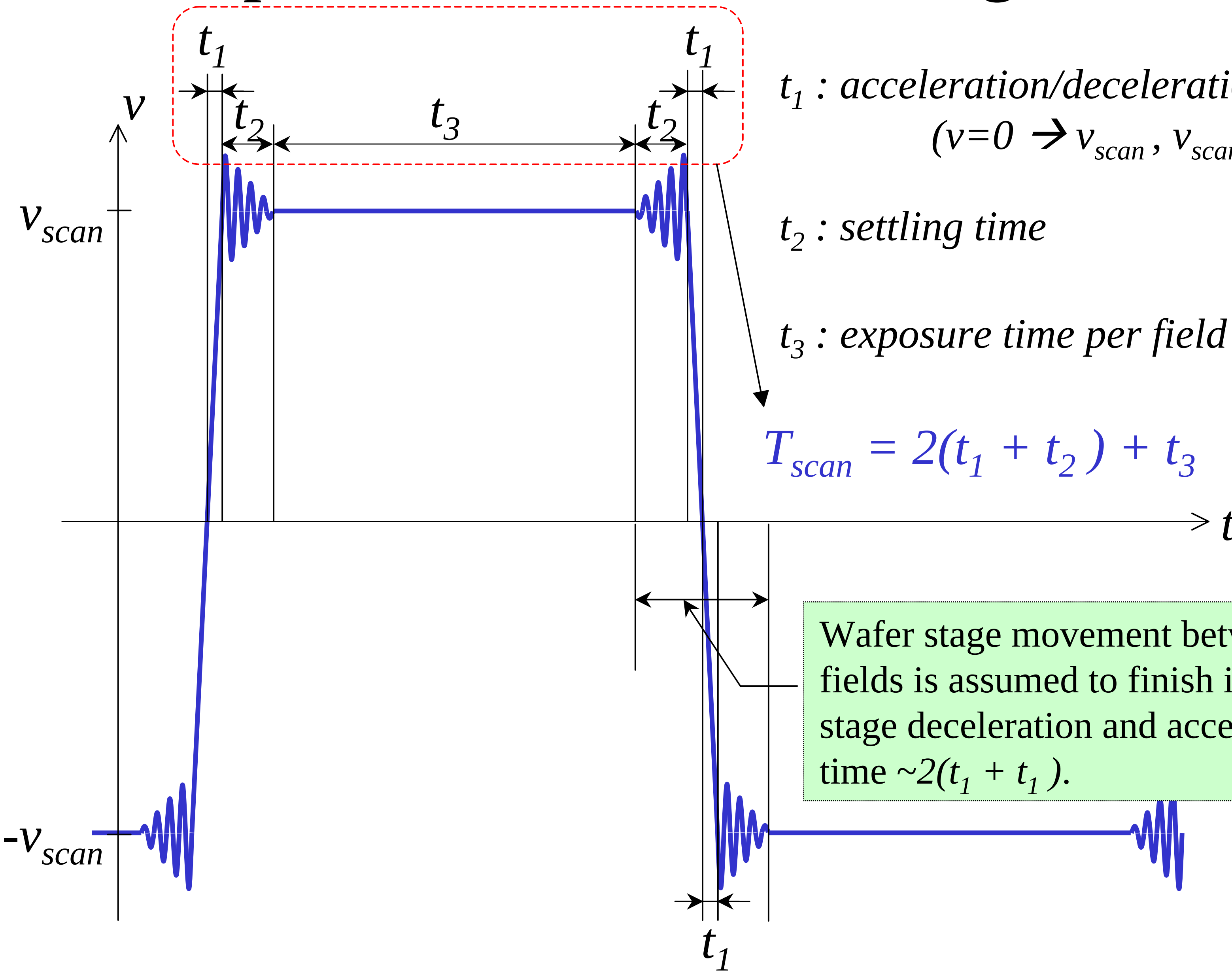
$$T_{exp} = T_{scan} * N$$

  - T_{scan}: *scanning time per field*
  - N: *number of the fields on a wafer*



- $T = T_{scan} * N + T_{oh}$
  - *Wafer stage movement between the fields is assumed to finish in reticle stage deceleration and acceleration time.*
    - *The performance of a wafer stage is ideal for simplification.*

