Converting a 1980s Video Camera into a Real-Time Polarimetric Imager

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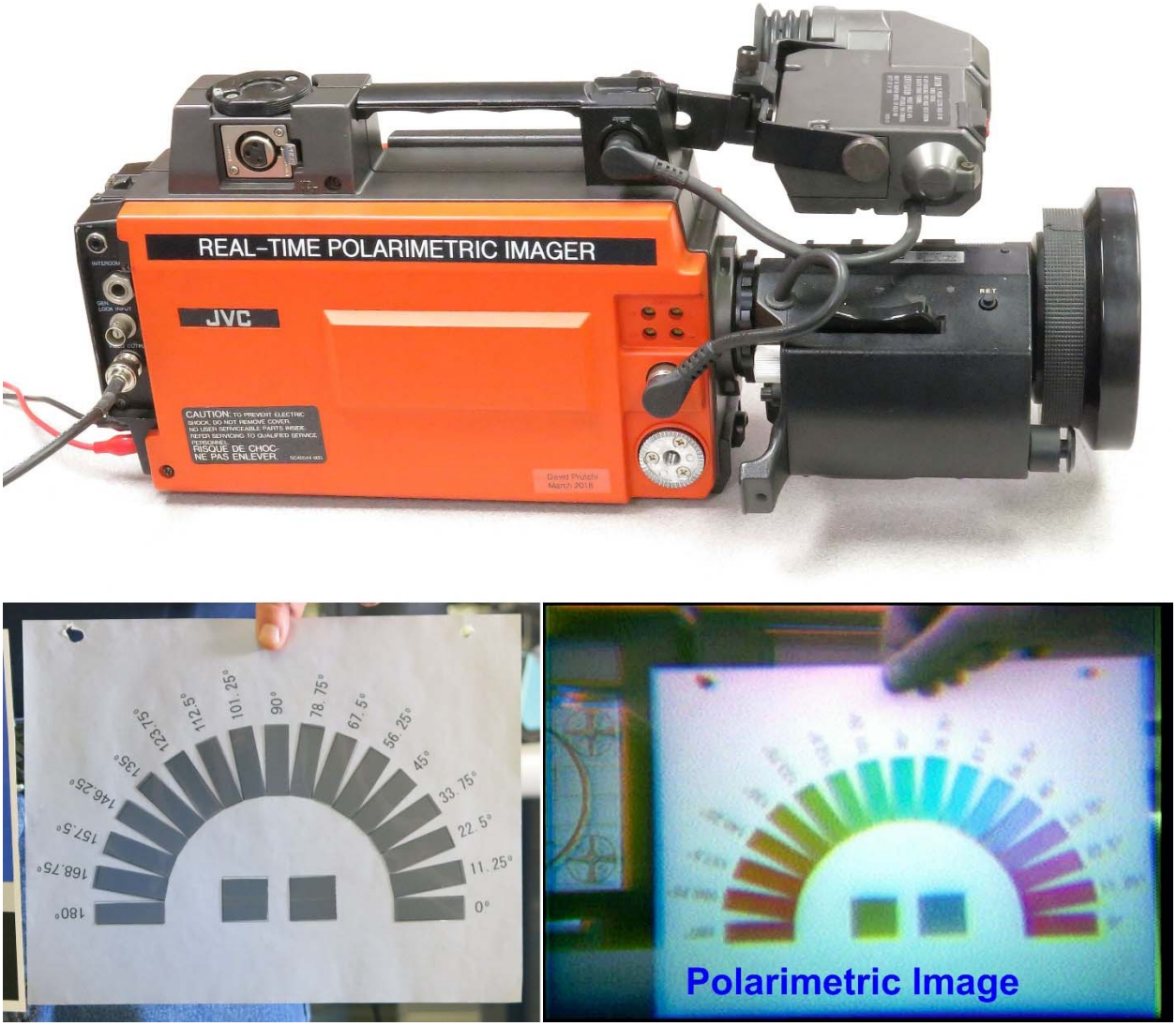


Figure 1 – I converted a surplus JVC KY-1900 three-tube color camera into this real-time polarimetric imager.

Abstract

Polarimetric imaging offers a path to develop game-changing applications across a wide range of fields – spanning all the way from environmental monitoring and medical diagnostics to security and antiterrorism applications. However, the very high cost of commercial polarimetric cameras has hampered research and development on polarimetric imaging. This paper presents detailed instructions for converting a surplus 1980s-era, 3-tube color camera into a real-time polarimetric imager. The camera used as the basis for this conversion is widely available in the surplus market for around $50.

Introduction

A light wave is characterized by its wavelength, which we perceive as a district color; its amplitude, which we perceive as an intensity level; and the angle at which it oscillates with respect to a reference axis (Figure 2). This last parameter is called the wave's "Angle of Polarization", and is a characteristic of light that unaided human eyes cannot distinguish. However, the polarization of light carries interesting information about our visual environment, and some animals are able to perceive it and rely critically on this sense for navigation and survival.

While we have used technology to expand our vision beyond the limits of our ordinary wavelength and intensity sensitivities, the unintuitive nature of polarization has slowed down the development of practical applications for polarization imaging. Polarization cameras do exist, but at over $20,000, they are mostly research curiosities that have found very few practical uses outside the lab. Nevertheless, polarimetric imaging may enable the development of game-changing applications across a wide range of fields – spanning all the way from environmental monitoring and medical diagnostics to security and antiterrorism applications.

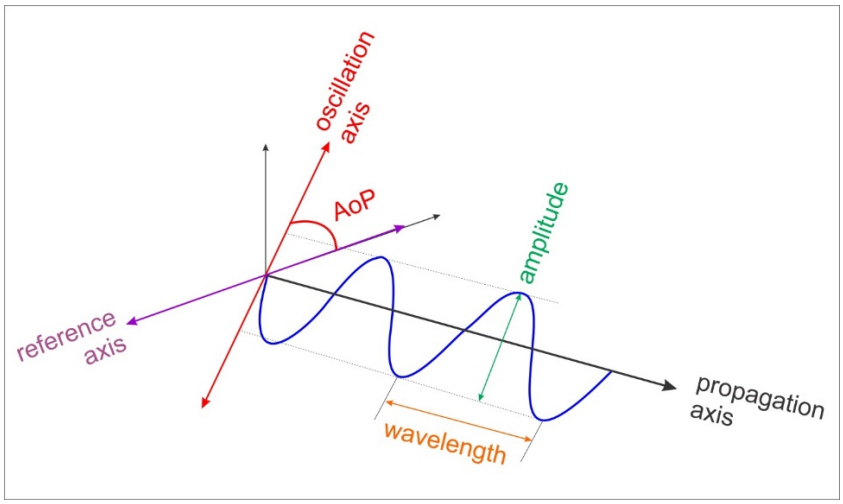


Figure 2 – A light wave is characterized by its wavelength, which we perceive as a district color; its amplitude, which we perceive as an intensity level; and the angle at which it oscillates with respect to a reference axis. This last parameter is called the wave's "Angle of Polarization", and is a characteristic of light that unaided human eyes cannot distinguish. However, the polarization of light carries interesting information about our visual environment, and some animals are able to perceive it and rely critically on this sense for navigation and survival.

Three years ago I developed the DOLPi polarimetric cameras [4] based on the Raspberry Pi. One used an electro-optical polarization analyzer, while the other used discrete polarization filters mounted on a filter wheel. The only issue with their performance was lack of speed.

Figure 3 – In 2015 I developed the DOLPi polarimetric cameras [3] based on the Raspberry Pi. One used an electro-optical polarization analyzer, while the other used discrete polarization filters mounted on a filter wheel. The only issue with their performance was lack of imaging speed.

I mentioned back then that high-speed polarization imagers have been built using multiple sensors, each with its dedicated, fixed-state polarization analyzer. As shown in Figure 4, a 3-way beamsplitting prism can be used to send copies of the scene to three CCD camera sensors, each placed behind a polarizer to acquire the complete linear Stokes parameter vector[1]. This is the approach taken by FluxData for its FD-1665 polarization camera.

[1] A detailed, and easy-to-understand description of polarimetric imaging and its applications is available in my whitepaper on the DOLPi polarimetric cameras available at: http://www.diyphysics.com/wp-content/uploads/2015/10/DOLPi_Polarimetric_Camera_D_Prutchi_2015_v5.pdf and its presentation on YouTube at: https://www.youtube.com/watch?v=A7bXkp8SWCA

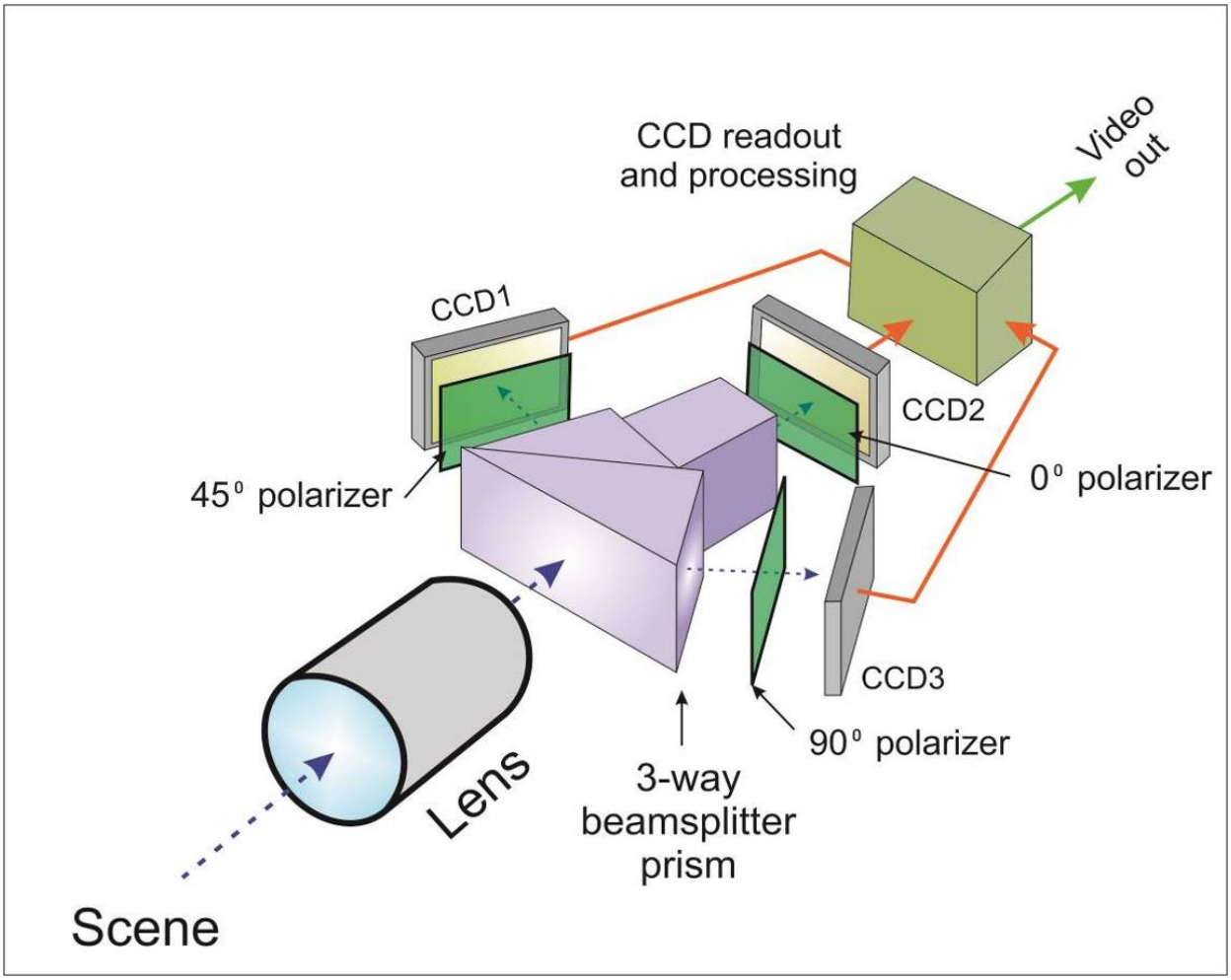


Figure 4 - A 3-way beamsplitting prism can be used to send copies of the scene to three CCD camera sensors, each placed behind a polarizer. This is the approach taken by FluxData for its FD-1665 polarization camera.

I tried working on a DIY version of this camera by replacing the color filters of a 3-CCD color camera by polarization filters. I was unsuccessful in my attempts to take apart the original beamsplitter prism and dichroic color filters to convert a 3-CCD JVC KY-F55BU color camera into an imaging polarimeter. So instead, I decided to go full retro, and as shown in Figure 1, hacked a 1980's 3-tube color camera which made it easier to disassemble and modify the 3-way beamsplitter. The advantage of working on a 3-tube camera instead of starting from scratch is that the mechanical alignment hardware, as well as the image-combining and color-encoding circuitry is already built.

The JVC KY-1900 3-Tube Color Camera

I purchased a JVC KY-1900 camera off eBay® for $65. The offering showed a very dusty camera and a case full of mud, so I wasn't very hopeful about its condition. My thought was to first disassemble this camera to figure out what I would need to do to modify a different, functional unit. I was pleasantly surprised

when the camera worked correctly when I connected it to a color NTSC monitor and powered it with 12VDC (Figure 5). All it took was a good cleaning to get it into pristine condition.

Figure 5 – I paid $65 on eBay® for this JVC KY-1900. I was pleasantly surprised that it worked correctly when I powered it with 12VDC.

I now see these cameras going for around $50 on eBay®. After working on mine, I realized that the KY-1900 was built like a tank, so chances are very good that any surplus unit will be fully functional if it looks good cosmetically. All it takes is to connect it to a NTSC color monitor and supply it with 12VDC (the camera draws around 1.7A).

JVC advertised the KY-1900 camera as:

> "Weighing less than 8 pounds, this super-compact three-tube camera is designed without compromising quality.
>
> - Three newly designed Saticon tubes
> - High performance dichroic multi-layer mirror optical system
> - Die cast aluminum frame
> - 52dB signal-to-noise ratio
> - 9dB gain available for really low light situations
> - Optional 6:1, 10:1, or 14:1 servo zoom lens
> - Automatic iris control with weighting detection circuit
> - Automatic Beam Control, knee compression and white clip circuits for highlight processing
> - Auto white balance with 8-bit memory
> - Built-in genlock and color bar generator"

The KY-1900 was a professional-grade camera. It was one of the few models to be produced with a plastic orange body, making it very distinctive, and a mark of high-end professionalism for camera crews. Back in 1982, this camera retailed for around $9,000 [1].

