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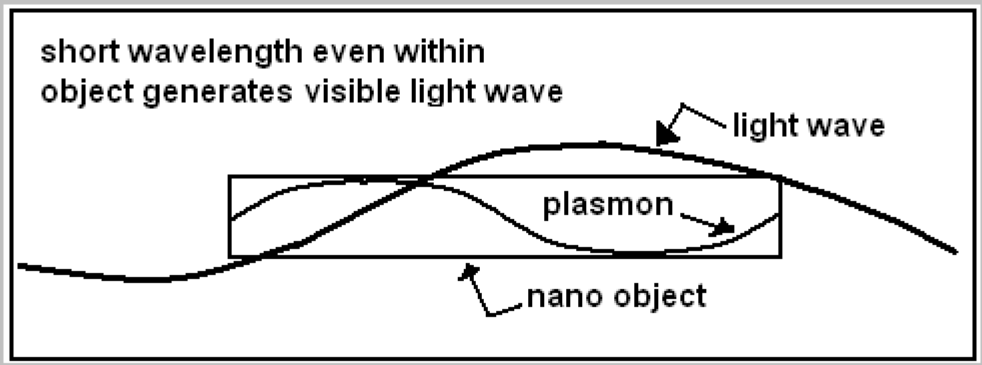
Breaking the nano-barrier

A laser device smaller than the wavelength of light is one better than nano, says S.Ananthanarayanan.

The great limitation of microscopy and telescopes is that with visible light we cannot see detail smaller than the wavelength of light. A work-around has been through imaging with light with smaller wavelength, like x rays, as in the Chandra observatory, or even the very short ***matter waves*** of high energy electrons, in the electron microscope. But the limit of visible light resolution has been of the order of microns.

But even in the sub-optical, that is, less than micron, region, there are periodic events, which is to say, wave-like disturbances, at frequencies near the optical, within those small dimension objects. Observing these optical frequency disturbances in the structure oa materials could open a window to their internal structure, which have been too small to see so far. One of these internal disturbances is in the motion of surface electrons in a metal. But the difficulty has always been to find signals arising from such motion in sufficient strength and then to detect them.



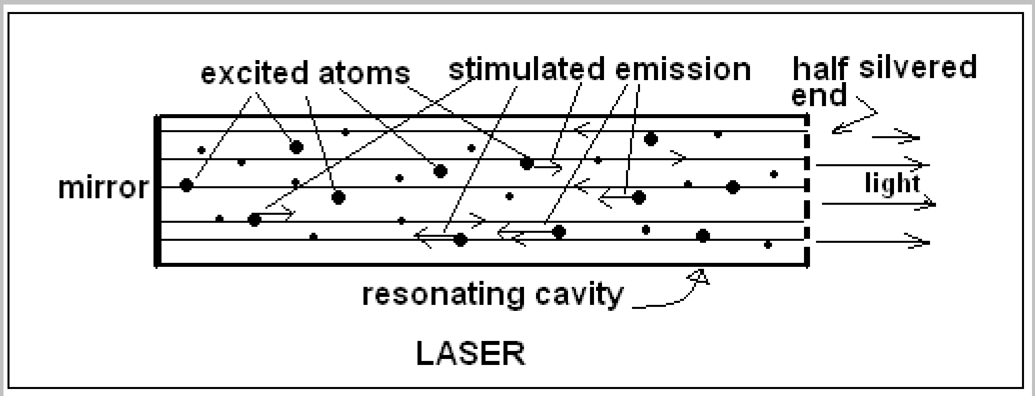
Plasmons

Atoms consist of a nucleus with a large positive charge, surrounded by successive shells of negatively charged electrons. In metals, the outermost shell has just a few electrons (like 1 or 2) and the large charge of the core is partly shielded by the inner shells of electrons. The outer electrons are thus not tightly bound and in a piece of metal, where the atoms form a lattice, the outer electrons of individual atoms are floating and free to move. But being charged particles, the electrons mutually push each other away and the motion at the surface is not uniform, but oscillating, like the vibration of a spring bed. The disturbances propogate as waves, which can behave like particles, just like particles of light. A gas of charged particles is called a ***plasma*** and just like packets of optical waves are called ***photons***, packets of wave energy in a plasma are called ***plasmons***.

