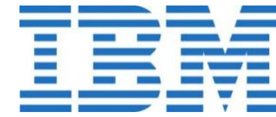
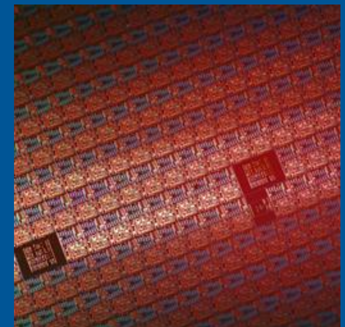


Accelerating the next technology revolution

Driving the Industry to a Consensus on High-NA EUV

Patrick Kearney



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The High-NA EUV Team

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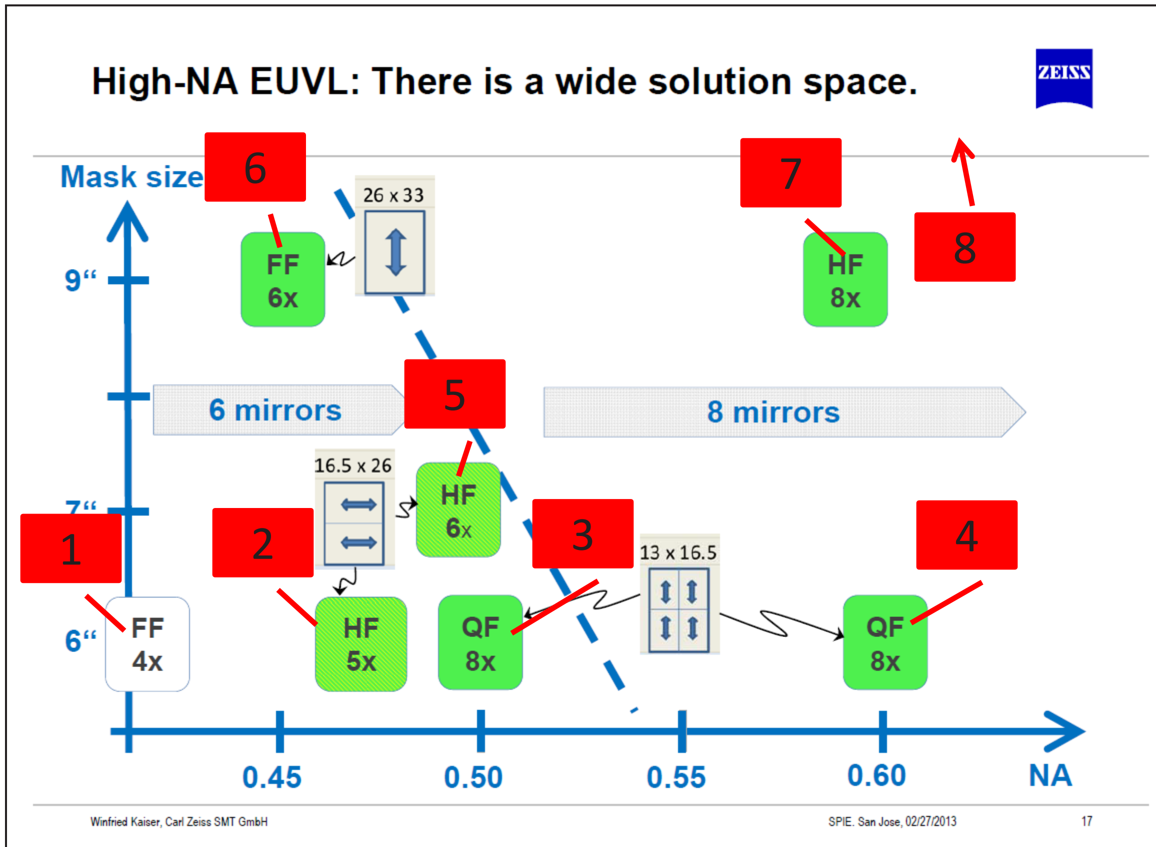
Potential solutions

SEMATECH



Throughput/mirrors:
8 mirror systems should have ~40% of the throughput of 6 mirror systems.
Throughput/field size:
Assumed HF reduced throughput to 74% and QF reduced throughput to 55%.
Throughput is just these two factors multiplied, represents throughput relative to case 1.

