

## Defects in Used Microscope Objectives

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### Summary

Amateur microscopists can spend considerable sums purchasing used (second-hand) microscope objectives. A number of defects can develop in objectives and other microscope optics, caused either through poor handling and storage conditions, or through conditions of use. As many used objectives will originally have been purchased and used in professional laboratories, they may have been subjected to considerable use and this is now reflected in high rates of defects. This article aims to provide both sellers and buyers of used microscope objectives with an awareness of the types of defects that may be present, their appearance and the inspection methods that can be used to detect issues with objectives.

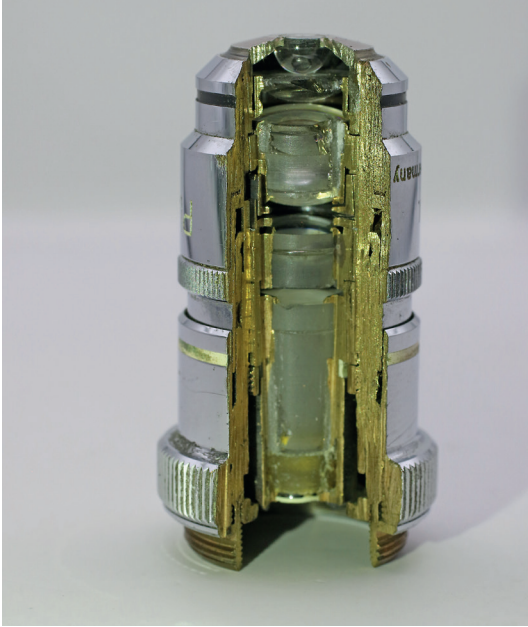
### Introduction

Much has been written about the tests that can be performed to assess the optical quality (resolution and freedom from aberrations) of microscope objectives. For example Spitta [1] devotes over 50 pages to this topic (despite being written over 100 years ago, this remains one of the best descriptions of the subject) whilst the subject is covered more recently in the books by Hartley [2] and Sanderson [3]. Tests that can be performed include the use of apertometers of various designs

to verify the numerical aperture of the objective [4], the Abbe Test Plate and Star Test for spherical aberration [2], Abbe's test for aplanatism [5] and Carpenter's Test Slide for chromatic correction [6]. An application of the Schlieren Test to microscope objectives has also very recently been published [7]. Test slides have been widely used since the early 19<sup>th</sup> Century to test resolution, including the use of finely ruled lines and gratings [8] together with various biological subjects including diatoms, insect scales and other parts, and hairs. An excellent review of test objects was provided in this Journal by Bradbury [5].

However, all of these tests relate to the optical quality of the objective based on its design and construction from new; they do not specifically test the lens for defects and damage that may have arisen during use or storage. Very little appears to have been published on this subject (a small section on delamination and fungal contamination is provided by Sanderson [3]). This is perhaps surprising when many if not most amateur microscopists will purchase their lenses second-hand and therefore pre-used. At the time of writing (December 2024) over 4,000 microscope objectives are listed for sale, with prices ranging from £8 to over £3,500.

Unfortunately, sellers cannot be relied upon to fully examine the lenses they have for sale, and to fully describe any defects or damage that may be present.



**Fig. 1. Cut-through of a Zeiss x100 PlanApo objective of 1970's vintage showing the complex construction of lenses cemented into different groupings. Defects can be present in any optical component but frequently occur at the interface between components.**

It is therefore recommended that buyers fully examine objectives, either prior to purchase where this is possible (e.g. tabletop sales meetings) or upon receipt (e.g. internet purchases) to ensure that the condition is acceptable for the intended use and commensurate with the price being asked. Even lenses from 'reputable' vendors should be carefully inspected; the author remembers some years ago purchasing an 'ex-demo' Leica x1.6 HCX Plan Fluotar objective direct from Leica which was found to have a large scratch across the rear lens (it was promptly replaced with a brand new objective!).

Microscope objectives of high correction (e.g. Plan Apochromats)

are complex with multiple optical components of different glasses, often cemented together in groupings (Fig. 1). Defects can occur not just at the easily inspected lower and back lens surfaces but at any layer within the optical groupings. Careful inspection is therefore required to detect all possible defects, and this article aims to help microscope users with those inspection techniques.

