DIY 4x5 enlarger and LED head

This is a project to convert a relatively portable medium format enlarger into a 4x5 large format enlarger. The reasoning behind it is to make a large format enlarger that can be readily moved by one person and fit into small spaces.

- Why even do this? -

Well, because my 'darkroom' is tiny. I've seen photographs of absolutely amazing home darkrooms on the web. Fantastic, purpose-built spaces with lots of workspace designed just for working with darkroom materials. I would dearly love to claim such a space as my own, but my reality is a cramped temporary space in a interior bathroom that I use for printing. I have to set up, print, and clear out within a nights' time. I'm limited by the small space and hampered by the width of the doors--a narrow 24" wide. While a full sized 4x5 enlarger would be great, I couldn't get one to fit through the door.

The enlarger I converted is a Beseler 23C II-XL. Its slim but tall size easily fits through narrow doors and the chassis is very sturdy. The modifications aren't difficult and can be done with a minimum of tools: a handheld drill, a Dremel tool and a small table saw (a jig saw or hand saw is fine, but the cuts aren't as neat). Nearly everything on the enlarger is reused--with the exception of the glass condensers and upper lamphouse as they were never meant to cover a large format 4x5 frame.

Please note: the changes I make to this enlarger make it unusable for 35mm film. Its sole function is to handle 4x5 film and 6x12 panoramic film. I keep a second unmodified 23C for 35mm and 6x7.

To begin, I completely disassembled the enlarger down to the carriage. This is also the ideal time to throughly clean all of the individual parts. I took particular care when removing the bellows, as I needed to reuse each set. The lower bellows are simply glued to the bottom of the negative stage of the 23C and can be carefully pried free with the flat end of a large bladed screwdriver. The upper bellows can be removed by grasping the ring shaped top half--where it attaches to the condensers--and pulling down. These bellows are also glued to the upper half of the negative stage, and need to be carefully pried free as well.

- Making a square peg fit in a round hole -

The first modification is to the negative stage. Beseler 4x5 negative carriers are too big to fit on the 23C, but interestingly Omega 4x5 negative carriers are ideal. I used contact paper with a self adhesive backing to draw out the outline of the Omega carrier on the negative stage of the 23C, then milled out the opening with a Dremel tool. The Dremel bits are small and this task can be a little tedious, yet careful attention to following the outline exactly (and lots of test fits) will create a neat and exact fit for the new negative carrier. The same process is done with the thinner upper negative stage; this will become the base for the LED head.

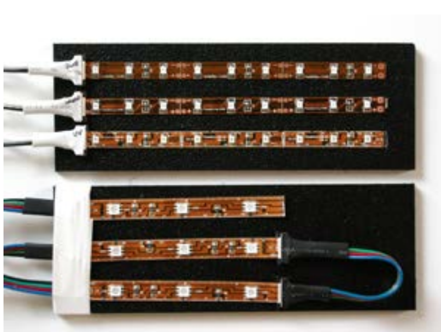
The second change is to the bellows. As-is, the original 23C bellows work, but are stretched to the limit for 4x5 use. To ensure plenty of bellows extension, I glued the upper and lower bellows together with contact cement into a extra-long set, and re-attached it to the bottom of the negative stage.

The next change to the enlarger is to its maximum focus travel. Originally, there isn't enough travel in the focus for the long focal length enlarging lenses (135mm, 150mm) needed for 4x5 film. On the 23C the condenser lamphouse, negative stage and the lens stage ride on the same set of chrome steel rods. With the condenser lamphouse removed, about half of the rods are left unused above the negative stage. The two rods are held in place by four set screws on the back of the negative stage, so by lowering the rods and re-tightening the set screws, many inches can be added to the focus travel. I cut and added a length of 1/2" thick plywood (as well as sanded, primed, painted for a nice finish) to extend the enlarger chassis for the lowered chrome rods. The plywood extension is held in place with six screws drilled through back of the the enlarger carriage. This extension is actually quite rigid!

The last task is the addition of some counterweight. With the top lamphouse and heavy glass condensers gone, some weight needs to be added to the carriage to re-balance it. The 23C has two metal springs running up both the sides of the frame that assist the carriage in smoothy cranking up and down. The tension of these springs isn't adjustable; I found some old telescope counterweights--small, heavy, and already finished in black to blend in with the enlarger. I bolted these to the rear of the carriage.