Case	Magnification	Field size	Mask size	"Resolution"	NA	Coatings	N mirrors	Throughput
Case 1	4x	FF	6 inch	9.9 nm	0.41	Advanced	6	100%
Case 2	5x	HF	6 inch	8.6 nm	0.47	TBD	6	74%
Case 3	8x	QF	6 inch	8.1 nm	0.50	Standard	6	55%
Case 4	8x	QF	6 inch	6.8 nm	0.60	Standard	8	22%
Case 5	6x	HF	7 inch	8.1 nm	0.50	Standard	6	74%
Case 6	6x	FF	9 inch	9.0 nm	0.45	Standard	6	100%
Case 7	8x	HF	9 inch	6.8 nm	0.60	Standard	8	30%
Case 8	8x	FF	12 inch	6.8 nm	0.60	Standard	8	40%

Tradeoffs

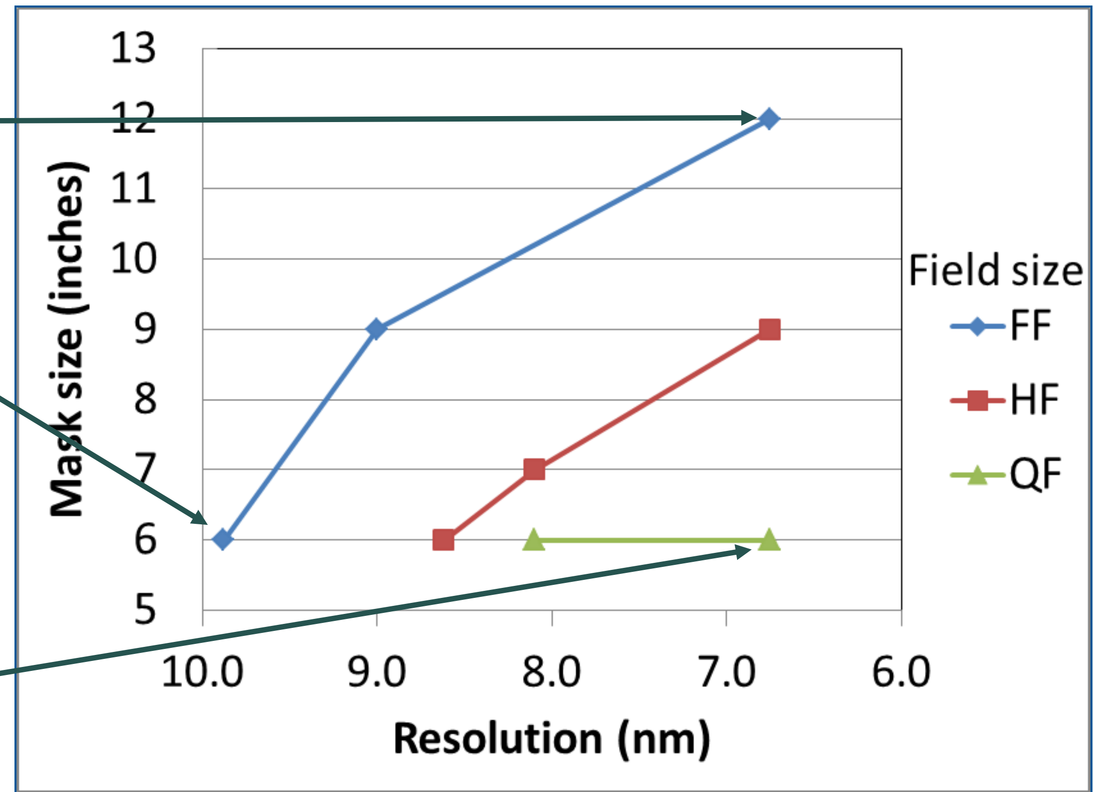
- Resolution
- 6” mask
- Full wafer field

