UCLA

Multiple E-beam Direct Write & REBL

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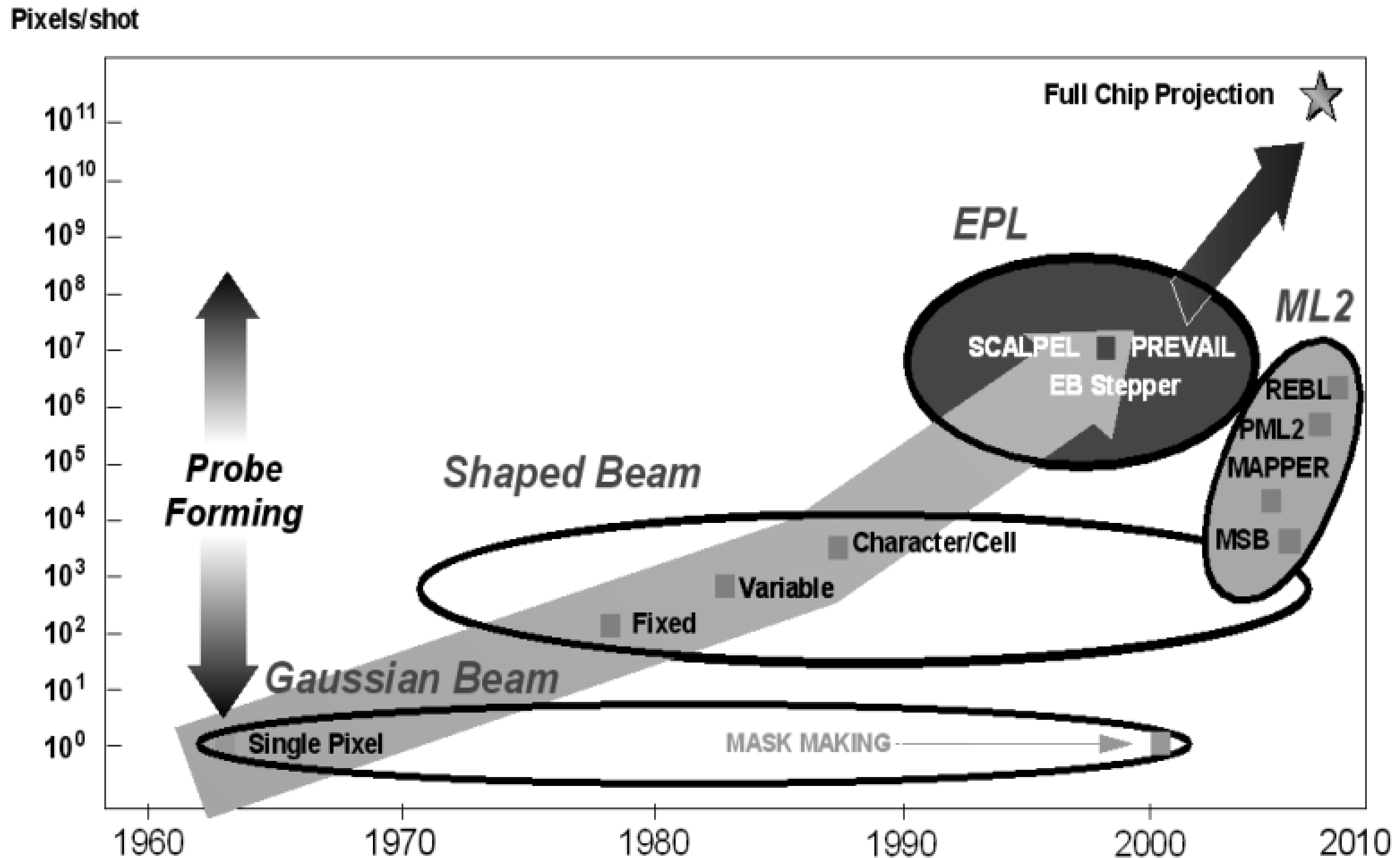
Electron Beam Lithography Evolution [5]



Motivation

"For the first time in half a century, electron-beam lithography shows signs of living up to its promise of manufacturing semiconductor circuits in high volume."