### **Defect Rates in Used Objectives**

A survey was conducted on 100 used transmitted light microscope objectives ranging in age from approximately 1920 to 1980; over 80% dated from the 1960's to 1970's, the era of microscopes that many amateurs now use. The lenses were derived either directly from professional laboratories (who were in the process of modernisation) or from amateur microscopists (these too were generally considered to have been used in professional laboratories prior to amateur use). 15 manufacturers were represented and lenses of all common designations were included: achromats, fluorite and apochromatic objectives, some with Plan designation. Each lens was examined carefully using hand lenses and defects categorised as described within this article.

The defect rate in this survey was surprisingly high, with visible defects in 46% of the objectives. Several lenses showed more than one type of defect. The most common issues (19%) were loss of clarity in the glass, with delamination

in 13%. Most manufacturers were represented by an insufficient number of objectives to draw conclusions regarding the defect rates between different makers; only E. Leitz, Olympus and Zeiss Oberkochen were adequately represented in this respect. Defect rates in Zeiss (37%) and Leitz (33%) lenses compare poorly with Olympus (6%) although this may be due to factors such as the level of use the lenses had been subjected to and the generally more complex correction of the Zeiss and Leitz lenses available for this survey. In general, the more complex the lens design, the higher the risk of optical defects which is not surprising considering the increased number of optical components in highly corrected objectives. What the survey demonstrates is the high rate of defects in used microscope objectives and the need for careful inspection, especially where lenses with more complex correction (and therefore more expensive) are being purchased.

### **Inspection Techniques**

Many defects in objectives may not be apparent when actually using the lens on a microscope to view a slide. The human brain compensates for imperfections in the image presented on the retina, but the camera is far less tolerant and objective defects can impact the quality of photomicrographs. It is therefore highly recommended that used objectives are inspected visually for problems prior to use on the microscope.

Visual inspection using hand

lenses (herein referred to as 'loupes' to avoid confusion with objective 'lenses') is the easiest technique and can be performed quickly at a sales meeting, where use on a microscope may be more difficult. Loupes with a range of magnifications are required. Higher magnification loupes make detection of defects easier but have a shorter focal distance and as such they often cannot be made to focus on the back of the rear lens element or 'through' the lens combinations. This is particularly an issue with higher magnification objectives and here a loupe of lower magnification must be used. The author employs three loupes, with magnifications of x3, x5 and x8, all of achromatic correction. Inspection of an objective commences with using the x8 to carefully inspect the tip of the objective and front lens. Holding the loupe at an angle to the front lens should reveal any physical damage such as scratches or chips, as well as dried immersion oil. It may help to move the objective during inspection to achieve different lighting conditions (Fig. 2). The angle of the objective is then



**Fig. 2. Inspection of the front lens and tip of an objective using a hand-held loupe of x8 magnification.**

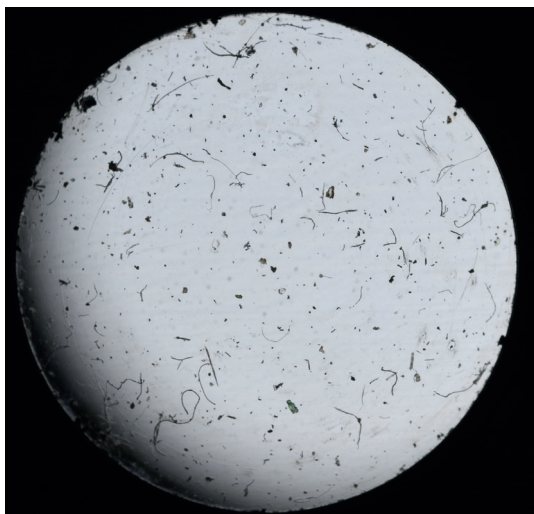
changed to be in line with the loupe and the objective pointed towards a bright, light surface (e.g. the ceiling or wall) and observed 'through the lens' again from the front lens. Delamination issues at the front lens element can now be detected.

Once the front of the objective has been checked, inspection commences from the rear of the objective. Here different magnification loupes must be tried, the aim being to use the highest magnification loupe that will focus on the rear lens element when held slightly above the top of the objective barrel. This then allows the loupe to be brought closer, permitting focus at the internal (lower) lens combinations within the objective. The objective should initially be pointed towards a plain brightly illuminated surface such as the ceiling or a sheet of white paper and inspected for defects. Movement of the objective to point at different surfaces (especially a boundary between light and dark surfaces), and rotation of the objective barrel whilst observing with the loupe will help. Finally, the objective should be pointed at a brightly lit subject some several feet or more away and inspected from the rear to ensure that a bright, clear and in focus image is formed. The objective should then be checked for any mechanical functions such as smooth rotation of a correction collar or movement and return of the spring tip of high power lenses when the tip is depressed by hand.