Industry must give up one

Give up 6” mask

Give up resolution

Give up Full wafer field



SEMATECH High-NA EUV Survey

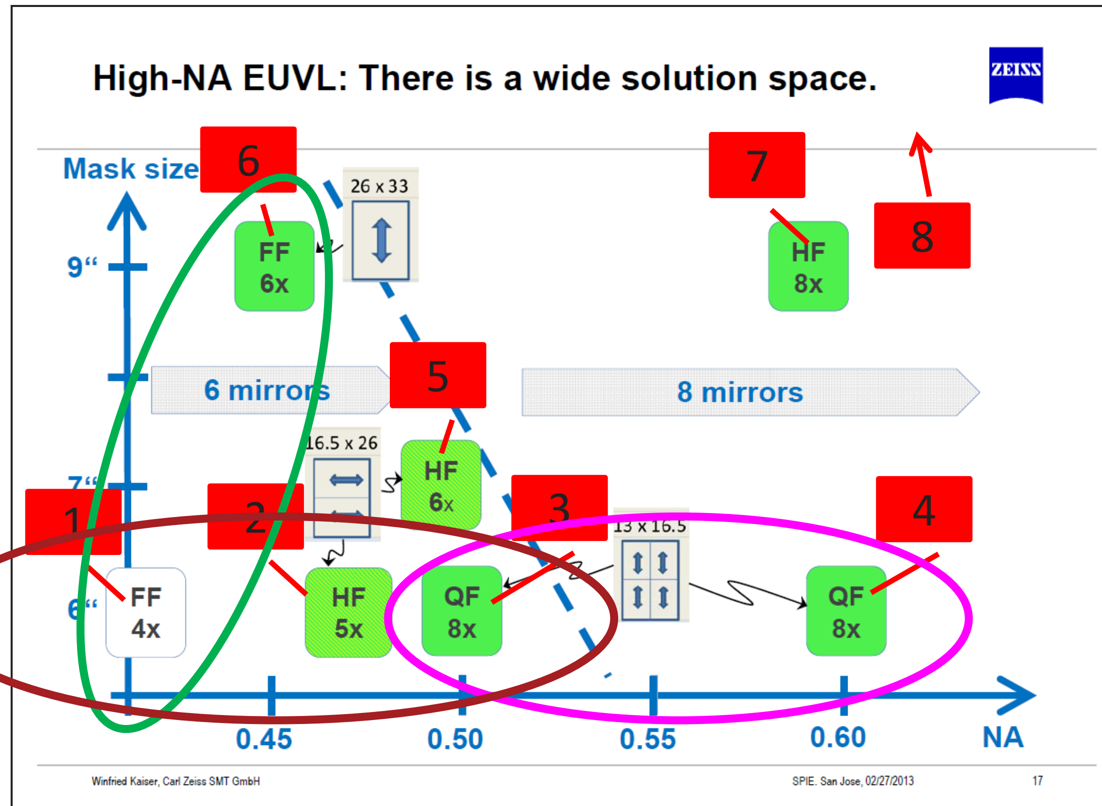
Get Industry Perspective on High-NA EUV

- Four anonymous surveys were conducted with each of the following stakeholder groups
  - Chip makers: 8 of 9 companies responded
  - Mask makers: 9 of 11 companies responded
  - Stepper suppliers: 4 of 4 companies responded
  - Mask tool/material suppliers: 18 of 22 companies responded

- All four surveys had excellent industry participation
- Survey conducted in Q2-2013

All Companies Feedback

High-NA Preferences



- Chip makers
- Mask makers
- Equipment and material makers

FF = Full Field
HF = Half Field
QF = Quarter Field

- Some overlap between chip makers and mask makers
- Some overlap between mask makers and equipment and material makers
- But there is no common ground yet between all three groups