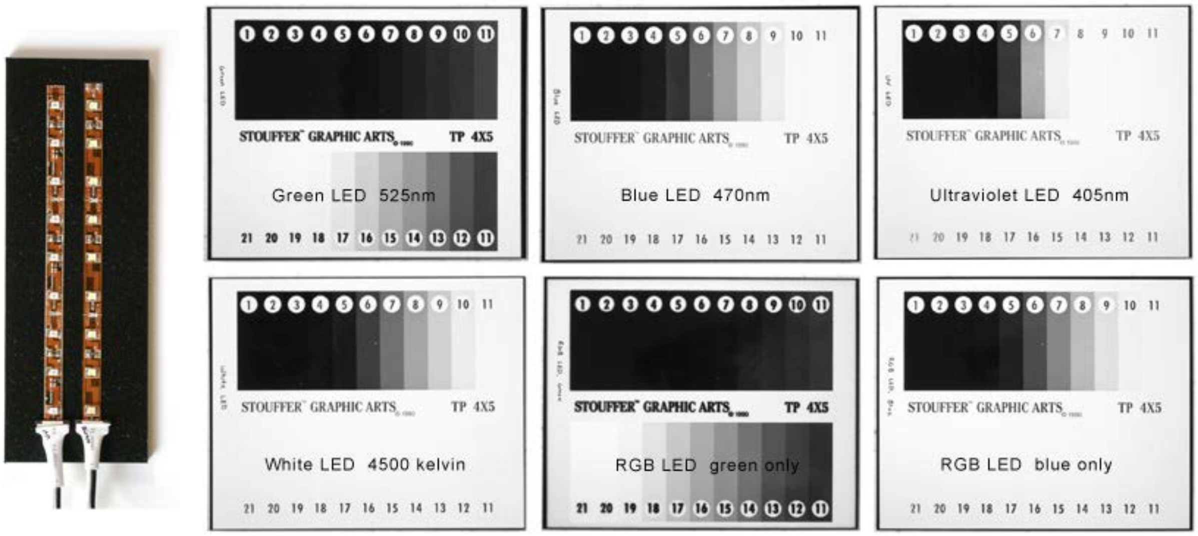
- The LED light source -

LEDs are a fascinating project to use for a darkroom enlarger. They're easy and fun to work with, but the right kind need to be used to get the best results. This webpage shows the second LED head I've built. The first version I made I just jumped in and put together a head to see if it'd even work. For this head I wanted to find the best combination of components.



My first task was to find out just how variable contrast black and white paper reacts to various LED colors. I'm not confident nor skilled enough to assemble and solder individual LEDs by hand, so I purchased some premade led strips from superbrightleds.com. The strips I chose run on a safe low voltage twelve volts DC, come in a variety of colors, are built on a neat flexible self-adhesive base and can be cut into two inch segments with ordinary office scissors. To make assembling the LEDs even simpler, the website also offers solderless interconnects which I would strongly recommend--the soldering pads on these LED strips are small and are difficult to solder unless you already have past soldering experience.

To test how the paper would react to each LED color, I put a samples of several colors--green, blue, white, ultraviolet and red-green-blue all-in-one LEDs--on a plastic board and clamped it to the top of my enlarger, LEDs facing down to the baseboard. I then contact printed a Stouffer 21-step wedge onto a piece of Ilford Multigrade IV RC paper. The paper was given enough exposure so that steps one and two of the wedge printed as maximum black. Step number three in the prints is a very dark gray, barely distinguishable above black. This was repeated for each color. By following this pattern, I ensured that each print had enough exposure to show a full range from paper base white to deepest black. The densities below show the resulting contrast ranges of the paper.



In variable contrast black and white darkroom paper, green colored light will lower print contrast while blue colored light will increase it. The prints of the step wedge above show how the various colors affect the contrast of Ilford Multigrade IV RC paper. Note that the blue LEDs (rated at 470nm by the manufacturer) aren't creating the narrow high contrast range as expected. I have read in two reliable sources--Ctein's Post Exposure Second Edition and Steve Anchell's The Variable Contrast Printing Manual--that modern variable contrast paper is ultraviolet sensitive, so I included ultraviolet LEDs in my step wedge test. It seems to hold up to theory--notice how much more narrow the contrast range is with ultraviolet to blue LEDs.

