HARPOINT
OBSERVATORY

The Optical Tube

The popular Schmidt-Cassegrain or Maksutov-Cassegrain the do not have many demands on the precision of the alignment of the primary mirror to the secondary mirror. This also applies to all his younger derivatives that are advertised with better imaging characteristics, but also use spherical mirrors. Spherical mirror can be produced cost-effectively as any other mirror. The optical axis of a spherical mirror is defined only by its edge, but not by its mirror shape to. Thus, the optics can even collimate easy if both mirrors are installed offset from one another. One nut only tilt a little. The Newton has ever only an image-forming optical surface. His tube makes problems with severe focal instruments rather because of its heaviness. The adjustment is also relatively easy because only one optical axis must be centered (you can the secondary mirror of Newton conceived as a kind of spherical mirror with an infinitely large radius of the sphere). Because the mirrors in these telescopes pronounced "sloppy" can be installed, let these telescopes also produce cost-effective and in masses. Only if you consider a Newtonian with corrective optics have slightly higher with the requirements on the collimation. R. Pressberger rather used the term centering instead of the word collimation. That would be the correct name, but the amateurs are always talking just of collimation.

The situation in the classical Cassegrain and even more in an RC is quite different. There, both mirrors have a different from the spherical shape. The greater the deviation from the spherical shape and the greater the curvature of the surface is more complicated to manufacture. Each mirror has also defines its own optical axis and not only a center of curvature as the spherical mirror. There are another much higher demands on the alignment of the two mirrors and the available adjustment possibilities. The reason: A misalignment of the optical axes to each other can not be alone largely compensated by the tilt of one of the two mirrors. Both mirrors have now tilted, and at least one of the two mirrors towards others can be fine also shifted laterally. Even then, you're taking an inclined optical image field into account, if you apply the wrong method and centered on the star only. The adjustment is more complicated because there are side optimas and is therefore to find the true optimum heavier.

This also means greater demands on the mechanics. The adjustment must be maintained in any angle of rotation of the tube. It should be resistant to vibrations and temperature changes. It should be resistant to different severe focal instruments. This also ensures that the mirror does not deform under its own weight. To this end, a superbly defined mirror support is needed for large, classical Cassegrain and RC primary mirror. So this is the reason why a Cassegrain tube is complicated and usually quite expensive.

Here a construction is presented, which perfectly meets all those requirements, which does not require carbon-fiber composites and other difficult to machine materials and items. And last but not least, you build it yourself. R. Pressberger invented it.

Considerations for material and connection technology

The use of steel as a material for an optical tube is rather unusual for amateurs. The most frequent argument against the great weight is given. However, if you consider that for the stiffness of the relationship between weight and elasticity modulus of the material is crucial, then you notice that aluminum case brings no advantage. To keep up with aluminum I have to achieve the same stiffness triple the thickness of the material, which picks up the weight advantage again. Weld than joining technology for aluminum is out of the question if you want to do it yourself. It requires expensive specialized welding equipment. One must be able to weld aluminum "blind" because you can not see the melt in the arc.

Steel to weld is much easier. Think of all the already predicted you'll realize that this is welding for the optical tube the best and most durable connection technology. You do not want a rusty telescope? Then do as we and use stainless steel.

The thermal expansion of the tube results in a focal shift due to temperature changes. This is the case of aluminum, of course, greater than that of steel. With a backlash free secondary mirror focusing and a little control technology temperature compensated focusing is possible. Quite incidentally such control may also offset the focus differences of various filters of a filter wheel. Therefore forget the arguing about focal shift.

Now always comes equal to the question on why modern carbon fiber composites not be used. Quite apart from the difficult production at home it is also harmful to health (the fibers are at the suspicion of the lung to act like asbestos). To use only those materials will not work either. The use of different materials (CFRP pipes and alloy) is in our opinion problematic because of the connection points of both materials. CRP may be useful for weight reasons in portable instruments, here at a high precision, stationary observatory telescope, no significant benefit though.

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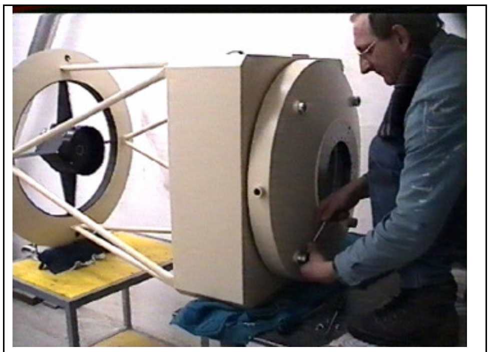
Structure features


