The Digital Holography Demonstration: A table-top setup for STEM-based outreach events

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ABSTRACT

The SPIE Student Chapter at the Air Force Institute of Technology (AFIT) is spearheading a new outreach project to encourage science, technology, engineering, and mathematics (STEM) in grades K-12. This new outreach project is referred to as the Digital Holography Demonstration (DHD). Using a table-top setup, the DHD estimates the both the amplitude and phase of the complex-optical field, and in so doing, illustrates several fundamental optics and photonics principles including diffraction, refraction, and the interference of light. These fundamental optics and photonics principles have direct ties to current technologies being developed in the medical, astronomy, and defense communities (to name a few). This paper celebrates the resourcefulness of the DHD for STEM-based outreach events and provides a parts list, cost breakdown, and brochures, so that future efforts can benefit from its design.

Keywords: digital holography, spatial heterodyne, STEM, outreach, SPIE student chapter, optics and photonics, SPIE Optics Outreach Games, physics education

1. INTRODUCTION

The DoD's investment in optics and photonics has led to significant advances in remote sensing, astronomy, industrial processing, and medical technology. To celebrate this rich heritage and promote public awareness in science, technology, engineering, and mathematics (STEM), the SPIE Student Chapter at the Air Force Institute of Technology (AFIT) participates in a wide range of outreach efforts. Most of these outreach efforts involve interactive demonstrations of electromagnetics, thermodynamics, and optics. With this in mind, the laser propagation demonstration (LPD) was the cornerstone for these outreach efforts[1], and the LPD is the result of a 2010 SPIE LaserFest Grant and a 2012 SPIE Outreach Grant.

After more than 5 years of continual use (in its current form), the LPD needed new parts; thus, we decided to change its design. As shown in Fig. 1, the resultant Digital Holography Demonstration, or DHD for short, leverages existing parts from the LPD to create a new table-top setup—one that is appropriate for a wide-range of audiences. This setup is the result of a 2018 SPIE Outreach Grant that we proudly debuted at the 2018 SPIE Optics Outreach Games in San Diego, CA.

In what follows, Section 2 of this paper provides an overview of the DHD. Here, the reader gets to see background material in the form of a brochure that will accompany the DHD in future outreach events. Section 3 then provides an overview of DHD's design and refers to a parts/price list located in the Appendix of this paper. Using this parts/price list, the interested reader can build their very own DHD! Section 4 provides a conclusion for this paper with a roadmap for future upgrades that are currently in the mix.

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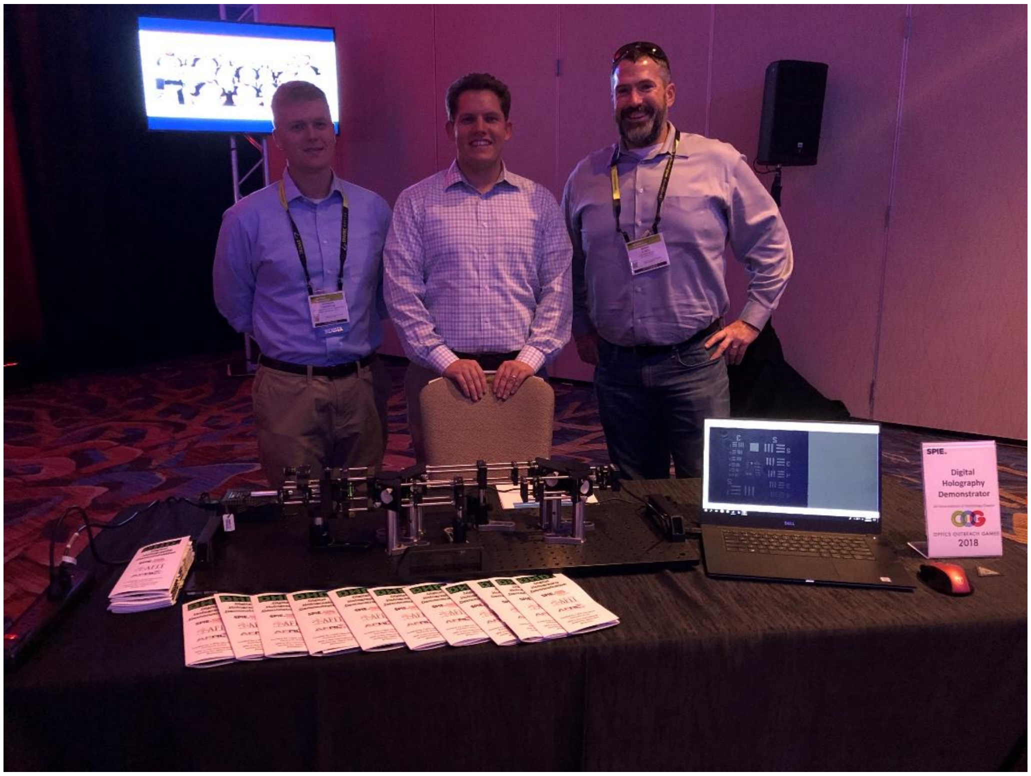


