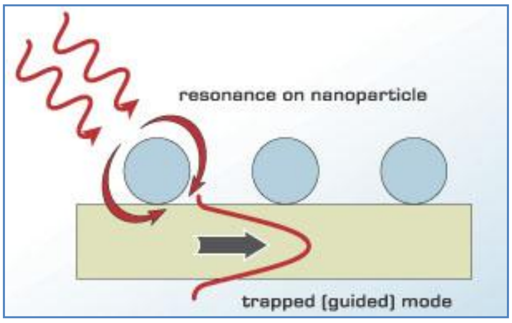
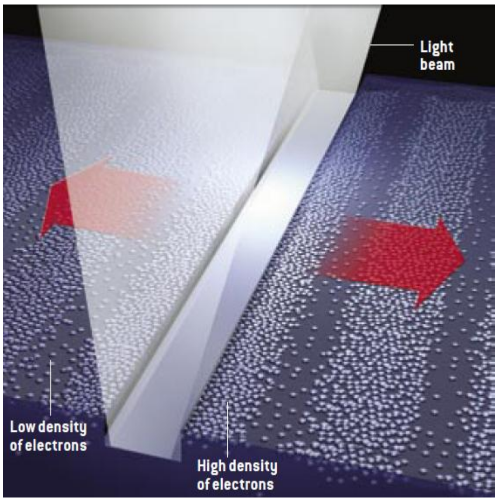
Plasmons and the idea of an Invisibility cloak – Taken from Scientific American

- In 1980s, researchers showed that when light waves are directed at the interface between a metal and a dielectric, under the right circumstances, the free electrons at the surface will resonate. The oscillations of the electrons at the surface match those of the electromagnetic field outside the metal.



- This produces PLASMONS – density waves of electrons that propagate along the interface like ripples in a pond after throwing a rock into it.



- Scientists have found by creatively designing the metal-dielectric interface, they can generate surface plasmons with the same frequency as the outside electromagnetic waves, but with a much shorter wavelength (light waves slow as they move across the metal interface). Therefore if these plasmons were used to transport information, they could store more information, as they are at a higher frequency.

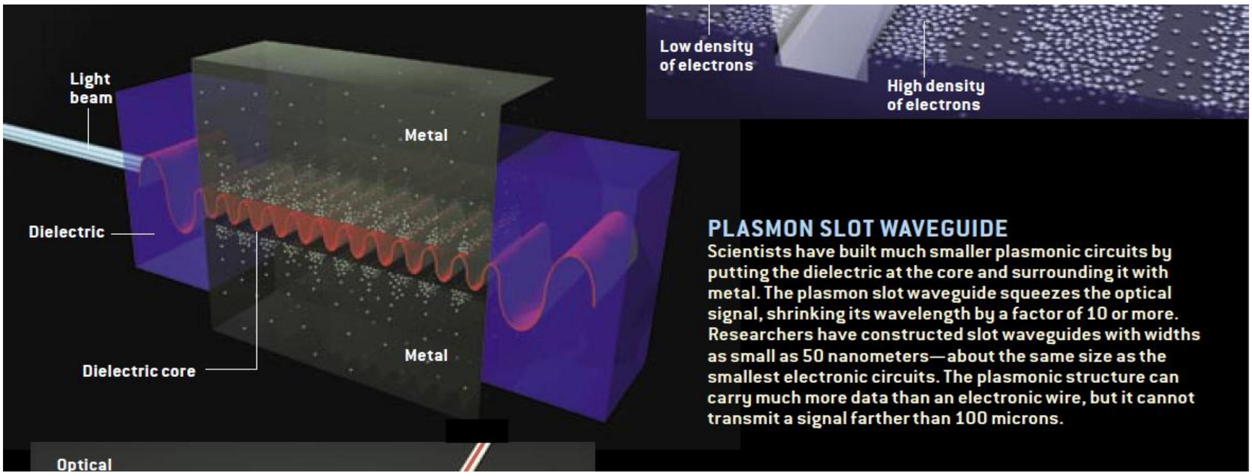
- Usually, it's not practical to use metals to transmit light signals because a lot of the signal is lost. As the electrons oscillate they would collide with the ions in the lattice and dissipate their energy. The plasmon losses are lower at the interface between a thin metal film and a dielectric because the electromagnetic field spreads into the nonconductive material, where there are no free electrons to oscillate, and hence no energy dissipating collisions.