Screwing the main mirror cell

The deflection of the optical tube under its own weight leads for conventional structures with full material tube to a mutual tilting of the optical axes. It is converted here by the Serrurier principle in a parallel shift of the secondary mirror relative to the support box. It is therefore not matter where and how the rods are fixed to the supporting structure of the tube and the Spider-ring, they must form between them 4 triangles. Each of the triangles in one direction must have a high rigidity. On the set of fixation must form pivot joints. Only correct arrangement of the rods the Serrurier principle really works. Otherwise, the effect is only partially present and it also comes at a truss tube to tilting of the axes. The Canadian Mark Serrurier invented it 100 years ago. Pressberger has realized the function and therefore also properly implemented. On the other side of the supporting structure of the tube (in our case this is the massive support box and not some windy frame) is a design application for which the Serrurier principle equivalent. It allows a very short distance of the main mirror to the declination axis. This is a great advantage when handling the telescope. At such short distances the original Serrurier principle brings no benefits but only complicates the structure. Unlike other Pressberger has recognized this: The primary mirror cell is hung up from 4 bolts on the support box. The deflection of the bolts under the weight of the primary mirror cell as now leads to a parallel displacement of the main mirror to the support box. The bolts are then dimensioned that both parallel shifts (from the primary mirror and the secondary mirror) cancel each other. The optical axes of both mirrors therefore aligned in any angle of rotation of the optical tube. This works of course only if the mirror cell is properly constructed. The Serrurier principle is useless when the main mirror can move due to insufficient lateral support. Look at the ridiculous lateral support in the mirror cells comparable telescopes. Since you do not need you wonder if there the Serrurier principle is not carried out correctly.

Why are our rods in the truss tube so thin where others have yet much thicker? Different thick rods front and rear are obtained when the method of finite elements is applied and the result takes over without thinking about alternative possibilities of the basic structure (Mr. Serrurier would still be satisfied). Modern tool in the design (like finite elements) can not replace the creativity of the engineer, but the creativity has already come from a true professional mechanic: Particularly amusing are the main mirror side truss tubes with single rectangular connecting plate between the mirror cell support and the frame where rods all come together. At this connection plate then the optical tube is hung up one side only. Even more, one can not falsify the Serrurier principle. If this blundering then coated with a film that simulates a carbon surface, it is ready for the raised amateur market. Even some astronomical institutes are not too bad, so to buy a junk for his students.

Should it disassembled or not?

Apart from the removable mirror cell and usable aperture tubes, consists of the remaining optical tube from a single welded part. We are of the opinion that the achievable high precision of optical centering can be saved that way. This applies especially if you want to use an RC optics. If for reasons of transportation wants a decomposition into Spider-ring, rods and support box should be either an Dobson build because of lower requirements on the optical centering, or select a smaller aperture, so that he does not have to disassemble the tube.

For the purpose of adjusting a screw connecting at the rods is not necessary. For the centering of the optics sufficiently stable adjusting elements are provided in the overall construction.

The main mirror cell

Characteristics

For the first time the technique of "contracted rings" is used here. Instead of a heavy thick-walled plate to use as a main mirror support, which is additionally fitted with welded ribs for stiffening (for other telescopes of the case), here comes a light construction from 1.5mm thick sheet metal for the application that is far superior in terms of stiffness. The additional use of ribs for stiffening in accordance with a calculation of the design engineer brings no further improvement of the rigidity. The truncated cone is the most mysterious.

The rear mirror support elements (support 9-point) lie onto a 2cm thick steel ring, which also serves as a flange for mounting the focal-plane instruments and their counterweights. This large and massive ring also carries weighty focal instruments and their change does not interfere with the effect of the Serrurier principle.

The lateral mirror support elements (support 6-point) based on a ring-shaped steel trussed from. The ratio of the stiffness to the material consumption is also extremely with this ring-shaped form. Furthermore, here is a compensation of the different thermal expansion between steel and material of the mirror construction permits. Either you will not find at other telescopes. The ring-shaped truss structure also contains the detachable connection to the support box of the optical tube (the 4 bolts). On top of this compound is inherently against the mirror adjustment.

The number of mirror support points applies to our mirror size. The tube of Pressberger with his 40" mirror of 300kg rear has 27 points and 12 points laterally.

The final main mirror cell looks notably elegant impression with its round shape on the square box of the optical tube support. This is not just an outer cladding. This is the supporting structure itself. So it must be with good engineering. Do you like telescopes with external skeletal bones of carbon? Then in the middle of the Grim Reaper insert the mirrors. If your telescope then rattles, it's the loose teeth of the skull.

Manufacture of sheet metal trough

After cutting the sheet metal parts (2 rings and two metal strips), the big ring is radially cut and cut out a segment. The original size of the ring and the segment can be determined with the knowledge of school geometry. Now the open ring is pulled together by hand. Automatically, he forms into a truncated cone. It requires two people to fix in the right form the conical shell with 2 Carpenters clamps because he is now with high mechanical pulling force. One will contract the ring, the other using the clamps. Then the cone shell is stitched together with MIG welding machine by individual welding points. Its production is possible so easy without special tools and without a single hammer blow. Later it is equally in the production of the spider ring.

The metal strips are welded to 2 cylindrical rings. These will now be properly placed and attached to the conical shell. Fix it only slightly. Then proceed with the top ring as well. Corrections by grinding and prying open the stitching points initially still easily possible. Only when all four sheet metal parts are stitched together and also fit, is welded between the fixing points. Here, one tries to compensate by individual opposing welding points, the resulting mechanical tension prevail. Under no circumstances should you pull a long weld beads in a passage, otherwise the workpiece warps hopeless.


