# “Keep-It-Simple Setups” (KISS) for Teaching Holography in the Simplest Way

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**ABSTRACT**

Thanks to the article “Simple Holography” (Jeong, T. H, Ro, and Iwasaki, M. SPIE Vol. 3956, pp. 241-244 (2000) Editors: S. Benton, S. H. Stevensen, T.J. Trout.), many teachers and students of holography know that one can make a reflection hologram with little more than just an inexpensive diode laser, a holographic plate and a chemical processing kit. What may be less familiar to students is how minor tweaks to the same setup, mostly without introducing any additional lab equipment or optics, can be used to make transmission holograms, multi-channel holograms, “omnigrams”, interferometric holograms, and even H1/H2 “floating” holograms and diffraction gratings. This paper presents six simple and cost-effective hologram setups for learning beginner- to intermediate-level holography in the classroom or home. The methods introduced are primarily based on unpublished and published articles the late educator Dr. Tung H. Jeong (or “TJ”) and this author Alec Jeong prepared together between 2003 and 2015 to foster holography in education and inspire a new generation of young holographers.

**Keywords:** teaching holography, making holograms, reflection, transmission, interferometry, multi-channel

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## 1. INTRODUCTION

In their article “Simple Holography”[1] published by the SPIE in 2000, authors Dr. Tung H. Jeong, Raymond Ro, and Masashi Iwasaki describe making a single-beam Denisyuk hologram using little more than a diode laser, a holographic plate, and an object. Contact-copy is advocated and no beam spreaders, mirrors or other optics are used.

Between the publishing of “Simple Holography” and the passing Dr. Tung H. Jeong in 2015, this author Alec Jeong collaborated with Dr. Tung H. Jeong to author educational materials to help first-time holography students discover the wonders of holography. The result is a collection of notes and articles, some published online (at www.integraf.com) and many unpublished. [2.3.4.5.6.7.8.9.10]

Among those articles are basic tutorials on how to make six types of holograms. By taking the simple setup introduced in “Simple Holography” as the foundation and then making minor tweaks to that setup or process, the tutorials present the simplest way for students to learn the basics for making a transmission hologram, an omnigram (which simultaneously combines a reflection and transmission hologram), a multi-channel hologram, an interferometric hologram, and even a “floating” H1/H2 hologram and a diffraction grating.

This paper summarizes the simple setups used for each of those different holograms.

## 2. “SIMPLE HOLOGRAPHY” REFLECTION HOLOGRAM

It is helpful to begin with a brief overview of the materials, setup and process used in “Simple Holography” before discussing tweaks thereof to accommodate making the other holograms.

In “Simple Holography”, the authors use Slavich PFG-01 holographic plates and the JD-2 developer. In a follow up article[11], the authors, in collaboration with Jeff Bythe and Riley Aumiller, advocate the use of Slavich PFG-03M holographic plates and JD-4 developer kit (also known as the “JARB” processing formula, an acronym for Jeong, Aumiller, Ro and Blythe).

A key part of their setup is the Integraf Holography Diode Laser, a 650nm diode laser, with an output of 4mW when operated by 3.0 volts DC, a coherence length exceeding 1 meter, and an adjustable collimating lens. By adjusting the lens, the student can spread or narrow the beam without use of any additional beam spreaders or optics. For making a single-beam Denisyuk hologram, the lens of the laser is removed altogether, thus naturally spreading the laser beam to expose the holographic plate and object with unhindered laser light.

As for the setup itself, items are positioned in the following order: object > holographic plate > laser. The object is placed directly behind and touching the holographic plate. The distance between the plate and the laser is approximately 30 to 40 cm, just enough for the laser beam to spread and cover the holographic plate. Exposure time is as short as 5 seconds, but further experimentation reveals that a 12-15 second exposure works better.

To help reduce vibration, a computer mousepad can be placed underneath the object. Alternatively, a tray of salt or sand will also work.

To make the exposure, the authors advocate placing the object, holographic plate, and laser on the same horizontal plane for a "straight-on" exposure.

