Abbe Condenser Upgrade

(including the long legs stand system)

User's Manual

Document created: 23.05.2023, Last edited: 26.05.2023

Manual prepared by **OptArc** – Designers and manufacturers of custom optical and optoelectronic systems using 3D printing rapid prototyping and based in the UK.
See **optarc.co.uk** for details.

Safety Information

Identification of risk

Throughout this manual please take heed of **warnings given in bold text and highlighted yellow** to avoid possible damage to equipment and/or harm to people.

Risk to vulnerable groups

PUMA microscopes and associated systems are not toys. They contain small parts which may come loose such as tiny metal screws and washers and glass components that may splinter or break or otherwise present a choking or sharp object hazard or chemical hazard (e.g. for batteries). **Please do not let babies or young children play with or gain access to any aspect of a PUMA system without close appropriate adult supervision. Likewise keep PUMA systems away from pets**.

Risk of damage to eyesight

When choosing and using a light source for a PUMA microscope, care must be taken to avoid the use of or exposure to light that could damage eyesight.

In particular **never allow direct or specular reflections of the sun to enter the microscope** through the illuminating mirror.

Also, **never allow laser light to enter the microscope through the illuminating mirror if any viewing is to be done by eye** (as opposed to recordings by a camera only).

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https://www.optarc.co.uk/support/

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Limitations of Use

The PUMA microscope and its associated systems do not have any certifications or regulatory approvals in any country for use in clinical diagnostics or treatment (human or veterinary).

The PUMA microscope and its associated systems are released to be used for research and educational purposes only.

Disclaimer

All PUMA project information including, without limitation, any CAD file or STL file and all documentation, advice and instruction (whether provided in video form, audible form, written form or otherwise) is provided 'as is' in good faith and is intended to be helpful but comes with no warranty whatsoever.

Anyone attempting to build or use a PUMA microscope or other PUMA-related material, accessory, module or derivative is hereby advised that there will be risk involved in 3D printing, post-print processing, assembly and usage of the resulting structures. This risk includes, without limitation, the risk of personal injury, damage and loss of resources.

Dr Paul J. Tadrous, TadPath and OptArc cannot accept any liability for any such injury, loss or other damages that may occur. All those who attempt to build or use any aspect of the PUMA project or derivatives thereof do so at their own risk.

Discrepancy in Appearance of Parts

The parts in your package may differ in exact appearance to the parts shown in this manual or in the associated videos or advertising materials because we always ship the latest versions of the scope and the manual and videos may have been prepared using earlier models. Functionality of the parts you receive will be the same or better than those illustrated in this manual and any associated video or advertising materials.

Abbreviations

Some common abbreviations used in this manual are listed below for convenience.

CAD	Computer-aided design
IAD	Illuminating aperture diaphragm (or the slot for this aperture)
NA	Numerical Aperture
PLA	Poly-lactic acid
PUMA	Portable Upgradeable Modular Affordable (3D printed microscopy system)
SLM	Spatial Light Modulator
STL	Stereolithography file format

Introduction

This manual pertains to the kit of parts supplied by OptArc that will enable you to upgrade the illumination system of a PUMA Foundation scope from its standard mirror illuminator into a more advanced illumination system using an Abbe condenser for higher numerical aperture (NA) illumination.

This upgrade includes the long legs stand system and a selections of filters for the IAD slot of the condenser.

For more information about the parts used in this kit and, in particular if you would like to print any additional or replacement parts, please see the PUMA GitHub repository.

PUMA GitHub Page

https://github.com/TadPath/PUMA

Features of this condenser upgrade kit

This kit will enable you to get maximum benefit, resolution and image quality from high NA objective lenses (such as x40 and x100 oil).

When used dry this condenser will allow a maximum NA of about 0.92. The top surface of the condenser may be oiled to achieve a maximum NA of about 1.14. You will also be able to use filters in the illuminating aperture diaphragm (IAD) slot to achieve specialist modes of illumination such as Schlieren phase contrast, Rheinberg illumination, oblique illumination and dark ground illumination (dark field illumination). You may need to supply your own filters to achieve some of the aforementioned modes but this kit makes it possible. See the videos on the PUMA microscope YouTube channel to learn more about what you can do with this system including adding more parts to increase the NA even further and for achieving polarisation microscopy.

