Leitz Dialux 20 – Focus Control

The coaxial focus control of the Leitz Dialux 20 microscope converts any turning of the coarse and fine focus controls into precise vertical movements of the stage. The mechanical design of the focus control is quite simple and appears very robust. An unusual quirk is that turning the coarse focus control makes the fine focus control to spin at a must faster rate.

The stage focus range is 37 mm and is covered by 9¼ turns of the coarse focus control. The turning of the fine focus control is geared down by a factor 20 relative to the coarse focus control. The fine focus knob has a scale 0-100 around its periphery. This means that turning the fine focus control one scale division corresponds to a focus change of 2 μm.

Scope

These maintenance notes describe the disassembly, cleaning, greasing, and reassembly of the Dialux 20 coaxial focus control including the focus slide. In large parts the notes should also be applicable for other contemporary Leitz microscope models (for example, Dialux 22.)

The main issues encountered with the Dialux 20 focus controls will most probably be sluggishness due to old, hardened grease. Thanks to the robust design purely mechanical faults should be rare but watch out for damage of the rack and pinion teeth that can happen if the microscope at any time has been exposed to rough shipping conditions (refer to subsection 5.)

The following functions will be disassembled, cleaned from old grease, and regreased with fresh grease:

- The focus range limiting mechanism,
- the roller bearing inside of the pinion,
- the focus slide's linear ball bearings,
- the main focus axle including the bearings at the axle ends,
- the worm wheel, and
- the plastic washers between the fine and coarse focus knobs.

"Super Lube Multi-Purpose Synthetic Grease with Syncolon® (PTFE), NLGI grade 00" is used for regreasing all of these items.

Limitations

There are a few things that you should know before you start to work with your focus control:

- If you find that some technical details of your Dialux 20 microscope differ from the descriptions in these notes the reason may be that the Dialux 20 microscope model underwent technical modifications and improvements during its years of production. I mention some of the differences that I have encountered, but certainly there will be other differences that I have missed.
- From my admittedly limited experience it seems that the dominating cause of a sluggish Dialux 20 coarse focus control is hardened grease in the main focus axle's bearings at both ends of the axle. The focus range limiting mechanism (under the left focus control knob) also appears to suffer from

hardened grease, although any sluggishness in this part only marginally affects the performance of the coarse focus control. The focus slide seems to move flawlessly on the original grease that still today appears healthy, so there is really no convincing reason to disassemble it. This means that you may be able to fix, at least temporarily, a sluggish coarse focus control by only removing the focus control knobs to clean the ends of the main focus axle and just apply a little fresh grease or oil to replace the aged grease. These are just my thoughts in hindsight; I haven't been able to try out whether such shortcuts really work, so I can't provide any specific information.

- Collimation is the procedure of aligning the optical axes of all optical components to have them to coincide into one common optical axis. Taking apart and maintaining the focus slide as described in these notes would in a professional setting require to be concluded by collimation and adjustment of the focus slide and the stage. Proper collimation requires training and special equipment which takes it beyond reach of the typical microscope amateur and is therefore not covered in these notes. If collimation is important to you, then you should not try to service your focus control according to these notes, or at least avoid to disassemble the stage and the focus slide.
- The choice of grease for the main focus axle is critical for the haptic feeling (smoothness) and reliability of the focus controls. I have tried a few greases in my efforts to mimic the grease protocol used by Leitz and chosen to use "Super Lube Multi-Purpose Synthetic Grease with Syncolon® (PTFE), NLGI grade 00". "NLGI grade 00" is an important parameter that indicates the thickness of the grease (semi-fluid, similar to apple sauce.) This grease provides a nice smoothness to the focus control, although not really with that exquisite feeling that was characteristic for Leitz. There certainly is room for more experimentation and improvement regarding the choice of grease.

Work Notes

1. Remove and protect the microscope optics.

To facilitate the work and to avoid contamination of sensitive optics, the objectives, the head with the eyepieces and the condenser should be removed from the microscope and stored protected from dust. The stage can remain on the stage holder, but the substage (i.e., the condenser holder and the condenser focus control, a.k.a. the condenser height adjustment) must be removed to allow access to the focus mechanism.

Protect the field lens in the microscope foot by covering it with a suitable lid (for example, from a food container) and tape it so it doesn't fall off.

2. Remove the condenser holder from the microscope.

Turn the coarse focus control to move the microscope stage to its highest position. Turn the condenser focus control to move the condenser holder to its lowest position. Put the microscope on its back on the table. Remove the condenser holder's stop screw indicated with a red circle in Figure 1. The tip of this screw reaches into a groove (black, on the right side of Figure 2) in the condenser focus block which determines the range of the condenser focus setting. With the screw out of the way, turn the condenser focus control all the way down, and then manually pull the condenser holder further down until it slides off from the dovetail mount.

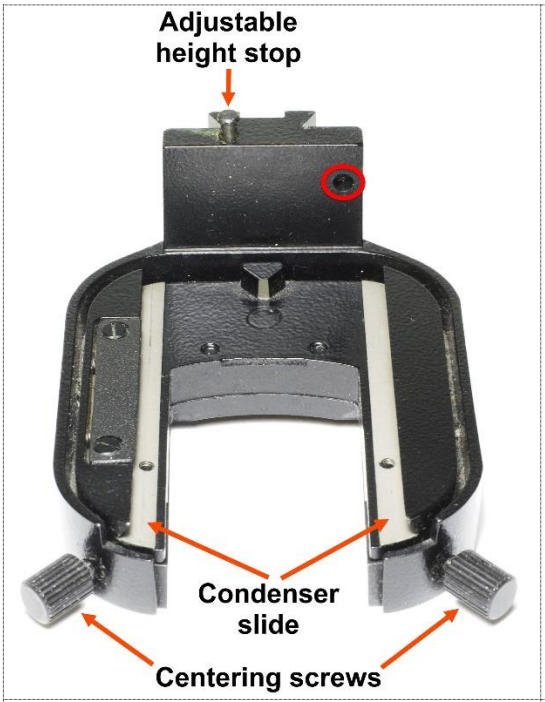


Figure 1: The condenser holder after removal from the microscope.

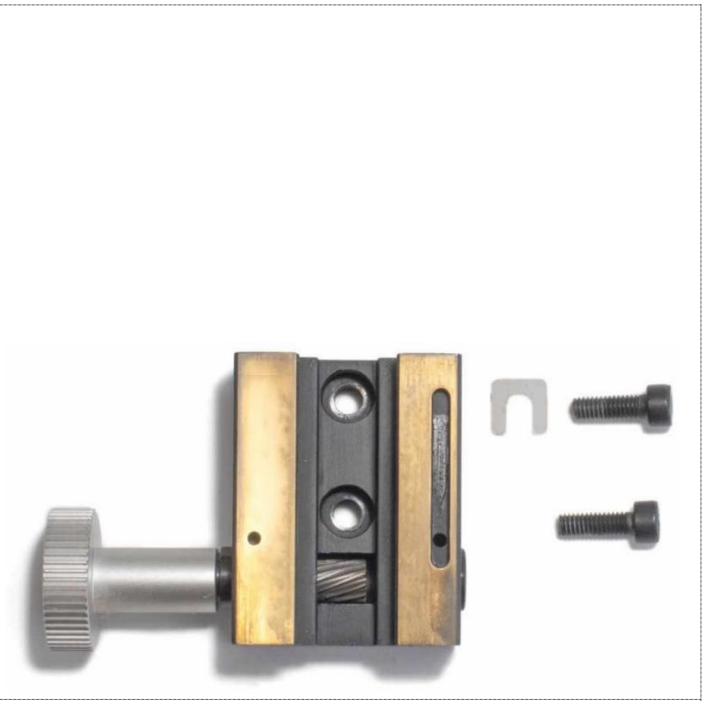


Figure 2: The condenser focus block and mechanism after removal from the microscope.

3. Remove the condenser focus block and mechanism.

Remove the condenser focus block and mechanism by unscrewing the two M4x12 screws with hex drives (Figure 2.) There may be one or a few thin metal shims around the screws between the block and the microscope stand that were put there at manufacturing to support proper condenser collimation. If there are any such shims, make sure to retrieve it/them and make a note of their location. Figure 2 shows an example of a 0.07 mm shim (to the left of the upper screw.) Sometimes a shim may fall out before you have had any chance to determine its location; in such cases it may still be possible to infer where it was sitting thanks to faint imprints left on the adjacent metal surfaces.

4. Remove the stage holder from the focus mechanism.

The stage can be left attached to the stage holder or removed (Figure 3), whichever appears most convenient. The stage holder must however be removed from the microscope stand.

Figure 3: The stage holder. The stage and the substage have been removed.

Unscrew the four M4x35 hex screws (surrounded by green circles in Figure 4) that attach the stage holder to the focus slide and remove the stage holder. Be prepared that the screws may be difficult to release (if the screws are stuck refer to Appendix 1: Stuck stage holder screws.) There may be a few thin metal shims around some of the screw holes between the stage holder and the focus slide (Figure 5, the shims in the image were 0.10 mm thick) – make sure to retrieve the shims and make a note of their location to make sure that they can be properly reattached later.

Unscrew the four M2.5x5 screws that attach the white-painted focus slide cover (Figure 5) and remove the cover. There may be several thin metal washers, even stacked, around the screw holes between the shield and the microscope stand – make sure to retrieve the washers, count them, and make a note of their location. The purpose of the washers is apparently to prevent the focus slide cover from rubbing against the focus slide thereby disrupting the microscope's focus adjustments. (It almost looks like an emergency remedy for some design error.)

With the stage holder and the focus slide cover out of the way we have got access to the focus slide (Figure 6). The focus slide consists of the vertically moving center bearing guide enclosed between the stationary left and right bearing guides (Figure 6.) The left and right bearing guides are attached to the microscope stand, while the center bearing guide (with the microscope stage attached) moves vertically as determined by the microscope's focus controls. Two linear ball bearings, one on each side of the center bearing guide, ensure that the slide moves smoothly as well as without any sideway play.

Figure 4: The microscope with the stage holder. The stage and the condenser assembly have been removed.

Green circles: Screws attaching the stage holder to the focus slide.
Purple circles: Screw holes where the condenser focus block was attached.

Figure 5: The microscope's focus slide after the stage holder has been removed.

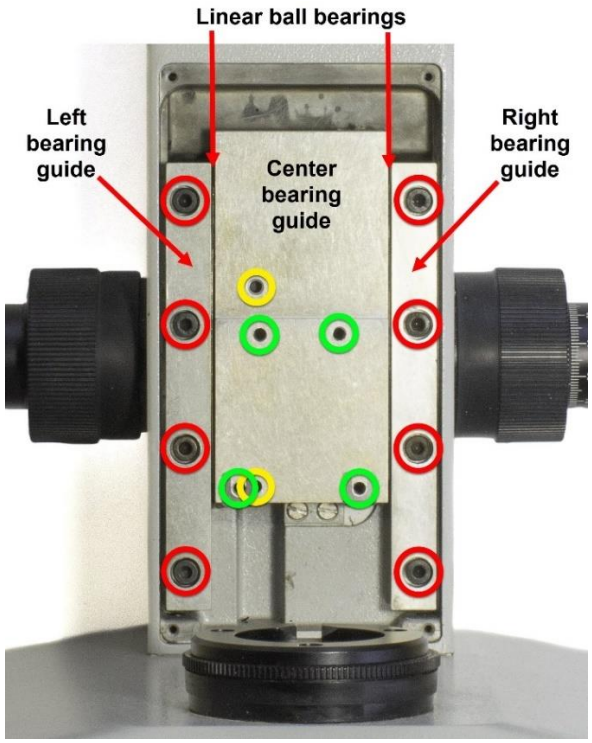


Figure 6: The microscope's focus slide after the stage holder and the focus slide cover have been removed.

Green circles: Screw holes for the screws attaching the stage holder to the focus slide.

Yellow circles: Screw holes for the focus rack on the back side of the focus slide (center bearing guide).

Red circles: Screws attaching the right and the left bearing guides to the microscope stand.

5. Disassemble and clean the focus slide.

Remove the eight black M4x12 hex screws (red circles in Figure 6) that attach the left and right bearing guides to the microscope stand. Be prepared that the screws may be difficult to release. Pull out the three bearing guides (left, right and center) and retrieve all parts from the two bearings (Figure 7.) Leave the rack (Figure 7) attached to the backside of the center bearing guide.

The bearings are linear ball bearings, each with a 4 + 4 arrangement of 3.5 mm steel balls (i.e., a total of 16 bearing balls) held by bearing ball retainers made of brass. The bearing balls run on thoroughly greased races in the sides of the bearing guides. The races consist of steel rods (45 mm long and approximately 1.8 mm diameter) that have been permanently jammed into grooves in the sides of the guides.

Use solvent to clean all bearing components (races, retainers, balls) from old grease.

With the focusing slide out of the way we get our first glimpse of the focus mechanism (Figure 9 and Figure 10) with its main focus axle, the worm and the pinion that engages with the rack. The rack is attached to the backside of the center bearing guide (Figure 7.)

