Leitz Laborlux D – Coaxial Focus Control

The coaxial focus control of the Leitz Laborlux D microscope converts any turning of the coarse or 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's focus range is 25 mm and is covered by 6 1/6 turns of the coarse focus control. The turning of the fine focus control is geared down by a factor 17¼ 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 2.3 µm.

Scope

These maintenance notes describe the disassembly, cleaning, greasing, and reassembly of the Laborlux D coaxial focus control including the focus slide. In large parts the notes should also be applicable for other contemporary Leitz microscope models.

The main issues encountered with the Laborlux D 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 6.)

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

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

From my limited experience it seems that the various Laborlux microscope models (Laborlux 11, 12, K, D, and S) from the 160 mm tube length employed two entirely different coaxial focus control mechanisms. There are a few subtle external appearance clues that can help to recognize which is which (compare Figure 1 and Figure 2.) First, the focus control knobs have different shapes – the Laborlux D knobs (both the fine focus knobs and the coarse focus knobs) have constrictions at their inward facing ends, while the Laborlux S knobs are sloping evenly without any constrictions. Second, the black plastic cover on the Laborlux D microscope's backside doesn't have any screws, while the Laborlux S cover has two black Philips screws. These maintenance notes cover only the Laborlux D coaxial focus control - there are separate maintenance notes for the Laborlux S coaxial focus control.

*Figure 1: **Laborlux D** coaxial focus controls viewed from the backside of the microscope.*

*Figure 2: **Laborlux S** coaxial focus controls viewed from the backside of the microscope.*

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 Laborlux D microscope differ from the descriptions in these notes the reason may be that the Laborlux D microscope model underwent technical modifications and improvements during its years of production.
- From my admittedly limited experience it seems that the dominating cause of a sluggish Laborlux D 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 nicely 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 the following:
    - For the focus slide's linear roller bearings: It has been argued that after cleaning from old grease microscope focus slides can be left ungreased because the lubrication doesn't last very long, partly due to grease aging and degradation, but also because the grease tends to catch dust and dirt. Going grease-free would therefore save you from more frequent cleaning and regreasing. If you however choose to grease the slide, the choice of grease is not particularly critical, just avoid too thick greases – don't go above NLGI grade 2. Two suitable and readily available greases are "Super Lube Multi-Purpose Synthetic Grease with Syncolon® (PTFE), NLGI grade 2" and "Mobil Polyrex EM, Electric Motor Bearing Grease".
    - For the main focus axle and its ball bearings: Here the grease choice is more critical. Based on experience with the similar focus slide on Dialux 20 microscopes I have chosen to use "Super Lube Multi-Purpose Synthetic Grease with Syncolon® (PTFE), NLGI grade 00". This grease is less common than the grade 2 version, but it is required to provide the desired smoothness to the coarse focus control.

  The "NLGI grade" is an important parameter that indicates the thickness of a grease. Grade 00 is described as "semi-fluid, similar to apple sauce", and grade 2 is described as "soft, similar to tomato paste".)

  My grease choices are obviously based on limited experience, so there certainly is room for more experimentation and improvement.

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 3. The tip of this screw reaches into a groove (black, on the right side of Figure 4) in the condenser focus block and 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 push the condenser holder further down until it slides off from the dovetail mount.

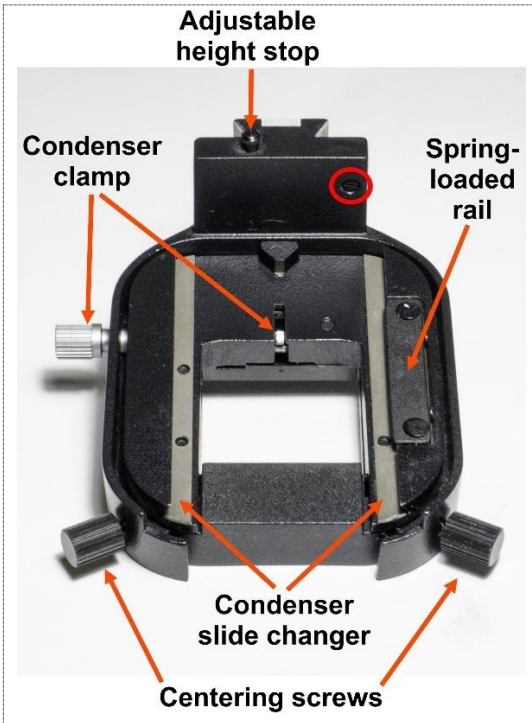

Figure 3: The condenser holder after removal from the microscope.

Figure 4: 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 4.) 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 4 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 5), whichever appears most convenient. The stage *holder* must however be removed from the microscope stand.

Figure 5: The stage holder. The stage and the substage have been removed.

Figure 6: The microscope with the bare stage holder. The condenser assembly and the stage have been removed. (It is however not necessary to remove the stage from the stage holder.)

Green circles: Screws attaching the stage holder to the focus slide.

Purple circles: Screw holes where the condenser focus block was attached.

(Note: The image shows a Laborlux S microscope, but all relevant information shown also applies for Laborlux D.)

Remove the four screws (surrounded by green circles in Figure 6) that attach the stage holder to the focus slide and remove the stage holder. The two lower are M4x25 screws and the two upper are M4x35 screws, all with 3 mm hex drives. Refer to Appendix 1: Stuck stage holder screws. if you have difficulties with releasing these screws.

There may be a few thin metal shims around some of the screw holes between the stage holder and the focus slide – if so, make sure to retrieve the shims and make a note of their location to make sure that they can be properly reattached later.

Figure 7: The microscope's focus slide after the stage holder has been removed.

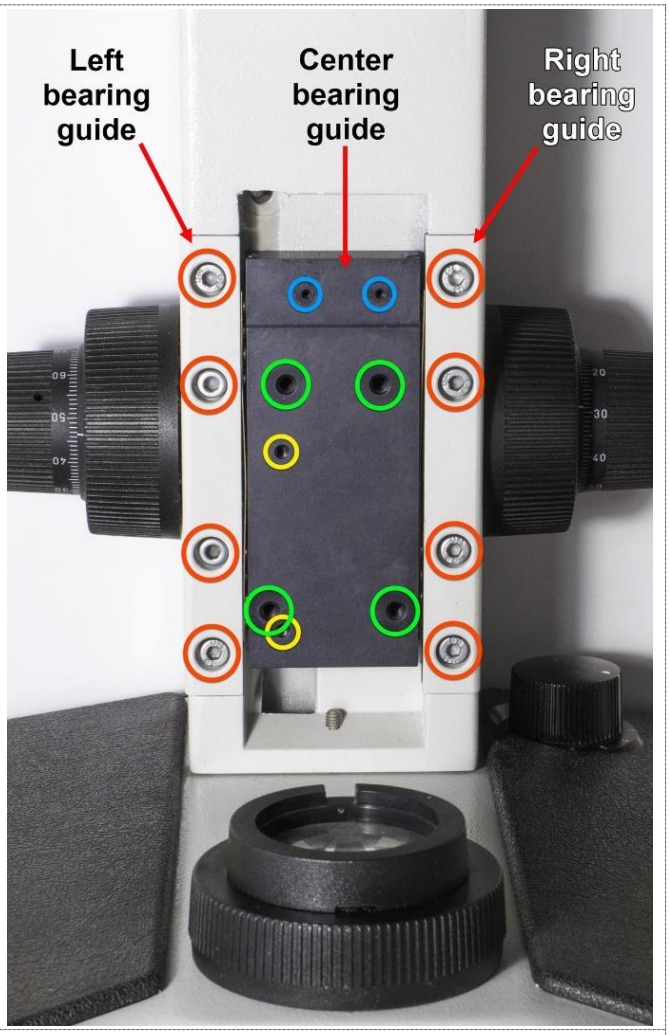

Figure 8: The microscope's focus slide after the stage holder and the white shield have been removed.

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

Blue circles: Screw holes for the screws attaching the white shield.

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

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

With the stage holder out of the way we have access to the focus slide (Figure 7 and Figure 8). The focus slide consists of the vertically moving center bearing guide enclosed between the stationary left and right bearing guides (Figure 8.) 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 focus slide moves smoothly as well as without any sideway play.

Remove the white shield (Figure 7) that is attached with two M2x4 screws to the upper end of the focus slide (the screw holes are circled in blue in Figure 8.)

5. Disassemble and clean the focus slide.

Remove the left and right bearing guides that are held by 4 + 4 chromed M4x12 screws with 3 mm hex heads (annotated with red circles in Figure 8.) Be prepared that the screws may be difficult to release. The left and right bearing guides are identical so there is no need to keep track of left vs. right. Retrieve the black center bearing guide and collect all parts of the two linear bearings (Figure 9.) It is almost impossible to avoid having some of the bearing rollers falling down into the microscope's focus mechanism bay. Disappeared rollers are somewhat difficult to retrieve because the bay is quite a labyrinth, and the rollers tend to stick to the walls due to the old grease - one has to shake and turn the microscope stand in various directions to get the rollers out.

