Imaging across the world

PMJ 2013 Panel Discussion
Challenges for future EB mask writers

Hiroshi Matsumoto, Munehiro Ogasawara and Kiyoshi Hattori

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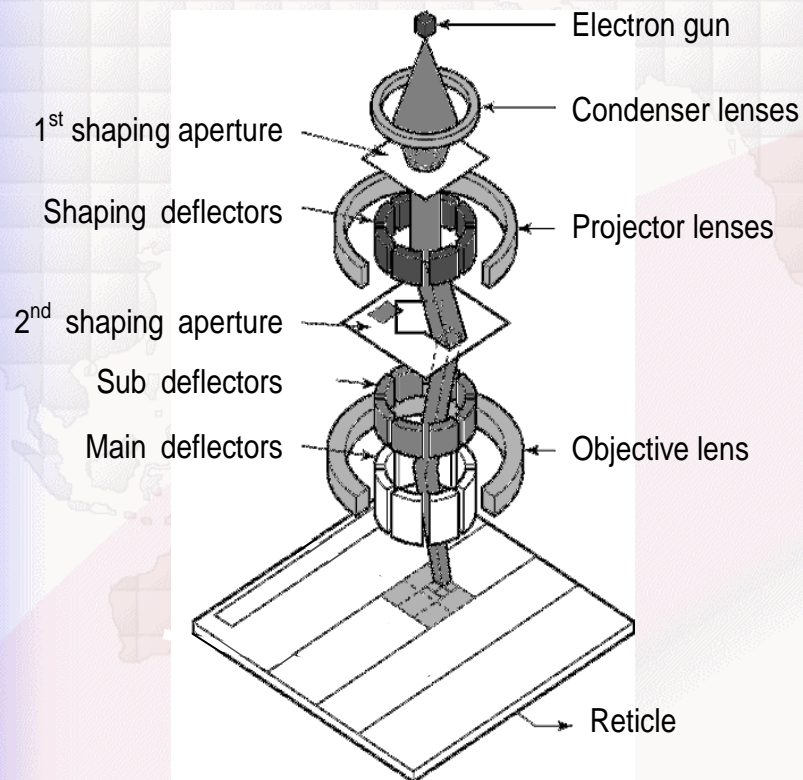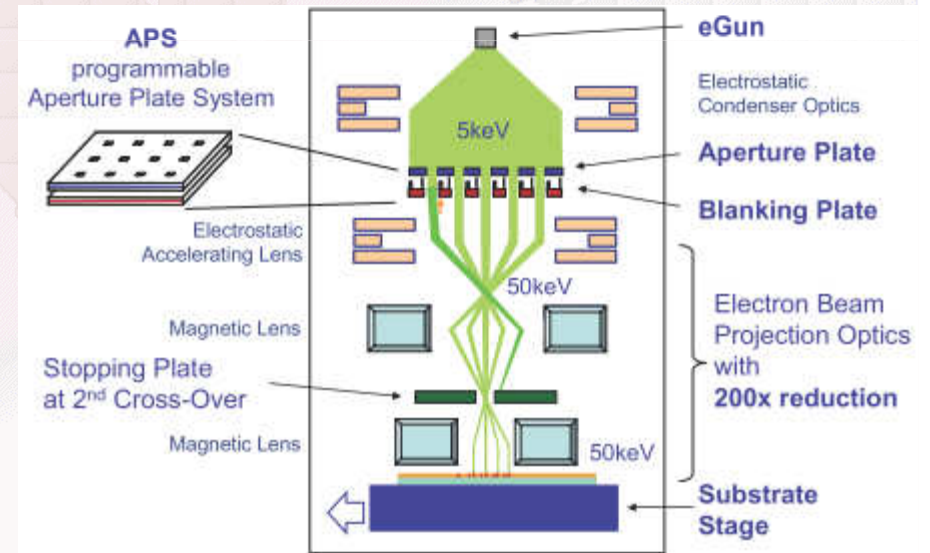
VSB vs. pixelated gray beam

VSB

Two shaping apertures used to form a triangular or rectangular beam.

Yoshitake *et al.*, Proc. of SPIE Vol. 8166 81661D-8, 2011

Pixelated gray beams

A number of square shaped beams, of fixed size, created by array of shaping apertures.

Platzgummer *et al.*, Proc. of SPIE Vol. 8166 816622-1, 2011

VSB vs. pixelated gray beam

VSB

Two shaping apertures used to form a triangular or rectangular beam.

Amplitude: 1.875V (0x1000⇔0xFFFF)
1LSB: 0.229mV (±15 V/ 17bit DAC resolution)

+/- 3mV

30ns
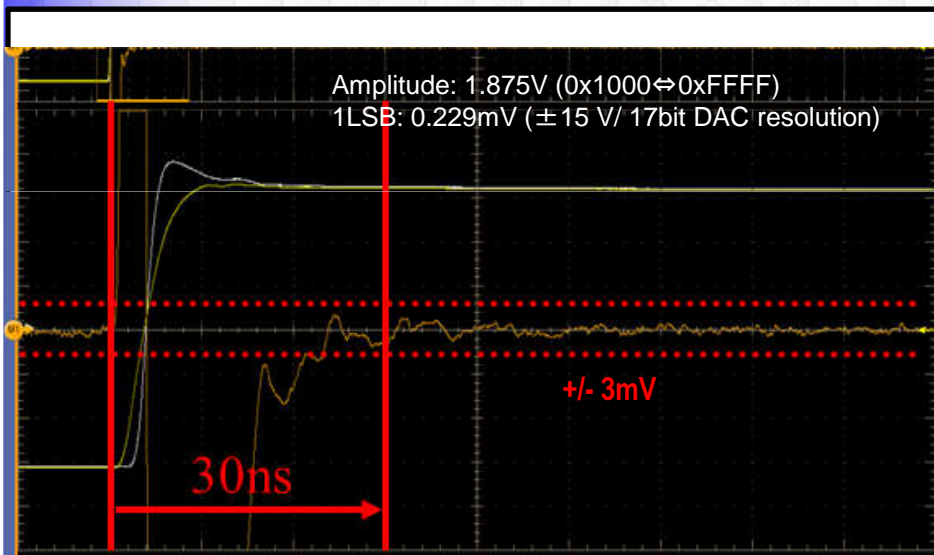
32 ns, or shorter, settling time was demonstrated on test bench with EBM-8000 Sub DAC Amp

