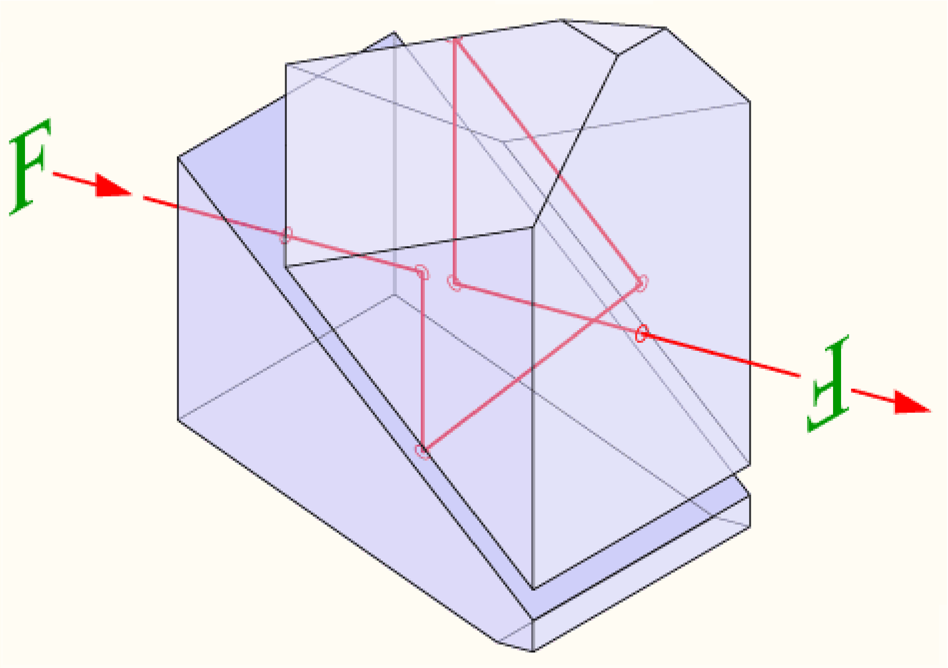
Centering Microscope

By P. J. Smith

I see quite a few of those very cheap straight through type of folding binoculars dumped.

People find that they are almost useful but, because of deficiencies don't get used. Often it's a mechanical deficiency - not maintaining a good focus. The Optics are usually adequate but not brilliant.

The prism system used in most straight through Binoculars is usually a Schmidt Pechan type.

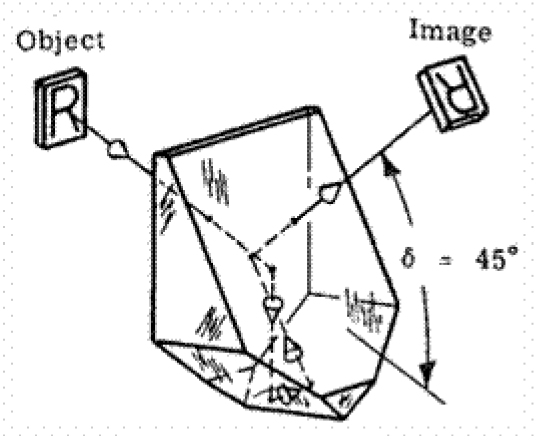


The top part is a Schmidt prism which deviates light approximately 45 degrees. The Roof part of this prism completely inverts the image.

The bottom part is a Pechan prism which deviates light approximately 45 degrees but produces no inversion. It is often used on the top of desk microscopes to produce a convenient orientation.

Both prisms are very useful and the Schmidt Prism is rather hi tec. Because they are quite small to suite the very small eyepieces in these miniature binoculars, there are few useful projects that derive from them.

If we discard one part of this system the remaining Schmidt prism will deviate an image by 45 degrees yet produce an inverted image - which is exactly what we want in a centering microscope because the objective lens produces an inverted image in the first case.



Schmidt prism

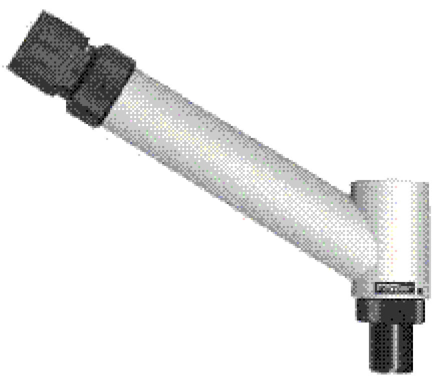
This may be clearer in the second diagram. Of course, the centering microscope will usually be oriented vertically. It is possible to design the prism to produce other angles apart from 45 degrees. Depending on the glass used and the design chosen, the prisms in the cheap Binoculars may not be exactly 45 degrees.

Although the Schmidt Prism is very small, if it is very close to a small objective lens as in a centering microscope, that's exactly what we want. It’s almost a use waiting to happen and far simpler than other options.

Examples

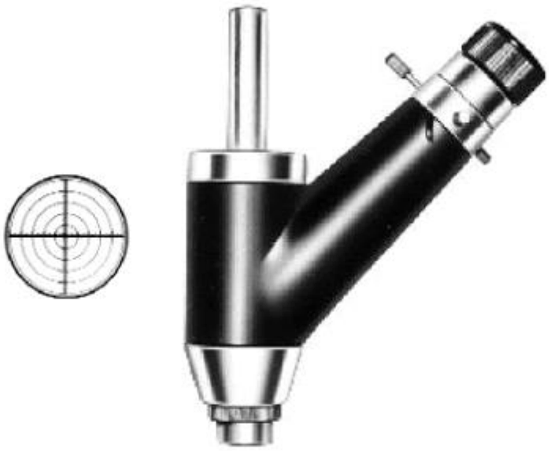
Centering microscopes are usually used on a Mill or sometimes a Lathe to assist centering to a line or other feature. Here are some examples.