The bearings are *linear crossed roller bearings,* where "crossed" means that each bearing roller's axis forms a 90° angle with its adjacent rollers (Figure 10.) Each bearing has a brass retainer with square holes for eight steel rollers in a 4 + 4 arrangement. The roller diameter is 4.0 mm, and the height is 3.9 mm. The rollers run in bearing races, each race consisting of two steel rails with a triangular cross section. The rails are "glued" (with thick grease) into the grooves in the bearing guide sides. As indicated above, the focusing slide (i.e., the center bearing guide) moves vertically by means of a rack and pinion mechanism and as determined by the coarse and fine focus controls. The rack is attached to the back side of the center bearing guide (Figure 6 and Figure 9.)

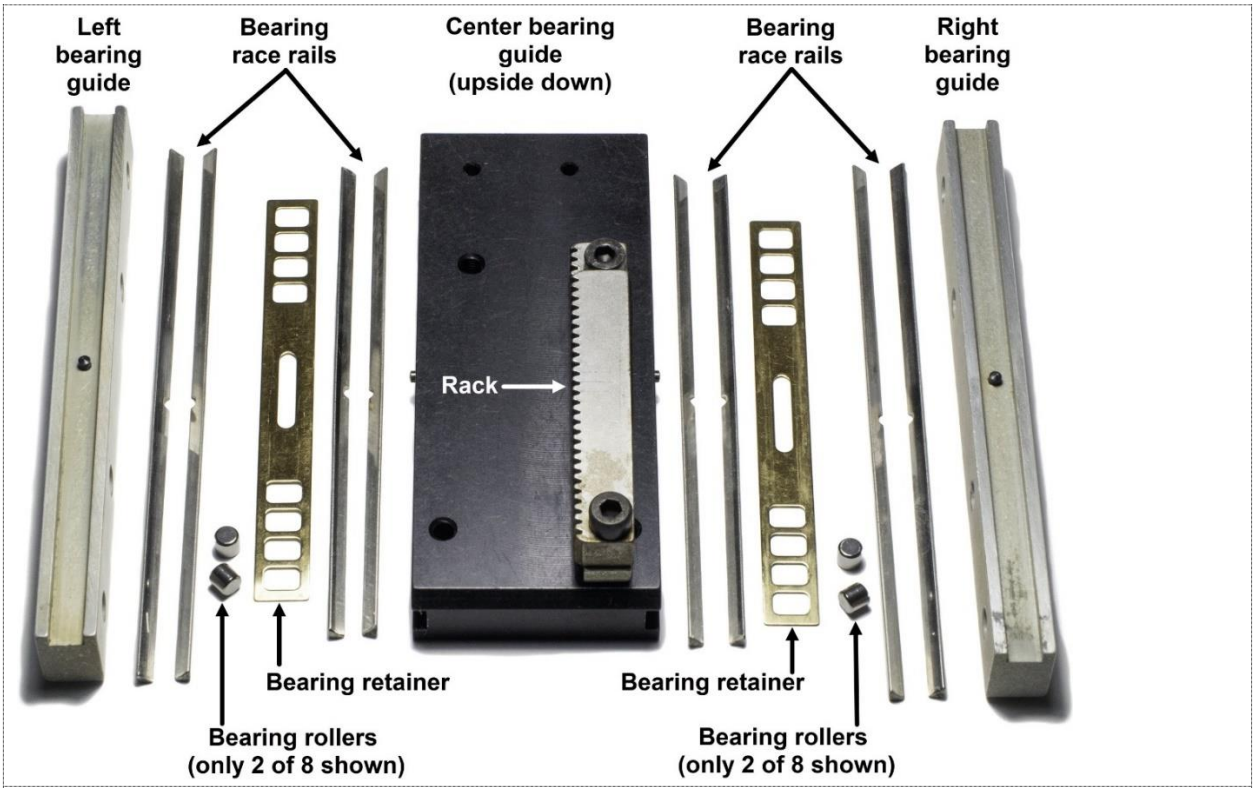

Figure 9: The disassembled focus slide with all roller bearing parts.

Figure 10: Detail view of one of the linear crossed roller bearings showing how the rollers are arranged.

On the backside of the center bearing guide the rack can be horizontally ("sideways") aligned a few tenths of a millimeter thanks to play in its screw holes. The horizontal alignment has some significance for how tightly the rack engages with the pinion (Figure 12.) Unless you need to replace the rack (if, for example, any of its teeth are broken) it is therefore best to leave it as it is attached on the guide.

Use solvent (e.g., white spirit) to thoroughly clean all bearing parts (guides, rails, retainers, rollers) from old grease. If you leave the bearing guides to soak in solvent be prepared that the "glued" (with very thick grease) triangular steel rails may come off from the guide grooves. If you instead clean the bearing rail surfaces only by using cotton swabs wetted with solvent, you will probably be able to retain the rails "glued" in the grooves and save yourself from reattaching them later. If the rails come loose, handle them carefully – it is important that their surfaces are straight and even, and they are particularly vulnerable to be bent at the small dent in the middle.

The rack on the backside of the center bearing guide wasn't greased at manufacturing, so it shouldn't need to be cleaned, unless it is visibly greasy or dirty.

6. The focus rack and possible shipping damage

Today, when used microscopes are purchased and shipped all over the globe, one too often sees microscopes that got damaged due to sloppy packaging, reckless parcel handling, or both. The focus control's rack and pinion are particularly vulnerable to shipping damage because they carry the entire weight of the combined stage + condenser. This kind of damage is particularly surreptitious because it may remain undiscovered unless the microscope is taken apart. Figure 11 shows a focus rack with one broken tooth due to rough shipping conditions. 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, refer to Appendix 3: Using a pinion that has one or a few bruised teeth.

Figure 11: A focus rack with shipping damage.

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.)

7. A look at the main focus axle.

With the focusing slide out of the way we get our first glimpse of the focus mechanism (Figure 12.)

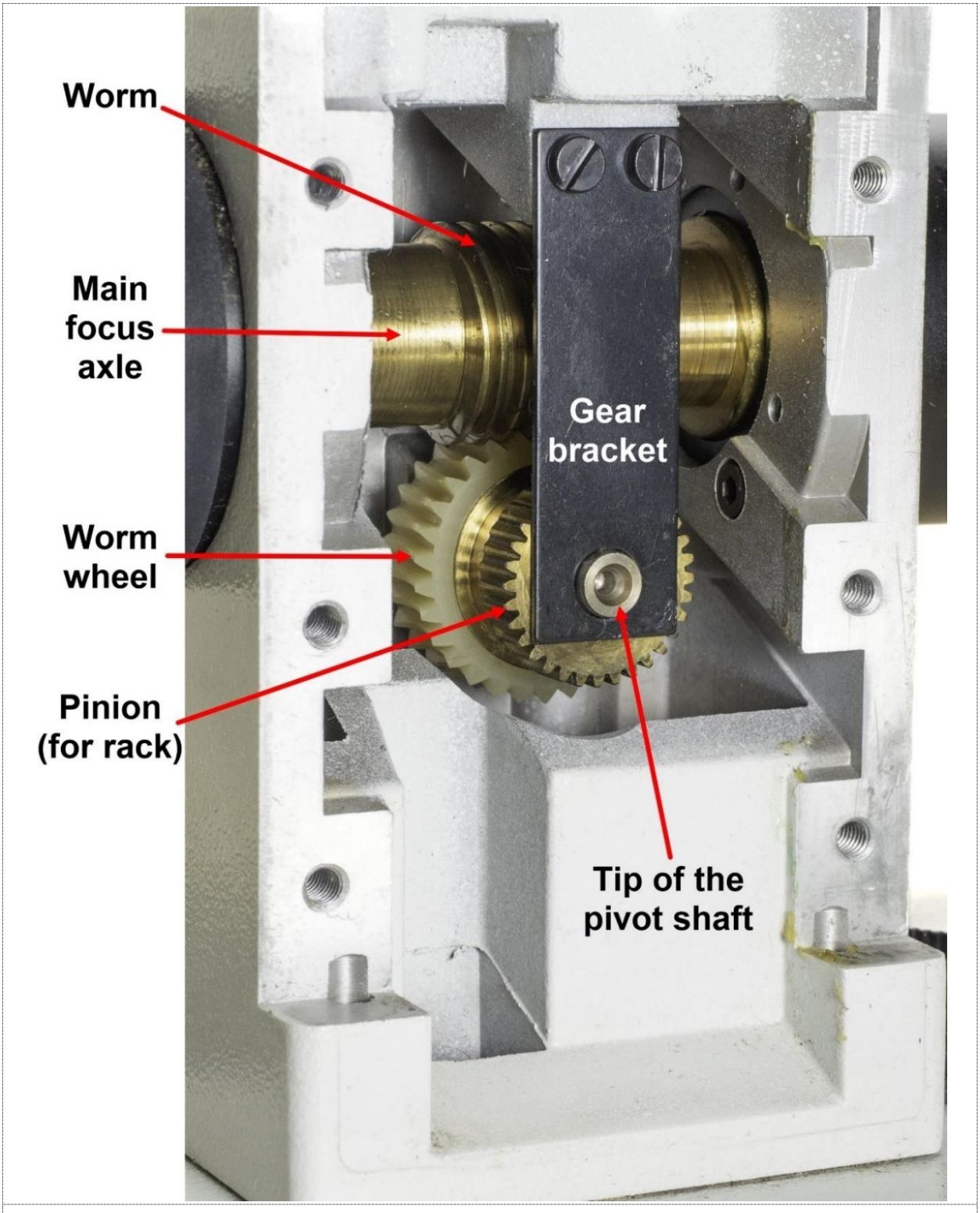

Figure 12: The focus mechanism after the focus slide has been removed.