Where a stereomicroscope is available, this can also be used to perform visual inspection of the objective lenses.

An incident light illuminator is needed to inspect the tip of the objective and front lens. A fibre optic lamp or flexible LED is more useful than a fixed built-in illuminator as the angle of the lighting can easily be changed to facilitate the inspection. Transmitted light is required for 'through the lens' inspections as the various layers of optical components in the objective are inspected by focussing down through the lenses. The only issue with using a stereomicroscope is how to support the objective in a vertical position for inspection, without risking the front of the lens being damaged through contact with the microscope stage. For a quick inspection a finger hold can be used but a more rigid holder allows the objective to be held stationary for detailed inspection. For photography of internal lens defects the author prefers to use a Canon MP-E 65mm macro lens on an optical rail; this provides magnifications variable up to x5 with the optical rail permitting easy adjustment of focus.

Finally, some authors suggest fitting the objective onto a microscope and observing the internal lenses using a phase telescope in place of the eyepiece. The phase telescope can indeed be made to focus 'down' through the various lenses of the objective but in the author's experience 'defects' can often be seen that are in reality magnified reflection of structures within the eye and nothing to do with the objective!



**Fig. 3.** Leitz No. 3 brass objective showing particulate contamination ('dirt') on the upper lens surface. This can usually be removed by careful cleaning.

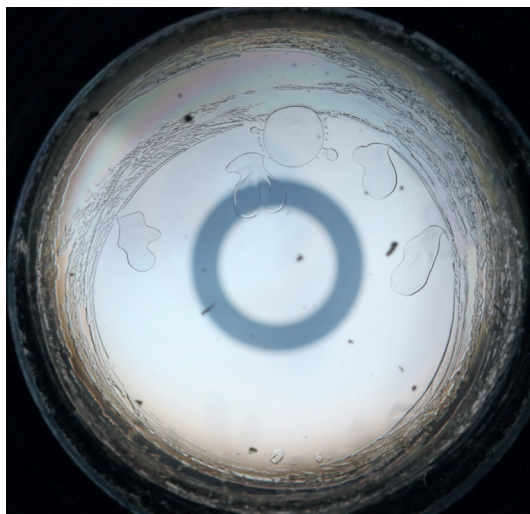
## Typical Defects

### 1. Dirt

Microscope objectives are often encountered that are dirty, typically with particulate contamination on the upper surface of the rear lens (Fig. 3) but also with dirt or dried immersion oil on the front lens. Being present only on the exposed surfaces (hopefully!), dirt can usually be removed by judicious cleaning.

### 2. Delamination

Delamination is probably the most widely known (and discussed) defect in microscope objectives. It occurs when the cement used to hold lens components together degrades, usually from the periphery of the lens, and subsequently progresses inwards. Delamination manifests as either concentric rings (Fig. 4) or as dendritic or flower-like growths

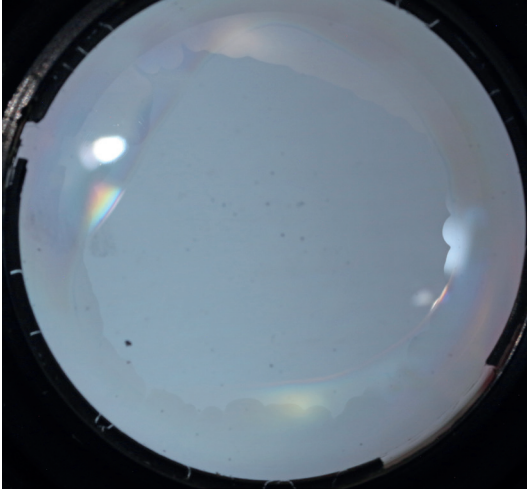


**Fig. 4.** Lomo x70 apochromatic phase contrast water immersion objective showing the classical concentric rings of delamination.