Figure 1. The DHD being debuted at the 2018 SPIE Optics Outreach Games in San Diego, CA.

2. OVERVIEW OF THE DHD

As shown in Figs. 2 and 3, illustrative brochures help the audience members to follow along with the overall demonstration. As a result, it is also our belief that the DHD is appropriate for a wide-range of audiences from our participation in many and varied outreach efforts with the LPD. For instance, sometimes you have 30 seconds to engage a passerby (given a booth-based expo) and sometimes you have the whole day to setup numerous lessons (given a classroom endeavor). The DHD is appropriate for all audiences, and it gives the AFIT SPIE Student Chapter the flexibility it needs to participate in a wide range of STEM-based outreach efforts.

To increase optics and photonics awareness to our target audience, the DHD will become the cornerstone of our chapter's outreach efforts. The goal is to use the DHD to give audience members a basic understanding of fundamental optics and photonics principles. For example, people who have less than perfect vision contain phase aberrations in their eye. When a person undergoes laser-eye surgery, the aberrations are first measured and then corrected by reshaping the cornea to improve vision. By connecting the principles illustrated by the DHD to more commonly known applications, optics and photonics becomes more relatable to audience members.

The majority the AFIT SPIE Student Chapter's outreach efforts include audience members which consist of young students (K-12) in the local community. Additionally, many of the students have not been exposed or are under exposed to optics and photonics. The DHD will enable our chapter to increase our demonstration capabilities to connect with these students. Since we always strive to have a strong impact with students, we also aim to motivate students to become the next generation of scientists and engineers and use optics and photonics to make significant advances in STEM.

Moving forward the DHD will be showcased at our chapter's many and varied outreach efforts with special attention given to SPIE (which made it all possible). Furthermore, the illustrative brochures (cf. Figs. 2 and 3) denote the special consideration received from our 2018 SPIE Outreach Grant. We planned to have the DHD completed by the 2018 SPIE Optics + Photonics Conference, so that we could showcase it in the 2018 SPIE Optics Outreach Games and present in Optics Education and Outreach V—accomplishments that we are now proud to showcase in this paper.

