# Bringing one of the great moments of science to the classroom

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# Notes

# Bringing One of the Great Moments of Science to the Classroom

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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 everyone."

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 behavior which Christian Huygens had linked with wave motion.

> "...It will not be denied by the most prejudiced," Young chided his skeptical listeners, "that the fringes (which are observed) are produced by the interference of the two portions of light."

His talk was published in the following year's *Philosophical Transactions*[1], and was destined to become a classic, still reprinted[2] and read today, giving in sparkling language the decisive evidence which first clearly demonstrated that light has the properties of waves.

This first light interference experiment used a method that 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 demonstration, it is an authentic recreation 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.

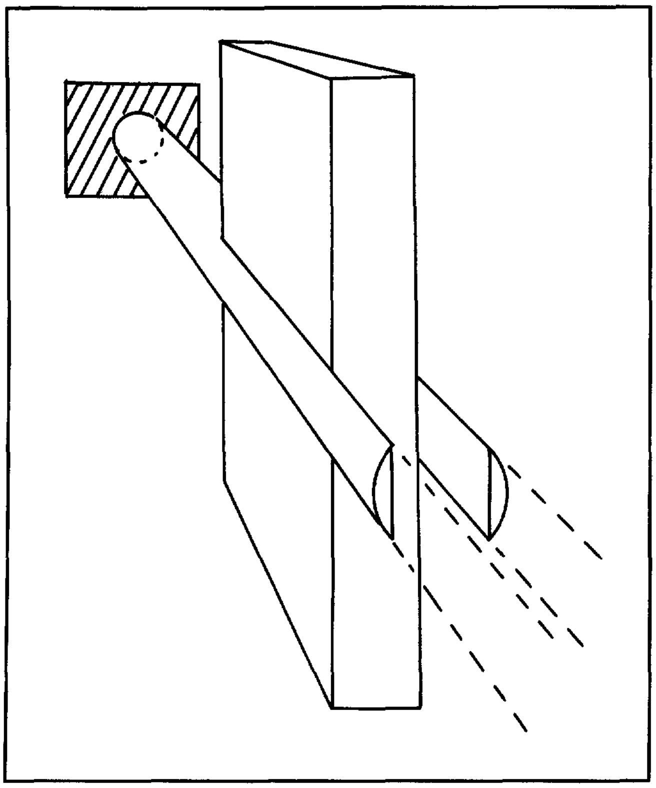

**Fig. 1.** *Slip of Card Schematic.* **A beam of sunlight (or laser light) from a pinhole is split by a "slip of card" placed edgewise into the beam. The resulting two sources are like those from a double slit. They interfere with each other and produce a pattern such as that shown in Fig. 3, produced using a HeNe laser source. If the source is white light, as in the sunbeam used by Thomas Young, the interference fringes will show rainbow color separation.**

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).