2 parts fixed together slightly


3 parts fixed together slightly


TIG- weld beads

Lathe workpieces

On the whole telescope there are some great turning parts with disc shape. If you can no longer put up on your own lathe, let them make of metalworking companies. They are the reason why we have recommended a lathe with large center height.

The above-mentioned 2cm thick steel ring is one of them. Let you cut out roughly him by a company. It is then turn off from all sides on the lathe. To improve the position on the conical shell can be provided with a notch rotated around it. For positioning of the numerous threaded holes a dividing head is very helpful.

Now come the smaller parts. This includes the secondary mirror cell made from one piece of aluminum. The axis on which it is screwed is also a fine rotating member. If you absolutely want to then take a material that counteracts the thermal expansion of the tube truss rods. We recommend to prefer the already mentioned electronic solution.

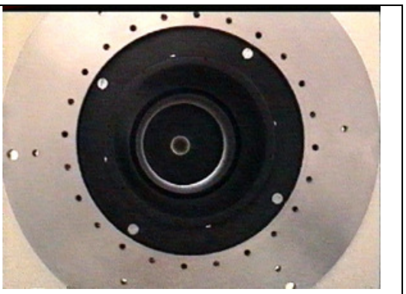
The four steel bolts where later the whole primary mirror cell is hanged on, at one end are provided with short fits and threads. In this fits steel bushings are pushed, which are welded later into the mirror cell. 3 more steel bushings are used to store the lateral mirror support elements on zinc bolts. All these parts can be well made with a smaller lathe itself. The same also applies to the three zinc bolts which have a front unscrewed ball. This ball can also be finished without special ball swivel device.

Temperature compensation at the lateral mirror support

Zinc as a material was chosen because of its high thermal expansion. Its expansion is against more that of steel. The lateral mirror support is thus depending on the sheet metal material of the mirror cell, in whole or partially compensated for temperature. The length of the zinc bolt together with the steel bushes in which they are held may also be changed for temperature compensation. Longer bolts then extend the side of the mirror cell out more. To calculate the length of the bolts in relation to the total radius of the mirror cell, taking into account the thermal expansion of both materials. The upper limit for the length of the bolt resulting from the fork opening and the angle of the zinc bolts for declination. The mirror cell must be able to pivot in the fork. If the extension of the bolt is not sufficient for the whole temperature compensation: Acrylic glass has more than twice the thermal expansion of zinc. However, acrylic glass does not have the similar degree of strength. You can use it only as a stamp within the steel bushing. It is to work well with the lathe.


produce a steel bushing


Measuring of the fit


the thick steel ring

Holes

The holes in the mirror cell for containing the 7 steel bushings (4 rear and 3 side) we have made with bi-metal hole-saws and a strong hand drill or on the lathe.


Side hole outside


Side hole inside


weld bushings (TIG)

Arranging the bushings

3 the steel bushes are laterally attached to the mirror cell individually welded. The 4 bushings for attaching the entire mirror cell must be used together with the matching bolts in their later arrangement. We draw up a simple device made of chipboard, which holds the 4 bolts parallel in the correct position. Alternatively, one can first produce the central part of the tube, the support box. The 4 bolts to attach the mirror cell are then welded already fixed in the support box. The holes for the 4 bushings are then adjusted accordingly.

Insertion of the steel ring

Probehalber einsetzen des Stahlringes

The 2cm thick steel ring is placed on the mirror cell that this against the 4 mounting bushings is level and centered. It is welded to the inside of the mirror cell. If the ring thereby distorted its later function as a planar mounting flange for focal-plane instruments is called into question. We also had this problem. We have it solved by the production of a second ring which is screwed with thin washers on the First and is then absolutely flat.

Main mirror support

Fundamentals

At the rear, the axial bearing of the primary mirror is a statically determined, 9-point mirror support. Radial, the main mirror is held by three supporting elements, which mounted temperature compensated with ball joints, touch the mirror at 6 sliding surfaces on the outer edge. In this manner, the mirror can be centered and fixed with respect to the focal instrument flange. These ball joints ensure that the mirror is movable along the sliding surfaces 6 on the outer edge and is thus not hindered in its axial bearing. It will thus be no deformation of the mirror surface and he is still not slip during pivoting of the tube. In addition to the light weight of the construction (in spite of steel as material), this is the outstanding at Pressberger's mirror cell. I have many other mirror cells viewed but these mechanically good solution I could not find anywhere else.

On the famous instrument maker Thomas Grubb from Ireland in 1838 declining, static nature of the axial mirror support is also called the American "floating whiffeltree". However, it is by no means outdated, certainly not compared to the approximately equal old astatic mirror support by William Lassell, with its many levers and counterweights. The only advantage of astatic lever is their subsequent individual adjustability when the optical system is installed. This advantage but affects only many points of support. However, a subsequent optimization of the mirror surface shape due to the many degrees of freedom of adjustment, however, so difficult that is usually waived. In lifetime of Lassell metal mirrors were in use. They were far from the precision of the current mirrors and some errors could perhaps be masked using the setting of individual forces on the bearing points. With the precision optical mirrors is now obsolete, but it is not to eradicate. We must not be confused with the modern adaptive optics where the computer controls the individual forces setting at the bearing points. A purely axial mirror support by Lassell is rarely used in large telescopes 40 years ago even when the mirror is to be held radially and fixed in its Cassegrain hole. The problem is the implementation of the lever joint. You may not create a breakaway torque, what they do, unfortunately in practice often even after a long quiescent persistence time. Even more problematic is the Lassell-bearing in the radial and axial design. The weight of the entire mirror cell together with mirror is almost doubled and the necessary fixation of the mirror can be difficult. Just think of the temperature balancing of the whole telescope with all these weights. Some telescope manufacturers think amateurish, build it today and still insist on its necessity. I've seen the astatic lever even at the secondary mirror cell where they selectively pull on the mirror. Mr. Pressberger has warned us of this mirror support.