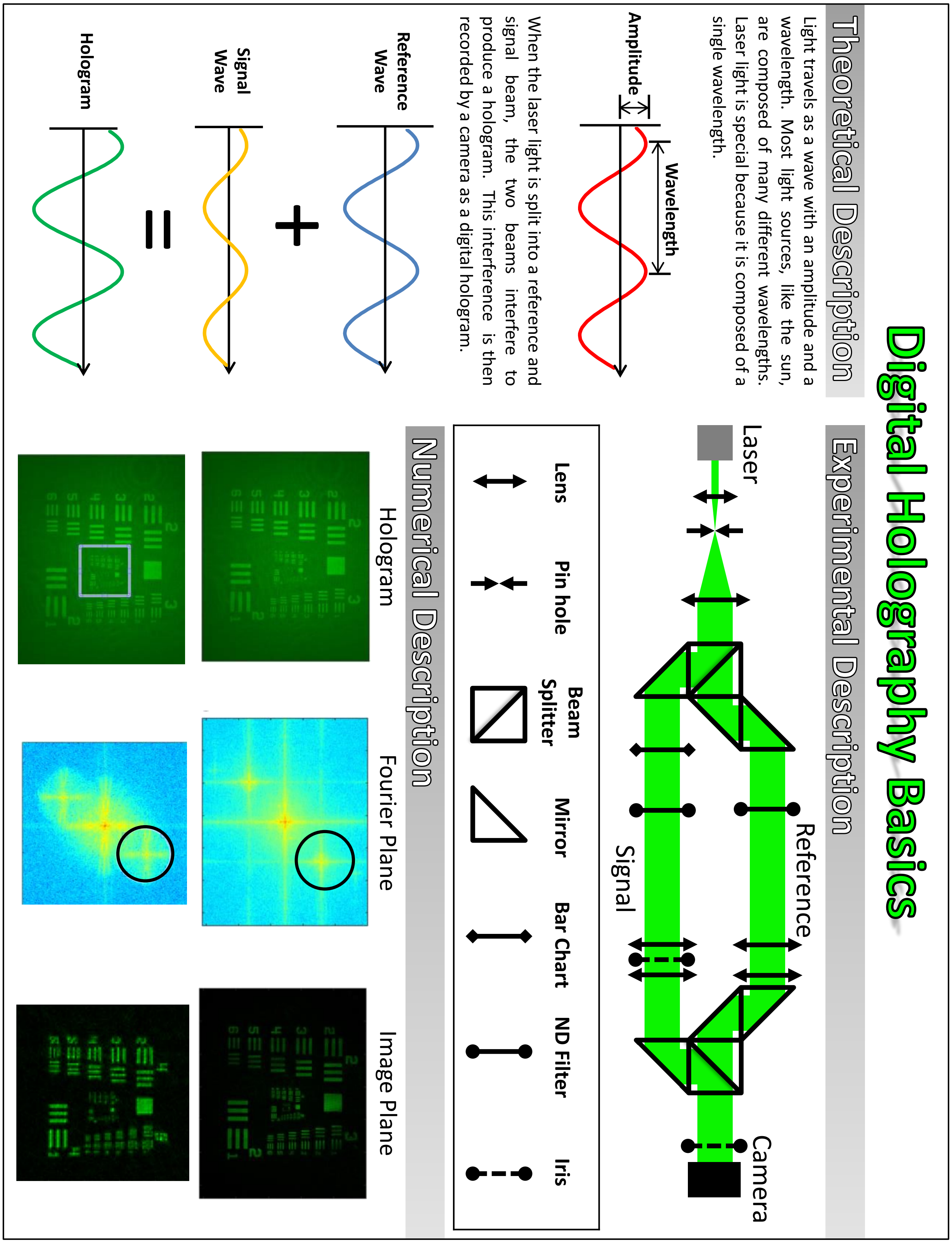


Figure 2. The handout associated with the DHD. This side gives theoretical, experimental, and numerical explanations.

Figure 3. The handout associated with the DHD. This side introduces applications.

3. OVERVIEW OF THE DHD'S DESIGN

The DHD uses an eye-safe, battery-powered visible laser diode with a 532 nm wavelength to create a reference beam and signal beam. As shown in Fig. 4, the signal beam travels through an object mask (and potentially a phase aberration) before being interfered with the tilted reference beam onto a camera. We then process the resultant digital hologram on a laptop to gain access to an estimate of the complex-optical field[2] (i.e., both the amplitude and phase), as shown in Fig. 5.

Provided the complex-optical field, we aim to display the following three things on the laptop screen (and a larger screen if available): 1) a degraded image of the object mask (implemented), 2) the phase aberration that degrades the image of the object mask (implemented), and 3) a corrected image of the object mask via digital-signal processing referred to as aberration correction (future work). In so doing, the DHD illustrates three main teaching objectives. The first objective is to demonstrate the wave and particle nature of light. The interference between the signal and reference beams is only possible due to the wave nature of light and the resultant digital hologram is only possible due to the particle nature of light. A second objective is to make it clear that we can only measure the power per unit area or irradiance of the complex-optical field with the camera. This outcome is the result of the optical oscillations being too frequent to measure the complex-optical field directly. In response, we can gain access to an estimate of the complex-optical field through the interference light and digital-signal processing. The third objective is that aberration correction[3-5] is possible because of digital-signal processing and has led to significant advances in remote sensing, astronomy, industrial processing, and medical technology. From these three main teaching objectives, it is our belief that audience members will walk away from the overall demonstration with a basic understanding of fundamental optics and photonics principles.