High-NA EUV Survey Conclusions

- Chip makers want full field solutions
  - Beyond 10 nm half-pitch this will require higher magnification and a larger mask
- Chip makers are evenly split between 9-inch and 12-inch mask preferences
  - 9-inch masks will support Case 6 for 9 nm resolution.
  - 12-inch masks will support Case 8 for 7 nm resolution
  - The industry only wants one mask size change
- Mask makers and equipment/material makers prefer to stay with the current 6-inch mask size
  - A switch to 9- or 12-inch mask sizes is expected to take 3 to 6 years
- Mask equipment/material makers do not expect fundamental changes required to their technology to accommodate larger mask sizes

July 9th Meeting Summary

- Mask equipment suppliers will not invest in a new mask size without more consensus from the chipmakers
- Chipmakers seem to be waiting for EUV to be successful before placing bets on High-NA EUV
- Since a size transition is expected to take 3-6 years, this either:
  - Forces a delay of High-NA EUV
    or
  - Limits initial High-NA EUV to the 6” mask size solutions.

Summary

- SEMATECH has laid out the options for High-NA EUV
- SEMATECH has surveyed the industry and found there is disagreement between the chipmakers, mask makers and supply chain about how to proceed
  - Equipment suppliers and mask makers prefer solutions that retain 6” masks
  - Chipmakers want full field solutions and at high resolution that implies larger masks
- If chipmakers don’t push for a larger mask soon, we may end up with a delayed implementation of High-NA EUV or limit ourselves to 6” masks
- There is a side meeting here at the EUV Symposium to get the key stakeholders in the same room to discuss how to move forward

Why consider High-NA EUV now?

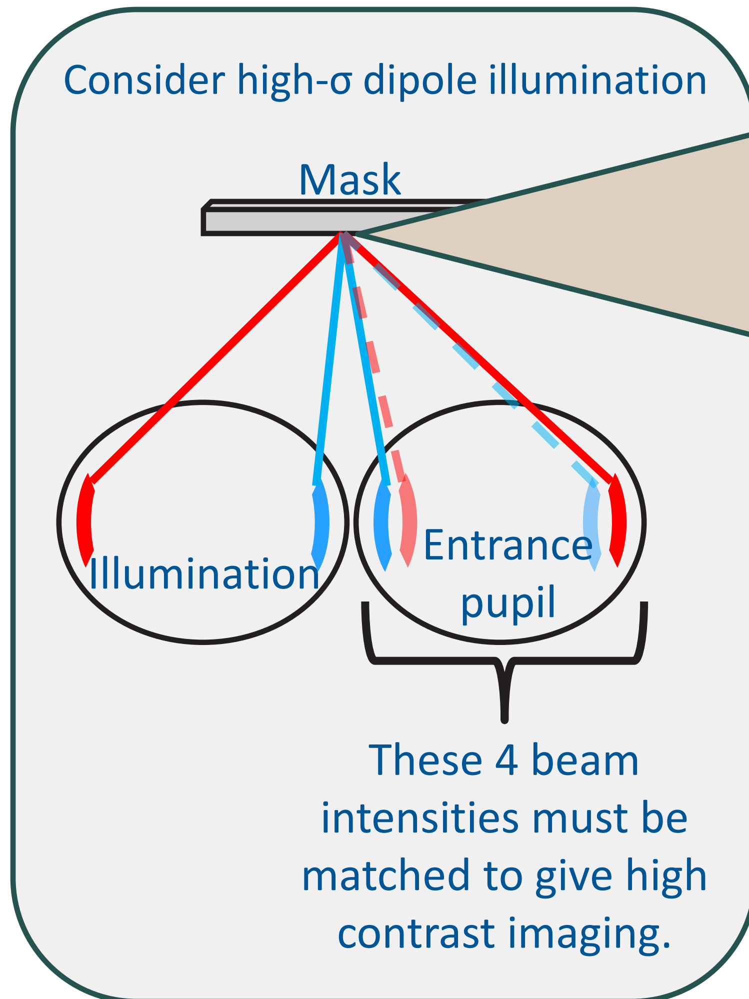
- Scanner roadmap predicts end of 0.33 NA single patterning at 13 nm feature size
  - For smaller features EUV double patterning or high-NA EUV is required
- A transition to high-NA EUV requires ~5 years to prepare
  - If high-NA EUV should be needed in 2018/19 then a decision on the high-NA EUV path has to be made by YE 2013
- Transitioning to high-NA EUV is an industry decision and needs to be broadly supported. This requires:
  - Understanding of what is and what is not acceptable to EUV stakeholders (chip makers, mask makers, tool and materials suppliers)
  - Stakeholders need to develop their own internal assessment and position with respect to high-NA EUV
  - Company positions on high-NA EUV need to be shared so that, as an industry, we understand where we agree and where we differ

