2004

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Recommended Citation

"Wire Diffraction Gratings", The Physics Teacher, 42, 76-77 (2004)

AAPT PHYSICS EDUCATION | The Physics Teacher

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Citation: The Physics Teacher **42**, 76 (2004); doi: 10.1119/1.1646480
View online: http://dx.doi.org/10.1119/1.1646480
View Table of Contents: http://scitation.aip.org/content/aapt/journal/tpt/42/2?ver=pdfcov
Published by the American Association of Physics Teachers

Wire Diffraction Gratings

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In the summer of 1972, I attended the workshop on recreating classic experiments in physics at Barnard College.[1] This was developed by Samuel Devons, and it was a defining experience that set me toward a research career involving early physics teaching apparatus. During the course of the workshop, I became curious about the original diffraction gratings developed by Fraunhofer and built a wire diffraction. A short note about the gratings was published in the *American Journal of Physics* the next year.[2]

The grating was made by cutting a shallow helical groove with 80 turns per inch on a 1/4-in diameter brass rod. Other gratings had 56 and 72 turns per inch. This was easily enough done, in principle, using a standard metal-cutting lathe with a calibrated lead screw. The cut was made in a single pass using a freshly sharpened bit with a V-contour. Side pieces were silver-soldered onto the ends of the turned rods, and lengths of #42 copper wire were stretched from one rod to the others, passing over the threads to get the regular spacing, and epoxied into place. The threaded rods were about 2 in apart and had 24 wires.

Recently I realized that small-diameter bolts could be used in place of the machined brass rods and laid in a stock of half-inch bolts and nuts with 56, 72, 80, and 90 threads per inch.[3] Since I did not want to do any soldering with these minute objects, I made side plates from aluminum and used three nuts on each bolt to hold the bolts in place, as shown in Fig. 1. This grating has 80 wires per inch, and is strung with #40 bare copper wire.

Another grating that I made and tested had strands of #43 bare copper wire stretched between the two

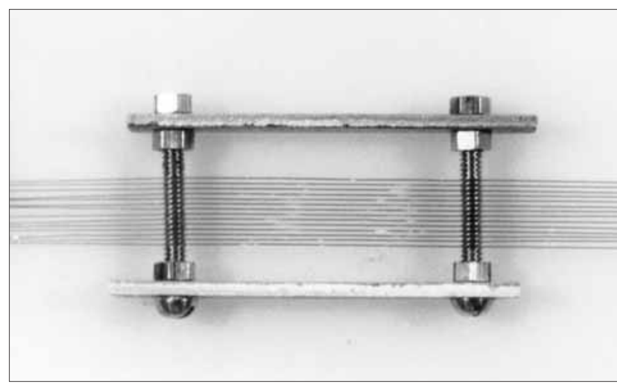

Fig. 1. The 2003 wire diffraction grating using brass bolts with 80 threads per inch.

bolts. In this example, there are 72 threads per inch, giving a grating space of 0.0353 cm. To string the wires across the blank, they were placed on a smooth, flat surface and secured with dabs of hot glue. One end of a wire was held down with a tab of masking tape, the wire was stretched over grooves in the bolts, and the other end was held with more masking tape. A line of epoxy was run over the threads to hold the wires in place. When the grating in Fig. 1 was started, I did not notice that the first wire was not quite perpendicular to the screws, but the reduction in the grating space is much smaller than any subsequent random error in measuring the diffraction angles for the various maxima.

The wire grating that I made in 1972 was tested by using it in a spectrometer. The sodium D-lines (0.6 nm apart) could be resolved, and about 15 maxima could be seen on either side of the central maximum. Since then, I have used the grating only in

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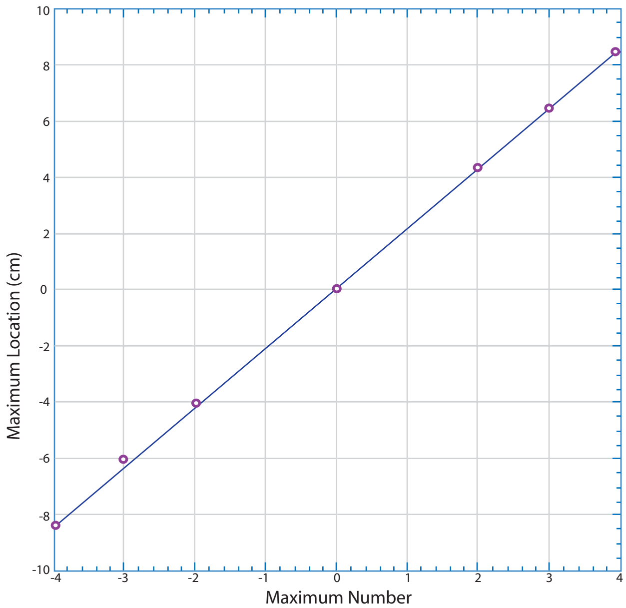

Fig. 2. A graph of maximum location as a function of maximum number for a grating with 72 wires per inch.

lecture demonstrations in which the beam from a He-Ne laser was passed through it and the interference dots on the distant lecture room wall observed.

This time I tested the grating by placing it in front of a He-Ne laser with λ = 632.8 nm. At a distance of 1146 ± 5 cm, the maxima were 2.12 ± 0.03 cm apart; this number was obtained by plotting the position of seven dots as a function of the dot number, and finding the slope and its uncertainty. The typical graph in Fig. 2 is missing the n = ± 1 data points; they were obscured by the direct beam of the laser, which had a rather larger divergence than I would have liked. However, the human eye is pretty good at locating the centers of blobs of light a couple of centimeters across, as the 1.5% uncertainty in the slope shows. The small-angle approximation is clearly applicable here, and the grating equation becomes $\lambda = d\theta$, where d is the grating spacing and θ is the angular separation of two adjacent maxima. The calculated wavelength of the laser light was 649 ± 6 nm, making the (probably unwarranted) assumption that there was no error in the stated pitch of the threads.

The first person to use this method was the Philadelphia instrument maker David Rittenhouse. His 1785 device used 50 hairs stretched between two fine screws. Since the apparatus was only a half-inch square, he used at least 100 slits per inch, giving a grating space no larger than 0.025 cm. About 1820 Joseph von Fraunhofer (1787–1826) used the same technique but substituted fine metal wires winding them around the screws. Fraunhofer used his wire gratings to measure the wavelengths of the black absorption lines (“Fraunhofer lines”) in the solar spectrum.[4]

References

1. Samuel Devons and Lillian Hartman, “A history-of-physics laboratory,” *Phys. Today* **23**, 44–49 and cover (February 1970).
2. Thomas B. Greenslade Jr., “Wire diffraction gratings,” *Am. J. Phys.* **41**, 730–731 (1973).
3. The nuts and bolts were obtained from Micro-Mark (http://www.micromark.com). The price is about $3.00 for a package of 10 items.
4. George Sweetnam, “Diffraction grating and ruling engine,” in *Instruments of Science*, edited by Robert Bud and Deborah Jean Warner (Garland Publishing, New York, 1998), pp. 171–173.

PACS codes: 01.65, 07.60, 42.10H

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