On these results I chose to make the head out of white LEDs. White is a mix of all colors, so both the green and blue wavelengths variable contrast paper requires is there in one LED. To adjust the contrast of the paper, I would use under-the-lens printing filters at the enlarger. Yet, previous experience with my first LED head (also using white LEDs) showed I had trouble with the head not printing at high contrast grades. I suspected that in my first LED head something was missing from the blue end of the spectrum of white LEDs that the paper needed. Based on this I decided to incorporate ultraviolet LEDs into the new head along with white LEDs to ensure it would have no problem with high contrast grades. **Caution: If you decide to use ultraviolet LEDs, do so safely. Don't look at ultraviolet LEDs without UV blocking glasses!**

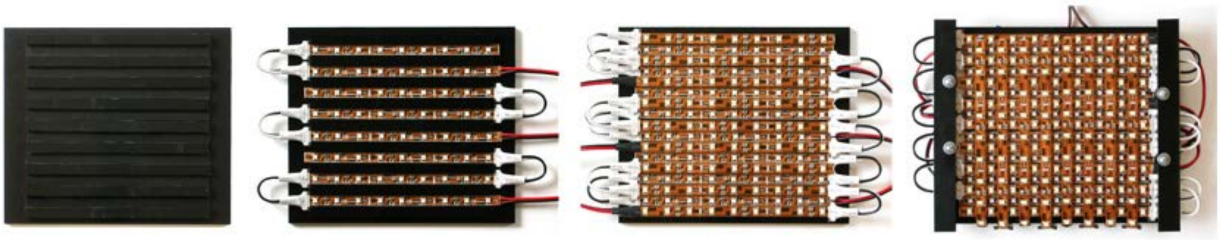
Update: please see my spectrometer page where I examined the LED colors more closely. What appears to be a solid color to the eye doesn't necessarily indicate what's really there!

- What about a green-blue LED head? -

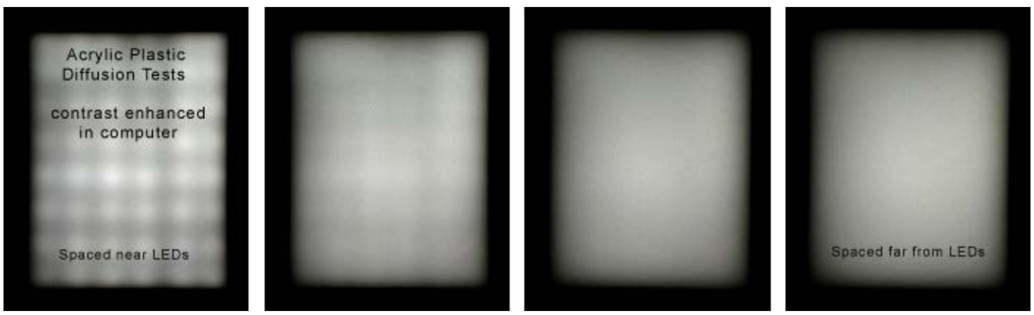
I didn't go this route as my step wedge tests showed that 470nm blue LEDs weren't enough by themselves to trigger the high contrast grades in variable contrast paper. What I would have had to make would be a three channel green-blue-ultraviolet head, with each color on its own circuit. Another complication I wanted to avoid was having to determine print grades on such a head. When I made the step wedge prints above, I was surprised how much the paper's sensitivity varied with each color. For example, the green exposure took six seconds to complete; the blue exposure required about half a second. Zeroing in to the maximum black times was not quick. My garbage can was loaded with test strips afterwards! Changing the color in a green-blue head will have a big effect on the exposure time of the print. I just didn't want the hassle of sneaking up on print contrast and having to make a test strip with every color change.

