

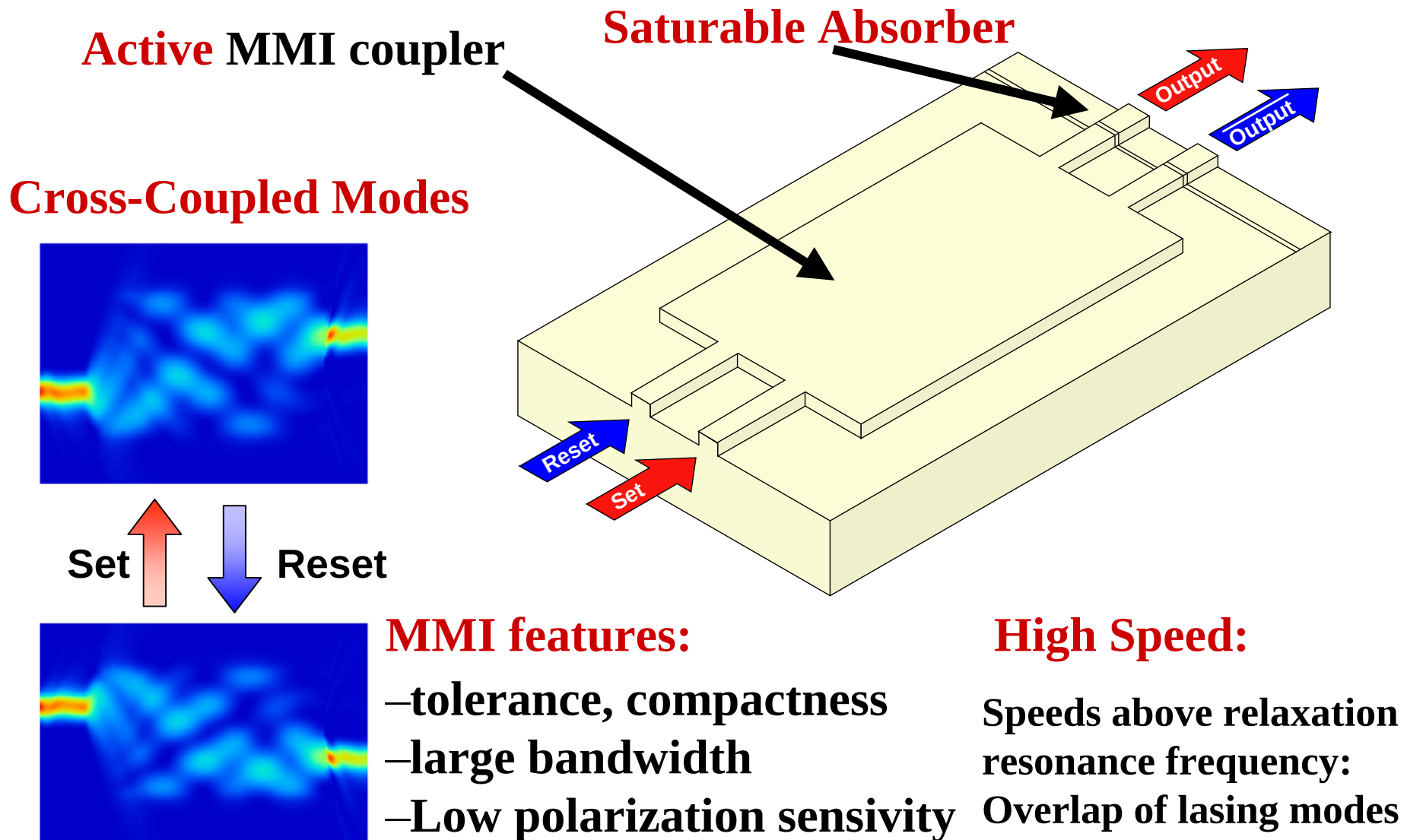
Simulations of Distributed Bragg Reflector Multi-Mode Interference Bistable Laser Diodes (DBR-MMI-BLDs)