This OptArc Abbe condenser upgrade kit will also be a pre-requisite for applying the OptArc Köhler illumination upgrade kit if you want to take your Foundation scope to the next level of illumination sophistication.

What is not included in this upgrade kit

This upgrade kit is designed to make use of components already supplied as part of the Foundation scope provided by OptArc. This means this upgrade kit does not include those parts. In particular it does not include a mirror illuminator (it assumes you will be using the standard PUMA mirror that came with your Foundation scope) and does not include the metal leg spacers because those already come with the Foundation scope. This kit also does not include any electrical or electronic light source or power supply.

What's included in the kit

This Abbe condenser upgrade kit includes the following items only (quantities in brackets) – see figures 1, 2 and 3:

- A PUMA Abbe condenser (1)
- A condenser protector cap (1)
- Condenser flange spacers, 0.48 mm thick (2)

Note: The condenser ships with one of the flange spacers in place on the condenser flange and with the protector cap threaded onto the condenser (figure 1). The other flange spacer is provided in a separate packet (figure 3) and is provided as a spare or additional spacer but is not normally required. Remove the protector cap before fitting the condenser but leave the single flange spacer in place on the condenser.

- The condenser gripper plates (1 pair)
- Condenser adjustment thumbscrews (4)
- The condenser mirror holder socket (1)
- An IAD filter tray (1)
- An IAD filter tray for oil immersion (1)
- Apertures for the IAD filter tray:
  - Phase 180 Schlieren (1)
  - Dark field aperture patch stop 2.5 mm diameter (1)
  - Dark field aperture patch stop 10 mm diameter (1)
  - Dark field aperture patch stop 11 mm diameter (1)
  - Dark field aperture patch stop 12 mm diameter (1)
- Apertures for the IAD filter tray for oil immersion (these are the larger diameter filters shown in figure 3):
  - Phase 180 Schlieren (1)
  - Plain clear aperture (1)
- The long legs stand system comprising the stand (1), its angled hind leg (1) with M3 fixing thumbscrew (1) and the rear leg adjustable extension (1). These parts have been pre-assembled for you (figure 3) but the adjustable extension is kept in a separate packet for transport and not mounted to the stand (figure 2, middle).
- M6 nuts (6) and M6 flexible plastic washers (3)

Figure 1. The condenser packet. Packet shown on the left. Parts in the packet shown on the right. Note that these three parts are all fitted together onto the condenser unit and have been removed and separated for the purpose of this illustration. Note that you must remove (unscrew) the protective cap before fitting the condenser to the stage. Note also that the single flange spacer (that is already fitted to the condenser in this packet) is all you need for normal use, so you do not need to attach the other (spare) spacer provided in the 'filters' pack (figure 3).

No other parts are included. You may require a 10 mm spanner or some long nose pliers to help tighten the M6 nuts as described in the upgrade procedure (see the next section).

You may need to make your own filters for use with certain objectives and to achieve certain illumination effects. The filters provided are just a selection to get you started. See the chapter 'Using the IAD filters and filter trays' in this manual for more information.

Please note that the condenser is made with the standard parts as described in the PUMA Microscope YouTube videos and GitHub repository. This includes use of the moulded glass lenses which may contain small surface defects as is normal for such lenses. This does not constitute a defect in workmanship.

Figure 2. Some other parts of the upgrade kit: On the left are the packs that come in the box. On the right are shown the contents of the packs. Top: The condenser gripper brackets. Middle: The 4 thumbscrews used to secure the gripper bracket plates to the stage and the adjustable hind leg extension for the long legs stand system. Bottom: The condenser mirror holder socket.

Figure 3. More parts included in the kit. Packs are shown on the left and their contents on the right. Top: The filter pack containing a selection of filters, two filter sliders (the one with the larger aperture is for use with oil immersion objectives) and a spare or additional condenser flange spacer. Middle: The long legs stand system ready assembled for you, Bottom: The 6 M6 nuts and 3 M6 flexible washers used to fix the long legs system to the scope.