The coarse focus knobs are directly attached with screws to the ends of the main focus axle. The worm reduces the turning of the coarse focus knobs (and the main focus axle) to make 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 17¼) reduces the turning rate of the fine focus as it is passed down to the main focus axle. The pinion axle with its worm wheel and pinion is held in place on the pivot shaft with a black metal gear bracket.

At manufacturing the worm, the worm wheel, the pinion and the rack were apparently left ungreased.

The play of the pinion axle against the worm of 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.

8. A brief look at the pinion axle.

The hollow pinion axle (Figure 13) turns on a lightly greased roller bearing on a robust steel pivot shaft (Figure 14 and Figure 15) that is attached to the backside of the microscope stand. The roller bearing consists of 13 steel rods that are 19.8 mm long with a diameter of 2.0 mm. The pinion axle and the bearing rollers are held in place on the pivot shaft by a gear bracket (Figure 12) made of black steel.

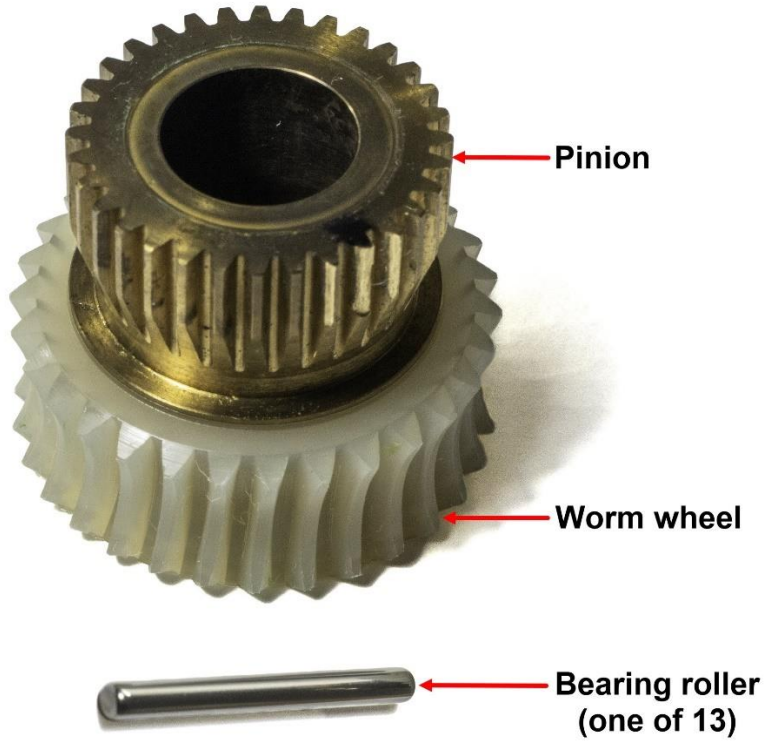

Figure 13:The pinion axle (on the top) with one of its bearing rollers.

Figure 14: The bare pivot shaft (after the pinion axle has been removed.)

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.

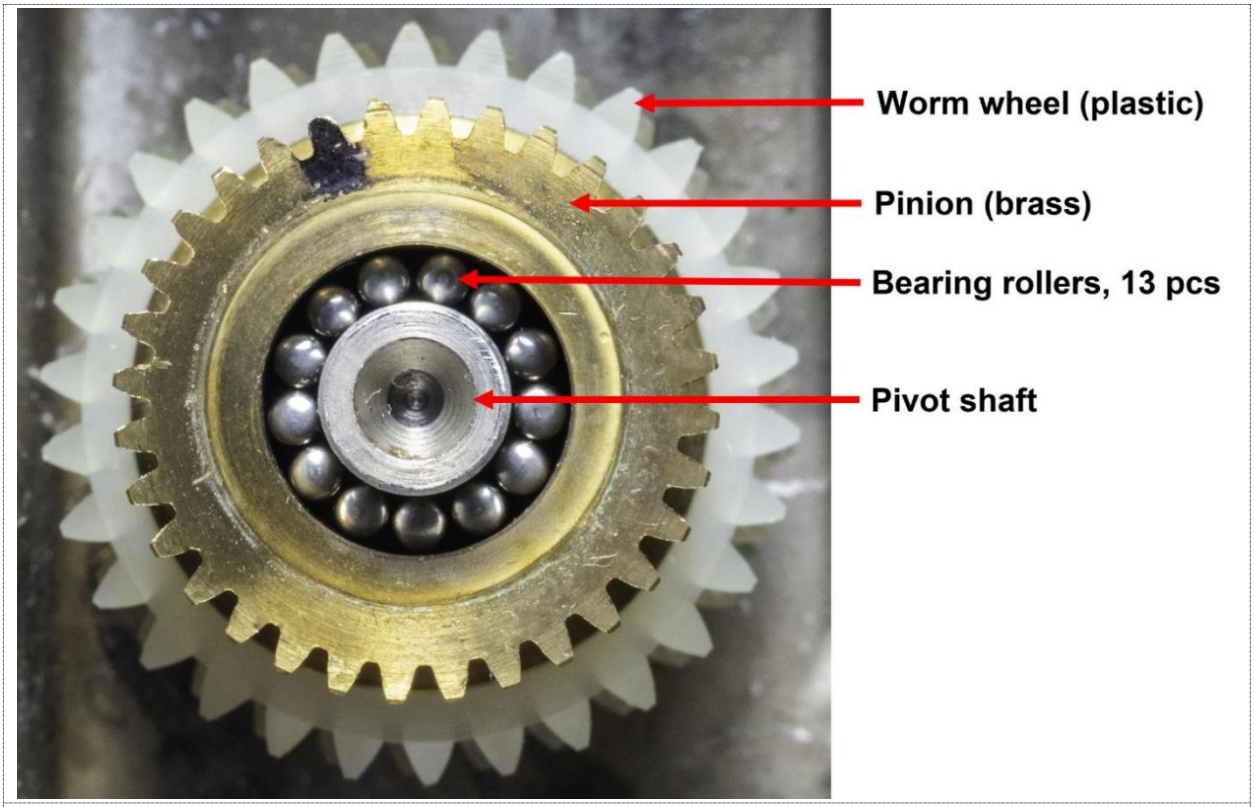

Figure 15: The pinion axle seen from above after the gear bracket has been removed.

9. 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 clear 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. 6.0 mm, i.d. 3.5 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, 170 mm long, diameter 3.5 mm) from the microscope's right side together with the still attached right fine focus knob (Figure 16.)

Figure 16: The fine focus axle (with the right fine focus knob) partly withdrawn from the inside of the main focus axle.

Retrieve the other transparent plastic washer (same dimensions as the previous) 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. Check that the fine focus axle is completely clean and free from any tarnish - if required, polish the axle with a metal polish (e.g., Autosol) applied on a piece of cloth. After polishing, remember to clean the axle thoroughly from any remaining polish abrasive.

10. 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 17.) The knob may be somewhat stuck on the main focus axle due to old, hardened grease.

Below on the right focus control base (Figure 18) is a circular brass cover (o.d. 39 mm, i.d. 26 mm, 3.5 mm thick, threads on the periphery) with two 3 mm holes (Figure 19.) 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 pressure on the washer is determined by how far down into the base the cover is screwed.

Figure 17: The face of the right coarse focus knob after the fine focus axle with the right fine focus knob have been removed.