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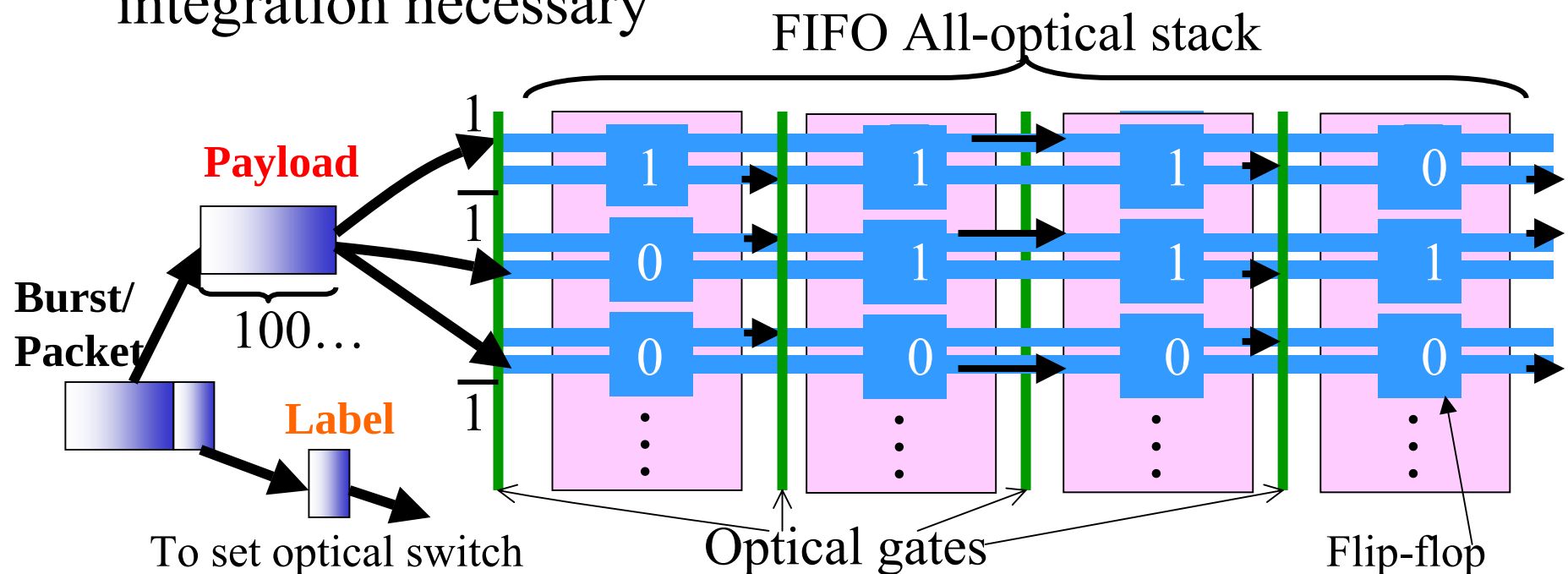
Yoshiaki Nakano

Cleaved-Facet MMI Bistable Laser Diode



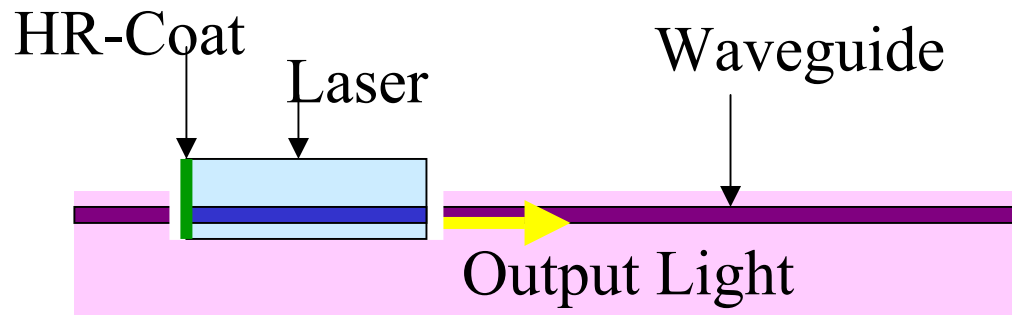
Need for Cascadable Flip-Flops

- Single flip-flop not very useful
- All-optical network switching:
 - Allow label-reading for routing including storage/retrieval from optical memory
 - Important for bit-length, TDM/WDM conversion
- Smaller, cheaper, more powerful circuits: on-chip integration necessary