Decomposition of field scanning time



t_1 : *acceleration/deceleration time* ($v=0 \rightarrow v_{scan}$, $v_{scan} \rightarrow 0$)

t_2 : *settling time*

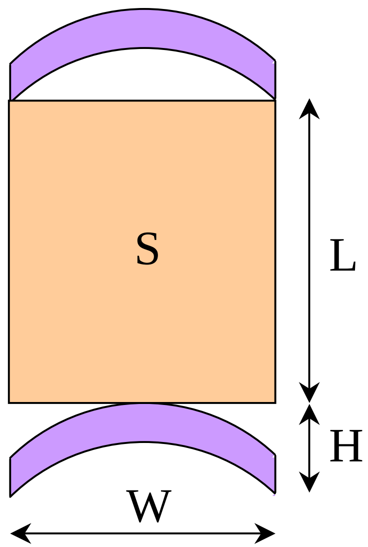
t_3 : *exposure time per field*

$$T_{scan} = 2(t_1 + t_2) + t_3$$

Wafer stage movement between the fields is assumed to finish in reticle stage deceleration and acceleration time ~$2(t_1 + t_1)$.

Scanning speed and Exposure time per field

- Wafer scanning speed is decided by intensity of the EUV light on a wafer and photoresist sensitivity.



W : field width, *L : field height*
S : area of the field, *H : arc height + slit*

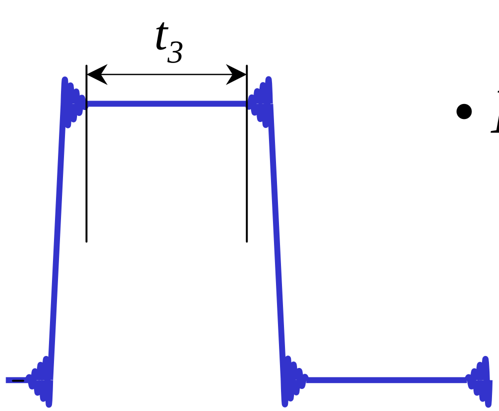
Energy required to expose the field

$E = R * S$ *R : photoresist sensitivity*

Time required to expose the field

$t_{field} = E / P$ *P : EUV intensity on a wafer*

$$v_{scan} = \frac{L}{t_{field}} = \frac{L * P}{R * S} = \frac{P}{R * W}$$



- *Exposure time per field*

$$t_3 = \frac{L+H}{v_{scan}} = \frac{(L + H) * W * R}{P}$$

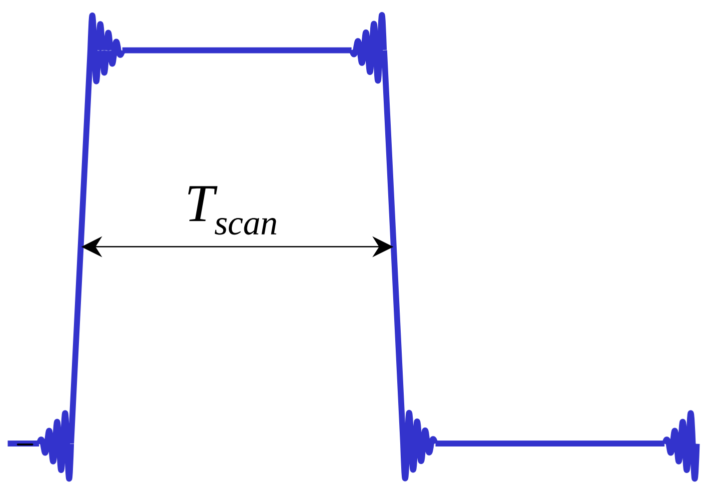
Acceleration time and Scanning time per field

- Acceleration time is decided by the scanning speed ~ v_{scan} and acceleration of a wafer stage ~ a_W.

$$t_1 = \frac{v_{scan}}{a_W} = \frac{P}{a_W * W * R}$$

- Scanning time per field ~T_{scan} is expressed as follows.