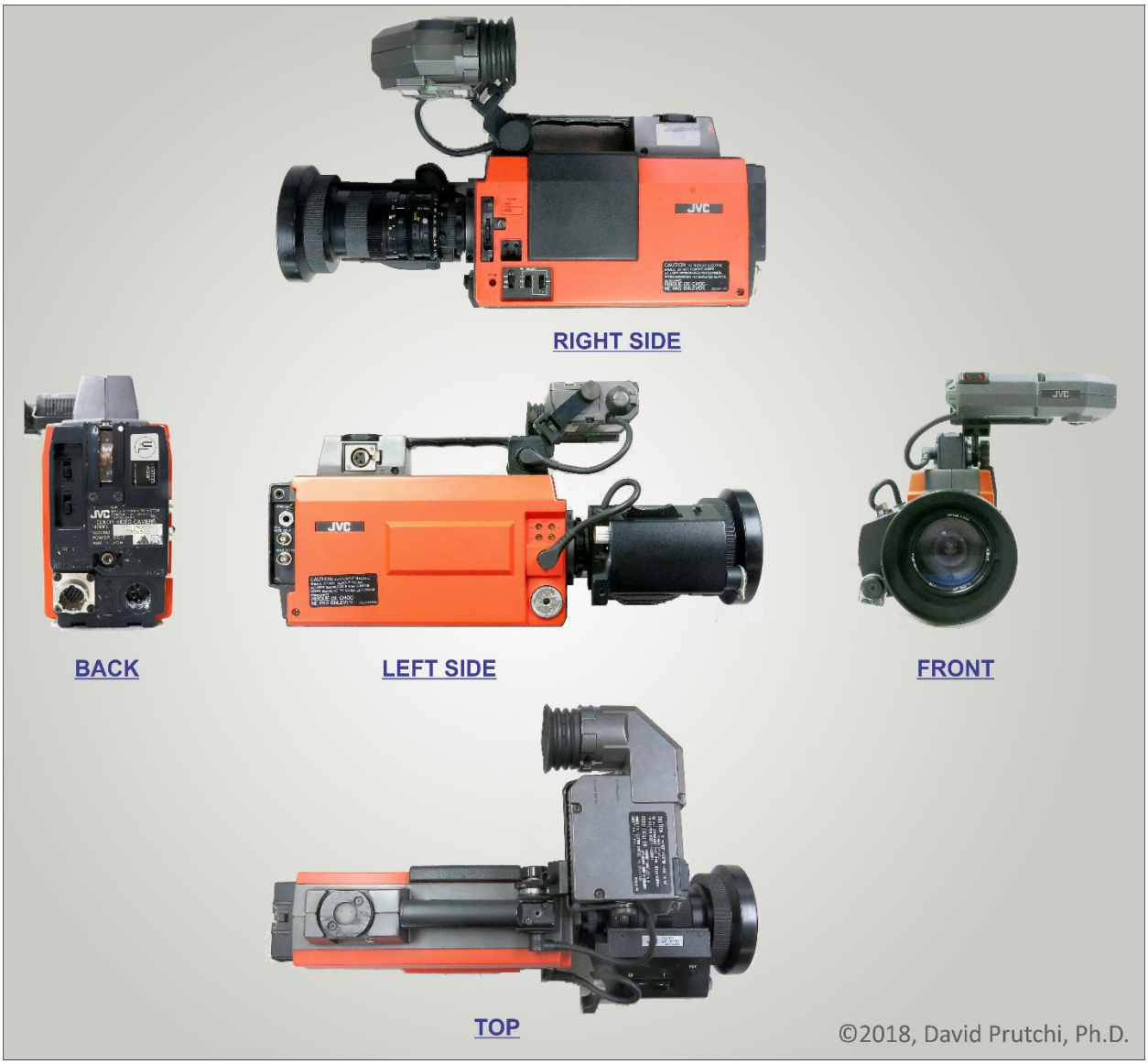


Figure 6 – My JVC KY-1900CH viewed from all its sides. These are the reference orientations that I will use throughout this whitepaper.

The KY-1900 is a three-tube type color video camera which employs separate pickup tubes (Saticons) for red, green, and blue channels. As shown in the block diagram of Figure 7, incident light through the lens

is split into three colors by the dichroic beamsplitters as shown in Figure 8. JVC added RGB color filters inside the second relay lenses to improve color reproducibility.

As shown in Figure 9, the modification to turn the JVC KY-1900 camera into a real-time polarimetric imager consists of exchanging the original dichroic beamsplitters by wideband beamsplitters, eliminating the color trimming filters, and adding polarization analyzers.

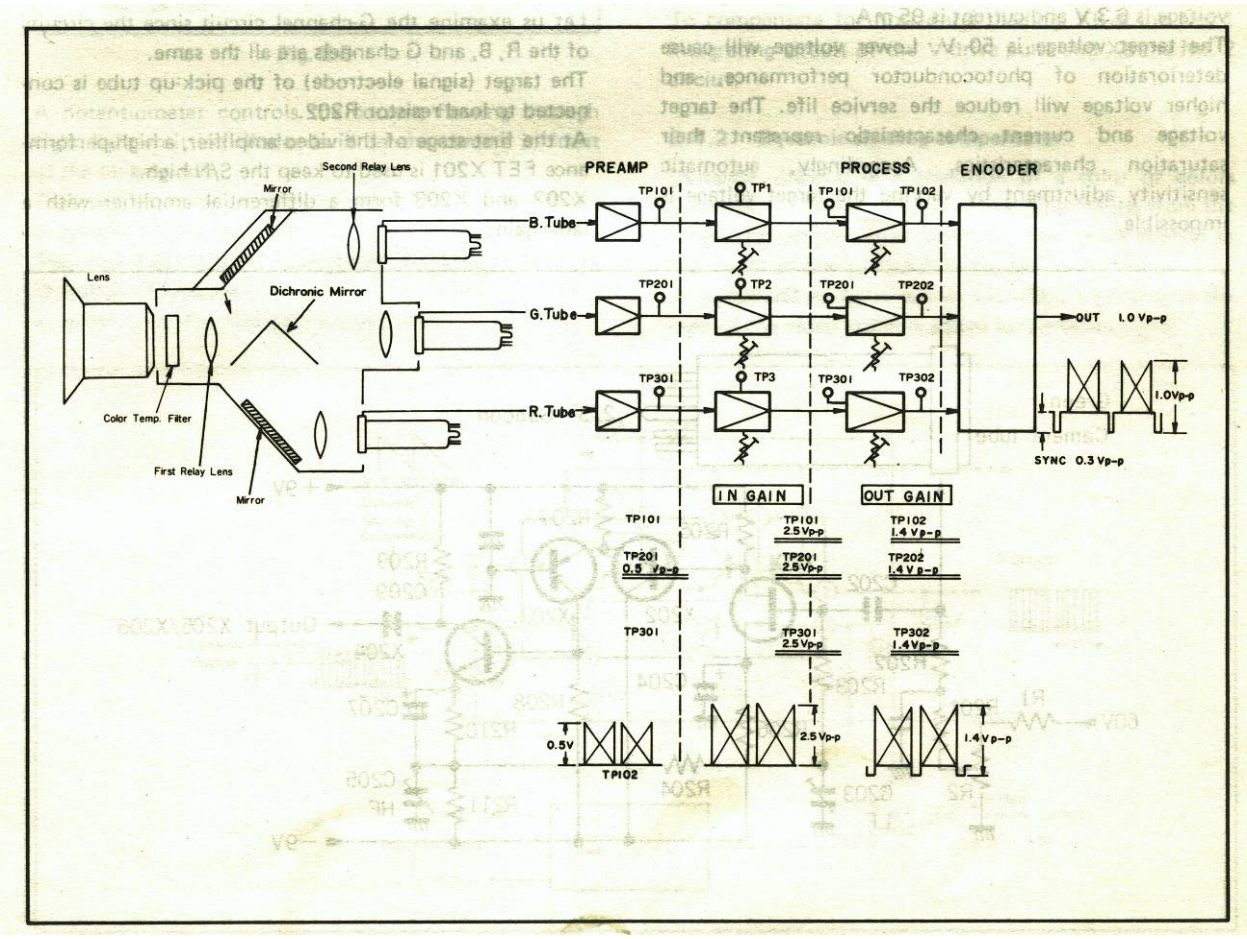


Figure 7 – Block diagram of the JVC KY-1900 camera [2].

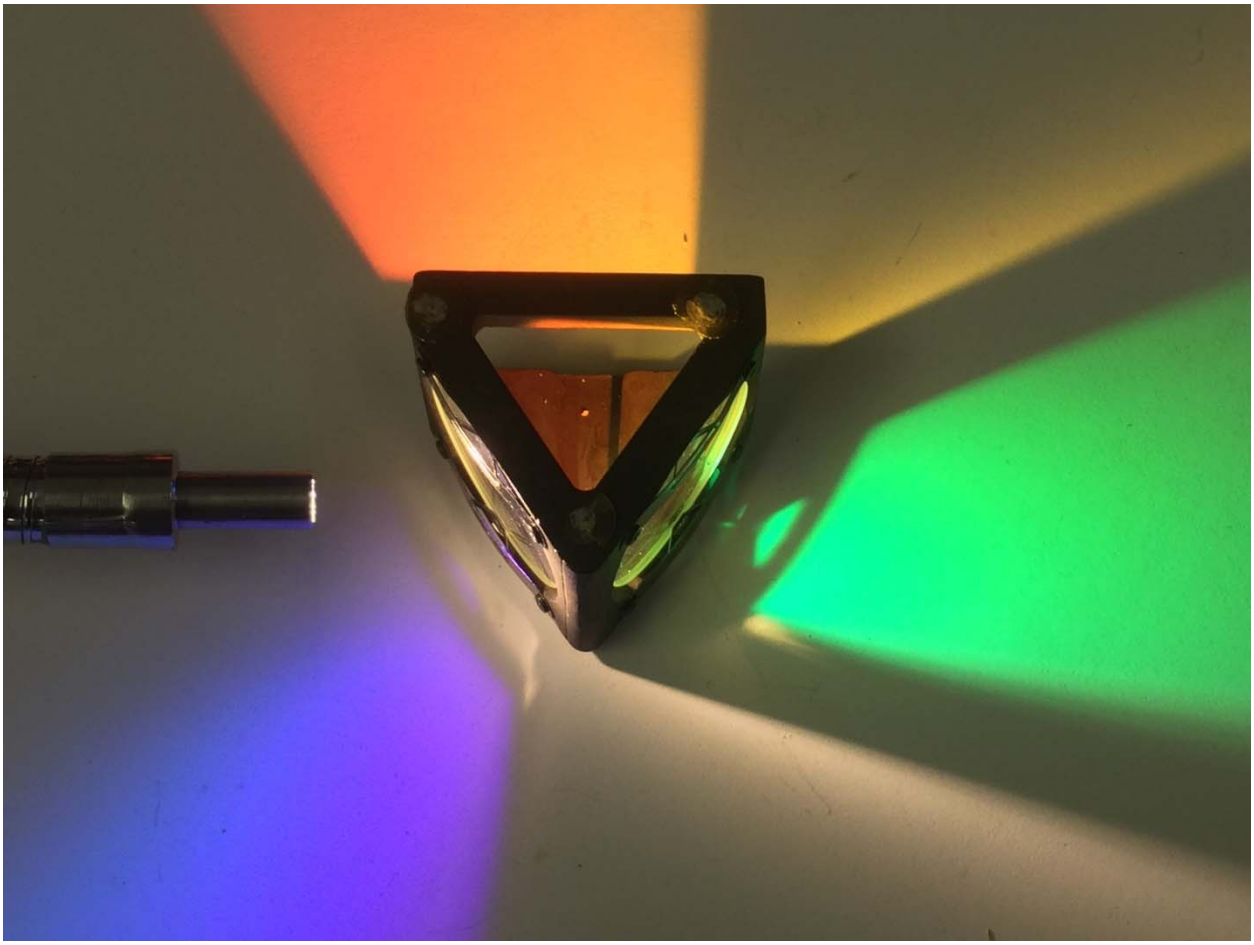


Figure 8 –Illuminating the original dichroic beamsplitter assembly with white light shows how it cleanly separates into red, blue, and green light cones. This is because the dichroic multi-layer beamsplitters are responsible for separating the image into its RGB components. The beamsplitters thus have to be replaced by wideband versions so that the assembly simply produces three equal copies of the image.

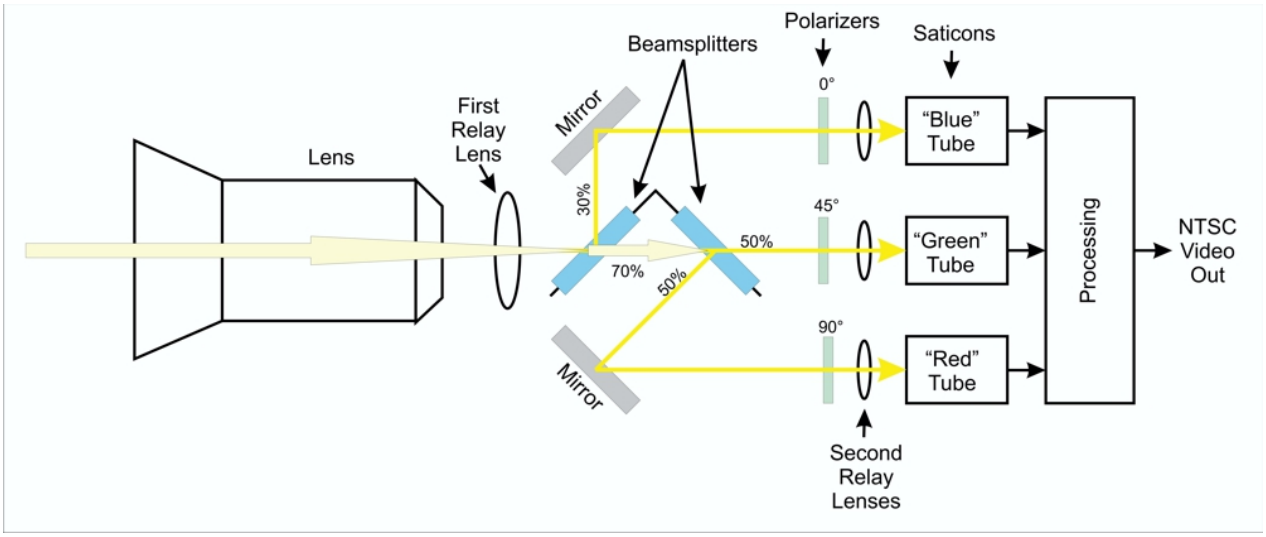


Figure 9 – The modification to turn the JVC KY-1900 camera into a real-time polarimetric imager consists of exchanging the original dichroic beamsplitters by wideband beamsplitters, eliminating the color trimming filters, and adding polarization analyzers.