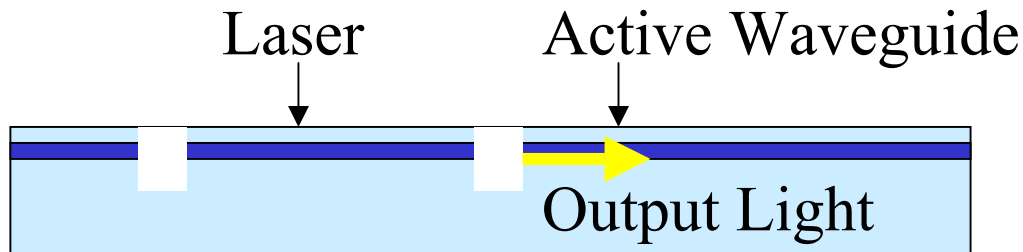


Techniques for Cascading Lasers with Waveguide Devices On-Chip

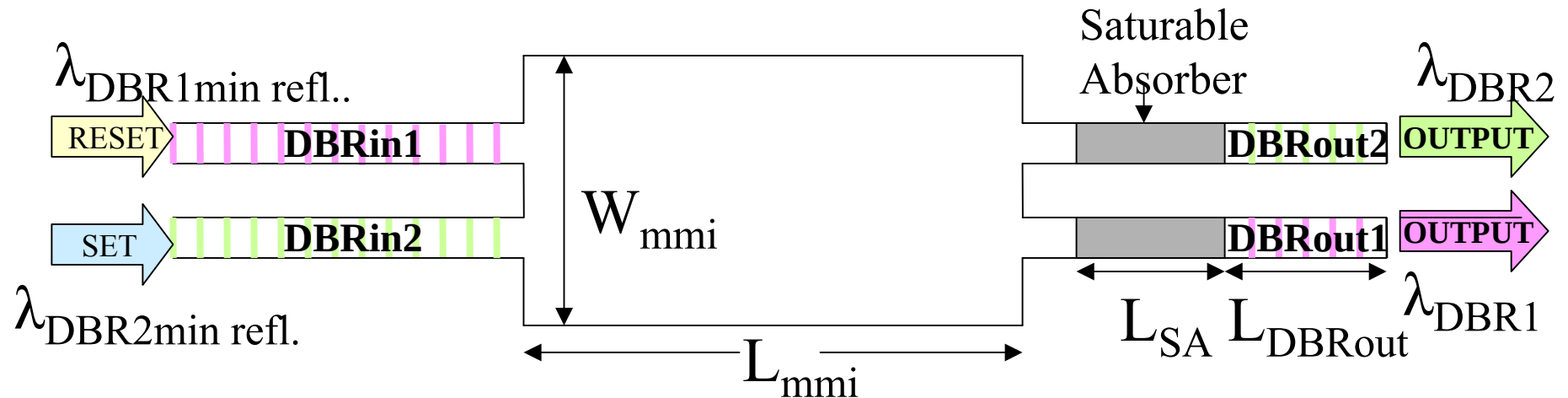
- Flip-chip bonding



- Etched facets



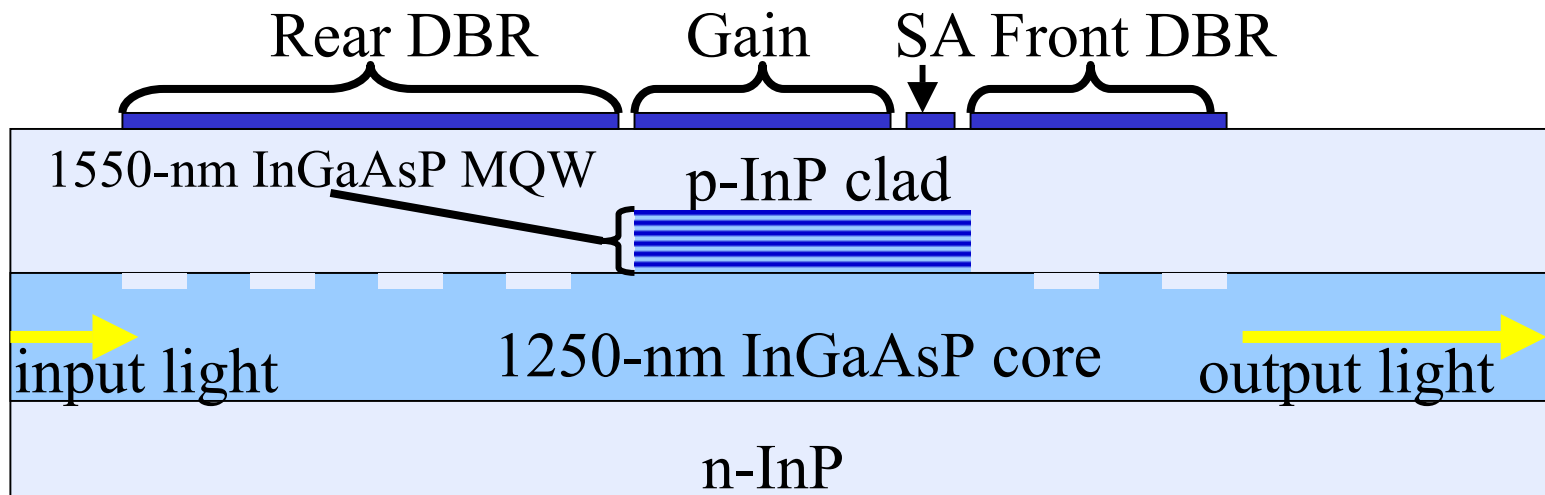
Distributed Bragg Reflectors for Cascadability



- Lasing with on-chip integration before and after flip-flop—no cleaved facets necessary
- Directional output
- Single-moded output
- Control of output wavelength
 - Different wavelengths for output and $\overline{\text{output}}$ possible
- Wavelength conversion
- $L_{\text{mmi}} \approx 600 \mu\text{m}$, $W_{\text{mmi}} = 12 \mu\text{m}$ all simulations

DBR-MMI-BLD structure

- Integration of active gain/SA region with passive DBRs and input/output guides
- Effective mirror method to account for DBRs