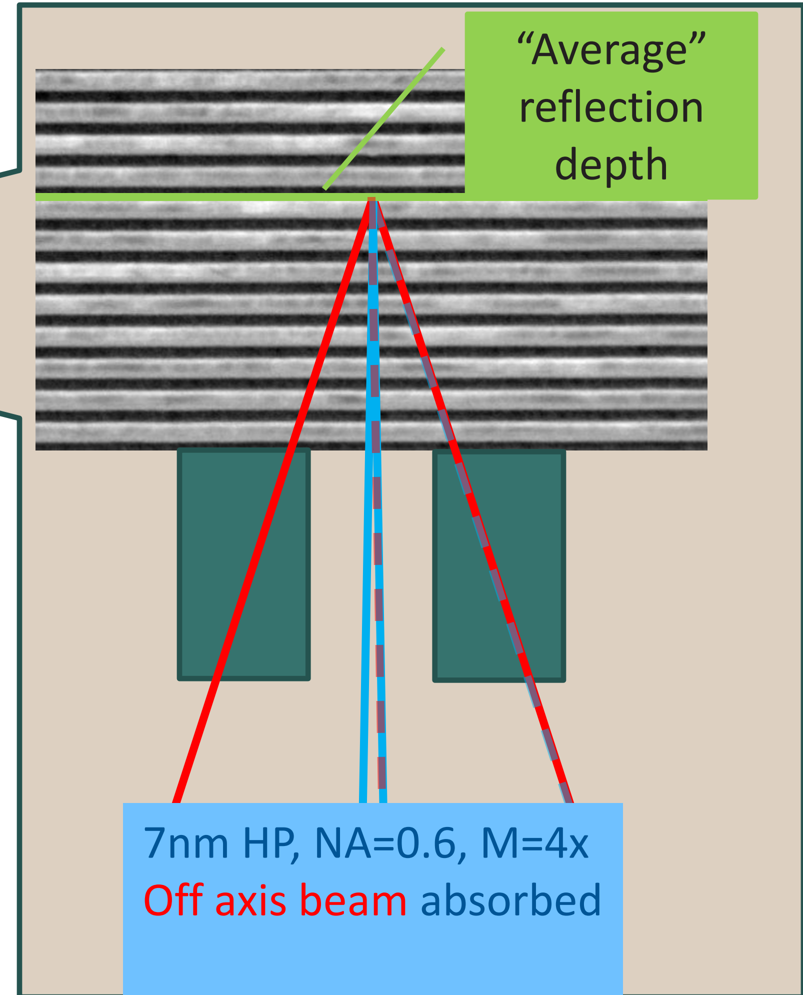
Team driving industry to a decision

Timeline / Milestones

- Q1 2013: Assess current status of high-NA EUV discussion
  - Review literature, assess the possibilities
  - Develop shared understanding of the current high-NA EUV options as they are being discussed
- Q2 2013: Share state of current high-NA EUV industry discussion with stakeholders / get early feedback
  - Face-to-face meetings with all stakeholders
  - Survey all stakeholders for their views
- July 9th: SEMATECH High-NA EUV Workshop at SEMICON West.
