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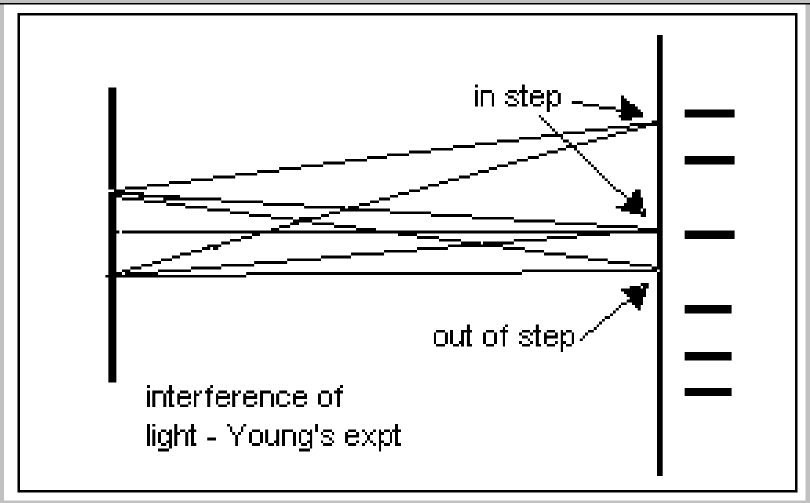
Looking back to go straight ahead

Going back in time can be useful in the here and now, says S.Ananthanarayanan.

Scientists in Central Florida have created a dream of many scientists, a beam of light that goes straight on, without spreading or dispersing. And the method they used is to work back from the image of a point source of light, which ends up a bit spread out, even when the camera lens is ‘perfect’.

The Airy Pattern

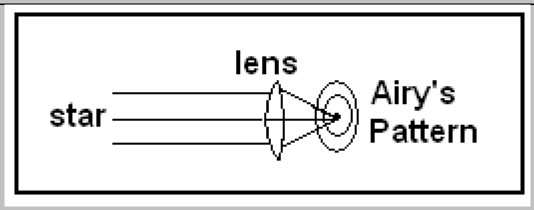
Going back in time a little, at the time of Newton, light was considered to move in straight lines and cast sharp shadows – like a stream of machine gun bullets, or ***corpuscles***, to use Newton’s word. The work of Grimaldi (1665), who had observed even before Newton’s time that shadows were not always sharp, was followed up by Thomas Young, who showed (1803) that light moved not in particles, but as a wave.



Young showed this by letting the light that came through two closely spaced slits to fall on a screen. Light from either slit uniformly illuminated the screen, but when both were open, a pattern of dark and light lines was formed. The only way to understand this is to consider light from each slit as a wave, so that they form a bright line where they reach the screen ‘in phase’, like waves that add up at the seaside. And where the reach ‘out of phase’ they cancel and produce a dark band.

The wave theory of light was a great success and on this was built the great structures of optics and the electromagnetic theory – with electrical engineering and wireless and all else.

But based on the wave theory, a British astronomer called George Biddel Airy showed that optics was never geometrical and the image of even a minute source of light, like a distant star, could not be focused to a point by a telescope of finite dimensions. The image would always be a set of concentric circles, formed because of interference of light waves. The bright spot in the centre is the Airy Disc and the circles are the Airy Pattern.



Quantum Theory

But light was also seen to display behaviour that did not follow from the wave theory. The way the heat from a warm object radiated – most of the radiant energy was at a ‘middle’ frequency and less at greater or lesser frequencies - could not be explained with waves. Nor also a phenomenon called the ‘photo-electric’ effect, where light produced electric currents when it fell on some materials. But both these could be readily explained by the quantum, theory, which proposed that the energy of a system increased not smoothly but in steps, called quanta. And light was nothing but quanta of energy, the amount of energy depending on the colour, or wavelength of the light.

Quantum theory goes further, to treat a material object as a ‘packet’ of waves of different frequencies, bunched together, to represent the position and speed of the particle. This ‘duality’, of a particle being in fact a wave creature, and a wave behaving like a particle whose energy depends on the frequency of the wave, lead to elegant parallels in the mathematics that describe both waves and particles which are described by quantum mechanics.

The mathematics of the Airy Pattern, in fact, is closely related to the quantum mechanical treatment of a particle which faces energy barriers (like a golf ball facing an upward slope) in three directions.

Back in time

Some 30 years ago, Michael Berry and Nandor Balazs had suggested a wave form related to Airy wave packets, which could move like a real particle, that is, without spreading, as a wave should. Such a wave packet would also be affected by external forces and change its direction of propagation, like a particle. A suggestion of how such a packet could be generated appeared from the way a point source of light can be rebuilt by passing light through a barrier that is built like the Airy Pattern of the image of the point source. This amounts to retracing the Airy Pattern back to its origin, to create a point source.

The Central Florida scientists went about creating the packet in a similar way, by shining light through an array of liquid-crystal droplets that can present paths of varying length to the boundary of the light waves falling in. The wavefront is then moulded in such a way that parts of it would interfere if it moved in any way but straight and narrow. This amounts to creating a particle using waves, according to a solution of the mathematics that is able to describe how the particle behaves.

The success in creating waves of light that will not spread out has tempting applications in technology. For communciation, for instance, such a beam of light can be used without boosting over very large distances. Such beams would also be useful to manipulate bilogical specimes and nano-particles without the need to allow for wave effects of using conventional light beams.