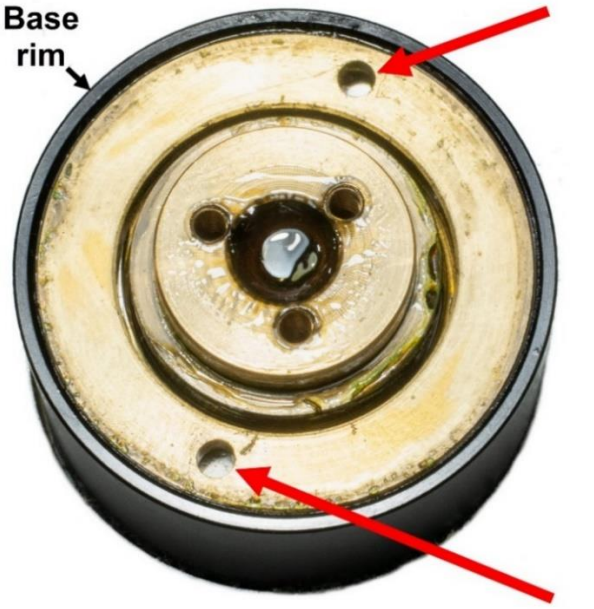

Figure 18: The right focus control base after the right coarse focus knob has been removed. To unscrew and remove the circular brass cover, a face pin spanner can be attached to the two 3 mm holes (indicated by the red arrows.)

Before removing the cover, it is a good idea 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 Laborlux D microscope used for Figure 18 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. The cover should typically be easy to remove.

Remove the large twin wave washer (Figure 19, steel, o.d. 36 mm, i.d. 26 mm, two 0.3 mm thick wave washers sandwiched together, drenched in old, hardened grease) below the cover.

Below the twin wave washer is a ball bearing race (Figure 19, brass, o.d. 37.5 mm, i.d. 25.0 mm, 3.2 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 19: 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 that may be more or less solidified. The balls can't yet be removed because they sit confined in holes in the 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 (fitting 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.

Use solvent (e.g., white spirit) to thoroughly clean the removed parts (knob, screws, cover, washers, race) from old grease. Solidified grease may need to be removed by scraping with a plastic scraper and wooden sticks (e.g., skewer sticks.) Tarnished brass surfaces may be cleaned with a suitable metal polish. After polishing, wash the parts thoroughly to remove any traces of abrasive.

11. 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 axial ball bearing that carries the left end of the main focus axle.

Keep the microscope standing on its foot. Unscrew the three M3x10 screws from the face of the left coarse focus knob (Figure 20) 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 is one tall screw head (Figure 21) that is a part of the mechanism that limits the focus range. Leave the screws as it is.

Figure 20: 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 21: The inside of the removed left coarse focus knob. The green arrow points to the tall screw head that belongs to the mechanism that limits the focus range.

Below the knob (on the left focus control base) we can see (Figure 22) first the left end of the main focus axle, then a metal wave washer, an axial ball bearing, a clear plastic washer, and finally, held together by a flanged guide tube, a stack of six plastic rings, each with a short arm that sticks out from the side.

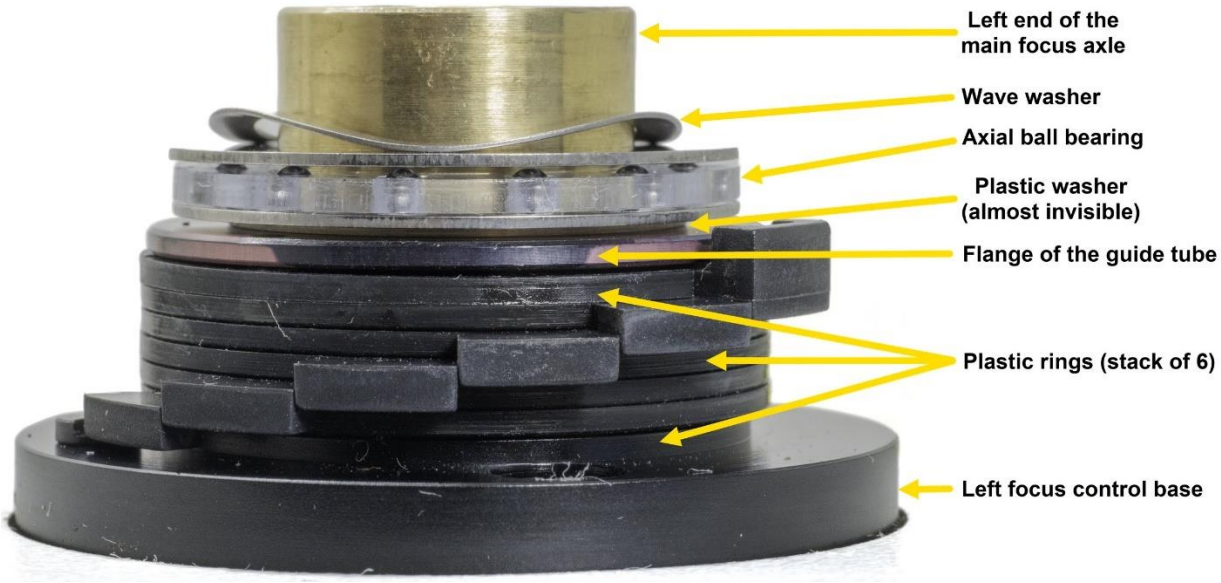

Figure 22: View from the side of the left focus control base after the left coarse focus knob has been removed.

The left end of the main focus axle, the wave washer, the axial ball bearing and the transparent plastic washer will all be covered with old, sticky, and hardened grease.

Begin by removing the wave washer (Figure 22 and Figure 23; o.d. approx. 22.5 mm, i.d. 18 mm, 0.3 mm thick) from the end of the main focus axle. The washer is covered with gluey grease but will be easy to remove.

Then remove the axial ball bearing (Figure 22 and Figure 23.) Due to the old and sticky grease the bearing 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 bearing race (the race looks like a steel washer; o.d. 27.0 mm, i.d. 17.2 mm, 0.6 mm thick). Continue by removing the transparent, plastic bearing retainer (o.d. 27.0 mm, i.d. 17.0 mm, 1.5 mm thick, with twelve 2.1 mm holes) together with its bearing balls (12 balls, each 2.0 mm diameter), and then remove the lower bearing race (identical to the upper race.)

Next, don't miss to remove the transparent plastic washer (Figure 22 and Figure 23; o.d. approx. 22 mm, i.d. approx. 17 mm, 0.5 mm thick) that sits between the bearing and the flange of the black guide tube. It is transparent and covered with sticky grease, and therefore easy to miss.

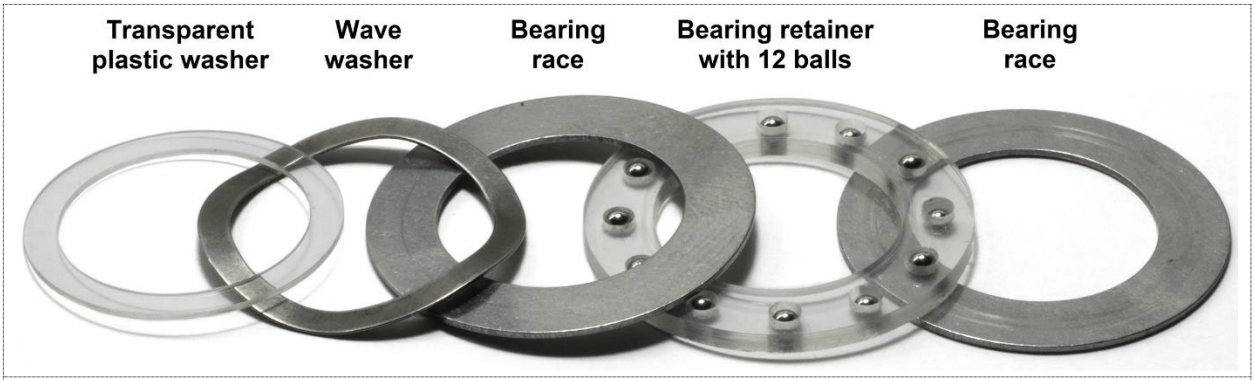

Figure 23: The two washers and the components of the axial ball bearing removed from the left end of the main focus axle.

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

12. How the focus range limiting mechanism works.

The focus range limiting mechanism is the part below the bearing and the washers that just were removed. The mechanism can be disassembled after the black guide tube (Figure 25) has been unscrewed and removed from the left focus control base. The flange of the guide tube has two holes (Figure 24) that comfortably accommodate a face pin spanner.

Six black plastic rings sit stacked on the guide tube (Figure 22.) Each of the rings has a short arm on its side with a downward bent hook (Figure 26.) The arm on the ring at the top additionally has a protrusion that sticks upward (Figure 27.)

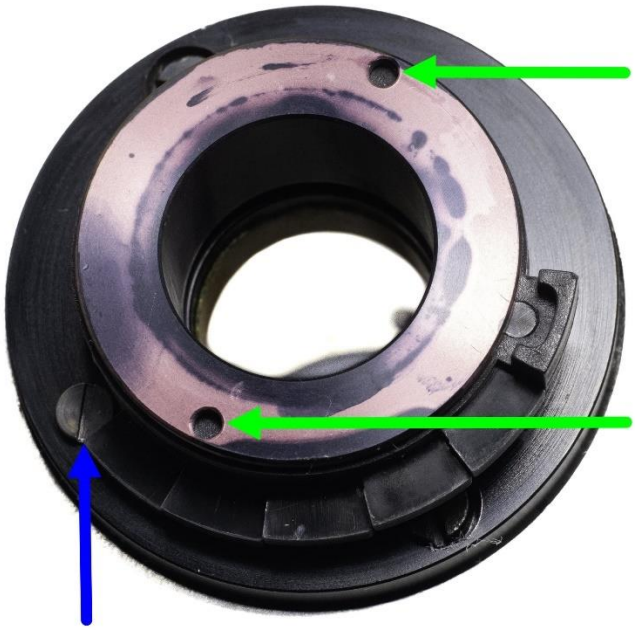

Figure 24: View from the top on the focus range limiting mechanism sitting in the left focus control base.

