Novel semiconductor heterostructures based upconversion devices and their use as implantable light sources

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Abstract

Optical upconversion that converts infrared light into visible light is of significant interest for broad applications in biomedicine, imaging, and displays[1]. Conventional upconversion materials, e.g., rare-earth, organic dyes and quantum dots, rely on non-linear light-matter interactions, exhibit incidence dependent efficiencies and require high power excitation. By taking advantage of a fully integrated heterostructures based on III – V materials with photon – “free electron” – photon processes, we report a near-infrared (~810 nm) to visible [630 nm (red) or 590 nm (yellow)] upconversion that is linearly dependent on incoherent, low-power excitation, with a quantum yield of ~1.5%. By means of the new upconversion strategy based on devices design, a linearly dependent on incoherent, low-power excitation, fast transient decay of infrared-to-visible light process can be realized [2]. By exploiting the advanced manufacturing method, encapsulated, freestanding devices are transferred onto heterogeneous substrates and show desirable biocompatibilities within biological fluids and tissues. These microscale devices are implanted in behaving animals, with *in vitro* and *in vivo* experiments demonstrating their utility for optogenetic neuromodulation[3].

To summarize, the concepts presented here demonstrate materials and device strategies for highly efficient IR-to-visible upconversion that bypass many limitations of previously explored techniques. Furthermore, other approaches like wafer bonding and transfer printing instead of direct epi-growth can be explored to realize highly compact, heterogeneously integrated structures. By combining with light-sensitive receptors or drugs, these miniaturized devices can be applied to deep-tissue light stimulation or therapy. These results provide routes for high-performance upconversion materials and devices and their unprecedented potential as optical biointerfaces.

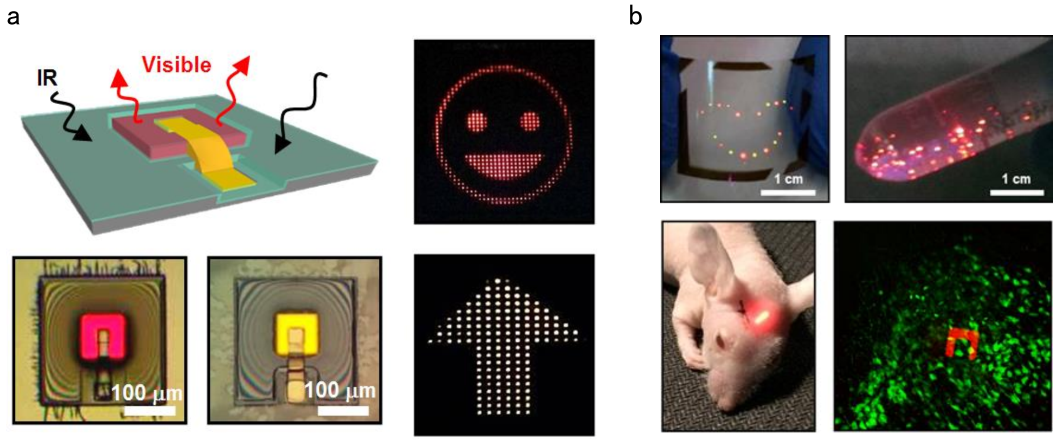

Figure 1: (a) Schematic illustration and microscopic image of the fabricated infrared – visible (red 630 nm, yellow 590 nm) upconversion device. (b) An array of devices transferred onto a flexible PET film, dispersed in PBS and implanted in the living animal nervous system under uniform IR illumination.

References

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