  - Share industry survey results on high-NA EUV
  - Stakeholders share their perspective and learn about the perspective of others
- Q3-Q4 2013: Industry discussion
  - Narrow options, drive industry consensus, and identify differences
  - Follow-up industry workshop co-located with EUVL Symposium
- End of 2013:
  - Achieve industry consensus on what high-NA EUV will look like
    or
  - Determine where the differences are

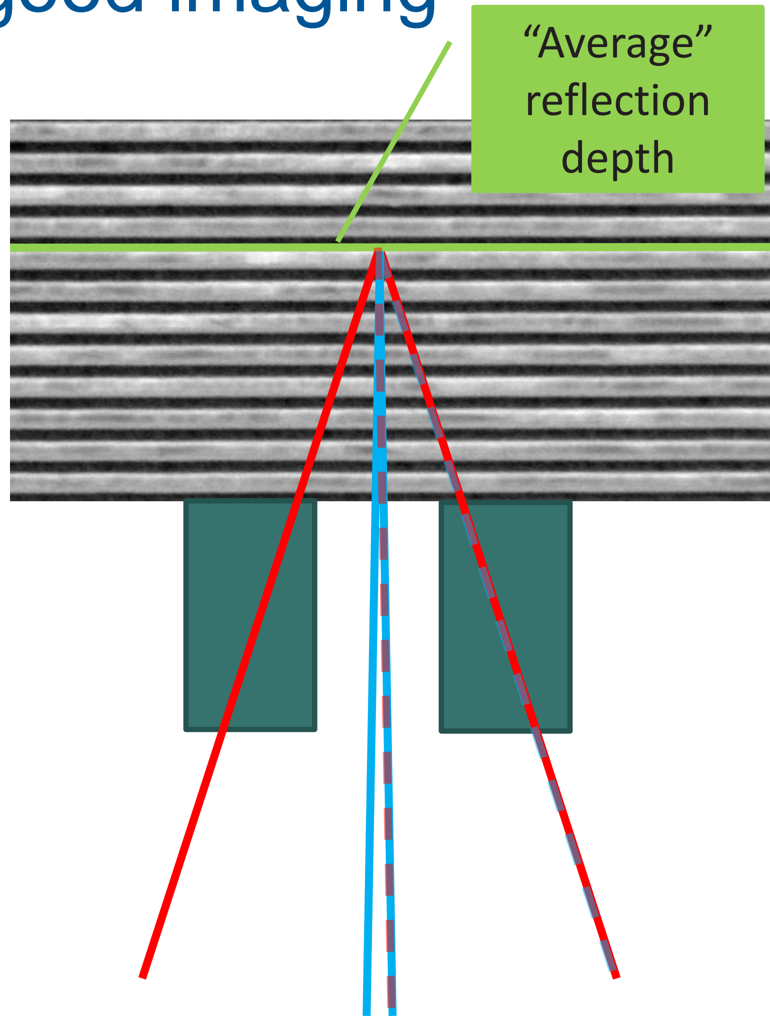
Image quality requires increasing demagnification as NA is increased