Yoshitake *et al.*, Proc. of SPIE Vol. 8166 81661D-8, 2011

Pixelated gray beams

A number of square shaped beams, of fixed size, created by array of shaping apertures.

Deflection electrode

9µm x 9µm opening

Ground electrodes
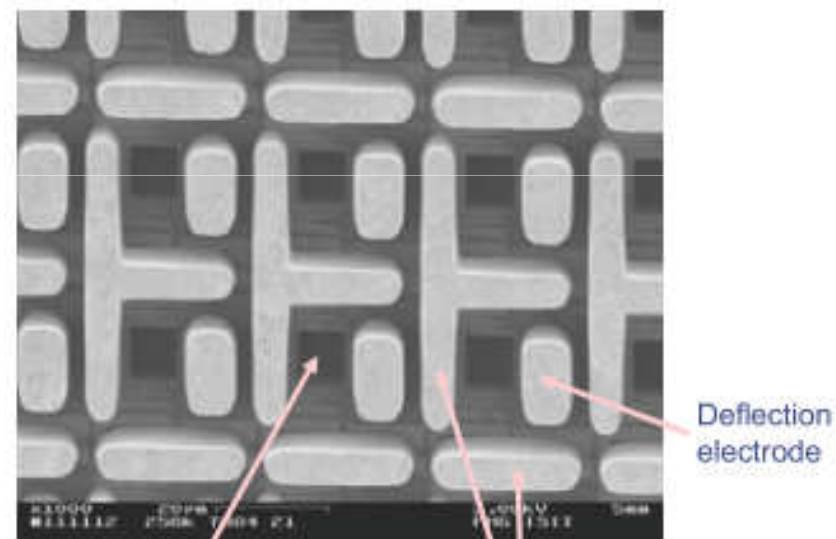
512x512 blanker array in 20 mm sq. chip

Platzgummer *et al.*, Proc. of SPIE Vol. 8166 816622-1, 2011

Motivation for multibeam technology

Throughput independent of pattern size

- In VSB systems smaller shot size results in smaller exposure current and larger shot count, to increase total exposure time and total settling time.

Curvelinear features can be written more easily

- VSB systems use rectangular or triangular figures.
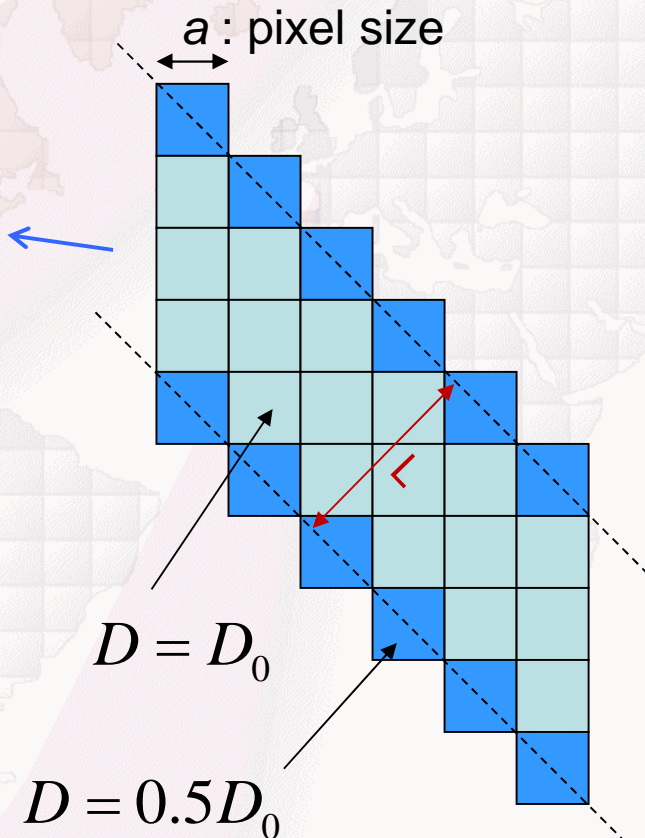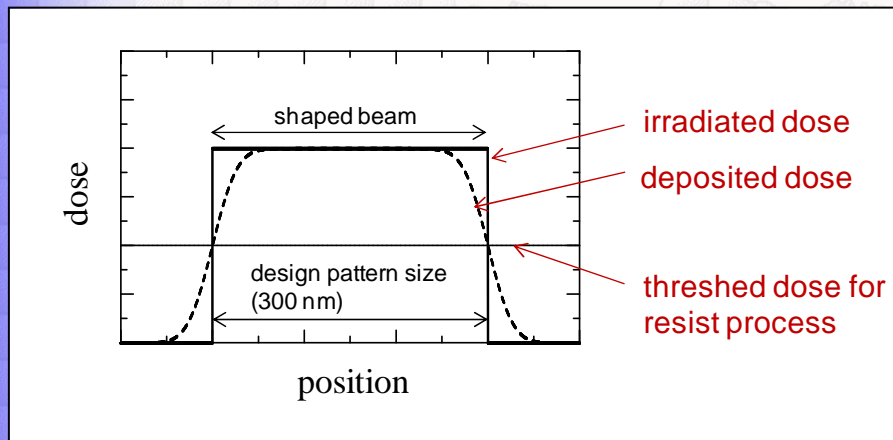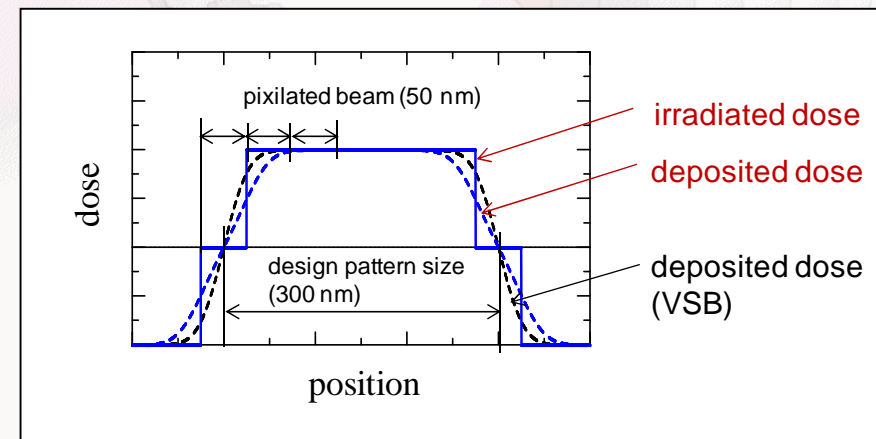
VSB vs. pixelated gray beam