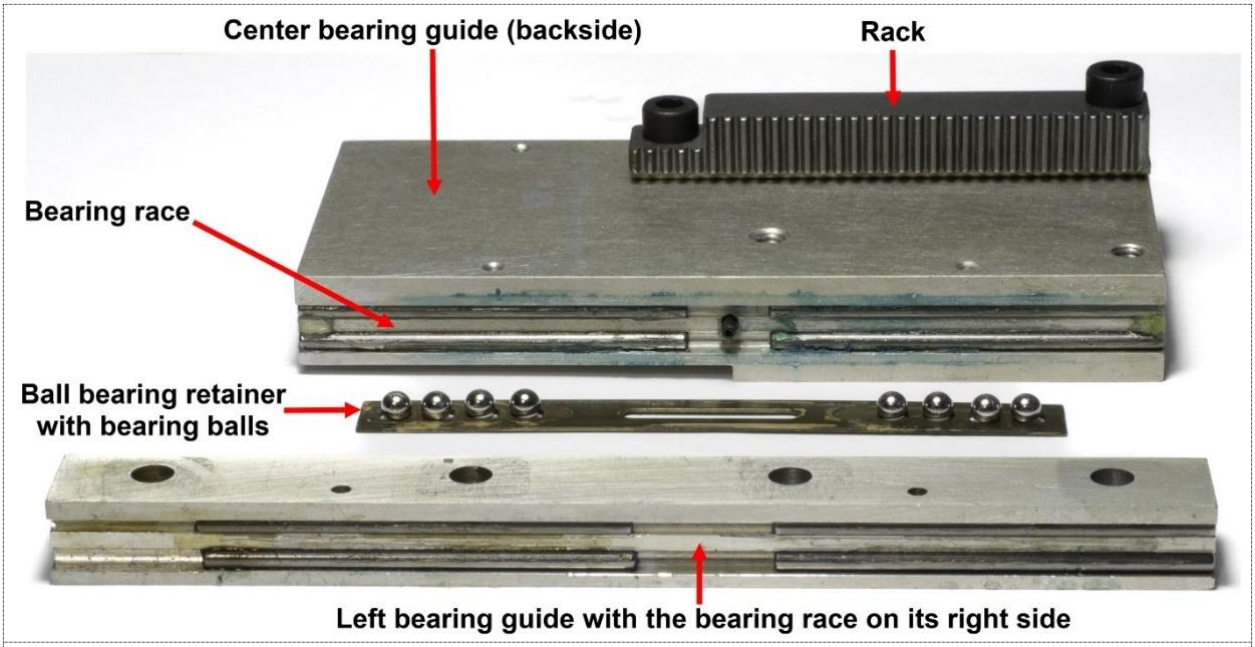


Figure 7: The disassembled focus slide (the right bearing guide and the right ball bearing are not included in the image.)

Microscopists are a tough bunch, but they fear one thing - shipping. In this eBay era, too often microscopes get damaged due to sloppy packaging, reckless parcel handling, or both. One just can't ship a microscope in the same way as a car tire and expect a good outcome. Figure 8 shows a focus rack with one broken tooth as a consequence of rough shipping conditions. Figure 12 shows the pinion from the same microscope. The microscope's focus control appeared to work OK when received after shipping, but its dirty secret spilled out after dissembling it. A damaged rack like this must be replaced (unless you know some miraculously capable person that can manage to repair it.) A bruised pinion may still be usable if one can apply the hack described at the end of subsection 14.

Refer to this article for more information about this kind of sad but avoidable event. Carl Hunsiger has published some very useful information about safe microscope shipping. (By the way, don't miss to check out his YouTube channel about servicing of Olympus BH-2 microscopes.)

Figure 8: A focus rack with shipping damage.

The coarse focus knobs are attached by screws to the sides of the main focus axle (Figure 9.) The worm reduces the turning of the coarse focus knobs (and the main focus axle) making the worm wheel on the pinion axle to turn considerably slower. The pinion and rack then convert the rotation of the pinion axle to the vertical movement of the microscope stage. The fine focus axle that goes through the hollow

main focus axle has a separate gear-down mechanism that significantly (by a factor 20x) reduces the turning rate of the fine focus as it is passed down to the main focus axle.

The worm was generously greased at manufacturing. Although Figure 9 and Figure 10 show a lot of green almost solidified grease on the worm, it was interesting to note that the microscope's coarse focus still appeared to work quite smoothly. The rack and pinion parts of the mechanism were apparently not greased at manufacturing.

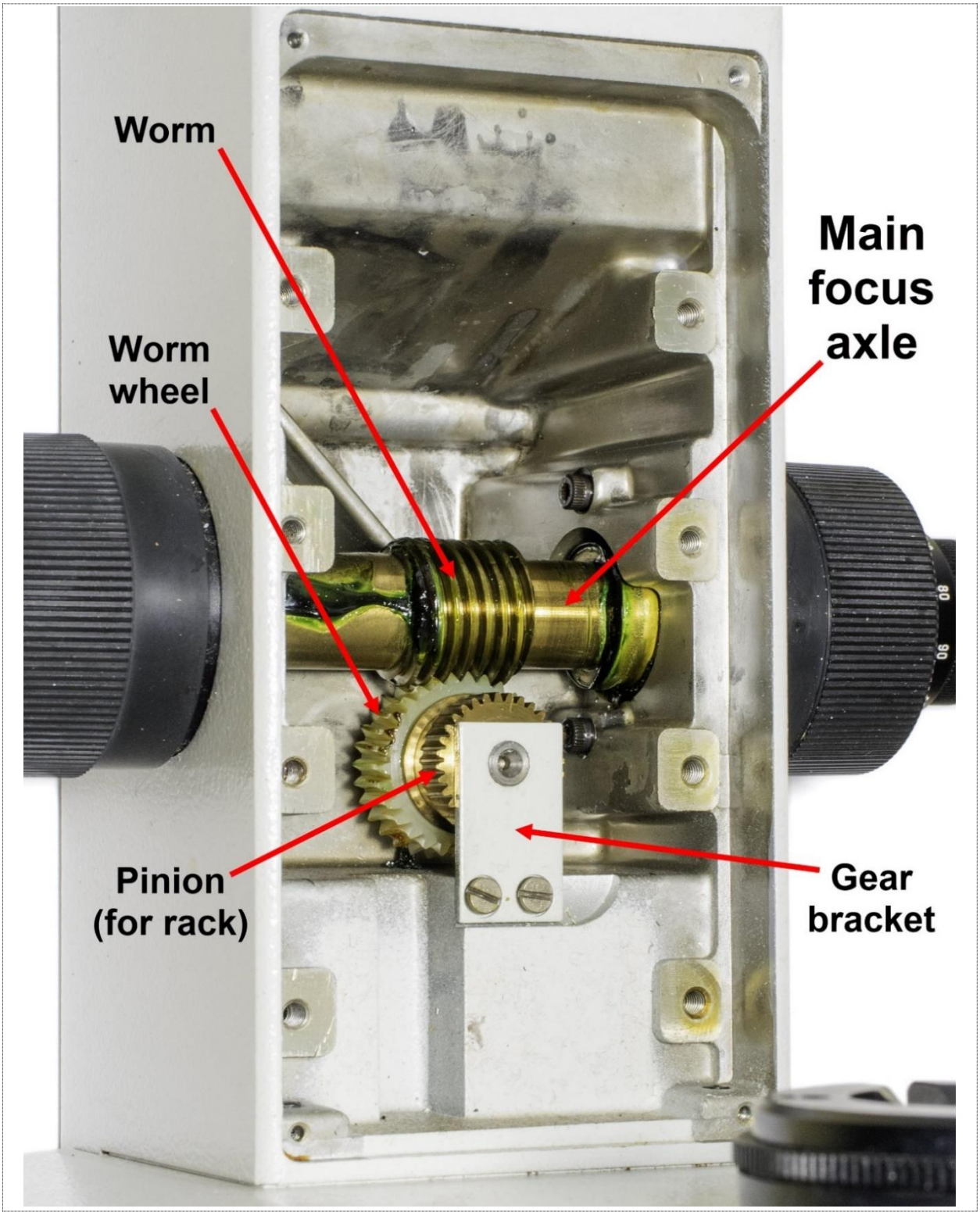


Figure 9: The focus mechanism after the focus slide has been removed.

The play of the pinion axle against the worm on the main focus axle can be checked by turning the worm wheel back and forth with one finger. It seems that a very slight play (one or a few tenths of a millimeter along the periphery of the worm wheel) is normal. The play should not impair the focus precision because the weight of the stage ensures that the teeth always catch on the same side.

The white metal plate covering the backside of the microscope stand is attached with four M3x6 screws. It doesn't need to be removed for any of the work described in these notes.

6. A look at the pinion axle.

Figure 9 and Figure 10 illustrate a design development in the Dialux 20 microscope. The hollow pinion axle (Figure 12) sits on a lightly greased roller bearing on a robust steel pivot shaft (Figure 11 and Figure 13) that is attached to the backside of the microscope stand. On earlier versions of the microscope the pinion axle was held in place on the pivot shaft by an E-clip on the tip of the shaft (Figure 10.) Later Dialux 20 models were modified by replacing the E-clip with a white metal bracket (Figure 9.)

The pinion axle with its roller bearing can be disassembled for cleaning of old grease and regreasing. We will however save that for later, because currently the main focus axle is locking in the worm wheel which makes the pinion axle impossible to remove from the pivot shaft.

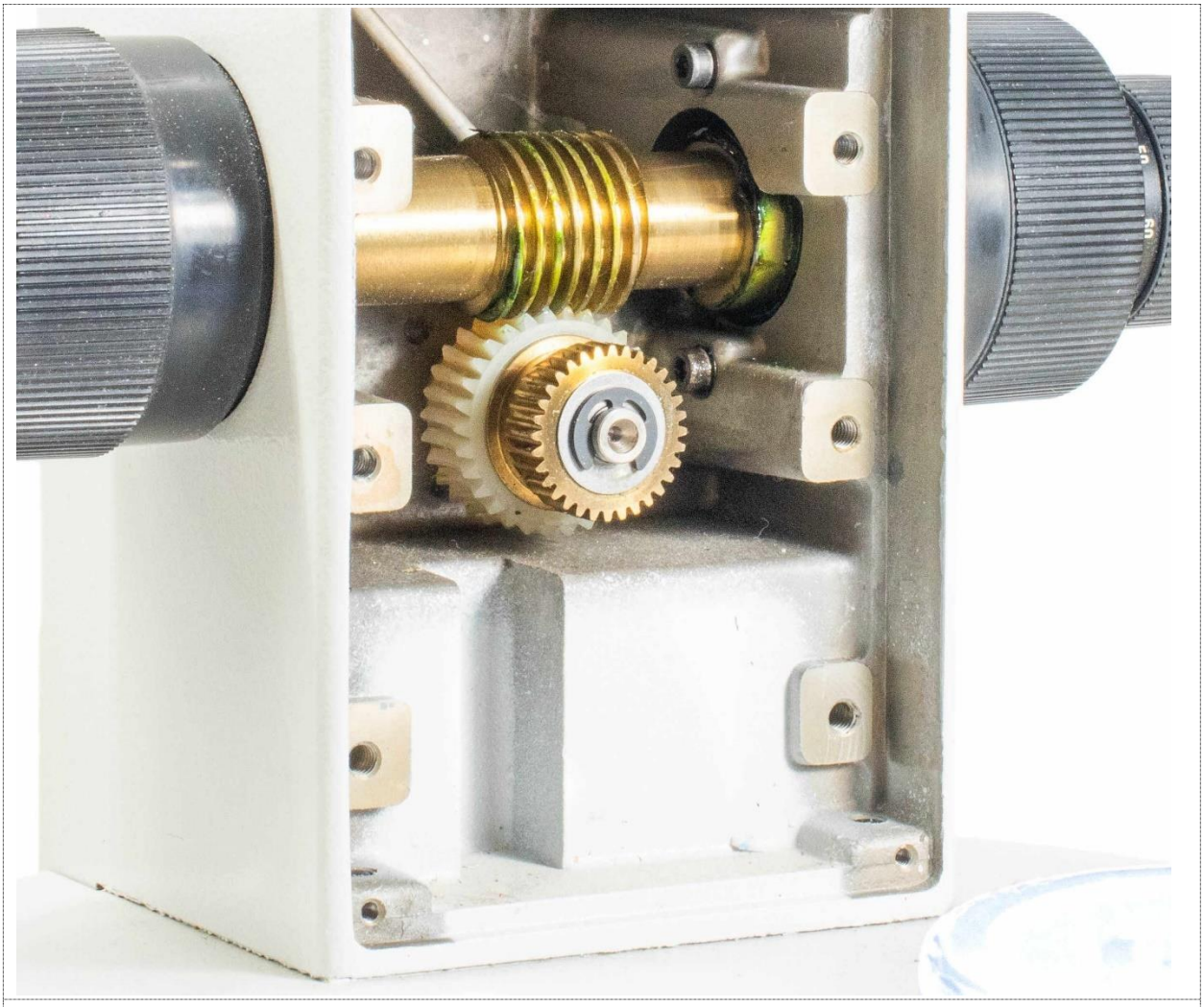


Figure 10: The focus mechanism in an earlier version of the Dialux 20 microscope. It doesn't have any gear bracket.