SA Material Absorption: Reverse Bias

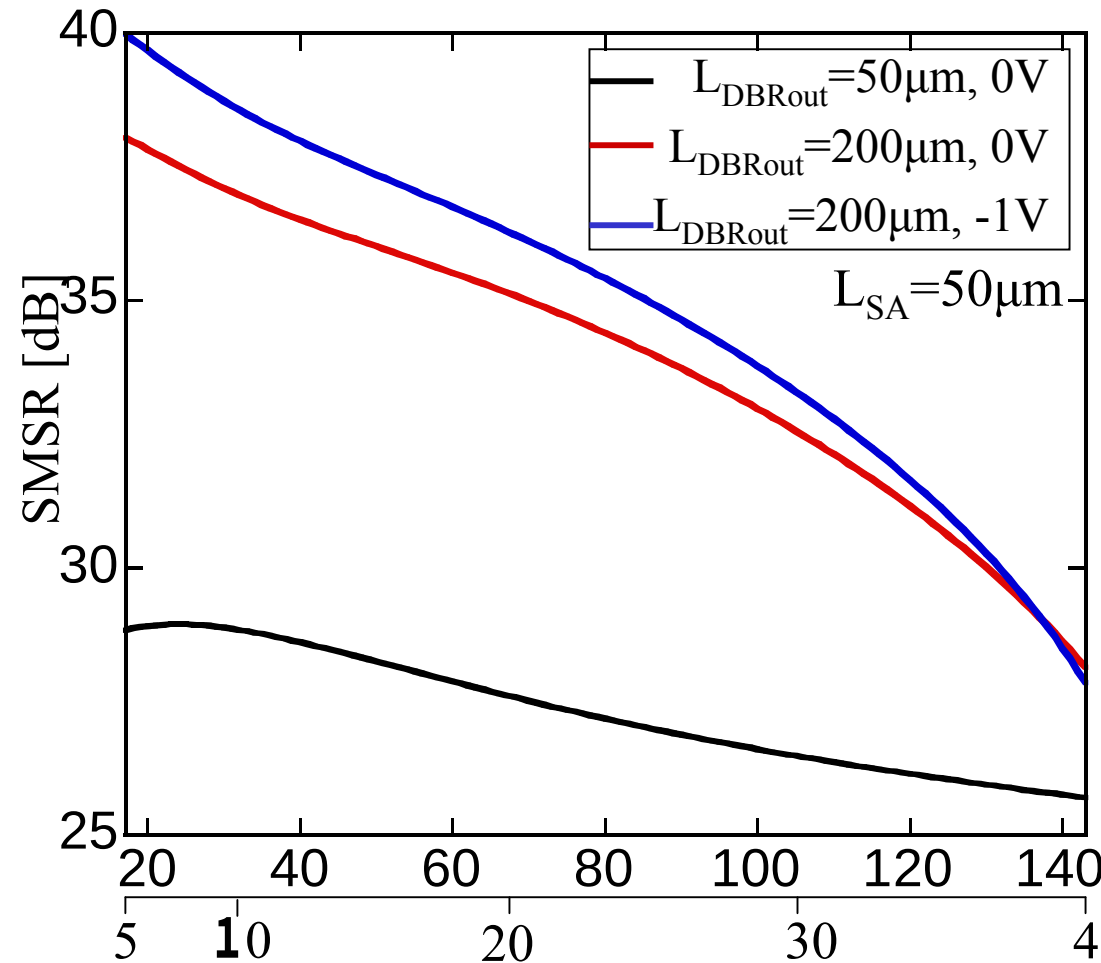
- Complete & rigorous calculation requires carrier density dependence, but difficult to obtain carrier density decay constant for reverse bias
 - Experimental estimate from 1-D BLDs:

$$\alpha(V_{rev}, N_p) = \frac{3300 \text{ cm}^{-1} (1 + 2.8 \text{ V}^{-1} |V_{rev}|)}{1 + \frac{N_p}{1.0 \times 10^{14} \text{ cm}^{-3} (1 + 0.6 \text{ V}^{-1} |V_{rev}|)}}$$

- Need to dampen as laser starts lasing
 - Carrier density-dependent absorption has “built-in” damping through rate equation
 - Damping dependent on magnitude and change of photon density

Side Mode Suppression Ratio (SMSR)

$$SMSR \propto \left(\frac{\alpha_{m,\lambda_1}}{\alpha_{m,\lambda_0}} - 1 \right) \left(\frac{P_{out}}{I_{th, "on"}} \right) \quad \alpha_m = \text{mirror loss}$$

