Femtosecond laser induced creation of color centers on the silicon-on-insulator platform and control of their emission directivity with Mie resonators

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Researchers and engineers have been exploring ways to integrate light sources in silicon photonics for decades. Recently, fluorescent point defects in Silicon, also known as color centers, have been explored as promising candidates for such light sources. Moreover, individual defects act as single photon sources which paves the way towards the integration of quantum photonic devices with existing silicon-based electronics platforms. However, the current processes for creating such defects are complex, commonly requiring one or two implantation steps. In this work, we have demonstrated implantation-free G and W-centers in commercial silicon-on-insulator substrates using femtosecond laser annealing (see Fig. 1a). Furthermore, we have observed that a low-temperature annealing annihilates the G-centers while slightly enhancing the emission of the W-centers. This allows us to isolate W-centers in a restricted area of a size close to the cross section of the femtosecond laser spot [1]. Furthermore, we have found a way to improve color center emission directivity by embedding them into silicon Mie resonators (see Fig.1 b and c) fabricated by dewetting, achieving an extraction efficiency exceeding 60% with standard numerical apertures. This approach could lead towards ultra-bright telecom band single photon sources in silicon [2].

References

[1] H. Quard, *et al.*, arXiv:2304.03551 (2023)
[2] M. Khoury, H. Quard, *et al.*, Adv. Opt. Mat. 10, 2201295 (2022)

Figures

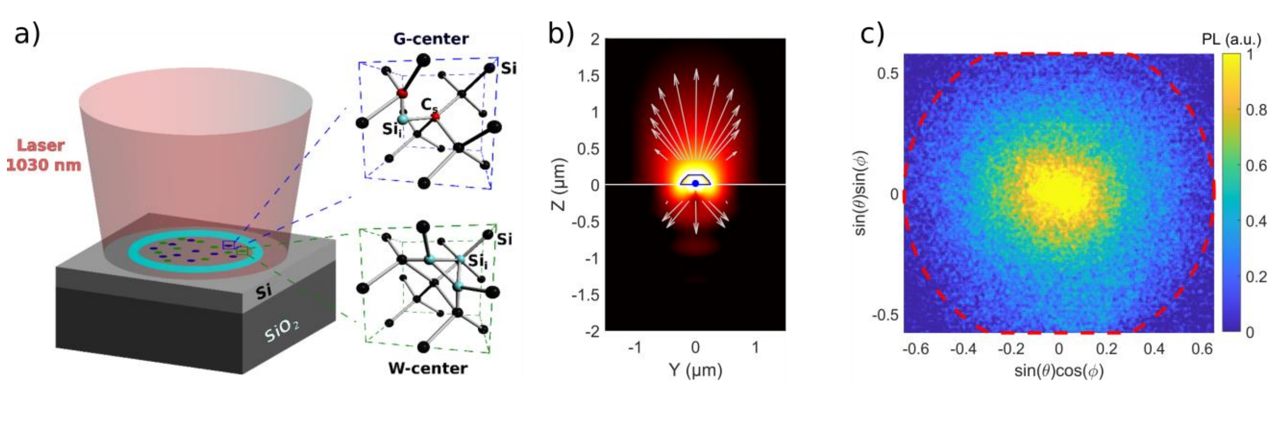

Figure 1: a) Schematic representation of the femtosecond laser irradiation process used to create G and W-centers. b) FDTD simulation of the Poynting vector of the emission of a dipole representing a color center embedded in a Mie resonator. c) Experimental far-field emission profile of G-centers embedded into Mie resonators obtained by angle-resolved photoluminescence spectroscopy.