--Burn Lin, TSMC, Taiwan

14 January 2013, SPIE Newsroom

Motivation (cont'd)

- Reasons:
  - Improvement in speed of e-beam writing
  - Can now support a several orders of magnitude increase in beam number
- Alternatively for same resolution as e-beam:
  - optical systems:
    - pitch splitting with multiple patterning➔ complexity and cost.
    - EUV: costly and difficult

E-beam

+ Resolution

+ Depth of Focus

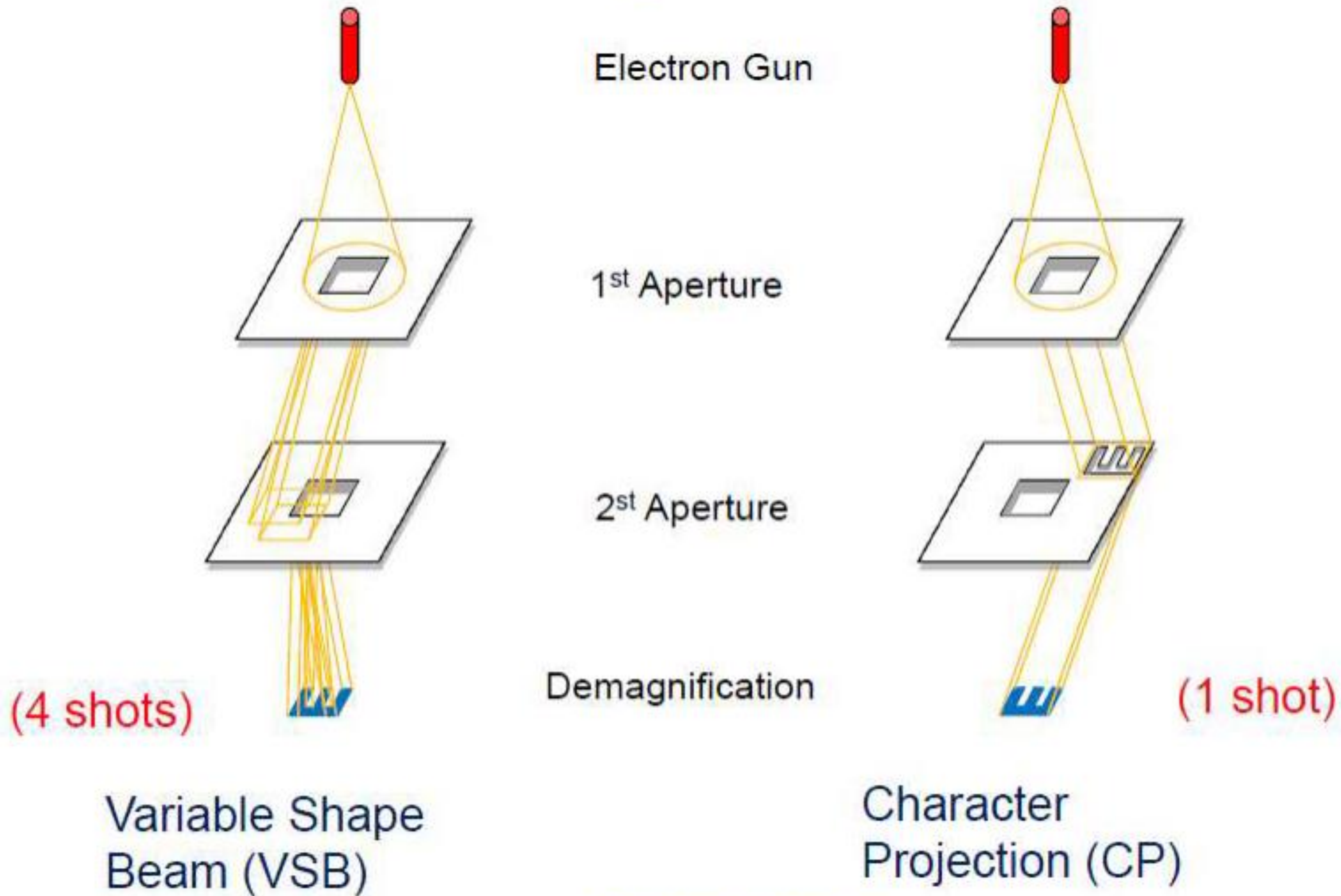
  – Ebeam: DoF> 1um with 10% exposure latitude.

