PROCESSING COLOR HOLOGRAMS RECORDED ON ULTIMATE HOLOGRAPHY MATERIALS U08

1. **Plate preparation (before recording)**

   1.1. **To avoid shift (optional and only if necessary) :** remove the plates from the fridge and put them in an oven for 2 hours at 50°C, then keep them 1 hour at room temperature before recording.
   1.2. **To avoid internal reflections:** Darken the upper edge of the plate with a black marker or put an adhesive black tape during the recording time.
   1.3. **Use safe sights in your room:** use low power green LEDs and project the beam on the ceiling. A rather bright green lightning in the room is acceptable but never directly on the plate which could then be fogged by it.

2. **Recording setup**

   2.1. **The Denisyuk configuration:** The single-beam recording technique introduced by Yuri Denisyuk allows the recording of ultra-realistic full color holograms with a 180° parallax, both horizontally and vertically. The typical recording setup uses three different lasers (red, green and blue) combined together to give a "white laser beam" and passing through the same beam expander and spatial filter. The beam illuminates both the holographic plate and the object (with an angle of approximatively 40°).

   2.2. **Lasers recommendations:** U08C is a material especially designed for reflection full-color Denisyuk hologram and is set iso-panchromatic for all the common lasers (442, 457, 473, 488, 514, 532, 633, 640 and 647 nm) used in color holography. Full-color holograms can be recorded with any possible RGB combinations but we recommend 640, 532 and 457 nm.

   2.3. **Electronic shutter with timer:** to control the exposure time precisely. A 10% overexposure can produce milky holograms. On the contrary, a 10% lack of exposure time can produce less bright holograms.

3. **Basic procedure for recording a RGB hologram:**
   The general principles are the following:

   1. Start by recording a **monochrome green** hologram that will be successful at **200µJ/cm²**

Figure 1. Monochrome Green hologram

   2. Then record a “yellow” (**red + green**) hologram successful at **150µJ+150µj/cm²**. At this point you can adjust the ratio Red/Green to obtain the right color balance rendition. You can compare under your laser set up with the real object and under your reconstruction white light. This will help you to achieve the balance you like. Once the Red/Green balance is achieved, don’t change it anymore.

Figure 2. Original test object and hologram under a Red + Green laser beam light.

3. Finally you can add the blue laser. Record the color hologram (**R+G+B**) using **120µJ/cm²** per color. Once again, adjust the color balance by varying only the blue one.
Usually the brightest holograms are achieved by decreasing the power of the blue a little bit, compared to the red and green a typical final ratio for 640 + 532 + 457nm lasers is: R 130 G 120 B 110 (µJ/cm²).

Figure 3. Three-color hologram under white light.

3.1. **Adjust color balance for other lasers**

3.1.1. **If you own a calibrated power meter:**

Ultimate is an iso-panchromatic photographic material but the human eye doesn't have a flat response over the white spectrum (there is a maximum sensitivity's eye at 540nm). The right color balance combining Red + Green + Blue to generate White depends on the wavelength used. The recommended ratio values on U08C are given in Table 1.

442	457	473	488	514	532	633	640	647	660
0.8	1	1.2	1.4	1.1	1	0.9	1	1	>1.5

Table 1. Laser ratio according to their wavelength.

3.1.2. **If you don't own a calibrated power meter:**

The correct Red/Green color balance can be found with a nice color test object with "pure" green and "pure" red parts. Vary the ratio until you get a hologram identical to the object (Fig.1). The white parts

should appear yellowish.
When a good (red + green) hologram is achieved, add the blue laser and vary the ratio until you get a hologram identical to the object.

3.1.3. **The reconstruction lamp:**
These ratios Red/ Green/ Blue must be adjusted too according the final lamp used for reconstruction. Halogen lamp and Warm White LED have almost no blue when White Cold LED or RGB LED have a lot.

3.2. **Exposure time**

For U08C, the typical recommended starting exposure energies (ON THE PLANE of the hologram) are:

- Monochrome : R (or G or B): 200 µJ/cm²
- Bichrome : R+G: (150+150) µJ/cm²
- Three-color : R+G+B: (120 +120 +120) µJ/cm

Do not over-expose. There is a maximum of diffraction efficiency and over-exposing would decrease the brightness (Fig.2).