The upgrade procedure

Important: Please ensure you read the notes in this chapter in addition to (and before) following the upgrade video because the notes contain information that may modify the procedures described in the video due to the fact that the parts in this kit are partially pre-assembled for you.

The main procedure is detailed in the first condenser video on the PUMA microscope YouTube channel, link opposite:

The video also give more general information about what an Abbe condenser is and how to build it from scratch and use it so the part of the video that is most directly relevant to performing the upgrade starts at about time index 09:24.

Condenser upgrade video

https://youtu.be/2wpsvA2cQgQ

Note that when it comes to fixing the long legs stand system to the microscope, you do not need to loosen the rear leg thumbscrew and adjust the rear leg position as shown in the video at timestamp 11:11 onwards because this has been done for you in the stand that ships in this kit. You can continue from timestamp point 12:11.

Note: When fixing the long legs stand in place with the last three M6 nuts (video timestamp 12:28) I now recommend you use the flexible plastic washer provided with your kit under the final M6 nut for extra stability to prevent wobble, to help protect the long legs stand plastic from over-compression when tightening and to prevent the M6 nut from working loose passively over time. This is illustrated in the video on the PUMA stabiliser module. See the link below at time stamp 3:29 to 4:02.

WARNING: Over-tightening the M6 nuts – especially when using a spanner – runs the risk of compressing, cracking and damaging the plastic of the long legs stand system. Take care not to over-tighten.

Stabiliser video

https://youtu.be/d8tMtWFhNY4

Note: In the condenser upgrade video at timestamp 13:24, the placement of a single condenser flange spacer over the condenser flange has already been done for you in the condenser provided with this kit so you do not need to do this. However you should ensure that the flat edge of the space lines up with the flat edge of the condenser flange, as described in the video.

The rest of the procedure is as described in the condenser upgrade video.

Using the IAD filters and filter trays

The filter trays supplied with this condenser upgrade kit are of two diameters. The smaller diameter tray holds the smaller filters that are suitable for dry objectives (that have smaller NA than immersion objectives). The larger aperture filter tray is for use with higher NA immersion optics.

The plain clear aperture filter provided for use with the oil immersion tray may be used to house some custom filter of your choice. For example you could stick a disc of tracing paper (drafting paper) onto this clear aperture with glue to form a diffuser for the IAD. This can help create even illumination even if you cannot find an area of plain illumination scenery to use with your mirror. You may alternatively glue some custom clear aperture plastic onto this filter so you can draw or print some custom colour filter onto it like a Rheinberg filter.

Placing and removing filters in/from the filter trays

The thin filters provided with this kit can be stacked up to 2 filters at a time into the wells in the filter trays.

You will notice that the filters have little side lugs and the filter tray wells have recesses for these side lugs (figure 4). This allows filters to be placed at a range of angles in the filter trays.

