DIY Image Intensifier for Quantum Physics Experiments and other Feeble-Light Observations

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After many years of use, the image intensifier tube (IIT) in the image intensifier system that I use for my experiments in quantum physics (Figure 1) [3] developed some nasty half-moon shadows in the periphery, so I decided to rebuild it with another MX-10160-type IIT. This document shows the build step-by-step.

Figure 1 - Single-photon, two-slit interference setup, a black-and-white CCD camera looks directly at the phosphor screen of the MX-10160 image intensifier tube. The interference pattern is projected directly onto the intensifier tube's photocathode. Reproduced with permission from Prutchi D, Prutchi SR, Exploring Quantum Physics through Hands-On Projects, 335 pages, John Wiley & Sons, Inc., Hoboken, NJ, 2012.

The MX-10160 Image Intensifier Tube

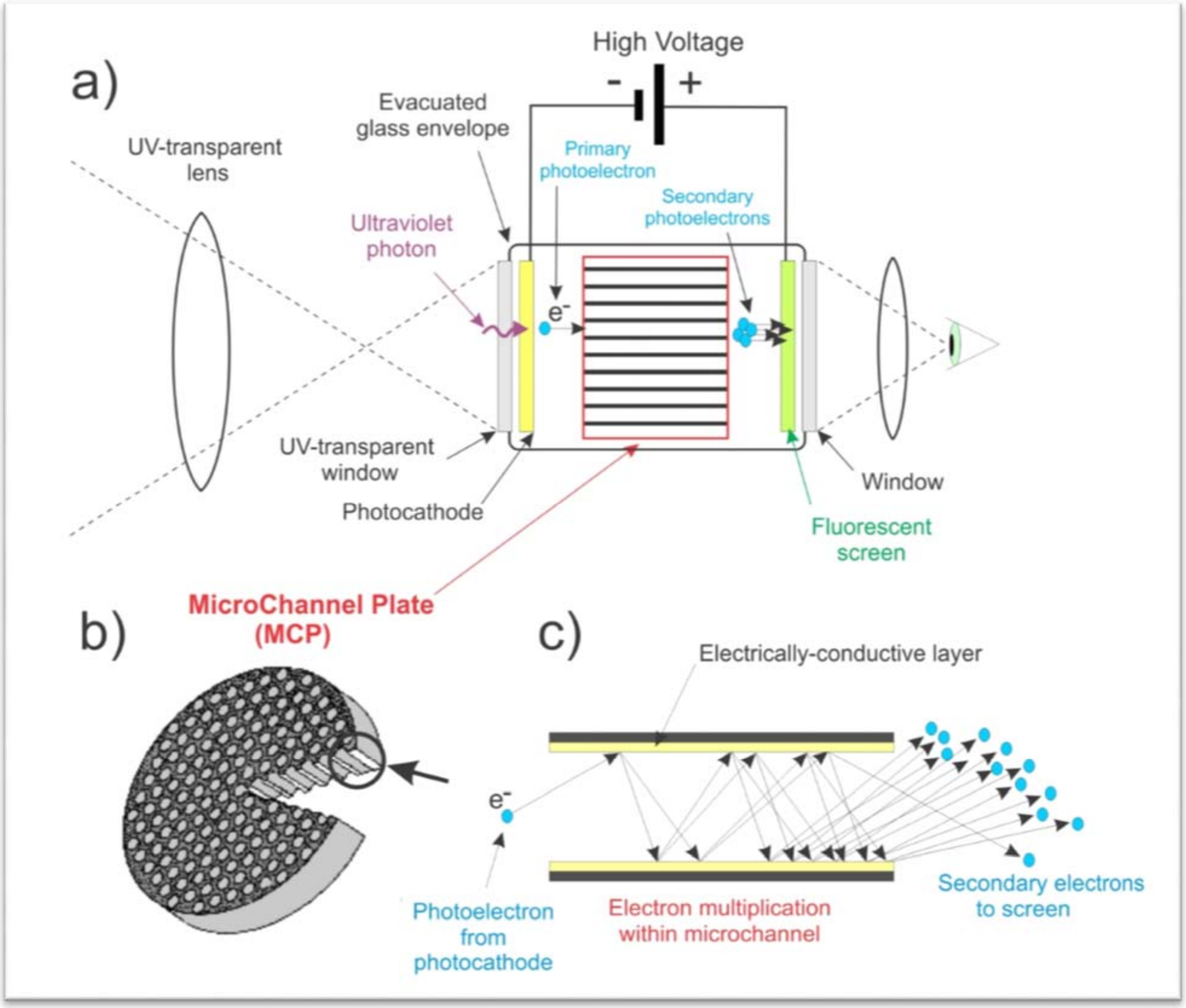


Figure 2 - Generation II and III image-intensifier tubes employ MicroChannel plate (MCP) electron multipliers to boost gain (a). b) MCPs are very thin plates of conductive glass containing scores of µm-diameter holes, c) in each of which a cascade of secondary electron emission occurs, directing an enormous amount of electrons towards the fluorescent screen for each electron entering the MCP. Reproduced with permission from D. Prutchi, diy Shortwave UV Image Converters for Solar-Blind and RUVIS Imaging, www.UVIRimaging.com Technical Note 2016-1, June 2016.

So-called "Generation I" image intensifier tubes are simple in design. They utilize only a single potential difference to accelerate electrons from the photocathode to the anode (screen). As such they achieve only moderate gain (a few hundred times), but provide high image resolution, a wide dynamic range, and low noise. In contrast, Generation II and Generation III tubes employ true electron multipliers to boost gain. That is, not only the energy but also the number of electrons