VSB

Shaped beam (triangle, rectangle) exposed with uniform dose.

Pixelated gray beam

Square beam exposed with modulated dose

a : pixel size
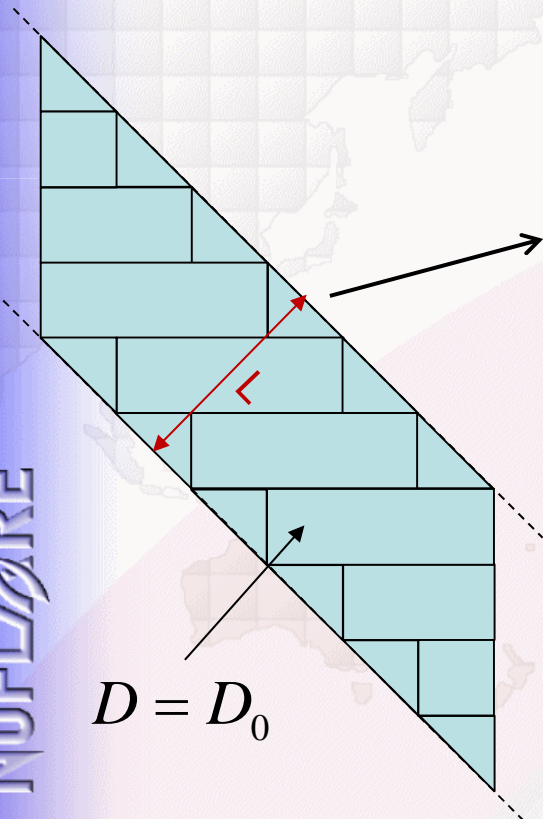
Dose profile can be reproduced with gray beam, if beam size is sufficiently small

$D = D_0$

$D = D_0$

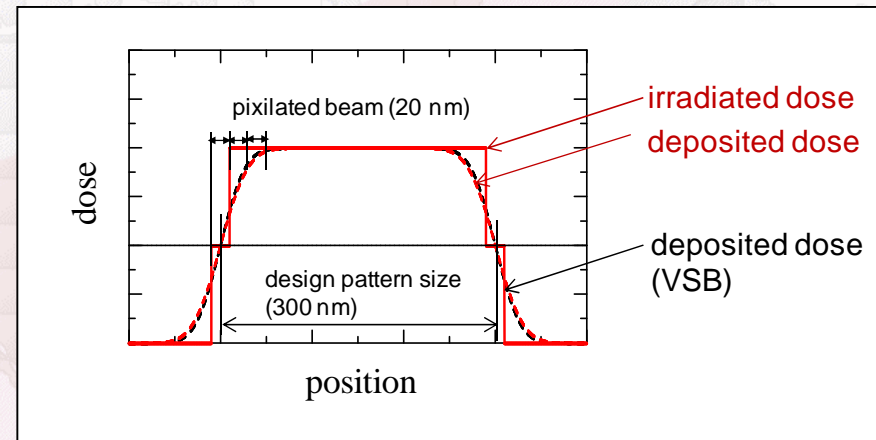$D = 0.5 D_0$

VSB vs. pixelated gray beam

VSB

Shaped beam (triangle, rectangle) exposed with <u>uniform dose</u>.

