The "Double Slit" Experiment

Background

It seems to be a little-known fact that the original, historic "Double Slit" experiment, demonstrating that light can be diffracted, and proving that light has wave properties, was not done with a double slit at all. The way the experiment was first done is simpler. It is easy to reproduce for classroom demonstration, and, more importantly, the central piece of equipment is easier for students to visualize than the more traditional slits scratched in a carbon deposit on a glass slide.

"The experiments I am about to relate ... may be repeated with great ease, whenever the sun shines, and without any other apparatus than is at hand to every one."

This is how Thomas Young speaking on November 24, 1803, to the Royal Society of London, began his description of the historic experiment. His audience, an august gathering of notables in science, was steeped in Isaac Newton's belief that light is made of tiny bullet-like particles, because it is always observed (or so Newton thought) to travel in straight beams, in contrast to the ripple-spreading behaviour which Christian Huygens had linked with wave motion.

"...It will not be denied by the most prejudiced," Young chided his sceptical listeners, "that the fringes [which are observed] are produced by the interference of two portions of light."

His talk was published in the following year's *Philosophical Transactions*, and was destined to become a classic, still reprinted and read today, giving in sparkling language the decisive evidence which first clearly demonstrated that light has the properties of waves.

A historic moment

This first light interference experiment used a method which in principle achieved the same result as the double slit, which, historically came only later. It is indeed as simple in design as Young claimed, so simple that it can be easily reproduced in the classroom, using a diffraction element which every student can make and whose dimensions are easily seen and measured.

Perhaps its greatest attraction is that it's the "real thing". It is the way it was first done.

As a classroom experiment or demonstration, it is an authentic re-creation of that great moment in history when a simple and clear experiment suddenly made it no longer possible to deny that light acted as a wave. Young's talk to the

Royal Society is so crisp and pointed, and yet so charming in its style, so human in its appeal to those who were not eager to accept the new view, that it makes good out-loud reading to accompany the demonstration.

The experiment

Here is how it was done: A narrow beam of sunlight was split with what Young described as "a slip of card, about one thirtieth of an inch in breadth (thickness)." The slip of card was held edgewise into the sunbeam, which was made to enter the room horizontally by means of a "looking glass" (mirror) and a tiny hole in a "window shutter". The sunbeam had a diameter slightly greater than the thickness of the card. When the card was placed properly it split the beam into two slivers, one passing on each side of the slip of card (Fig. 1).

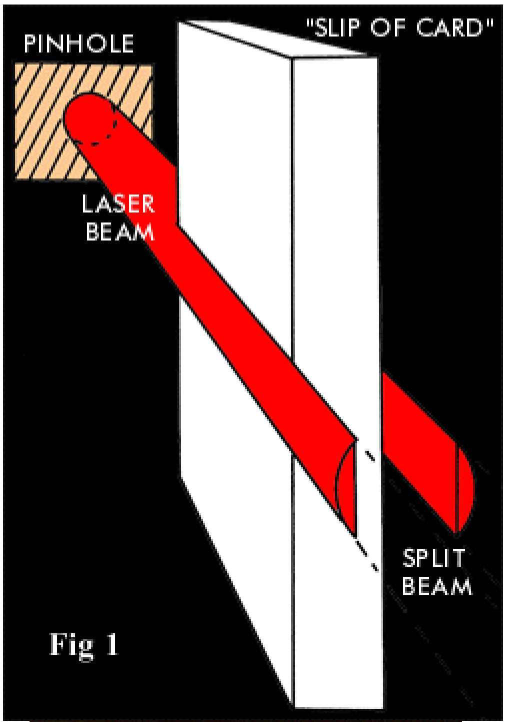


Fig 1

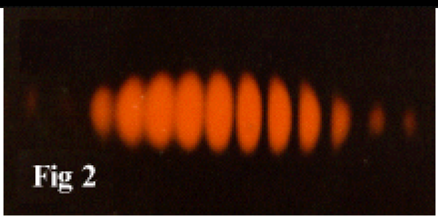


Fig 2

While the arrangement with the pinhole and the mirror is not impossible to reproduce, most teachers will not wish to be so dependent upon sunshine. Furthermore, if teaching above the first floor, a teacher may not easily be able to place an assistant outside the window to keep the "looking glass" properly adjusted! Using a room-length projection distance, it is quite easy to produce a pattern with clearly defined interference fringes, with measurable fringe separation (Fig 2), using an inexpensive demonstration helium-neon laser such as the 5mW model shown in Fig 3.