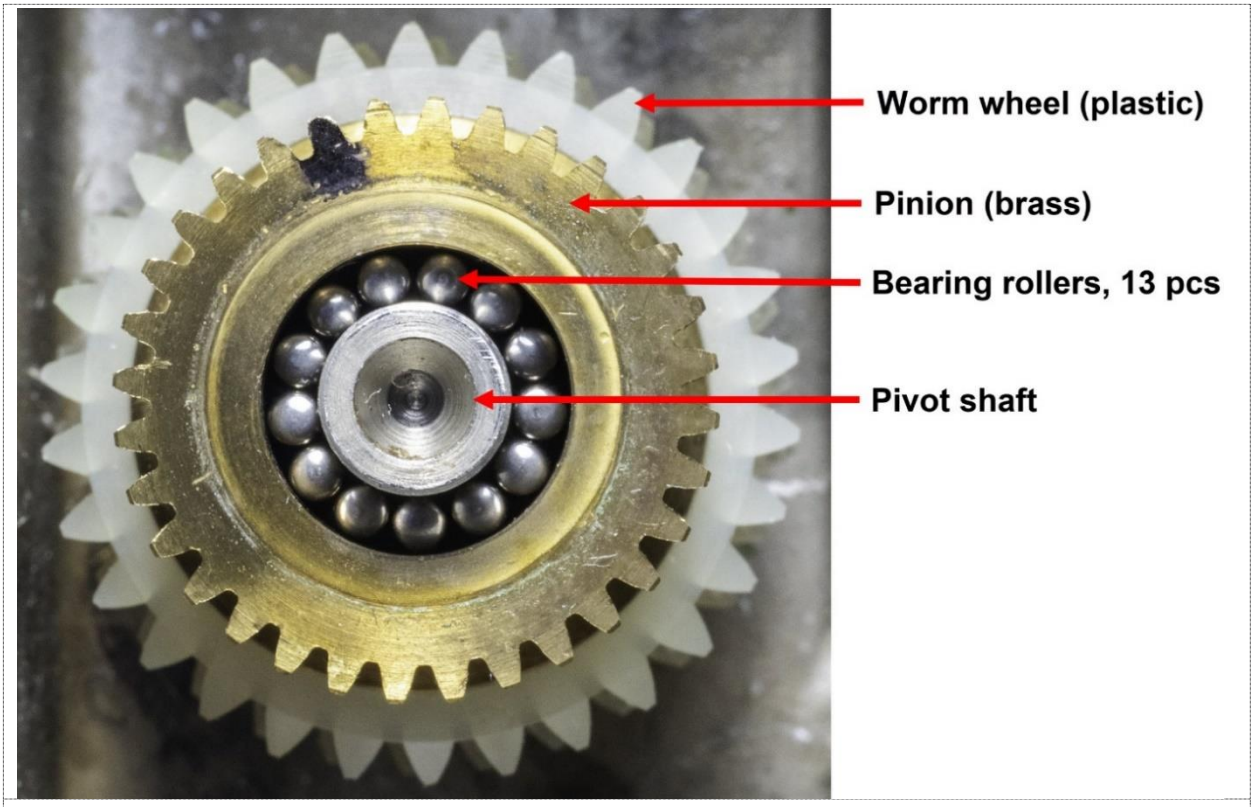


Figure 11: The pinion axle seen from above after the E-clip and the washer have been removed.

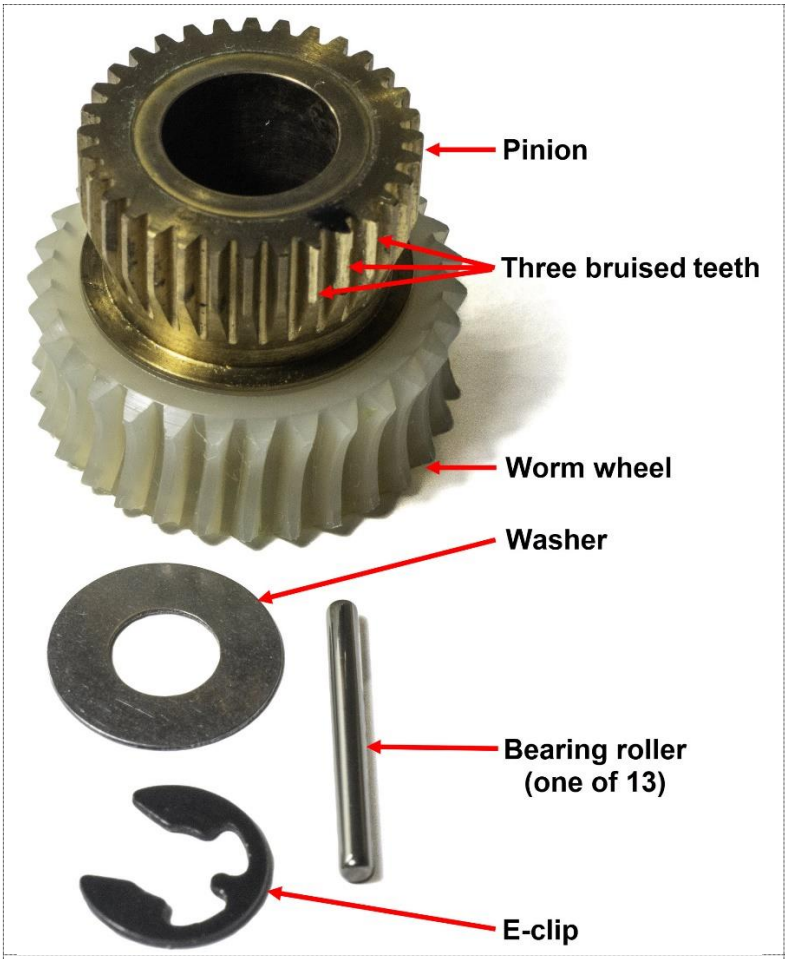


Figure 12:The pinion axle (on the top) with some of its associated parts.

Figure 13: The bare pivot shaft.

7. Remove the left fine focus knob and the fine focus axle.

Loosen the tiny hex screw (using a 1.5 mm hex wrench) deep in the side of the left fine focus knob. Don't remove the screw, only unscrew it by two full turns (two turns will allow it to go free from the small lip on the end of the fine focus axle  .) Grab the fine focus knobs with each hand and pull them carefully apart while turning them slightly back and forth in opposite directions until the left knob releases from the fine focus axle and can be removed. Retrieve the transparent plastic washer (o.d. 8.9 mm, i.d. 4.1 mm, 0.5 mm thick, greased) between the left fine focus knob and the left coarse focus knob. Pull out the thoroughly greased fine focus axle (stainless steel, diameter 3.0 mm) from the microscope's right side together with the still attached right fine focus knob (Figure 46.) Retrieve the smaller transparent plastic washer (o.d. 6.0 mm, i.d. 3.2 mm, 0.5 mm thick, greased) between the right fine focus knob and the right coarse focus knob. Leave the right fine focus knob (i.e., the knob with the engraved scale) attached on the fine focus axle.

Use solvent to remove old grease from the fine focus axle, the plastic washers, and the knobs.

8. Remove the right coarse focus knob and the ball bearing components below.

The right coarse focus knob covers the gear mechanism (a ball bearing with three large bearing balls) that reduces the turning rate of the fine focus control before it is passed over to the main focus axle.

Remove the right coarse focus knob after unscrewing the three M3x8 screws from the face of the knob (Figure 14.)

Figure 14: The face of the right coarse focus knob after the fine focus axle with the right fine focus knob have been removed.

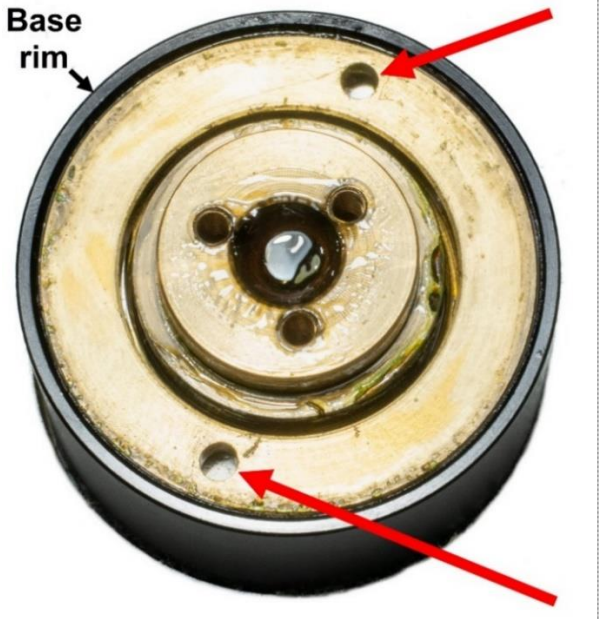


Figure 15: The right focus control base after the right coarse focus knob has been removed. To unscrew and remove the circular brass cover, a face pin spanner can be attached to the two 3 mm holes (indicated by the red arrows.)

Below on the right focus control base (Figure 15) is a circular brass cover (o.d. 39 mm, i.d. 26 mm, 3.6 mm thick, outside threads) with two 3 mm holes (Figure 16.) The cover is attached by threads in the right focus control base and exerts pressure on a wave washer (actually two wave washers sandwiched

together) just below; the force of the pressure is determined by how far down into the base the cover is screwed.

Before removing the cover, it is recommended to use a sliding caliper to measure and record the distance between the upper surface of the cover and the rim of the focus control base. On the microscope used for Figure 15 the upper surface of the cover was 0.5 mm below the rim of the base.

Unscrew the cover using a suitable face pin spanner.

Remove the large twin wave washer (Figure 16, steel, o.d. 36 mm, i.d. 26 mm, two 0.3 mm thick wave washers sandwiched together, drenched in grease) below the cover.

Below the twin wave washer is a ball bearing race (Figure 16, brass, o.d. 37.5 mm, i.d. 24.6 mm, 3.0 mm thick) – its upper surface is flat, while the inner part of its lower surface is tapered inward to hold the bearing balls confined. Remove the race. It sits loose on top of the bearing balls, but may be difficult to remove due to a lot of aged grease. Use cotton swabs wetted with solvent to wipe off any grease within reach, turn the microscope with the right focus control base down, and shake it to allow the race to fall out.

Figure 16: From the left side to the right side: The cover, the twin wave washer, and the ball bearing race.

The ball bearing below the race has three large steel bearing balls (diameter 16.0 mm) drenched in lots of grease. The balls can't yet be removed because they sit confined in holes in the hollow main focus axle. On the inside of the main focus axle the balls will press against the fine focus axle holding it centered, ensuring that the fine focus turns smoothly and easily, and most importantly, gearing down the turning rate of the fine focus axle to a 20x slower turning rate of the entire main focus axle.

The right focus control base is attached to the microscope stand by two hex screws (for a 2.5 mm key) from the inside of the microscope stand. There is however no need to remove the base, so we will leave it where it is.

9. Remove the left coarse focus knob and the components below.

The left coarse focus knob covers the mechanism that determines the upper and lower limits of the microscope's focus range. It also covers the bearing that carries the left end of the main focus axle. There were (at least) two different bearing designs in the Dialux 20 microscopes. The earlier models had a simple plain bearing (i.e., no ball bearing), which later was changed to an axial ball bearing. We will start by looking at the later designs with the axial ball bearing.

Keep the microscope standing on its foot. Unscrew the three M3x10 screws from the face of the left coarse focus knob (Figure 17) and remove the knob. This will release the main focus axle (and allow it to uncontrollably fall out from the other side of the stand if the microscope had been put on its side.)

On the inside of the knob are two tall screw heads (Figure 18) that are parts of the mechanism that limits the focus range. Leave the screws as they are.

Figure 17: The face of the left coarse focus knob after the left fine focus knob has been removed. A bright imprint from the plastic washer that was between the knobs can be seen between the screw heads.

Figure 18: The inside of the removed left coarse focus knob. The green arrows point to the tall screw heads that are parts of the mechanism that limits the focus range.

Below the knob (on the left focus control base) we can see (Figure 19 and Figure 20) first the left end of the main focus axle, then an axial ball bearing, a metal wave washer, a clear plastic washer, and finally, held together by a flanged guide tube, a stack of 10 plastic rings, each with a short arm that sticks out from the side.

Figure 19: View of the left focus control base after the left coarse focus knob has been removed.

The brass-colored part on the top is the left end of the main focus axle. Below is an axial ball bearing, a wave washer (not visible in this image), and then finally the 10 plastic rings that belong to the focus range limiting mechanism.