- Building the LED head -

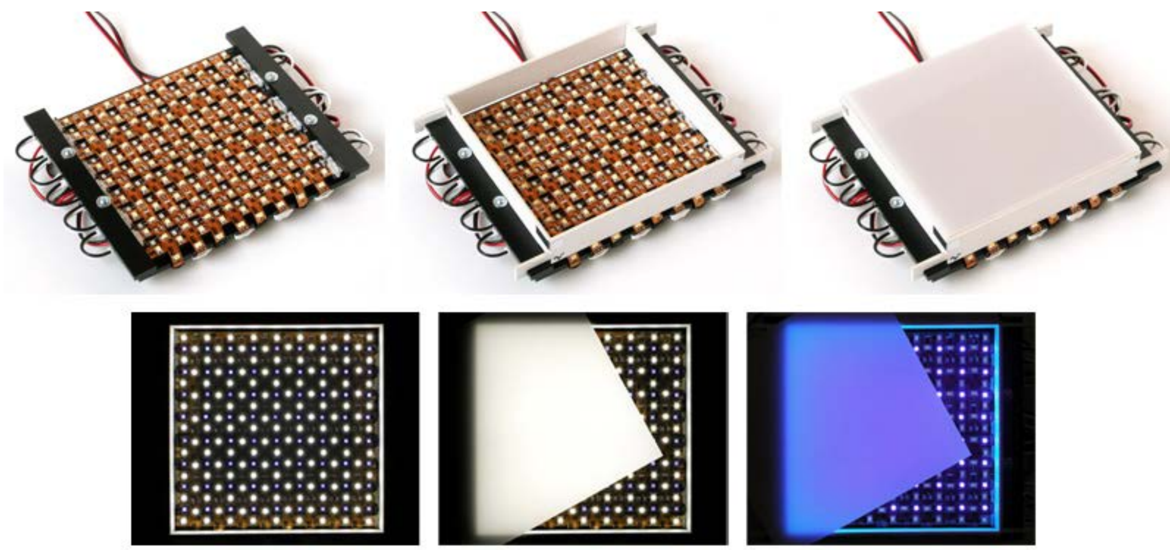
The base the LEDs are attached to is a sheet of 3/16" black acetal plastic seven inches by six inches from U.S. Plastic. Each LED strip is six inches long, not including the interconnects. The solderless LED interconnects don't lie flat with the LED strips, so to the base I glued a series of plastic ridges of alternating heights to raise or lower each LED row so the interconnects wouldn't interfere with each other. There is a single set of UV LEDs, and two sets of 4500 kelvin white LEDs: one set running horizontally and the other set running vertically. There are a total of 217 LEDs in the head. The UV and white LEDs each have their own power cord.



The most practical way to even and smooth out the numerous sources of light from so many LEDs is diffusion, so I ordered a sheet of 1/8" white acrylic (manufacturer #2447, 54% light transmission) from U.S. Plastic to use as a light diffuser for the LED head. The next task was to determine the optimum height the diffusing plastic sheet should be from the LEDs. If the sheet is located too close to the LEDs, the light from the LEDs creates dozens and dozens of hot spots. Pulled farther away, the lighting can be made completely even but too far creates light falloff (due to the inverse square law). The trick is to get it close, but just far enough away so the light is completely uniform.



To determine the optimum diffusion distance, I made a series of mat board frames at various heights to incrementally space the acrylic plastic from almost touching to a few inches away from the LEDs. The various spacers were placed on the LEDs, and the plastic on top of the spacer. The LEDs were turned on, and the arrangement was then photographed with a digital camera; the exposure in the camera was locked in manual mode with the white balance also locked. Each spacer was photographed using the same exposure and white balance. In the computer, I opened each photograph, cut and pasted each image into a long single row, and hit the collage hard with the levels tool in Photoshop to exaggerate and highlight any unevenness of light on the plastic sheet. The first visually even surface was my optimum distance.



Above is the finished spacer, diffuser and images of the lighting pattern.

- The finished LED head -

The entire assembly is fitted in a mat board enclosure I carefully made to fit the top of my enlarger exactly. These LEDs generate little to no heat, so just about any material can be used to house them. The interior of the box is lined with several layers of aluminum tape making it light-tight. The top slides on and off like a shoe box, and has a small hole for the two power cords going to the LEDs; one for the white, the second for the UV.

- A important note about power supplies -

Do be aware of the type of power supply used to power the LEDs. I used a compact plug-in wall supply like those commonly used for small electronics (you see them on cordless phones, battery chargers, etc). There are two types of these power adapters: "switching" and "fixed"--also called "linear".

