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Reply to 'On nanostructured silicon success'

Shen *et al.* reply — We recently demonstrated an ultracompact integrated polarization beamsplitter (PBS) utilizing nanophotonic dielectric structures[1]. Sigmund *et al.* raised concerns regarding our paper[2]. Our response is as follows.

First, Sigmund *et al.* point out the ambiguousness of defining performance metrics for such devices, while reducing their footprint. It is well known that the performance of many integrated photonic devices is intimately linked to their size. The approach we followed was to design devices whose performance is on par with conventional devices, but with a greatly reduced footprint. For example, in our paper, the PBS has a designed average transmission efficiency of ~75% over an operating bandwidth of 80 nm, which is comparable to that of conventional integrated photonic PBS devices that are ~19 times larger[3].

Second, Sigmund *et al.* cast doubt on the claim that our PBS is the smallest ever demonstrated by citing Guan and colleagues' simulations of a plasmonic PBS[4]. However, Guan *et al.* did not experimentally demonstrate their device as we carefully pointed out in our paper. Therefore, we reiterate our claim that our PBS is the smallest such device (experimentally) demonstrated to date.

Third, we acknowledge the pioneering work of Sigmund *et al.* and apologize for the honest mistake of missing this work.

Fourth, Sigmund *et al.* point out that in-plane geometric variations of a device are more important than device thickness. We did analyse the impact of in-plane geometric errors on device performance, which is included in the Supplementary Information associated with our paper. We emphasized the impact of device thickness in the main text for two reasons. First, we treated this as an optimization variable to improve the device performance, and custom-made the requisite silicon-on-insulator substrates. The device thickness varies due to our process limitations. Second, the technique used to etch our devices (focused-ion-beam lithography) is not very selective to silicon compared with silicon dioxide, which means that the top silicon layer can be over-etched and the oxide layer beneath is unintentionally affected. Therefore, we need to account for possible discrepancies between the device (silicon) thickness before and after etching.

Sigmund *et al.* are worried that our computation time would increase significantly with the increase in our design variables. We acknowledge that our approach is computationally intensive, but also point out that unlike the previous approaches, we are able to design devices with performance that is comparable to much larger conventional devices. Most importantly, our design algorithm is parallelizable and using larger clusters of processors will significantly decrease the computation time.

Finally, Sigmund *et al.* claim that we speculated about the use of our technique in a variety of applications. We point out that this is not speculation, as we have demonstrated many of these devices, including free-space metamaterial polarizers[5], free-space metamaterial diodes[6], integrated metamaterial diodes[7], integrated free-space-to-waveguide couplers[8], and a variety of designs for enhancing light-trapping in thin-film photovoltaics[9–13]. We agree with Sigmund *et al.* that topology optimization has developed over two decades. However, its application to enhancing photonic functionality (for example, by combining mode conversion and polarization splitting into a single device), while decreasing the footprint of integrated photonic devices as we show in our paper is unique. ❐

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Reply to 'On nanostructured silicon success'

Piggott *et al.* reply — Our recent Letter[1] reports the first experimental demonstration of our 'objective-first' inverse design method[2] applied to a practical device. As such, the introduction in our Letter was intended to provide a brief but broad overview of both computational design methods and demonstrated structures. Our previous works[2,3] provide a more thorough overview of the field. Sigmund *et al.* have raised concerns regarding our paper[4]. For the benefit of the reader, we provide the following broad historical survey of computational electromagnetic design, and place the objective-first method in that historical context.

At the heart of any computational design method for optical devices is an optimization algorithm. Some methods, such as genetic algorithms[5], particle swarm optimization[6], and random search[7], sample the parameter space in a brute force fashion. Although these methods can work well in specific cases, their computational cost is