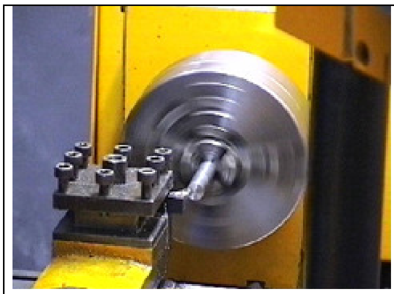
A well-designed mirror support of Grubb type provides, however, from the outset the correct bearing forces for the mirror. Valid at any angular position of the optics. If some amateurs argue otherwise send them back to school. You'll nothing to configure on the bearing forces. Incidentally, modern large telescopes (unless they are adaptive or active optics) have no Lassell lever. But usually a computer-aided hydraulic or pneumatic and thus also statically determined mirror support. Pictures of the new 1.8m Auxillary Telescopes of ESO show mirror support of Grubb type in its classical form.

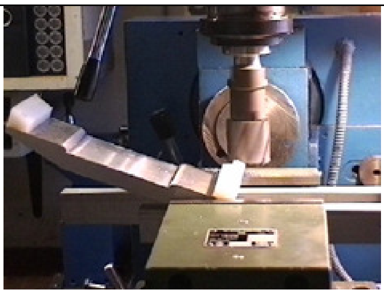
Whiffeltree elements


Whiffeltree elements within the mirror cell

The six supporting elements of the primary mirror (3 triangular plates axially and radially balance arm 3) are made of aluminum plates. The aluminum parts are finally black anodized (anodizing is described separately). If it is a particularly thick and heavy primary mirror, you'd better make the lateral elements of steel. A coarse trimming of aluminum is possible using a circular saw table by hand. For further processing use the Burr Attachment with end mills. The points of contact with the main mirror will be provided with Teflon disc. The triangular plates of the 9-point mirror bearing elements rest on three hardened steel balls. These are based on bolts from below (polished with fine male thread) and on steel coupons which are fitted into the triangular panels above. The balls themselves held by felt rings in the triangular plates. The location of the triangular plates is defined with 2 additional holes in the triangular plates. At the central steel ring of the mirror cell vertical pins are welded from steel. From below they engage quite loose in the 2 holes. Who here has concerns about the friction, which may employ small Teflon bushings in both holes.

The three radial support elements (balance arm) are also supported with ball joints. This avoids an obstruction of the statics at the rear mirror support. You get 6 touch lines laterally. Each balance arm further provided with securing cam, which is to prevent the falling out of the primary mirror in case the tube should tend downwards due to a disturbance of the telescope control. The ball joints themselves are produced on a small lathe and are fixed at the end of the discussed zinc bolts. Here, a perfect spherical socket in the support element is not absolutely necessary, it is sufficient a bore having a good sanded twist drill. The ball will then be fitted without space in each bore.


produce zinc bolts


milling of the balance arm


finished zinc bolt with knurled wheel and ball

Now, a recommendation of R. Pressberger: If you can not acquire in rod form the zinc, it is advisable to pour it in an iron water pipe. After cooling, it can be driven off from the tube. For the alternative use of acrylic glass has the following should be noted: Finished the bolt from aluminum, finished the acryl stamp and push him into a bore of the bolt. To the other side would now not bad a slide bearing. It's your fantasy left as you use optimally the metal ball of the joint.

One of the three zinc bolt is provided at the end with a thumb wheel. With this, the mirror may be released by loosening the bolt. Do that in the downtime when the telescope points to the zenith. This is advantageous with time for the material of the mirror.

Thus, the primary mirror can slide well on the Teflon-bearing elements, it should be processed as smooth as possible on the bottom sideways as well (ground or polished).

Der Spider-Ring

Similar to the mirror cell 2 cut rings of steel sheet (1 mm thick) are drawn together to a truncated cone and welded. Then they are exactly placed upon and stitched together. Thus, the Spider-ring is formed with a characteristic cross-sectional profile in the shape of an acute triangle. This profile gives the Spider-ring its unsurpassed rigidity.

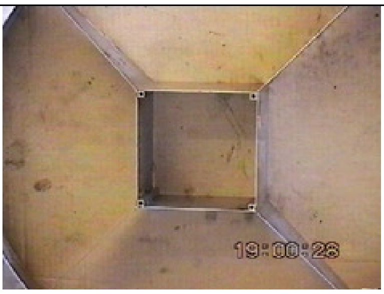
The spider legs

The 4 spider legs with its triangular shape should be cut slightly longer than that corresponding to the plan. Only after you have welded it to the ring shorter it to the correct length. Then you attached it to the ring exactly opposite.

