While there have been several previous reports of enhanced Raman signals in Si nanostructures, including the dependence on diameter for nanowires and longer cylinders [6,38,42,66], in this work we emphasize the direct correlation between the Raman enhancements and the independently measured optical resonances of the nanostructures, and we unambiguously identify through simulations the modal characteristics of these resonances. This approach is general and can be applied to understand the Raman signal dependence reported elsewhere. For example, using somewhat longer Si nanowires, Khorasaninejad *et al*. [38] reported that the maximum Raman signal excited with 633 nm excitation is observed when the diameter is 135 nm for pitches ranging from 400 to 800 nm. This diameter that yielded their maximum Raman signal is quantitatively consistent with our results, which indicate a resonance near 630-650 for 133 nm diameter nanopillars as illustrated by the resonances observed in Fig. 1(b) and 1(d), as well as Fig. 2(b). Furthermore, we observe a 17–fold enhancment in the overall Si Raman intensity excited at 785 nm incidence from arrays of ~184 nm diameter nanopillars, Fig. 7(b). In this case also, the enhancement occurred when the Mie resonance wavelength (*mode 1*) of the nanopillar array spectrally coincided with the Raman pump laser wavelength.

4. Conclusion

In conclusion, we have shown that periodic arrays of Si nanopillars interact with incident electromagnetic radiation to produce Mie resonances that are consistent with dielectric nanocavities. This leads to the confinement of a large portion of the incident EM field within the subwavelength Si nanopillars as evidenced by FDTD and FEM simulations as well as μ-Raman measurements. The resonances are observed to blue-shift linearly with decreasing nanopillar diameter, and less so with decreasing array pitch. The strong dependence of the resonance wavelength on the diameter of the Si nanopillars indicates that the local Mie resonance and the resonance-enhanced extinction in the high index Si nanopillars dominate the overall optical properties of the arrays. The pitch-induced shifts can be considered as the relatively weak, coherent coupling between these Si nanopillar Mie resonators, similar to effects studied widely for arrays of plasmonic particles. In addition, the dependence of these resonances on the nanoparticle and array parameters demonstrates that these resonances can be tuned to preferred wavelengths with specific linewidths and bandwidth for a given application. This can be useful in the development of photonic and plasmonic/photonic hybrid devices such as higher-efficiency photovoltaic solar cells and enhanced optical emitters and detectors.

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