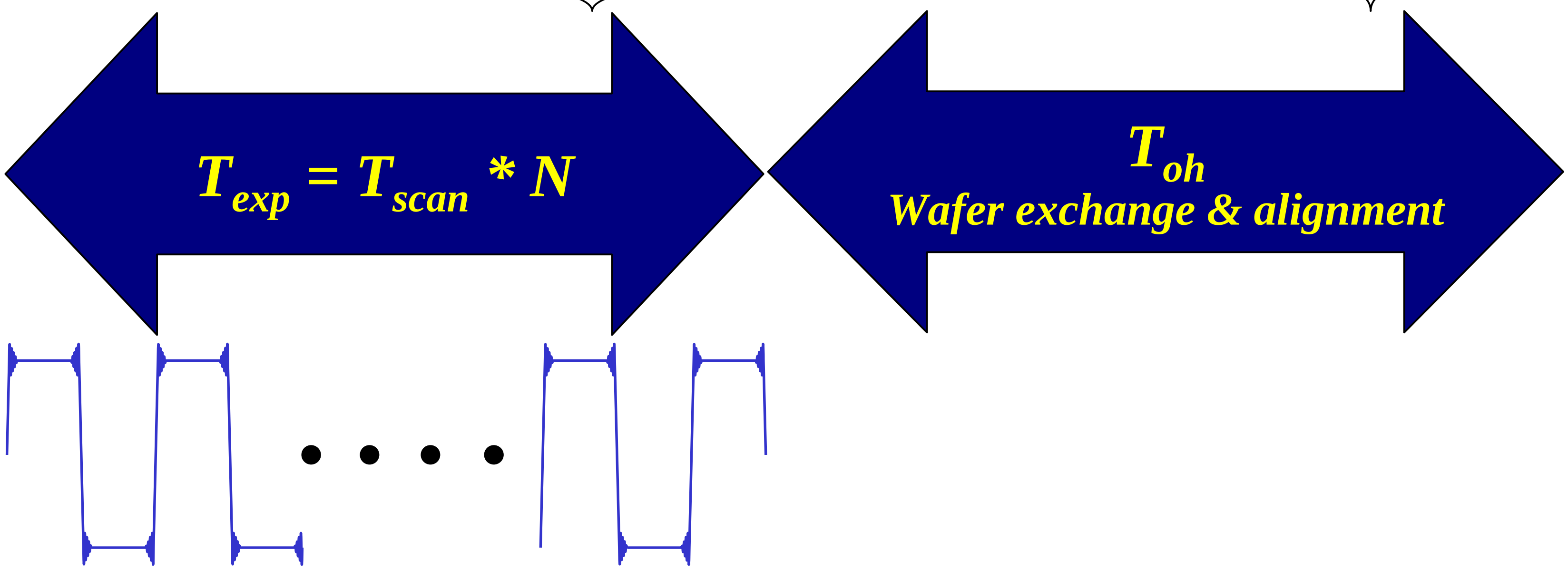
$$T_{scan} = 2(t_1 + t_2) + t_3 = \frac{2P}{a_W * W * R} + 2t_{settle} + \frac{(L + H) * W * R}{P}$$