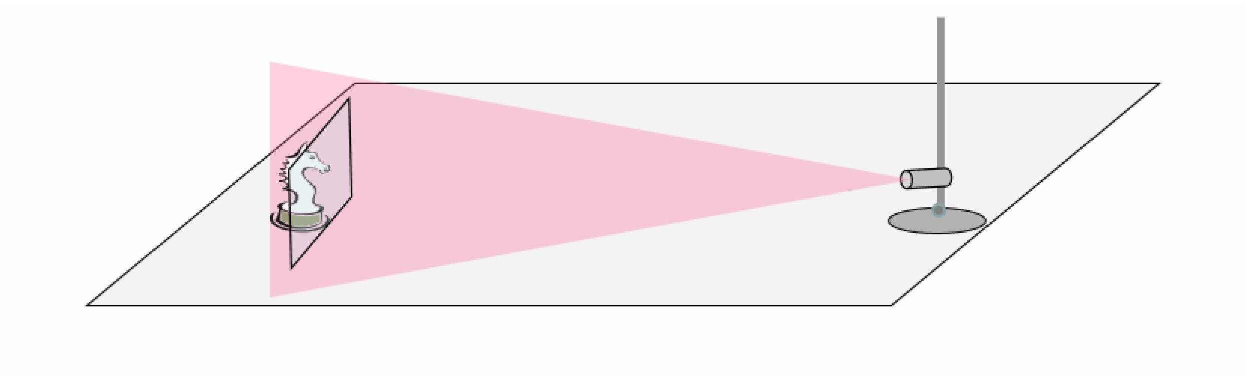

Figure 1. "Straight-on" exposure with the object, holographic plate and laser on the same horizontal plane.

Alternatively, students can use a "top-down" exposure, where the holographic plate is placed on top of a flat object and then exposed by the spread laser beam from above at a roughly 45° angle. A sturdy flower vase turned upside down or a lab stand can be used to elevate and position the laser.

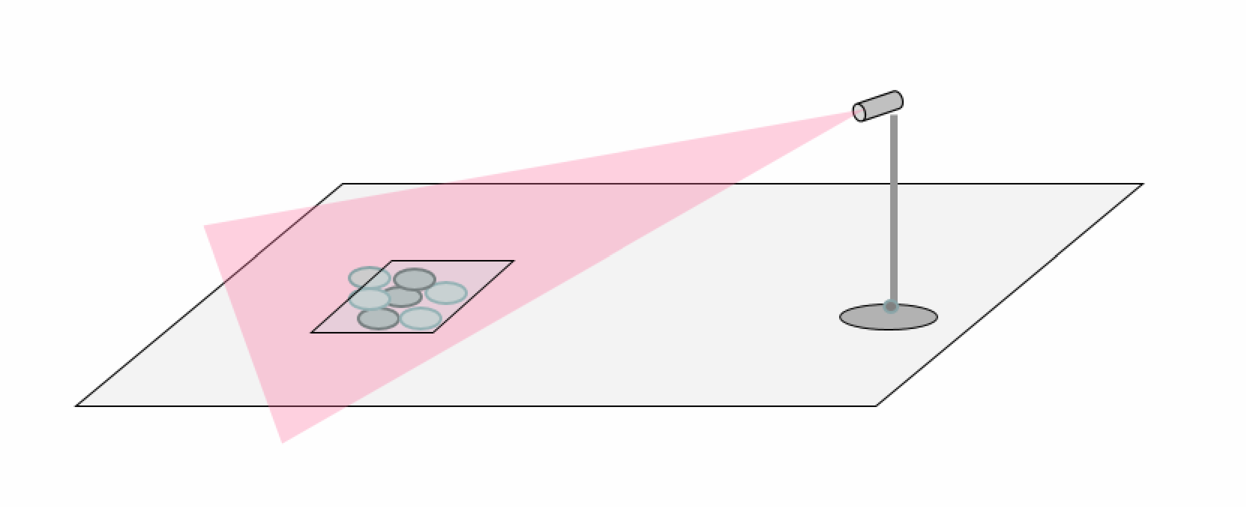

Figure 2. "Top-down" exposure with the laser light spread from above at a roughly 45° angle.

The straight-on exposure is well suited for objects that are bulky. The top-down method is ideal for flat objects, such as a collection of coins or jewelry. The top-down has other advantages: Because the holographic plate lies on top of the object, it and remains relatively stable without need for anything to brace it. The top down angle also approximates the Brewster's angle for glass (53°), thus minimizing unwanted reflections caused by the holographic glass plate itself.

After exposure, the holographic plate can be processed in about 5 minutes following the instructions that come with the chemical developer kit.

After drying, students can view the finished hologram with a point source of incandescent light such as that from a projector or flashlight, or sunlight.

## 3. TRANSMISSION HOLOGRAM

A small tweak to the setup for making reflection holograms allows students to easily make transmission holograms. Unlike reflection holograms, where the object is placed behind the plate exposed by laser light, transmission holograms are made with the object is placed in front or slightly to the side of the holographic plate.

The tweaked order is therefore: holographic plate > object > laser.

As in the case for making reflection holograms, a "straight-on" or the "top-down" angle for laser exposure can be used for making transmission holograms.

For straight-on exposure, the object and plate are split apart at about a 90° angle to each other, with the spread laser beam shining at each with equal intensity. Extra care must be given so that the object does not inadvertently cast a shadow on to the holographic plate. Position the object so that some of the laser light hitting the object bounces toward the holographic plate.