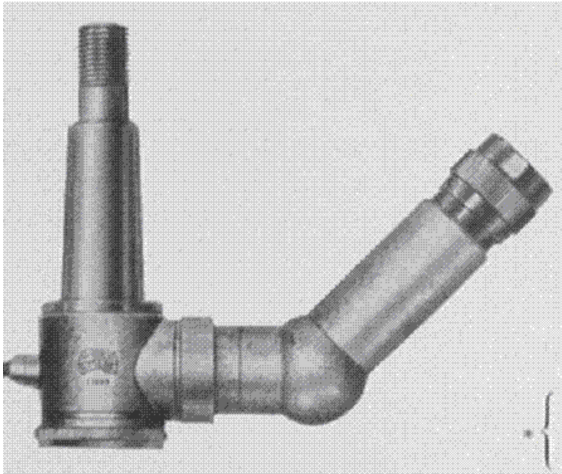
Rather than bring the eyepiece out at 90 degrees, most commercial units slope the eyepiece upward at from 30 to 45 degrees.



Commercial Units 1 and 2

Depending on the application and the machine tool, these lower angle units may be the most convenient. The prism found in a cheap straight through Binocular, however, suites 45 degrees (or very close to 45 deg) which is also common in commercial units.



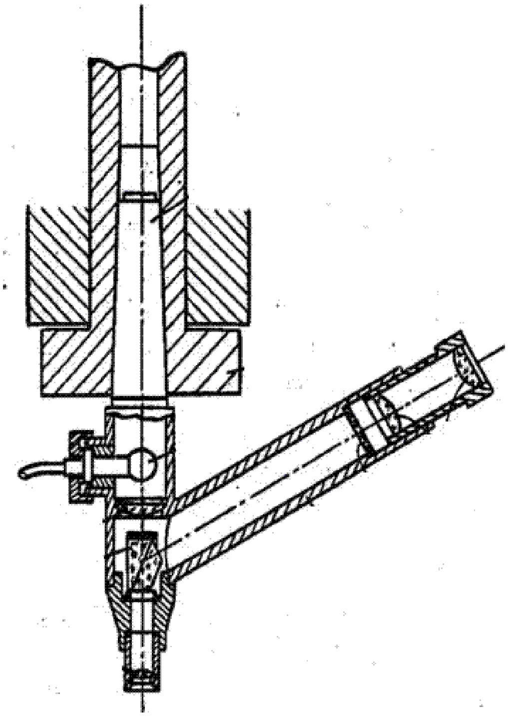


Commercial Units 3 and 4

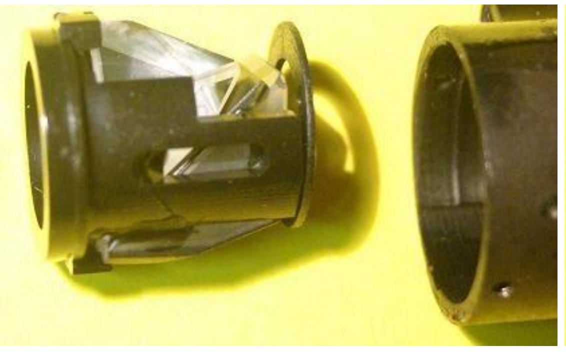
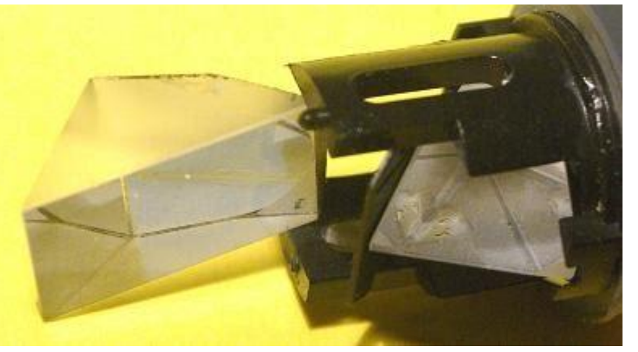
Leitz offered a 90 deg/45 deg combination type that would have probably been the most convenient to use.

Ironically, by combining the Schmidt and the Pechan prism to be found in the cheap Binoculars, we could achieve this, but, apart from increased complexity, the small prism makes this impractical. Nor is mounting and aligning a series of prisms a trivial exercise.

A schematic from a Patent is interesting in that it shows how the combined Schmidt and Pechan prisms could be used to provide illumination. For best operation, one surface will need half silvering and bonding to the other prism so it's impractical for us.



Harvesting the Optics

Here is the prism assembly removed from the binocular. The roofed prism is visible on the top left. It is accessible by removing the right-hand disk and withdrawing the Pechan prism.

Delay mounting the prism until all is ready. It is very easy to drop, lose or chip.

Be particularly careful not to chip the fine roof top edge. Put away the second prism cluster as a spare and work over a towel. Once it is bonded to the prism shelf it is much easier to handle and clean safely.

Because ALL prism reflections occur within one piece of glass there are no issues about precise alignment of more than one prism or mirror - and the image is reverted correctly which is messy with other systems.


One eyepiece, when disassembled, provides the objective lens.