Summary of a wafer throughput model

- *The time taken to process one wafer is as follows.*

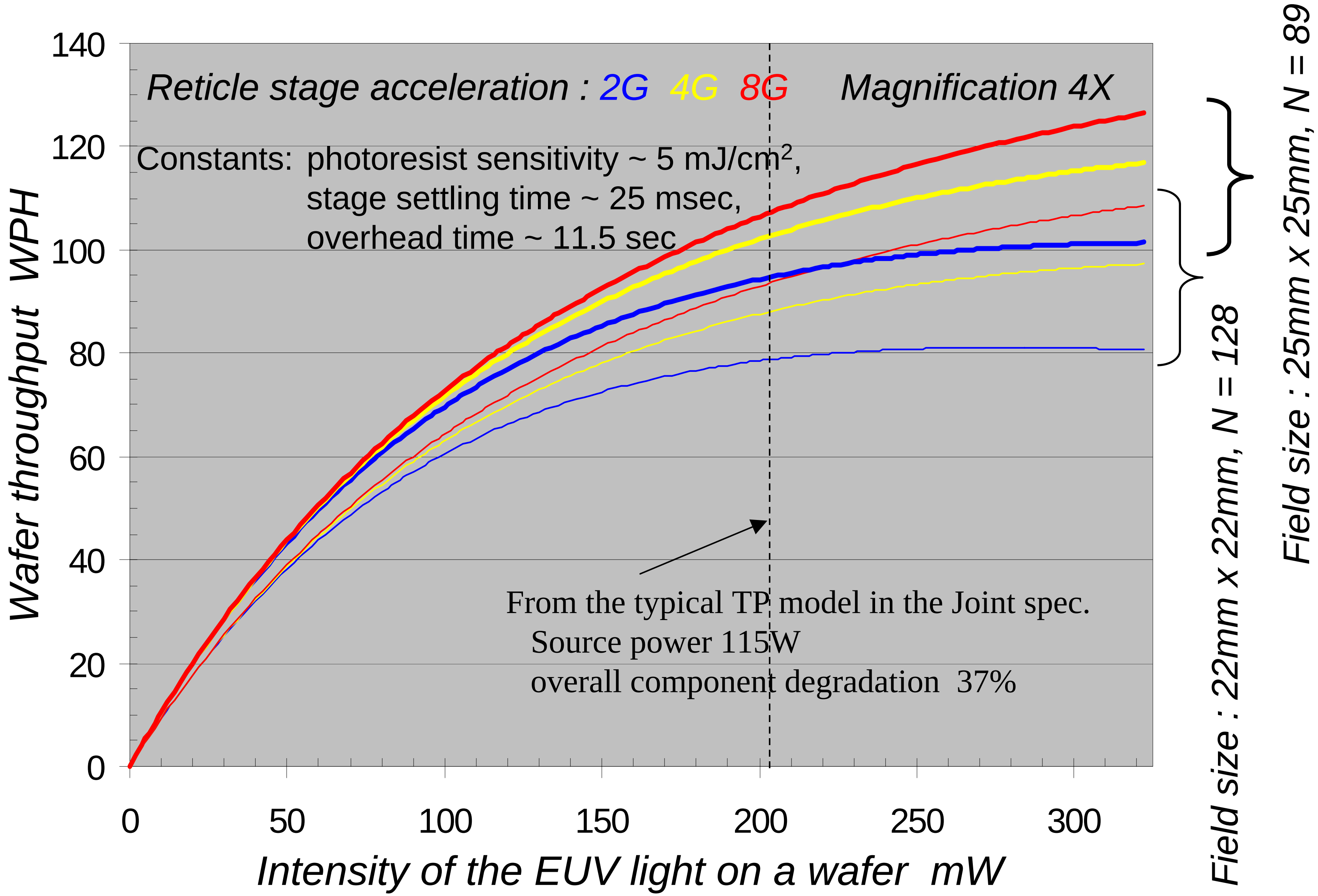
$$T = T_{scan} * N + T_{oh} = N\left\{ \frac{2P}{a_W * W * R} + 2t_{settle} + \frac{(L+H) * W * R}{P} \right\} + T_{oh}$$