At this point a note: Some people want to have curved spider legs. Or he wants to spider legs that do not face each other. You've seen at professional large telescopes? If you do not want to breach the principle of Serrurier, forget it. Especially if you use RC mirrors. The secondary mirror with its weight presses on the axis and to tilt with soft spider legs again. Large telescopes have indeed active secondary mirror and prevent this with electronics. Moreover, they are azimuthally and therefore subject to different forces. What we learn from this? Prefer the figure of the spikes in the images to accept and remember you can make sharp CCD sensor with their help using single bright star. We do now on with the cooking recipe.

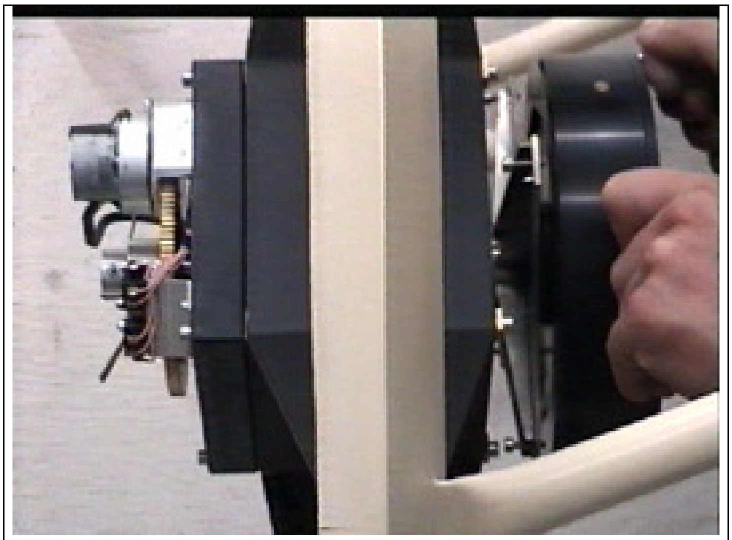
4 metal strips are then rolled into quadrants and then complete the triangular profile of the Spider-ring. Before attaching to the ring connection should be used in one of the quadrants, a recess, where it abuts against the leg spider. Through this slot later a flat cable for supplying power to the secondary mirror cell may be placed. This was needed for the electrical secondary mirror focusing, the limit switch, a heater in the dew shield or a safety tilt switch. It does not hurt to install reserves here. A heater in the dew shield you do not need for use of the telescope, but maybe during his downtime when it becomes very humid inside the dome.

Only now be expanded to a full weld, the welding points. Where again the rule, to pay close attention to the distortion phenomena and the welding points strategically correct to put in a sense, so that not the whole ring distorted one-sided. If the two conical surfaces are evenly slightly domed at the end, then you have reached the optimum.

 Spiderring	 Spider legs	 Square box

The bending sheets of the secondary mirror focusing unit later screwed to a square box that is connected in the center of the ring with the spider legs. This box of four rectangular plates and 4 bars of 8mm square profile is now ready. If he has the correct form, the far too long spider legs sheets to be cut with a jigsaw so that the box in the center of the Spider-ring used to fit and can be welded. The tensile stresses occurring in this welding process drag the Spider sheets straight. The whole construction is stiffened it.

Secondary mirror cell and focusing unit


Secondary mirror unit seen from the side

With this construction, the secondary mirror is moved by a fine thread, driven by a stepper motor via a spur gear. The spur gear and its pinion can be purchased as a standard machine part of gearbox manufacturers. The stepper motor, optionally with an additional reduction gear is available at electronics mail order. For weight saving reasons, it is moving a hollowed shaft that is bolted to the bending sheets and the mirror cell. This enables a backlash free up / down movement of the secondary mirror by about 2mm without the slightest tilting or lateral displacement. The path length at the focal point of the entire system is correspondingly larger. This is ideal for precise fine focus, a temperature compensation or adaptation to different filter thicknesses in a filter wheel. More path length you do not need. More change in the distance between the two mirrors is not advisable for reasons of optical calculation. Even if you look at your old Celestron Telescope other.

Bending sheets of the focusing unit

We have cut the bending sheets of 0.5mm thick spring bronze with the jigsaw. The lower plate is reinforced with brass washers soldered around the four outer mounting holes. The location of the four outer mounting holes is determined by taking measurements on the finished square box from Spider-ring.