Equipment

Laser light is used primarily for its small divergence angle, though for teaching purposes it is also an advantage to use monochromatic light to avoid the complication of the colour dispersion until the basic principles are understood. The split beams are projected on a screen in a darkened classroom from an arrangement quite like the classic one described in 1803 by Young, with the exception of the laser. A small strip of an ordinary 3x5 card about 2mm wide and long enough to be mounted edgewise to the front of a 35mm slide frame, is placed

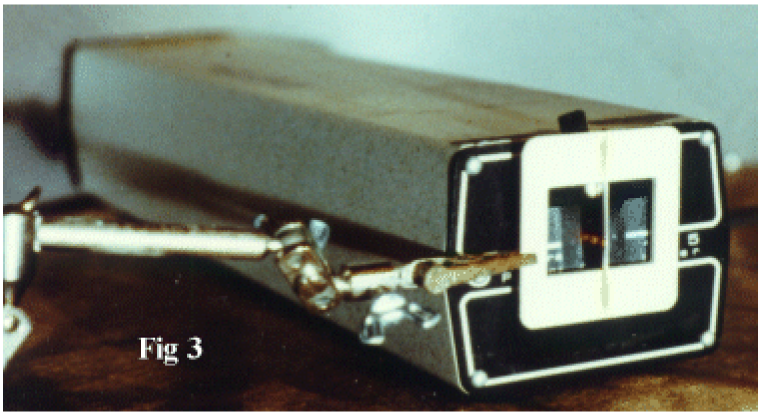
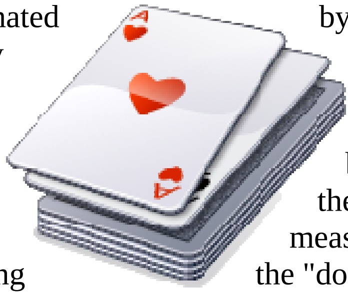


Fig 3

directly in front of the laser beam, held by some movable support such as the "third hand" alligator clip shown in Fig. 3, or a sliding block of wood to which the slide frame is glued. The thickness of a 3x5 card is approximately .0.2cm, which is somewhat thinner than Young's "slip of card," and will therefore produce a diffraction pattern with wider spacing than that which Young described, making it more clearly visible to students.
To control the beam diameter so that it is just slightly greater than the card thickness, it is usually necessary to pass the laser beam through a pinhole in a piece of black paper or tape mounted over the opening of the laser. An ordinary needle will usually make a pin hole of the proper diameter.
Correct placement of the card so it splits the beam is usually not difficult. A little twisting and sliding to insure that the card is edgewise to the beam and cuts it down the middle, is all it takes.
The experiment can be used not only to demonstrate the fact of interference, but to obtain an approximate value of the wave length of the light used. This value can then be compared to its book value (633nm for a HeNe laser).

Measurements

All the critical measurements can be made by students without special equipment. The thickness of the "slip of card" can be estimated by measuring the thickness of a package of 100 cards, and dividing by 100.



A student can be asked to measure the distance between fringes on the screen. The diffraction angle (in radians) between adjacent fringes is the ratio between the fringe separation on the projection screen and the distance from the laser to the screen, which another student can measure with a meter stick. The wave length is then obtained by solving the "double slit", or grating equation. The sine of the diffraction angle is equal to the ratio of the wave length to the slit separation. The "slit separation" in this case is approximately equal to the card thickness. Such a calculation typically produces a result within 10% of the book value of the laser wave length.
Students find this a fascinating deduction, considering the formidable challenge involved in measuring "anything" as small as a few hundred nanometres and as abstract as a light wave