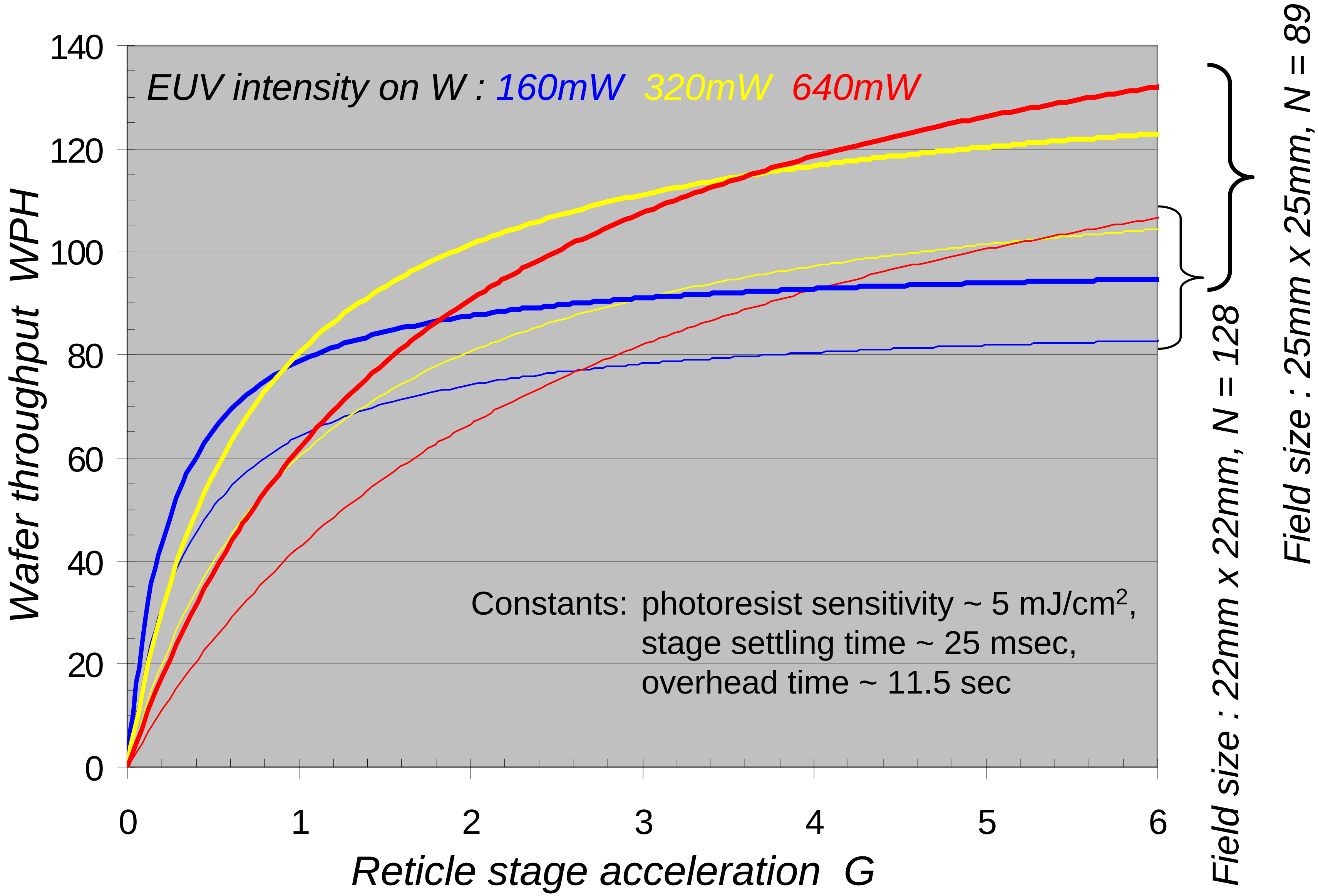
- *The wafer throughput is as follows.*

$$TP = \frac{3600}{T}$$

Example 1 ~ Throughput vs EUV intensity



Example 2 ~ Throughput vs stage acceleration



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Introduction of evaluation functions

- An evaluation function is introduced to balance each parameter in the throughput model.

$$F(x) = \frac{\partial TP}{\partial x} x$$

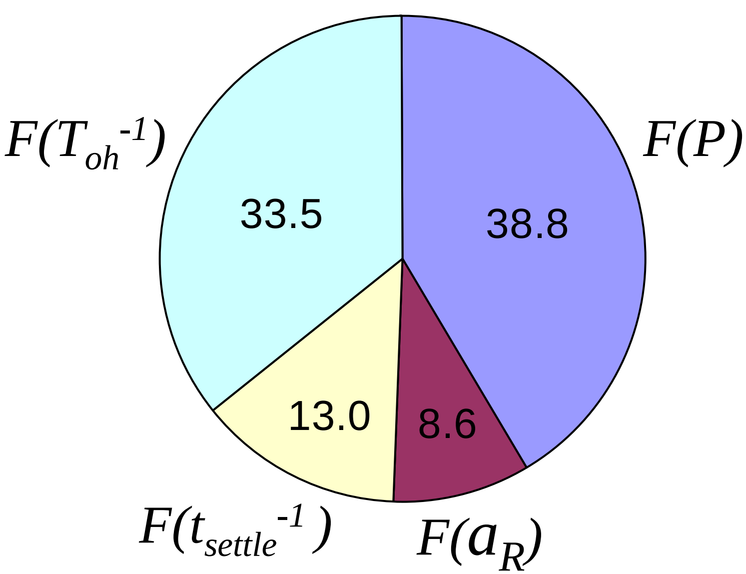
- This evaluation function means how much throughput changes when the parameter changes.