Bending sheets

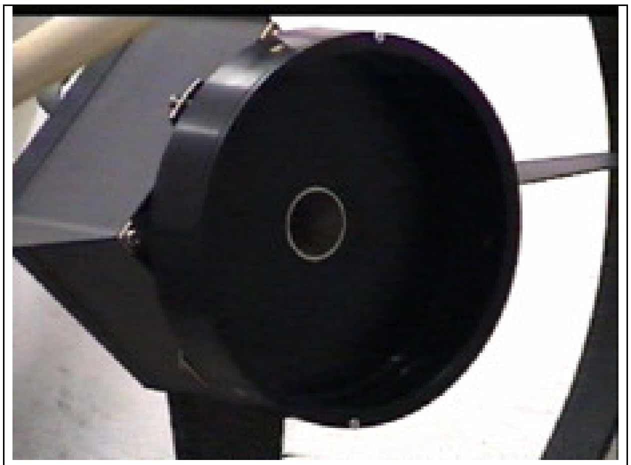
The axis of the secondary mirror cell

The axis of the mirror cell is taken from the bending metal sheets together with the spacer sleeve of both bending sheets, the mounting nut and the screw nut pressed for the focus adjustment is a workpiece on the lathe. The 3mm supporting plate with stiffening ribs, with the aid of a tilting of the secondary mirror cell is intended for optical centering, we have cut out with the jigsaw and welded to the axle with fine TIG welds.


Axis with compression spring

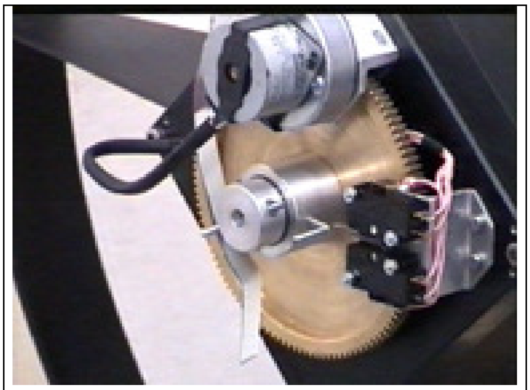
The secondary mirror cell

It is turned out of aluminum round stock. Via a screw thread can be screwed onto the axis. Care must be taken to a defined stop. The rear wall of the mirror cell is to be kept thin, so that the tilt of the mirror is possible by bending the rear wall. Laterally, the mirror cell is made thick-walled. The mirror only touches a ring at the bottom of the mirror cell. Because our mirror on the back is not plan, and for optical testing during polishing of LOMO he has a concave optical surface, it is held as an optical lens similar. A second ring which attached with M3 screws on the mirror cell, covers the edge of the mirror and fixed the mirror. By fixing the mirror to only 3 points at an angle of 120 °, a mechanical tension of the mirror is avoided. This ensures that the mirror can not shift laterally. The side-mounted screws help mirror centrally installed in the cell.


Screwed secondary mirror cell on axis

You can loosen it after centering and fixing the mirror. The mirror should not be pushed sideways as we here do not have temperature compensation, in contrast to the primary mirror. All points that come into contact with the mirror are provided with self-adhesive Teflon of 0.5mm thickness. The whole cell with the covering is black to anodize. Did I mention that you can make anodize yourself? Until now you can as an Islamic terrorist buy the necessary chemicals without getting into the suspicion. After I wrote those words, I must have an umbrella wherever I go. So I protect myself from the targeted bomb missiles, against me from your country.

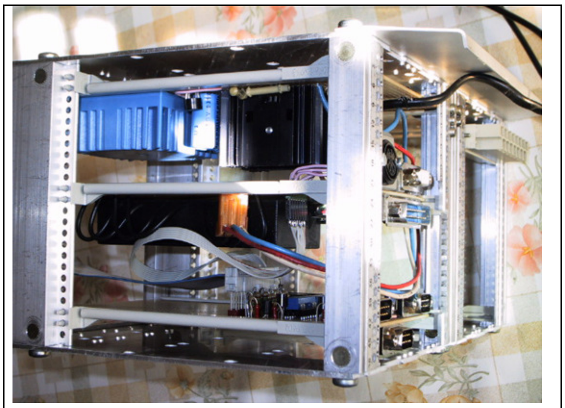
The base plate for the focus gear



Focusing gear, trailing pointer, limit switch

This massive part of 4-edge aluminum is one of the few larger milled parts. He is undermining on the bottom with the pin milling cutter, to make room for the compression spring and the retaining nut of the axle. The spur gear and the focus motor with its limit switch attached to the top of the base plate. If you have used limit switches usually only a single rotation of the spur gear as the focusing range. With trailing pointers (with ball bearings), the focusable range on two or more revolutions of the fine thread screw be increased.

The focus control electronics



Focus control unit with power supply

Initially, we used a ready-made simple stepper motor interface via the parallel port of a computer for focus control. As we had a computer ATARI ST. Nowadays you can used industrial stepper motor driver IC's. With a common I / O controller card, you control this via USB. We now make it that way. The self-written program generates the necessary pulse sequence for the stepper motor and is part of the new observatory control system. Thus, the fine focusing is also possible via hand controller, two buttons on the hand controller are connected with 2 digital inputs of the computer. 1 further input is in conjunction with two limit switches (see above).

Have you ever operated with electronics? Then it is time for you. There are commercially available small microcontroller development kits for children. They are called Arduino and cost very little money. You can find it all on the internet, looking after. In a few hours you move then the accompanying toy dinosaur computer controlled. A board for your own extensions is attending. You will learn to program in C + +. You will learn to get along without operating system and to make your single program to run in a loop. If the kids can do you try that also. Anyway, as a small Arduino is perfectly suited for focus control. You can install the Arduino into the telescope next to the focus gear. It is smaller than a cigarette pack. Remote controlled, it is equipped with a serial interface. If you do it yourself it is much better than the expensive purchasable junk with the complicated ASCOM interface.