There has hence been a suggestion that if these packets, called ***surface plasmons***, are generated in strength, so that they excite the surrounding media, this may provide a window into a world that too small for ordinary light to visit.

Laser and spaser

A means to generate powerful radiation inside a material is the ***laser***. The laser works by photons moving inside a gas or a crystal getting absorbed by atoms of the gas or crystal, to be re-emitted when struck by another photon. When a good number of photons are 'stored' like this, back and forth reflection of emissions from de-exciting atoms can cause a 'cascade' of emissions, which is the laser pulse. The photons emitted by the de-exciting atoms emerge in the same direction and with their periodic oscillations just 'in step' with the photon that causes the emission and the light is thus powerful, of accurately one colour and with the waves all 'in phase', which makes laser light a useful scientific and industrial tool.



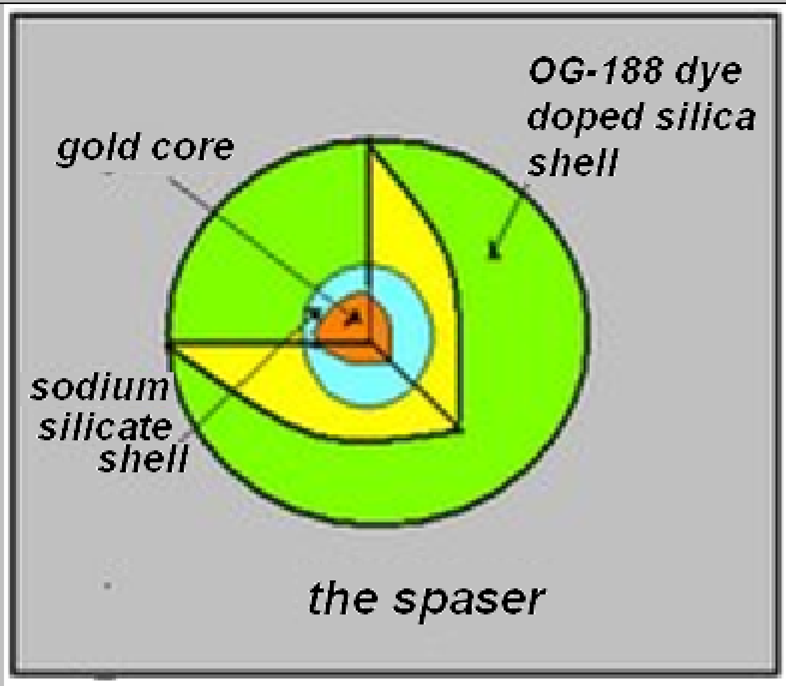
It was suggested in 2003 that a similar process could be used to amplify the plasmons within, or on the surface, of a metal, to help communicate with an external medium. The laser process is so named as an acro\nym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation (**LASER**). The same thing for **S**urface **P**lasmons would then become a **SPASER**.

There was hence a flurry of research after 2003 to develop the Spaser, but without significant success, till the work of Mikhail Noginov and colleagues, a multi-state team in USA, which they have reported in Aug 2009 in a paper in the journal, ***Nature***.

The nanolaser

Noginov and Co. used nano-particles of gold, coated with silica, doped with a fluorescent dye. This is the idea of the ***Cornell dot***, a device of associating dyes with entities, like molecules, which are too small to be seen. If a molecule is tagged with a fluorescent dye, a microscope that cannot see the molecule can still track the molecule with the help of the dye envelope.

The idea of using a nanoparticle of gold is that gold is rich in free electrons and the particle provides a resonator, for plasmons to be able to form standing waves of optical fluorescence of surrounding material.

Noginov and Co. covered the gold nanoparticle with dye, called Oregon Green 488, and a silica shell, to create a prepared, composite nanoparticle – with the gold core for the Spaser and the dye shell for advertisement, as visible light! The nanoparticles were only 14-15 nanometres across, and the light given off had a wavelength over 30 times larger, at 531 nanometres (in the green-yellow region).	

This "makes our system the smallest nanolaser reported to date and to our knowledge, the first operating at visible wavelengths. Now that it has been realized experimentally, we anticipate that the spaser will advance our understanding of fundamental nanoplasmonics and the development of practical applications", the authors say in the abstract of the paper.