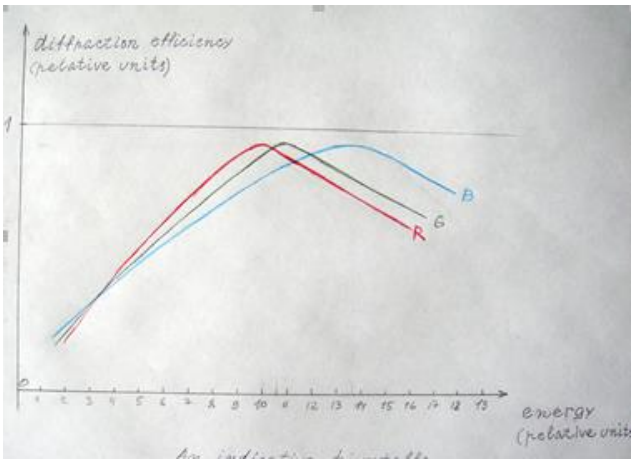


Figure 2. An example Diffraction efficiency according exposure, for a test batch of U08C, measured by Vladimir.

4. Development

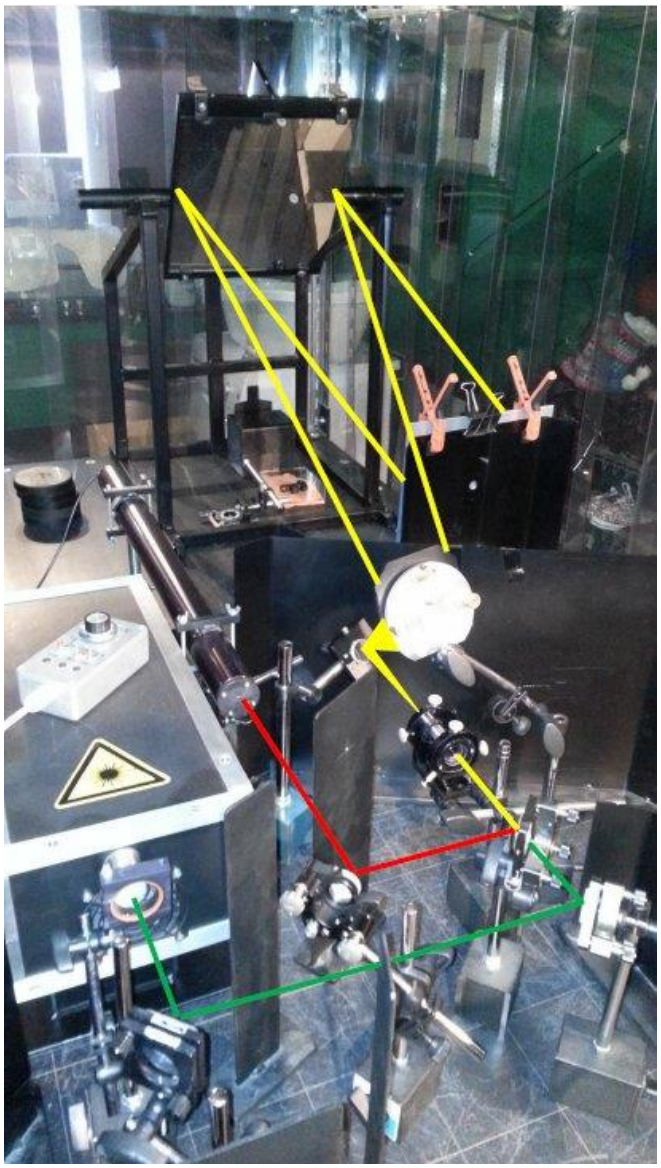
The hologram is developed with the safe and easy to use two baths of chemicals recommended (Table 2):

Processing Step	Time (minutes)
Develop in Ultimate Developer at 22 °C (diluted 1:10)	6
Wash (running water)	0.5
Bleach in Ultimate Bleach at 22 °C	until clear (about 3)
Wash (running water)	3
Wash with Kodak Photo-Flo	1
Vertical Dry	20

Table 2. Standard Ultimate processing steps.

Examples of set-ups by two clients:

Kris' set-up:

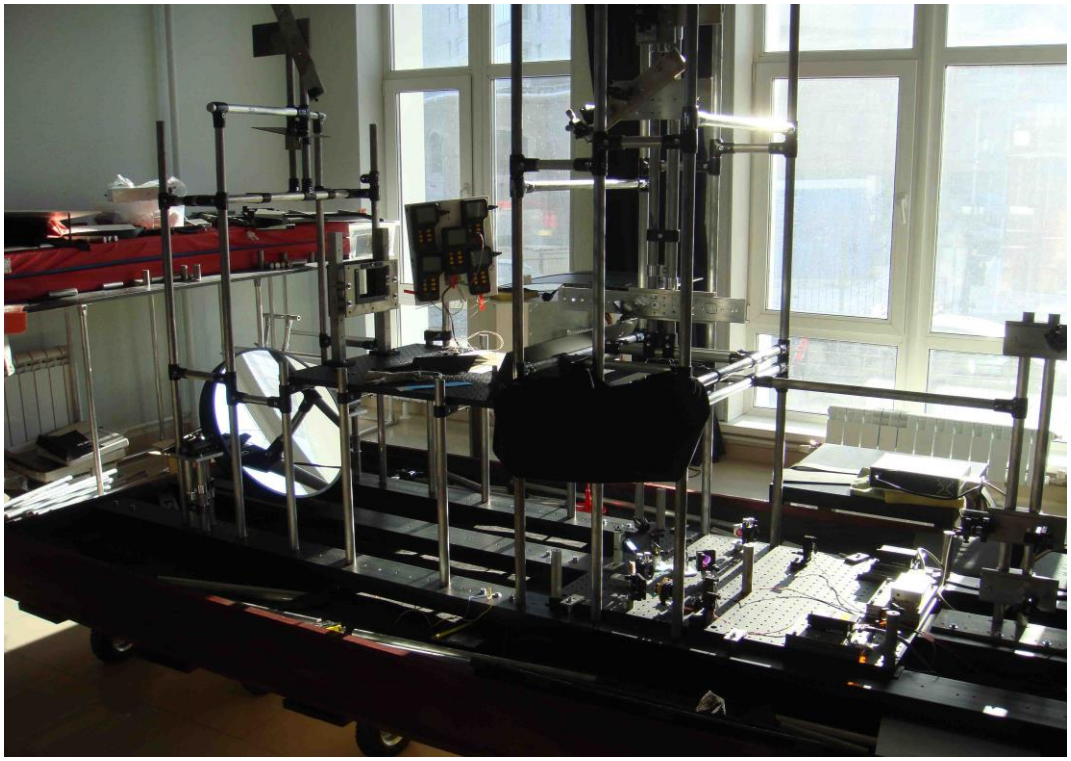


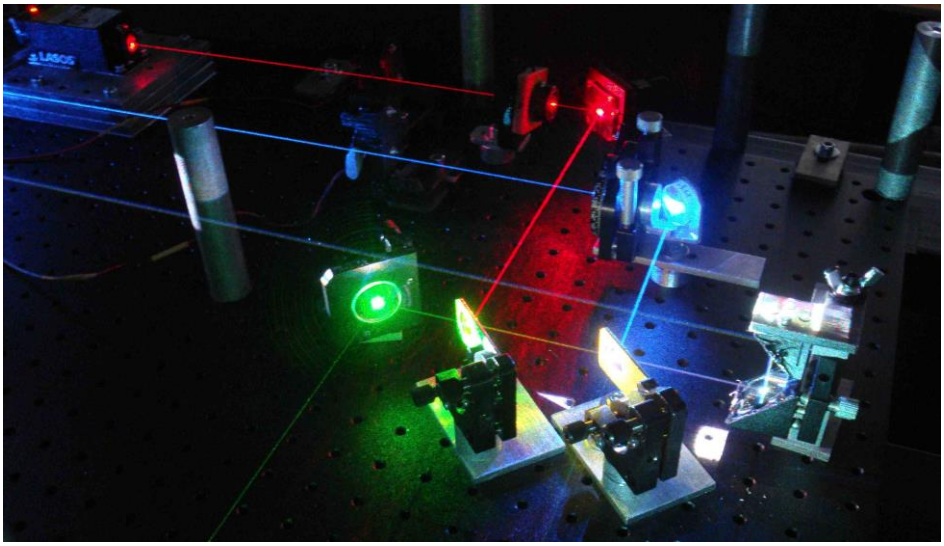
In his set-up there are:

- 6 mirrors, including a 300x300mm front surface mirror for the object beam.
- A beam combiner.
- Spatial filters.
- An electronic shutter with an electronic timer.
- A coherent 315m laser 532nm, 80mWatt (The output power is controlled down to 20mWatt).
- A uniphase 1145P HeNe laser, 20mWatt.

The optic table is homemade from steel (500kg), resting on inner tubes and foams.
Around the table there is a transparent curtain.
Throw angle is around 40 degrees.
The objects are not laying down but standing up.

Vladimir’s set-up:





In this set-up there are:

A red laser 640 nm (Lasos),
A green laser 532 nm - 47 mW (Lasos),
A blue laser 480 nm - 200 mW (Coherent Sapphire).
A pinhole - 15 mm, 40X lens SP.

The throw angle to the normal of the plate is 36 degrees.

The projection goes directly from the pinhole, without a mirror.