between the photocathode and the screen is significantly increased. Multiplication is achieved by use of very thin plates of conductive glass containing scores of minute holes (each a few µm in diameter) inside which a cascade of secondary electron emission occurs. As shown in Figure 2, each hole in a *microchannel plate* (MCP) acts as a miniature photomultiplier tube. The difference between the second and third generations resides in the type of material used in the photocathode. The “multialkali” photocathodes in second generation tubes yield a current of around 300µA per lumen, while the gallium-arsenide photocathodes in third generation tubes have a luminous sensitivity of approximately 1,200µA per lumen, meaning that “Gen III” intensifier tubes can reach higher gains (up to 10^7 photons from the screen for every photon hitting the photocathode) than Gen IIs. Gain doesn’t come for free though – in general, Gen II and Gen III intensifier tubes have lower resolution and produce more noise than Gen I tubes.

For my system, I use the MX-10160, which is a Gen III 18mm image intensifier tube found in the AN/AVS-6 & 9 Aviators Night Vision Imaging Systems (ANVIS), most Gen III weapon sights, and many different goggles and monocular systems.

The MX-10160 series image intensifier consists of a high efficiency GaAs photocathode bonded to a glass input window, a microchannel plate current amplifier, and a P-43 phosphor screen deposited on an inverting fiber optic output window. The Gen III photocathode is very sensitive to low radiation levels of visible and, especially, near infrared light. Tube lifespan is an average of 12,000 hours continuous use.

MX-10160 is not a model number, but a very general specification for a Gen III 18mm IIT. The performance level is roughly defined by the “OMNI” (omnibus) contract under which a tube was purchased. However, all tubes of the MX-10160A/AVS-6 family perform roughly the same regardless of the OMNI contract and year of manufacture [2].