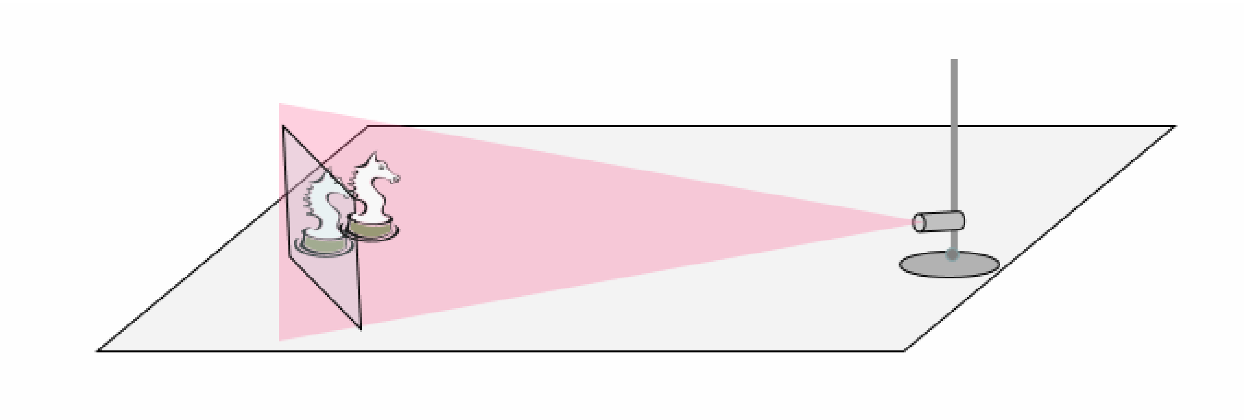

Figure 3. Transmission hologram setup with straight-on exposure.

Top-down exposure is easier to do and has the added benefit of allowing deep scene holograms with visual depth of 6 inches (15cm) or more. With top-down exposure, students can place and expose flat objects, such as a collection of coins, directly in front of the holographic plate without risk of casting shadows. If bulkier objects are still desired, position them along the side as done so with the straight-on method.

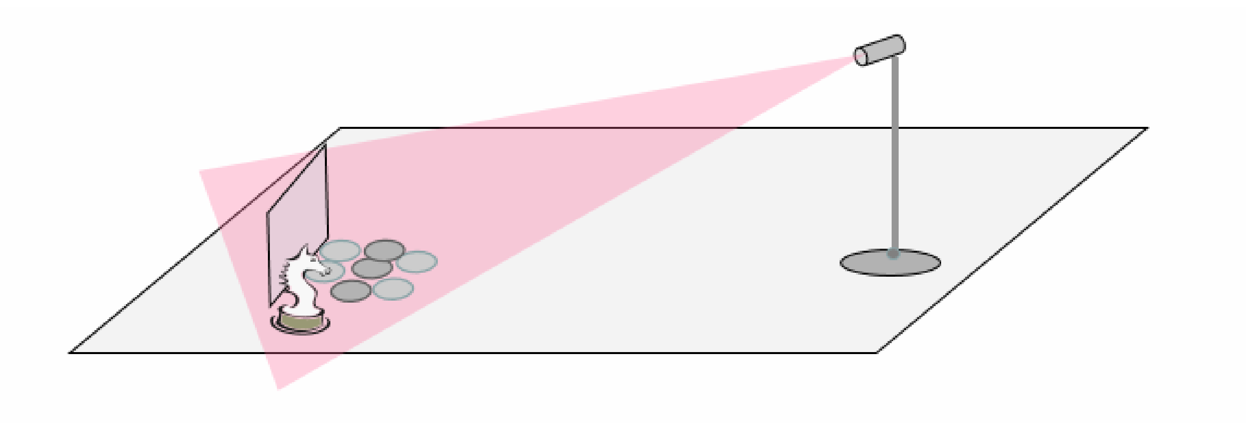

Figure 4. Transmission hologram setup with top-down exposure.

Exposure time is 12-15 seconds for “straight-on” exposure. For “top-down” deep scenes, expose for 30 seconds. Chemical processing follows the same 5-minute regime used for reflection holograms.

Students should view the transmission hologram with laser light. To view the “virtual image”, position the developed hologram at the same location and orientation used during exposure, and then look through the hologram toward the location where the object had been originally placed. To view the hologram’s projected “real image”, replace the collimating lens on to the laser and focus the beam onto small spot far away. Then shine the beam laser through the finished hologram in exactly the reverse direction as to how it had been exposed, and then place a white card at the original location of the object. The projected image will appear on the white card.