Conversion

I'm writing this section with step-by-step instructions in case that someone else wants to build his/her own real-time polarimetric imager. Now, I wasn't able to locate a manual for the KY-1900, but did so for the KY-2000 [2]. The cameras seem to be very similar, so the manual proved helpful. Please take note of this in case you follow my instructions and notice discrepancies between the sections of the manual that I present and my photographs.

In fact, from a cursory look at the service manual, it looks to me that the same instructions would apply to the KY-1900's slightly younger sibling, the KY-2000. It's possible that these instructions may even be applicable to the KY-2700.

Before proceeding with the modification, connect a color monitor (Figure 10) to the video output BNC connector to make sure that the camera is in working order and well aligned. You may use JVC's original instructions shown in Appendix II to align your camera and check that it works correctly.

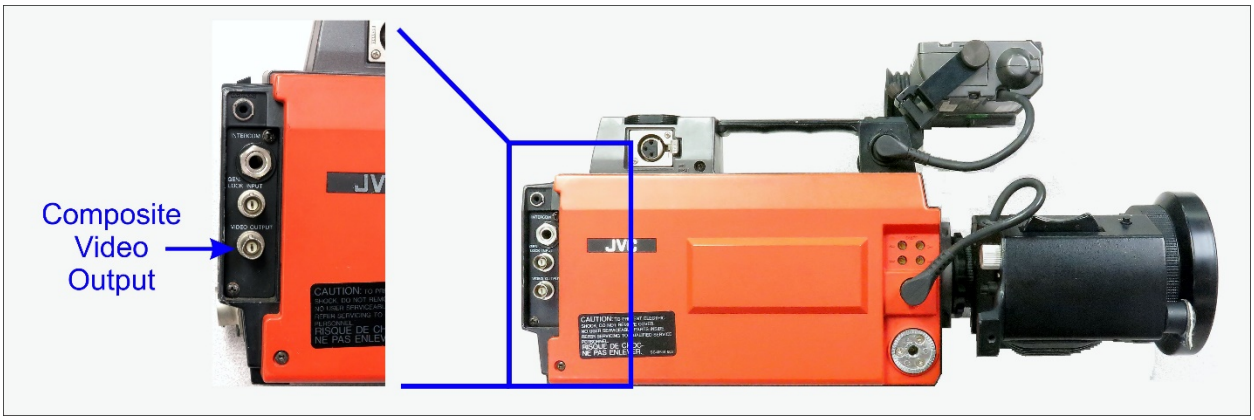


Figure 10 – A standard composite-video color monitor should be connected to the JVC KY-1900 camera's video output for alignment and viewing.

Step 1 – Access Optical Assembly

The first step is to access the camera's optical assembly, which involves the following steps:

Take apart the camera's left cover by removing the screws indicated in the following picture:

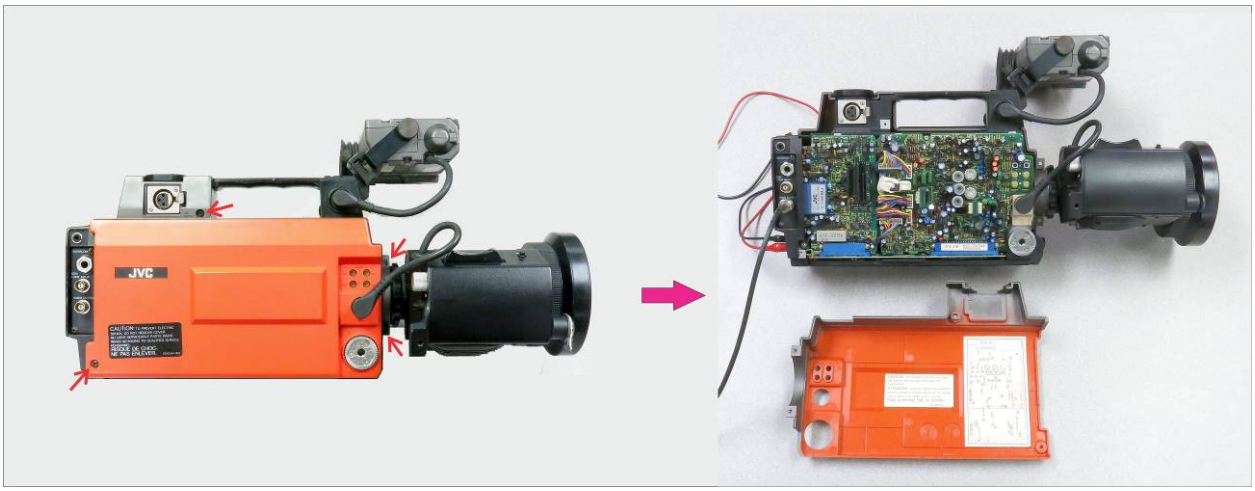


Figure 11 – Screws that need to be removed to take apart the camera's left cover. The two screws on the lens retainer are accessible from the camera's right side.

Next, remove the DF printed circuit board as shown in the following picture:

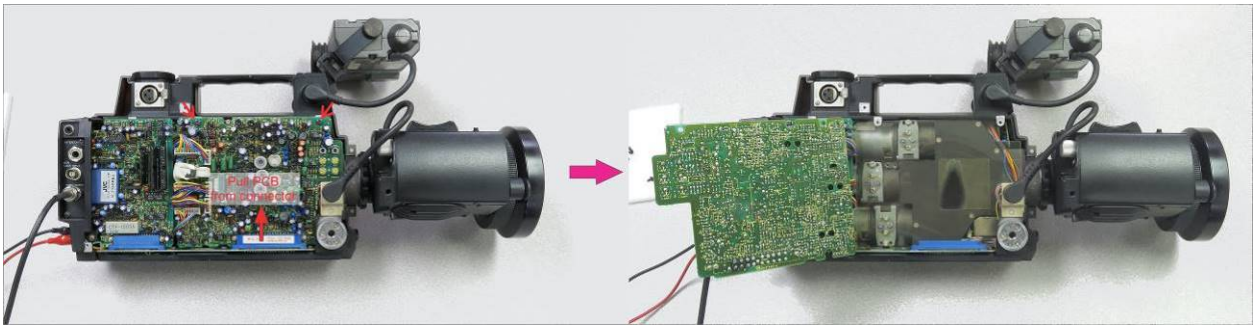


Figure 12 – Removal of the DF printed circuit board

Next, peel-off the plastic isolation sheet that is attached with double-sided tape to the optical assembly's outer cover plate. Remove the plate as shown in the following picture:

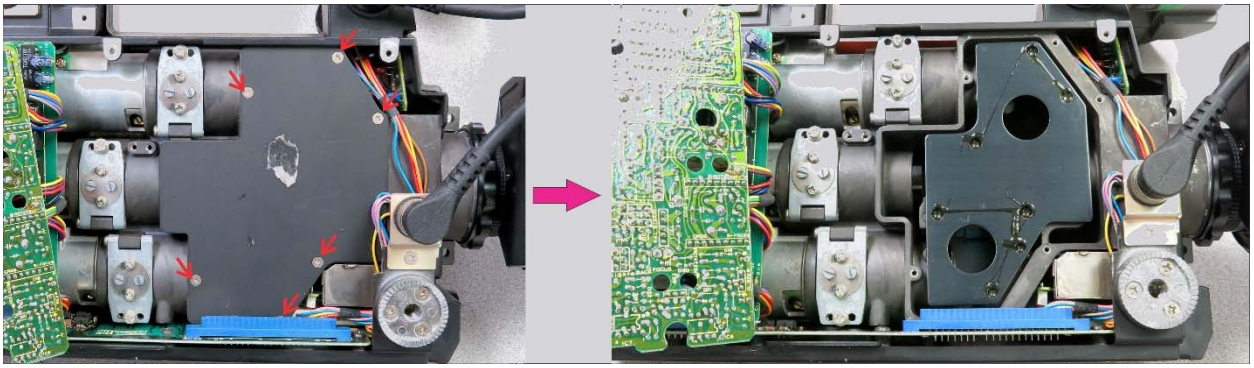


Figure 13 – Removal of the optical assembly's outer cover plate

Next, pry off the inner optical assembly cover plate. This plate is glued to the assembly. The plate won't be used again, so don't worry about distorting it. However, be careful not to damage the optical elements within the assembly.

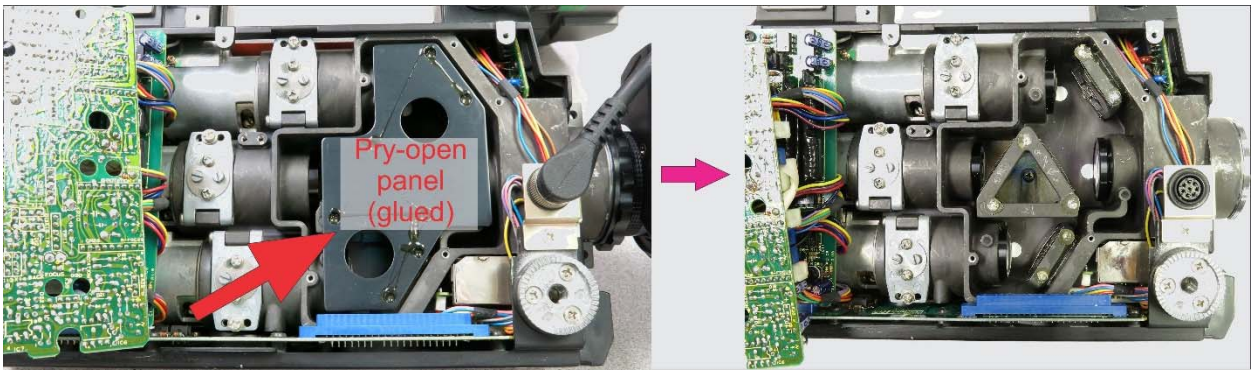


Figure 14 – The inner optical assembly cover plate is glued to the assembly. It must be pried-open, being careful not to damage the optics underneath.

Figure 15 shows the optical assembly of the unmodified JVC KY-1900 camera. Incident light through the First Relay Lens is split into three colored images by the dichroic beamsplitters before they are sent to their respective Saticon image pickup tubes via Second Relay Lenses. The modification into a real-time polarimetric imager will be explained in the next steps which involve exchanging the original dichroic beamsplitters of the Dichroic Beamsplitter Assembly by wideband beamsplitters, eliminating the color trimming filters inside the Second Relay Lenses, and adding polarization analyzers.

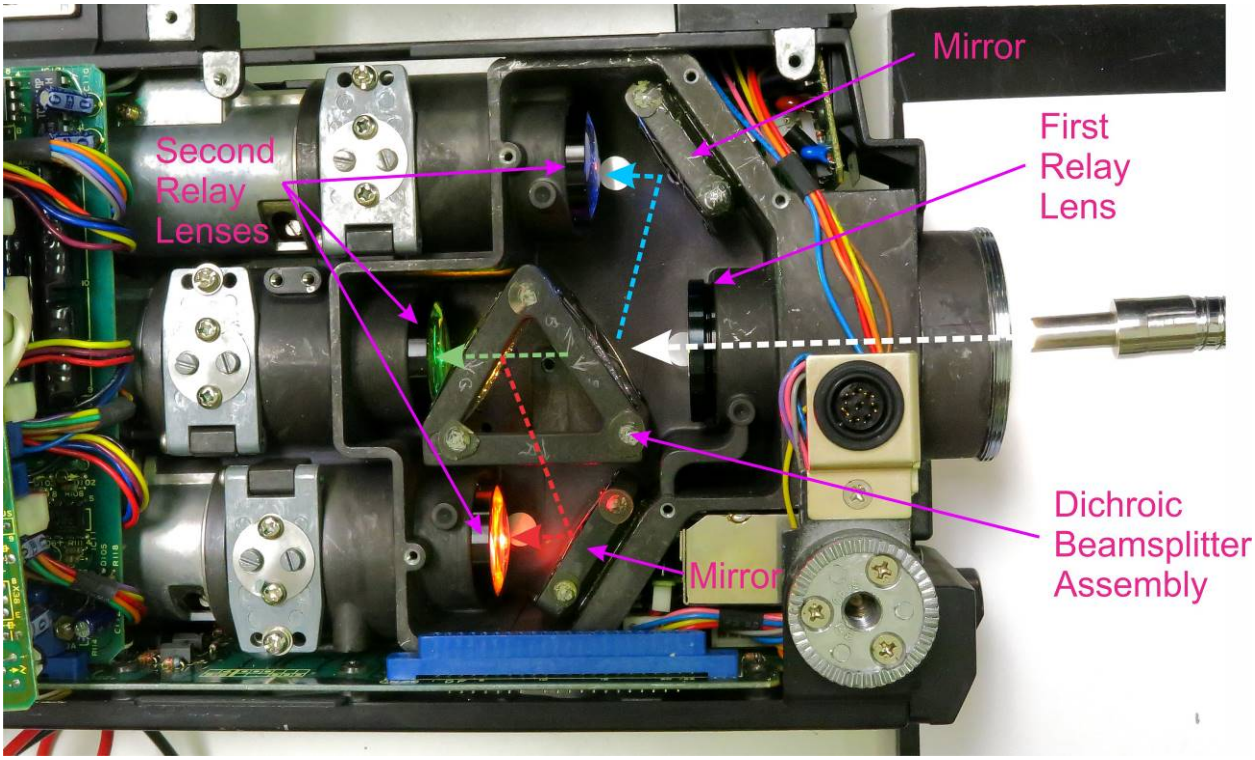


Figure 15 – The optical assembly before modification. Incident light through the First Relay Lens is split into three colored images by the dichroic beamsplitters before they are sent to their respective Saticon tubes via Second Relay Lenses (see Figure 7).