As shown in Figure 3, The MX-10160 IIT that I found on eBay® is a Model M890-DF1 made by L^3. This is an aviator-grade tube with Gen III photocathode. It has a thin-film ion barrier to extend Gen III I^2 life, an inverting optical element and electromagnetic shielding. It comes in a silver bullet housing. It only requires a +3VDC supply to operate. The M890 is an “OMNI IV/ OMNI V” tube meant for Aviator's Night Vision Imaging Systems (ANVIS). Dimensions for this IIT are shown in Figure 4. Approximate specifications for this tube based on NGEOS datasheets are as follows [2]:

- Resolution: 64 lp/mm
- Photocathode sensitivity: 1800 µA/lm@2,856°K, 80 µA/lm@880nm
- SNR: 21
- Gain: 40,000 – 70,000 f_L/f_c
- FOM: 1,344
- EBI: 2.5×10^{-11}
- MTF@25lp/mm: 38
- BLR: 12
- Halo: 1.25 mm
- Phosphor: P-43
- Year of manufacture: 1996 - 1999

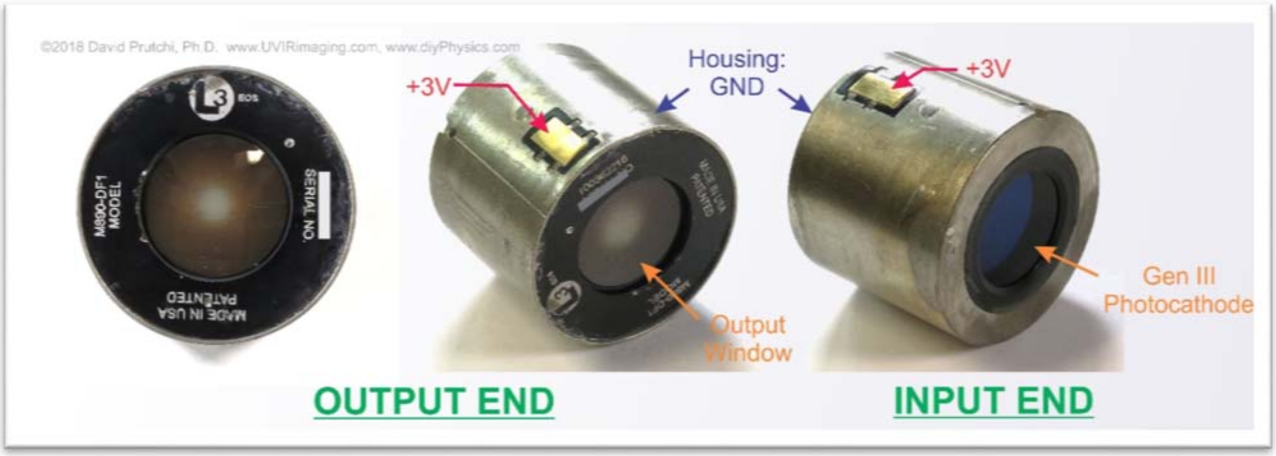


Figure 3 – The MX-10198 IIT that I bought on eBay® is a Model M890-DF1 made by L[3]