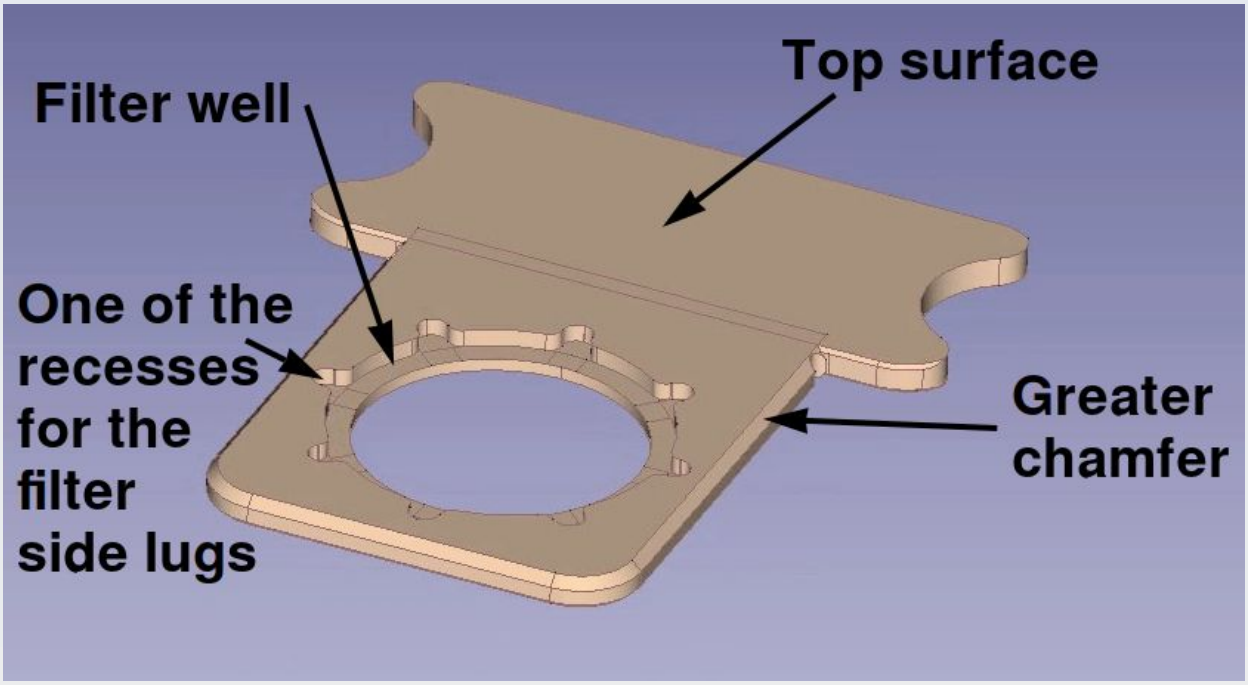

Figure 4. Parts of a filter tray seen from the top surface of the tray.

You should place the filters into the filter wells with the flattest surface of the filter facing down into the well in the filter tray. You may need to press the side lugs down with a blunt instrument (like the tip of a ball-point pen or a paper clip or thin wooden stick) to ensure they go all the way down into their socket.

If the filter fit is a bit loose, you may adhere the filter into the socket by means of a small amount of blue tack (or white tack) pressed into the lug space with a blunt implement. If you do this you should ensure that no tack is raised above the surface of the filter tray or it may get stuck in the IAD slot and subsequently fall onto and soil the lenses or make it difficult for filter trays to fit into the slot in future.

Note that these plastic filters are very thin and so can easily be (permanently) bent or destroyed with rough handling. Take special care when removing them from the filter trays.

Inserting filter trays into the IAD slot of the condenser

The filter trays are designed to only go into the IAD slot one way (one side up).

They have a greater bevel on the top surface (the surface of the filter well) compared to the lower surface (the surface with the flatter, smoother, finish). The IAD slot is similarly bevelled. **You must only insert the filter trays with the cavity of the filter well facing upwards (towards the top, smaller, lens of the condenser) as shown in figure 5**.