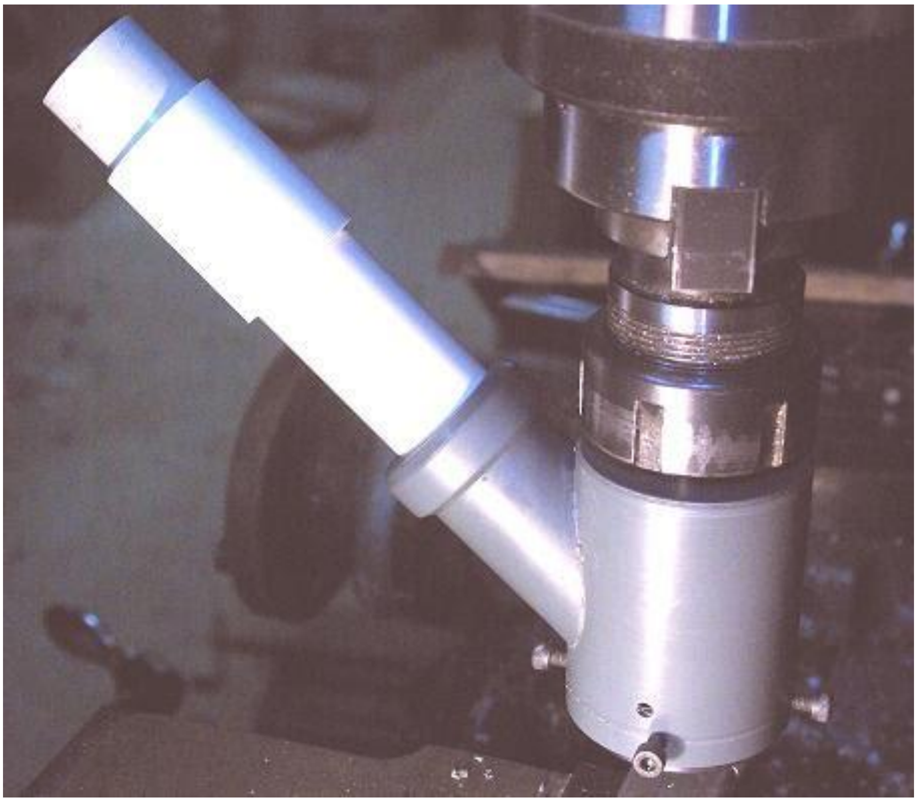
The Project

Using a prism and lenses from one of these binos, it is possible to make a centering microscope with an angled 45 deg eyepiece.

Maybe Leitz would disown it, but it does work. By sourcing other lenses it could easily be improved but my aim has been to keep the project as simple and cheap as possible.

The centering microscope which will be described could easily be improved. It is not very elegant. But it does work and shows what can be done with a few junked optical components. I also find that unless something is simple and quick to use it stays in the drawer

Unscrew the plastic retaining ring, discard the single lens, and keep the doublet. **It should have its flatter surface facing the specimen** and be stopped down by a small aperture in front of the lens. Try a 4 mm diameter hole. There is no precise prescription here – anything reasonable will work adequately.



The proof of concept was all made from PVC and used the original prism and lens mounts. PVC was on hand and it is possible to glue on pieces to test new design ideas. The item to be described may differ slightly from that pictured here because experience suggests improvements.

Experienced workers may take quite a different approach but the general design and a description of various pitfalls and important points should still be of use.

Little precise machining is needed because the final alignment is done with the adjustment screws visible at its base. There are, however, some critical operations which must not be skimped.

I will not give detailed dimensions because you may have different size lenses, prisms and other parts. Any dimensions mentioned should be considered a guide only

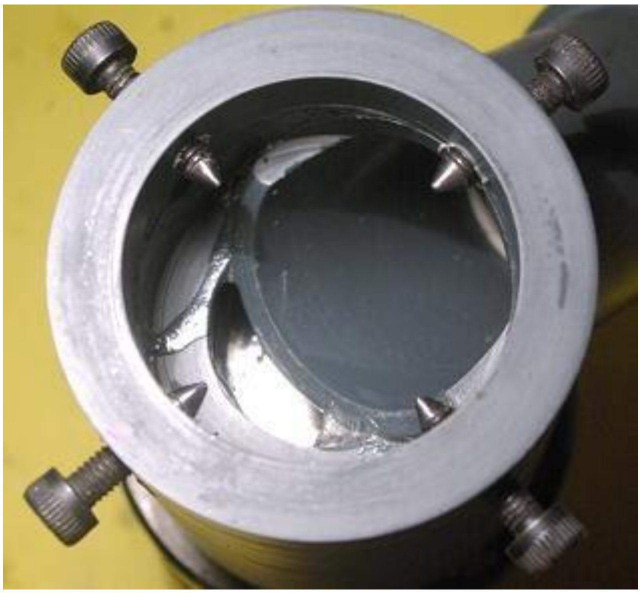
Because it will enhance the long term accuracy and promote smooth adjustment, the lens and prism mounting has been changed to a stainless unit and an Aluminium cross hair cell installed below the eyepiece. Apart from that, I see nothing wrong with the PVC concept and the use of standard ¾ inch water pipe PVC fittings for tube and eyepiece.

Visible are a few 'mistakes' caused by a change of plan. None affect accuracy.