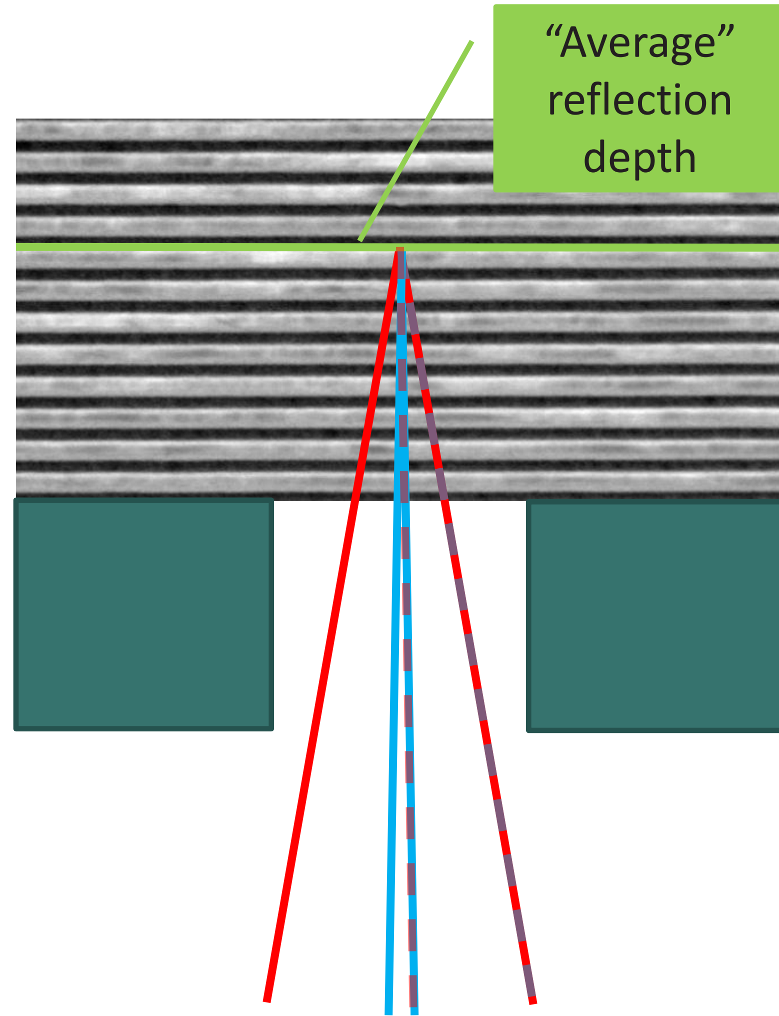




Off axis beam is absorbed, poor image quality.

Increasing demagnification can bring back good imaging





Field size and magnification

- Since the magnification increases, either the mask gets bigger or the wafer field gets smaller.
- Consider 3 cases for wafer field:
  - Full Field (FF) – 26x33 mm
  - Half Field (HF) – 16.5x26 mm
  - Quarter Field (QF) – 13x16.5 mm
- Consider 3 cases for mask size:
  - 6" square
  - 9" square
  - 12" square

Mask size for combinations of field size and magnification

Field size	4X	6X	8X
FF	6"	9"	12"
HF	6"	9"	9"
QF	6"	6"	6"

Limiting Factors—Optical design

- High-NA large field steppers require more mirrors (8).
  - 8 mirror steppers will have ~40% of the transmission of 6 mirror steppers
  - 8 mirrors are required for NA = 0.6 steppers

Design parameters

- Feature size & k1 → minimum NA
- Imaging requirements & NA → minimum demagnification
- Demagnification & field size → minimum mask size
- NA, demagnification & field size → number of mirrors
- Number of mirrors & field size → stepper throughput

- The “free” parameters are field size, demagnification at each NA
- Useful demagnifications range from 4x to 8x

Cost drivers

- Stepper
  - Stepper throughput will drive cost in operation
    - Larger wafer fields increase throughput
    - Fewer mirrors increases throughput
  - Higher demagnification, higher NA, larger field steppers will be more expensive, but this is anticipated to have a relatively small effect
- Mask size
  - Changing mask size will be expensive, requiring retooling throughout the supply chain

Summary of High-NA Options

- Increasing NA much above current levels will require increased stepper demagnification
- Keeping 6” masks will require reducing the wafer field size
- Alternately, there are larger field solutions possible for 9” and larger masks
- We have presented an overview of the possible solutions
- Our task is to drive the industry toward consensus by YE 2013