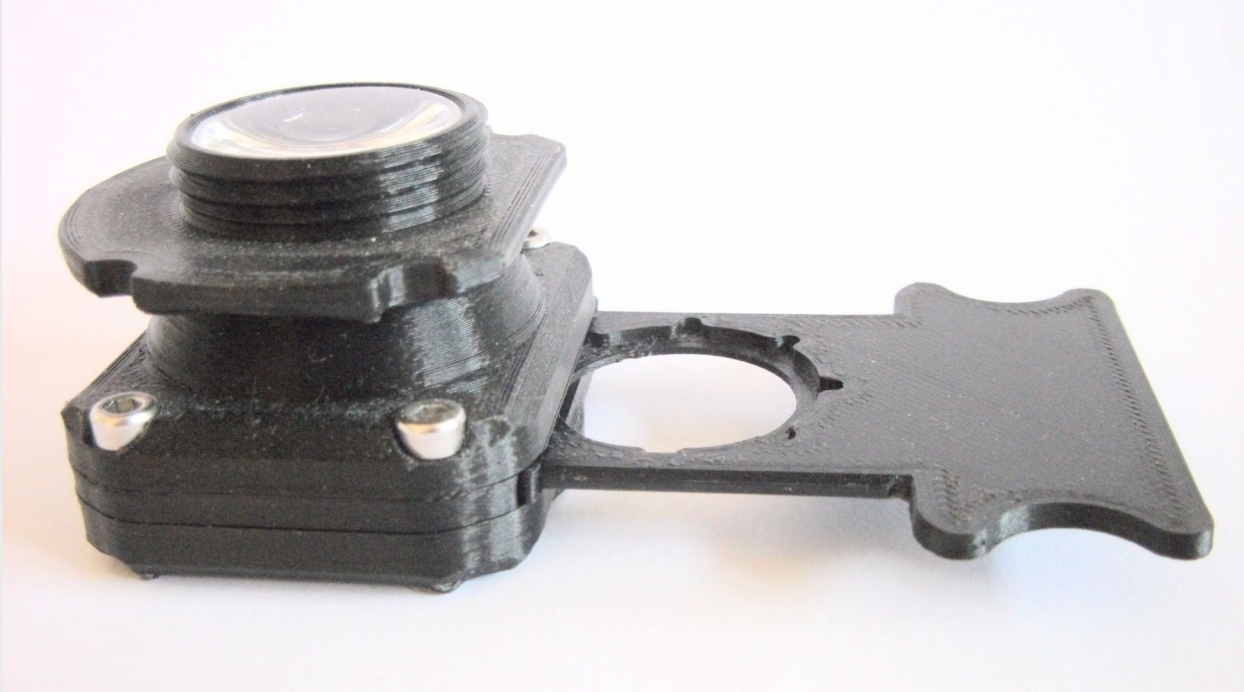

Figure 5. The correct way up to insert a filter tray into the IAD slot of the condenser is with the filter cavity facing upwards.

It may be possible to force the filter in the other way round but this is incorrect and will have adverse consequences such as:

it will wear out the slot and filter trays to give an ultimately looser fit

it will allow filters to drop down into the IAD cavity and this can result in filters being destroyed when you try to remove the filter tray from the slot. This is a particular hazard if

you use a custom glass coverslip as a filter because you will end up with many tiny pieces of glass falling down onto the mirror or other lenses (if you have a Köhler illuminator) or onto the table or other work surface you are using and this will be a laceration hazard to anyone who comes into contact with them and an ingestion hazard.

Using generic transparent filter

As shown in the video on the spatial light modulator (SLM), it is possible to use a 25 mm diameter round coverslip as a clear surface on which you can draw any aperture you want, in monochrome or colour (figure 6). These coverslips are extremely thin and fragile so if you chose to do this bear in mind that **the glass may shatter resulting in a laceration and ingestion hazard (especially for children, pets, etc.)**.