Step 2 – Remove Dichroic Beam Assembly

Before proceeding forward, it is a good idea to check that the camera still works. You can plug in the DF PCB, making sure that nothing shorts against the exposed parts of the optical assembly.

The Beamsplitter Assembly is held with three screws, one from the front and two from the back. As such, the right-side cover, PCB, and plastic film must be removed as shown in the following figure:

Figure 16 – The right-side cover, printed circuit board, and transparent plastic film must be removed to access the backside screws that retain the Dichroic Beamsplitter Assembly.

The Beamsplitter assembly can then be removed by taking three screws as shown in the following picture:

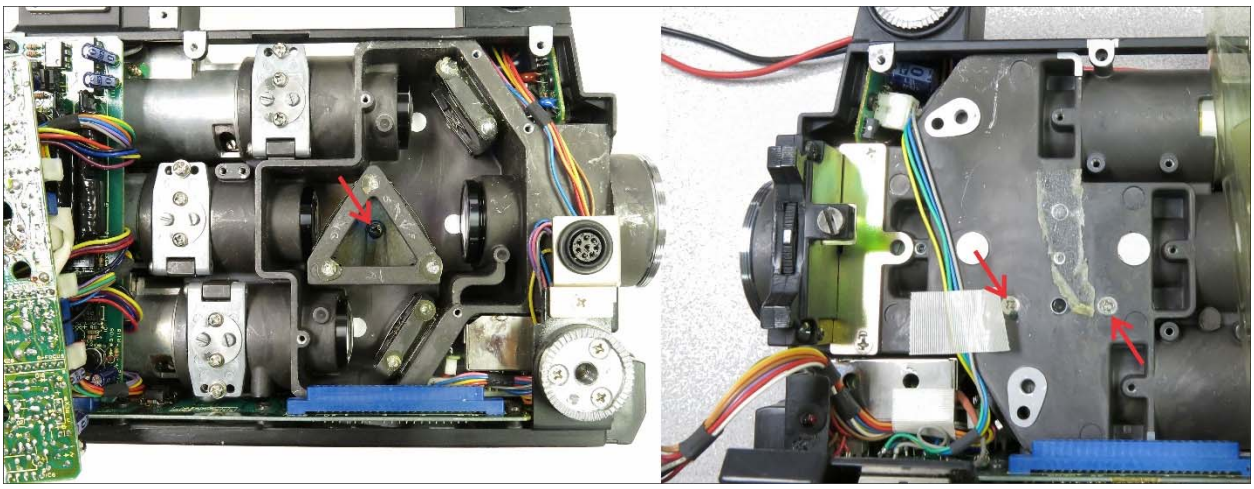


Figure 17 - The Beamsplitter Assembly is held with three screws, one from the front and two from the back.

Step 3 – Replacing the Dichroic Beamsplitters by Wideband Beamsplitters

The next step in the conversion process is to replace the dichroic beamsplitters by wideband beamsplitters. The image needs to be more-or-less equally split into three images, so the first beamsplitter needs to reflect around 33.33% of the incident light, while allowing 66.66% of the light to go to a second beamsplitter that should then split this portion evenly. The original dichroic beamsplitters were 34.8mm diameter, which is not standard, so instead I chose to use the following 1" commercially-available beamsplitters as good approximations for the job:

- Thorlabs BSS10, Ø25.4mm, UVFS, 70/30 Beamsplitter, BBAR 400-700nm ($97.92)
- Thorlabs BSW10, Ø25.4mm UVFS, 50/50 Beamsplitter, BBAR 400-700nm ($97.92)

My friend and colleague Jason Meyers designed and 3D-printed a retainer ring to hold these in place. A schematic of this adapter ring is presented in Figure 18. CAD and 3D-printing files are available here.

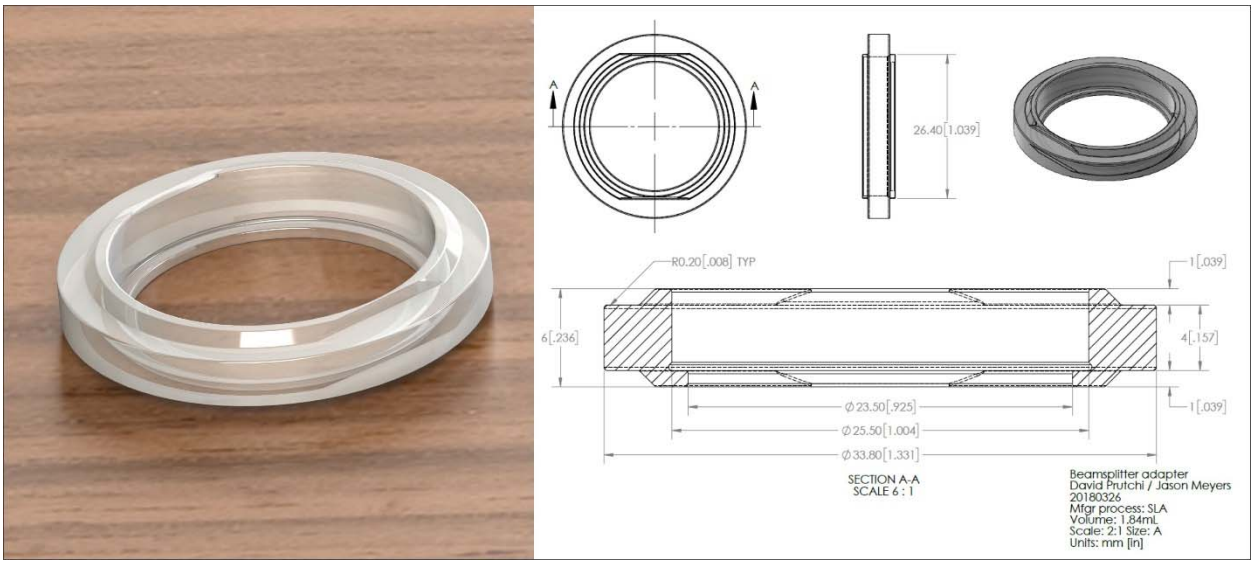


Figure 18 – Beamsplitter adapter ring designed and 3D-printed by Jason Meyers

The wideband beamsplitters within the retainer rings should then be installed in the assembly as shown in the following figure:

Figure 19 – I used 1" wideband plate beamsplitters to replace the original dichroic beamsplitters. 3D-printed retainer rings are used to hold the plate beamsplitters in place.

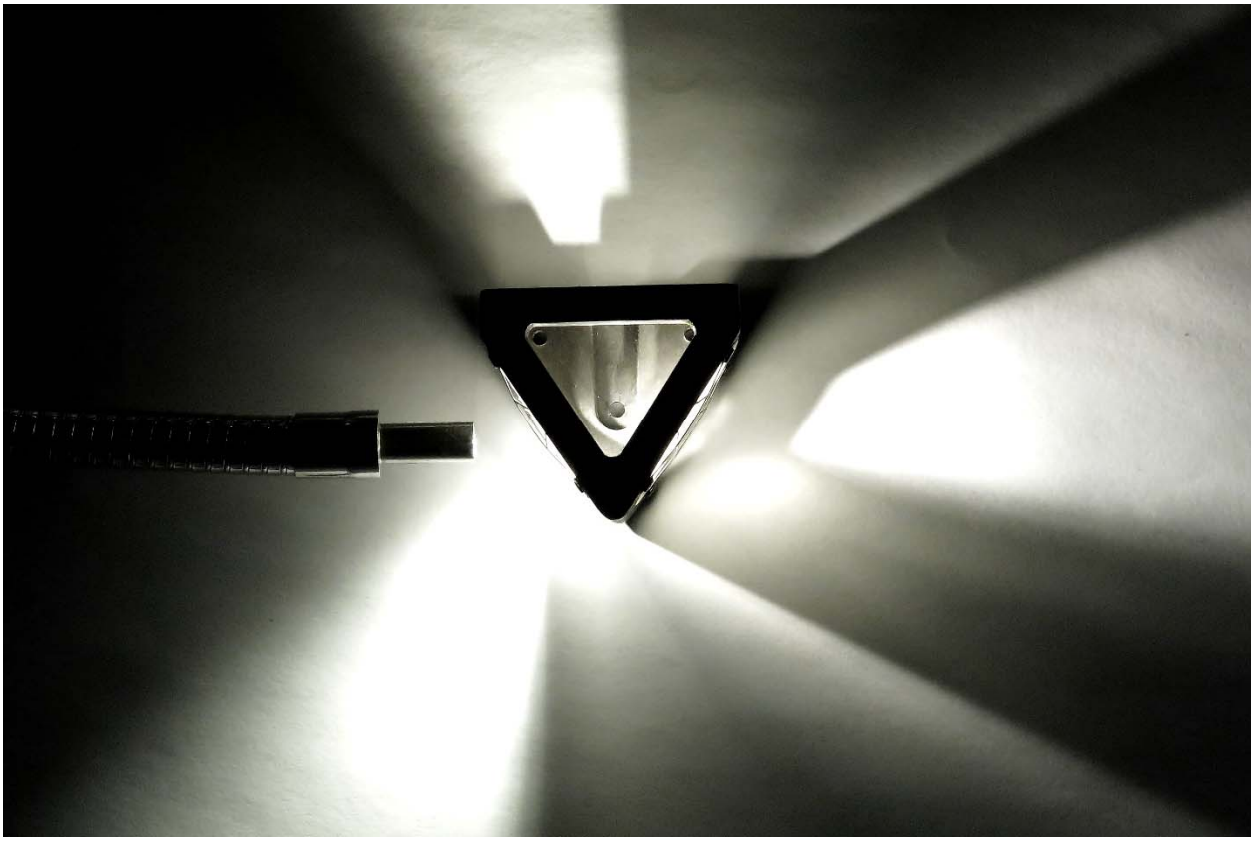


Figure 20 – The modified Beamsplitter Assembly splits an incident white-light beam into three beams of approximately equal intensity.

The modified Beamsplitter Assembly can now be installed back in place. Temporarily reconnect the circuit boards. Making sure that nothing shorts against the exposed parts of the optical assembly, power-up the camera. Only minor adjustment of the horizontal/vertical potentiometers should be needed to reach alignment if you correctly placed the beamsplitters. You will notice that the image is still in color, albeit a bit washed-out in comparison to the original image. The image still shows up in color because there are very strong filters within the Secondary Relay Lenses that still need to be removed.

Step 4 – Removal of Color Filters from Secondary Relay Lenses

Removing the Secondary Relay Lenses from the optical assembly takes some additional disassembly of the camera. This is because the Saticon tubes must be removed before the Secondary Relay Lenses can be taken out.

Start by taking out and disconnecting the printed boards from the cable assemblies. Then remove the back of the camera as shown in the following figure:

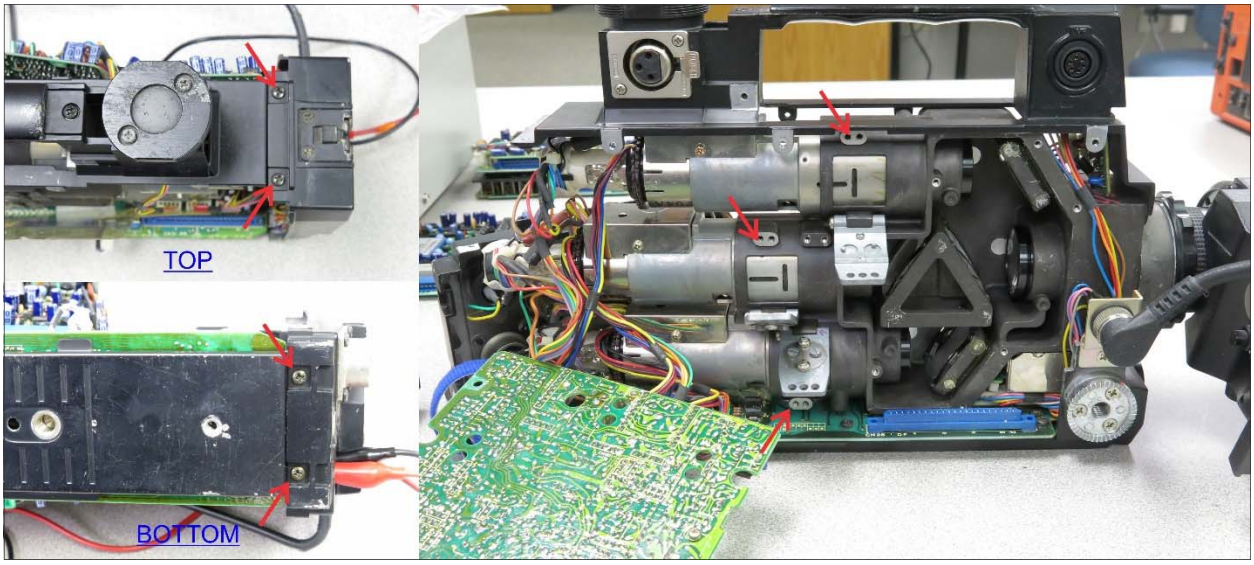


Figure 21 – Access to the tubes requires removing the right- and left-side PCBs, as well as the camera's back.