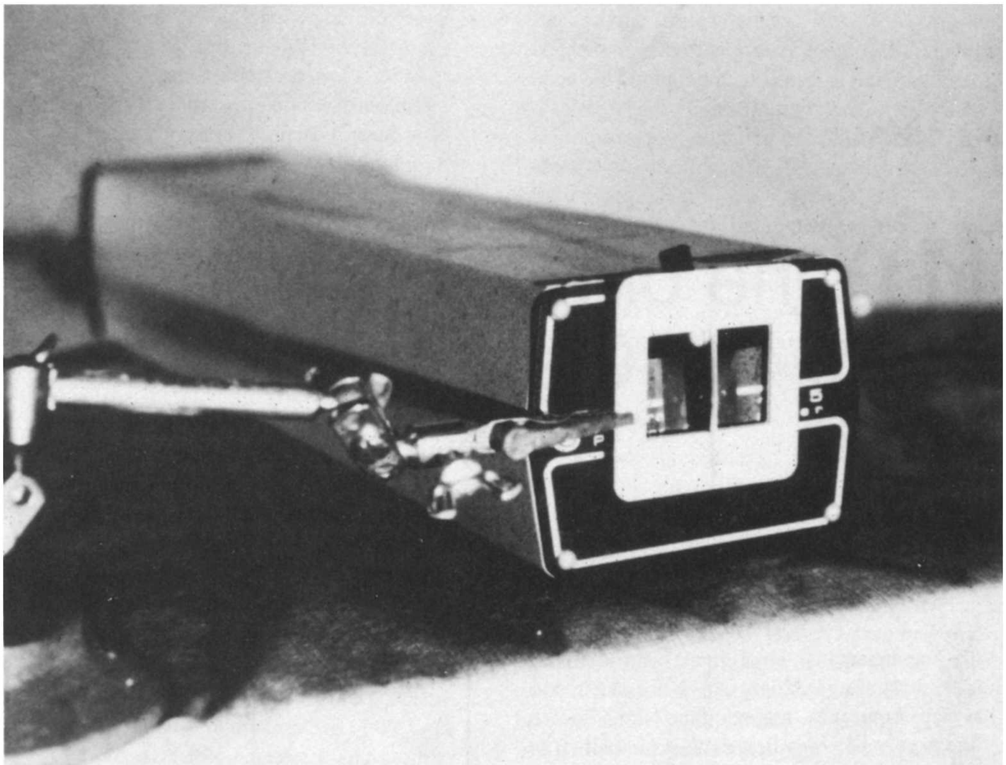

**Fig. 2.** *Slip of Card Apparatus.* **A slip of 3 x 5 card mounted edgewise on a 35 mm slide frame and held in front of a 0.5 mW HeNe demonstration laser produces the interference pattern shown in Fig. 3.**

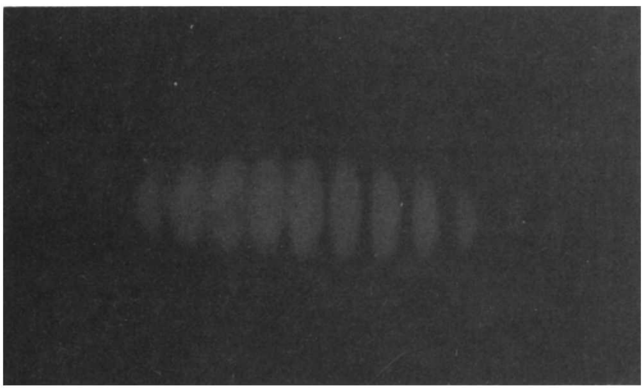

**Fig. 3.** *Evidence for the Wave Nature of Light.* **Interference pattern projected by the apparatus of Fig. 2 on a screen. A beam of 633 nm light (from a HeNe laser) split by a typical card 0.02 cm thick, projected onto a screen 5 m from the source, produces fringes about 1.5 cm apart and clearly visible from all parts of a darkened classroom.**

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 (and if teaching above the first floor, it may not be easy to place an assistant outside the window to keep the "looking glass" properly adjusted) and will prefer to produce a modern-day replica of the light source, using an inexpensive 0.5 mW helium-neon laser such as shown in Fig. 2. Laser light is used primarily for its small divergence angle, though for teaching purposes, using monochromatic light avoids the complication of color dispersion until the basic principles are understood.

The interference fringes (Fig. 3) 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 3 x 5 card, about 2 mm wide and long enough to be mounted edgewise to the front of a 35 mm slide frame, is placed directly in front of the laser beam, held by some movable support such as the "third hand" alligator clip shown in Fig. 2, or a sliding block of wood to which the slide frame is glued.

The thickness of a 3 x 5 card is approximately 0.02 cm, 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 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 aperture of the laser. An ordinary needle will usually make a pinhole 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 interference, but also to obtain an approximate value for the wavelength of the light used. This value can then be compared to 633 nm, the wavelength for a HeNe laser.

All the critical measurements can be made by students without using 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 wavelength can then be obtained by solving the "double slit," or grating equation. The sine of the diffraction angle is equal to the ratio of the wavelength 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 laser wavelength.

Students find this a fascinating deduction, considering the formidable challenge involved in measuring *anything* as small as a few hundred nanometers and as abstract as a light wave. □

## References


1. Thomas Young, "Experimental Demonstration of the General Law of the Interference of Light," *Philosophical Transactions of the Royal Society of London*, vol. 94 (1804).
2. The Young article (Ref. 1) is reprinted in Morris Shamos, ed., *Great Experiments in Physics* (Holt Reinhart and Winston, New York 1959) pp. 96-101.