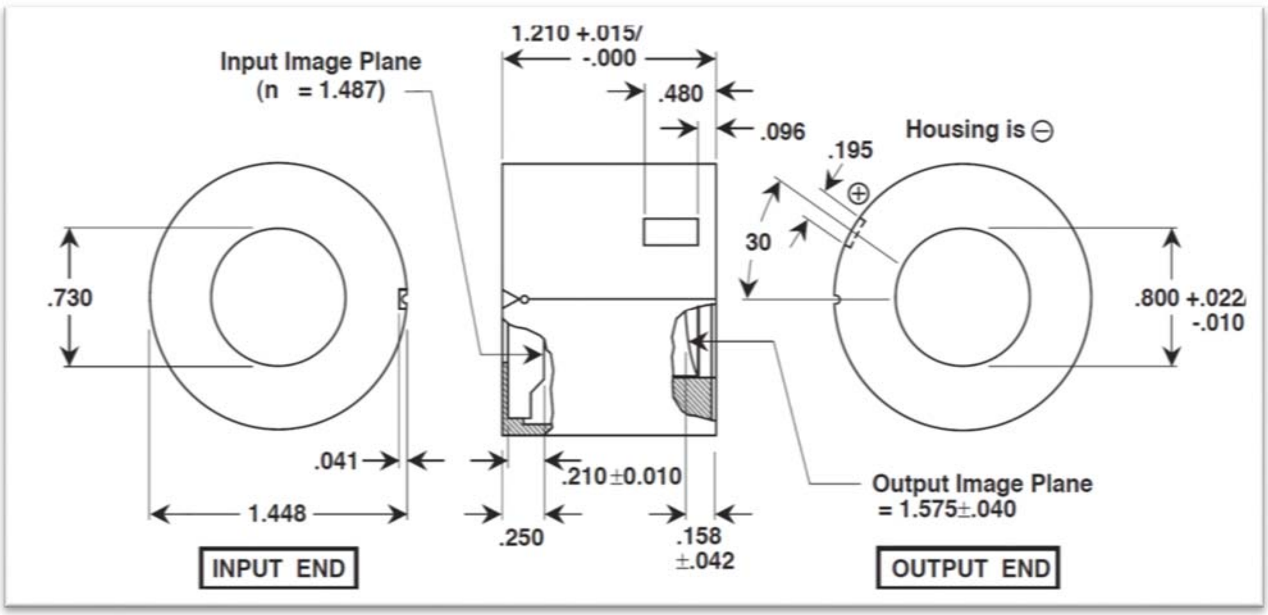


Figure 4 – Dimensions (inches) and connections of the MX-10160 Image Intensifier Tube. Image credit: ITT Industries [1]

The diy Image Intensifier System

The MX-10160 IIT is completely self-contained, so the assembly that I use simply involves housing the tube in a suitable optical enclosure, and powering it with a 3V battery.

In quantum physics experiments the "image" is usually projected by the quantum optics system directly onto the Gen III photocathode. However, I also use the image intensifier system for other more typical applications (e.g. night vision), so I designed the housing to allow me to use "Pentax Thread Mount" M42-mount lenses that were popular in 35mm SLR cameras. These are widely available in the surplus market at amazingly low prices given their performance. M42-mount lenses have a flange focal distance of 45.46mm, which means that I needed to place the photocathode at a distance of 45.6mm away from the edge of the mounting ring.

The Pentax Thread Mount has a metric screw thread of 42 mm diameter and 1 mm thread pitch. I found some telescope eyepiece T-mount adapters in my junkbox (Figure 5) which do a decent job at grabbing a M42 lens (the T-mount shares the 42mm throat diameter of the M42, but differs by having a 0.75mm thread pitch). The T-mount telescope eyepiece adapters that I use are similar to Edmund Optics #52-303. I also found a 50.8mm-long T-mount (external threads) to 38mm eyepiece adapter to house the MX-10160 IIT. I used two additional eyepiece diameter adapters to couple a loupe as an eyepiece, or a C-mount lens for imaging with a standard video camera.

Figure 5 – T-mount-to-telescope-eyepiece adaptors that I used as the basis for the IIT's housing

As shown in Figure 6, I used two pieces of copper tape soldered to wire-wrapping Kynar® wire to connect the power cable to the IIT. I used Kapton® tape to firmly hold the copper tape against the IIT's terminals. A few layers of electrical tape ensure a snug fit of the IIT within the housing's body. I used two 1.5" OD, 1"ID × 0.31" thick rubber O-rings (one of them cut in half and shaven down to make a stack of around 0.25" thickness) to prevent light leakage around the cable entry to the IIT, as well as to prevent the IIT from moving and thus changing the flange focal distance. Figure 7 shows the completed assembly.

Figure 6 – I used two pieces of copper tape soldered to wire-wrapping Kynar® wire to connect the power cable to the IIT. I used Kapton® tape to firmly hold the copper tape against the IIT's terminals. A few layers of electrical tape ensure a snug fit of the IIT within the housing's body.