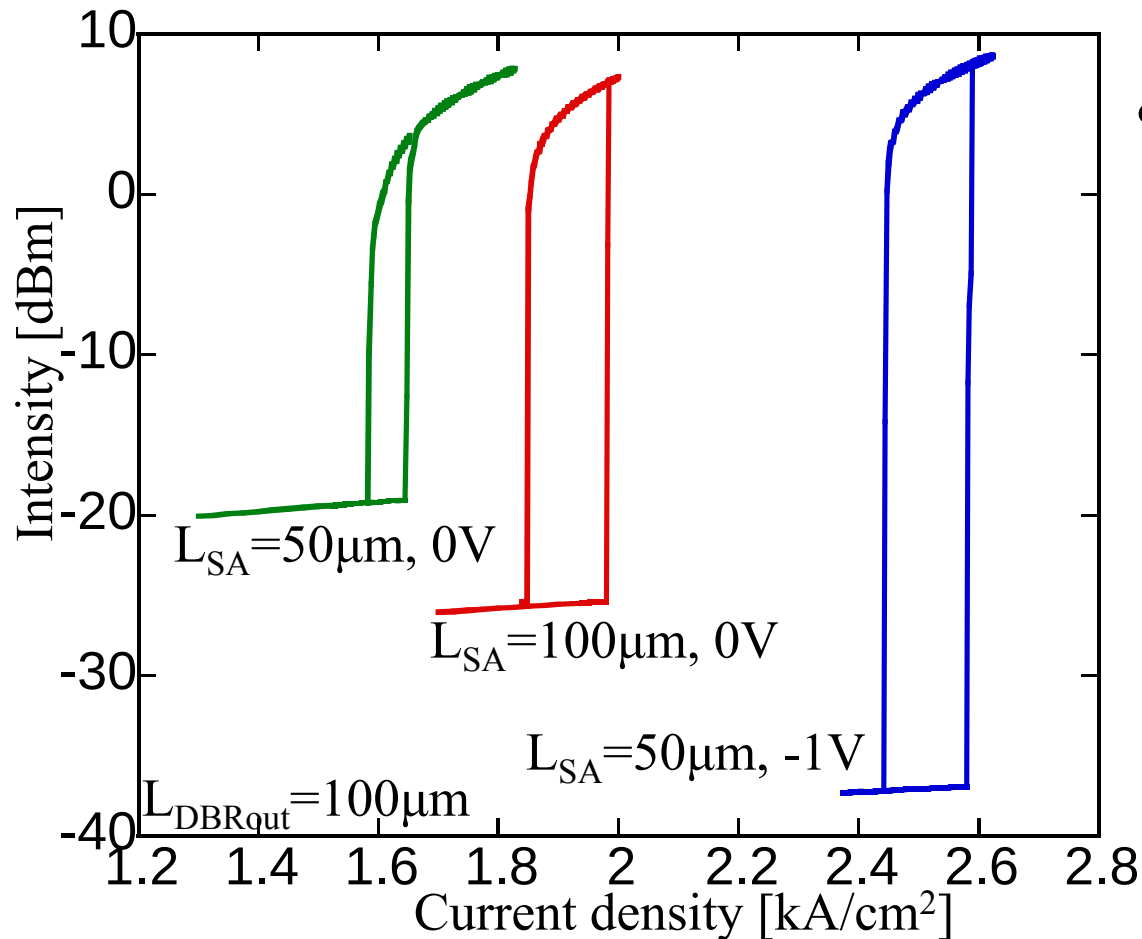


Choose fraction of power emitted from output=0.8

Gratings must not be too deep/short from SMSR, but cannot be too shallow from DBR length issues:

$\kappa \approx 30 \text{ cm}^{-1}$ for $SMSR > 35 \text{ dB}$

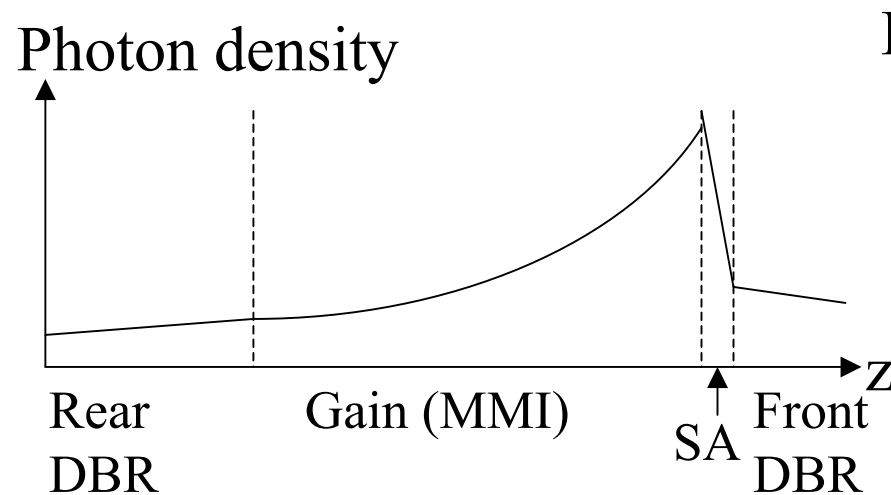
L-I Simulations: Reverse Bias



- Threshold current and hysteresis width increase with SA loss

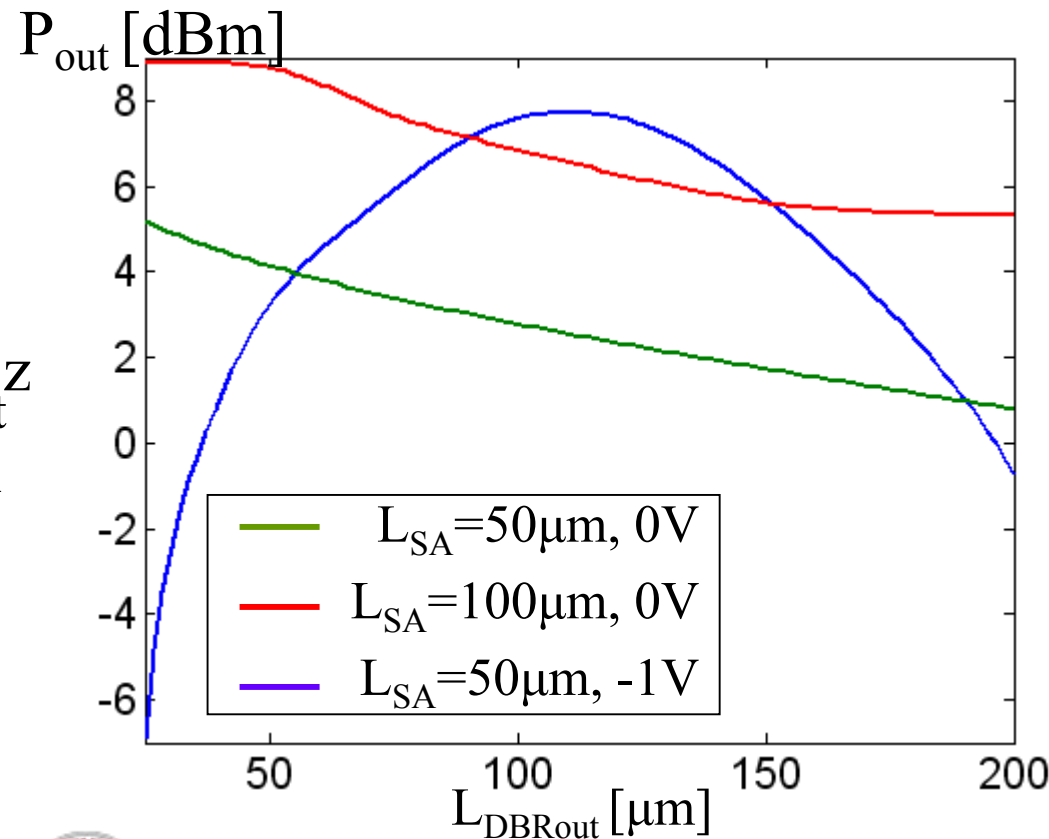
“On” State Output Power

- As mirror reflectivity increases, less power out of laser
- Large SA absorption, small reflectivity: SA absorption changes little “on” vs. “off” so $I - I_{th}$ small



Uniform photon density:

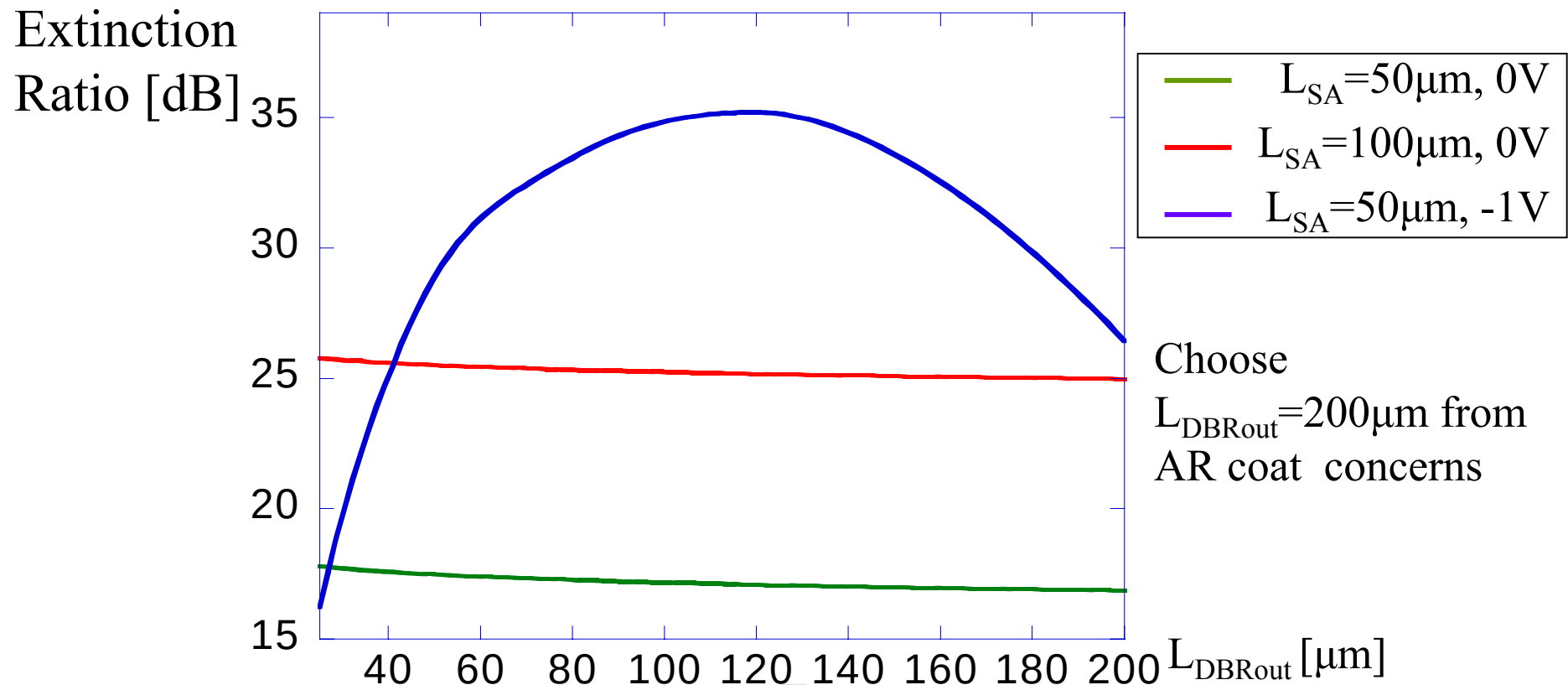
$$P_{out} \propto \frac{\alpha_m}{\langle \alpha_i \rangle + \alpha_m} (I - I_{th})$$