  – Optical systems: DoF <100nm.

+ No mask

-Throughput

E-beam Character Projection

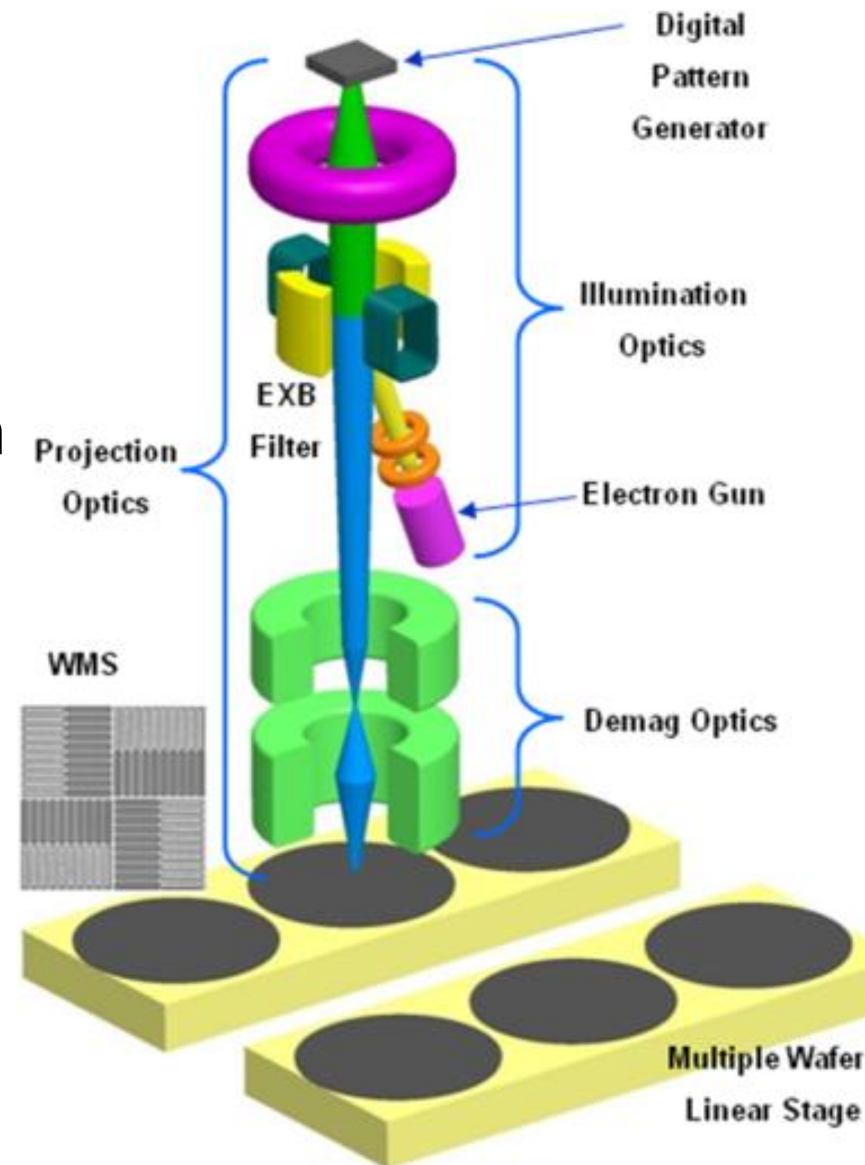


Design for E-beam: Character Projection [4]

- Co-design of the standard cell library with the stencil mask
  - once per library
  - 10-20X speedups in e-beam