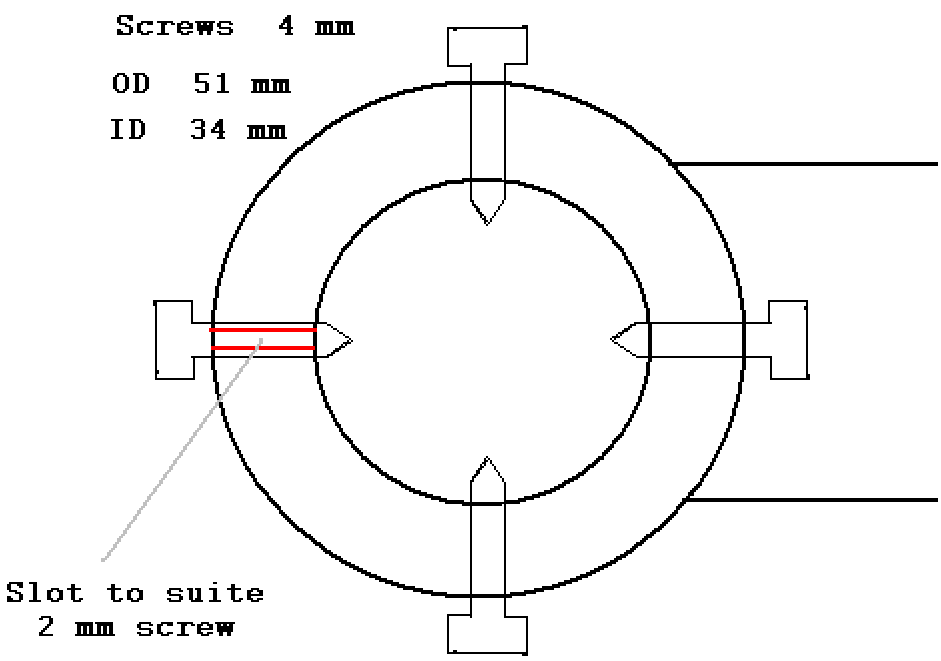
The microscope consists of three main components plus some means of mounting to a machine tool. I would suggest ½ or ¾ inch diameter chromed rod press fitted into the body.

Visible above are the main body and eye tube. Underneath is a nosepiece carrying a lens and prism.

Looking into the base of the body we see how the Nosepiece is held in place and adjusted to centre the image.

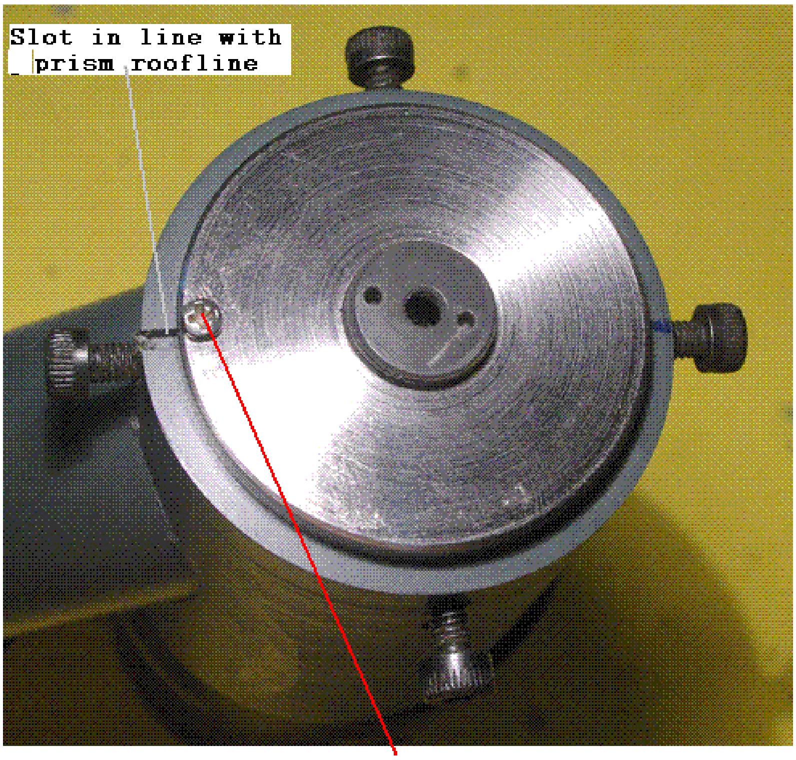


No slot has yet been cut.



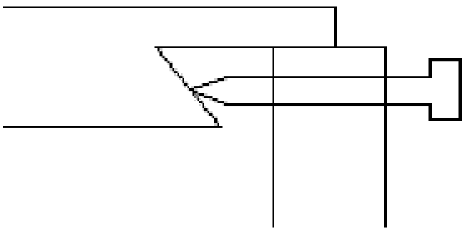
The slot should be the last item – after the base has been trimmed. See adjustment.

The nosepiece is held in place by 4 adjustment screws. These centre and draw back the nosepiece which has a dovetail turned in place. I suggest 30 degrees.



2 mm screw in line with
Prism roof line

The small screw and slot make adjust much easier because the nosepiece cannot rotate as one adjusts the screws. It is the final machining after the base is trimmed to length and the adjustment screws fitted.



The end angle of the adjustment screws must be smaller than the Nosepiece bevel angle so the only contact occurs at the end of the screws. This minimises the tendency for the screws to rotate the Nosepiece as they are tightened.

After forming a coned point on the end of the screws, lightly strop the ends to produce a polished spherical tip.