Remove the axial ball bearing (Figure 19, Figure 20 and Figure 21) from the end of the main focus axle. Due to old, solidified grease it may be stuck and even appear impossible to remove. Wet it with a few drops of white spirit and let the solvent work for a few minutes before carefully prying off the upper race (the race looks like a steel washer; o.d. 27.0 mm, i.d. 17.1 mm, 0.6 mm thick). Continue by removing the transparent, plastic retainer (o.d. 26.9 mm, i.d. 17.0 mm, 1.6 mm thick, with twelve 2.1 mm holes) with its bearing balls (12 balls, each 2.0 mm diameter), and then remove the lower bearing race (identical to the upper race.)

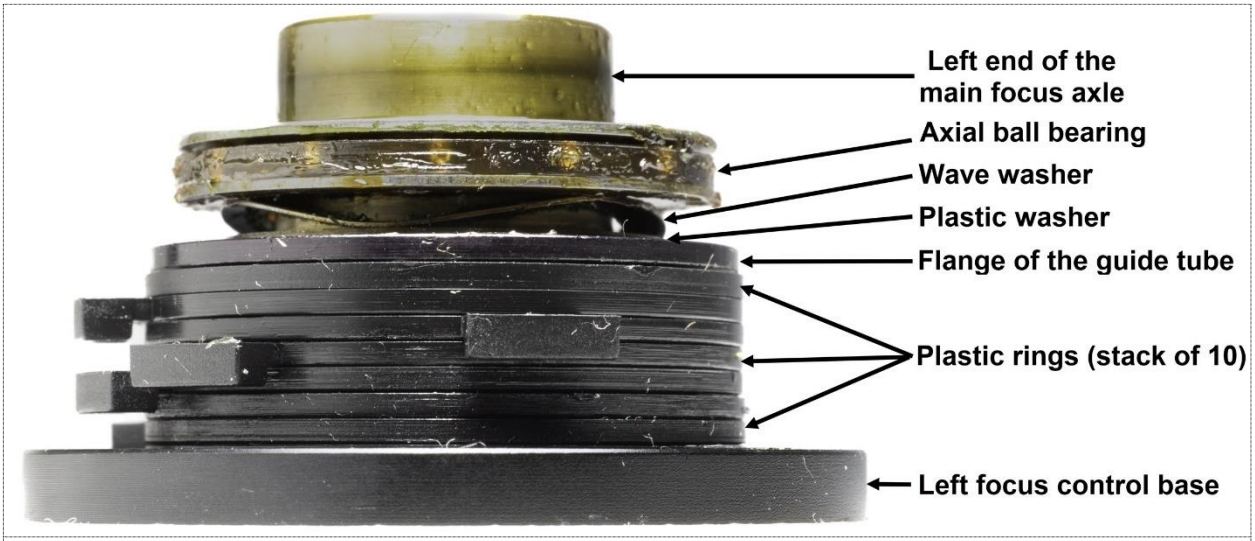


Figure 20: View from the side of the left focus control base after the left coarse focus knob has been removed.

Figure 21: The two washers and the components of the axial ball bearing removed from the left end of the main focus axle.

Remove the greased wave washer (Figure 20 and Figure 21; o.d. approx. 22.5 mm, i.d. 18 mm, 0.3 mm thick) below the ball bearing and finally remove the transparent plastic washer (Figure 20 and Figure 21; o.d. approx. 22 mm, i.d. approx. 17 mm, 0.5 mm thick) that sits on the flange of the black guide tube.

Use solvent (for example, white spirit) to clean the ball bearing components, the washers, and the inside of the left coarse focus knob from old grease.

And now over to the earlier Dialux 20 models with the plain bearing (Figure 22.) Follow the notes above starting with the removal of the left coarse focus knob and then proceed just making a few obvious procedure modifications that will be required due to the design differences:

The inside of the left coarse focus knob differs slightly (Figure 23) from the knob on the later Dialux 20 – the space is more constrained as a consequence of the simpler and more compact plain bearing.

The plain bearing design is quite simple, basically three greased washers (Figure 24) that are stacked on top of each other (starting at the top):

- Wave washer, o.d. 22.6mm, i.d. 18.1 mm, thickness 0.3 mm
- Metal (steel) washer, o.d. 21.8 mm, i.d. 17.5 mm, thickness 0.3 mm
- Plastic (transparent) washer, o.d. 21.7 mm, i.d. 17.3 mm, thickness 0.5 mm

Due to old, solidified grease the washers may appear stuck. Wet the washers with a few drops of white spirit and let the solvent work for a few minutes before carefully removing them.

Use solvent (for example, white spirit) to clean all plain bearing components, the washers, and the inside of the left coarse focus knob from old grease.

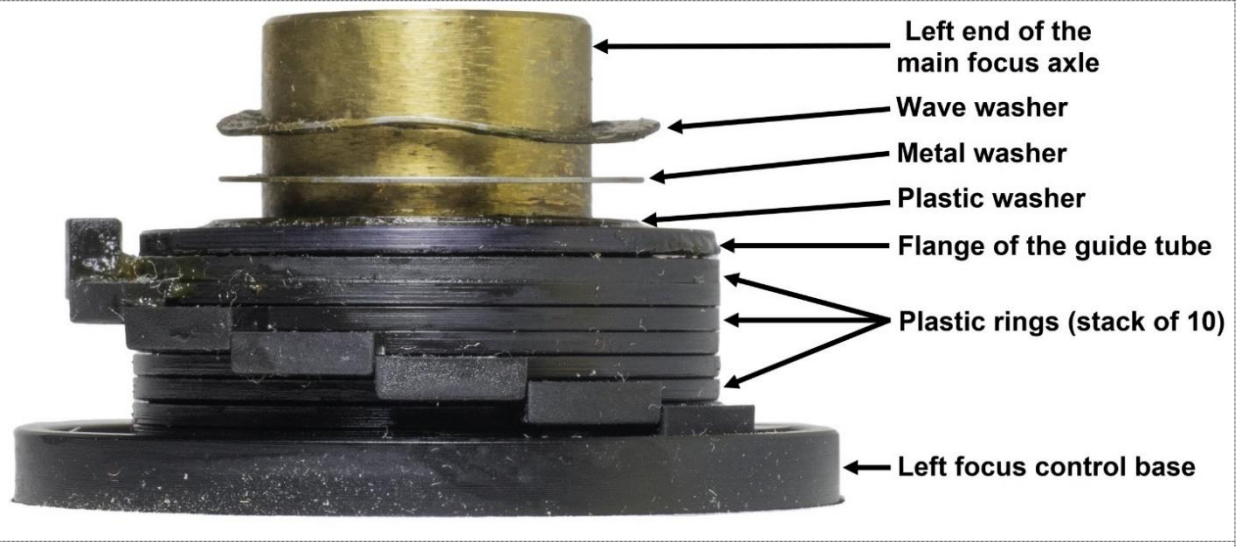


Figure 22: View from the side of the left focus control base after the left coarse focus knob has been removed.

Alternate design: Compared with Figure 20 the axial ball bearing has been replaced with a plain bearing made of two washers.

Figure 23: The inside of the removed left coarse focus knob. Compared with the knob in Figure 18 it has less space for the bearing.

Figure 24: The washers from the (alternate) plain bearing.

10. Disassemble, clean, regrease, and reassemble the focus range limiting mechanism.

The focus range limiting mechanism can be disassembled after the black guide tube (Figure 26) has been unscrewed and removed from the left focus control base. The flange of the guide tube has two holes (Figure 25) that comfortably accommodate a face pin spanner.

10 black plastic rings sit stacked on the guide tube (Figure 19 and Figure 20.) Each of the rings has a short arm on its side with a downward bent hook (Figure 27.) The arm on the ring at the top additionally has a protrusion that sticks upward (Figure 28.)

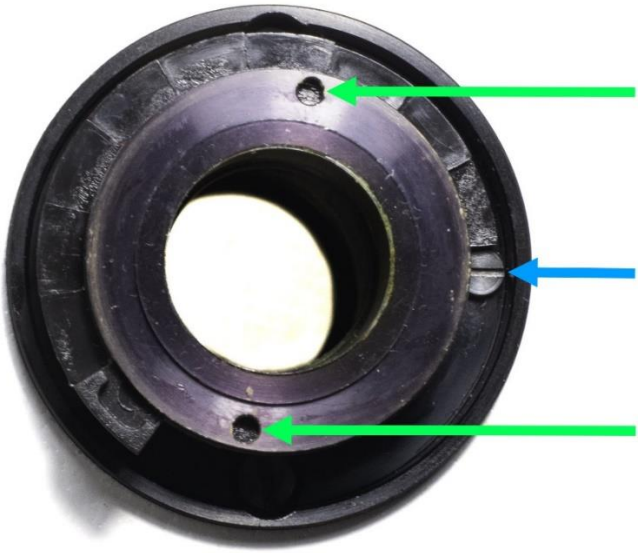


Figure 25: View from the top on the focus range limiting mechanism sitting in the left focus control base.

The green arrows point to the 2 mm holes in the guide tube flange that are used to release the guide tube with a face pin spanner.

The blue arrow points to the protruding screw head in the left focus control base that stops the turning of the lowest of the plastic rings.

Figure 26: The black guide tube from the focus range limiting mechanism. The flange is facing downward in this image.

The guide tube holds the stack of the 10 plastic rings (removed here.)

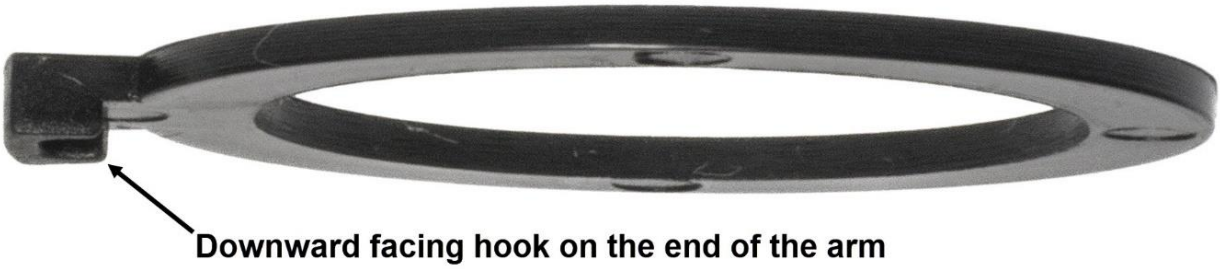


Figure 27:One of the 9 plastic rings closest to the bottom of the focus range limiting mechanism.

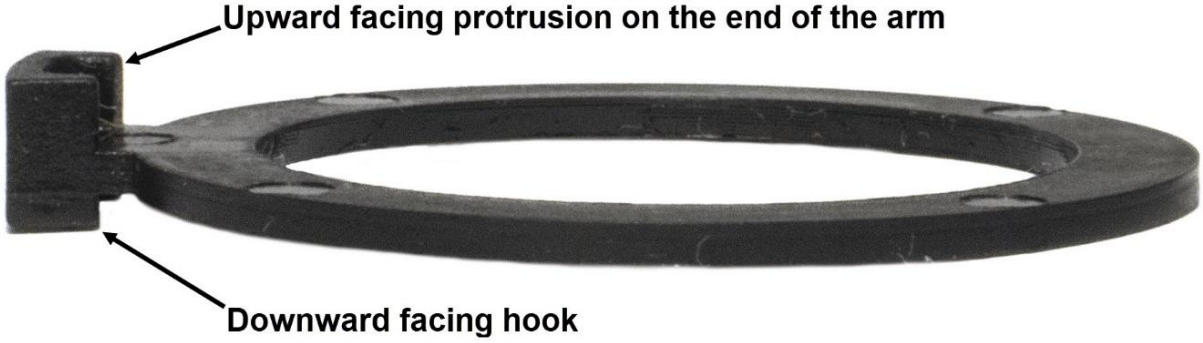


Figure 28: The plastic ring at the top of the focus limiting mechanism.

Here's how the focus range limiting mechanism works: Let's say that we start to turn the coarse focus control in one direction. As we turn the control one of the two tall screw heads in the inside of the left coarse focus knob (Figure 18) catches the upward facing protrusion of the ring at the top of the stack (Figure 28 and Figure 29.) This forces the top ring to turn with the coarse focus control. But before the top ring has been pushed through its first turn its downward facing hook will catch the side of the arm of the next ring below and will force this ring, too, to join in with the coarse focus control. In the same way, one after the other, each of the rings below gets engaged, and eventually all 10 rings turn together. The turning comes to a halt when the hook of the ring at the bottom collides with the screw head that sticks up from the focus control base (Figure 25 and Figure 30.) The focus control can't be turned beyond this point.

Figure 29: The arrow shows where one of the screws inside of the left coarse focus knob catches the top ring protrusion.

Figure 30: The entire train of the rings have here reached the focus range limit by colliding with the screw (blue circle) that sticks up from the left focus control base

If we proceed to turn the focus control in the other direction, the other tall screw in the left focus knob's inside catches the top ring's protrusion and again brings the top ring to turn with it. One by one the entire succession of rings engages in the same way as before until the bottom ring's arm collides with the screw head in the base, this time from the other side. And again, the focus control can't be turned further - we have reached the other end of the focusing range.