The Appendix to this paper contains the parts list needed to build the DHD. For us, these parts complemented the previously procured parts for the LPD[1], which saved us approximately $1500 in overall costs. Based on this parts list, we asked for and received $3900 from our 2018 SPIE Outreach Grant. These funds, in addition to our yearly chapter budget, enabled the AFIT SPIE Student Chapter to outright own the parts needed for the DHD. In turn, we will have dedicated access to the DHD for our future outreach events. The reader should note that we will also use our yearly chapter budget to support extraneous costs, such as food and beverage costs and brochure-printing costs.

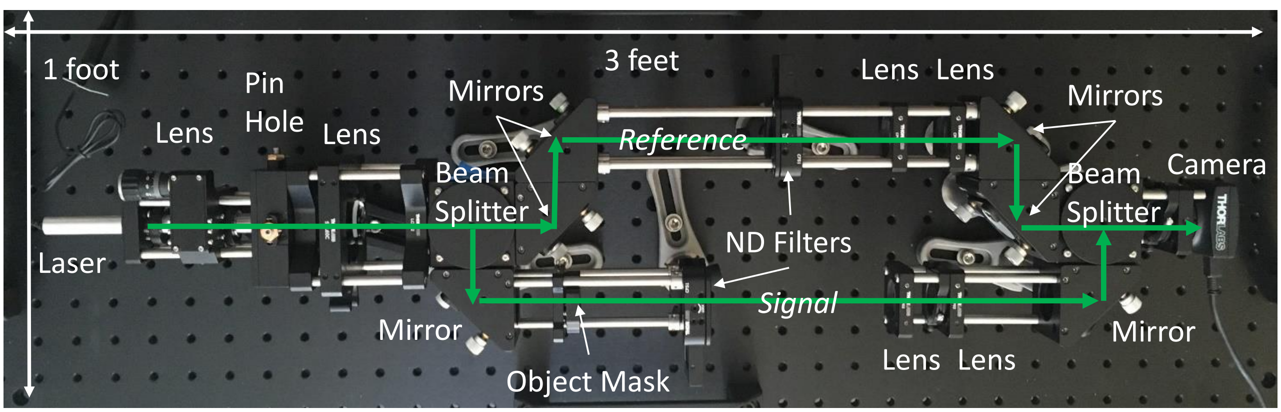
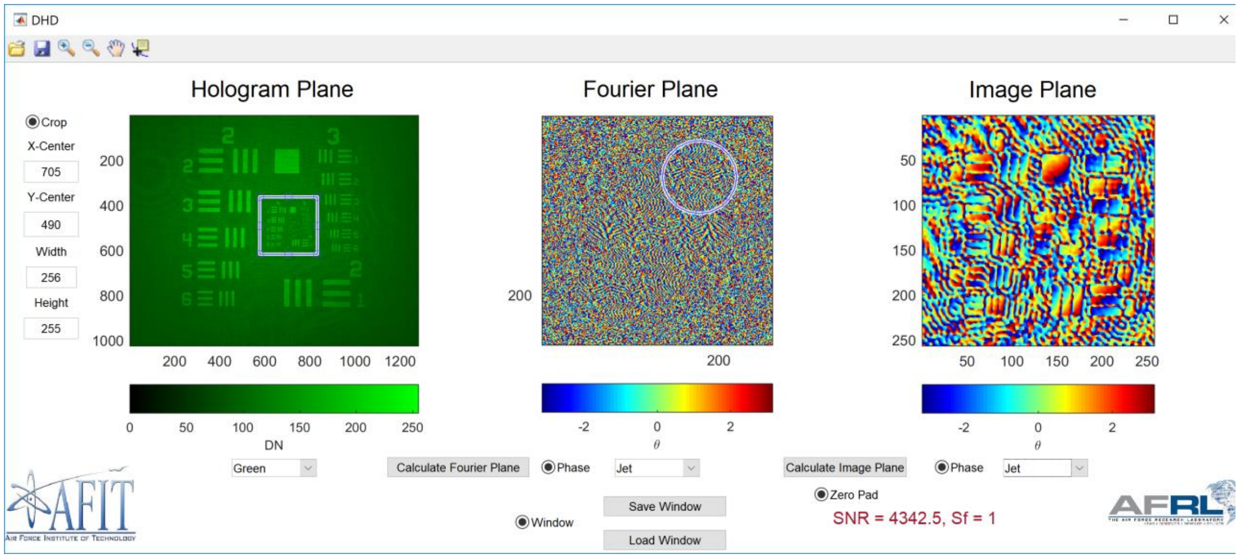
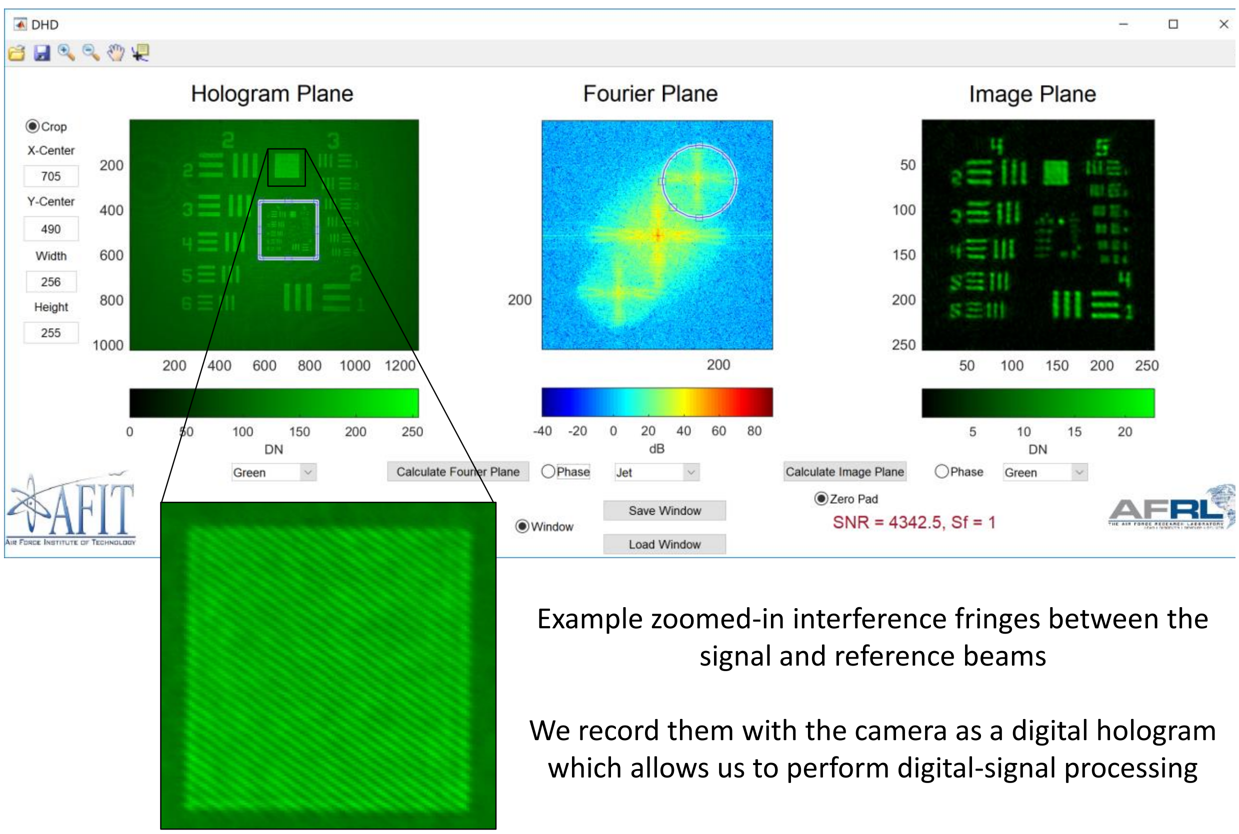


Figure 4. Description of the DHD. A parts/price is given in the Appendix.