The Saticon tube assemblies can then be pulled off the tube housings of the optical assembly, giving access to the Secondary Relay Lenses as shown in the following figure:

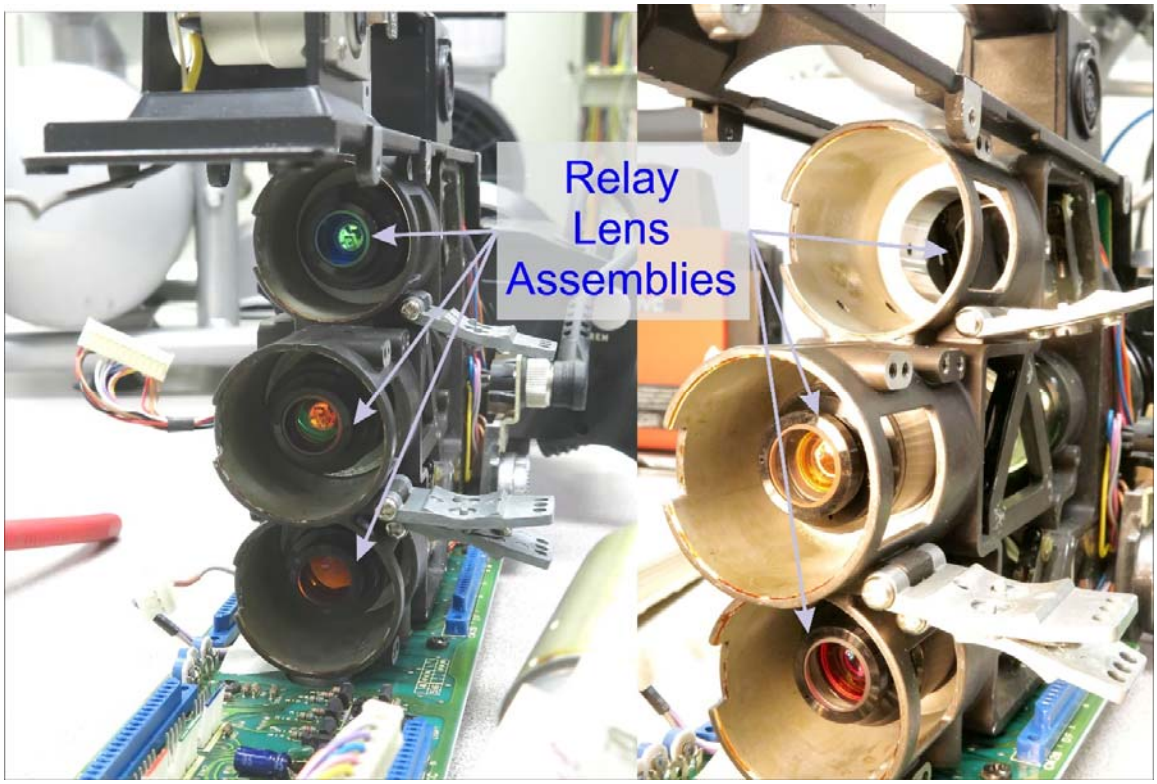


Figure 22 – The Secondary Relay Lenses can be accessed once the Saticon tube assemblies are removed from the housings.

The Secondary Relay Lenses are held in place by well-hidden, small setscrews accessible from the right side of the optical assembly as shown in the following picture:

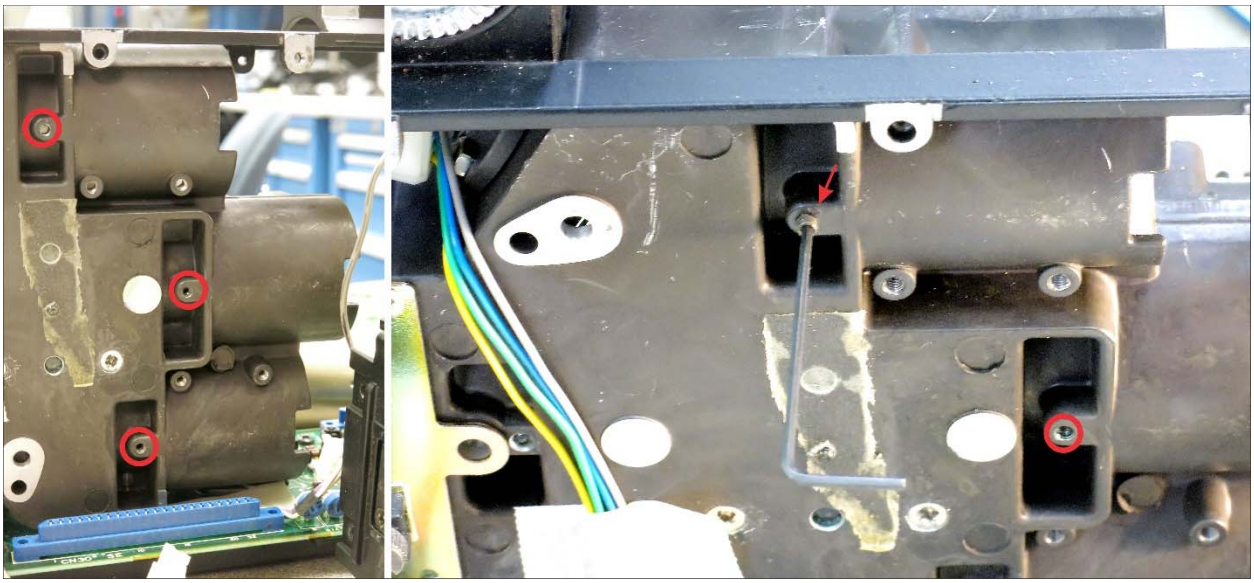


Figure 23 – The Secondary Relay Lenses are held in place by small setscrews

IMPORTANT: Work on one Secondary Relay Lens at a time. As shown by the dimensions of the filters in Figure 24, each lens assembly is different than the others.

Figure 24 – The color filters inside the Secondary Relay Lenses have different diameters.

Once the setscrew is open, pull out the Secondary Relay Lens on which you are going to work. Wrap a few layers of thick electrical tape over the two sides of the optical tube and open it using pliers as shown in the following figure:

Figure 25 – A relay lens can be opened by first wrapping its optical tube with thick electrical tape to prevent marring, and then unscrewing it apart using pliers.

The color filter can then be removed by unscrewing the retainer ring using a spanner wrench or very pointy tweezers. After removing the filter, simply reassemble the lens and finger-tighten.

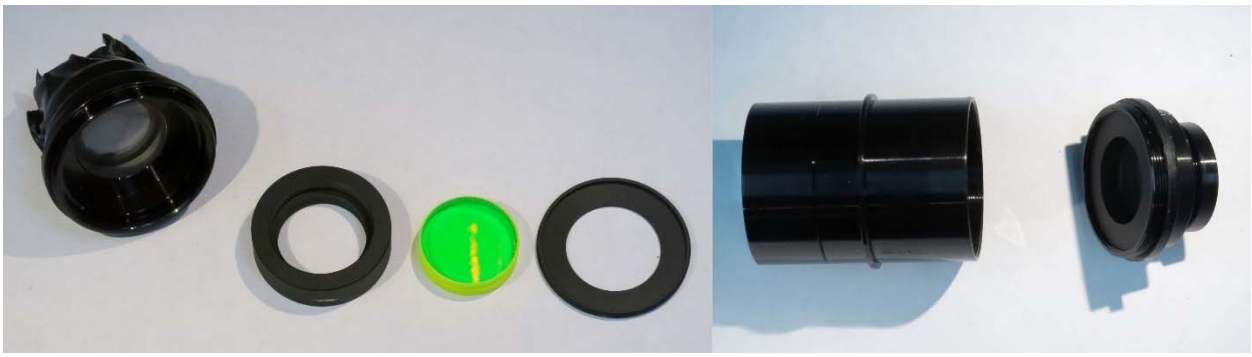


Figure 26 – The Secondary Relay Lens should be reassembled without the color filter.

Eliminating the color filter shifts the focal point of the Secondary Relay Lens, so it shouldn't be reinserted all the way into the optical assembly. Instead, as shown in the following figure, the modified Secondary Relay Lenses should protrude only about 2.5mm:

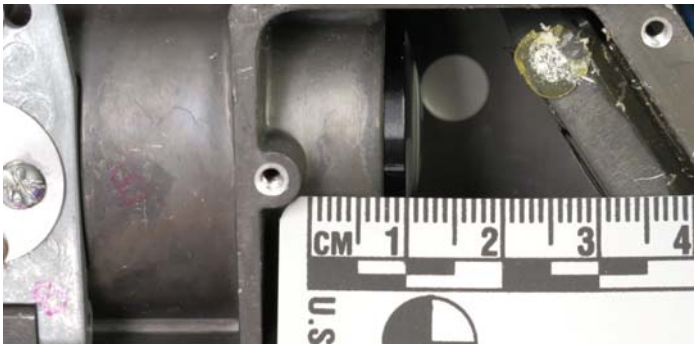


Figure 27 - Eliminating the color filter shifts the focal point of the Secondary Relay Lens, so it shouldn't be reinserted all the way into the optical assembly. Only 2.5mm should protrude from the die-cast frame.

The camera can be reassembled after installing and securing with setscrews all of the modified Secondary Relay Lenses. Leave the optical assembly accessible, and only reconnect the DF board temporarily, making sure that it doesn't short-circuit with the optical assembly.

Step 5 - Alignment

Now is time to align the camera very carefully so that it produces a perfectly black-and-white picture. Some level of color fringing will always be seen because the Secondary Relay Lenses were designed for a narrow band of wavelengths and are now being used over the full bandwidth of visible light. The fringing is especially noticeable at the edges of the image when the zoom is pulled all the way back, but decent registration can be achieved by patiently following the procedure outlined in Appendix II. The simple pattern in Appendix I was most helpful in this tedious task.

The two following figures show the location of the trims of the PCBs of the KY-1900 camera:

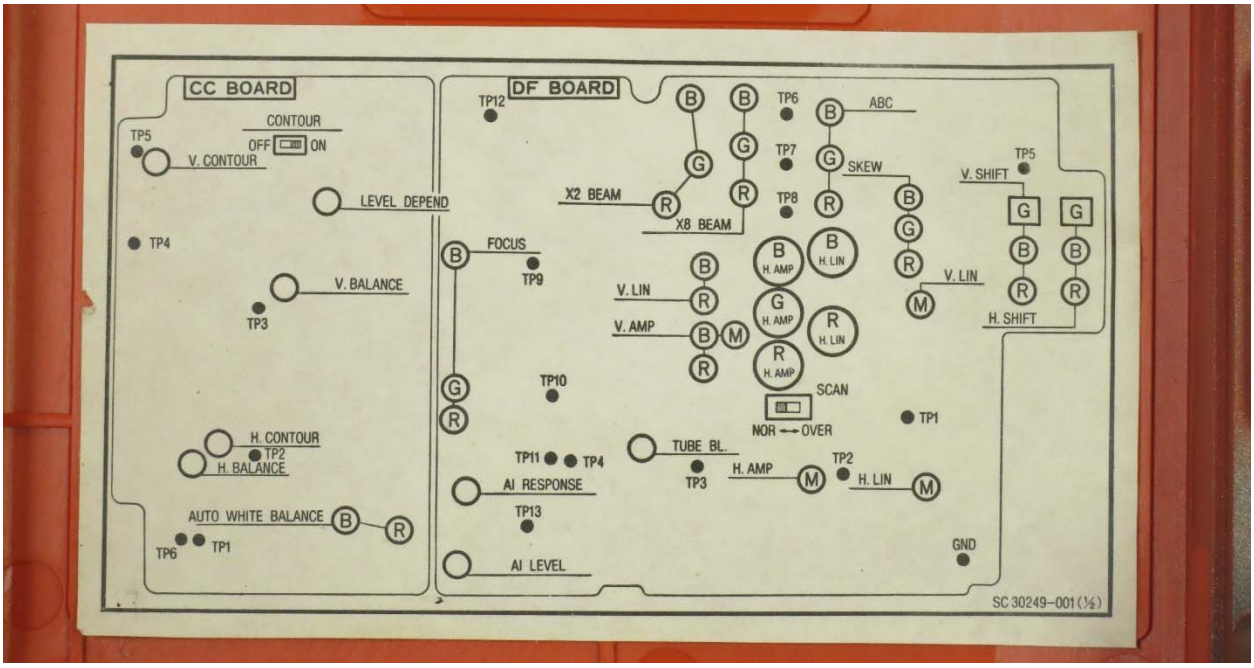


Figure 28 – Trims on the left-side PCBs of the JVC KY-1900 camera

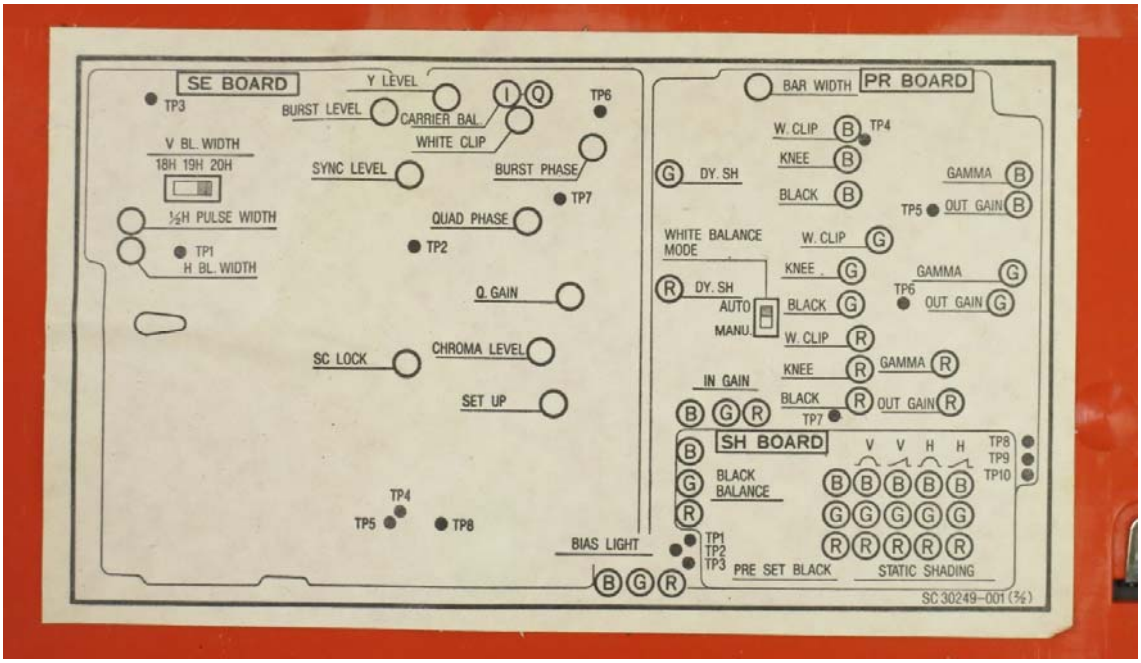


Figure 29 - Trims on the right-side PCBs of the JVC KY-1900 camera

Step 6 – Adding the Polarization Analyzers

The last step in the conversion process is to add polarization analyzers in front of each channel. I cut three 1.42”×1.42” squares out of a sheet of Edmund Optics 86-188 150 x 150mm, 0.75mm Thickness, Polarizing Laminated Film ($50). I chose this film instead of cheaper offerings because it features a very high extinction ratio, as well as high transmission, which make for better polarimetric images. Notice in the following figure that one of the squares is cut at 45° with respect to the other two.