- This property naturally confines plasmons to the metallic surface next to the dielectric; in a sandwich with dielectric and metal layers, for example, the surface plasmons propagate only in the thin plane at the interface.

- One such structure that has been made to transmit these light signals consists of silica core, the dielectric, surrounded by a thin layer of gold. This reduces absorption losses as there are fewer metal ions for the electron waves to collide with.

- Plasmons cannot travel very far, only a few centimetres, but how far they travel can be altered by changing the structure of the nanoshells. If the nanoshell is built in such a way to push a greater proportion of electromagnetic energy away from the metal film then there fewer energy losses.

- The frequency and wavelengths of the plasmons can be adjusted by altering the size and thickness of the metal film, thereby changing the wavelength at which the electrons oscillate at resonance. A device called a plasmon slot waveguide can change the wavelength of the plasmons by adjusting the thickness of the dielectric core.



- The plasmon slot waveguides squeeze the optical signal, and can reduce its wavelength by a factor of 10 or more, but the frequency remains the same.
- Small plasmonic devices with arrays of narrow dielectric strips could guide the waves of positive and negative charge on a metal surface. This would be similar to an alternating current along a wire. However, since the frequency of an optical signal is so much higher than that of an electric one, the plasmonic circuit could carry a lot more data.
- Electrical charge doesn't travel from one end to another, the electrons bunch together and spread apart rather than streaming in a single direction – the device is not subject to effects of resistance!

Use in the Medical world

Varying the size of the particle and the thickness of the metal film will change the wavelength at which the particle (nanoshell) resonantly absorbs energy.

Using this, it's thought plasmonic effects could be used to destroy cancerous tumours. Doctors would inject nanoshells into the blood stream. Since cancerous cells have a greater blood flow towards them, these nanoshells would be delivered to the tumour and embed themselves within it. Human and animal tissues are transparent to radiation at certain infrared wavelengths, and this would be safer than using the high energy X-rays and gamma rays. If this near infra-red light is pointed at the cancerous area, it would travel through the skin and induce resonant electron oscillations in the nanoshells, heating and killing tumour cells. When researchers performed this experiment on mice, experimenters found that the resonant absorption of energy in the embedded nanoshells raised the temperature of the cancerous tissues from about 37 degrees Celsius to about 45 degrees C. The photothermal heating killed the cancer cells while leaving the surrounding healthy tissue unharmed. In the mice treated with nanoshells, all signs of cancer disappeared within 10 days.

Invisibility

Exciting a plasmonic structure with radiation that is close to the structure's resonant frequency can make its refractive index equal to air. Therefore it would neither bend nor reflect light, the light would just pass straight through. The structure however would absorb light, but if it were laminated with a material that amplified the light, the increase in intensity would offset the absorption losses and you would be invisible in a selected range of frequencies. An invisibility cloak would need to work for all frequencies of light.

In 2006, John B. Pendry of Imperial College (BOO HISS BOO) and his colleagues showed that a shell of Metamaterials could reroute the electromagnetic waves travelling through it, diverting them around a spherical region. Metamaterials can have a negative refractive index, bending light in the opposite direction for particular frequency ranges of light.

This technique can only be used to "hide" very small objects - microscopically small objects - and usually the effect would only work with objects of a very specific shape and with light of a particular wavelength. Since the effect would only work when the wavelength of the light being scattered is similar to the size of the object being shielded, it would not work for objects the size of people or space ships unless the wavelength of radiation used to "see" with was very large.

Light is made up of an electric and magnetic field oscillating perpendicular to each other. So technically electricity and magnetism can be used to control how it propagates within an object, but atoms only interact weakly with magnetic fields oscillating over at over 500THz.