Pixelated gray beam

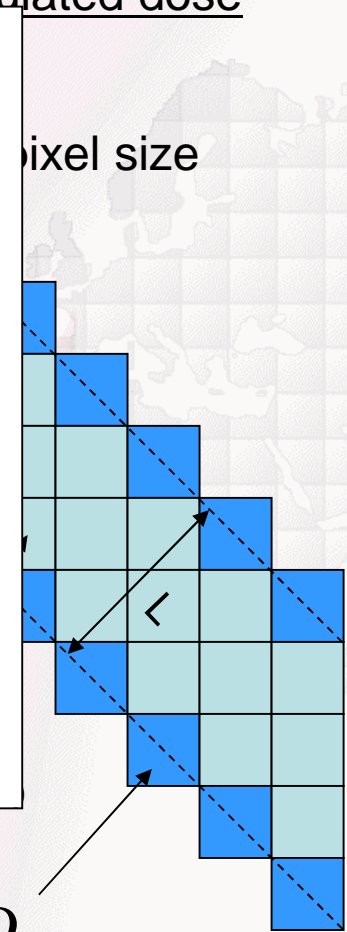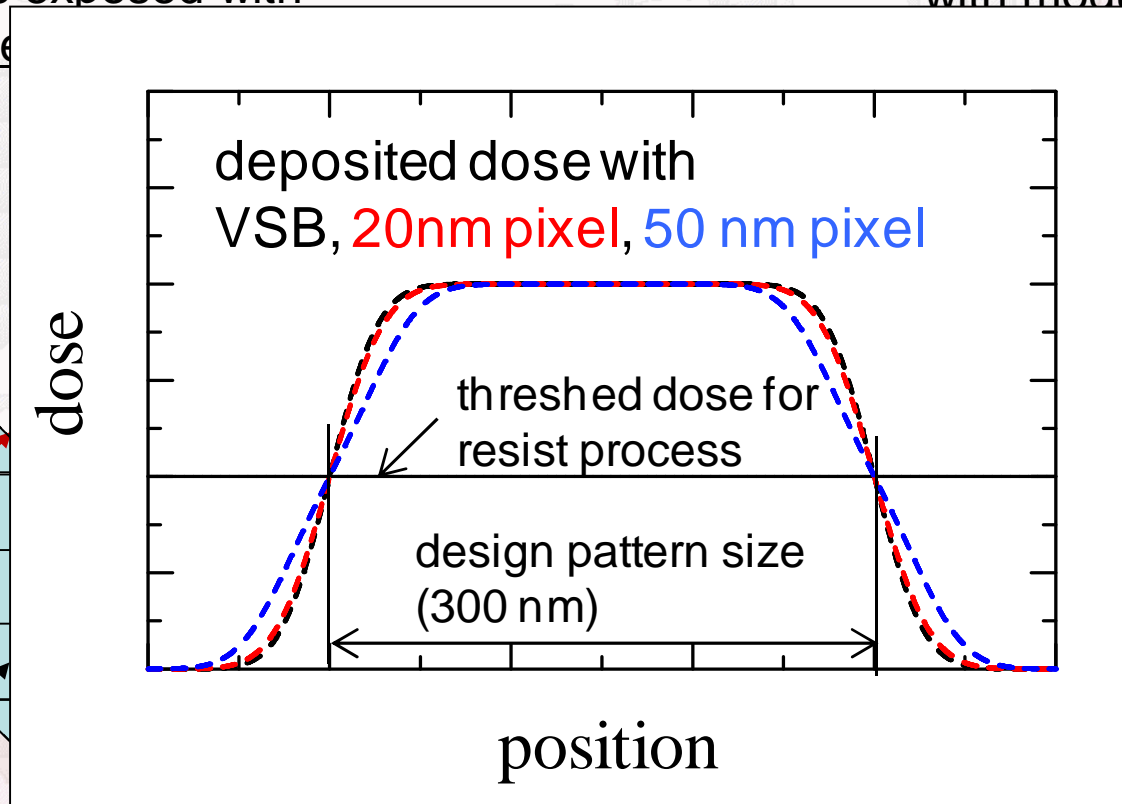Square beam exposed with <u>modulated dose</u>

VSB

Shaped beam (triangle, rectangle) is exposed with uniform dose

$D = D_0$

Pixelated gray beam

Square beam is exposed with modulated dose

pixel size

$D = 0.5 D_0$

deposited dose with VSB, 20nm pixel, 50 nm pixel

threshed dose for resist process
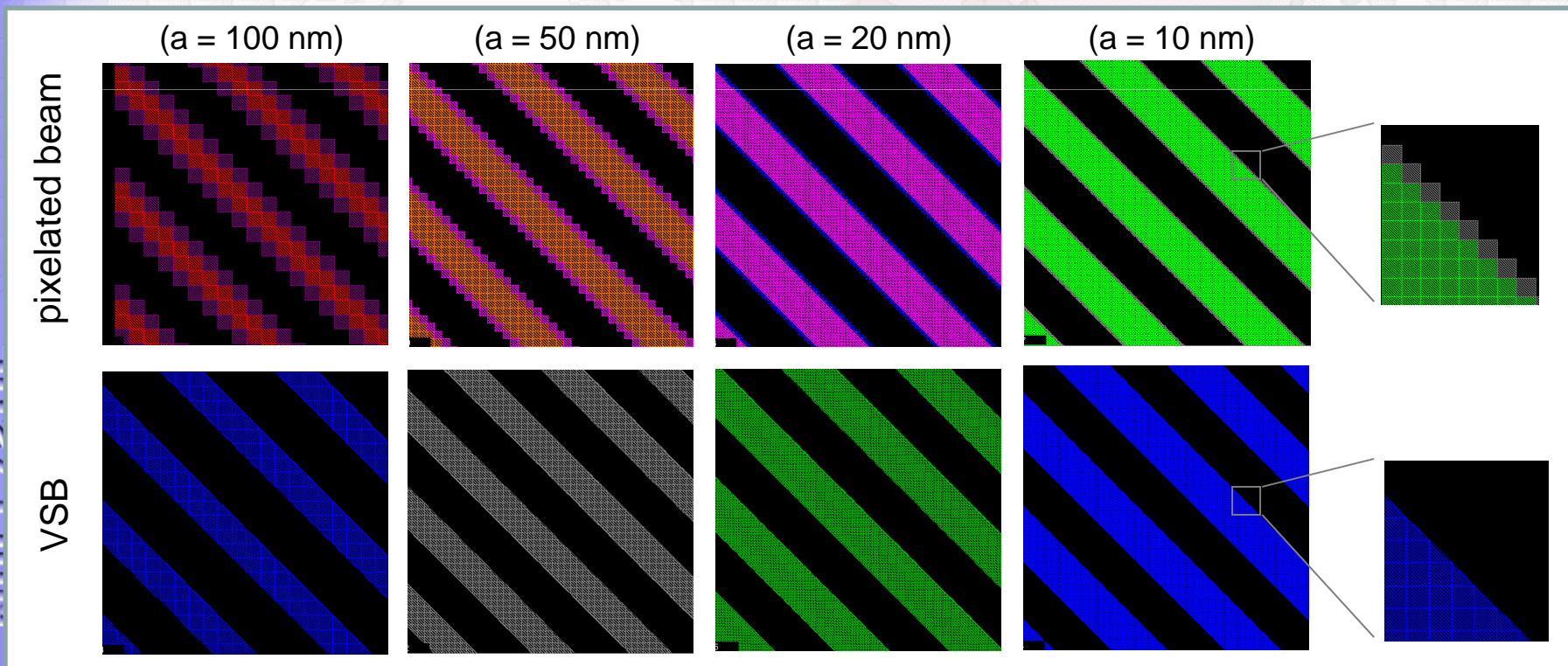
design pattern size (300 nm)