arising from the edge (Fig. 5). The marks may be colourless or grey, or show 'Newton's rings' interference colours (Figs. 6 & 7). Objectives require careful examination for delamination issues as these can be present in 'internal' layers of the body of the objective. Sanderson [9] states that delamination is caused either by optical components



**Fig. 5.** Dendritic or 'flower' pattern delamination in the front element of a Baker x2.5 objective.

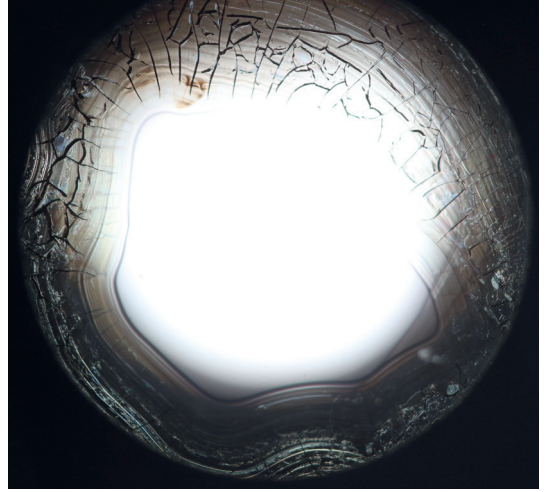


**Fig. 6. Grey delamination occurring around the periphery of the lens in a Zeiss x4 Plan Achromat. Careful inspection against different background lighting conditions can be required to detect this diffuse delamination.**

being exposed to excessive heat from the illumination source (e.g. halogen lamps) or from prolonged exposure to fluctuating room temperatures during storage. Delamination is particularly associated with Zeiss Oberkochen objectives and this is borne out by the survey performed here whereby 20% of Oberkochen lenses were affected. Objectives from other manufacturers are of course also prone to delamination to varying degrees.

### *3. Loss of Clarity*

Lens components can exhibit a loss of clarity due to chemical changes in the glass or the lens cement, and in extreme cases this can render the lens totally opaque. This was particularly associated with the first Zeiss apochromats introduced in 1886 (Figs. 8 & 9), but can occur in more recent objectives. The

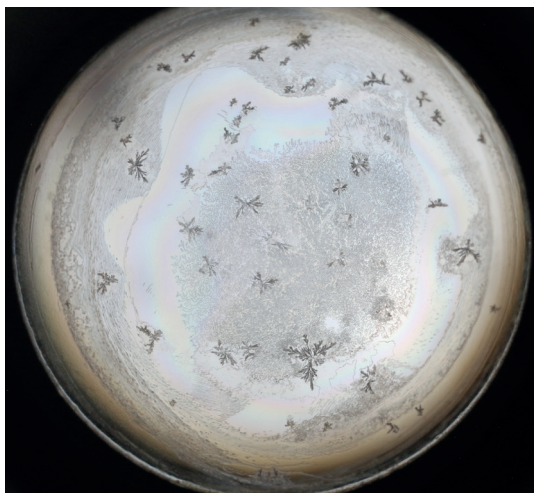


**Fig. 7. An extreme case of lens cement failure and delamination in a Leitz Pv (phase) Achromatic x90 oil immersion objective.**

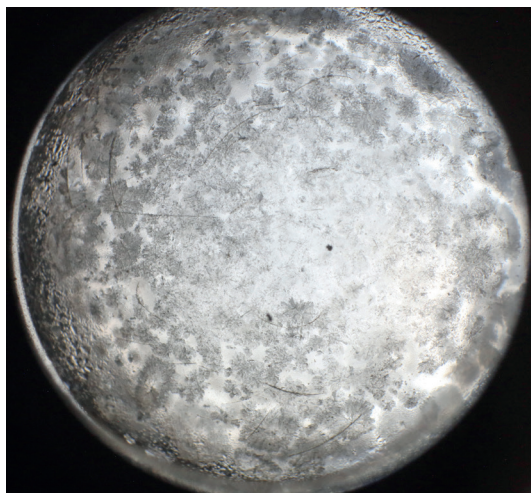
problem was evident by 1890 when Zeiss offered free replacements using different glass components. Clarity issues are easily detected during inspection, independent of the 'layer' of the lens in which the problem occurs.