The focus range limiting mechanism limits the focus range to 9¼ turns of the coarse focus control. A focus range that is less than 9¼ turns (like 8¼) indicates that the tall screws inside of the left coarse focus knob may stick down too far and improperly catch the arm of the ring that is just next below the top ring.

Later, after the focus slide has been attached to the microscope, we will adjust the focus range limiting mechanism to make sure that is properly matched with the position of the focus slide (and the stage.)

The left focus control base is attached to the microscope stand by two black screws that can be accessed after the focus range limiting mechanism has been removed from the base. There is however no need to remove the base, so we will leave it where it is.

Let's return to the maintenance work:

Use a face pin spanner to unscrew and remove the black guide tube (Figure 25 and Figure 26) from the left focus control base. Remove the plastic rings from the guide tube and clean all ring and tube surfaces from old grease with white spirit. Pay particular attention to the inside of the guide tube – it may have solid old grease deposits that are difficult to see. It necessary, soak it in white spirit and scrape its inside with a suitable plastic or wooden stick.

Apply fresh grease to the outside of the guide tube and to all surfaces of the rings. Don't forget to grease the surface between the base and the lowest ring.

Reassemble the focus range limiting mechanism. Make sure that the hooks on the rings are turned the correct way, refer to Figure 22, Figure 27 and Figure 28. When you screw the guide tube to the base and tighten it, be careful so the bottom ring doesn't move sideways into the thread and get pinched there before the guide tube has been screwed down all the way. Check that the bottom ring always turns freely. Tighten the guide tube to the base with the face pin spanner and check that all rings still can turn freely.

11. Remove and clean the main focus axle.

Liberated from the coarse focus knobs and the bearings below the knobs, the main focus axle (Figure 31) can now be pulled out from the right side of the microscope stand. Due to old, hardened grease (the green deposits on the upper axle in Figure 31) the axle may be difficult to pull out. Careful rocking of the axle while pulling usually helps. Alternatively, penetrating oil (for example, WD-40) could be applied to the sliding surfaces in both ends. Catch the large bearing balls before they fall out – they are covered with a lot of grease.

Use solvent (for example, white spirit) to clean off all grease from the bearing balls and both the outside and the inside of the main focus axle. Be prepared that some grease may have hardened completely and can be difficult to dissolve. If necessary, use a plastic scraper to remove solidified grease. Also thoroughly clean the inside of the right focus control base, even from the inside of the microscope where you can expect to find deposits of petrified grease.

The brass axle will probably be tarnished by oxidation and corrosion due to the old grease. Remove the tarnish by rubbing with a cloth wetted with a suitable metal polish. After polishing, wash the axle thoroughly with isopropanol, then with an old toothbrush and warm water and detergent, and finally dry it.

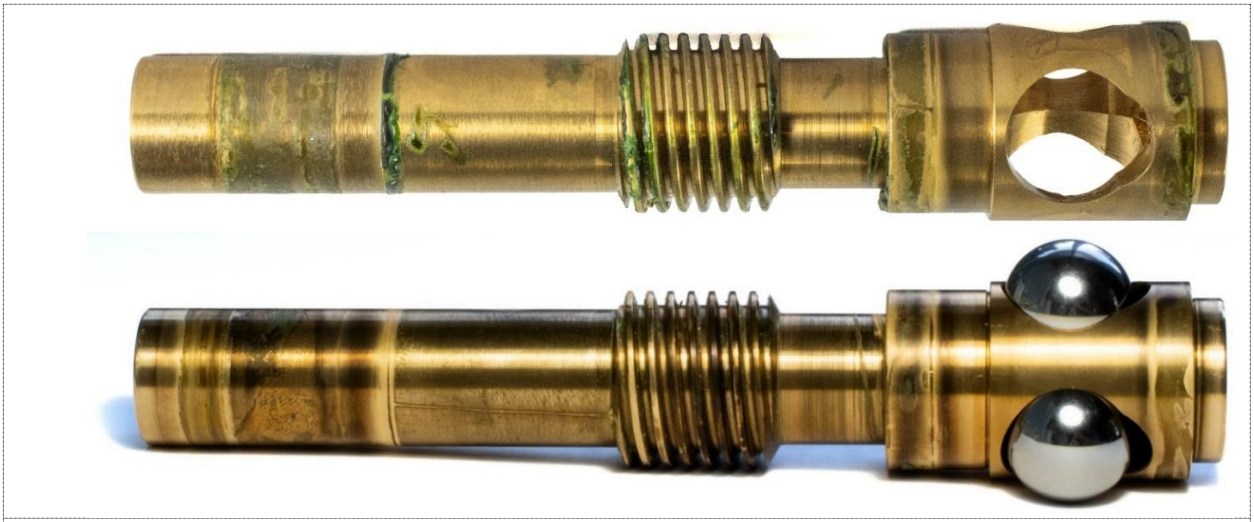


Figure 31: The main focus axle. The upper axle has green deposits of old hardened grease. The lower axle has the three large bearing balls still sitting in its right end. Both axles have tarnished patches from old grease.

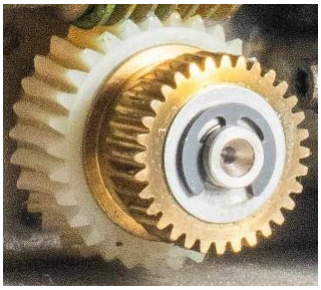
12. Clean, grease, and reassemble the pinion axle.

The pinion axle's roller bearing appears to be quite robust, so if the pinion axle rotates freely on the pivot shaft there really is no need to disassemble and regrease it - you can then just skip over this subsection.

With the main focus axle removed the pinion axle is available for removal, cleaning, and greasing.

For the older Dialux 20 microscope models with an E-clip on the pivot shaft's tip:

Pry off the E-clip from the tip of the pinion axle. This is most conveniently done with a special E-clip removal/installer tool but can also be accomplished with needle-nose pliers or even a small screwdriver. Remove the loose steel washer (o.d. 14.0 mm, i.d. 6.5 mm, thickness 0.4 mm) below the E-clip. Proceed with "Clean and grease the roller bearing" below.



For the newer Dialux 20 microscope models with a bracket over the pivot shaft's tip:

Remove the two M3x6 screws from the front of the bracket. Use pliers to carefully pry off the bracket from the tip of the pivot shaft. It sits quite tightly attached to the tip, so its removal will require some forceful wiggling and turning with the pliers. Be very careful not to bend or scratch the bracket and particularly not to damage the teeth of the pinion below – these parts are made of soft brass and therefore very vulnerable to damage. Proceed with "Clean and grease the roller bearing" below.

Clean and grease the roller bearing.

The liberated pinion axle (Figure 12) turns around a lightly greased roller bearing on a robust steel pivot shaft (Figure 11 and Figure 13, o.d. 6.4 mm) that is attached to the backside of the microscope. The roller bearing consists of 13 very lightly greased steel rollers (o.d. 2.0 mm, length 19.6 mm.)

Pull out the pinion axle and retrieve the 13 bearing rollers. Clean the inside of the pinion axle, the rollers, and the pivot shaft with solvent (white spirit.) This is also a good time to check and, if necessary, remove any remaining grease from the worm wheel and the pinion (Figure 12.) Let the cleaned parts dry.

Put back the pinion axle over the pivot shaft. Apply grease very sparsely to the bearing rollers and push them down, one after the other, into the space between the pinion axle and the pivot shaft.

For the older Dialux 20 microscope, very lightly grease the steel washer, attach it on top of the pinion axle, and attach the E-clip.

For the newer Dialux 20 microscope, apply a small amount of grease on the bracket surface that is adjacent to the pinion. Push the bracket over the tip of the pivot shaft leaving only a minimal play between the bracket and the pinion. Attach the screws that hold the bracket.

Rotate the pinion axle for a minute to distribute the grease over all roller bearing surfaces.

13. Replace a broken focus rack.

This subsection only applies if you need to replace a focus rack because it has one or more broken teeth (Figure 8.)

Used replacement racks (sometimes still attached to the center bearing guide) can occasionally be found on eBay. Fortunately, several Leitz microscope models, both from the “gray” 170 mm era and the “white” 160 mm era, used the same rack, so the task to find one should not be hopeless. Just make sure to verify the dimensions (height, length, and width) and the number of teeth before you commit to purchase.

Before removing the broken rack from the backside of the center bearing guide you should use a digital caliper to measure the distance between the backside of the rack and the adjacent long side of the guide, see the yellow arrows in Figure 32. On my microscope it was 7.00 ± 0.02 mm in both locations.

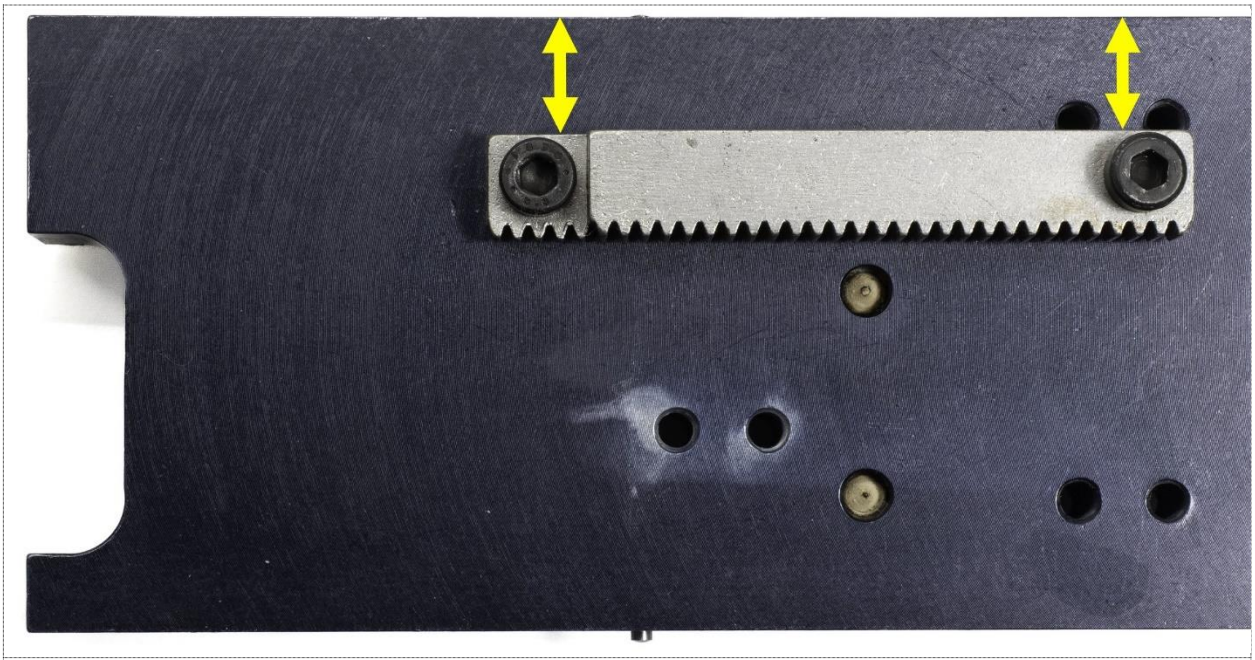


Figure 32: The yellow arrows show the two approximate locations where you should measure the distance between the backside of the rack and adjacent long side of the center bearing guide.
(This image pertains to a Leitz Diaplan microscope, unfortunately I neglected to take a corresponding image for the Dialux 20 microscope.)

Remove the faulty rack by unscrewing the two screws that attach it to the center bearing guide. Below the rack is a rectangular metal spacer approximately 1-1½ mm thick. The screw holes in the rack are wide which allows for some adjustment of the rack alignment. Attach the replacement rack together with the original spacer. Use a digital caliper to position the rack to the same distances as you found for the old rack, try to get within ± 0.05 mm of the desired values. Measure and align the rack while successively tightening the screws.

14. Grease and reassemble the focus slide.

It may appear strange that we will assemble the focus slide before the main focus axle has been attached. The reason is that we need to ensure that the focus slide moves freely but without any play, and this can't be done with the main focus axle attached because it would constrain the movements of the focus slide.

Assembling the focus slide with its ball bearings and attaching it to the microscope requires some dexterity. The challenge is to manage to assemble and hold the bearings safely joined until the slide is resting in the focus slide bay in the microscope stand (Figure 38.) Before the focus slide is secured in the bay the slippery bearings behave like skittish squirrels that try to escape from your hands. The tiniest slip may make the bearing balls to dislodge, and then you will need to check the bearings by taking them apart, and to do any necessary corrections before reassembling them again. The procedure described here uses rubber bands to hold the bearings safely joined while attaching the entire focus slide to the microscope. If you feel that you would like to try a different approach, please feel free to do that.

It is most convenient to assemble the focus slide with the microscope's backside downward on the table with the focus slide bay facing upward.