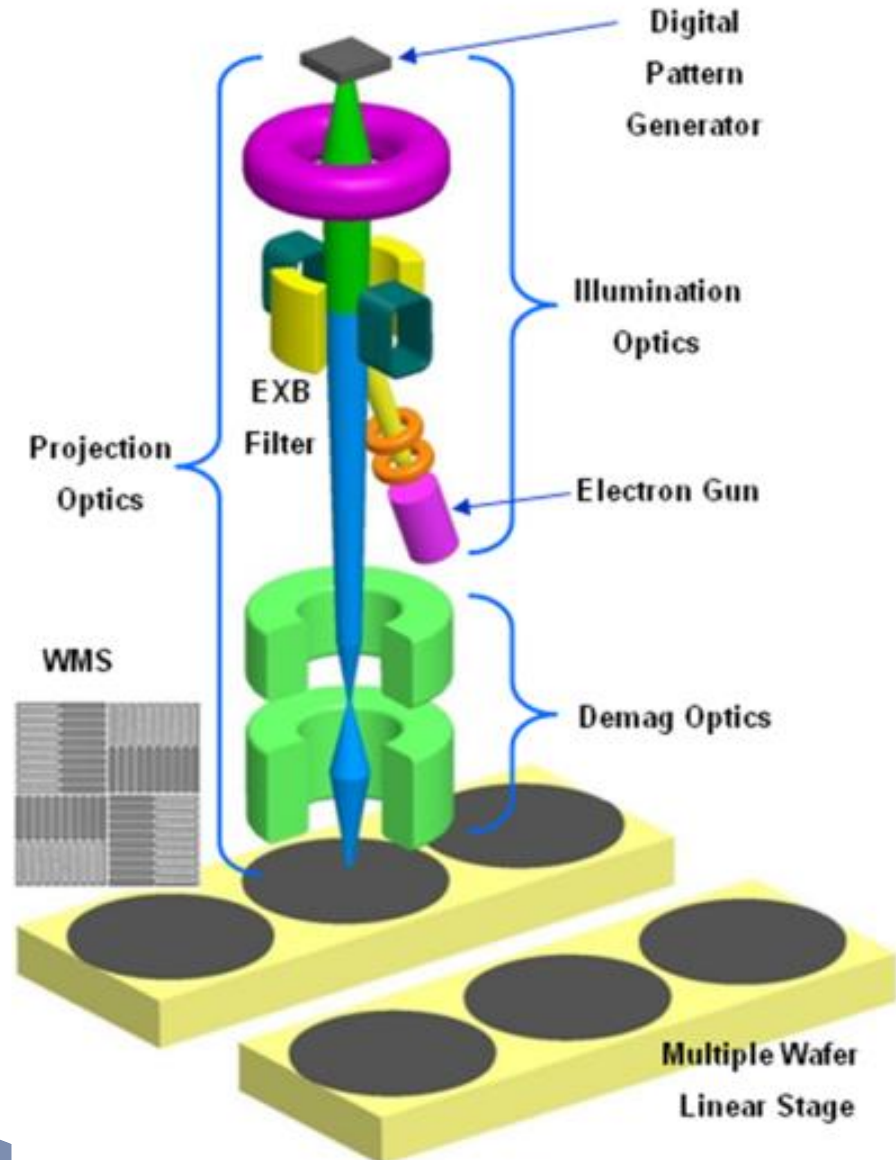
Reflective Electron Beam Lithography (REBL) [2]

