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Accelerator based extreme ultraviolet (EUV) sources for lithography
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Abstract: Extreme ultraviolet lithography (EUVL) is a next-generation lithography technology using an extreme ultraviolet (EUV) light source, currently at 13.5 nm. We review a few accelerator based approaches for EUV source generation, including Laser Induced Microbunching (LIM) schemes, High-Gain Inverse Compton (HGIC) source, etc. Besides the high average power required by EUVL; for industrial applications, EUV source’s reliability, stability, reproducibility, and repeatability are all important measures. A storage-ring based steady state microbunching (SSMB) configuration (Chao, Int. J. Mod. Phys. A, 2015) is a very promising approach providing EUV source at kilowatts level average power meeting the high throughput requirement for EUVL. A reversible SSMB a promising configuration. The SSMB system size is also carefully addressed to fit industrial requirement for EUVL. A reversible SSMB a promising configuration. The SSMB system size is also carefully designed aiming to be compatible with the lithography tools. Such accelerator based EUV sources are compared to others approaches, such as laser-produced plasma (LPP) source.

Introduction: Coherent and Incoherent

\[ I_N \propto I_1 \left( N + \sum_{i=1}^{N} \sum_{j=1}^{N} \delta(\vec{r}_i - \vec{r}_j) \right) = I_{Inc} + I_{Coh} \]

Laser Induced Microbunching

Laser-electron interaction in an undulator, whose dispersion leads to microbunching:

[red \rightarrow yellow \rightarrow green \rightarrow blue \rightarrow cyan]

Ginzberg-Landau phase transition


A New Storage-Ring Light Source

Steady-State Micro-Bunching (SSMB)


- The beam is microbunched and strongly focused, so it readily radiates at the desired short wavelength (13.5 nm for lithography) at an appropriate radiator, yielding high peak power \( \propto N^2 \) instead of \( \propto N \).
- The beam is microbunched in a steady state in a storage ring, so it radiates every turn with a high repetition rate. With a bunch spacing of 10 \( \mu \)m, the repetition rate is 300 GHz.

[As. Chao, Int. J. Mod. Phys. A 30(22), 1530051 (2015)]

High-Gain Inverse Compton (HGIC) source

High-Gain Thompson-Scattering X-Ray Free-Electron Laser by Time-Synchronic Laterally Tilted Optical Wave


Extreme Ultraviolet (EUV) Lithography

SSMB

- Mirrors high reflectivity (>0.999)

<table>
<thead>
<tr>
<th>HGIC</th>
<th>Cymer</th>
<th>GigaPhoton</th>
<th>XTREME Tech</th>
<th>HZB/PSI</th>
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<tr>
<td>Type</td>
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<tr>
<td>Technology</td>
<td>HGIC</td>
<td>LPP</td>
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<td>FEL</td>
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<tr>
<td>Power (if) (w)</td>
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<td>200</td>
<td>15</td>
<td>10</td>
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<tr>
<td>Bandwidth (%)</td>
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<td>&lt;2</td>
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<tr>
<td>Spatial Angle (( \alpha ))</td>
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<tr>
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<td>Footprint (mm)</td>
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<tr>
<td>Cost (M)</td>
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<td>15</td>
<td>13</td>
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</table>

Summary and Conclusion

Accelerator based EUV source can provide sufficient power for high-volume manufacturing lithography. Design to fit industrial requirements is feasible; ask for input from lithography tool builders and customers.

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