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Focused Emission Beams from Ring Quantum Cascade Lasers

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Quantum cascade lasers (QCLs) have become powerful, versatile and desirable light sources, emitting in a wide range from the mid-infrared to the terahertz spectral region. Therefore, such lasers are suitable for many applications in science, medicine and industry. Compared to conventional Fabry-Pérot devices, ring QCLs convince with an enhanced performance in terms of output power and lasing threshold. Moreover, they exhibit much more focused emission beams with a 20 times smaller full width at half maximum. We present an approach for further decreasing the divergence of this emission beam. At the same time the light emission at greater angles of radiation will be eliminated. Due to their second order distributed feedback grating, ring QCLs show surface and substrate emission. Our approach uses the substrate emission and is based on an on-chip metamaterial fabricated directly onto the substrate below the laser. The metamaterial layer is a few micrometers thick and consists of several sub-wavelength holes. They form a refractive index gradient, which behaves like a collimation lens. With this on-chip focusing element the measured peak intensity in the center of the far field amounts to more than 600 percent of the initial value, while the overall output power is not changing. In addition, the peak-to-average intensity doubles with the metamaterial substrate. Our focusing principle also works using pi-phase shift ring QCLs in order to simultaneously control the polarization and divergence of the emitted beam.

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