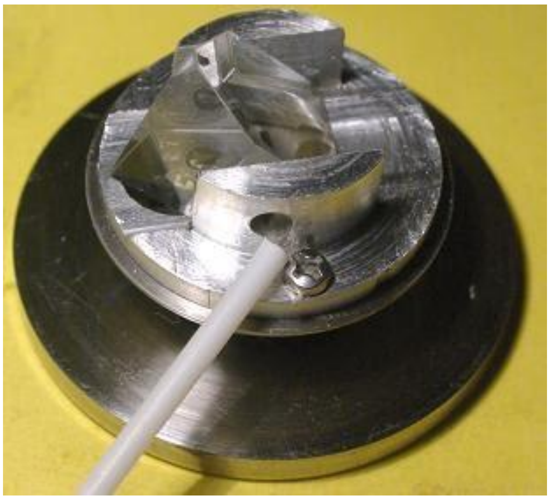
These screws will be the last item after the body has been trimmed to length. See later.

Making Nose Piece and Prism Shelf

This is the first item to make.

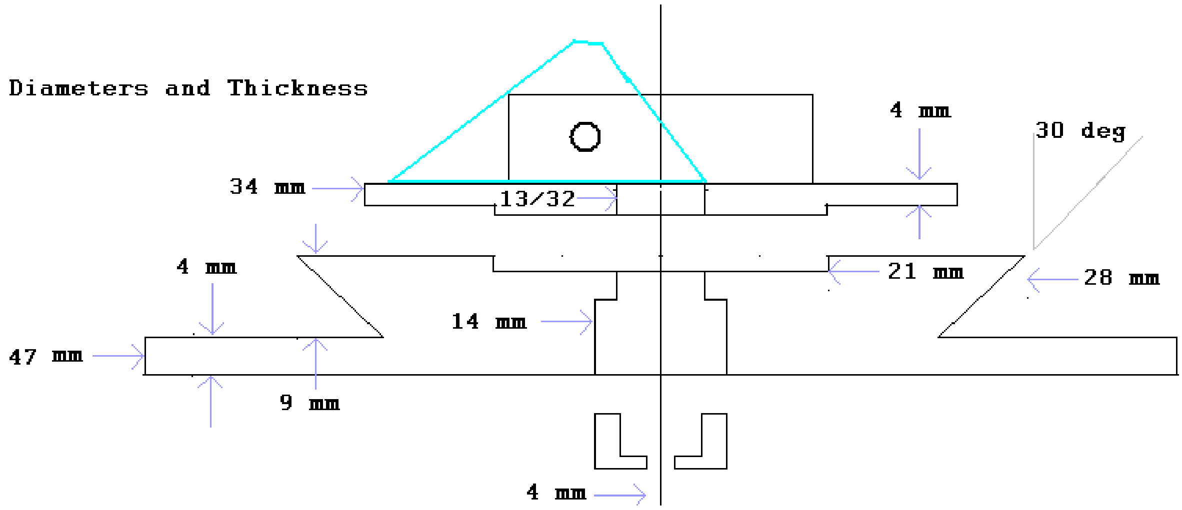
A prism shelf made from Aluminium spigots in place on the Stainless Nosepiece. 2mm screws hold it in place.

The prism is permanently bonded to the shelf allowing this assembly to be removed so the base of the prism may be cleaned. Note that the entire prism base **MUST** be accessible for cleaning because it serves two functions – one being to reflect light internally. The 'slot' through the base is 2 mm less than the width of the prism which gives sufficient base support.



Two holes serve to introduce glue for bonding. The only surfaces which may be bonded are the small ground side areas. A few drops of glue can be pumped in while the prism is slid a little. The prism should have about 0.005 inch clearance. An improvement for unobstructed cleaning would be to trim away the Aluminium where it overshoots the prism roof. The prism appears to be mounted off centre. It is important that **The prism should be slid as far forward as possible just keeping the edge over the central hole. I drilled a central 13/32 inch hole.**

This is more obvious in the following diagram.



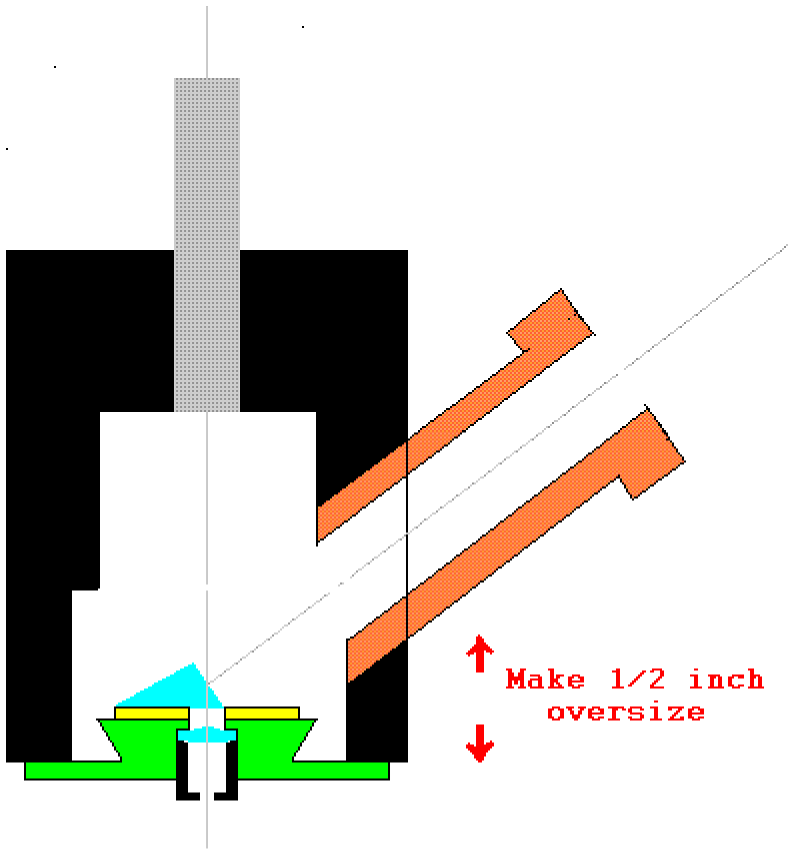
For what it’s worth, here are some dimensions that I used.