dose

position

Writing experiment (1)

VSB writing and pixelated gray beam writing were compared in writing experiments using the EBM-8000 (single VSB writer) and FUJIFILM PRL-009

- Shot sizes of 10, 20, 50 and 100 nm, with 50% dose for edge pixels.
- Edge pixels were written in different write pass.
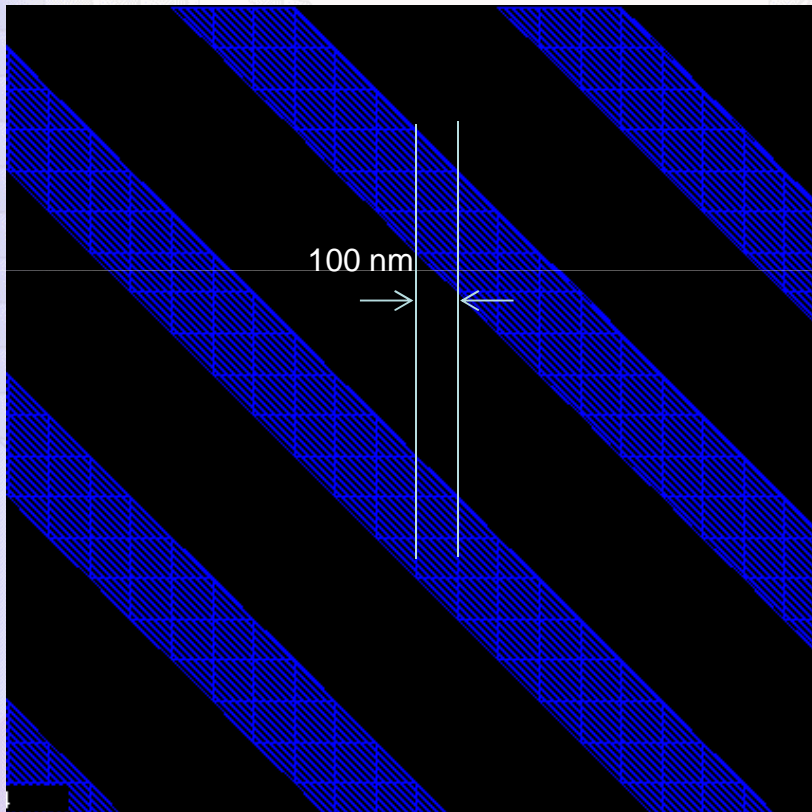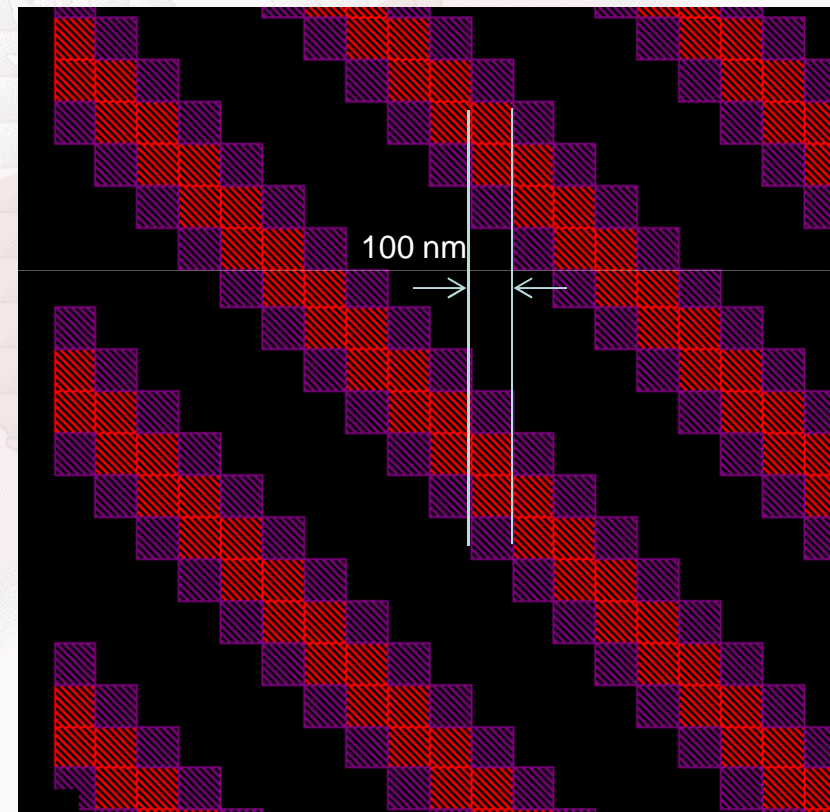- Several chips were written with different dose D.