Figure 30 – The polarization analyzer filters for the polarimetric camera are cut from Edmund Optics 86-188 150 x 150mm, 0.75mm Thickness, Polarizing Laminated Film. Note that one of them is cut at 45° with respect to the other two.

After peeling the protective films, I attached the polarization analyzers with clear tape as shown in the following figure:

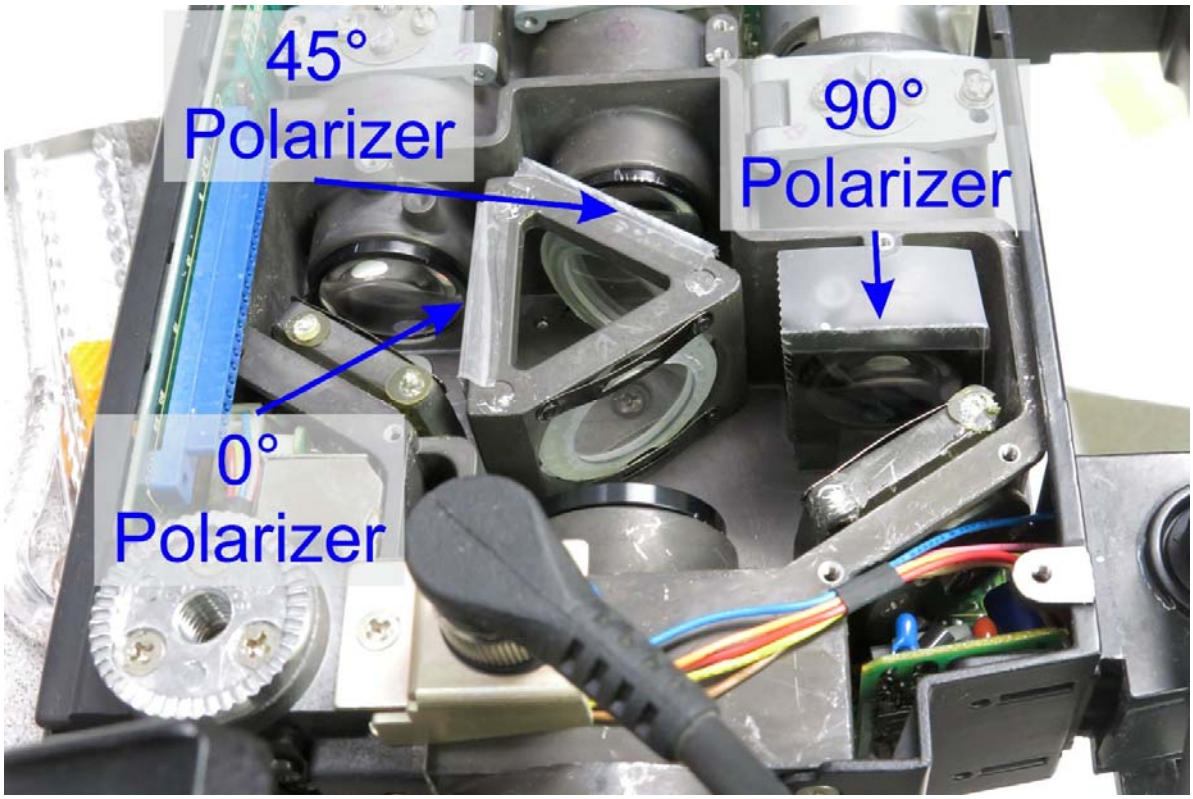


Figure 31 – The three polarization analyzers are placed in the optical path leading to their respective Secondary Relay Lenses.

That's it! The conversion is complete. You can test the camera at this stage before reassembling the optical assembly's cover (I discarded the inner cover), reattaching the plastic sheet, reconnecting the DF board, and closing the camera's enclosure.

Performance

One of the reasons to check the camera before modifying it is to see what would be the best possible image that the unmodified camera could produce. I had forgotten how bad TV images were back in the early 1980s compared to today's 4K UHD. In addition, cameras of the time were rather insensitive, so good illumination is needed to yield a decent image.

The Saticon tubes resolved around 400 horizontal TV lines (HTVL), which means that 200 distinct dark vertical lines and 200 distinct white vertical lines can be counted over a horizontal span equal to the height of the picture. HTVL is an inherent quality of the camera and should not be confused with the 525 horizontal scanning lines of the NTSC broadcast television system (although vertical TVL is affected by the number of scan lines). By comparison, modern broadcast-quality analog cameras achieve a TVL of 540 with an approximate resolution equivalent to 352×240 pixels. This is very coarse compared to even the

lowest high-definition mode (720p at 1,280×720 pixels), not to mention 4K UHD at 3,840×2,160 pixels. As such, the converted camera cannot reach the resolution of DoLPi cameras, which use the Raspberry Pi camera with a resolution of up to 3,280×2,464 pixel.

Beyond the lack of spatial resolution, the other major issue with this conversion is the lack of polarimetric resolution and reproducibility. Remember that I'm relying using the color separation and encoding scheme of a NTSC camera, whereby TV techs asserted that "NTSC"[2] stands for "Never the Same Color." From my experiments using a video-to-USB converter that yields 8-bits per RGB channel, I estimate that at most 5 to 6 effective bits per channel can be expected from this camera. So, unless the polarimetric application allows for low polarization resolution, and proper calibrations are used prior to making measurements, I would consider this camera to yield qualitative-only results. In comparison, the Raspberry Pi camera that I used in the DoLPi polarimetric cameras yields a solid 10-bit depth, which is certainly enough to produce scientific quality data useful for many high-performance applications [3]. Additionally, the analog nature of the camera does not permit direct use of a dynamically-scaled colorspace, hence preventing subtle differences in polarization to be visualized.

However, what this polarimetric camera lacks in resolution, it makes up in speed. The NTSC standard ran at 29.97 frames/s (nominally "30 frames/s"), which is dramatically faster than a frame every few seconds for the DoLPi-Mech, or even 8 frames/s for the DoLPi-EO in 640×480 pixel low-resolution mode. Moreover, and unlike the DoLPi cameras, the three polarization images used to create the RGB-encoded image are acquired simultaneously by the three Saticon tubes, so moving objects do not produce false polarization ghosts.

Figure 32 and Figure 33 show results with sample targets constructed from pieces of polarizing plastic at angles between 0° and 180°. The target as captured from the modified JVC KY-1900 camera shows non-polarized elements of the picture in gray-scale, while the polarized items are brightly colored, encoding their angle of polarization in NTSC's RGB space.

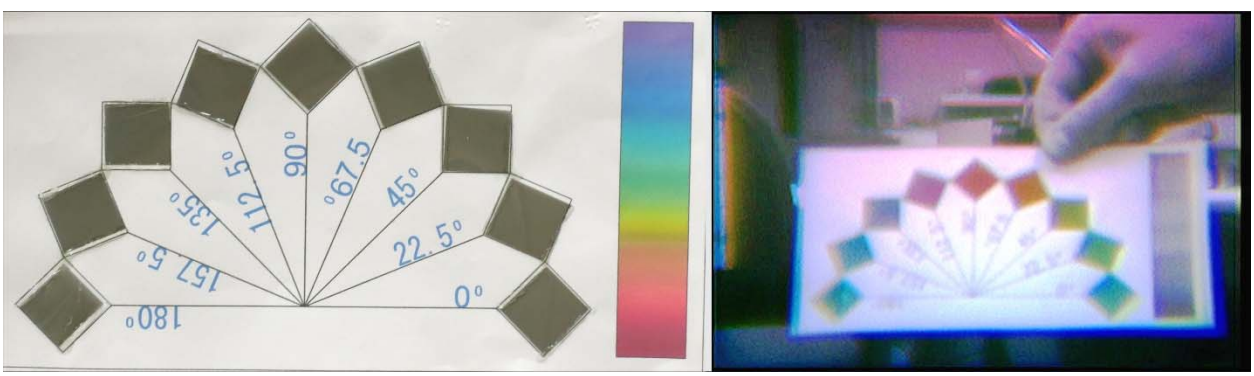


Figure 32 – Left: a sample target with pieces of polarizing plastic at angles between 0° and 180° along with a colorbar. The target as captured by the modified JVC KY-1900 camera shows the colorbar and other non-polarized elements of the picture in gray-scale, while the polarized items are brightly colored, encoding their angle of polarization in RGB space.

[2] NTSC actually stands for "National Television System Committee"

Figure 33 – Left: a sample target with pieces of polarizing plastic at angles between 0° and 180°. The target as captured from the modified JVC KY-1900 camera encodes the angle of polarization of the polarizing plastic samples in RGB space.

Acknowledgements

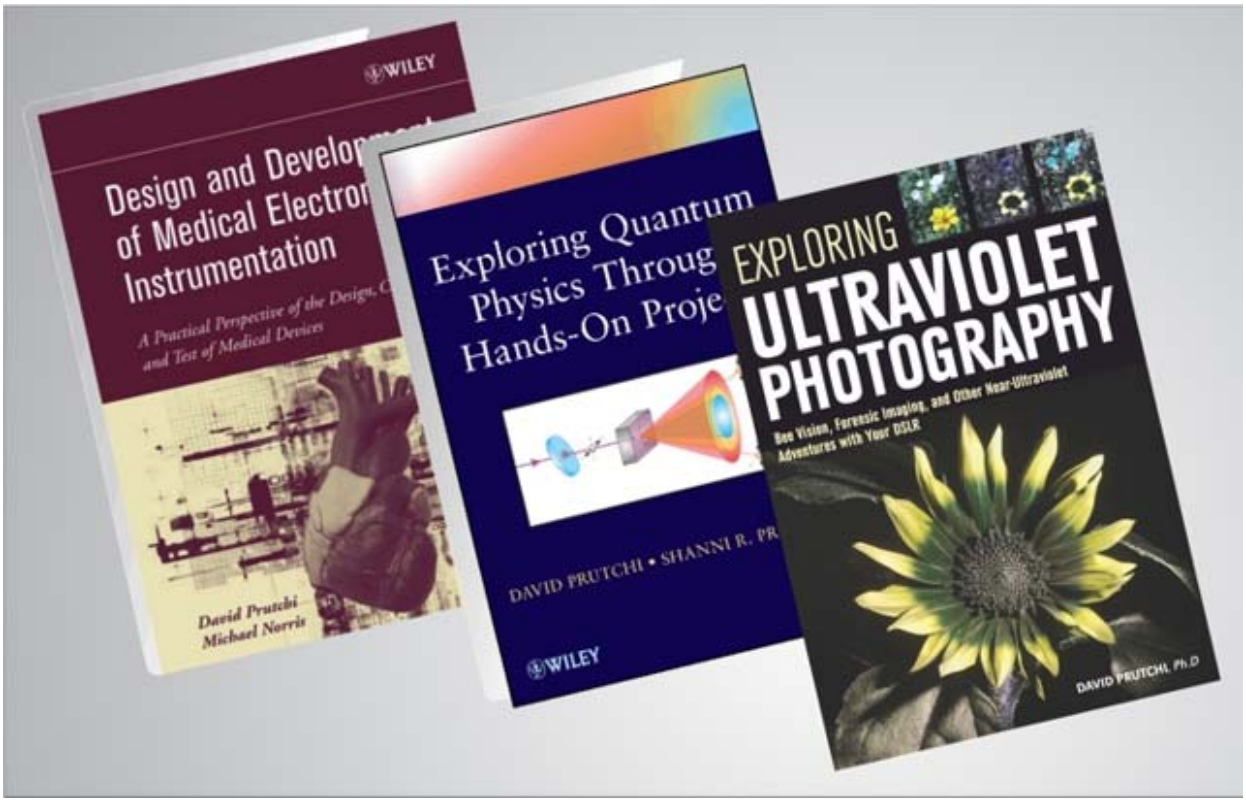
Thanks to Jason Meyers not only for designing and 3D-printing the beamsplitter adapters, but for all the help figuring out how to take apart the relay lenses!