The lens retainer contains a small aperture (about 4 mm). I used a 14 x 1mm thread because I had taps and dies. Finer thread (32 tpi) may be an advantage.

Bore the lens pocket with sufficient clearance. Glass lenses easily bind during assembly which is best done by placing the lens on top of the retainer and lifting it into place. If the lens jams at all do not force it.

Making the Body

The body was made from a piece of 2 inch diameter PVC and seems quite satisfactory. If you have the facilities, welded Aluminium or brazed Brass would be excellent. The body, in black below, ends up about 2.5 inch long.



I do wonder if a 1.5 inch PVC pipe Y fitting may be a good starting point but you would also need some solid PVC to glue into the ends etc.

The side tube must be bored at the correct angle to suite the prism ***which may not be exactly 45 degrees.*** Depending on the glass used in the prisms, the internal prism angle may differ slightly from 45 degrees.

Order of operations is important

Ensure the base of the main body tube is at least ½ inch too long

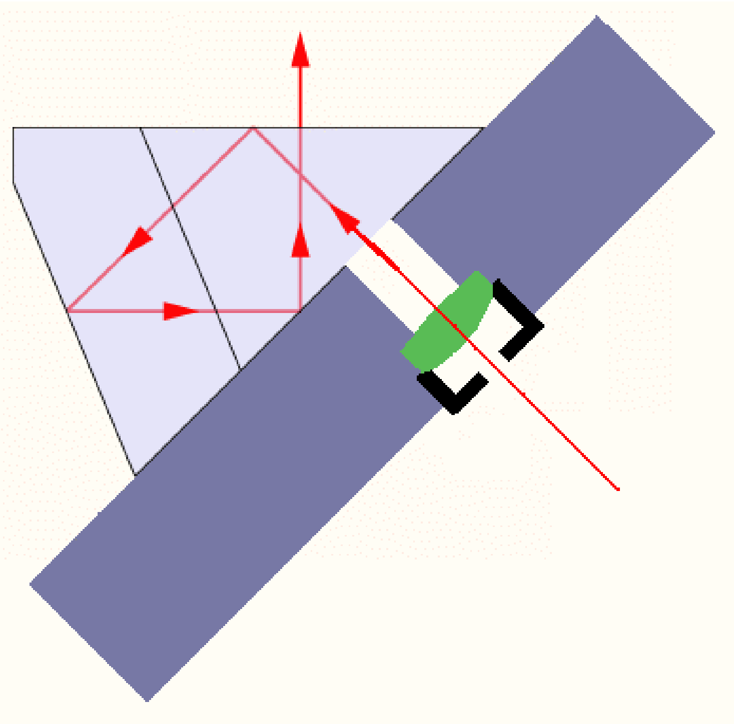
1. Bore through the body allowing a press fit for the mounting stub. I used ¾ inch stainless steel but suggest chromed rod. You may, of course choose any convenient size or other fitting but this suits my 'standard' for mounting most tooling to a mill collet chuck.
2. Press fit the stub.
3. Hold by stub and lightly turn outside diameter.
4. Bore a pocket for the prism housing in the base - about 1 inch depth - leaving a wall of about 5/16 inch thick.
5. Setup to bore the angled eyepiece tube collar. Do not forget that the base needs to be a good ½ inch too long with respect to the eyepiece tube. The final adjustment will be to gradually reduce this with the nosepiece and prism in place so the axis of the eye tube and body meet at the prism face. Look through the eye tube to assess this.
6. Once the length has been trimmed, drill and tap for the adjustment screws and slot end.

Boring for Eye Tube - setting prism face horizontal

Setting up for boring is the hardest part.

This is important – see note on accuracy below. I found that the best way was to bore oversize and glue in a PVC piece, then let the glue dry leaving it in the mill. Later, drill and bore this piece for the actual eyepiece tube. This overcomes any inaccuracy from gluing and allows one to experiment with different eyepiece tubes.

One could simply measure the angle of the prism, then set the body to the required slope and bore. It needs care and correct calculation. The other method is to simply set the top prism face parallel to the table (rotated so the roof lines up with the mill table). Sounds simple, but because we probably do not want to traverse a dial indicator across the prism face, becomes rather more complex. But, if this limitation can be solved, it is the best method.