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 25: 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.)

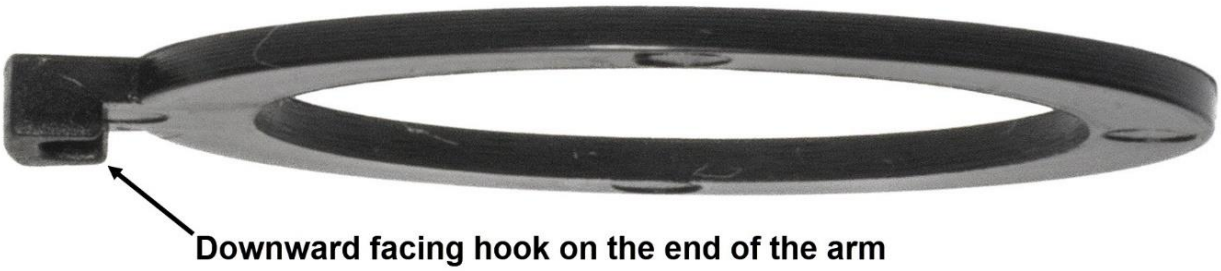

Figure 26:One of the 9 plastic rings closest to the bottom of the focus range limiting mechanism.

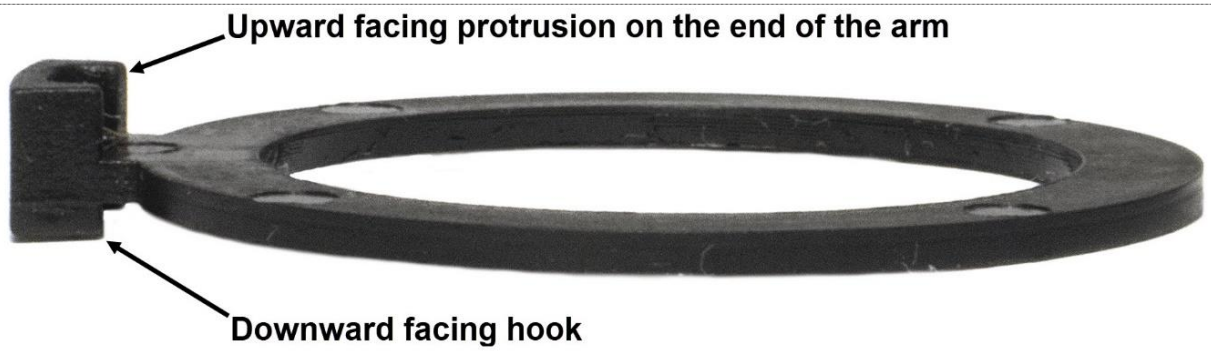

Figure 27: The plastic ring at the top of the focus limiting mechanism.

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 the tall screw head in the inside of the left coarse focus knob (Figure 21) catches the upward facing protrusion of the ring at the top of the stack (Figure 27 and Figure 28.) 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 six rings turn together. The turning comes to a halt when the hook of the ring at the bottom collides with a screw head that sticks up from the focus control base (Figure 24 and Figure 29.) The focus control can't be turned beyond this point.

Figure 28: The arrow shows where one of the screws inside of the left coarse focus knob catches the top ring protrusion.

(Note: This image shows the base of a Dialux 20 microscope, but the general idea also applies for Laborlux D.)

Figure 29: 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.

(Note: This image shows the base of a Dialux 20 microscope, but the general idea also applies for Laborlux D.)

If we proceed to turn the focus control in the other direction, the tall screw in the left focus knob's inside catches the top ring's protrusion from the other side 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 again 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 $6\frac{1}{6}$ turns of the coarse focus control. If the focus range that is less than that (like $5\frac{1}{6}$ turns), it indicates that the tall screw head 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 should leave it where it is.

13. Optional disassembly, cleaning and regreasing of the focus range limiting mechanism.

It seems that at manufacturing Leitz didn't grease the black plastic rings of the Laborlux D microscope, but it may be the case that some of the microscopes indeed may have got their rings greased. It's easy to check – turn the rings with a finger and it will immediately be clear whether the rings turn completely freely or whether they are sluggish. If they turn freely, there is no need to disassemble the mechanism - just skip this subsection.

Use a face pin spanner to unscrew and remove the black guide tube (Figure 24 and Figure 25) 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 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.

Decide whether you wish to regrease the rings with fresh grease or leave them ungreased.

If you decide to regrease, apply fresh grease (use a low viscosity grease, the grease choice is however not critical) to the outside of the guide tube and to all sliding surfaces of the rings. Also 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 26 and Figure 27. When you screw the guide tube into 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.

14. Remove and clean the main focus axle.

Liberated from the coarse focus knobs and the bearings below the knobs, the main focus axle (Figure 30) can now be pulled out from the right side of the microscope stand. Due to old, sticky, and hardened grease (the green and brown deposits on the upper axle and the bearing balls in Figure 30) the axle may be difficult to pull out. Careful rocking of the axle while pulling usually helps. Alternatively, penetrating oil (e.g., WD-40) could be applied to the sliding surfaces in both ends. Catch the three large steel bearing balls (diameter 16.0 mm) before they fall out – they are covered with a lot of grease.

The main focus axle is made of brass, it is 118 mm long, the diameter at the left end is 17.0 mm and at the right end 20.0 mm.

Use solvent (e.g., white spirit) to thoroughly 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 both the left and 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 most 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 (e.g., Autosol.) After finished polishing, wash the axle thoroughly with isopropanol, then with an old toothbrush and warm water and detergent, and finally dry it.

Be careful while handling the main focus axle. It has some very sharp edges, mainly at the worm, but also at the holes for the bearing balls, and it is easy to get cuts on the fingers.

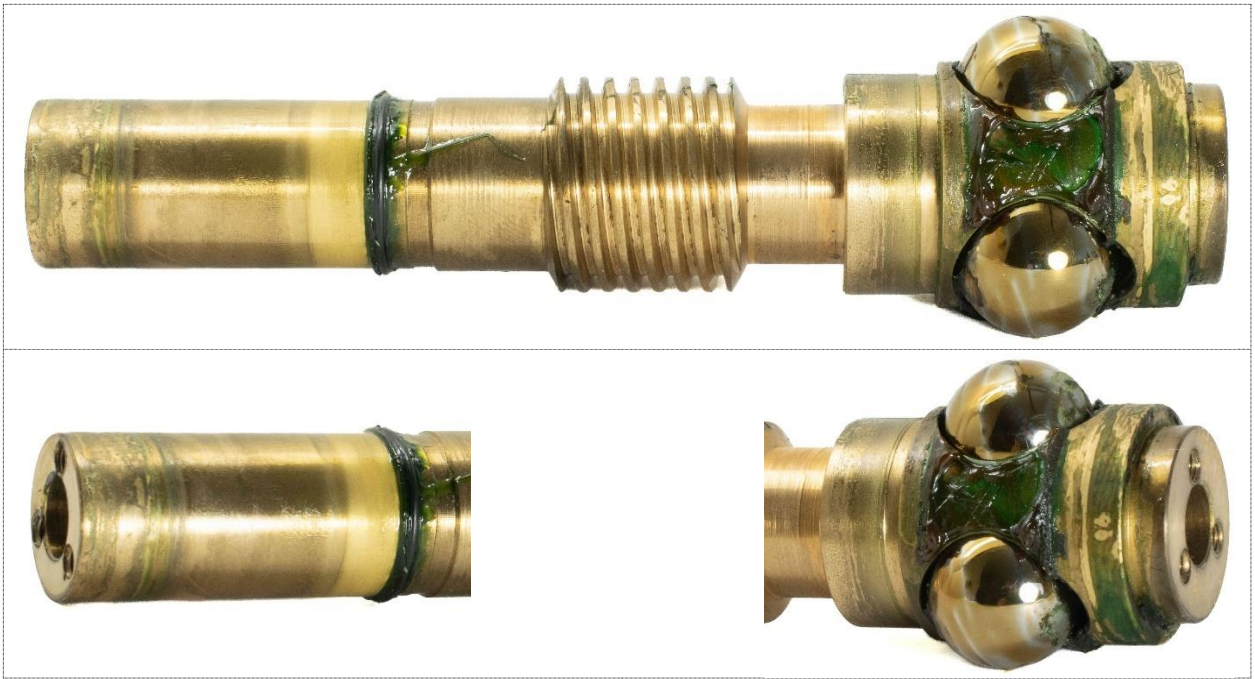

Figure 30: The main focus axle. The upper image shows the entire axle with green and brown deposits of old hardened grease. The lower images show oblique views of the axle ends.