The following functions are implemented in the observatory control system with us:

- Focus + (single step or continuous operation)
- Focus - (single step or continuous operation)
- Focus to middle position (initialization of the focus position in the controller with limit switches)
- Save / recall of the stored position
- by name selection of focus positions
- One-time tracking of the focus position corresponding to the temperature
- Continuous tracking of the focus position on the temperature (Auto Focus)

As a temperature sensor, a commercially available wireless sensor to a weather station serves. A compound of the future filter wheel is designed and requires only a software extension.

The cover of the focus gear

It is made of thin aluminum sheet in the manner of a folding box. We have a sheet thickness of 0.3mm used. The "box" we've painted with black blackboard paint. You could have also anodize, but we had just the sulfuric acid empty.

The central support box of the optical tube

The central part of the tube consists of a box with a square outer cross section. It consists mainly of steel sheet of 1.5mm thickness. The sheet is reinforced only in those places where later added the two declination bearings. We have the material thickness increases even where the Serrurier-rods are welded. The 4 bolts which support the mirror cell, have already been mentioned in the main mirror cell. They are together with internal stiffening sheets firmly connected to the support box.

You start at the top surface and first attach to the rolled cylinder. If you have not yet made the mirror cell, then the 4 bolts are now attached and aligned in parallel. If you (like us) the mirror cell already done, set the 4 bolts in the mirror cell and screw. You put the lower cover plate over it and set the cylinder with the upper cover plate on it. Now the stiffening plates are used and tacked together everything. The mirror cell can be unscrewed again now. If everything fits, are mutually more welding points set between the stitching points, until the weld is complete. Since the spot welds are made inside the box, a post-processing unnecessary.

		
support box welding inside	Mirror cell aligns the bolt parallel	Welding points from the outside

Next, the four corner connection plates are welded. They give the tube not only its elegant appearance, but can also be easily accessible connected to the 4 radial stiffeners.

Now the outer side cover sheets are attached. Where these sheets collide with the internal stiffening, holes are drilled in order to connect through the bores with the welder, the stiffening plates with the side cover plates.

		
stiffening plates welded	the finished support box	Welding points inside

Finally, the two 1cm-thick plates for the declination axis are cut from 10cm flat steel and provided with the large bore for receiving the declination bearings. Concentrically around this hole M6 threads are arranged. They are needed for a circle of many pull-and push-screws, on the large delta friction drive wheel is held and adjusted.

The bearing plates are (after exact positioning) welded to both the edge and also through the bearing bore through it with the side cover plate (if possible with TIG).

Although the primary mirror cell is ready, you'll surely can not resist both finished tube parts try screwing together. Do not worry if the mirror cell now is not "smooth" slips on the pin of the support box. A few sharp blows with the "sledgehammer" to the bolts in the right place, and it will fit perfectly. Please do not forget to mark the correct position to each other. Otherwise it may happen that you slightly desperate in the final assembly of the telescope.

Serrurier rods

The bars of the truss tube (named after Mark Serrurier) are made of steel pipe with 2.5cm diameter and 1mm wall thickness. They are first cut off with a little extra length. The ends of the pipes are pinched off at an angle corresponding approximately their subsequent oblique position, in the vise. This results in the static "joints" that match the Serrurier principle. At the upper end of the optical tubus each 2 struts collide with a certain intersection. They are cut as one another corresponds to the sectional area at this point. By finishing with a file it is ensured that the cut surfaces match exactly. Now they can be arranged in the correct angles of the posterior oblique position, are welded together with the TIG machine. Now it shortens the 4 now "V"-shaped pairs of struts to their final exact length.

End of Serrurier rods to the support box (left) and the Spider Ring (right)

Assembling the optical tube

First, the four "V"-shaped pairs of struts are attached to the support box with the welder. The Spider-ring is placed on top. It is now important, the Spider-ring to center opposite the main mirror cell while keeping the "Spacing", the calculated distance between the main and secondary mirrors set properly. There are 2 options:

- Application of the optical centering gauge. The rotatable gauge operates either with a laser or with an alignment telescope. It is later used also for perfect centering of the two mirrors. Construction and application is described in a separate chapter.
- Preparing a mechanical centering gauge in the form of a tube with welded round neck disks at the ends. The disks must have an accurate common axis of rotation. The distance between the disks must provide the correct distance between the two mirrors. Who wants to customize it (or make DIY) used a strong rigid iron pipe (3 "water pipe) and welded to the ends of it two iron disks. Spacing and diameter of the iron disks should be such that a slice of the mounted secondary mirror cell can be recognized, the other disc is fitted to the mounting flange for the focal-plane instruments mounted primary mirror cell. To this the whole gauge should best be rotated on a large lathe in one setting.

use of centering gauge

Kindly provided R. Pressberger has made the mechanical centering gauge for us. We like to give the gauge other amateurs on loan at disposal. It is made of mirror-distance 40", flange and secondary mirror size about 8". With additional adapter rings can the gauge be used for different dimensions.

directions for use the mechanical centering gauge

Support box and primary mirror cell is bolted together, then the centering gauge pushed through in the middle and mounted on flange for focal-plane instruments. Spider-ring with mounted secondary mirror cell is simply placed on it. Now the Serrurier struts may be attached and then welded fix.

