A Very Low-Cost Assembly for Studying Interference and Diffraction in Remote Laboratories

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Abstract: We present a modular, 3D printed assembly used with a laser pointer for very low-cost (<$10) study of interference and diffraction in introductory physics. The apparatus was designed for at-home laboratories during the COVID-19 pandemic.

1. Introduction

The accommodations required by COVID-19 for the 2020/2021 academic year have made instruction more challenging for both students and instructors. The pandemic has been particularly challenging in science and engineering laboratories where equipment requirements make online/hybrid instruction more difficult and social distancing requirements can introduce challenges for allowing students enough access to the lab to perform experiments. In response to the lock-down beginning in March 2020 we began development work on laboratory exercises that could be done by students at home with a minimal set of equipment assembled from inexpensive materials readily available from general merchandise suppliers (i.e. little or no purchases from specialty science education or science research suppliers). As part of that project we present a very low-cost and simple apparatus that allows students to study interference and diffraction phenomena at home. We have used the apparatus with algebra-based and calculus-based introductory physics students during the Fall 2020/Winter 2021 academic year and find it very promising as a means of allowing flexible instruction (i.e., suitable for both on-campus and remote teaching).

2. The Apparatus& Curriculum Context

The apparatus, shown in Fig. 1 parts a and b, consists of a 3-D printed holder and a set of optical inserts. The holder accommodates a laser pointer such that when the laser pointer slides into the retaining ring the power button is held depressed, allowing continuous operation. The ring provides a relatively tight friction fit, which holds the laser in place (though it can be rotated for a small degree of alignment adjustment). We use a commonly available generic/unbranded laser pointer which produces a 650 nm rectangular spot with less than 1 mW of output power. This Class 2 laser, along with clear, detailed safety instructions allows for safe performance of the experiments without laser safety eyewear [1]. The inserts allow various targets to be placed in the laser beam so students can observe, record and measure their diffraction/interference patterns with nearly alignment-free ease. The relatively large divergence of the laser pointer ensures the targets are typically properly illuminated upon insertion of the laser. In rare instances when the target is not well-illuminated, rotation of the laser provides sufficient degree of freedom to yield good illumination. We have used two-slit, single-slit and thin wire targets in our laboratory courses. We have also made an empty insert which can be used to mount other targets of interest. While our inserts have low reflectivity, we can imagine wanting to use targets that are reflective (e.g. foils). Our design safely blocks any back-reflections that such targets could produce. We are exploring other targets, including circular apertures, plastic sheet diffraction grating material and half-barriers as well. We have made the kits using both a Prusa i3 MK3S+ kit, which retails of $749 [2], and with a lower-cost Creality Ender 3 printer which retails for $160 [3]. In both cases we used polylactic acid (PLA) filament and both produce good results. The total cost of a kit in filament, wire and laser pointer is ∼$7. We have used this in place of our usual set of He-Ne lasers on optical rails with slit cards, which cost around $1000, are more difficult to align and can produce uncontained back-reflections.

Typical interference and diffraction patterns for single slit, double slit and thin wire are shown in Fig. 1 parts c-e. The quality of the diffraction patterns is clearly sufficient for introductory laboratory measurements. The design parameters for the targets and sample measured values for targets are shown in Table 1. Predictably, there was considerable variance in student-measured values, but students were able to obtain similar results. The 3-D

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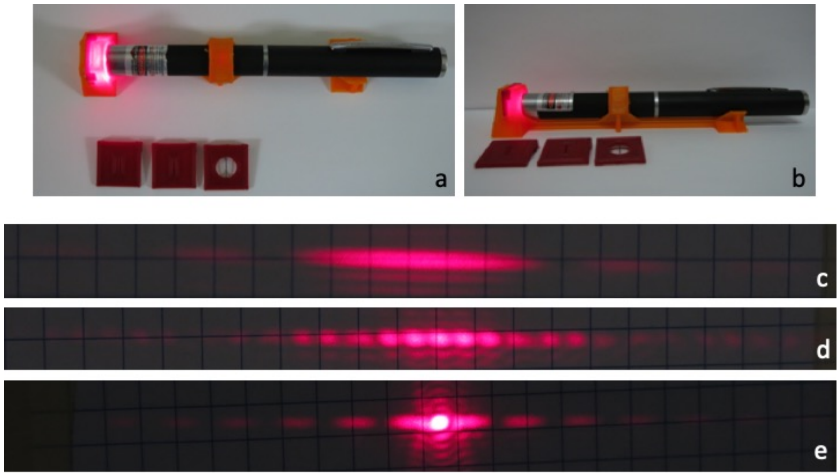

Fig. 1. The apparatus is shown in a (top view) and b (side view). The observed interference and diffraction patterns for a single slit (c), double slit (d) and thin wire (e) are shown as observed at a distance of 6 meters on quarter-inch quad-ruled paper.

printing resolution is limited to about 0.1 mm, and introduces a higher degree of variances in the slit-width as compared to purchasing high-precision slits. While the measured quantities may not agree with design parameters to within measurement error (due to limitations in printer accuracy), from a pedagogical perspective this can be viewed a feature. A class of students may now be able to resolve and measure the distribution variances for the target parameters. This could lead naturally to discussions of manufacturing tolerances and how to improve them. 3-D resin printers may be an option for higher resolution and accuracy, though at higher cost.

Table 1. Design parameters & measured parameters for the single slit, double slit and wire thin wire.

	Design		Measured	
	Width (mm)	Separation (mm)	Width (mm)	Separation (mm)
Single Slit	0.3	-	0.16±0.02	-
Double Slit	0.2	0.8	0.10±0.01	0.90±0.1
Thin Wire	0.37	-	0.37±0.04	-

The apparatus was used within a pedagogical structure in which students were given a written document explaining the physical concepts, experimental procedure and data analysis procedures via the learning management system (LMS) along with instructional videos. The videos provided an audio-visual presentation of the the same information, but further allowed students to see an instructor demonstrate the equipment's use, and verbally explain (with Powerpoint graphics) the theory and data analysis. These were generally made available to the students the week before the experiment was to begin. Students were required to complete a short 5 question pre-lab quiz via the LMS before the experiment. The students had been provided the equipment at the beginning of the semester and they had the option of performing the experiment on-campus in the lab or at home. While the majority of students chose to complete their lab at home we did observe a small, but consistent portion of students who came in to perform experiments each week. Students were asked to return their kits at after the semester and the vast majority did so and in working order, thus the kit is not disposable, further improving the economic value.

3. Conclusions

In conclusion we have presented a very-low cost apparatus for students to study interference and diffraction using 3-D printed components and a laser pointer. The ∼$7 assembly is two orders of magnitude cheaper than traditional apparatus commonly used, yields good optical results, and can be used by students at home.

References

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