15. Disassemble, clean, (optionally) grease, and reassemble the pinion axle.

The pinion axle's (Figure 13) roller bearing (Figure 15) appears to be quite robust, so if the pinion axle rotates freely on the pivot shaft (test it by turning it with your fingers) there really is no need to disassemble and regrease it - you can then just leave it where it is and skip this subsection.

Otherwise, with the main focus axle removed, the pinion axle is now available for removal, cleaning, and greasing.

Remove the two M3x6 screws from the front of the black gear bracket (Figure 12.) 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. Use the pliers a safe distance away from the pinion.

The pinion axle (Figure 13) turns on a roller bearing around a robust steel pivot shaft (Figure 15 and Figure 14, o.d. 6.4 mm) that is attached to the backside of the microscope. The roller bearing consists of 13 steel rollers (o.d. 2.0 mm, length 19.6 mm.) I'm not able to determine whether the roller bearing has been greased, or not. It appears marginally sticky, but the pinion axle turns flawlessly without any resistance. Both the worm wheel and the pinion appear however to be free from grease.

Pull off the pinion axle (Figure 13) from the pivot shaft (Figure 14) and retrieve the 13 bearing rollers. Similarly as with the bearing rollers from the focus slide in subsection 5, try to avoid allowing any of the rollers to fall down into the microscope stand as they are somewhat difficult to retrieve.

Clean the inside of the pinion axle, the rollers, and the pivot shaft with solvent (white spirit.) In case you discover that there indeed is grease on the worm wheel or on the pinion, also use the solvent to clean off any remaining grease from these parts. Let the cleaned parts dry.

Put back the pinion axle over the pivot shaft. Now you need to decide whether you wish to regrease the roller bearing with fresh grease or leave it ungreased. If you decide to grease it, apply a low-viscosity grease very sparsely to the bearing rollers, to the sliding surface on the underside of the worm wheel, and to the sliding surface on the top side of the pinion.

Put the rollers, one after the other, into the space between the pinion axle and the pivot shaft.

Push the gear bracket (Figure 12) 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 while to test that it turns freely and, if applicable, to distribute the grease over all roller bearing surfaces.

16. Replace a broken focus rack.

This subsection only applies if you need to replace a focus rack because it has got one or more broken teeth (Figure 11) as described in subsection 6.

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, width, and the distance between the screw holes) 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 exact distance between the backside of the rack and the adjacent long side of the guide, see the yellow arrows in Figure 31. It will be somewhere close to 7 mm. The numbers are important to allow the replacement rack to be attached in exactly the same place as the original rack. This will ensure that the rack engages properly with the pinion through the entire focus range; neither too tightly, nor too loosely.

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 that may be 1-4 mm thick. The screw holes in the rack are wide which allows for some adjustment of the rack’s 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. Successively measure, align the rack, and tighten the screws.

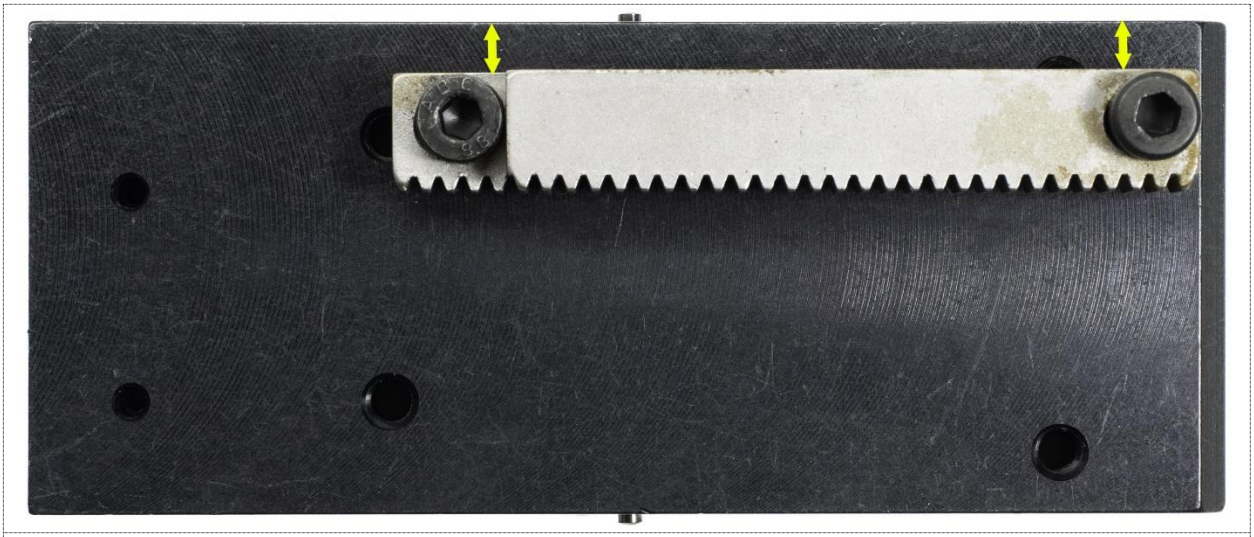

Figure 31: The backside of the focus slide's center bearing guide. The yellow arrows show the two approximate locations where you should measure the distance between the backside of the rack and the adjacent long side of the center bearing guide.

17. 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 and prevent any adjustments.

If during cleaning your bearing race rails (Figure 9) got separated from the bearing guides (refer to subsection 5), then you must first reattach the rails again. Recall that the rails have a triangular profile with their hypotenuse sides facing the bearing rollers and that the rails sit loosely "glued" with thick grease in the bearing guide race grooves.

Apply small and rather thin blobs of a suitable medium to thick grease to both ends of all four of the focus slide's bearing guide grooves - two grooves on the sides of the center bearing guide, and one groove on each of the left vs. right bearing guide. The red ovals in Figure 32 indicate the location and approximate size of the grease blob areas.

Figure 32: The upper bearing guide shows where in the groove the "glue" grease should be applied.
The lower bearing guide shows the guide after the bearing race rails have been attached.

Note that the grease should not be applied along the entire length of the groove, it should only be applied as 5-8 mm blobs at the ends. The type of grease is not critical, it should just be thick enough to keep the bearing race rails secured in the grooves while the focus slide with its bearings is assembled. I have used the very thick grease NyoGel 767A – it worked very well as a "glue", but it was so thick that it was somewhat difficult to wipe off the excess. In hindsight, a medium thick grease, for example Molykote 111, would probably work as well but be easier to wipe off.

Put the race rails into the grooves. Position them properly and push them down so they sit firmly in the corners of the grooves and with the hypothenuse side of the rails facing the bearing rollers, see Figure 32 and Figure 33. Use several cotton swabs to thoroughly wipe off any superfluous grease from the rails but be careful not to disturb the rails. Only wipe, don't use solvent. It is important to remove all grease from any exposed surfaces, leaving only the thin layers that act as a "glue" between the ends of the race rails and the grooves (Figure 33.)

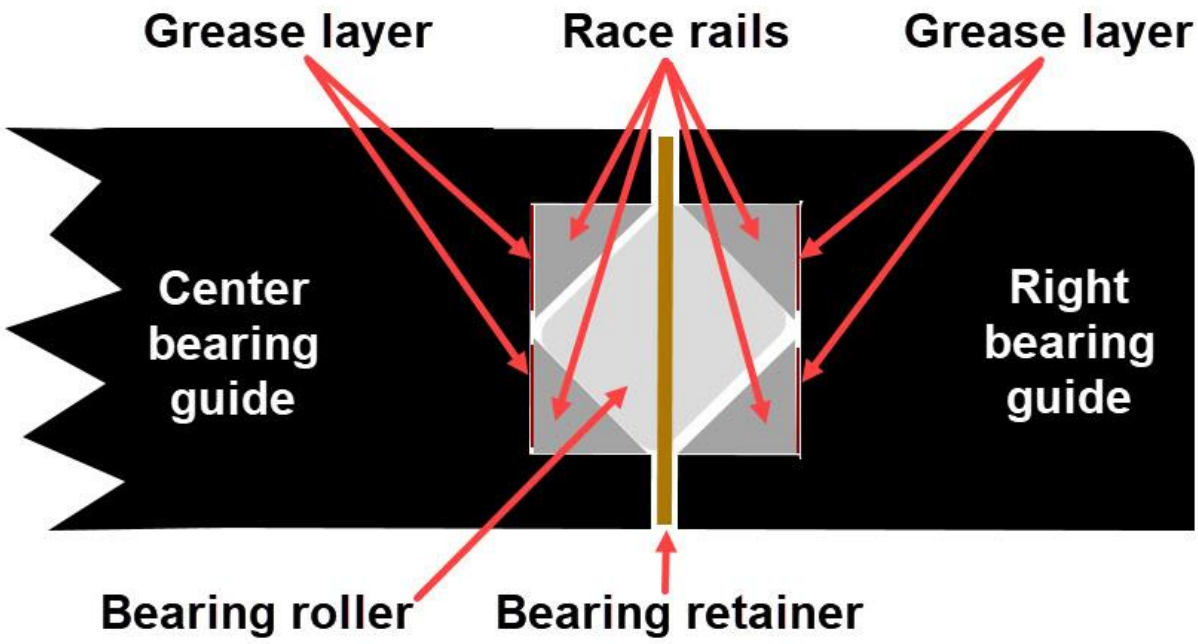

Figure 33: Drawing of the focus slide's linear crossed roller bearing viewed from the side. The center bearing guide moves perpendicularly to the image plane.