Writing experiment (2)

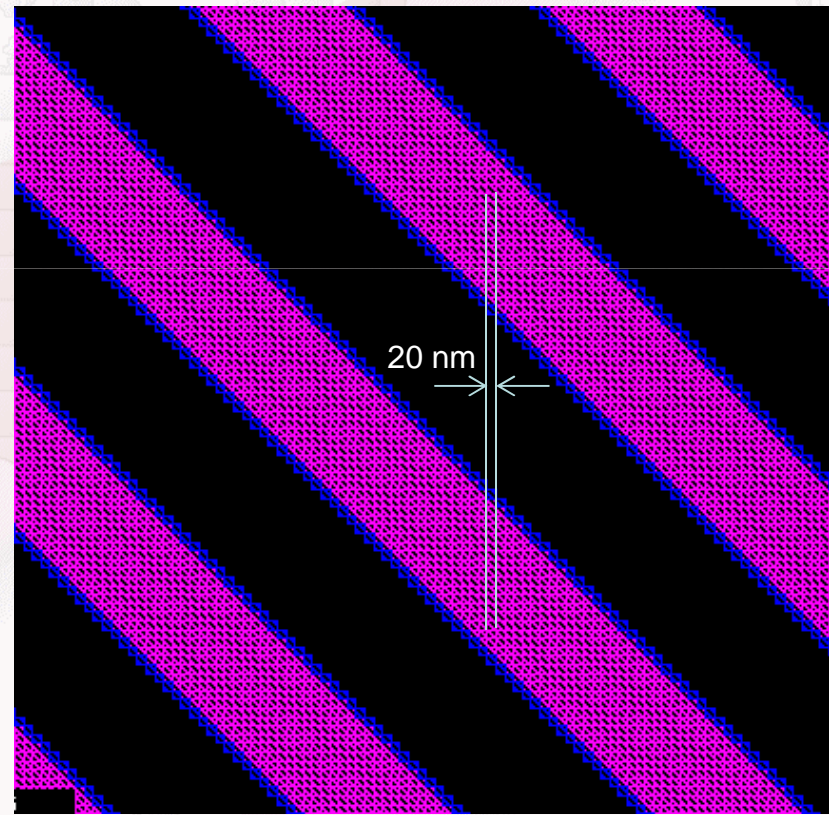Shot size : 100 nm

VSB

pixelated beam

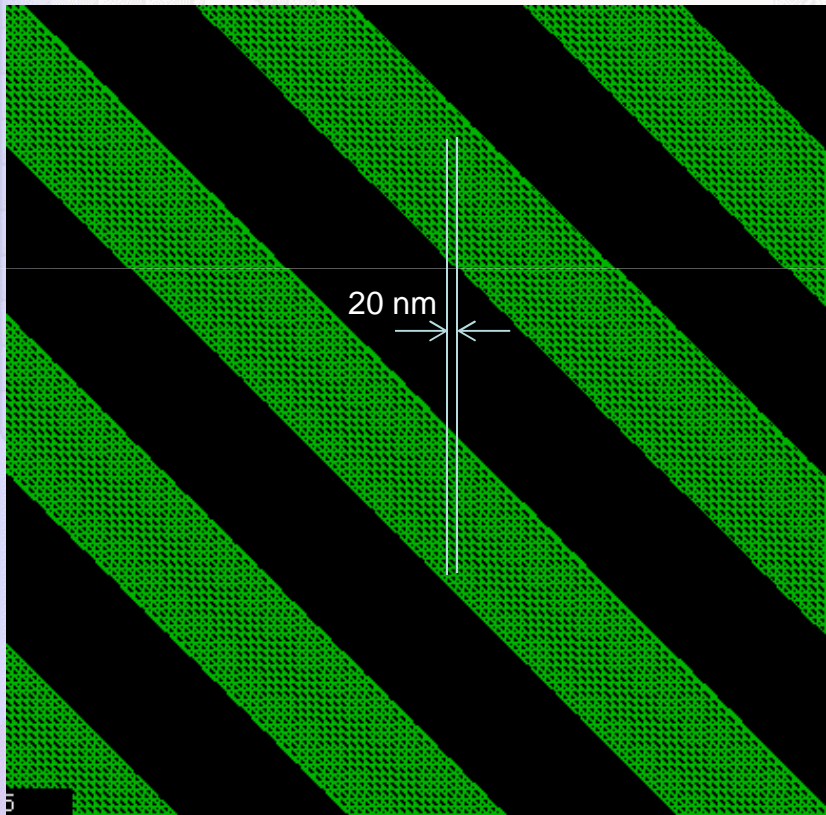100 nm

100 nm

Shot size : 20 nm

VSB

pixelated beam

20 nm

20 nm
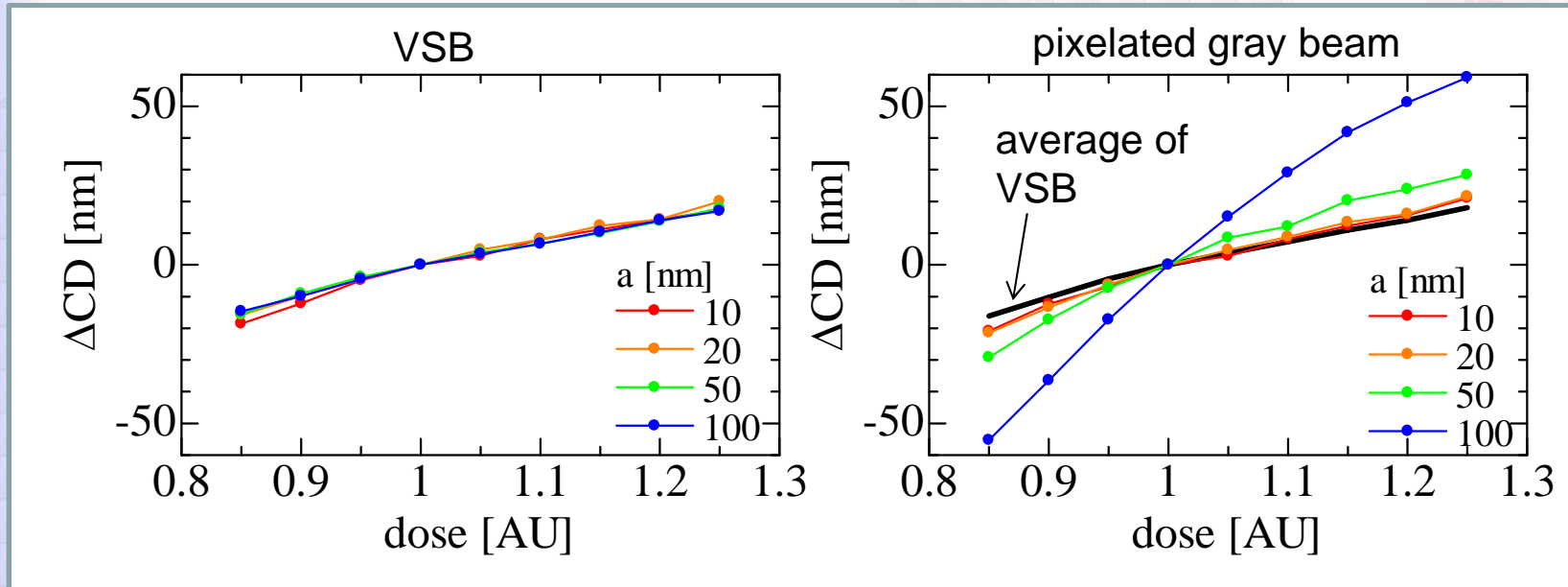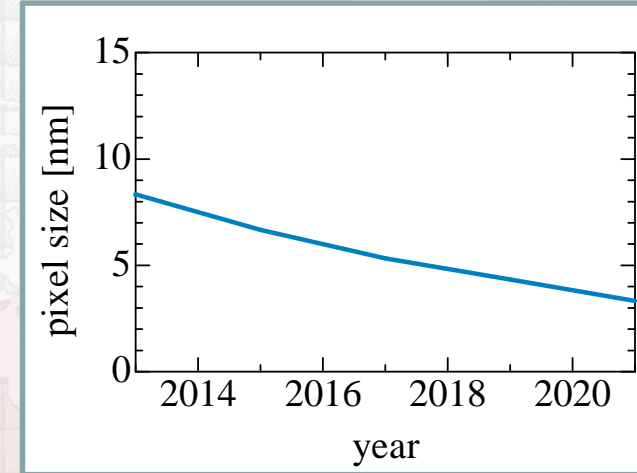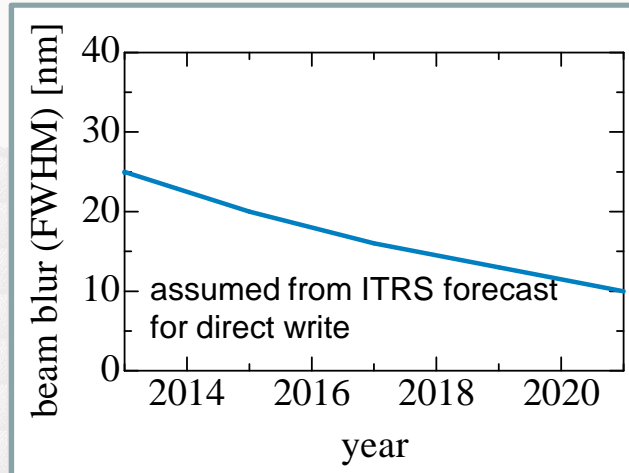
Writing experiment (4)

Writing accuracy of pixelated beam improves as beam size decreases.