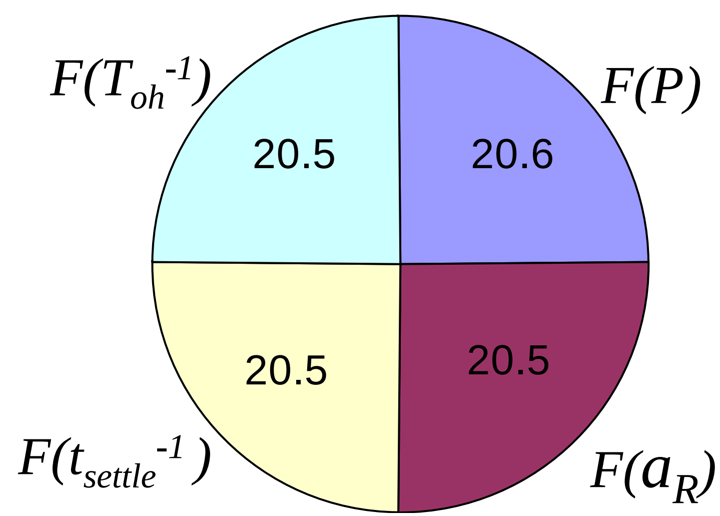
- The following parameters are evaluated in this paper.
  - Intensity of the EUV light on a wafer ~ P
  - Reticle stage acceleration ~ a_R
  - Stage settling time ~ t_{settle}^{-1}
  - Overhead time ~ T_{oh}^{-1}

Example of parameter optimization 1

Field size = 25 mm x 25 mm

Initial conditions 1	Optimized 1
$P = 202\ mW$	$P = 234\ mW$
$a_R = 4\ G$	$a_R = 1.94\ G$
$t_{settle} = 25\ msec$	$t_{settle} = 39.4\ msec$
$T_{oh} = 11.5\ sec$	$T_{oh} = 7.01\ sec$
$TP = 102.5\ WPH$	$TP = 102.7\ WPH$

