Significant progress has been made fabricating photonic integrated circuits on Si and integrating them with CMOS ICs, but the need for compatible optical gain elements (laser sources and optical amplifiers) still remains. Recently researchers at UCSB and Intel have had good success integrating III-V gain elements with Si-based dielectric waveguides using evanescent coupling [1]. At MIT, we have developed an alternate approach that uses co-axial coupling of III-V ridge waveguide devices and Si-based dielectric waveguides. This integration process includes first fabricating micro-scale device platelets, such as laser diodes (LDs) or optical amplifiers (SOAs), from commercially grown heterostructures, and then assembling these platelets in dielectric recesses etched through silicon oxy-nitride/silicon dioxide waveguides on Si wafers (ultimately this step will be done on IC wafers).

The essential ingredients for efficient coupling between the ridge waveguide devices and the dielectric waveguides are (1) matching the mode profiles, (2) accurately aligning the waveguides laterally and vertically, and (3) minimizing the separation between the guide segments. Standard dry-etch processes can be used to keep the space between the recess wall and the side of the laser small; the vertical offset between the core of the dielectric waveguide and the active region of the in-plane laser is kept small by monitoring layer thicknesses during epitaxy and deposition. To keep the gap between the guide ends small while also having a good cavity end facets, we use precision micro-cleaving; this enables us to control the cavity length to within 1 micron.

Measurements on integrated assemblies with air filling the gap between the guides indicate that coupling losses as low as 5 dB are obtained when the guides are well aligned and the gap is less than 1 micron [2]. Other measurements and computer simulations indicate that using a gap fill with $n \approx 2.2$ (e.g., silicon nitride) and improving tailoring of the vertical mode profile in the III-V guide can reduce this loss to below 1 dB. Other work in progress in this program includes integrating angle-mounted SOAs with dielectric waveguides and developing a new laser design using a silicon oxy-nitride waveguide DFB structure and a high-index gap fill.

References