We are now ready to assemble the focus slide and its bearings. The bearing race rails should at this stage be attached in the grooves in the sides of all three guides.

If your pinion has one or a few broken teeth review Appendix 3: Using a pinion that has one or a few bruised teeth.

Put the microscope on its back on the table. Place the center bearing guide into its place in the focus slide bay (Figure 34.) The rack on its backside should engage with the pinion on the pinion axle. Move the guide so it sits centered in the bay, both horizontally and vertically, as in Figure 34. To keep the center bearing guide in this position clamp it gently with a C-clamp of a suitable size (Figure 36.) *Gently* means here that the guide should be held in the bay, but it should still be possible to push and shove it upwards or downwards. To save the microscope and guide surfaces and to ensure a soft grip attach self-adhesive floor protectors to the clamp's gripping edges (Figure 35.)

Turn the microscope with its left side facing upwards and use some support (for example, a book as in Figure 36) to level the center bearing guide's left race horizontally.

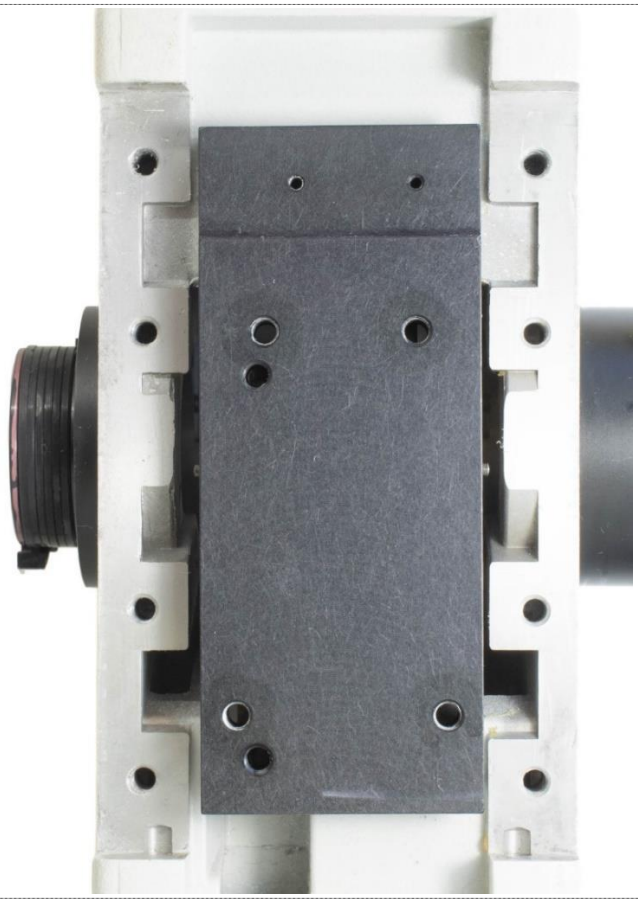

Figure 34: The center bearing guide placed centered in the microscope's focus slide bay.

Figure 35: A C-clamp with self-adhesive protectors attached to the gripping edges.

Apply a thin layer of grease (Super Lube Multi-Purpose Synthetic Grease with Syncolon® (PTFE), NLGI grade 2 *or* Mobil Polyrex EM, Electric Motor Bearing Grease) on the left race (which now faces upward) of the center bearing guide and on the race of the left bearing guide (Figure 9.) Also grease both sides of a bearing retainer (Figure 9.) Place the retainer approximately in the middle of the center guide's race. Use forceps to put the bearing rollers into the retainer holes so each roller's axis forms a 90° angle with its adjacent rollers (Figure 10.) Push down the rollers into the retainer holes to make sure that they are properly seated (Figure 37.) Put down the left bearing guide (don't confuse its upside with its downside) over the rollers to close the bearing, make sure that the rollers are not allowed to dislodge. Attach the left guide to the microscope stand with its four M4x12 screws. Don't yet tighten the screws - screw them all the way down but leave them loose enough so the left bearing guide still can be pushed sideways a few tenths of a mm as allowed by the play in the screw holes.

With the clamp still holding the center bearing guide, turn the microscope with its right side upwards. To provide space for assembling the right bearing move the C-clamp to the other side of the microscope arm: With your fingers hold the center bearing guide firmly attached in the focus slide bay, loosen the C-clamp, and reposition it to hold the center bearing guide from the other side of the microscope arm.

Figure 36: The center bearing guide lightly clamped in the focus slide bay by a padded C-clamp. The microscope is supported with a book.

Figure 37: The bearing retainers and rollers placed on the center bearing guide's left race.

Similarly as with the left bearing, apply a thin layer of grease on the right race of the center bearing guide and on the right bearing guide's race. Grease both sides of the bearing retainer. Place the retainer approximately in the middle of the center guide's race. Use forceps to put the bearing rollers into the retainer holes so each roller's axis forms a 90° angle with its adjacent rollers. Push down the rollers into the retainer holes to make sure that they are properly seated. Put down the right bearing guide over the rollers to close the bearing, make sure that the rollers are not allowed to dislodge. Attach the right guide to the microscope stand with its four M4x12 screws. Don't yet tighten the screws - screw them all the way down but leave them loose enough so the left bearing guide still can be pushed sideways a few tenths of a mm as allowed by the play in the screw holes.

18. Adjust the tension over the focus slide and collimate it.

Put the microscope back on its foot again. Remove the C-clamp. The loosely tightened screws will hold the bearings together, but still allow for small sideways adjustments for collimation, i.e. alignment of the focus slide with the microscope's optical path. Microscope manufacturers and professional service technicians have special tools and skills for collimation, but as amateurs we have to resort to doing it by the eye.

With your fingers press hard across the slide with your fingers on the outsides of the left and right guides. Now do the best you can to align the focus slide as vertically as possible and successively tighten all 8 screws that hold the left and right guides. Also try to keep the slide centered horizontally on the stand. The goal is to have the slide as tight as possible to avoid any lateral play, but not so tight so it inhibits its vertical movement through the focus range. Test the vertical movement by pushing the focus

slide upwards as far as it goes in the microscope stand, and let go of it. As long as the slide falls down by gravity only, and does that through the entire focus range, you will know that the slide isn't too tight.

Attach the white shield to the upper end of the center bearing guide (Figure 7 and Figure 8.)

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

For all work described in this subsection use Super Lube Multi-Purpose Synthetic Grease with Syncolon® (PTFE), NLGI grade 00. To use "NLGI grade 00" is an important parameter here!

Generously grease the lower (stationary) ball bearing race in the bottom of the right focus control base (Figure 38.)

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

Very generously grease the insides of the three ball bearing holes at the main focus axle's right end (Figure 39.)

Moderately grease around the sliding surface approximately ⅓ inward from the left end of the axle, and around the axle's sliding surface located between the worm and the large ball bearing (refer to the arrows in Figure 39.) Don't grease the worm.

Figure 38: View of the inside of the right focus control base. The red arrows point to the stationary ball bearing race.

Push the focus slide upward to move it into its highest position. Insert the three large (16 mm) 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. Push in the axle all the way through until the three large bearing balls reach the race in the bottom of the right focus control base. During the insertion 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 at the same time pushing against the main focus axle's right side to keep the large bearing balls tight on the race and turn the axle to check that the focus slide moves as expected.

Figure 39: 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 right end slide, and inside of the holes for the three bearing balls.)

Hold the main focus axle in place so it doesn't slide out on the right side. Grease and attach the transparent plastic washer over the left end of the main focus axle and on top of the guide tube's flange (Figure 22 and Figure 23.) Grease, assemble (bottom steel race, plastic retainer, 12 pcs 2 mm bearing balls, and top steel race), and attach the axial ball bearing on top of the plastic washer (Figure 22 and Figure 23.) Grease and attach the wave washer over the bearing.

Grease the black slide on the inside of the of the left coarse focus knob (Figure 21) 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 large bearing's brass race (Figure 19) 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 19), fit them together snugly so they exactly overlap (as in Figure 40, but not as in Figure 41), and put them on top of the brass race.