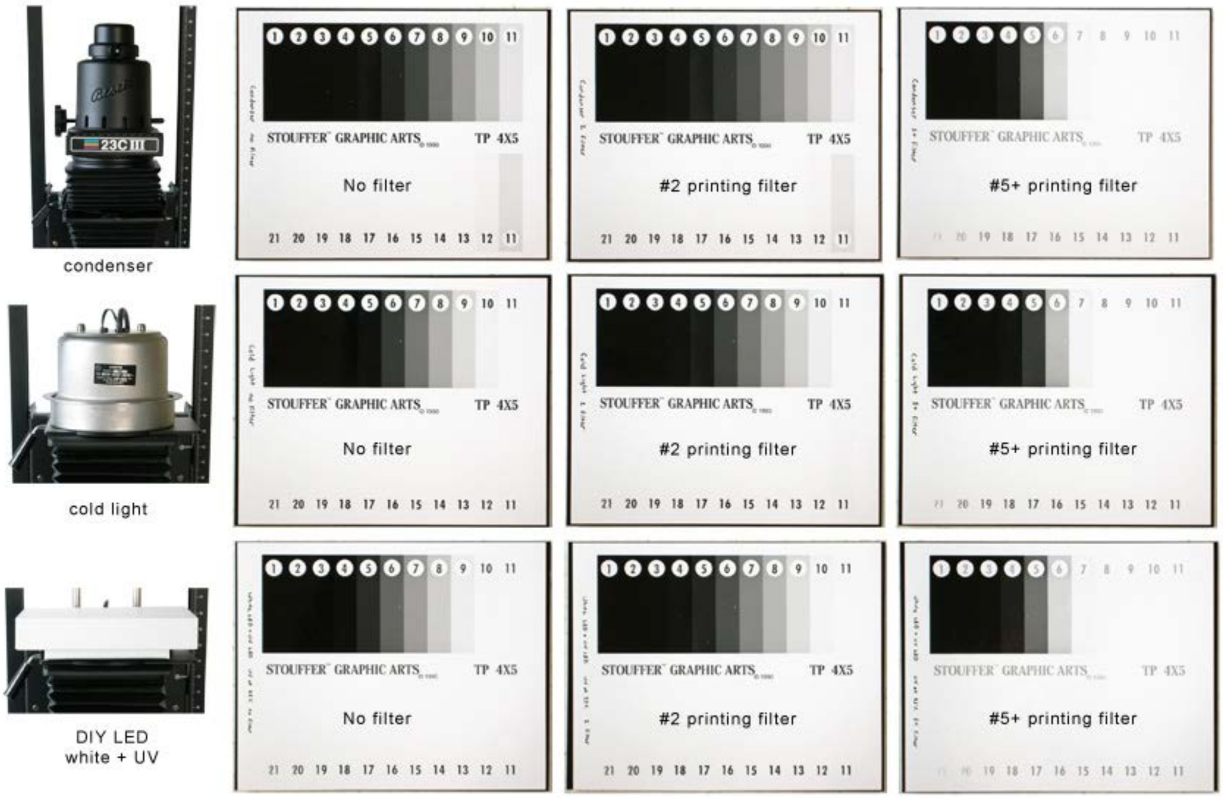
Ordinarily the switching type is preferred as they're more versatile. Regrettably, they have one trait that makes them a problem for the LED head. A switching adapter has circuitry within it that detects what kind of load it's attached to and automatically adjusts itself to provide the correct amount of current. Normally that's a good thing. The problem is when these adapters are plugged in; there is a delay of several seconds while the adapter powers up. When one of these is plugged into a enlarger timer, each time the timer turns the light on, there's that delay before the LEDs will come on. That can be a real headache in printmaking!

This can be solved via a relay; mechanical or solid state types work very well. A relay is kind of like a wall switch. When electrical power is applied to the "coil" side of the relay (a magnet), it activates a internal switch that turns on a separate electrically isolated set of terminals on the other side. In use it works like this: the wall adapter is plugged directly into the wall so it's always on and ready to go. One of the leads from the wall adapter is wired to the switched terminal of the relay. The matching lead to the LEDs goes in the corresponding terminal. On the other side of the relay, a cord from the enlarger timer is wired to the coil of the relay. When this coil is energized (enlarger timer clicks on) the relay switches on its terminal. So, timer goes on, relay switches on, the connection is made from the wall power adapter to the LEDs. When the timer cycle is done, everything clicks off. By not having to directly power the adapter itself on and off, the relay provides an instant on and off solution. It's not difficult to wire (once you know what each terminal does) and it's a really neat fix--but unfortunately for me it revealed a hidden problem. My digital timer didn't play nicely with my relay thanks to something called a "snubber" circuit in the timer and I spent several weeks figuring out a remedy that I was never completely comfortable with.