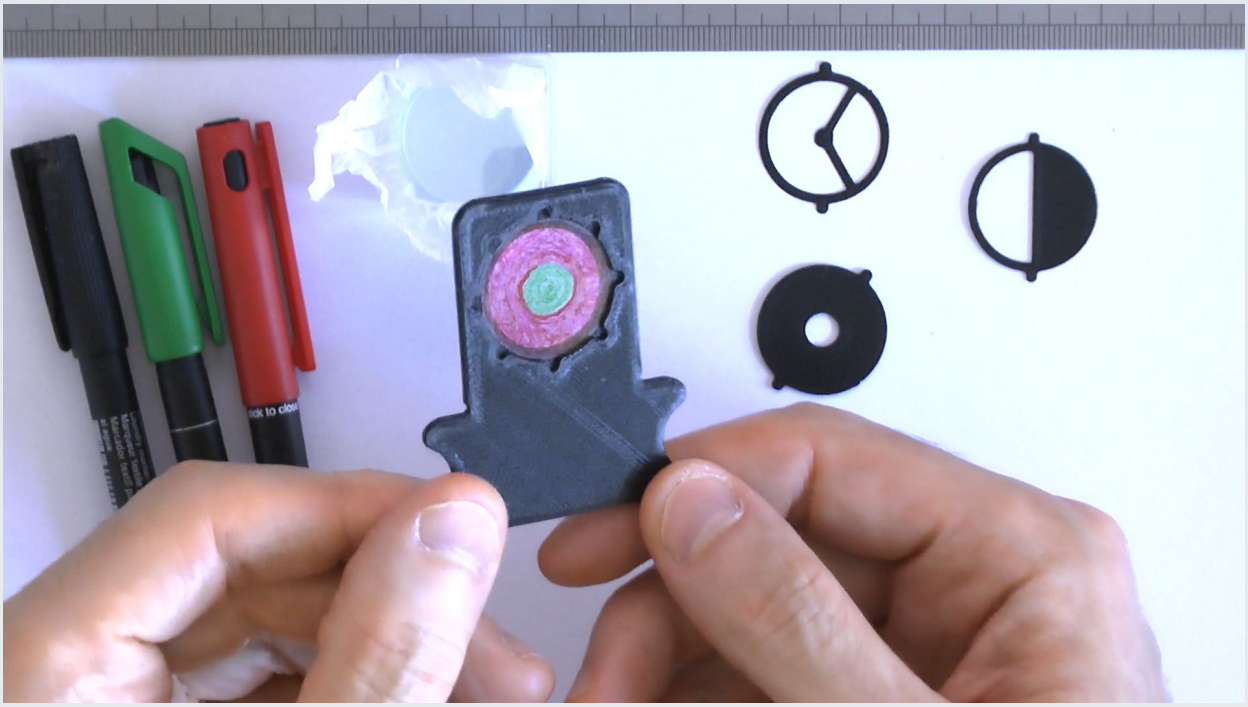

Figure 6. Screenshot from the SLM video showing a plain round glass coverslip used as a generic filter (a Rheinberg filter in this example). However it would be safer to use a round piece of thin clear plastic because glass coverslips can easily break and cause sharp glass hazards.

It would be a lot safer to use a disc of thin clear plastic stuck onto the clear aperture filter provided with this upgrade kit as an alternative substrate for drawing / printing custom apertures. In fact you could use clear transparent film for laser or inkjet printers for this purpose – to print your own custom apertures to stick to the clear aperture filter provided with this upgrade kit.

Oil immersion

The highest NA possible with this condenser can only be achieved if both the condenser-sample transition and the sample-objective transition are immersed in a matched refractive index fluid. It is important to do this properly without over-use of immersion fluid.

Oil or water immersion should only be attempted with objective lenses that are designed for use with immersion (such as the OptArc x100 oil immersion objective or other oil or water immersion objectives). **Using oil, water or other immersion liquid with objective lenses that are not designed for such immersion could damage the objective lens beyond economic repair**.

For the detailed procedure of how to use oil immersion with this condenser please see the section entitled 'How to insert and remove a specimen for use with the x100 (oil immersion) objective' in the 'OptArc x40 dry and x100 oil Objectives, User Guide' which is available as a free PDF download from the 'Support' page of the optarc.co.uk website.

Important points to note are that you should not use excessive oil (on either the condenser or the coverslip of the specimen) and you should wipe all oil off the top lens of the condenser with an absorbent household tissue or paper towel immediately after you have finished you imaging session.

Please note that the top lens of the condenser is just a push fit into its socket. It is not sealed with any sealant. This means that it may be possible for oil or water to seep into the lens housing and condenser cavity if excessive immersion fluid is used or if immersion fluid is not wiped away immediately after an imaging session. If the occurs and becomes a problem (e.g. condensation build up inside the condenser) the condenser may need to be completely dismantled and cleaned from the inside then re-assembled. The following videos give information that may be relevant to such dismantling and re-assembly:

Condenser Upgrade

https://youtu.be/2wpsvA2cQgQ

Condenser 2

https://youtu.be/80MFESeIbnc

Further information

The Abbe condenser upgrade is an essential pre-requisite if you intend to upgrade to full Köhler illumination using the OptArc Köhler illumination upgrade kit (when this becomes available). See the user manual for that upgrade kit for details.