### *4. Physical Damage*

Objectives can become damaged through poor handling during use, for example from focusing down too far so that the tip of the objective makes contact with the slide, from placing the objective when removed from the microscope 'lens down' onto a hard surface, or by dropping the lens. Poor handling can result in scratches to the front lens surface, chipping of glass or loosening of lenses within the objective barrel (e.g. by dropping). Inappropriate cleaning can also result in scratches to the upper surface of the back lens. Modern infinity



**Fig. 8. Decomposition of glass within an early Zeiss 4mm Apochromat.**



**Fig. 9. A second example of the degree of breakdown in the early Zeiss Apochromats.**

tubelength objectives may be more prone to ‘drop’ damage in this respect as they are often constructed without an upper flange (Fig. 10), making the objective more difficult to grip when fitting it into the microscope nosepiece.

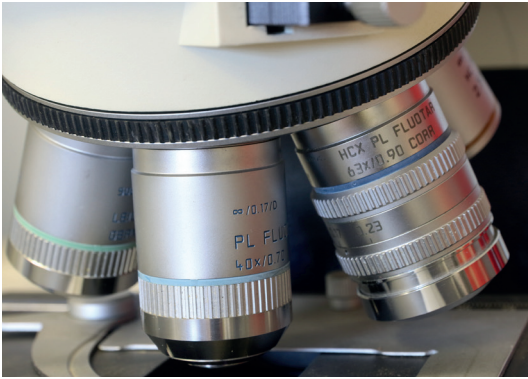
##### *5. Fungus and Other Contaminants*

Fungal hyphae can sometimes be seen in objectives (and other microscope components such as binocular prisms). This is more likely to occur where the instrument has been used or stored in an environment of high humidity (Fig. 11). The problem is often stated to be more of an issue with microscopes used in tropical countries, but the author well-remembers the high incidence of fungal contamination in microscopes used by an institution in the English Lake District where annual rainfall is similar to that of tropical rainforests. Fungal hyphae can be removed by cleaning where growth is on the upper surface of the back lens, but can be impossible to remove where

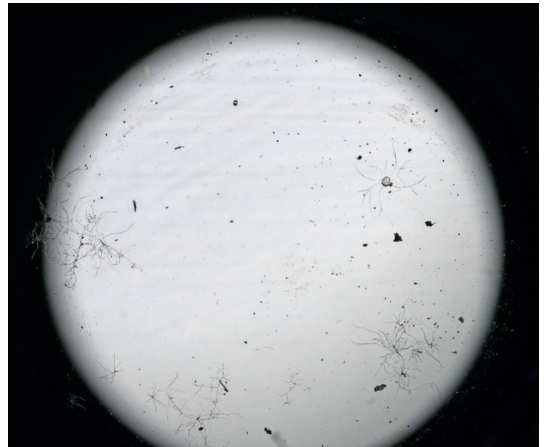
partial separation of lens components has enabled hyphae to penetrate between lenses. Other contaminants such as mites (Fig. 12) can also sometimes be seen but are generally easily removed with careful cleaning.

##### *6. Mechanical Defects.*

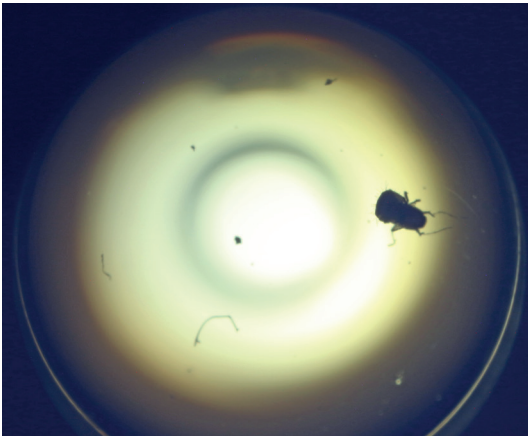
As well as optical defects, objectives can have mechanical problems such as loose optical components (detectable by gently shaking the objective and listening for any ‘rattling’ noise), stuck spring-loaded front lenses, or stuck coverslip correction collars (where these are fitted). Sometimes stuck components can be encouraged to work again by gently warming (either close to a domestic heating boiler or by careful use of a hair dryer). The use of solvents to try and loosen stuck grease is not recommended due to the risk of penetration into the optical components of the objective.