- By KLA-Tencor
- **Target:**16nm
- **Throughput target:** 100 wph



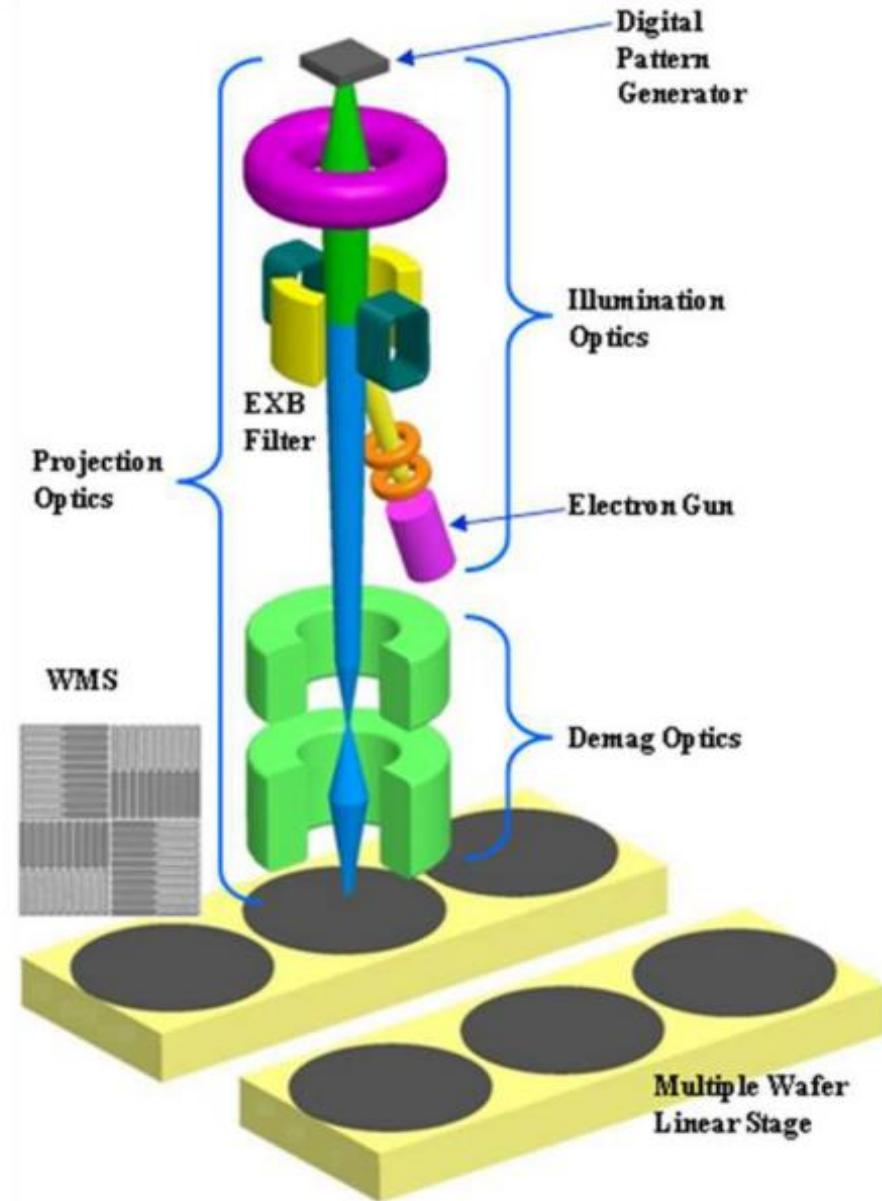
Reflective Electron Beam Lithography (REBEL) [2]

- uses a reflective **dynamic pattern generator** (DPG)
  - to modulate the aerial image of a large area electron beam



