High-Q Si_3N_4 ring resonators for locking 780nm GaAs-based distributed feedback laser

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High-Q microring resonators have applications in gyroscopes, frequency comb generation, and feedback systems to control narrow linewidth integrated lasers [1-3]. This paper demonstrates the highest Q values measured for microring resonators at 780 nm wavelength. These sub mm integrated cavities can be used to provide an error signal for locking a distributed feedback laser (DFB), **Fig. 1(a)**, using the Pound-Drever-Hall (PDH) method. High stability DFBs can also be achieved using a micro-electro-mechanical system (MEMS) cell containing ^{87}Rb vapour and taking advantage of the absorption line at 780.24 nm. This provides an absolute reference for locking the laser but only to the ^{87}Rb transition wavelengths. The microring resonator can be tailor made for any wavelength but is susceptible to thermal effects; this could in part be overcome using a top cladding with a thermo-optic coefficient that counteracts that of the waveguide core.

Silicon nitride (Si_3N_4) waveguide cores are fabricated from a low-pressure chemical vapour deposition at 750°C. The Si_3N_4 core material is deposited onto a 4 µm thick thermal SiO_2 layer grown by wet oxidation at 1000°C. The waveguide pattern is written using electron beam lithography and etched using a CHF_3/O_2 reactive ion etching. A SiO_2 top cladding layer can be added using plasma enhanced chemical vapour deposition at 300°C.

Initial experiments varied the gap spacing between the bus waveguide and microring resonator to find the highest resolvable Q for a given waveguide geometry, **Fig. 1(b)**. As the gap spacing is increased, the power coupling is over-coupled, critically coupled, then under-coupled. The highest measurable Q values are found for under-coupled microrings, this limits application for frequency comb generation but provides the greatest error signal for laser locking. The microrings were measured with and without a top SiO_2 cladding layer. Higher Q values were achieved with the top cladding; when directly comparing microrings with similar power coupling the Q value is shown to approximately double with the addition of the cladding. The most significant loss mechanism at 780nm wavelength is scattering due to line-edge roughness of the etched waveguides. The top cladding layer deposition should have minimal effect on the material absorption suggesting that the loss is limited by scattering. Q can therefore be improved by increasing the waveguide width, **Fig. 1(c)**. This reduces the intensity of the modal field at the waveguide sidewall. With this approach, a Q value of $\sim$800,000 has been demonstrated for microring resonators without a top cladding. For rings with a top cladding, Q values greater than 1 million are expected.

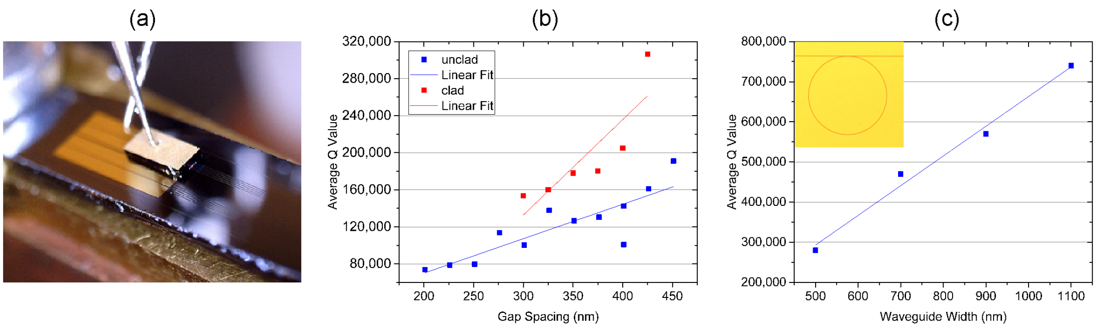

Fig. 1(a) A DFB laser coupled to a Si_3N_4 waveguide on-chip **(b)** Average Q values for 500 nm wide, 200 nm thick, 300 µm radius waveguide microring resonators of varied gap spacing **(c)** Average Q values of 300 µm radius, 200 nm thick waveguide microring resonators of varied waveguide width. Insert: a microscope image of a Si_3N_4 microring resonator.

Example References

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