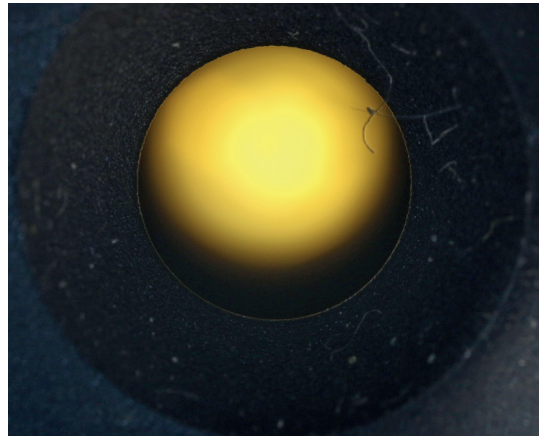
**Fig. 10.** Modern infinity tubelength objective, here a Leica Plan Fluorite x 63 with correction collar. Many lenses such as this no longer have a flange for the fingers to grip when screwing the objective into the nosepiece. This allows the manufacturer to fit more objective positions into the nosepiece (six and seven places now being commonplace) but does make the objective easier to drop onto the stage if the microscopist is not careful when changing lenses on the nosepiece.



**Fig. 11.** Fungal hyphae within a generic (unnamed) MF5 objective. This lens had been used at an institution in the Lake District and had no doubt been exposed to periodic levels of high humidity.



**Fig. 12.** An arthropod present on the back lens of an objective. Defects such as this are usually easily removed by cleaning although one wonders at the storage conditions that allowed the animal to enter the objective.



**Fig. 13.** Wild x100 oil immersion objective showing penetration of oil into the lens components. This may result from the use of inappropriate solvents to wipe clean the front lens after use, causing softening of the lens cement.

### 7. Oil penetration

Penetration of immersion oil into optical components is occasionally seen due to incomplete sealing of the front lens element into the objective barrel (Fig. 13). This may arise due to the incorrect use of organic solvents to remove immersion oil from the front lens after use, resulting in softening of the lens cement. Water immersion lenses are also prone to penetration of the immersion fluid into the objective, and this can allow fungal contamination to develop between optical components.

### Conclusions

All optics of the microscope are at risk of damage and decay during their lifespan. Physical damage can occur to the field lens, the components of the condenser, eyepieces, and viewing head prisms. However, it is the objective that has the greatest complexity of lens components and is also possibly the most at risk of damage through incorrect handling and use. Objective lenses are also the most numerous optical components in most microscope systems. Amateur users typically purchase their objectives pre-used, and many users have multiple objectives within their collections. The rate of defects in used objectives reported in this article confirms the need for careful visual inspection. Other microscope optics can of course also be inspected for defects using the techniques described.

Objectives and other optics with defects may not be beyond use. Paul James clearly illustrated acceptable image quality from a severely scratched

Leitz objective [10] and Dave Walker showed good quality images with delaminated Zeiss objectives [11]. Repair of some defects is possible. Dirt or other particulate matter and fungus on the accessible lenses of the objective may be removed by careful cleaning, as can dried immersion fluid on the front lens. However scratches, delamination and opaqueness issues in objectives are unlikely to be repairable. Some authors have proposed that delamination can be repaired by either heating the objective to the point where the lens cement melts and reseals the air gaps, or by dissolving the cement, disassembling the lenses and reassembly with new cement. Either approach is highly likely to result in a completely ruined objective, but may be feasible with delaminated condensers and eyepieces.

Do defective objectives become worse over time? This question has often been asked but only anecdotal opinions are available; no long-term studies of the same objective over time appear to have been set up or reported. Some defects such as surface scratches or particulate contamination clearly will not worsen unless the same poor handling or storage conditions are repeated. Fungal growth on lenses may continue for as long as high humidity conditions prevail, and the obvious solution here is to store objectives at low to normal room relative humidities. Where this cannot be achieved e.g. in tropical climates, the use of moisture absorbents and sealed storage containers is recommended. Progression of opaqueness and

delamination issues is less obvious. However, if the main cause is long-term heating from high intensity illumination systems in professional laboratories (especially in fluorescence applications with mercury vapour lamps), these conditions are unlikely to be repeated in amateur ownership. Where there is concern about heat from the light source, a heat absorbing filter placed on the field lens would be a sensible precaution, as would stable room temperature conditions in storage.

Finally, although the scope of this article does not extend to cleaning of microscope optics, any reader requiring guidance on this subject is referred to an in-depth review of cleaning methods by Colin Duke [12].

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