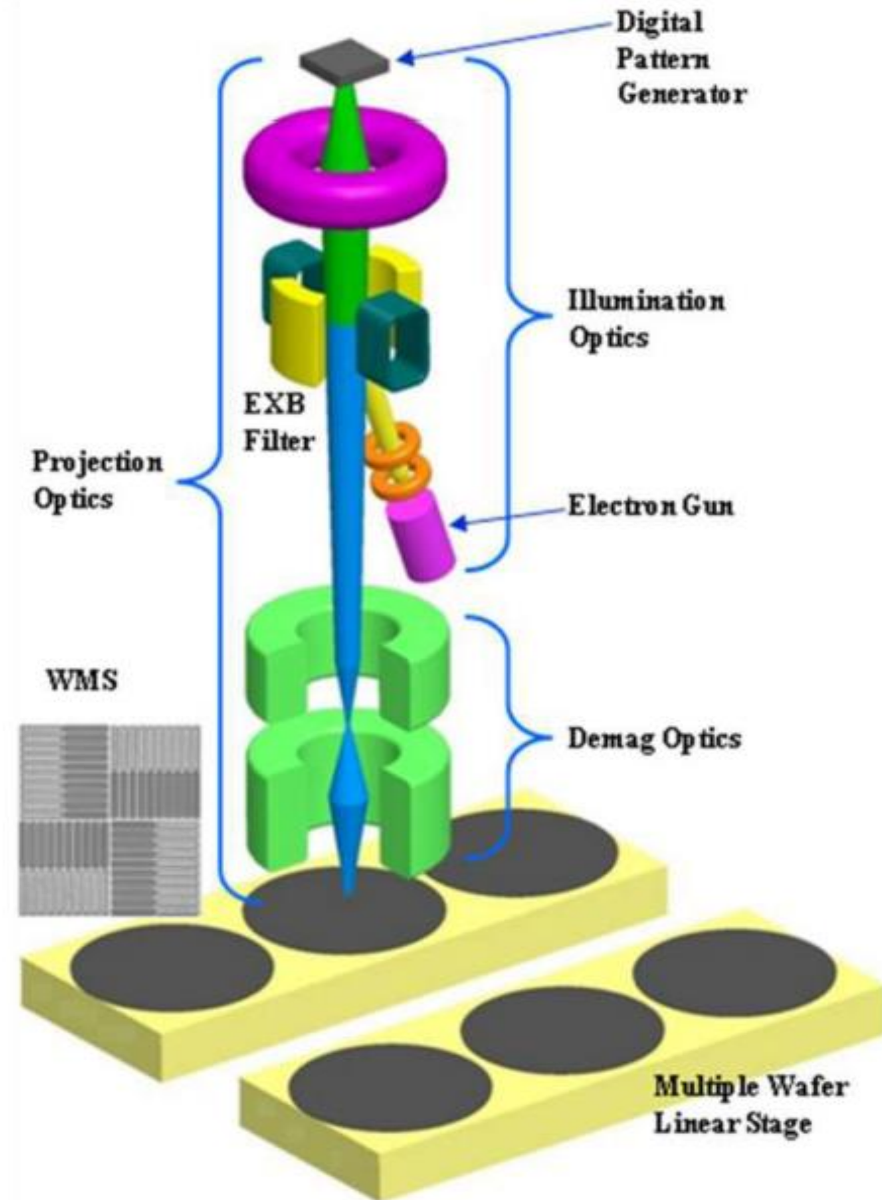
REBL (cont'd)

- Reflective DPG (Dynamic Pattern Generator):
  - array of 248 by 4096 pixels
  - each pixel separately controlled by a CMOS circuit underneath it
  - microfabricated lenslets on top of pixels to prevent crosstalk