Grease the worm wheel (Figure 9) in the microscope stand. Use enough grease to fill the valleys between the teeth. Don't grease the brass pinion just above the worm wheel. (Greasing the worm wheel must be done before the slide is assembled, the worm wheel will not be accessible after that.)

Put the right bearing guide (Figure 33) on the table with the race facing up and the wide screw holes for the screw heads facing you. Put the guide on two hexagonal screwdriver bits (or something similar) as supports (Figure 37.) The bits will hold the slide slightly elevated above table which makes it much easier when we later will apply the rubber bands. The hexagonal shape of the bits prevents them from rolling on the table.

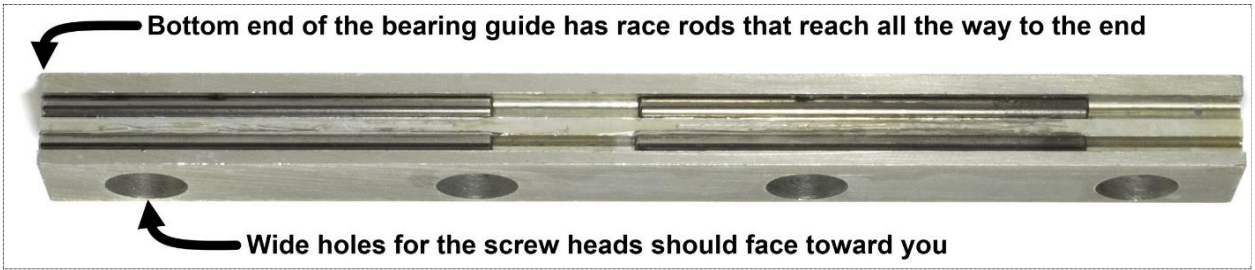


Figure 33: How to identify the focus slide's right bearing guide.

Before we start to assemble the focus slide, a warning about misalignment of the bearing retainers. The retainers have an annoying tendency to get stuck lopsided on the bearing race. It will happen if the retainer is allowed to slide sideways and its side is caught against the inside of the race (as shown in the bearing guide on the right side of Figure 34.) With the retainer misplaced in this way the bearing balls will not properly run in the middle of the race, but instead be forced to run on top of one of the race rods. It is easy to miss this mishap, and it inevitably results in a dysfunctional bearing. One way to spot this failure after the bearings have been joined is to check the width of the bearing crevice between the bearing guides – it should be quite narrow, like in Figure 38. A wider crevice with clearly visible bearing balls indicates that the bearing retainer has been misplaced.

Figure 34: A properly seated bearing retainer on the left side and an erroneously seated retainer on the right side.

Grease the race of the right bearing guide and both sides of one of the bearing retainers. Place the retainer centered over the race rods and put the 8 bearing balls into the retainer holes (Figure 35.) Thoroughly push down the balls into the retainer holes to ensure that the balls as well as the retainer are properly seated and centered on the race. Double check for retainer misalignment.

Figure 35: The focus slide's right bearing guide, greased, and with the bearing retainer and the bearing balls on top of the race. (The guide rests on two drill bits that are not visible in this image.)

Grease both races of the center bearing guide, the race on the left bearing guide, and both sides of the other bearing retainer. Put the center bearing guide (make sure it is turned the right way!) right over the right bearing guide on the table to join the bearing races over the bearing balls (Figure 36.) The small pin

in the middle of the race of the center bearing guide should go into the long opening in the middle of the bearing retainer. Don't separate the races again – this may dislodge the bearing balls and jeopardize the integrity of the bearing. Lean the center bearing guide slightly against a vertical support (perhaps the side of the microscope, like in Figure 36) before you let go of it.

Figure 36: The right bearing guide and the center bearing guide joined over the ball bearing. (The right bearing guide still rests on two drill bits that are not visible in this image.)

Place the other retainer on the upper race of the center bearing guide and put the 8 bearing balls into the retainer holes. Thoroughly push down on the balls to ensure that they are properly seated on the race. Double check that the retainer and balls really are OK.

Put the left bearing guide (make sure it is turned the right way!) right over the race of the center bearing guide to join the bearing races over the bearing balls. Be careful now - the slide with the greased bearings is very prone to slip and fall apart.

Put two rubber bands across both ends of the focus slide to prevent that it falls apart and the bearings separate (Figure 37.) The rubber bands should be tight enough so the ball bearings remain safely joined when the slide is carried over to the focus slide bay in the microscope stand. On the other hand, if the rubber bands are too tight it will be more difficult to apply them without messing up the bearings. Don't let the rubber band on the lower end of the slide go over the rack on the backside of the center bearing guide. Adjust each rubber band so the tension is approximately the same on both sides of the slide. Applying the rubber bands is somewhat challenging, mainly because the right and left bearing guides are wiggling on the bearing balls.

If your pinion has one or a few broken teeth review the paragraphs following "**Addendum only for the case that your pinion has one or a few bruised teeth …**" at the end of this subsection.

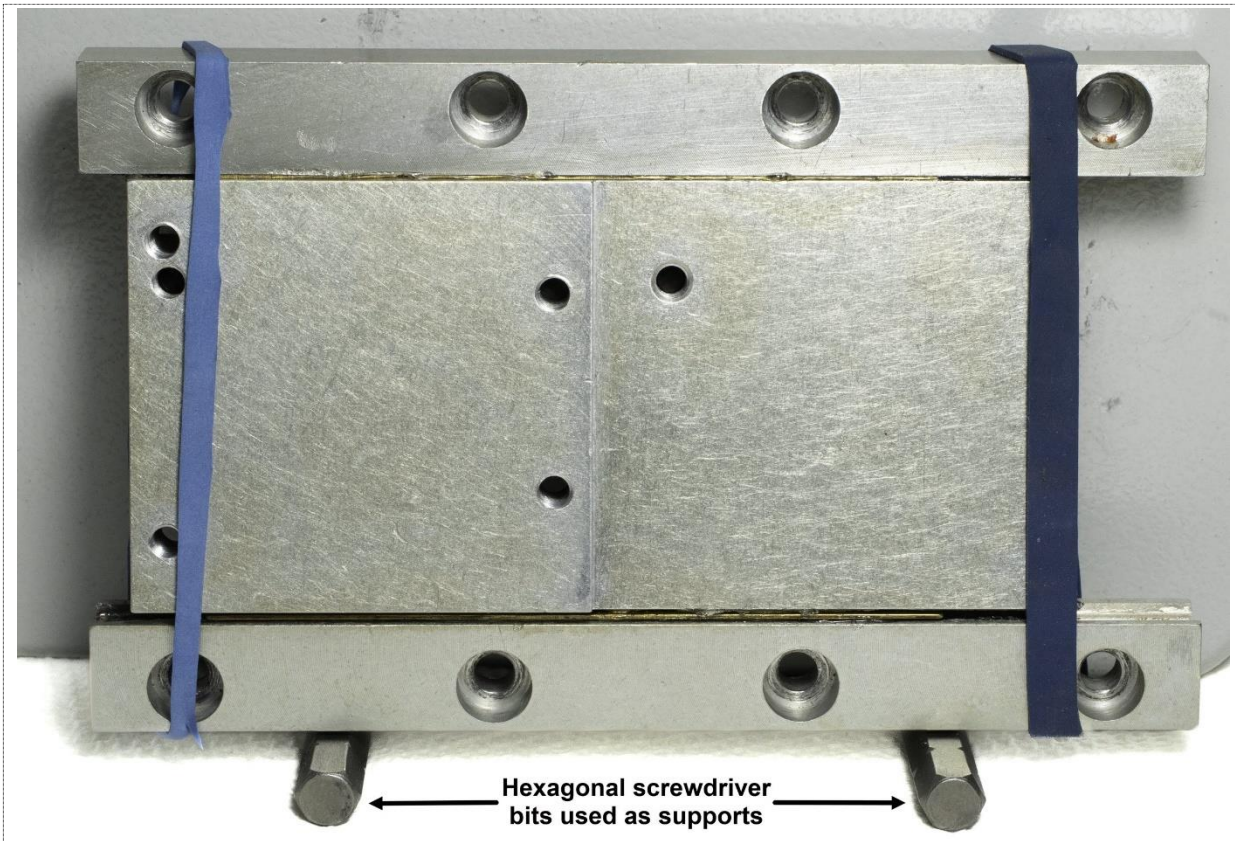


Figure 37: The focus slide after its ball bearings have been assembled. Now ready to be placed into the focus slide bay the slide is held together with two rubber bands.

Take the slide with one hand holding the slide by the center bearing guide (the rubber bands should be tight enough to keep the bearings joined and intact) and carefully place the slide into the focus slide bay in the microscope stand (Figure 38) making sure that the rack is catching the pinion. The rubber bands help to hold the focus slide together, but this maneuver still requires a steady hand and well choreographed movements.

With the focus slide safely in the focus slide bay secure the right and left bearing guides to the microscope stand with the eight M4x12 screws, but don't yet tighten the screws, only screw them down until their heads stick out approximately 1 mm above the guide surfaces. The screws will ensure that the bearings don't separate and fall apart after the rubber bands are removed.

Use scissors to cut and carefully pull out the rubber bands. Forceps and a dental probe may be helpful.

Check that the bearings appear intact. Verify that both races of each bearing are aligned and parallel – a dental mirror helps to check from the underside of the slide. Also look into the bearing crevices to check that the bearing retainers appear to be correctly positioned and that the crevices are tight (the bearings balls should be only barely visible in the crevices.)

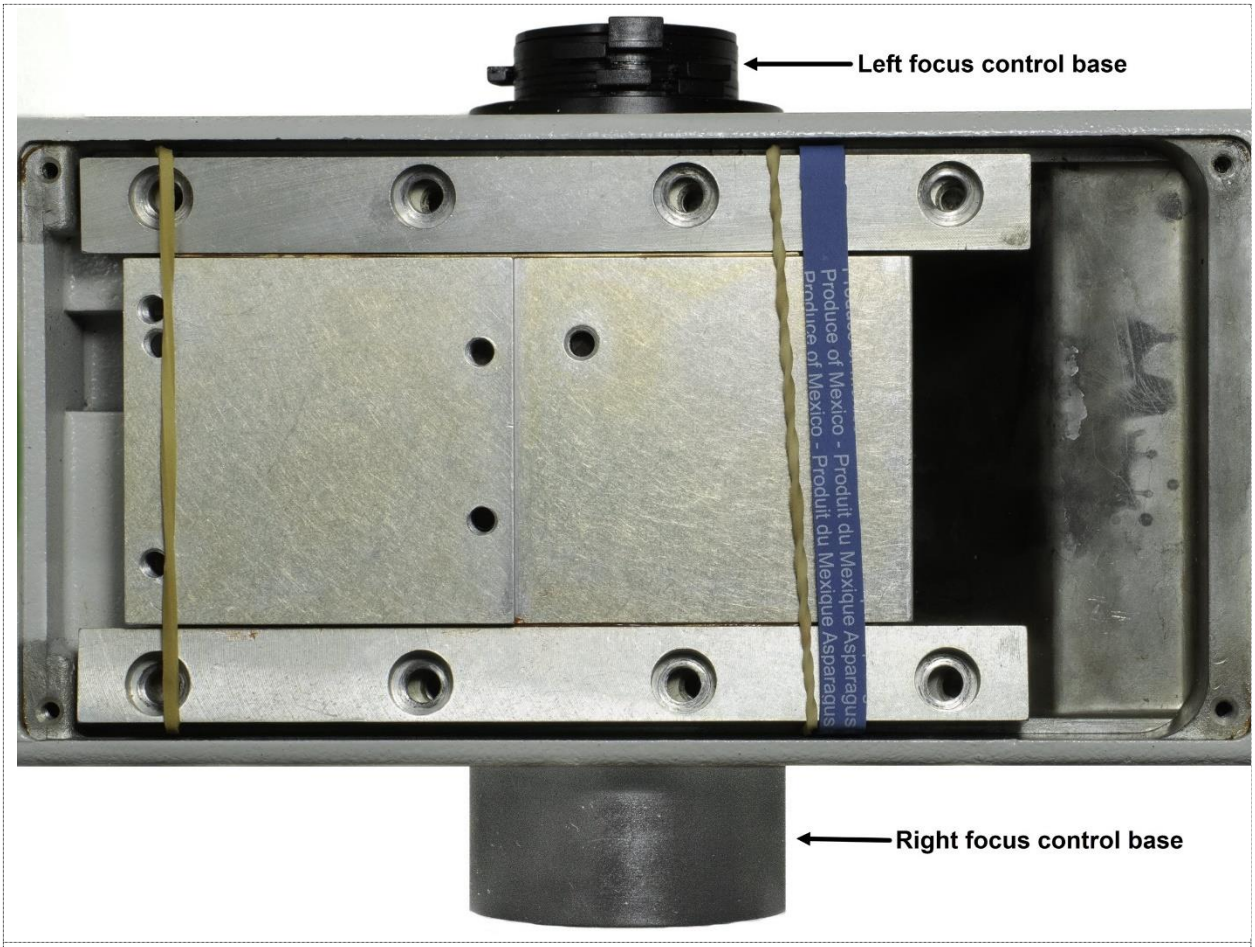


Figure 38: The focus slide has just been placed in the microscope stand's focus slide bay.