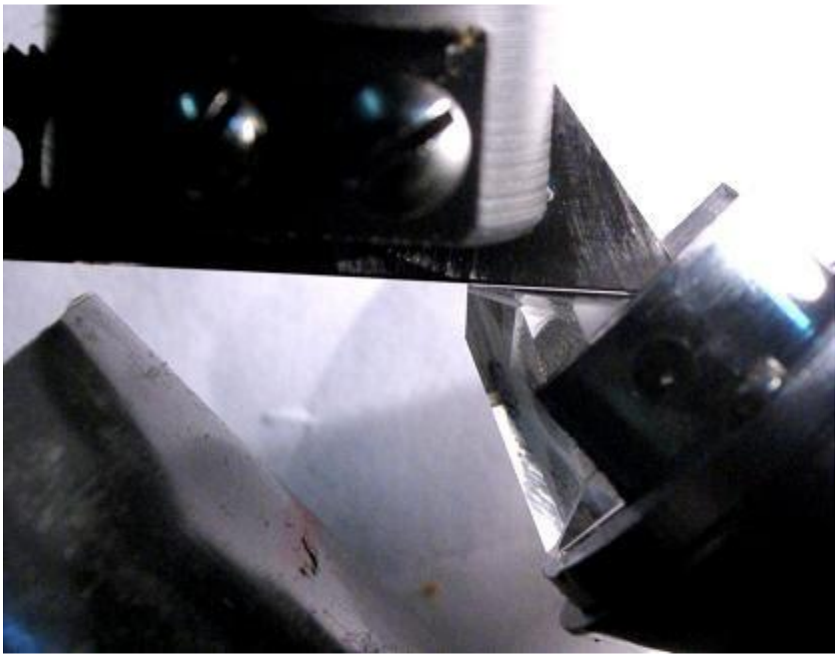


A method that everyone can use to adjust the angle when boring for the eye tube is shown.

There are better methods – like reflection of a laser from the horizontal prism surface and other fancy options – but, used with care, this is accurate enough.

A small straight edge was made by grinding a piece of hack saw blade and mounting as shown.

The tilt of the whole body is adjusted so a small even light gap results.

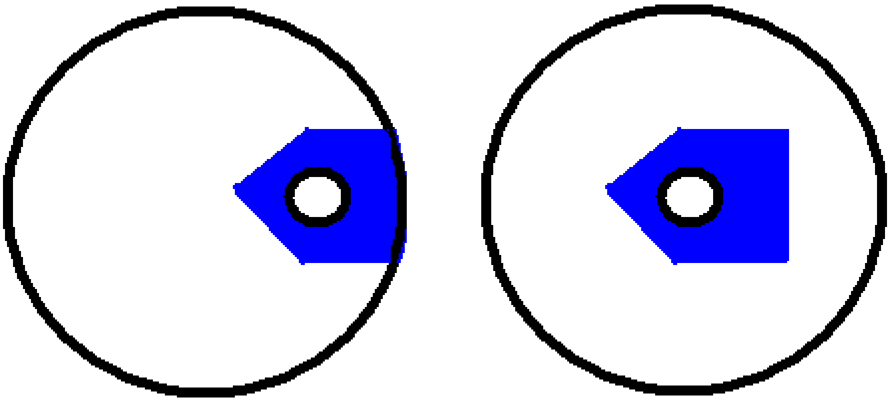


Trimming the base to length

This is not difficult but important.

FIRST hold the nosepiece central, then look down the eye tube.

The base is faced off until the lens orifice as seen through the prism, when looking down the eye tube, appears central. The left image indicates that trimming is needed. Trim until it looks like that on the right.



The X hairs

Many centering microscopes have complex Graticules involving lines and circles.

To keep things simple we are limited to a simple cross. It is easy to make a home-made cross optically as good as any commercial unit. The X hair holder is Aluminium which is an easy push fit into a piece of ¾ inch PVC water pipe. Four small cuts are arranged in the end along with ripples to assist gluing of the X hairs.

The internal 'threading' is simply a quick hand feed using a threading tool. This produces a surface which does not reflect much light at grazing angles.

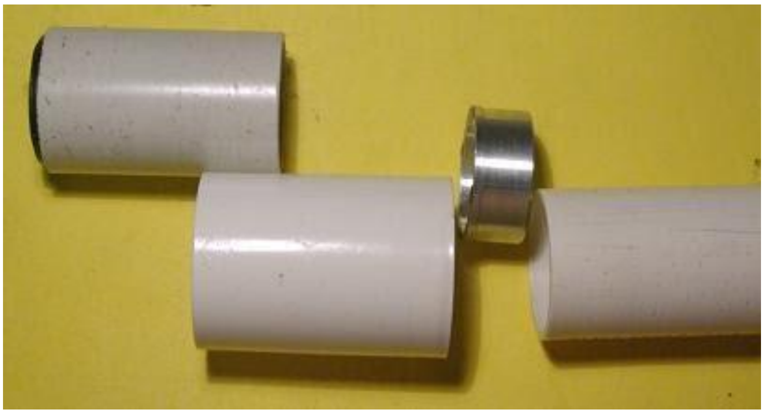
Forming the X hairs using Dental Floss strands.

Since I have described making X hairs in more detail elsewhere, this is only sparsely covered.

See more details at http://pjoptical.udjat.nl/Xhairs.pdf

The Eye Tube

The whole eye tube and eyepiece is crude but will work.



1. The Right Hand tube is bored for a neat fit of the X hair assembly.
2. Aluminium X hair ferrule. It has a small lip so it cannot fully enter the tube.
3. PVC socket. Leave the standard pipe socket taper internally on the right so when forced onto the RH tube it squeezes the tube and locks the X hair ferrule in place. Alternatively the RH tube could be split but PVC is flexible enough to omit this. The LH side is bored a little over half way so the eyepiece slides easily into place.
4. At left is an eyepiece made from standard PVC ¾ water pipe. It is lightly bored so the objective cells from the binoculars enter on the left. The eyepiece tube needs trimming to length so the X hairs focus just short of bottoming.