## 4. OMNIGRAM

The “omnigram”, introduced by Tung H. Jeong in 2012 at the 9$^{th}$ International Symposium on Display Holography[12], combines a reflection hologram and a transmission hologram recorded at the same time.

It logically follows that the setup for making an omnigram integrates the previously described setups for reflection and transmission holograms. No additional optics or modifications is required. The only tweak is that two objects, instead of one, are used.

Specifically, one object is placed behind the holographic plate (to produce the reflection hologram image) and a second object in front or to the side of the same holographic plate (to produce the transmission hologram image). A straight-on or top-down laser exposure can be used.

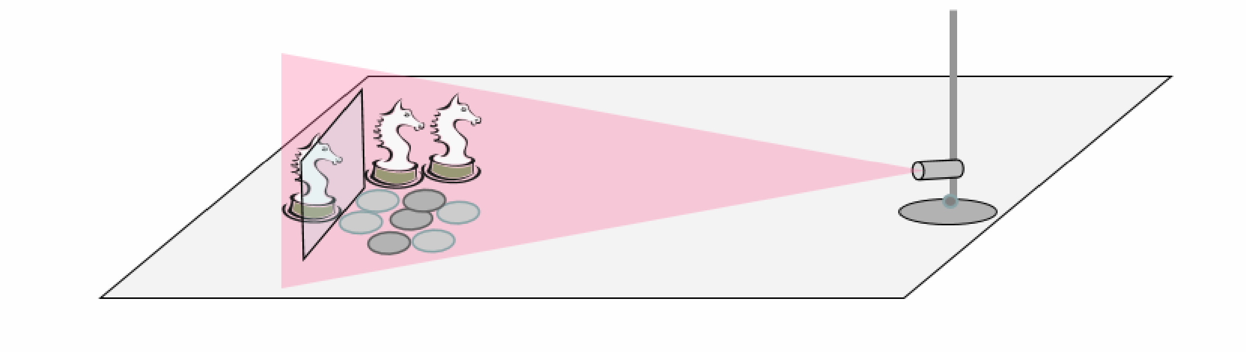

Figure 5. Omnigram hologram setup with straight-on exposure.

  

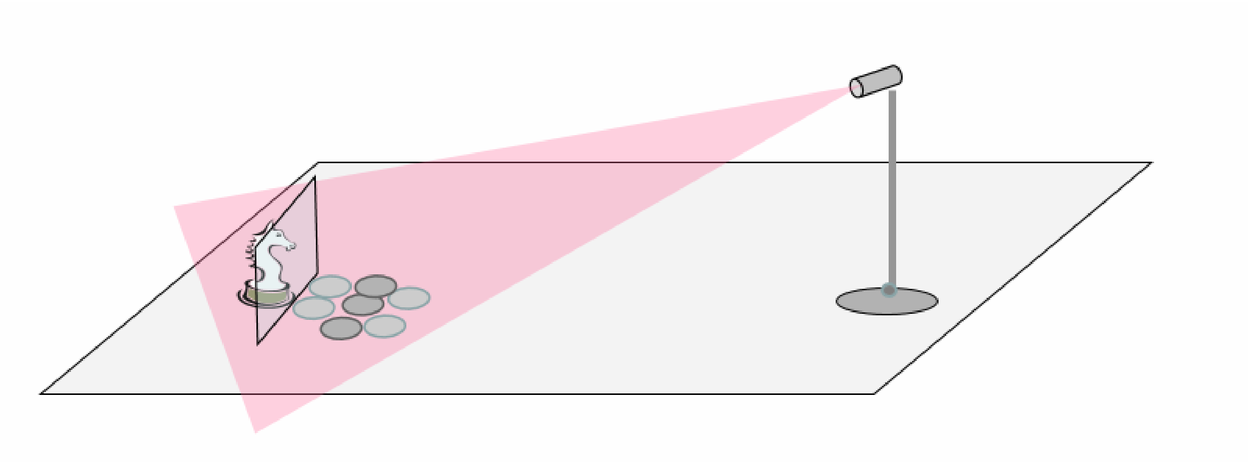

Figure 6. Omnigram hologram setup with top-down exposure

How does one view the omnigram? The reflection hologram can be viewed with white light or with laser light, while the transmission hologram should be viewed with laser light. To illuminate both images at the same time, use laser light.

## 5. MULTI-CHANNEL

It's easy for students to make a multi-channel hologram that displays different images as viewing angle changes. The student can use any of the setups described earlier for the reflection hologram, transmission hologram or even omnigram, and either a straight-on or top-down laser exposure.

The process described below illustrates making a two-channel reflection hologram with top-down exposure, which is the easiest method for first-time holographers.