The focus slide should now be free to move up and down along the bearings, although there will be some play sideways.

Addendum only for the case that your pinion has one or a few bruised teeth as in Figure 12: Bruised teeth in the focus mechanism's rack-and-pinion may not be immediately noticeable during routine microscopy, but a critical user may eventually recognize that parts of the focusing suffer from lack of precision. As previously mentioned (in subsection 5), a broken tooth on the rack will require replacement or repair, but fortunately one broken tooth (or a few adjacent broken teeth) on the pinion can be tolerated. A fix is possible because the pinion only turns approximately ⅔ of a turn through the microscope's entire focus range. By turning the pinion into a particular position when the focus slide is placed into the microscope's focus slide bay one can make sure that the bruised tooth/teeth never engage(s) with the rack. Here's how to do that:

With a marker put a black dot on the face of the pinion to indicate where the bruised tooth is (Figure 11.) Turn the pinion so the bruised tooth is at the 10:30 o'clock position (Figure 39.) After the rubber bands have been put over the focus slide but before the slide is placed into the focus bay align the three (right, left, and center) bearing guides so their lower ends are approximately level. On the rim of the microscope's focus slide bay draw a line to mark a level that is 9 mm above the lower rim of the focus slide bay (Figure 40.) Place the slide into the focus slide bay as described above, but use the 9 mm mark to make sure that the lower end of the center bearing guide ends up 9 mm (± 1 mm) above the lower rim of the focus slide bay when the rack catches the pinion (Figure 40.) Properly done, this will keep the

bruised pinion tooth/teeth away from the rack through the microscope's entire focus range. Proceed by attaching the screws and the right and left bearing guides to the microscope, etc., as described above.

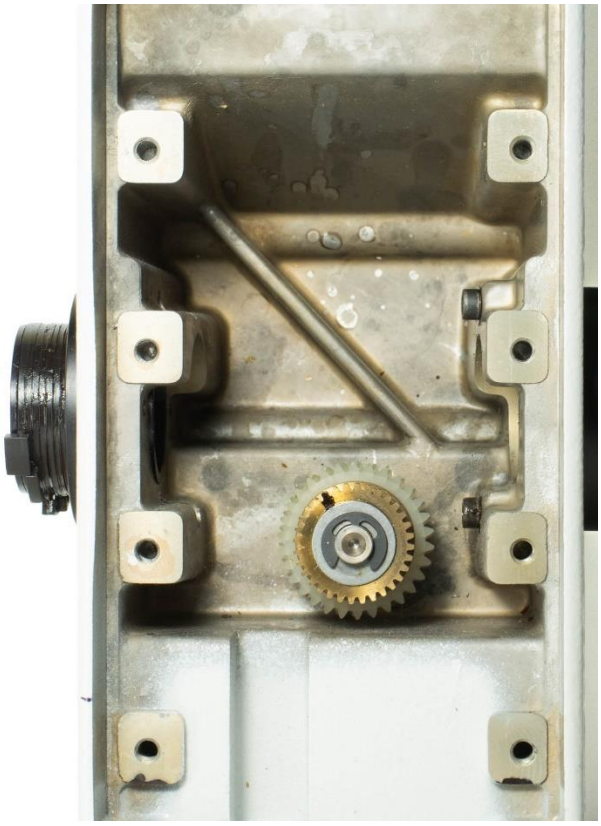


Figure 39: The focus slide bay with the pinion turned with the bruised tooth (under the black dot) at the 11 o'clock position.

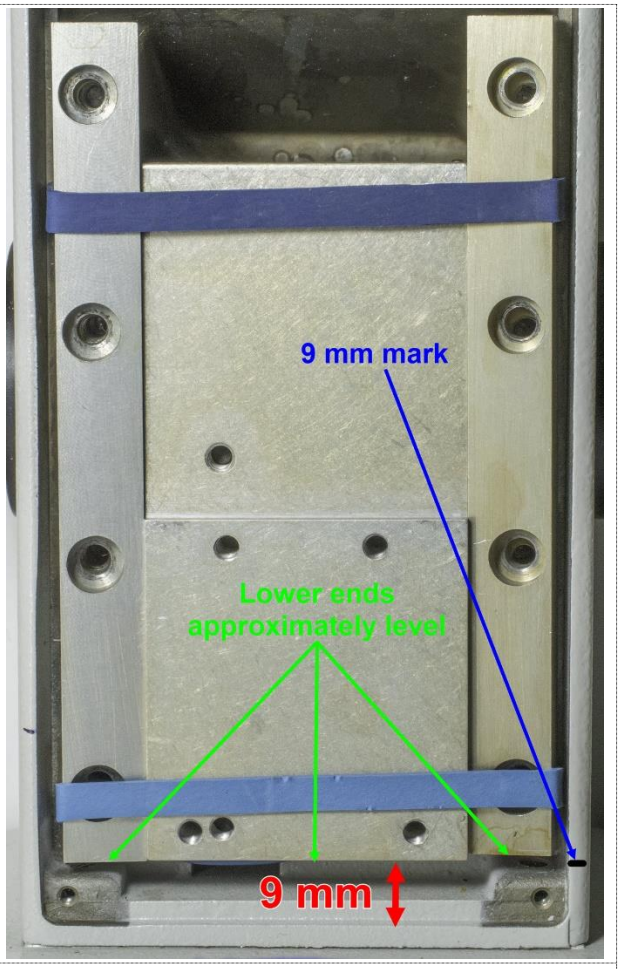


Figure 40: The focus slide with the three guides' undersides aligned at even levels and with the underside of the center guide 9 mm above the inside of the rim of the focus slide bay.

15. Collimate the focus slide.

Now we need to collimate the focus slide, i.e., to align it so it moves in line with the microscope's optical axis. Microscope manufacturers and professional service technicians have special tools and skills to do this, but as amateurs we have to resort to less sophisticated ways. We will assume that the vertical insides of the microscope's focus slide bay are straight and in line with the microscope's optical axis and therefore begin the procedure by aligning the right bearing guide with the right inside of the bay.

Screw down the four M4x12 screws in the right bearing guide all the way, and then release them only just enough so the guide can be moved sideways. The sideways movement will be restricted by the play in the guide's screw holes.

Put two 1.2 mm* temporary spacers into the crevice between the inside of the microscope's focus slide bay and the outer side of the right bearing guide (Figure 41.) Two 1.2 mm feeler gauges would make the optimal spacers, but any two 1.2 mm items can be used - just verify with a sliding caliper that the items

are 1.2 mm thick and, more importantly, that they have the same thickness. The blunt ends of two 1.2 mm drill bits were used as spacers in Figure 41.

Place the spacers approximately 20 - 25 mm (3/4” - 1”) from each end of the guide. Unfortunately the inside of the focus slide bay is slightly sloping, so don’t push the spacers all the way down to the bottom – push them down only by 1-2 mm into the crevice. Push the right bearing guide (or the entire slide if that works better for you) firmly against the spacers and successively tighten the four screws until the right guide is secured. Remove the spacers. Make a final check that the bearing guide still is properly aligned with the inside of the focus slide bay.

* I choose a spacer size of 1.2 mm based on very limited experience. You may find that a slightly different spacer thickness works better for your microscope. Due to the limited play allowed by the M4x12 screws in the right bearing guide it is quite important to estimate a good spacer thickness. If the spacers are too thick, it will result in a slide that is jammed between the bearings preventing it from running freely. If the spacers are too thin, the slide will suffer from sideways play because the left bearing guide can’t be adjusted enough tightly to the slide.

  The play between the rack and the pinion is another factor that is affected by the sideways alignment of the focus slide. Forcing the slide too much towards the right side (i.e., with spacers that are 1.0 mm, or less) would push the rack on the backside of the slide hard against the pinion which could lead to strained slide movements. Ideally there should be a very small play between the rack and the pinion through the entire focus range.

Figure 41: View showing how the temporary spacers (drill bits) are put between the inside of the focus slide bay and the right bearing guide.

16. Adjust the tension over the focus slide.

We will now adjust the left bearing guide until we get a well-balanced tightness over the focus slide’s ball bearings. By well-balanced we mean that we must find the sweet spot where the slide is completely

free from sideways play, while at the same time it still can move freely and easily up and down through the entire focus range.

Put the microscope upright and standing on its foot. The focus slide is now quite loose because we haven't yet put any tension over the bearings, and therefore the slide will drop down by gravity all the way toward the microscope foot. The slide's rack will engage the pinion (Figure 9) but because the pinion axle rotates easily and unhindered by the main focus axle it will not restrain the movement of the slide. If you push the slide upward as far as it goes and then release it, it will again drop down toward the microscope foot. If you wiggle the slide, you will find that it has sideways play. Our task is to adjust and attach the left bearing guide in such a way that the focus slide is compressed between the bearings as tightly as possible, while the vertical slide movements still remain unrestricted. The criterion for "unrestricted" is that if you push the slide upwards with your fingers and release it, its weight and gravity should make it to drop down again without any signs of jamming. And this must work through the entire focus range.

Tighten all four M4x12 screws of the left bearing guide, and then release them just as much as is necessary to allow the guide to move sideways as far as the screw holes allow.

With your fingers and with the help of some suitable wood or plastic wedges (for example, pointed wood toothpicks or wood skewers) press the left bearing guide against the focus slide while successively tightening its M4x12 screws, testing the slide movements, and readjusting the pressure over the slide. It's an iterative trial-and-error procedure, so be patient and persistent, because you will typically need to tighten and release the slide a couple of times before you get it right. When you are satisfied with the slide, make sure that all M4x12 screws are well tightened.

If the slide can't be properly adjusted and remains too loose, redo the collimation of the right bearing guide as described in subsection 15, but use a slightly larger spacer thickness, perhaps 1.4 mm. Try again to adjust the tension over the focus slide.

If the slide can't be properly adjusted and remains too tight, redo the collimation of the right bearing guide as described in subsection 15, but use a slightly smaller spacer thickness, perhaps 1.0 mm. Try again to adjust the tension over the focus slide. By using a smaller spacer thickness you will be moving the right bearing guide further to the right side. This will allow for more space for the slide between the right and the left bearing guides, but it will also force the pinion and the rack on the backside of the slide tighter together. Having too much tightness between the rack and pinion may result in a sluggish focus slide. Therefore, we should now check that there still is at least a very small play between the pinion and the rack. Check the play by putting your finger through one of the focus control bases and turn the worm wheel back and forth while holding the focus slide fixed so it doesn't move. If there is no play, you may consider moving the rack slightly (say 0.2 mm) to the left (i.e., referring to Figure 32 you would shorten the distances indicated by the yellow arrows.) Refer to subsection 13 for guidelines how to measure and realign the rack.

Reattach the white focus slide cover (Figure 5) over the focus slide bay. Don't forget to include any washers that may have been used as spacers between the bay and the cover. (The microscope in Figure 5 had three 0.1 mm washers below each of the four screws, to simplify I just replaced each of these washer sets with one 0.4 mm washer. Other microscopes may not have any washers.)

17. Reassemble the main focus axle and the focus knobs.

Generously grease the lower (stationary) ball bearing race in the bottom of the right focus control base (Figure 42.)

Figure 42: View of the inside of the right focus control base. The red arrows point to the stationary ball bearing race.

Put the microscope on its back with the focus slide facing up.

Generously grease the sliding surfaces of the main focus axle: The worm, the insides of the three ball bearing holes at the axle's right end, around the sliding surface close to the left end of the axle, and around the axle's sliding surface located between the worm and the ball bearing (Figure 43.)

Push the focus slide upward to move it into its highest position. Insert the three large bearing balls into the greased holes in the main focus axle and hold them in place with your fingers. Carefully insert the main focus axle through the right focus control base while at the same time rotating the axle to distribute the grease. Push the axle all the way through until the three large bearing balls reach the race in the bottom of the right focus control base. The worm will engage with the worm wheel and the pinion, which in turn will push the focus slide downwards. Turn the main focus axle (while pushing at its right side to keep the large bearing balls tightly on the race) to check that the focus slide moves as expected.

Figure 43: The main focus axle. The red arrows point to the areas that should be greased (from the left side to the right side; the left end slide, the worm, the right end slide, and the holes for the three bearing balls.)

If your microscope had the axial ball bearing (Figure 20) on the left end of the main focus axle: Hold the main focus axle in place, grease and attach the first the plastic washer and then the wave washer over the left end of the main focus axle and on top of the guide tube's flange (Figure 20 and Figure 21.) Grease, assemble, and attach the axial ball bearing (Figure 19, Figure 20 and Figure 21) on top of the wave washer.

If your microscope had the plain ball bearing (Figure 22) on the left end of the main focus axle: Hold the main focus axle in place, grease and attach first the plastic washer, then the metal washer, and finally

the wave washer (Figure 24) over the left end of the main focus axle and on top of the guide tube's flange (Figure 22.)