The following videos on the PUMA Microscope YouTube channel give information that may be of interest when using your PUMA microscope with this Abbe condenser upgrade kit:

Condenser Upgrade

https://youtu.be/2wpsvA2cQgQ

Köhler Illuminator

https://youtu.be/XEE-el7vC5k

Long Legs Stand System

https://youtu.be/W5CvPGi-eL8

SLM

https://youtu.be/yW9H66BlUjU

Condenser 2

https://youtu.be/80MFESeIbnc

Köhler 2

https://youtu.be/gDGqXsudmgE

Stabiliser

https://youtu.be/d8tMtWFhNY4

See also the project GitHub repository for more information and details of any future upgrades or additions to the parts:

https://github.com/TadPath/PUMA

Maintenance

This chapter discusses routine user maintenance. For details about how to fully take-apart your condenser and re-assemble it see the PUMA Microscope YouTube channel videos.

Avoid excessive heat

The 3D printed parts are made of PLA plastic which has a glass transition temperature of about 60 ºC (140 ºF). This means it will start to soften and may deform if allowed to get near that temperature. It is advisable to avoid exposing the microscope to temperatures in excess of 40 ºC (104 ºF).

Under no circumstances should the scope be placed on or near a room heater or radiator (e.g. to dry off if it gets wet or for any other reason).

Avoid keeping the scope in a vehicle on a sunny day or in a transparent closed cabinet exposed to the sun.

Moisture and condensation

The 3D printed parts are made of PLA plastic which can withstand moisture by water and many solvents but it is not completely solid or waterproof meaning that if submerged or exposed to excessive wetness that liquid might find its way into the air cells inside microscope components and take a long time to evaporate. Furthermore PLA plastic is biodegradable so having aqueous solutions stagnating inside its components could hasten degradation (although noticeable effects may take several years).

For these reasons please protect your components from the rain and do not immerse the parts in liquid. The correct use of immersion oil is fine but the oil must be removed after use with absorbent tissue and do not use excessive oil.

Lens care

The lenses in the condenser are strong moulded glass but if dropped on a hard surface they may crack or shatter so take care to avoid this.

The lenses in the condenser are not coated with any special coatings but due to the proximity of the top lens to glass specimen slides this lens is at risk of being scratched so take care when inserting and removing glass specimen slides on the microscope stage and take care if using metal stage clips that these also do not contact and scratch the surface of the condenser lens.

To clean the exposed surfaces of the condenser lenses or other optical surfaces use an air duster or pneumatic soft lens brush to blow away any surface debris first. **This is important because the kind of dust particles that accumulate on the top of the condenser may include fine glass fragments from microscope slides. Failure to blow or brush away such glass dust before wiping may result in scratches.**

Once surface dust is removed as described above, with these condenser lenses it should be possible to use ordinary soft absorbent household tissues to wipe away any oil or

moisture. However, when cleaning oil from oil immersion objective lenses you must only use only special purpose lens cloth on the objective lens surface.

When using oil-immersion objectives only use synthetic immersion oil that is designed for use with microscope objectives because other types of oil may damage the lens surface or cements used in fixing the lenses in place. Do not let oil seep into the spring mechanism of the objective (so keep an oiled objective facing downwards until you have wiped the oil off it). Wipe oil off an oiled objective immediately after observations have ceased using a special purpose lens cloth / lens paper prior to storing the objective in its protective case. Do not use any kind of oil or other immersion medium with lenses that are not specifically designed for immersion use. For more detail see the 'OptArc x40 dry and x100 oil Objectives, User Guide' which is available as a free PDF download from the 'Support' page of the optarc.co.uk website.

Disposal and Recycling

The optics are made of glass.

The metal fixings are made of steel (mostly stainless steel but some elements may be galvanised steel).

The 3D printed plastic parts are made with poly-lactic acid (PLA) plastic. The following advice is current as of 2021. Consult your local authorities for the latest situation.

Recycling of PLA Plastic in the UK

Most councils in the UK do not accept PLA plastic in green or food waste.

PLA can be recycled but only by a very few specialist facilities. Most councils in the UK will not accept PLA plastic in their recycle bin waste.

PLA should therefore be disposed of in general household waste or sent to a specific facility that will accept it for recycling. Those with the ability to do so may also grind used PLA and reform it into usable 3D printer filament.

Recycling of PLA Plastic outside the UK

Please consult with your local authorities for recycling advice.

Electronics

The PUMA Abbe condenser upgrade kit has no electronic components.

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