Extinction Ratio

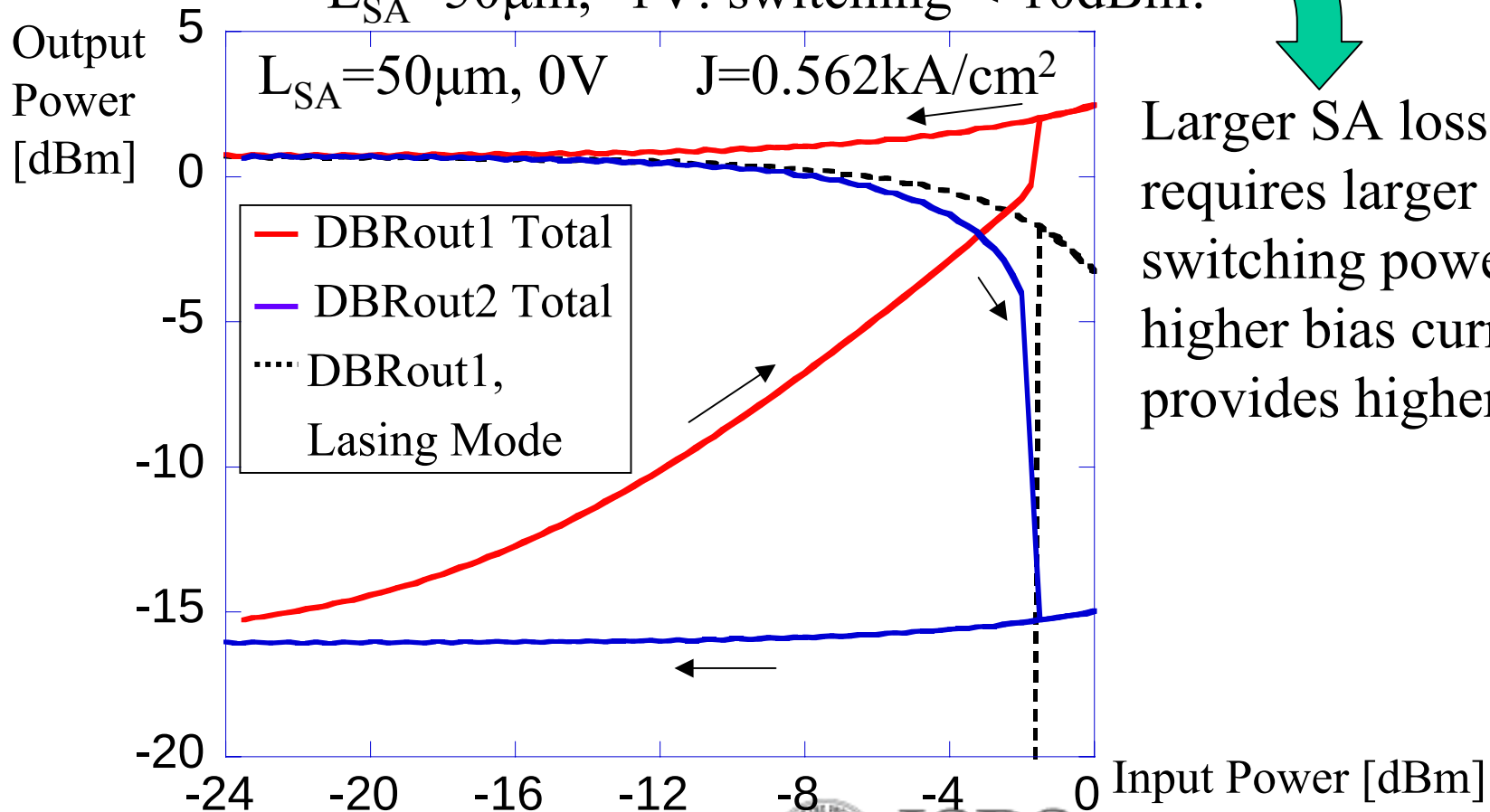
- Dominated by MMI splitting, practical value $\sim 15\text{dB}$

$$\text{Extinction Ratio} \approx \frac{P_{out}}{(mmi_splitting)P_{out}e^{-\Delta\alpha_{SA}L_{SA}} + P_{SPONT}}$$



All-Optical Switching: $L_{\text{DBRout}}=200\mu\text{m}$

- $L_{\text{SA}}=50\mu\text{m}$, 0V: Switching achieved at -2dBm
 - $L_{\text{SA}}=100\mu\text{m}$, 0V: switching $\sim 2\text{dBm}$
 - $L_{\text{SA}}=50\mu\text{m}$, -1V : switching $< -10\text{dBm}$!