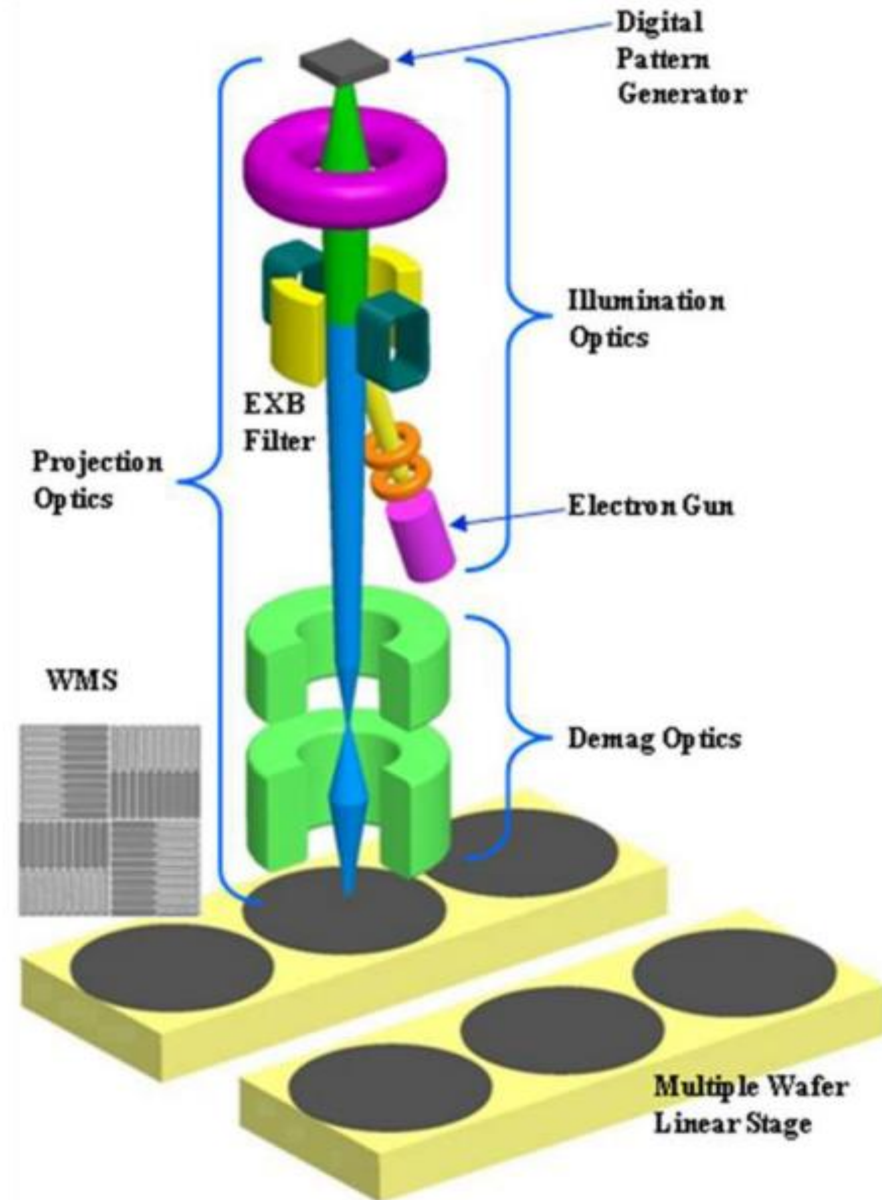
REBL (cont'd)

- Reflective DPG (Dynamic Pattern Generator):
  - By switching voltage (2v) of electrode of pixel, electrons from electron gun can be either :
    - reflected back into projection optics ("on" pixel) or
    - absorbed by electrode ("off" pixel).



REBL (cont'd)

- EXB: electromagnetic filter
- Projection optics:
  - demagnify DPG image by 100X onto moving stage.
- WMS: Wafer metrology site
  - Optically measures wafer position



Mask Data Preparation

- Proximity Correction using LP [6]
  - Minimize total exposure time
  - Subject to :
    - all required pixels receive above-threshold dose and
    - non-required pixels receive below-threshold dose

Rendering Data

- Render the data: convert it into pixels with gray level assignments.
  - Use proximity corrected data
- Converted pattern sent for writing
- Gray level pixel data distributed to each DPG during the writing process

Multiple beams in REBL

- As many as 36 columns can be clustered on either a rotary stage or six linear stages.
  - However seems like their current only uses one column
- Performance target: 100 wph [2]

References

[1] Burn Lin; “Multiple-electron-beam direct-write comes of age”; SPIE Newsroom, Jan **2013**

[2] McCord, M. A.; Petric, P.; Ummethala, U.; Carroll, A.; Kojima, S.; Grella, L.; Shriyan, S.; Rettner, C. T. & Bevis, C. F.; “REBL: design progress toward 16 nm half-pitch maskless projection electron beam lithography”,*Proc. SPIE,* **2012**

[3] McCord, M. A.; Petric, P.; Ummethala, U.; Carroll, A.; Kojima, S.; Grella, L.; Shriyan, S.; Rettner, C. T. & Bevis, C. F.; “REBL: design progress toward 16 nm half-pitch maskless projection electron beam lithography”, **2012**

[4] Fujimura, A.; “Design for e-beam: design insights for direct-write maskless lithography”; *SPIE Photomask Technology,* **2010**

[5] Pfeiffer, H. C.; “Direct write electron beam lithography: a historical overview” *Proc. of SPIE Vol,* **2010**

[6] Carroll, A. M.Proximity-effect correction with linear programming; *Journal of Applied Physics, AIP,* **1981**