Inverse Designed Diamond Nanophotonics

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Abstract: Combining inverse design optimization methods and quasi-isotropic etching techniques, we develop compact, flexible and efficient photonic components in diamond for applications in quantum technologies.

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1. Introduction

Color centers in diamond are promising candidates for optically active quantum nodes for quantum computation or quantum communication. The quantum nature of these color centers allows them to operate at the level of single photons but requires efficient optical interfaces in form of nanophotonic cavities to increase light-matter coupling [1]. While such cavities have been explored extensively in diamond, quantum technologies require the integration of emitter-cavity systems into large-scale photonic circuits. Through site-controlled implantation of ions, arrays of color centers are within reach, however, imperfect implantation precision and conversion efficiencies require highly flexible circuit designs. Moreover, fabrication in diamond is challenging and comes with stringent fabrication constraints. In our work, we use inverse design optimization techniques, which allow us to develop highly flexible and efficient device components. Through our optimization methods we can exploit the full potential of a recently developed quasi-isotropic etching technique [2] and fabricate suspended diamond photonic components with rectangular cross section.

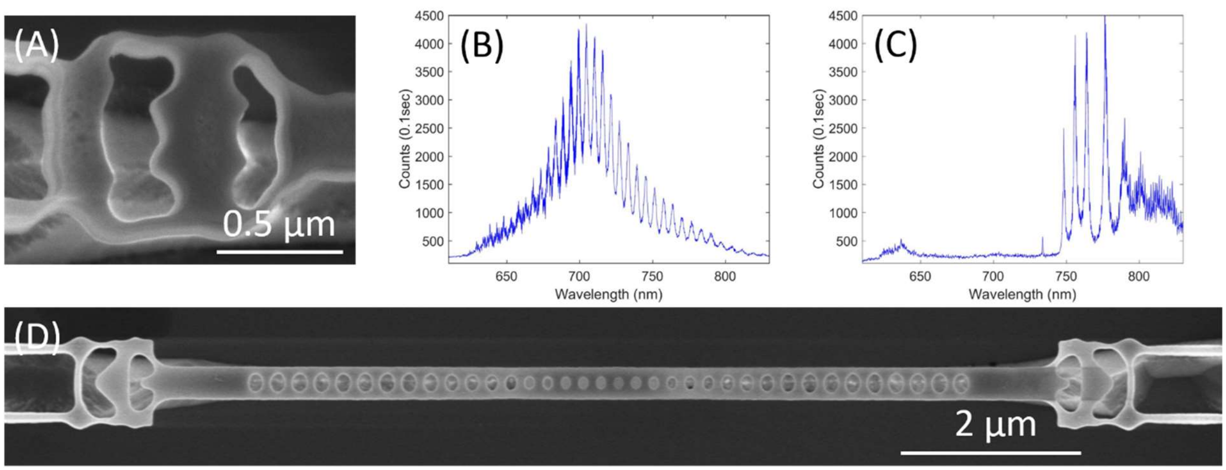

Figure 1: Diamond Photonics. (A) Inverse designed diamond vertical coupler. (B) Transmission spectrum of the device shown in (A). (C) Transmission spectrum of the device shown in (D), consisting of vertical couplers and a nanobeam photonic crystal cavity.

2. Diamond Photonics

We apply an inverse design optimization approach for device optimization, which allows us to search the full parameter space, while traditional optimization methods mainly rely on parameter sweeps. As a result, our device designs are non-intuitive (see Fig. 1(A)), but are fabricable using standard techniques, are robust against typical fabrication errors, and outperform their traditional counterparts in footprint, efficiency and stability. As an example, we develop vertical couplers (Fig. 1 (A)), which couple light from the free space fundamental mode to the fundamental waveguide mode and vice versa with efficiencies >25% (see Fig. 1(B)) for transmission spectrum). In most material systems such devices can be designed using traditional design methods, however, challenging fabrication protocols and stringent requirements for quantum optics applications. Due to the flexibility of our optimization methods, which can incorporate fabrication constraints as part of the optimization, we can improve on the coupling to photonic crystal cavity systems by >550 times in transmission experiments (see Figs. 1(C) and 1(D)).

3. Summary

Combining inverse design optimization and quasi-isotropic etching techniques, we open up the path towards flexible photonic circuits for quantum applications. The capability of inverse design to incorporate fabrication constraints as part of the optimization has the potential to accelerate the development of photonic circuits in any novel promising material platform with quantum emitters and potentially challenging fabrication protocols.

4. References

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