Figure 40: 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 41: 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 19) and attach it over the twin wave washer. Use a face pin spanner to screw the cover into the right focus control base (Figure 18) while making sure that the threads catch cleanly. 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 both sides of one of the small (o.d. 6.0 mm) transparent plastic washers, push it over the fine focus axle and against the underside of the right fine focus knob. (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. 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 penetrates the constrained space between the bearing balls.

Tighten the brass cover (Figure 18) with the face pin spanner to apply a suitable pressure over the large ball bearing. Screw it down to the same depth as measured during the disassembly in subsection 10. (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: Adjust the tension over the main focus axle's 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 42.)

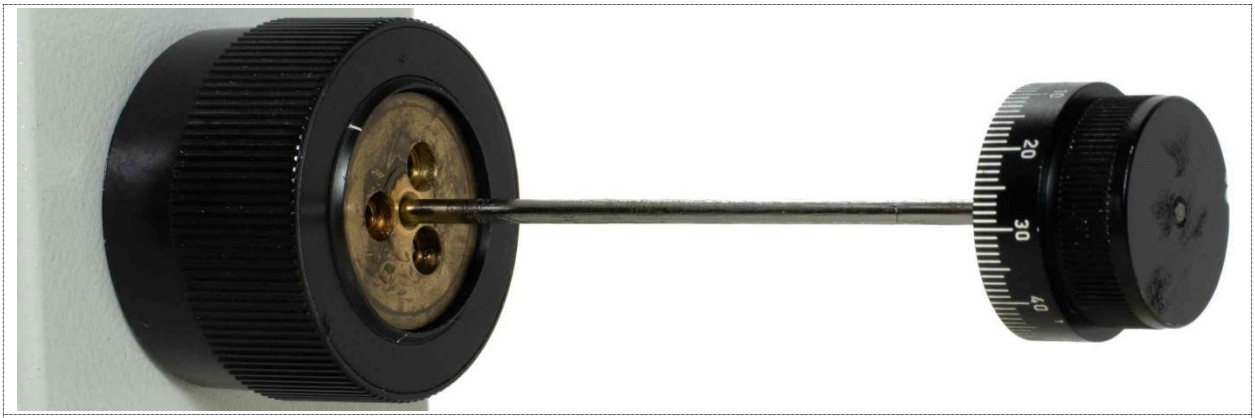

Figure 42: The right focus control knobs just before the coarse knob is attached with the screws.

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 the focus range limiting mechanism must be adjusted 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!) This will release the screw head in its inside (Figure 21) from the focus limiting mechanism's upper plastic ring (Figure 22 and Figure 27.) Turn the right coarse focus control to move the focusing slide close to the bottom leaving a 5 mm gap between the center bearing guide's bottom edge and the bottom edges of the left and right bearing guides (Figure 43.) Hold the right coarse focus knob steady at this position. With your other 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 limiting mechanism blocks it from turning any more. Attach the left coarse focus knob to the main focus axle with its 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 covered by approx. $6\frac{1}{6}$ turns. At the lowest focus setting there should still be a 5 mm distance between the lower edges of the center bearing guide and the left or right bearing guides.

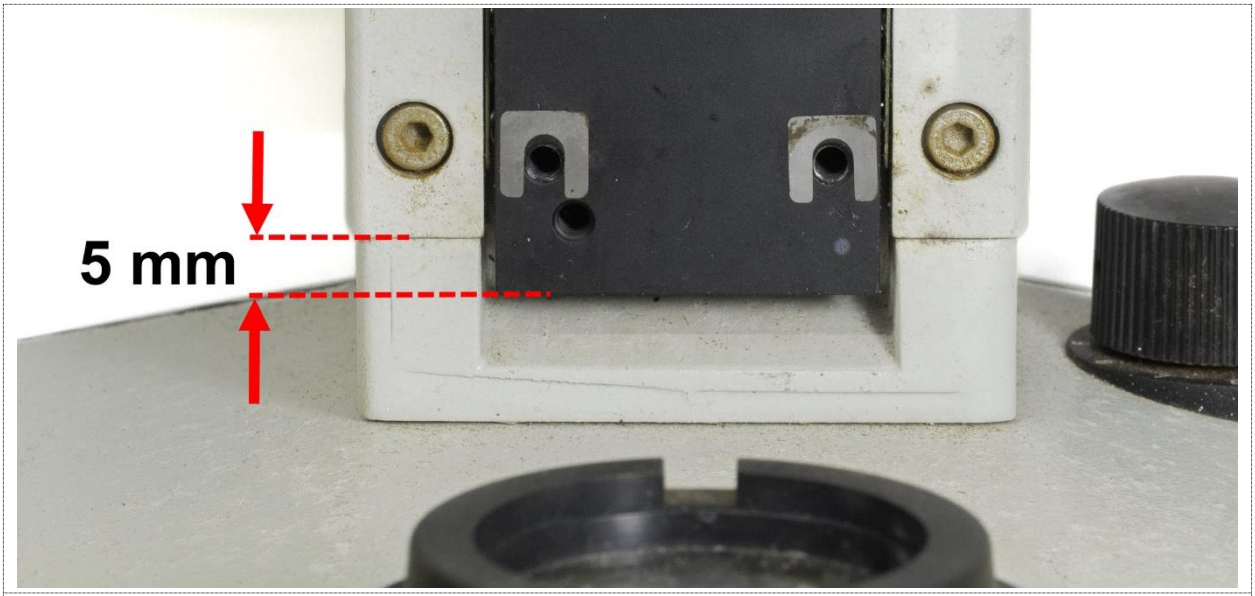

Figure 43: The lower end of the focus slide showing how to set the lower focus range limit.

Grease both sides of the other small (o.d. 6.0 mm) transparent plastic washer, push it over the fine focus axle that sticks out on the left side, and press it against the brass surface on top of the left coarse focus knob (Figure 20.)

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.

20. Attach the stage and the condenser holder.

If the XY-stage was removed from the stage holder (Figure 5), attach it now (with 3 M4x8 hex screws) to the stage holder. Don't forget to reattach any shims, if applicable. Note that the stage must be attached to the stage holder before the condenser holder is attached.

Attach the stage holder with the stage to the focus slide (Figure 6 and Figure 8) using the M4x25 and M4x35 screw pairs. Before tightening the screws try to align the stage holder's sides as parallel as possible with the sides of the microscope arm.

Attach the condenser focus block (Figure 4) to the stage holder using its two M4x12 screws; the condenser focus knob should be on its left side. Don't forget to include any shims, if applicable. Before tightening the screws try to adjust the condenser focusing block so it is aligned as vertically as possible.

Apply grease to the slide on the condenser focus block and to the slide on the backside of the condenser holder (Figure 3.) 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 a red circle in Figure 3) that limits the condenser focus range.

Remove the temporary protective cover from the field lens in the microscope foot and put back the microscope's 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 6) 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 44) 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.

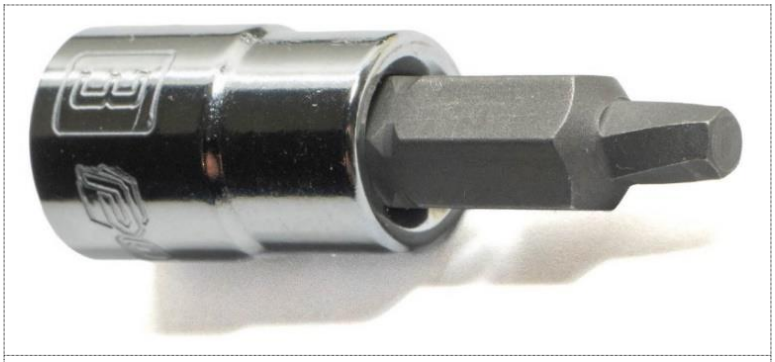

Figure 44: A 3 mm hex screw extractor bit.

Appendix 2: Adjust the tension over the main focus axle's 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 9 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 42.)

Remove the three M3x8 screws from the face of the right coarse focus knob (Figure 17) 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 19) 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.

Appendix 3: Using a pinion that has one or a few bruised teeth

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 range suffer from lack of precision. As mentioned in subsection 6 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. The fix is possible because the pinion only turns approximately half of a turn through the microscope's entire focus range. By turning the pinion into a particular position when the center bearing guide 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:

Before you place the center bearing guide into the focus slide bay (subsection 17 and Figure 34) use a marker to put a black dot on the face of the pinion to indicate where the bruised tooth is (Figure 15.) Turn the pinion so the bruised tooth is at the 3 o'clock position (i.e., pointing straight to the right, or away from the rack.) Now place the center bearing guide into the middle of the focus slide bay. Put the bearing guide straight down without turning the pinion axle. Properly done, this will keep the bruised pinion tooth/teeth away from the rack through the microscope's entire focus range.

Proceed as per subsection 17 by clamping the guide, etc.