Thus, the tube is finished except for the paint job.

aperture tubes

Aufschrauben der Blendenrohrverlängerung

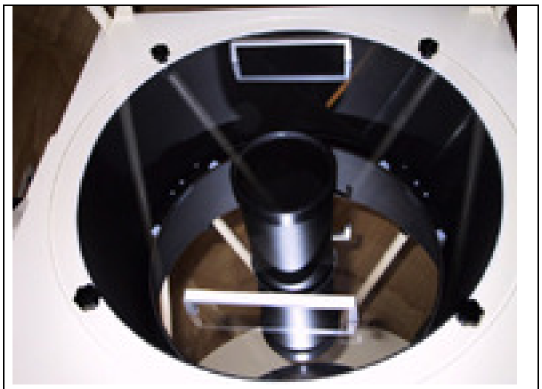
The aperture pipes must prevent direct light into the eyepiece or on the CCD, so the light bypassing the optics. On the other hand, an overly restrictive dimensioning of the aperture tubes results in a vignetting of the field. The dimension for a desired field of view is performed by full-scale drawing of the light path on paper or graphically on the computer. You look at this, only the peripheral light rays. We have even developed a small program to calculate, written in Qbasic. The optical data of the mirror system are input. You choose the diameter of the desired glare-free field of view in degrees. Will be calculated the diameter of the secondary mirror and the dimensions of the aperture tubes. Since the front hood cap increases the obstruction, you will have to find a compromise.

The aperture tubes consist of 2 parts. In the drawing by R. Pressberger they are not shown. The rear aperture tube is inserted from the rear through the primary mirror cell, and the bore of the main mirror and fixed inside to the flange for mounting the focal-plane instruments. Make your own ring to fix him and screw him with it. The front aperture hood cap is seated around the secondary mirror cell, acts as a dust cap and is connected to the dust cover of the secondary mirror can be closed.

The rear aperture tube we have rolled thin stainless steel sheet metal and TIG welded. For attachment to focal instrument flange a bezel is turned from aluminum and black anodized. The tube itself is roughened with sandpaper and painted matte black with blackboard paint. We have divided the rear aperture tube and provided with a threaded connection. This allows us to use a single dust cover for the main mirror.

The front panel was rolled aluminum sheet for weight reasons. The weld makes you a professional. Black anodizing do it yourself.

Dust cover for the optics


Dust cover made of acrylic glass

The airtight dust cover for the main mirror is very important. Otherwise, it comes in daytime (resting position of the telescope) with rapid temperature rise to fogging of the mirror with dew. In addition, insects can be kept away from the main mirror in this way. These problems are well known to all owners of stationary mounted telescopes. The transparent cover made of acrylic glass allowed at any time control of the mirror. The transparent cover plate allows day visitors a look at the mirror. Stubborn proponent the thesis "*my little refractor provides yet sharper stars*" may also look through our large telescope, but only with attached acrylic glass cover, so that their illusion is not destroyed.

Counterweight rings

It would be completely wrong, the weight balance for a heavy focal plane instrument to do with smaller weights nearby the secondary mirror. First, it centering is disturbed (see design features) and second, the natural frequency of the telescope is reduced. Mechanical vibrations then decrease more slowly. The weight of the secondary mirror unit is crucial for the entire structural design. This weight should be as small as possible. Also, placing a sliding weight on the tube is to be rejected for the same reasons.


Gegengewichtsring mit 34cm Durchmesser

A weight balance is considered exactly achieved relative to an axis of rotation when the center of gravity of the rotating mass to lie exactly on the axis of rotation is (balance in any position). Otherwise, you'll only receive above equilibrium (unstable equilibrium) or below (stable equilibrium). Due to the symmetry of the construction of Pressberger with the counterweight rings we always have balance in every situation.

A maximum weight for focal instruments is used as the basis of the Tube construction. Will lighter focal-plane instruments (eg eyepieces) used the tube would tip forward. Therefore, it is the difference in weight balanced by counterweights which are concentric about the focal instrument to be fixed around also at focal instruments flange. This method is the same used in professional telescopes.

You're doing a set of iron counterweight rings which are tuned in weight in about one another. They can be screwed together. As corrosion protection for the rings themselves offers black galvanizing.

We have at our telescope a maximum Equipment weight of about 15kg available and can thus also use heavier CCD cameras or photometer and the filter wheels and visual insight. Now show me once a Newtonian telescope where this is possible.

Paintwork

finished optical tube made of stainless steel from welding slightly "dented" before painting

As a result of the mechanical stresses generated during welding, the finished tube before painting has a slightly "dented" look. In the later function, this has no effect. In the reflective metallic surface of stainless steel sheet metal which is especially noticeable (see picture). Who puts on an aesthetic appearance value before the actual paint scraper putty applied commercially needed out of the car finish and achieve a smooth surface after curing thereof by grinding. A detailed description of the operations carried out in a later chapter. There will also be shown how to get to the appropriate two-tone paint (White exterior, interior black).

apply putty