(a)



(b)

Figure 5. A detailed look at the processed a.) phase and b.) amplitude in the image plane given a specified region of interest (blue square) in the hologram plane. The reader should note that the appropriate term is windowed in the Fourier plane (blue circle) to obtain these results.

4. CONCLUSION

This paper reviews the recent completion of the DHD—AFIT's new outreach effort in optics and photonics. It is our hope that the interested reader can improve our design and share it with the STEM-based outreach community. The SPIE Student Chapter at AFIT plans to continually upgrade the DHD as well. In the near future, we plan to implement the ability to perform aberration correction using additional digital-signal processing.

The views expressed in this paper are those of the authors and do not reflect the official policy or position of the U.S. Air Force, Department of Defense, or the U.S. government.

APPENDIX

Table 1 below gives a parts/price list for the DHD design shown in Fig. 4.

Table 1. Parts/price list for the DHD.

Part Number	Item	Product URL	Qty	Price	Subtotal
	LASER				
CPS532-C2	Collimated Laser Diode Module 532 nm 0.9 mW Round Beam Ø11 mm Housing	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=1487	1	162.18	162.18
KAD11F	SM1-Threaded Kinematic Pitch/Yaw Adapter for Ø11 mm Cylindrical Components	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=11830	1	65.79	65.79
CPS1	5 VDC Battery Pack for CPS Laser Diodes 10 000 mAh	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=8861	1	35.45	35.45
	SPATIAL FILTER				
MA2	Ø1.5" Post Mounting Adapter 1/4" Clearance / #8 Clearance	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=1308	1	17.54	17.54
SM1A3	Adapter with External SM1 Threads and Internal RMS Threads	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=1524	1	17.44	17.44
SM1Z	Z-Axis Translation Mount 30 mm Cage Compatible	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=188	1	193.8	193.8
ST1XY-A	XY Translator with 100 TPI Drives	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=184	1	342.72	342.72
E09RMS	Extended RMS to M9 x 0.5 Adapter	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=1749	1	33.41	33.41
C260TMD-A	f = 15.29 mm NA = 0.16 Mounted Geltech Aspheric Lens AR: 350-700 nm	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=3810	1	80.58	80.58
P5H	Ø1" Mounted Precision Pinhole 5 ± 1 µm Pinhole Diameter	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=1400	1	74.5	74.5
	COLLIMATING LENS				
SCL60C	60 mm Cage-Compatible Self-Centering Lens Mount Ø0.15" (Ø3.8 mm) to Ø1.77" (Ø45.0 mm) 8-32 Tap	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=8220	1	198.9	198.9
LBF254-040-A	Ø25.4, F=40.0, N-BK7, -A Coated, Best Form Lens	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=4874&pn=LBF254-040-A#8086	1	53.81	53.81
	IMAGING LENSES				
CP02	SM1-Threaded 30 mm Cage Plate 0.35" Thick 2 Retaining Rings 8-32 Tap	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=2273	6	16.4	98.4
LBF254-200-A	N-BK7 Best Form Lens Ø1" f = 200 mm ARC: 350-700 nm	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=4874	4	53.81	215.24
	MIRRORS				
BB1-E02	Ø1" Broadband Dielectric Mirror 400 - 750 nm	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=139	6	75.1	450.6
KCB1	Right-Angle Kinematic Mirror Mount with Tapped Cage Rod Holes 30 mm Cage System and SM1 Compatible 8-32 and 1/4"-20 Mounting Holes	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=6813	2	143	286
KCB1C	Right-Angle Kinematic Mirror Mount with Smooth Cage Rod Bores 30 mm Cage System and SM1 Compatible 8-32 and 1/4"-20 Mounting Holes	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=6813	4	143	572
	BEAM SPLITTERS				
B1C	Blank Cover Plate	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=6858	2	18.77	37.54
B3C	Fixed Cage Cube Platform for C4W/C6W	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=6852	2	24.89	49.78
C4W	30 mm Cage Cube	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=3929	2	60.44	120.88
FFM1	30-mm-Cage-Compatible Rectangular Filter Mount	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=6850	2	58.4	116.8