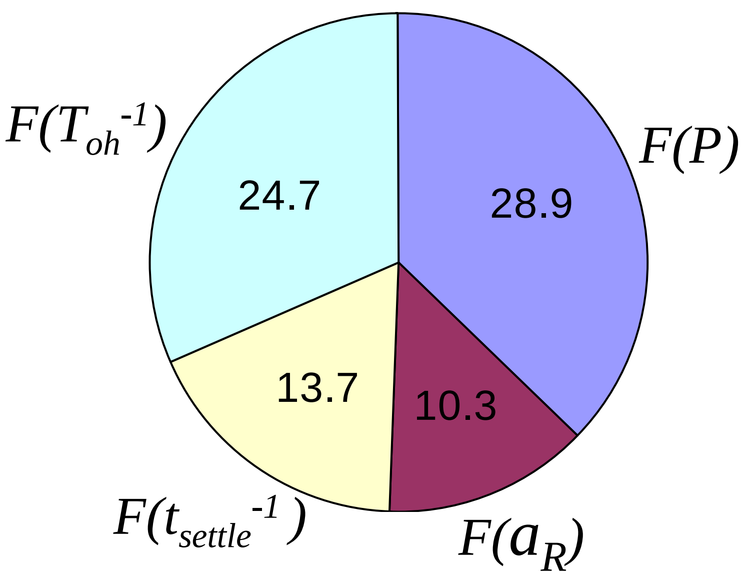


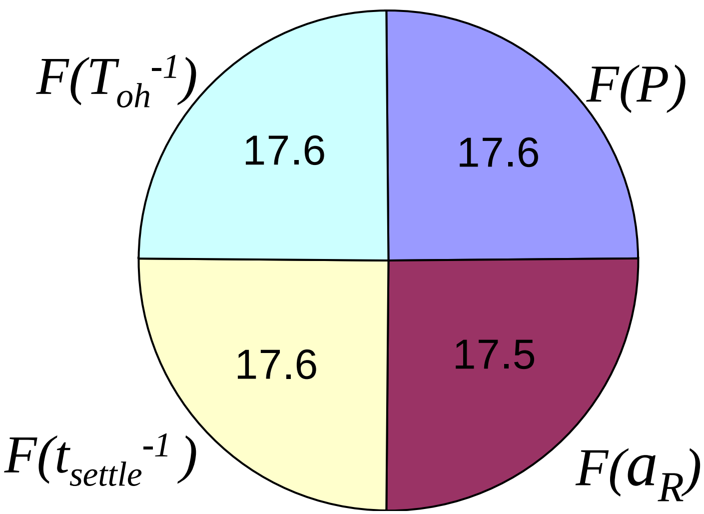


Example of parameter optimization 2

Field size = 22 mm x 22 mm

Initial conditions 2	Optimized 2
$P = 202\ mW$	$P = 225\ mW$
$a_R = 4\ G$	$a_R = 2.61\ G$
$t_{settle} = 25\ msec$	$t_{settle} = 32.0\ msec$
$T_{oh} = 11.5\ sec$	$T_{oh} = 8.2\ sec$
$TP = 87.9\ WPH$	$TP = 87.9\ WPH$





OUTLINE

- *To introduce a wafer throughput model.*
  - *Simple and easy to understand.*
- To balance each parameter.
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  - Impact on each element.