Grease the inside of the of the left coarse focus knob (Figure 18 for the axial ball bearing, or Figure 23 for the plain bearing) where it touches the bearing and attach the knob the to left side of the main focus axle with the three M3x10 screws (don't confuse them with the shorter M3x8 screws that belong to the right knob). Tighten the screws only lightly for now, we will soon need to remove them again. If you now are taken aback by how sluggishly the main focus axle turns, don't worry, things will improve greatly later, after the fine focus axle has been attached.

Generously grease the surfaces of the three large bearing balls on the right side of the main focus axle.

Grease both sides of the brass race (Figure 16) and attach it over the right end of the main focus axle and on top of the 3 large bearing balls. Make sure that the race's tapered side faces the bearing balls.

Grease both of the washers that comprise the twin wave washer (Figure 16), fit them together snugly so they exactly overlap (as in Figure 44, but not as in Figure 45), and put them on top of the race.

Figure 44: The twin wave washer properly put together. Both washers are snugly attached and in close contact over the entire surface. You may need to turn the washers a couple of times to find the proper configuration.

Figure 45: The twin washer improperly put together. The two washers are not tightly attached to each other.

Grease the thread and the underside of the brass cover (Figure 16) and attach it over the twin wave washer. Use a suitable face pin spanner to screw the cover into the right focus control base (Figure 15.) For now, screw it down only by a few turns so approximately half of it still sticks out above the rim of the base.

Grease the smaller (o.d. 6.0 mm) of the transparent plastic washers, push it over the fine focus axle and against the underside of the right fine focus knob. (We are assuming that the right fine focus knob has been left attached to the fine focus axle.)

Stick the fine focus axle through the center of the right coarse focus knob (not yet attached to the main focus axle!) and then generously grease the entire fine focus axle where it sticks out from the underside of the right coarse focus knob.

From the right side of the microscope push the fine focus axle (with the coarse focus knob still loosely attached) though the main focus axle and through the center of the three large bearing balls. But don't put the axle through all the way yet, push it only approximately halfway in. Note that there will be some resistance when the fine focus axle needs to penetrate the constrained space between the bearing balls.

Tighten the brass cover (Figure 15) with a face pin spanner to apply a suitable pressure over the large ball bearing. Tighten it to the same depth as measured during the disassembly in subsection 8. (It appears that Leitz typically left its upper surface 0.5 mm below the rim of the right focus control base.) The tightness affects to some extent the smoothness of the coarse focus control and can be adjusted even after the focus control has been assembled, refer to Appendix 2: Adjusting the tension over the right-side ball bearing. Leaving the cover too loose, e.g., with its upper surface at 0.5 mm, or more, above the rim of the focus control base will make the fine focus control prone to slip.

Attach the right coarse focus knob with the three M3x8 screws to the right end of the main focus axle (the fine focus axle should still be hanging out of the knob as in Figure 46.)

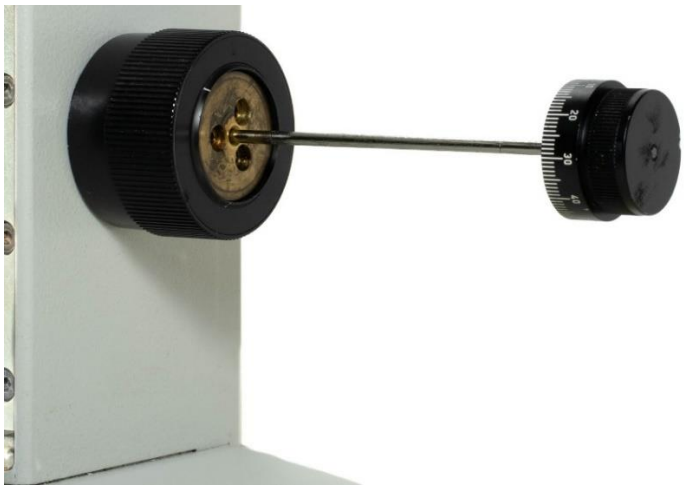


Figure 46: The right focus control knobs just before the coarse knob is attached with the screws.

Figure 47: The focus slide set to its lowest position. The red arrows point to the 1 mm gap between the bottom of the focus slide and the lower edge of the focus slide cover.

Push the fine focus axle all the way through the main focus axle until the right fine focus knob touches the right coarse focus knob (with the greased plastic washer between.)

Now we need to adjust the focus range limit mechanism to ensure that its limits are properly set for the focus slide. Remove the three M3x10 mm screws from the left coarse focus knob. Pull out the left coarse focus knob by approximately 5-6 mm (but not more!) Turn the right coarse focus control to move the focusing slide close to the bottom leaving a 1 mm gap between its lower end and the lower edge of the focus slide cover (Figure 47.) With your hand push the left coarse focus knob tightly against the main focus axle and then turn the knob in the same direction that would lower the focus slide. Turn it as far as it goes until the focus range limit mechanism blocks it from turning any more. Attach the knob to the main focus axle with three M3x8 screws (you may need to turn the knob back slightly.) With this the focus range limits will be properly set for the focus slide. Check that it works as expected: Turn the coarse focus control as far as it goes in one direction. Then turn it the other way as far as it goes while counting the number of turns. The range should be approx. 9¼ turns and the lowest focus setting should still leave a small gap (approximately 1 mm) between the lower end of the focus slide and the lower edge of the focus slide cover as in Figure 47.

Grease both sides of the larger (o.d. 8.9 mm) transparent plastic washer, push it over the fine focus axle that sticks out on the left side, and press it against the top of the left coarse focus knob (Figure 17.)

Wipe off any grease from the left end of the fine focus axle and attach the left fine focus knob to the axle with the hex screw in its side. Make sure to turn the knob so the tip of the screw meets the flat end of the axle, but don't yet tighten the screw. Carefully push the left fine focus knob down on the fine focus axle to minimize the axial play while still allowing the fine focus controls to turn completely freely. In this case a small axial play can be tolerated, it is more important that the fine focus knobs are allowed to turn absolutely freely without rubbing against the coarse focus knobs. Finish by tightening the hex screw in the left fine focus knob and verify that the fine focus still turns freely.

18. Attach the stage and the condenser holder.

If the XY-stage was removed from the stage holder (Figure 3), attach it now (with 3 M4x8 hex screws) to the stage holder. Don't forget to reattach any shims, if applicable. Note that the XY-stage must be attached to the stage holder before the condenser holder is attached.

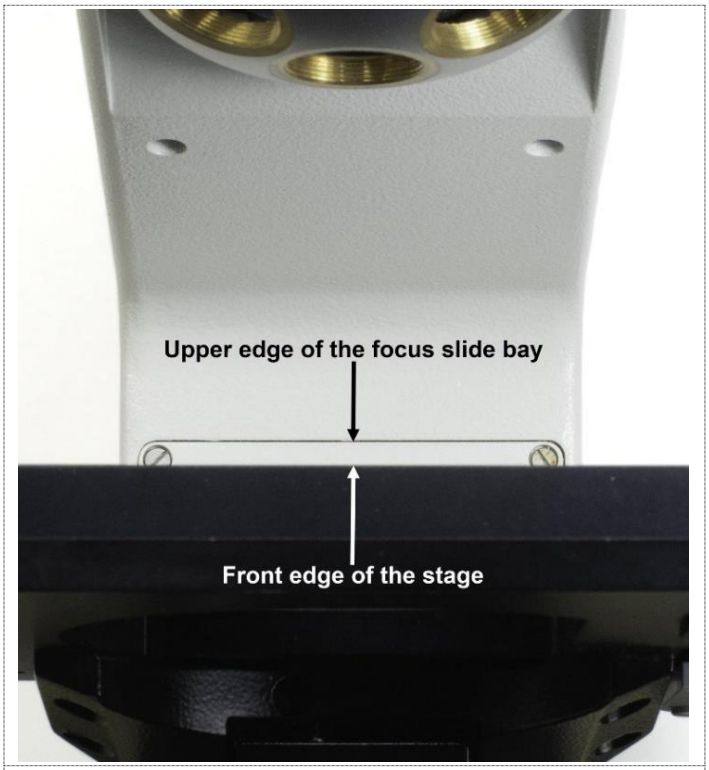


Figure 48: Sideways alignment of the stage.

Place the microscope on its back with the focus slide facing up. Attach the stage holder with the stage to the focus slide (Figure 4) with the four M4x35 screws. Don't forget to reattach any shims (Figure 5) in their original positions, if applicable. Due to the play in the screws the stage can be very slightly tilted/adjusted sideways, therefore, before tightening the screws we will try to align the stage to make it perpendicular to the microscope's optical axis, and not sloping sideways. Professional microscope service technicians have special collimation equipment to do this, we need to resort to a simpler approach:

Tighten the four M4x35 screws lightly. The screws (particularly the two lower screws) should be tight enough so any shims between the stage holder and the focus slide don't fall out when the microscope is put on its foot (the shims will be difficult to retrieve if they accidentally fall down into the focus slide bay), but they also need to be loose enough so the sideways tilt of the stage still can be adjusted with your fingers. Now put the microscope upright on its foot. Turn the coarse focus knobs to move the stage as high up as possible. Position yourself so you can view the upper edge of the focus slide bay just above and as close as possible to the edge of the stage's front (as in Figure 48, where the distance between the edges has been exaggerated.) Manually adjust the sideways tilt of the stage until the front edge of the stage is parallel with the upper edge of the focus slide bay, then tighten all four screws.

Use the two M4x12 screws to attach the condenser focus block (Figure 2) to the stage holder; the condenser focus knob should be on its left side. Don't forget to reattach any shims, if applicable. Before

tightening the screws try the best you can to align the condenser focus block so it is as vertically aligned as possible.

Apply grease to the slide on the condenser focus block and to the slide on the backside of the condenser holder (Figure 1.) Move the microscope's coarse focus control to its highest position. Attach the condenser holder by sliding it into the condenser focus block from below while making sure that the pinion of the condenser focus control gently catches the rack on the backside of the condenser holder. With the condenser holder halfway up in the condenser focus block attach the small stop screw (with red circle in Figure 1) that limits the condenser focus range.

Remove the temporary protective cover from the field lens in the microscope foot and put back the microscope head, eyepieces, and objectives.

Appendix 1: Stuck stage holder screws.

The stage holder is attached to the focus slide with four long M4 hex screws (Figure 4) that require a 3 mm hex key for removal. Occasionally these screws may be stuck and difficult to remove. Typically, in such cases one would first try to apply some penetrating oil. If that doesn't help, the next step would be to use pliers to increase the torque over the key. With some luck the pliers may fix the issue, but after all, a 3 mm hex key and an M4 screw both have their limits, and there is a risk that the added torque may break the key or, worse, strip the hex corners on the inside of the screw head.

A safer and very efficient method is to remove the stuck hex screw with a special hex screw extractor (Figure 49) that can be used with a regular ¼" socket wrench. The tip of the screw extractor is slightly tapered and cleverly twisted so the harder you turn it to release the screw, the deeper it digs down and bites into the screw head. The screw extractor is very sturdy, so if the screw after all won't budge, then the high torque may instead break either the screw body or the screw head.

Figure 49: A 3 mm hex screw extractor bit.

Appendix 2: Adjusting the tension over the right-side ball bearing.

After some time of using your reassembled microscope, you may find out that you would like to readjust the tension over the right-side ball bearing (with the three large bearing balls.) This is quite easy to do.

Similarly as described in subsection 7 loosen the tiny hex screw (using a 1.5 mm hex wrench) deep in the side of the left fine focus knob. Don't remove the screw, only unscrew it by two full turns (two turns will allow it to go free from the small lip on the end of the fine focus axle.) Grab the fine focus knobs with each hand and pull them carefully apart while turning them slightly back and forth in opposite directions until the left knob releases from the fine focus axle and can be removed. Don't lose the transparent plastic washer between the left fine focus knob and the left coarse focus knob.

Pull out the fine focus axle approximately halfway from the microscope's right side together with the still attached right fine focus knob (Figure 46.)

Remove the three M3x8 screws from the face of the right coarse focus knob (Figure 14) and pull the knob off over the fine focus axle all the way against the right fine focus knob.

Use a face pin spanner to adjust the circular brass cover (Figure 16) to apply the desired tension over the right-side ball bearing. For your record use a digital caliper to measure the new distance between the upper surface of the cover and the rim of the focus control base.

Reattach the right coarse focus knob with its three M3x8 screws. Push back the fine focus axle all the way through the main focus axle until the right fine focus knob touches the right coarse focus knob (with the greased plastic washer between.) Wipe off any grease from the left end of the fine focus axle that sticks out through the left coarse focus knob. Reattach the left fine focus knob together with the plastic washer to the left end of the fine focus axle. Turn the left fine focus knob so the tip of the grub screw in its side meets the flat end of the axle, but don't yet tighten the screw. Carefully push the left fine focus knob down on the fine focus axle to minimize the axial play while still allowing the fine focus controls to turn completely freely. Tighten the hex screw in the left fine focus knob. Check that the fine focus turns freely and as desired.