BSW4R-532	25x36mm 50:50 532LASERLINE NON-POL. PLATEBEAMSPLITTER	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=11471&pn=BSW4R-532#11483	2	300	600
	TARGET				
CP90F	30 mm Removable Cage Plate Front and Back Plate Internal SM1 Threading	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=3773	1	49.98	49.98
R1DS1N	Negative 1951 USAF Test Target Ø1"	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=4338	1	130.56	130.56
SM1A39	Adapter with External C-Mount Threads and External SM1 Threads	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=1524	1	19.99	19.99
	CAMERA				
DCC1545M	USB 2.0 CMOS Camera 1280 x 1024 Monochrome Sensor	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=4024	1	365.65	365.65
	BREADBOARD				
MB1236	14049-001 Rev E Breadboard	https://www.thorlabs.com/thorproduct.cfm?partnumber=MB1236	1	326.4	326.4
BBH1	Breadboard Lifting Handles (set of 2)	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=2806&pn=BBH1#2806	2	14.89	29.78
RDF1	Rubber Dampening Feet (set of 4)	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=1867&pn=RDF1#5749	1	5.25	5.25
	CAGE ASSEMBLY				
ER1.5-P4	Cage Assembly Rod 1.5" Long Ø6 mm 4 Pack	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=4125	1	22.22	22.22
ER1-P4	Cage Assembly Rod 1" Long Ø6 mm 4 Pack	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=4125	1	19.19	19.19
ER2-P4	Cage Assembly Rod 2" Long Ø6 mm 4 Pack	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=4125	1	23.18	23.18
ER3-P4	Cage Assembly Rod 3" Long Ø6 mm 4 Pack	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=4125	2	25.08	50.16
ER4-P4	Cage Assembly Rod 4" Long Ø6 mm 4 Pack	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=4125	3	26.98	80.94
LCP02	30 mm to 60 mm Cage Plate Adapter 8-32 Tap	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=3021	2	39.78	79.56
ER025	Cage Assembly Rod 1/4" Long Ø6 mm	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=4125	24	5.05	121.2
	POSTS				
RS2	Ø1" Pillar Post 1/4"-20 Taps L = 2" 8-32 Adapter Included	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=241	1	22.44	22.44
PF175	Clamping Fork for Ø1.5" Pedestal Post or Post Pedestal Base Adapter Universal	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=887	1	18.26	18.26
RSH2	Ø1" Post Holder with Flexure Lock Pedestal Base L = 2"	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=6204	1	31.37	31.37
TR3-P5	Ø1/2" Optical Post SS 8-32 Setscrew 1/4"-20 Tap L = 3" 5 Pack	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=1266	1	24.39	24.39
CF125C	Clamping Fork 1.24" Counterbored Slot 1/4"-20 Captive Screw	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=887	1	11.02	11.02
PH3-P5	Ø1/2" Post Holder Spring-Loaded Hex-Locking Thumbscrew L = 3" 5 Pack	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=1268	1	41.35	41.35
CF125C-P5	Clamping Fork 1.24" Counterbored Slot 1/4"-20 Captive Screw 5 Pack	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=887	2	52.46	104.92
RS3.5P	Ø1" Pedestal Pillar Post 1/4"-20 Taps L = 3.5"	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=851	6	32.9	197.4
BE1-P5	Ø1.25" Studded Pedestal Base Adapter 1/4"-20 Thread 5 Pack	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=887	1	47.43	47.43
	OTHER				
CP20S	30 mm Cage System Iris Ø20.0 mm Maximum Aperture	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=8376	2	88.49	176.98
CFS1ND	Sliding Filter Mount Bundle with Two CFS1-F1 Inserts and Four ND Filters 8-32 Tap	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=10262	2	275.4	550.8
	TOOLS				
SPW301	Spanner Wrench for an M9 x 0.5 Optics Housing Length = 1"	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=1430	1	14.3	14.3
CPA1	30 mm Cage System Alignment Plate with Ø1 mm Hole	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=7296	1	12.75	12.75
CPA2	30 mm Cage System Alignment Plate with Ø5 mm Hole	https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=7296	1	12.75	12.75
				TOTAL:	6413.58

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