1. Expose the hologram using only one-half of the usual exposure time (about 6 seconds instead of 12).

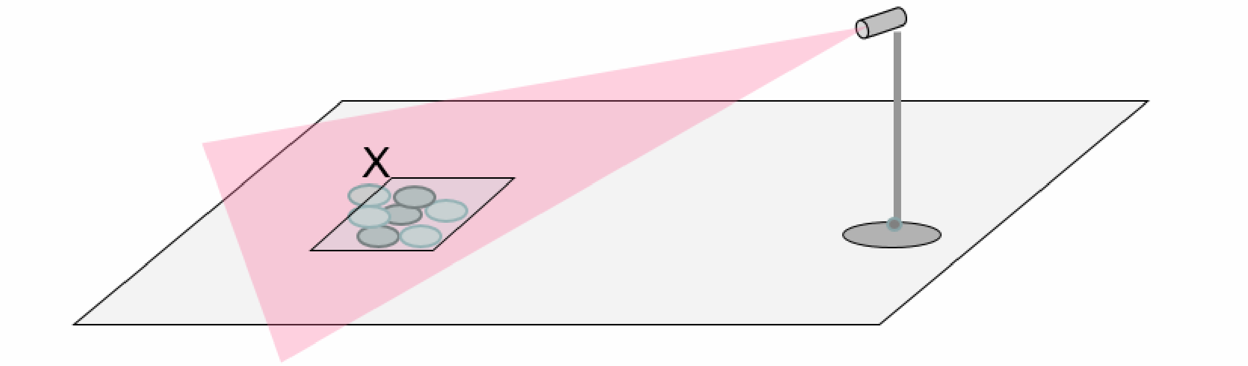


Figure 7. Multi-channel hologram, first exposure. For illustrative purposes only, an "X" is drawn in the diagram help the reader identify the orientation of the plate.

2. Block the hologram and object from laser light.
3. Change the object.
4. Place the holographic plate back on top of the new object
5. Rotate the hologram plate 90°. Let everything settle for 30 seconds.

  

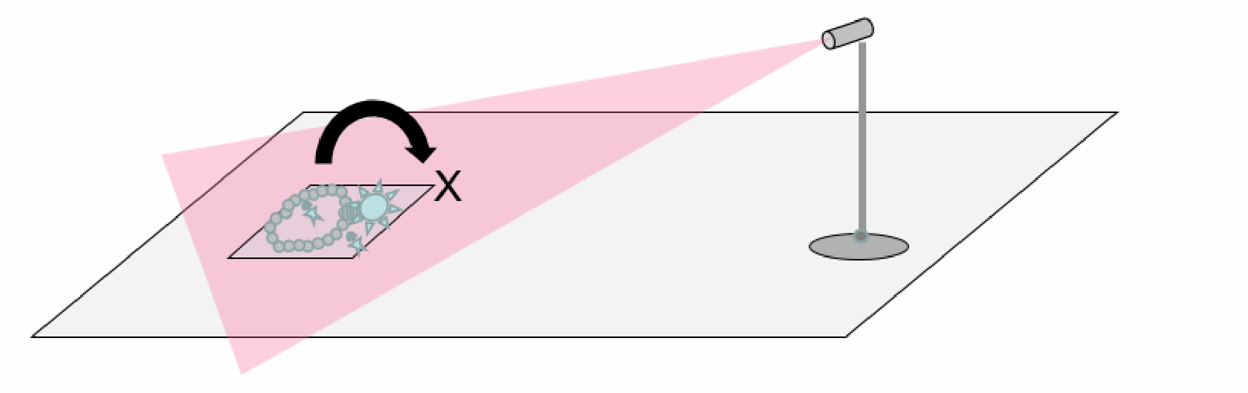


Figure 8. Multi-channel hologram, second exposure with holographic plate rotated 90° and object replaced.

6. Make a second exposure of the same duration as the first exposure (about 6 seconds).
7. Process as usual.

After drying, view the hologram in its first orientation, then rotate it 90 degrees and see the second channel.

## 6. INTERFEROGRAM

An interferometric hologram (or interferogram) allows one to observe and measure small microscopic deformations and changes in an object when stress, strain, or movement is applied to that object. In the real-world, engineers apply interferometry to understand the structural integrity of machinery, automobiles, airplanes, among many other things. In the holography lab, students can simulate such application by using a metal toy car and a light coin (such as a dime) as a weight, as illustrated below.

While there are various ways to make an interferogram, the easiest way is by making two straight-on exposures of the holographic plate and object using the transmission hologram setup. Between the first and second exposure, the object is ever so slightly modified.

1. Place a light weight on top of the object. Wait 30 seconds to let it settle.
2. Expose for one-half the normal exposure time (about 6 seconds).