The simplest solution is to use a fixed/linear output adapter. This is what I'm now using with my enlarger. When these are plugged in, power goes to the LEDs immediately. There's no delay for these to power on. All I had to do was plug it directly into my timer. However, because these supply full power at all times, they need to be matched to the amount of current you require. The LEDs won't be harmed if the adapter generates more current than what the LEDs actually use--but if that excess current isn't used up, the power adapter behaves like a capacitor--it temporarily stores energy. The effect is when the power is turned off (timer switches off) the LEDs will slowly dim, then finally extinguish as they gradually use up the residual current in the power supply.

Blah, blah, blah. How's it actually print?

Pretty well. Here are step wedges of a Beseler 23C III condenser, Aristo D2 series V54 cold light, and the DIY LED head. Interestingly, the condenser prints with the lowest inherent contrast.

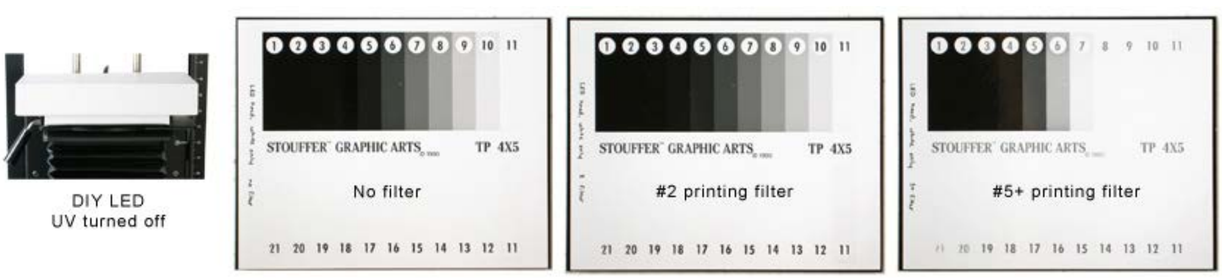


In terms of brightness of each light source, I measured each with a handheld incident digital light meter. I set up the enlarger for a 11x14 sized print, set the enlarging lens wide open for each light, and recorded how bright the light was at the easel. The cold light and the DIY LED head measured the same (the LED was actually 2/10ths of a stop brighter) but the hands down winner in brightness was the condenser enlarger; it was four times brighter than the other two.

Basically, if you have a condenser enlarger turn it on and close the lens two stops. That's how bright my LED head is to a condenser. If you have a Aristo D2 cold light, it's exactly the same, the light is just white instead of blue-green.

The unexpected

I was absolutely convinced from what I read in Ctein and Steve Anchells' books, and from the high contrast problems with my first LED head that I had to have UV light to work with the high contrast grades in variable contrast paper. I did one last step wedge series, white LEDs only, just to see what the contrast range was. I didn't expect this:



White LEDs alone worked fine! No problem with a 5+ filter. If anything, without the UV it's a near perfect match for the contrast of the Aristo V54 bulb.

Long-term practical printing will be required to be sure, but two possibilities come to mind: one, the white LEDs are generating a little ultraviolet and I didn't even need to put the separate set of ultraviolet LEDs in there (groan!) or two, Ilford Multigrade paper doesn't require ultraviolet to print at high contrast. It also could be that the paper is merely violet sensitive instead of ultraviolet.

Update: I have narrowed down a possible explanation by examining the light spectrum of several light sources. Please see my spectrometer page where I examined several LED colors, including the white I used in this project.

The complete enlarger

Before and after photographs of the DIY enlarger. Looks and works pretty good considering the Frankenstein-like treatment this old enlarger got. It fits through small doors with ease, it handles 4x5 film, and the entire project can readily be done by one person in the corner of a their garage. The light source is a bunch of LED strips in a mat board box, yet the illumination absolutely even and completely homemade. Pretty cool! Overall dimensions are 17 1/2" wide (including side elevation handle), 26" deep, 45 1/2" tall and the weight of the enlarger is 45 pounds.



Comments or questions? Please email me at the address below. I spent many months and went through a lot of parts, trial and error to complete this enlarger. Benefit from my mistakes. :) I would be happy to help with or discus any part of this project!

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