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The relatively low Purcell factor as compared to the ideal value  $F_{p,ideal}$  of Eq. (7) follows from three effects: (i) the polarization factor 1/3, as the Er emitter dipoles are randomly oriented; (ii) the uniform spatial distribution of the dipoles in the plane, instead of having dipoles at the cavity center; (iii) the non-optimal location of Er layer on top of the silicon slab, instead of having dipoles at the middle of the slab. All these effects are contained in the formula (9) and are taken into account in the FDTD evaluation of the Purcell factor. Effect (iii) could be overcome by fabricating similar PhC cavities in which the active material is placed inside the crystalline silicon, in order to improve the overlap between the active layer and the cavity region, by using e.g. vertical slot waveguides [42]: this solution would be especially advantageous, as it would also reduce the effective volume  $V_{eff}$  by the slot effect leading to enhanced electric fields in the slot region.

## 5. Conclusions

In summary, we have successfully demonstrated coupling between Er atoms and the optical modes of an L3 photonic crystal cavity realized in crystalline silicon by coating the cavity with a thin Y-Er disilicate layer. The PL of Er atoms in the cavity region is enhanced by the increased extraction efficiency and the Purcell effect, the extraction efficiency being maximized using far-field optimization. By measuring the emitted power, we estimate that 30% of Er population is excited; this opens the route for further improvements through an optimization of both active material and photonic structure. The Purcell factor that we extract from time-resolved photoluminescence measurements is  $F_p \approx 2.3$ , close to the calculated value of  $F_p \approx 3.2$ . However, we expect  $F_p$  to increase in optimized PhC cavities in which the active material can be inserted spatially closer to the region of highest field confinement. Finally since our photonic structure is fully fabricated in crystalline silicon and coated with a very thin insulating layer, it is possible, in principle, to fabricate an electroluminescent device. The Er atoms could be excited through an impact excitation mechanism, with carriers tunneling through the active layer, a scheme that has already been used to demonstrate electroluminescence in other silicate-based devices [13]. This would greatly broaden the range of applications for the present Si-based nanoemitters opening the route to the development of small-sized Er light source and amplifiers.

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