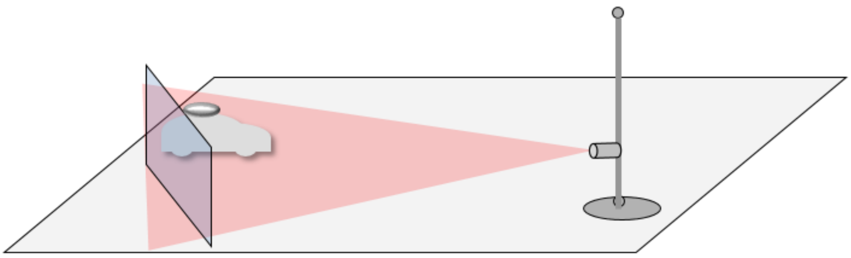

Figure 9. Inteferogram setup for the first exposure with a coin placed on top of a sturdy metal toy car.

1. Block the laser light from reaching the holographic plate by placing a book or opaque board between the laser and the object. Carefully remove the weight from the object with a pair of tweezers so to avoid making any extraneous movement to the object and lab setup.

  

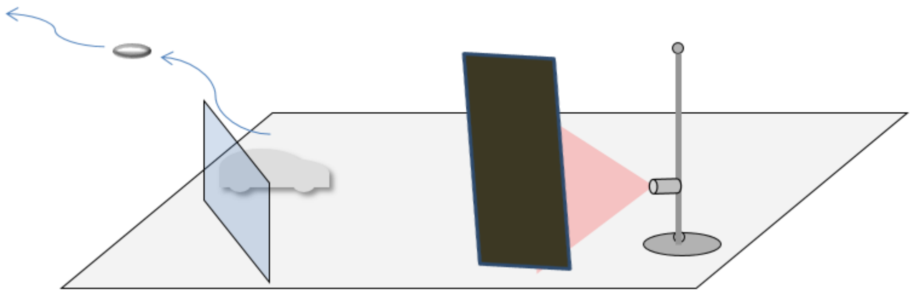

Figure 10. Blocking the laser light and removing the weight off the object.

2. Allow 30 seconds to allow everything to settle
3. Make a second exposure of the same duration (6 seconds).

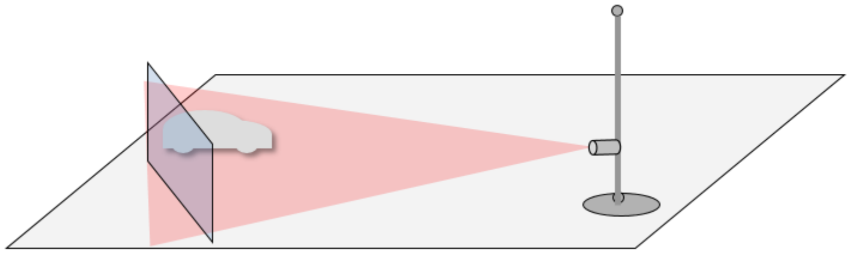

Figure 11. Second exposure without the weigh on the object.

Changes to the object due to the removal of the weight can be observed on the resultant double-exposed hologram by the appearance of dark bands (fringes).

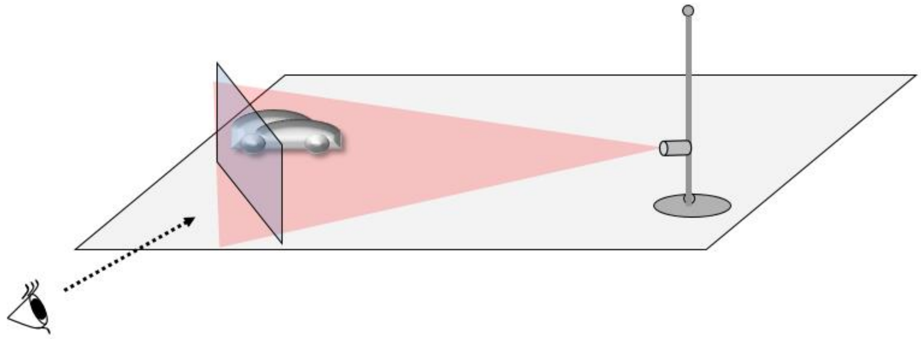

Figure 12. Dark bands (secondary fringes) appear where object had changed.

It’s important to do everything possible to avoid extraneous vibrations and movement, even microscopically. This way, the only physical change captured by the hologram is how much the object transformed when the weight is removed.

First-time holographers will find it easier to make an interferometric transmission hologram than an interferometric reflection hologram. Reflection holograms have finer fringe spacing than transmission holograms do and are thus more sensitive to movement or vibration. Conversely, transmission holograms have wider fringe spacing and are slightly less sensitive to distortions caused by unintended movement.

