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Can silicon change photonics?

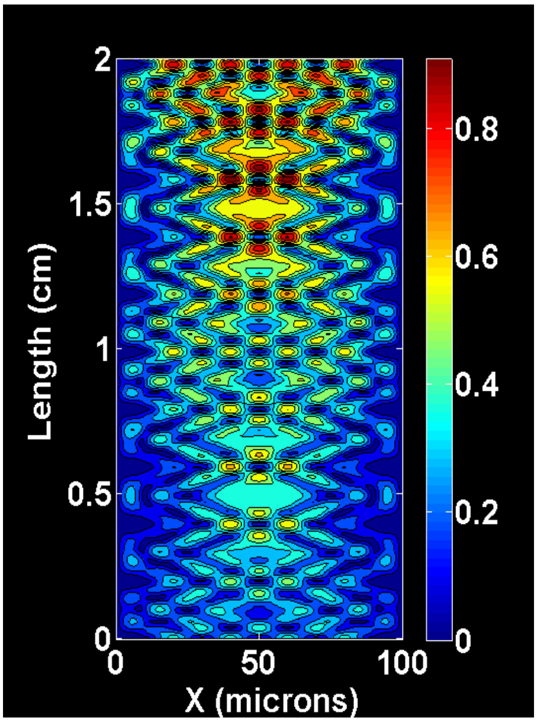
Optical amplification and enhanced nonlinear optical properties in silicon bring fully integrated electro-optical circuitry one step closer

Undoubtedly, silicon is the working horse of modern micro technology. But can this multitalent-material, once more, reinvent itself to utilize existing fabrication facilities for pathbreaking electro-optical applications? For a long time optical amplification and lasing have been considered forbidden in silicon. Typically, the indirect bandgap has been blamed for silicon's inability to amplify light and hence to lase. Besides that, silicon has some excellent material properties that are important in photonic devices such as a high thermal conductivity, high optical damage threshold or high third-order optical nonlinearities. In recent years it could be shown that by scaling down the size of photonic circuits, strong optical confinement can be reached that enables nonlinear optical interactions such as Raman and Kerr effects to appear. Further efforts have been undertaken that soon resulted in the development of silicon based optical amplifiers, optically pumped lasers and wavelength converters.

The highest impact of silicon photonics may be in optical interconnections between electronic chips. Optical devices built on silicon chips may well transfer digital files at rates as high as 10 GBps (gigabits per second) which is a 4-order magnitude improvement of nowadays transfer rates. Silicon could also play a key role on the production of disposable mass-produced biosensors, e.g. like lab-on-a-chip devices that can both measure and analyse, or optical transceiver chips for low-cost components in optical communication networks. Using silicon for light modulation devices, thus competing with other materials like $LiNbO_3$, is also conceivable, but challenging. Silicon has been known for decades as photodetector at wavelengths below 1000 nm where band-to-band absorptions occur. Technically important are the fiber optical communication bands around 1300 nm and 1550 nm where silicon happens to be transparent. Growing germanium on silicon substrates could be a solution but the question remains whether the strain resulting from Si–Ge lattice mismatch and the problem of the Ge passivation can be overcome. By now it has been demonstrated that silicon can be used as optical amplifier and used as lasing medium. So far, these results where achieved using an external pump laser. Electrical to optical conversion efficiency is very limited in silicon and there is an interest in growing III–V semiconductors on silicon, to introduce rare-earth impurities, quantum confinement or use Raman scattering to overcome or circumvent this problem. As great as the promises are, the challenges keep pace. If indeed such process and material compatibilities can be achieved there would be an excellent chance to equip silicon with electrically injected laser functionality.

Whether silicon, and not other competing materials, determines the future of photonics and enters our everyday life seems to depend mainly on two points. First of all, the significance of silicon photonics is strongly bound to our capability of finding production methods that are compatible with today's manufacturing processes in the chip industry. Then, silicon can be attractive as low-cost photonic device. Secondly, the thermal dissipation problem currently known from problems in chip design in microprocessor industry has to be solved for silicon based photonic devices, too. Has the time for silicon photonics come?

(Guido Fuchs, pss Editor)



Silicon Image Amplifier. A pixilated image is simultaneously amplified and imaged as it propagates through a multimode waveguide (vertical axis represents the propagation direction).

See also:
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Contacts:
Bahram Jalali, Corresponding author, jalali@ucla.edu
Sabine Bahrs, Series Editor, pss@wiley-vch.de, Tel. +49 (0) 30 4703 1339
physica status solidi, Wiley, Rotherstr. 12, 10245 Berlin, Germany

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