The Eyepiece

The original objective cells were parted off leaving about ½ inch beyond the lens. Slide into slightly bored ¾ inch PVC water pipe.

There are two options which give different magnifications:

1. If both objectives are mounted about ¾ inch apart, the final magnification is about 25 – 30 depending on eyepiece tube length.
2. If only one objective is used the magnification is halved, and extremely long eye relief results. If the eye and head positioning near the mill is a problem this may be the preferred option. The extreme eye relief will take some getting used to and reduce the apparent field of view.

It is easy to experiment with both options.

Internal Reflections

Internal reflections from the walls are a real killer in optical instruments. The difference in performance once these are eliminated can be stunning. Never assess any optical lash up without addressing this problem.

Matt Black paint is a difficult and usually unsatisfactory solution. The worst internal reflections in this instrument are in the lower white eyepiece tube. The easiest way to eliminate these is to cut a piece of dull black wet and dry carborundum paper, roll it carefully, and insert into the tube. The myriads of minute sharp edges do a wonderful job of eliminating grazing reflections.

This also solves another problem. Some light passes through the white PVC water pipe which is now eliminated.

If the main body is made from metal you may have to look further to eliminate internal reflections but the dull PVC finish after wiping with solvent reflects light poorly.

Another ploy is the 'fine turn' surfaces producing a ripple finish.

Adjustment

Proper adjustment is dependent on accurate eyepiece tube angle and body length.
Read notes on these parameters first.

The bottom adjustment screws are sensitive and a little fiddly. Ideally we should first rotate the lens/prism plate so the roof is in line with the eye tube and maintain this orientation when the adjustment screws are moved. In practice, rotation of the plate may be induced by the screws. This must be watched carefully and guarded against. See note on adjustment screws.

A later modification uses a slot and screw to eliminate rotation. This is highly recommended.

I found the quickest way to adjust to centre was to drill a small dimple on a piece of Aluminium using a centre drill in the mill. Then, using the same mill setting, attach the microscope and adjust for centre. The mill head should be accurately perpendicular to the table. If there is any doubt, ensure the height of the drill tip and microscope focal point coincide.

If the light does not enter the objective lens exactly on axis, an error will be introduced as we focus above or below the object. See below. Be careful to focus properly before use.

Final focusing is best done by parallax, not by clarity.

First, focus the cross hairs via the eyepiece. Then adjust the microscope height so there is no parallax between image and X hairs. This is ensured by moving the head slightly sideways while watching the image in relation to the X hairs. If any apparent movement occurs refocus.

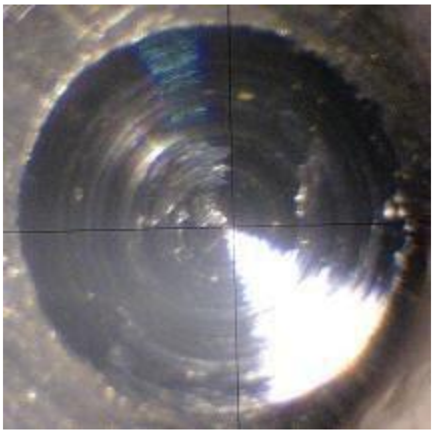
Adjustment should follow the sequence.

Before mounting the microscope, adjust the screws lightly so the bottom plate is central.

Accuracy

Trials indicate better than 0.001 inch repeatability when removing and replacing the unit.

My estimate is that 0.00025 inch is achievable with care. Adjusting the cross hairs to this accuracy is trying, however.

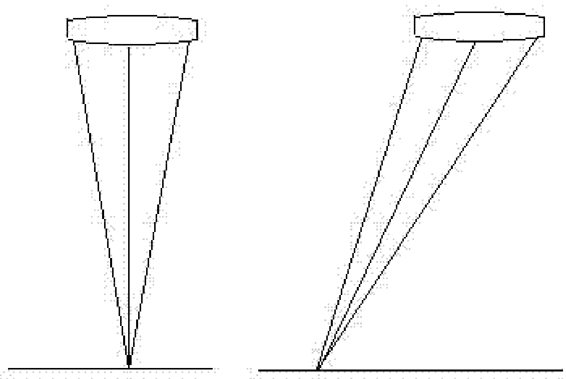


This is a typical view of a 1 – 2 mm dimple. The centering is off by about 0.002 inch.

The photograph does not show the true resolution available.

It is worth considering the crucial elements required for precision.

1. All optical components forward of the X hairs, and the X hairs themselves, must be rigidly fixed. The eyepiece can, however, flop around with no effect on accuracy.
2. The cone of rays focused by the objective should be close to perpendicular to the nosepiece. This must be built in by accurately angling the eye tube, length spacing the base, and rotating the nosepiece to a 'central' position first.
3. The instrument should be accurately focused for zero parallax. This counteracts any type 2 error.



Lighting

I simply used a small low voltage desk lamp for illumination. This leaves something to be desired but is quick and easy. A problem with lighting from one side is that uneven illumination may pull the centering off to one side. I did not have the time to go further with this.

Suggestions and Wish List

Fine adjustment of Graticule.

This would not be hard. A system can be seen in the Commercial Unit picture no 3.

It is possible, however, to survive without a fine graticule adjustment although it is fiddly.

Circles and other scale marks on the Graticule are possible but this was intended to be a simple project.

A longer focal length objective and shorter focal length eyepiece would longer working distance but that needs different lenses.

Four LEDS would work nicely to give better illumination