## 7. “FLOATING” H1/H2 HOLOGRAM

How does one make the hologram image look as if it is floating in front of, instead of behind, the surface of the finished hologram? The answer is by making a hologram of a hologram. Specifically, using the simple holography framework, one makes a transmission hologram (H2) of a holographic image projected from a hologram master (H1).

Making this type of H1/H2 hologram is accomplished using the diode laser, the object, two holographic plates, and a stretched straight-on exposure position.

The Integraf diode laser, assumed in all the previously described setups, has a particularly long coherence length and an adjustable collimating lens, allowing the student to attempt this more advanced hologram with the most basic of setups possible. Notwithstanding, this hologram project takes patience, trial and error and the slightest movement or vibration can nullify the hologram altogether.

Unlike other setups, the exposure is made not from 40cm away but rather 2.5 to 3.0 meters away. Also, one does not remove the collimating lens from the laser to spread the beam but rather simply adjusts it. The goal is to keep the beam as narrow as possible while enough to cover the holographic plate. Maintaining a vibration-free environment is critical to making this hologram.

The basic steps are as follows:

1. Make the original transmission hologram (H1). Expose for about 15 seconds. Then develop and dry as usual.
2. Replace the original object with the developed H1 hologram.
3. Make a second transmission hologram (H2) of the image projected from the original hologram (H1). Expose for about 15 seconds. Then develop and dry as usual.

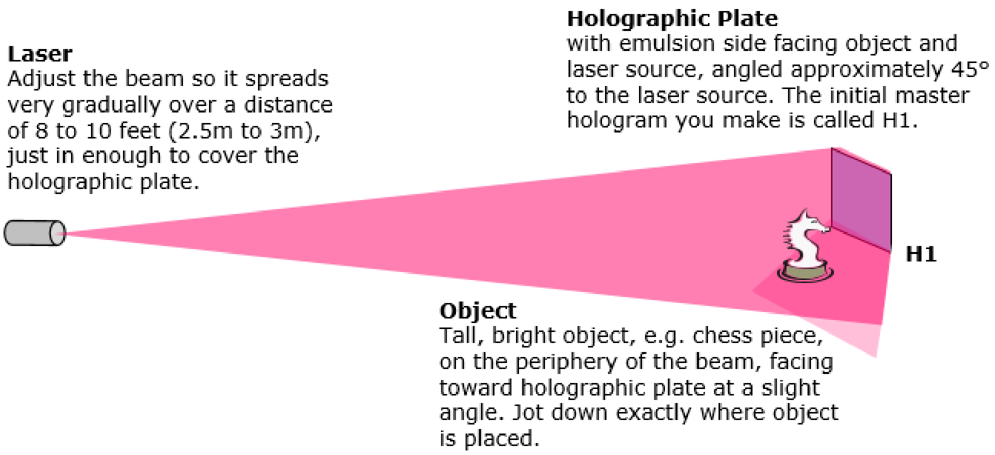


Figure 13. Setup for making the H1 hologram.

To align H1 and H2 prior in step 3 above, consider doing a trial first. Block the reference beam from reaching the location of H2. Substitute the H2 plate with a white cardboard of the same size. Rotate H1 around until a sharp real image is seen on the white card. Now place the H2 plate in the exact location of the white card with its emulsion side facing away from the reference light.

  

To minimize unwanted refraction of laser light that catches the edges of your holographic plate, consider blocking the laser light from reaching the edges with tape, a permanent marker, or simply a cast shadow upon that edge.

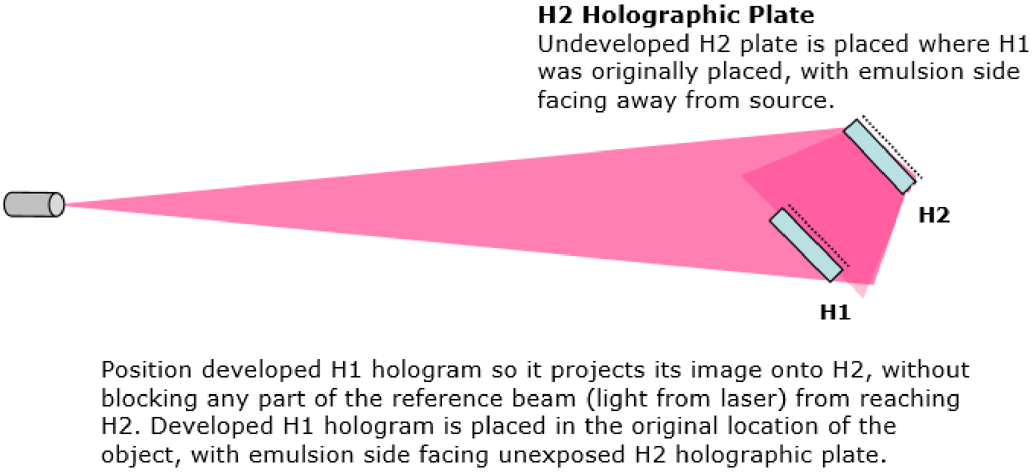


Figure 14. Setup for making the H2 hologram.

