Single-Mode Emission in InP Microdisks on Si using Au Antenna (Supporting Information)

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Selectivity of Orthogonally Placed Antennae

One possible explanation why no side-mode suppression is observed for cavities with orthogonal antenna is the potential poor overlap between the electric field distribution of the resonant mode and the antenna itself. To check if single-mode emission can be achieved with wider orthogonally placed antennae, we performed additional measurements with antennae with larger cross sections. Fig. S1(a) shows the peak ratio of peak 1 (925 nm) and peak 2 (960 nm) at different excitation powers for a bare cavity and devices with orthogonal antennae for varying cross sections and widths. Fig. S1(b) - (f) shows the SEM images of the respective antennae. While parallelly placed antennae show a clear trend towards a higher peak ratio for larger cross sections (see Fig. 2d, Fig.
there seems to be no mode selectivity for the orthogonally placed antennae with similar cross section areas. These results indicate that both antenna size and orientation play an important role for effective single-mode emission.

**Figure S1.** (a) Peak ratio of peak 1 at 925 nm and peak 2 at 960 nm for a bare cavity and orthogonal antennae with varying sizes. The shaded part highlights the region where the peak ratio is greater than 10, the dashed line marks the level where both peaks have the same intensity (peak ratio is equal to 1). The points with the “single mode” label mark the excitation powers up to which a certain device is single mode, i.e., where only one resonant emission peak is visible. Inset: SEM image of the device with an antenna which has a cross section of 0.021 µm². (b) – (f) SEM images of the respective antennae, for which the peak ratios were extracted.

**Optical Simulations**

To illustrate the importance of the positioning of the antennae with respect to the resonant modes, we performed 3D finite-difference time domain (FDTD) simulations using the commercial software Lumerical. Fig. S2(a) and (b) show the simulated mode patterns at 973 nm for the bare cavity in the middle and at the top of the microdisk cavity. Figure S2(c) shows the pattern at the antenna/InP interface with a parallelly placed antenna, and Figure S2(d) with an orthogonally placed antenna. We can see that the electric field is concentrated along the antennae edges. In the
case of the orthogonally placed antenna, however, the original cavity mode is still visible whereas this is not the case for the parallelly placed antenna, indicating the smaller overlap between the resonant mode and the antenna. Deviations between simulated resonant modes and wavelengths compared to experimentally measured ones can arise due to a difference in the refractive index used in simulations and the real one and due to fabrication related imperfections, such as tilted sidewalls, side-wall roughness, and variation in the antenna shape amongst others.

![Figure S2. FDTD simulations of a mode pattern of a bare cavity at (a) the middle of the microdisk and (b) the top of the microdisk (cavity-air interface). Simulated mode patterns of a microdisk cavity with (c) a 70 nm wide and 250 nm long parallelly placed antenna and (d) the same antenna placed orthogonally. The electric field is recorded at the antenna-microdisk interface and is concentrated along the antenna. In the case of the orthogonally placed antenna, a significant fraction of the field is distributed at the periphery of the microdisk as well.](image)

**Emission Characteristics at 200 K**

Linear light-in-light-out (LL) curves of devices at 200 K (see Fig. 6a in the main text for spectra) are shown in Fig. S3. In the case of the bare cavity, the threshold (0.3 pJ/pulse) is considerably lower than at room temperature, due to a stronger material gain and reduced losses. The device
with a parallelly placed antenna has a similar threshold (1 pJ/pulse) as at room temperature. One reason might be the weaker overlap between the material gain and the resonant mode at lower temperatures, since the band gap of InP will increase for lower temperatures and the bulk emission will shift to shorter wavelengths. Therefore, harder pumping of the cavity will be needed to overcome the losses.

**Figure S3.** Linear light-in-light-out curves for a cavity with (light blue, solid symbols) and without (dark blue, hollow symbols) extracted from PL spectra acquired at 200 K.