References

1. Johnston P, *JVC KY-1900 "Back to the Future" 1984*, 2012, http://www.hdwarrior.co.uk/2012/01/22/jvc-ky-1900-back-to-the-future-1984/
2. JVC, *JVC Service Manual for Color Video Camera model KY-2000*, JVC Service Manual No. 6331, 1979
3. Pagnutti MA, Ryan RE, Cazenavette GJ, Gold MJ, Harlan R, Leggett E, Pagnutti JF, "*Laying the foundation to use Raspberry Pi 3 V2 camera module imagery for scientific and engineering purposes*," J. Electron. Imag. 26(1) 013014 (11 February 2017) Available online at: https://www.spiedigitallibrary.org/journals/journal-of-electronic-imaging/volume-26/issue-01/013014/Laying-the-foundation-to-use-Raspberry-Pi-3-V2-camera/10.1117/1.JEI.26.1.013014.full?SSO=1
4. Prutchi D, *DOLPi – A Low-Cost, RasPi-based Polarization Camera Duo*, 2015, http://www.diyphysics.com/wp-content/uploads/2015/10/DOLPi_Polarimetric_Camera_D_Prutchi_2015_v5.pdf

Further Reading and Experiments

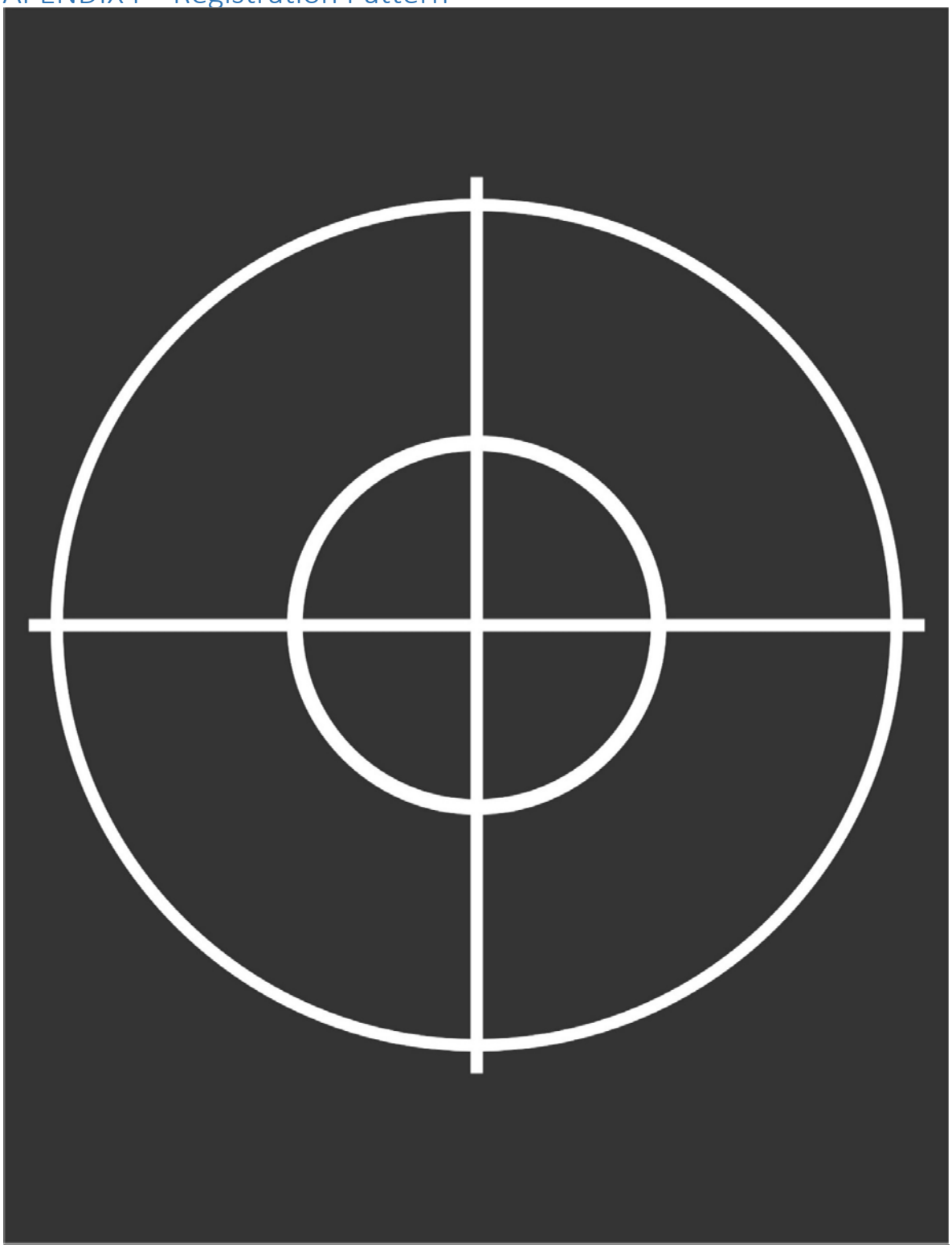
For more interesting experiments on physics and photography of the unseen world, please look through my books (click here for my books on Amazon.com):



and go to my websites:

www.diyPhysics.com and www.UVIRimaging.com

APENDIX I – Registration Pattern



Appendix II – Alignment Procedure

NOTE: This procedure is from KY-2000 service manual [2], which has a DF board that closely matches that of the JVC KY-1900.

5.2 INTRODUCTION

The procedure of this section is to be used for alignment of the KY-2000 color video camera under 3200 Kelvin illumination.

If the JVC KY-2000 should fail, be sure to check all voltage and waveforms before attempting any adjustments. Note that correct operation is achieved only when all circuits are properly adjusted, and therefore, improper adjustment of a single "block" of circuits may disrupt all functions. The best procedure is to locate the cause of trouble first, then begin repair, replacement or adjustment.

5.3 ALIGNMENT EQUIPMENT

5.3.1 Equipment needed

The following equipment is required in order to perform the alignment:

- Oscilloscope : Tektronix 465, or equivalent
- Monochrome monitor : High-resolution type with underscan
- Color monitor : Tektronix 650, or equivalent
- Vectorscope : Tektronix 520A, or equivalent
- Lighting : 3200 K lamps more than 4000 lux (370 fc)
- Light meter : Minolta Autospot or equivalent
- Standard test patterns : 1. Resolution, EIA/RETMA or equivalent
  2. Gray scale, EIA Log. or equivalent
- Power supply : AC adaptor AA-C20
- Voltmeter : VTVM or digital voltmeter (accuracy within ± 1%)
- Following simple jig : Fig. 5-1

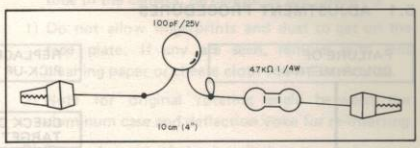


Fig. 5-1 RC jumper

5.4 GENERAL SET-UP

1. See Fig. 5-2.
2. Lighting
   Be sure to use an illumination lamp offering 3,200 K color temperature. Also adjust illumination intensity of the pattern surface at approximately 2,500 lux (230 Fc). Simultaneously adjust the distance between the camera lens and the pattern to maintain uniform illumination. In this instance, note that improper adjustment may produce a poor waveform.
3. Application of oscilloscope EXIT TRIG terminal
   Apply video signals to the VIDEO OUT terminal on the color TV monitor.
4. Checking waveform of composite video signals
   Use the VIDEO OUT terminal on the TV monitor connected with a 75 Ω resistor to check the waveform of the composite video signals.

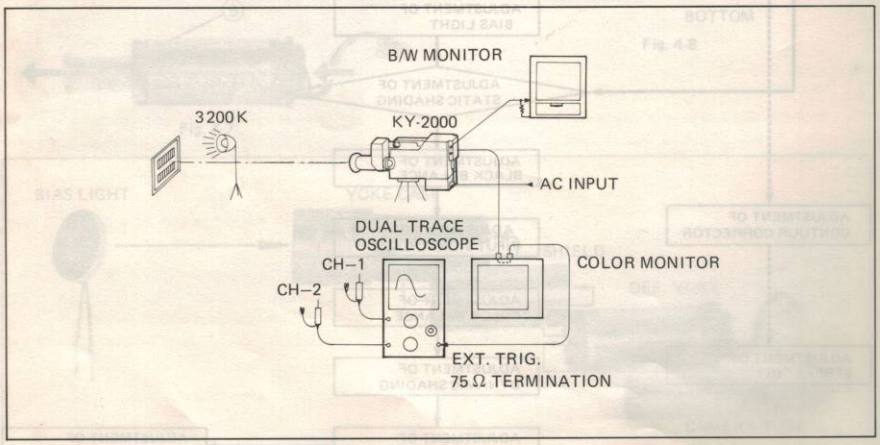


Fig. 5-2

5-2

5.5 PRELIMINARY ADJUSTMENT

5.5.1 Adjustment of +9 V power source

(1) Connect a VTVM or equivalent to TP9 on the DF board.

(2) Adjust "+9 V ADJ" (R161) to read 8.9–9.1 V.

5.5.2 Adjustment of filament voltage

In this camera, the filaments of the three pick-up tubes are connected in series.

(1) Connect the voltmeter to TP8 on the DF board.

(2) Adjust "+18.9 V ADJ" (R156) to read 18.5–18.9 V.

5.5.3 Adjustment of regulated FOCUS voltage

The camera's electrostatic focus may become worse after this adjustment. Adjust it with potentiometer FOCUS of each pick-up tube.

(1) With the voltmeter, select a range higher than 200 V.

(2) Connect the voltmeter to TP3 on the DF board.

(3) Adjust "180 V ADJ" (R17) so that the reading is 175–185 V.

5.5.4 Checking the electrode voltage

Use VTVM or digital voltmeter to check following voltages (of DF board).

1. HM-1 side . . . . . +950 ± 50 V
2. CN24 ⑨ Pin . . . . . +570 ± 30 V
3. D9 Cathode . . . . . +300 ± 20 V
4. C33 ⊖ side . . . . . –95 V ± 10 V

5.6 ADJUSTMENT OF AFTER THE CAMERA TUBES REPLACED

5.6.1 Adjustment of target voltage (PA board)

1. Check the voltage at test point TARGET (TP1) on the PA board with a voltmeter.
2. Adjust potentimeter TARGET VOLTS (R2) if the voltage is not 50 ± 1 V.
   Never allow the voltage to exceed 65 V.
   This completes adjustment of the three pick-up tubes.

5.6.2 Adjustment of focus (DF board and optical block)

1. Use the "C" lens. The HZ-2000P standard lens may be used if the "C" lens is not available.
2. When the HZ-2000P is used, loosen the lock screw shown in Fig. 3-10 of HZ-2000P Manual, align the reference marks accurately, and tighten the lock screw.
3. Set switch SCAN on the DF board to "OVER".
4. Open the lens apertuture. Take the picture of the resolution or registration test pattern.
5. Confirm that the test pattern appears on a monitor TV connected to TEST OUTPUT.
6. Operate switch VF & TEST OUTPUT SELECT to examine the R, G, and B pictures. If nothing appears, the beam current is absent or the illumination is too low.
7. If there is no beam current, turn the potentiometers (R40 for R, R26 for G, and R43 for B) on the DF board clockwise.
8. Set switch HI-SENS to 0 dB. Open the lens aperture fully. Illuminate the object so that it is just visible on the monitor TV. The brightness is 500 to 1,000 lux (49 to 98 fc) at this time. Adjustment is easy in this condition.
9. Set switch VF & TEST OUTPUT SELECT at G.
10. Focus the lens at the telephoto end.
11. Adjust potentiometer ELECTRIC FOCUS (R26) on the DF board for optimum focus.
12. Zoom the lens to the wide-angle position. Adjust the back focus screw of the G-channel pickup tube for optimum focus. The screw is accessible with a screwdriver through a hole in the DF board. Loosen the LOCK screw by one or two turns prior to adjustment, and tighten it after adjustment.
13. For the R and G channel pick-up tubes adjust the ELECTRIC FOCUS potentiometers and BACK focus screws in the same way.
    Set switch VF & TEST OUTPUT SELECT at a suitable position prior to adjustment.
14. For a C-mount lens, measure the distance between the test pattern and camera accurately and turn the lens focus ring to the measured distance instead of operating the zoom ring. Then adjust the ELECTRIC FOCUS and BACK FOCUS screws.

5.6.3 Adjustment of picture size on pick-up tubes (DF board)

1. Monitor a green channel. Zoom the lens fully to the telephoto position. Adjust the angle of the camera or pattern so that the registration pattern come to the center of the mask and is parallel with the camera. Adjust the ROTATION screw if the mask and pattern cannot be made parallel with the raster.
   Loosen the LOCK screw one or two turns before adjusting the ROTATION screw and tighten it after adjustment. (Fig. 5-3)

5-3

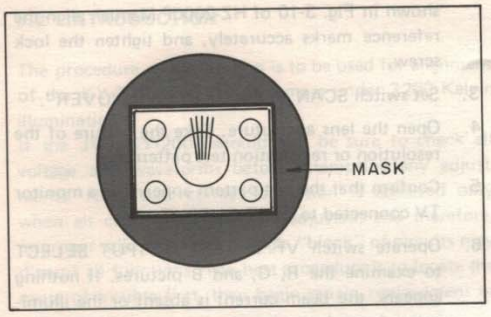


Fig. 5-3

2. Set switch SCAN on the DF board to NOR (normal scanning) after adjustment for G (Fig. 5-3).
3. Now the picture becomes dark. Increase illumination or open the aperture.
4. Adjust the GH AMP (L7) and Master V AMP (R91) so that the test pattern just appears on the screen of a TEST monitor TV (underscan-type professional black-and-white TV).
5. Adjust registration for R and G, and B and G. Refer to the section 5.7 describing registration adjustment.

5.6.4 Adjustment of beam current (DF board)

1. Illuminate the gray scale pattern with approximately 5,000 lux (460 Fc).
2. Connect an oscilloscope to TP201 (green) on the PA board and set the time division to 20 μsec and vertical gain to 0.5–1 V.
3. Take the picture of the gray scale with the size reduced to one third of the screen.
4. Open the lens aperture to raise the maximum output level to 1.5 V.
5. If 1.5 V is not reached, turn potentiometer BEAM (R42) for G on the DF board clockwise until 1.5 V is reached because the beam current is not enough.
6. Adjust the lens aperture so that the output signal level become 1.5 V.
7. Reconnect the oscilloscope to TP301 (red).

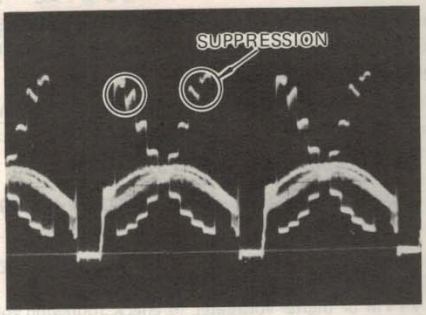


Fig. 5-5

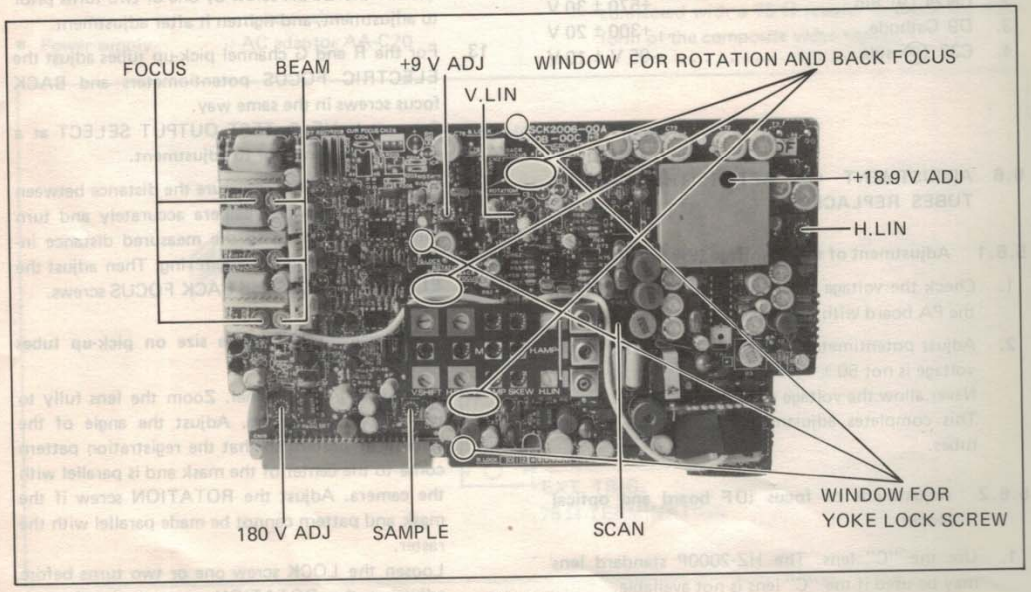


Fig. 5-4

8. Adjust BEAM (R40) for R on the DF board so that the output signal is just before suppressed.
9. Reconnect the oscilloscope to TP101 (blue).
10. Open the lens aperture by one f-stop from the values set in step 6.
11. Adjust BEAM (R43) for B on the DF board so that the output signal is just started suppression.

