# The ‘Light-well’: A Tuneable Nanoscale Free-electron Light Source On-a-Chip

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**Abstract:** We report on a tuneable light source, a nanoscale analogue of the free-electron laser. A free-electron beam passing through a nano-hole in a periodically layered metal/dielectric structure creates an optical photon source – a ‘light-well’.

We report on the first experimental demonstration of a new type of electron-beam-driven optical source, a ‘light-well’, which can be used as a nanoscale tuneable emitter of optical radiation. With a lateral size of just a few hundred nanometres and a structure compatible with silicon-based technologies, such structures may be employed in nanophotonic circuits as chip-scale free-electron light sources, or in densely packed ensembles for optical memory and display applications.

The light-well is based on a similar concept to the free-electron laser (FEL), wherein a beam of electrons from an accelerator passes through a magnetic undulator or ‘wiggler’ that forces periodic transverse accelerations of the electrons along their path, resulting in the release of photons. In an FEL the wavelength of emitted light can be tuned by adjusting the energy of the electrons or the parameters of the undulator. The optical source reported here is a close nanoscale analogue of the FEL: in the light-well, a beam of free-electrons passes through a tunnel in a periodically layered metal-dielectric nanostructure and optical photons are emitted as a result, at a wavelength dependent on the energy of the incident electrons.

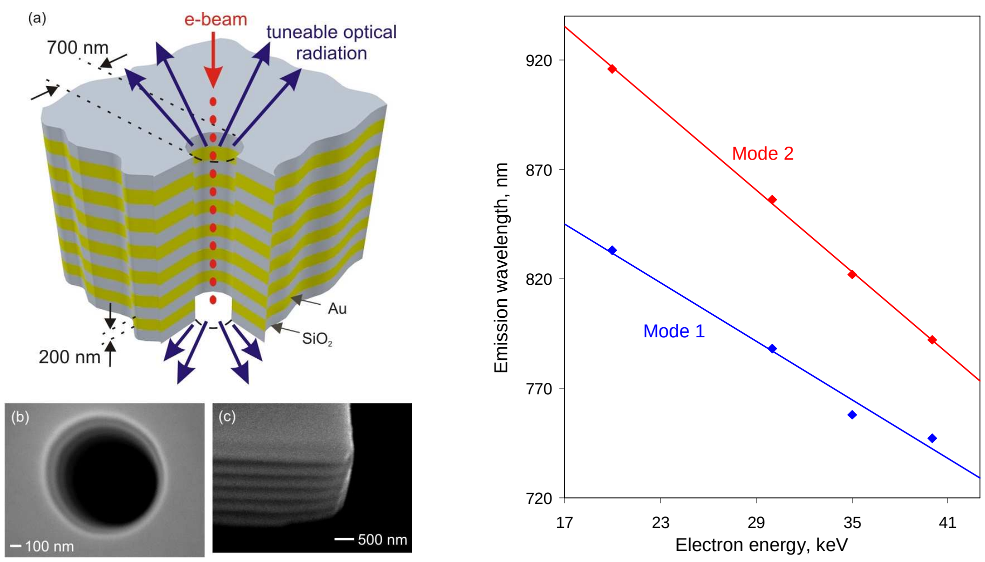


Figure 1: (a) Schematic cut-away section of a light-well. (b) Secondary electron image of a light-well fabricated in the gold-silica multilayer shown in (c). (d) Emission spectra for the light-well shown in (b) for a selection of electron acceleration voltages (traces are offset vertically for clarity).

Light-wells were fabricated in a stack of alternating 200 nm gold and silica layers sputtered onto a silicon substrate (see Fig. 1a-c). Nano-holes were milled through the stack, perpendicular to the plane of the layers, using a focused ion beam. Experimental measurements of light emission were performed in hyperspectral cathodoluminescent imaging mode under a scanning electron microscope equipped with a spectrograph and nitrogen-cooled CCD array for detection and analysis of emitted light. When the electron beam is injected into the nano-hole, the emission spectrum is found to contain two peaks (modes 1 and 2) with spectral positions that depend on the electron acceleration voltage (Fig. 1d). The total emission intensity is found to increase with beam current and as the injection point approaches the wall of the light-well.