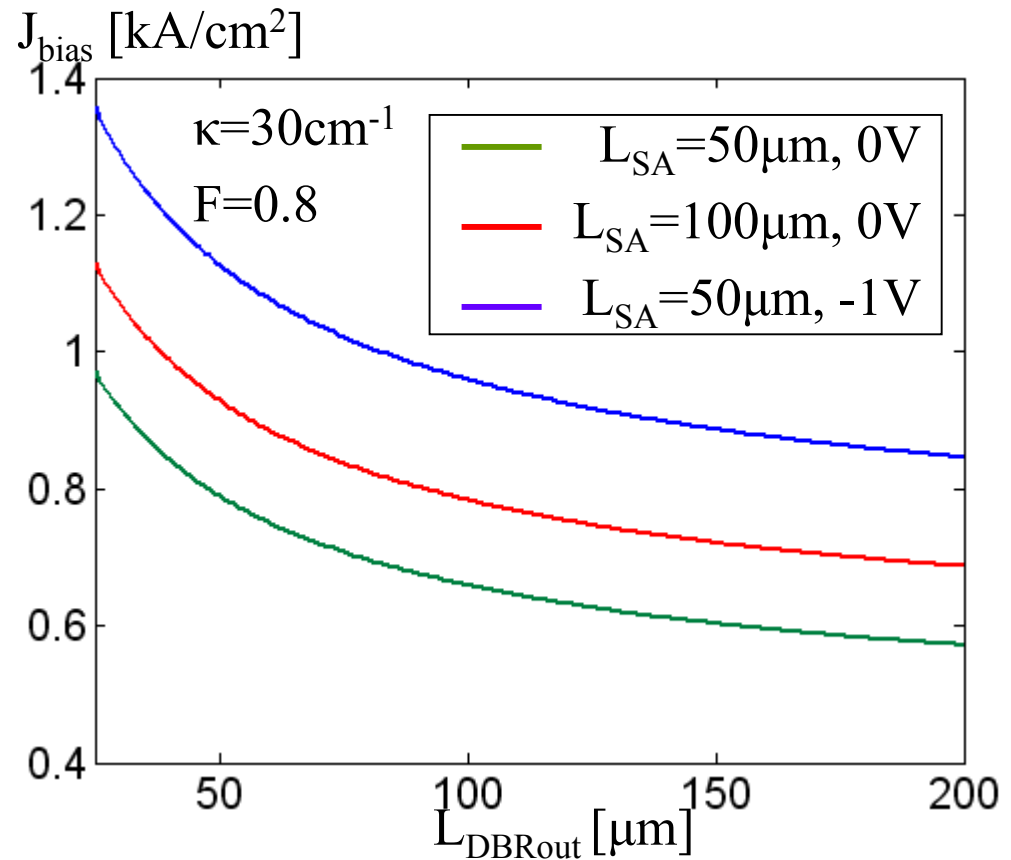
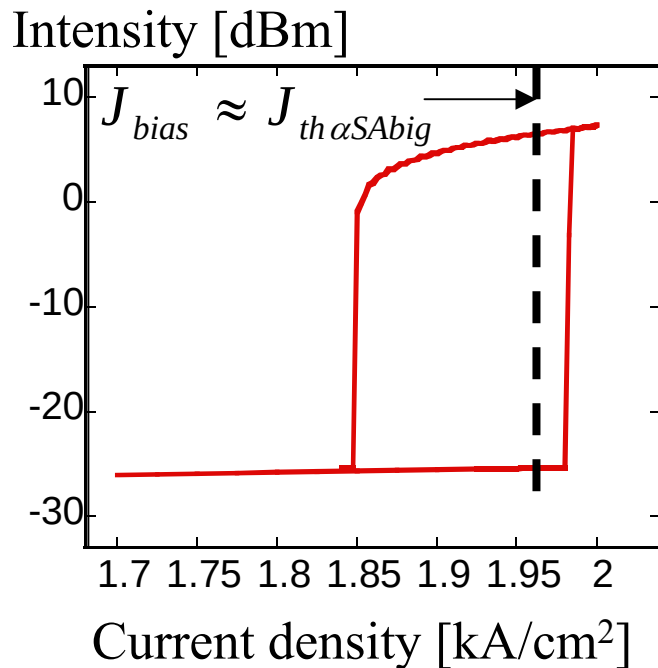


Conclusion

- $\text{SMSR} \approx 35\text{dB}$ predicted
- L_{DBR} , L_{SA} , and reverse bias affect output power, extinction ratio
- Total prototype device length 1.2mm
- DBRs offer not only cascadable, directional, good SMSR devices but also control over output power and extinction ratio

Bias Current

- Bias current determined by device dimensions, SA bias—not much flexibility



DBR Length vs. Grating Depth

- Gratings must not be too shallow
- Choose splitting fraction $F=0.8$

$$F = \frac{P_{out_DBRout}}{P_{out_DBRin} + P_{out_DBRout}}$$