- Beam size of 10nm and 20 nm brings the same CD accuracy, with a discernible slope difference to VSB writing.

Challenges for multi-beam writers

**Beam size needs to shrink, as beam blur reduces.**

- Introduction of multi-pass exposure with grid offset can improve gray beam write accuracy, but this is not addressed in this discussion.
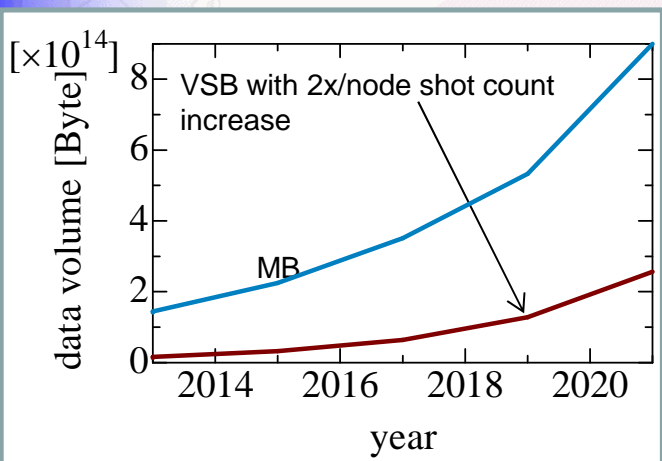
How can pixel size shrink?