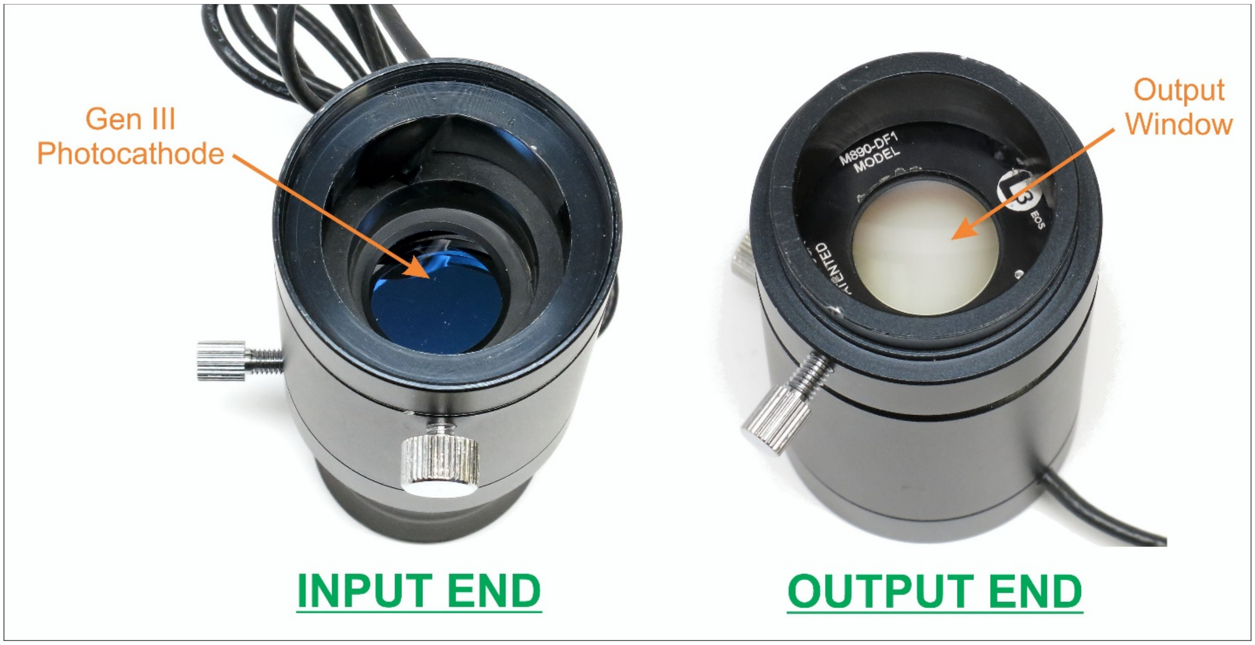


Figure 7 – Input and output ends of the completed image intensifier assembly.

MX-10160 Image Intensifier Tubes require 3V to operate. As shown in Figure 8, I supply the tube from 2 AA cells. I modified the battery holder to have a small toggle switch to turn the unit ON/OFF.

Figure 8 – MX-10160 IITs require 3V to operate. I supply the tube from 2 AA cells. I modified the battery holder to have a small toggle switch to turn the unit ON/OFF.

The eyepiece is simply an inexpensive plastic loupe for which I cut threads in one of the telescope adaptor rings (Figure 9). I found a rubber eyepiece shield in my junkbox that happened to fit this loupe to reduce light leakage around the eye. In addition, I glued (using a cyanoacrylate + filler adhesive) the other eyepiece adaptor to an auto-iris, C-mount, macro zoom CCTV lens. This allows the IIT to be viewed by a standard video C-mount camera Figure 10.

Figure 9 – The eyepiece is simply an inexpensive plastic loupe for which I cut threads in one of the telescope adaptor rings. I also found a rubber eyepiece shield in my junkbox that happened to fit this loupe.

Figure 10 – I glued a telescope eyepiece adaptor ring to an auto-iris, C-mount, macro zoom CCTV lens. This allows the IIT to be viewed by a standard video C-mount camera.