View the finished hologram with laser or spotlight from the original position of the laser during the recording and flipping the H2 by 180 degrees so the emulsion side faces you.

## 8. DIFFRACTION GRATING

With the addition of a front surface mirror to the setup, students can make a holographic diffraction grating.

A diffraction grating is really a hologram of a ray of light. In other words, the “object” exposed for the hologram is not a collection of coins, a chess piece or a toy car per se, but rather the laser light itself.

1. To have the laser light serve as the object, a front surface mirror is positioned to reflect the laser light on to the holographic plate. This is most easily done using the top-down exposure method.
2. Place the holographic plate on top of a sturdy matte black platform (the black backside of a mousepad will suffice). The matte black surface helps the student avoid making a hologram of anything underneath the holographic plate.
3. Adhere black electrical tape to the front edge of the holographic plate to block extraneous light from the laser from coming through the edge of the plate. This minimizes optical noise.
4. Position the front surface mirror vertically and securely to avoid movement.
5. Spread the laser beam profile across the mirror and holographic plate vertically, and not horizontally. This ensures correct orientation of the beams’ polarization.
6. Expose for about 10 seconds and develop and dry as usual.

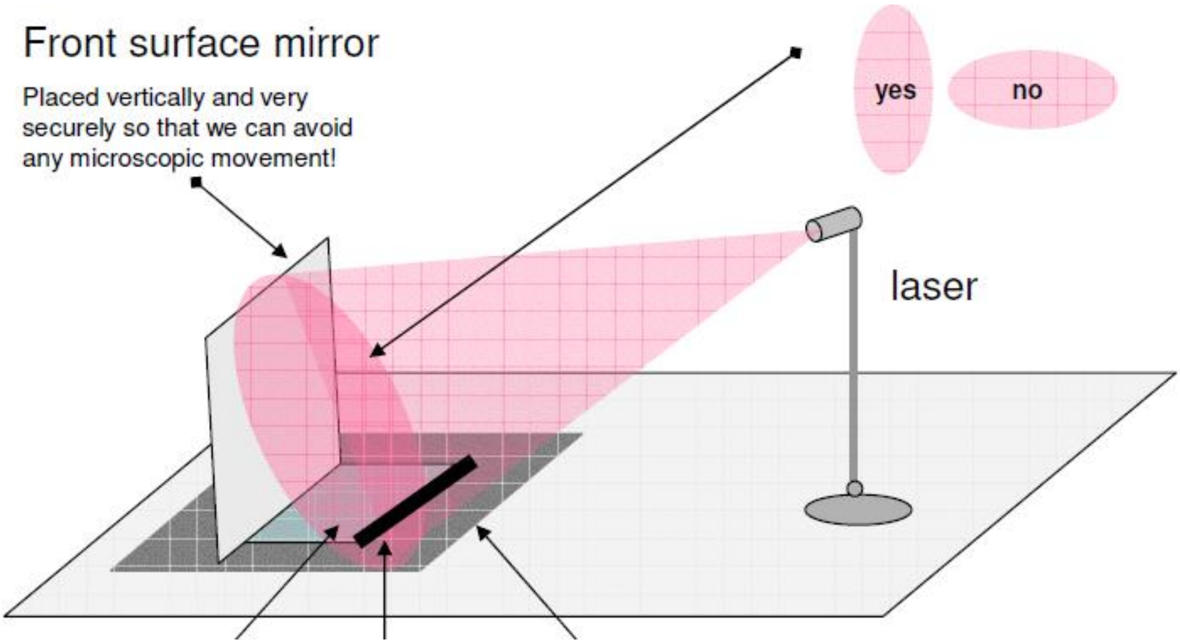


Figure 15. Setup for making a diffraction grating.

## 9. CONCLUSION

The simplicity extolled by the "Simple Holography" method for making single-beam reflection holograms is completely transferable to making other types of holograms. By making small tweaks to the setup or process, students can make a wide range of holograms, including transmission holograms, omnigrams, multi-channel holograms, interferograms, H1/H2 floating holograms, and diffraction gratings.

These simple setups can help first-time holographers learn the basics quickly, easily, and inexpensively. In doing so, these setups may help inspire students to further explore the important field of holography.

Albert Einstein stated that "Everything should be made as simple as possible, but not simpler." Today, in America at least, that idea is often translated as "KISS" (that is "Keep it simple, Stupid!"). But for holographers, let's just call it "Keep-It-Simple-Setups" for making holograms in the easiest way.

## ACKNOWLEDGEMENTS

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