Quantum Dot Lasers Grown on Silicon

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Silicon Photonics

Increasing demand for bandwidth

Silicon offers an economic-friendly solution

![Graph showing demand versus capacity from 2010 to 2016.](image)

Image courtesy of Daehwan Jung

- **InP**: 4.55 $/cm² (6 inch)
- **GaAs**: 1.65 $/cm² (8 inch)
- **Si**: 0.20 $/cm² (18 inch)
The Flaws of Using Silicon

- Dislocations from the GaAs-Si mismatch cause diminishing device performance.
Quantum Dot Laser Structure

- **Mirrors**
- **P Cladding**
- **Active Region**
- **N Cladding**

[Diagram showing layers of the laser structure: P cladding, Active Region, N Cladding, Mirrors, with labels for probe metal, p contact, QDs, n cladding, 7 µm, GaAs/Ge buffer, and Silicon.]
Molecular Beam Epitaxy
Quantum Dots

Quantum well
• 2-D confinement
• Discrete energy levels

Quantum Dot
• 3-D confinement
• Discrete energy levels
Characterizing a Laser

Modular Integrating Sphere

Gathers power output from laser

Optical Spectrum Analyzer (OSA)

Gathers wavelengths emitted from laser

Power vs. Current

Power vs. Current
Device Threshold

<table>
<thead>
<tr>
<th>Device</th>
<th>Threshold (mA)</th>
<th>Avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>GaAs (red)</td>
<td>44.2 mA</td>
<td></td>
</tr>
<tr>
<td>Quantum Dot (blue)</td>
<td>42.1 mA</td>
<td></td>
</tr>
</tbody>
</table>

- Thresholds for quantum dot lasers are comparable to those grown on GaAs
Device Injection Efficiency

- Efficiency of quantum dot lasers comparable to GaAs

![Graph showing device width (um) vs efficiency for GaP/Si and GaAs]
Summary

• GaP/Si devices performed within range of similar GaAs devices
• Commercial viability
• Applications in data centers
Future steps

Comparing different compositions and thicknesses of cladding layers

<table>
<thead>
<tr>
<th>Cladding</th>
<th>Quantum Dot active region</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 nm pGaAs</td>
<td>7x 46 nm GaAs/InGaAs/InAs/InGaAs QDWell</td>
</tr>
<tr>
<td>50 nm pGaAs → pAl0.4Ga0.6As</td>
<td></td>
</tr>
<tr>
<td>1.4 μm pAl0.4Ga0.6As</td>
<td></td>
</tr>
<tr>
<td>20 nm pAl0.4Ga0.6As → pAl0.4Ga0.6As</td>
<td></td>
</tr>
<tr>
<td>30 nm pAl0.4Ga0.6As</td>
<td></td>
</tr>
<tr>
<td>12.5 nm GaAs</td>
<td></td>
</tr>
<tr>
<td>50 nm GaAs</td>
<td></td>
</tr>
<tr>
<td>30 nm nAl0.2Ga0.8As</td>
<td></td>
</tr>
<tr>
<td>20 nm nAl0.2Ga0.8As → nAl0.4Ga0.6As</td>
<td></td>
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<tr>
<td>1.4 μm nAl0.4Ga0.6As</td>
<td></td>
</tr>
<tr>
<td>50 nm nAl0.4Ga0.6As → nGaAs</td>
<td></td>
</tr>
<tr>
<td>500 nm nGaAs</td>
<td></td>
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<tr>
<td>III-V on Si Growth Template</td>
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</table>
Acknowledgements

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