Figure 11 – An Asahi (Pentax) Takumar 50mm f1.4 lens turns the image intensifier into a superb night vision scope which easily outperforms small units like the AN/PVS-14

Performance

I am very satisfied with the performance of this diy Image Intensifier System. Of course, all of the heavy work is credited to the MX-10160 IIT, but the optomechanical arrangement that allows the use of M42-mount or T-mount telescope adapters makes this system especially good and flexible. Figure 12 shows two images that I acquired using an inexpensive USB video frame grabber connected to a Mintron color camera with the adapter of Figure 10 looking directly at the output of the IIT. All of the illumination for the scenes came from pilot lights in my workshop. The live image looks even better than shown in the photos!

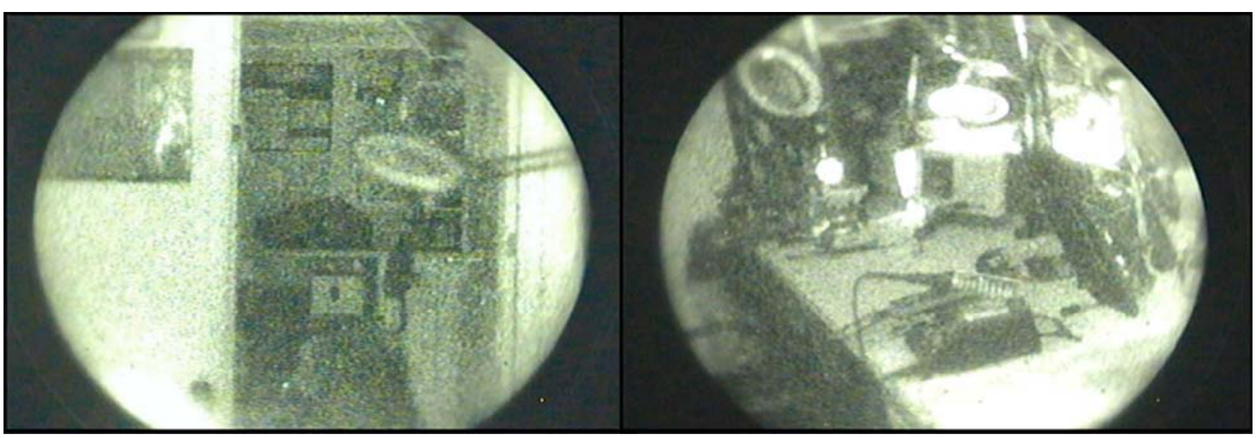


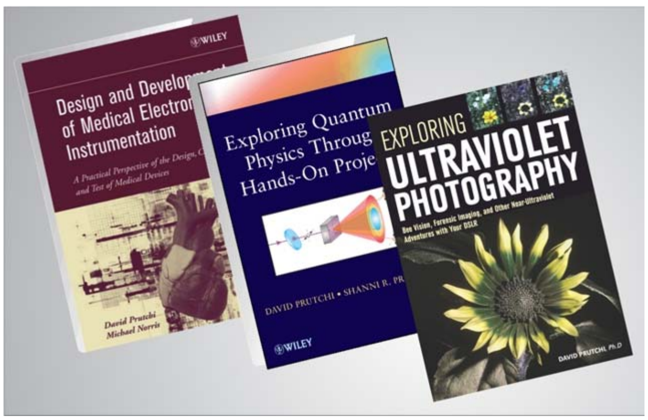
Figure 12 – Images of my workshop taken in pitch darkness (to my unaided eyes) using the setup shown on the right of Figure 10.

References

1. ITT Industries, *Product Performance, Image Intensifier, Generation 3, 18-mm MX-10160 (F9800 Series)*, 2005.
2. CJ7HAWK, Tube Data and Omni Classifications. Update: 5th December 2010. http://aunv.blackice.com.au/forum?index=discussions&story=omni
3. Prutchi D, Prutchi SR, *Exploring Quantum Physics through Hands-On Projects*, 335 pages, John Wiley & Sons, Inc., Hoboken, NJ, 2012.
4. Prutchi D, *diy Shortwave UV Image Converters for Solar-Blind and RUVIS Imaging*, www.UVIRimaging.com Technical Note 2016-1, June 2016

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):



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