Throughput improvement requirement 1

Field size = 25 mm x 25 mm

Optimized 1

$P = 234\ mW$

$a_R = 1.94\ G$

$t_{settle} = 39.4\ msec$

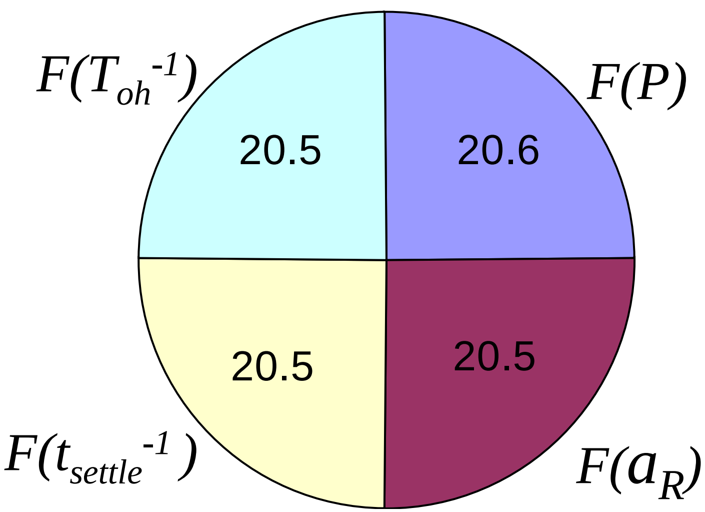
$T_{oh} = 7.01\ sec$

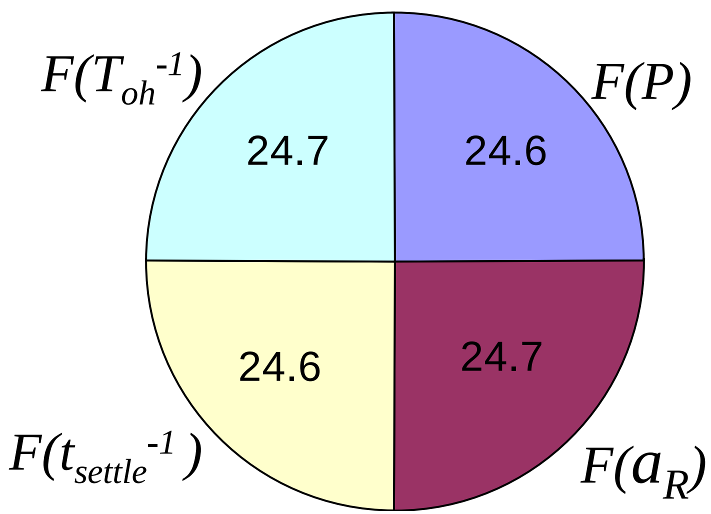
$TP = 102.5\ WPH$

20%

Improved 1

$P = 281\ mW$	**20%**
$a_R = 2.79\ G$	**44%**
$t_{settle} = 32.8\ msec$	**20%**
$T_{oh} = 5.84\ sec$	**20%**
$TP = 123.3\ WPH$	





Throughput improvement requirement 1

Field size = 22 mm x 22 mm

Optimized 2

$P = 225\ mW$

$a_R = 2.61\ G$

$t_{settle} = 32.0\ msec$

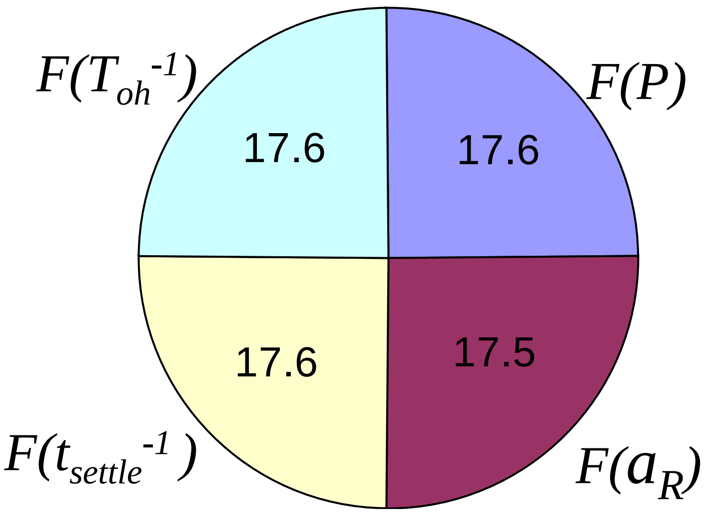
$T_{oh} = 8.2\ sec$

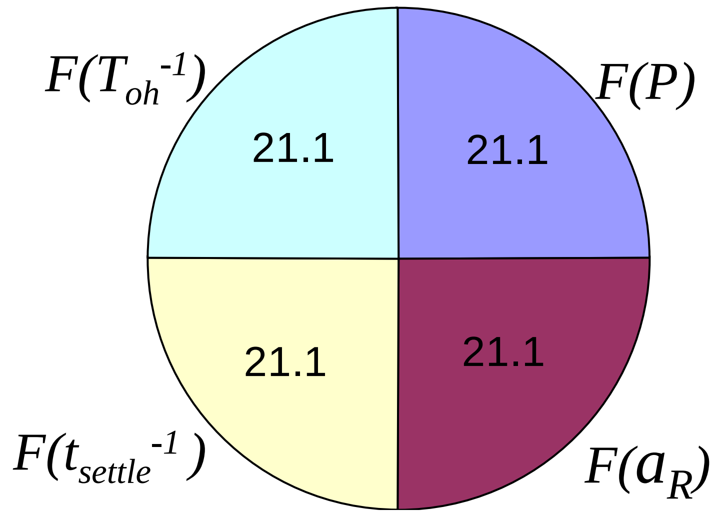
$TP = 87.9\ WPH$

20% ↗

Improved 2

$P = 270\ mW$	**20%**
$a_R = 3.76\ G$	**44%**
$t_{settle} = 26.7\ msec$	**20%**
$T_{oh} = 6.83\ sec$	**20%**
$TP = 105.4\ WPH$	





Summary

- A simplified EUV wafer throughput model was shown.
- How to balance each parameter was shown.
- The impact of the throughput improvement request was shown.
  - *(Stage acceleration)* $\propto$ *(Throughput)*^{2}