- Increased demagnification
  - Performance of high demag. optics is questionable.
- Reduction of aperture size, accompanied by either of :
  - Increased # of beams with reduced beam pitch
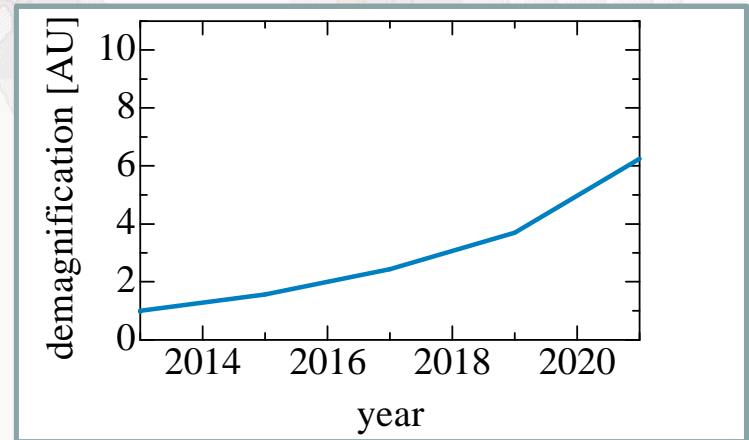 - Increased beam current density
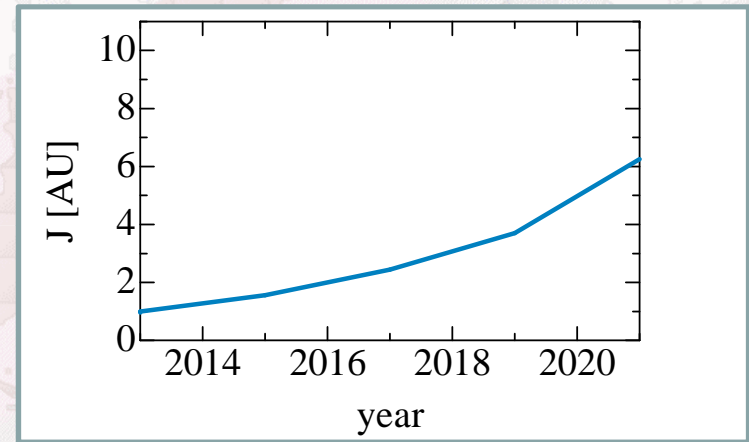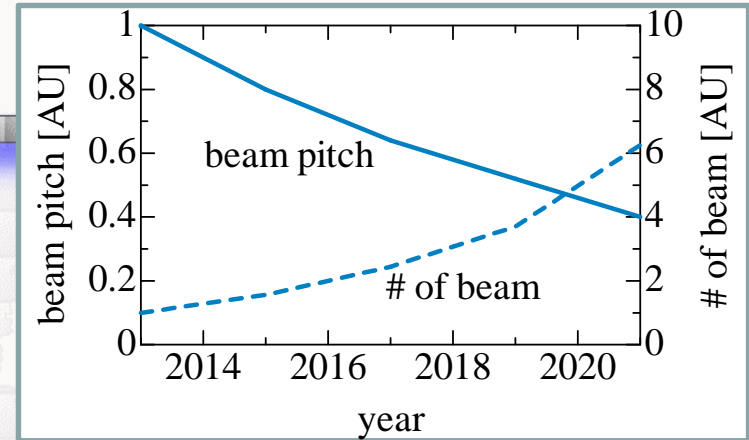
Challenges for MBMW

Which is the practical option ?
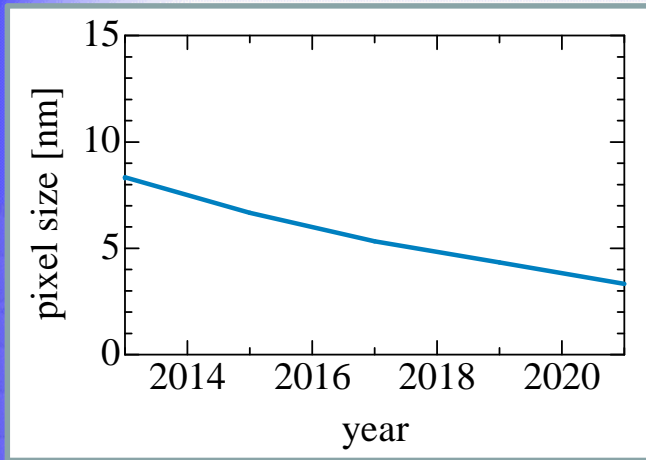
Inevitable

Low sensitivity resist may multiply write passes and data volume

NuFLARE

Summary

Pixelated gray beam can have writing accuracy equivalent to VSB, with sufficiently small beam size

- Error budget is needed to estimate feasible accuracy, as actual, beamlets have error in position, size and exposure current. .

Challenges for multi-beam mask writers

- Smaller beam size for <u>smaller beam blur</u>
  - Multi-pass writing with grid-offset is necessary.
  - Shrinkage of beam pitch required with increase of # of beams. Otherwise, J or optical demag. should be increased.
- Integrity of explosive data volume
- Roadmap for 10-year evolution

Challenges for VSB mask writers

- Smaller shot size for <u>smaller patterns</u>
  - Further increase of J and reduction of settling time is required.
- Shift to multi-column strategy

END