5.6.5 Beam alignment (DF board);

1. Take the picture of the registration test pattern so that it fills the screen of the TEST monitor TV (underscan-type professional black-and-white monitor TV required).
   Illuminate the test pattern with approximately 3,000 lux (284 fc).
2. Set switch VF & TEST OUTPUT SELECT at G.
3. Turn potentiometer ELECTRIC FOCUS (R26) on the DF board about 30° to the left and right a few times.
4. If the center of the test pattern moves to the left or right or up and down, adjust the two magnet rings fitted on the rear part of the green pick-up tube.

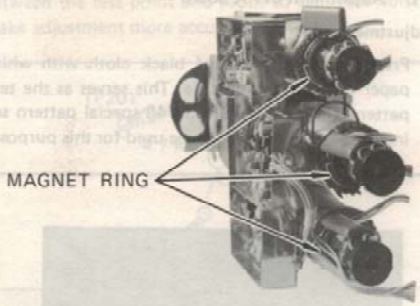


Fig. 5-6

5. If the adjustment is correct, it appears as if the center of the test pattern moves backwards and forwards.
6. If the test pattern moves on the TV monitor screen as adjustment is performed, adjust G-centering potentiometers R63 (H) and R109 (V) until the pattern just fits on the TV screen.
7. Perform the same adjustment for each of the R and B pick-up tubes.
9. Apply paint to lock the magnet rings after adjustment.

5.7 ADJUSTMENT OF REGISTRATION (DF board)

After making the following preparations, align the red or blue video signal relatively to the green video signal.

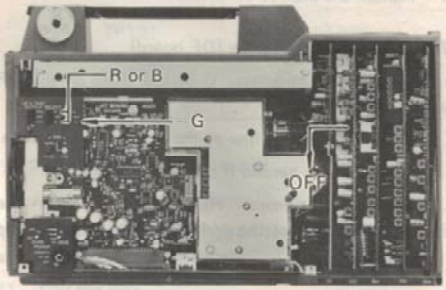


Fig. 5-7

1. Turn off switch CONTOUR (aperture correction switch) on the CC board. (Fig. 5-7)
2. Select −G instead of G with VF & TEST OUTPUT SELECT switch. This facilitates adjustment.
3. Let the registration test pattern just fits on the TEST monitor TV screen.

The adjustment described for the R channel below is the same as adjustment of the B channel but related controls should be moved.

5.7.1 Adjustment of rotation (optical block DF board side)

1. Set VF & TEST switch so that the images of both −G and R appear on the TEST monitor TV at the same time.
2. Watch the horizontal line at the center of the screen.
3. Adjustment is needed if the dark line (R image) is titled as shown in Fig. 5-8.

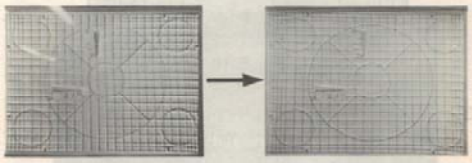


Fig. 5-8

4. Loosen the LOCK screw, shown in Fig. 5-4, one or two turns. Turn the ROTATION screw slowly until the white line (G image) becomes parallel with the dark line.

5. Tighten the lock screw firmly.

5.7.2 Adjustment of skew (DF board)

Do not move potentiometer G SKEW (R89 on the DF board) normally.

1. Watch the vertical line at the center of the screen.
2. Adjustment is needed if the dark line is tilted.
3. Adjust potentiometer RED SKEW (R88) on the DF board so that the dark and white lines become parallel.

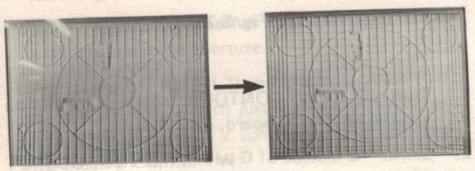


Fig. 5-9

5.7.3 Adjustment of horizontal size

Do not move MASTER H AMP and H-LIN normally.

1. Adjust potentiometer R-H REG1 (R56) so that the vertical lines become a single line at the center of the screen.
2. Linearity adjustment is needed if dark lines are shifted in the same direction at the left and right sides of the screen as shown in Fig. 5-10.

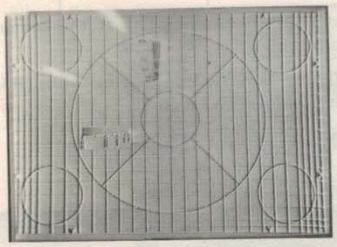


Fig. 5-10

3. Adjust the RED H. LIN potentiometer (R76) and red H. SHIFT potentiometer so that the dark and white lines come to the correct position.
4. If the horizontal lengths of the dark and white lines differ, it is necessary to adjust potentiometer red H. AMP (HORIZONTAL SIZE, L6).
5. Move red H. AMP and red H. SHIFT so that the lengths of the dark and white lines are equal.

5.7.4 Adjustment of vertical size

Do not move potentiometer V-LIN (R84) normally.

1. Move potentiometer red H. SHIFT (R56) until the horizontal lines at the center of the screen are aligned.
2. If the vertical lengths of the dark and white lines differ, it is necessary to adjust potentiometer V. AMP (VERTICAL SIZE, R95).
3. Move red V. AMP and red V. SHIFT so that the the lengths of the dark and white lines are equal.
4. Adjust red V. LIN (R178) if necessary (provided later models).

5.8 ADJUSTMENT OF VIDEO AMPLIFIER

Warm up the camera for an hour in a room at a temperature of 20° to 25°C before starting to adjust the video amplifier.

5.8.1 Adjustment of PA board

1. Adjustment of streaking

(1) Prepare a large piece of black cloth with white paper glued in the middle. This serves as the test pattern (Fig. 5-11). SPS-33/48 special pattern set includes a chart which can be used for this purpose.

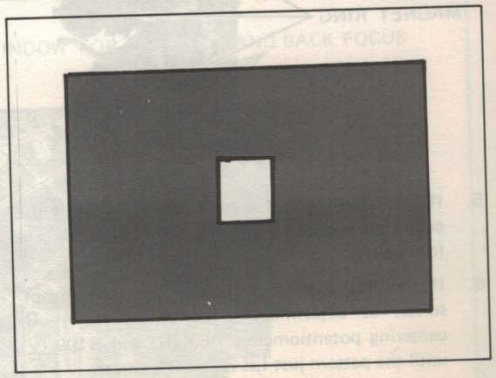


Fig. 5-11

(2) Illuminate the test pattern with about 3,000 lux (290 fc).

(3) For the G-channel, connect an oscilloscope to TP201 and set its time division to 20 μsec and vertical gain at 0.1–0.2 V/cm.

Appendix III – Saticon Tube Replacement Procedure

NOTE: This procedure is from KY-2000 service manual [2], which has a tube assembly that approximately matches that of the JVC KY-1900.

SECTION 4
REPLACEMENT OF CAMERA TUBE

IMPORTANT: Saticon handling

a. The Saticon is the heart of the camera. If a shock of more than 2.5G is applied to the face plate of the Saticon, the photoconductive film will be damaged.

b. Keep the face plate absolutely free of dirt and stains.

c. Clean the target ring well. Avoid staining the Saticon with finger marks.

4.1 REMOVAL OF CAMERA TUBE ASSEMBLY

1. To replace a pick-up tube, remove all plug-in boards but the mother and PA boards from the camera first. To remove the DF board, disconnect connectors CNC21 through 26 for the deflection yoke and camera tube and CN27 for the transistor X25 on the DF board.

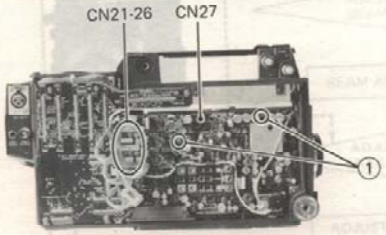


Fig. 4-1

2. Remove two screws (1), then, pull the circuit board up and remove.

3. Remove the shield cover from the PA (preamplifier) board. (Remove two screws (1) shown in Fig. 4-2.)

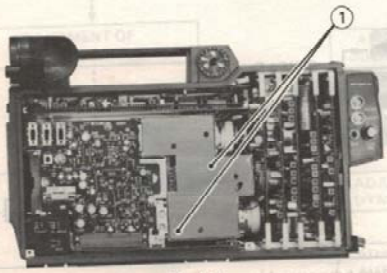


Fig. 4-2

4. Unsolder the target lead and grounding leads of the camera tube to be replaced and the leads of the bias lights.
See Fig. 4-3.

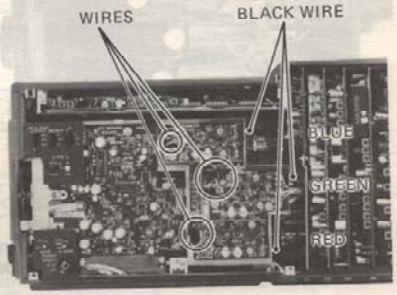


Fig. 4-3

5. Loosen screw (2) fastening the deflection yoke case of the camera tube. Remove two screws (3) and then the back focus and rotation mechanisms.
See Fig. 4-4.

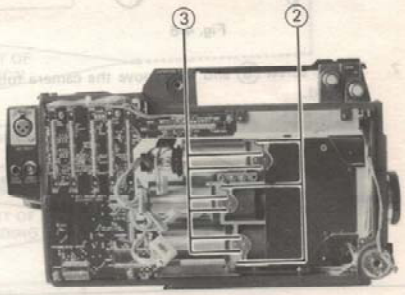


Fig. 4-4

6. Unsolder the grounding side of a capacitor from the shield case of PA board.

4-1

7. Pull the back of the deflection case in the direction of arrow to remove it from the optical block.

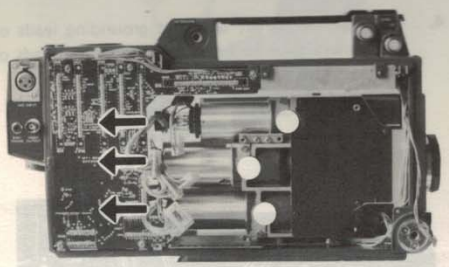


Fig. 4-5

4.2 REMOVAL OF CAMERA TUBE

1. Remove six screws (1) and (2) from the side of the camera tube assembly then remove the deflection yoke assembly.

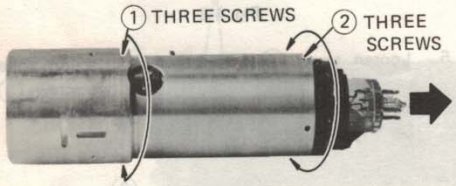


Fig. 4-6

2. Loosen screw (5) and then move the camera tube forward.

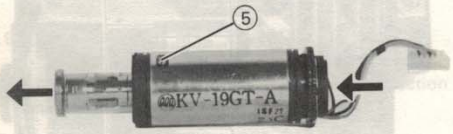


Fig. 4-7

4.3 REPLACEMENT OF CAMERA TUBE

1. By the reverse procedure, install a new camera tube in the camera. Be careful of the following.

1) Do not allow fingerprints and dust to get on the face plate. If any are seen, remove with lens cleaning paper or cheese cloth soaked in alcohol.

2) Note for original rotating angle between the aluminum case and deflection yoke for re-inserting.

3) The index pin of the installed camera tube must be horizontal with reference to the optical system. See Fig. 4-8.

4) The bias light assembly has index slots. If you removed the assembly, fit the keys into the slots when installing it into the aluminum case.

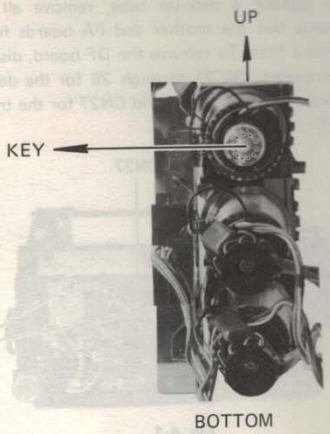


Fig. 4-8

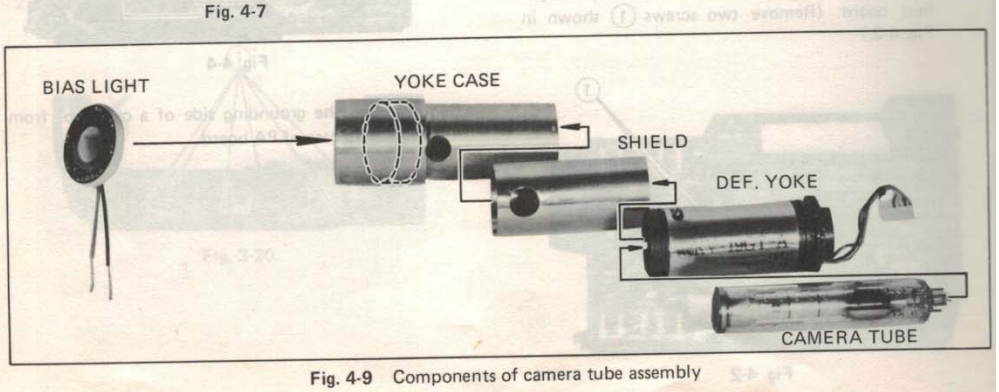


Fig. 4-9 Components of camera tube assembly

4-2