Correcting lenses for underwater use

By Peter Scoones and Peter Rowlands

One of the main advantages of using a land camera in an underwater housing is the wide choice of lenses you can use but this advantage can become a problem as the lenses are designed for use on land rather than underwater. One solution is a dome port which helps to eliminate most of the optical problems but the dome must be considered as one element of a two element lens system in order to get the full focusing range of your lens.

This is something most housing manufacturers do not emphasise enough and it can lead to an underwater photographer not getting the best performance from the lens/ port combination.

Assuming that we want to get the best quality underwater photographs it is neccessary to keep the water in between you and the subject to a minimum. It is the water which produces colour loss, definition reduction and overall clarity/contrast loss in our photographs so by keeping it to a minimum we can maximise the quality of the resulting underwater image.

Wide angle lenses

The most effective way to keep the water distance to a minimum is to use a wide angle lens but if they are used behind a flat port there are

certain optical problems which affect the quality of the image. These are caused by refraction at the air water interface because water is denser than air. For simplicity purposes we assume that the thickness of the port is small relative to the lens/subject distance so the refractive effect of the port material (glass, plexiglasss, perspex) is ignored.

Flat ports

When using a lens behind a flat port there are a number of disadvantages. The first is a reduction in lens angle. There is an effective reduction in angle of approximately 1/3rd making a 28mm become a 35mm, 20mm become a 24mm and so on.

The second problem is a loss of edge definition. This is known as 'chromatic abberation' (most severe at the edges) caused by distortion to the red and blue images which give the appearance of colour fringes and overall image softness towards the edge of the frame (not to be confused with 'out of focus').

The third problem is the loss of geometric quality. Pincushion distortion will render straight lines as curved. This is not neccessarily a major problem as there are very few straight lines underwater.

The fourth problem is a reduction in focusing range resulting in the lens not being able to focus as close as it would on land. This may not be a major problem with wider angle lenses which have a greater depth of field but it is best to retain the full land performance of your lens underwater.

Dome ports

A simple way of compensating for the effects of a flat port are to use a hemispherical dome as the port. If correctly set up, a dome system can greatly improve the photographic performance.

A dome port can restore lens angle, minimise chromatic abberation and restore (and even improve) focus

range and depth of field, as well as correcting pincushion distortion.

Since the dome, when used in contact with water, becomes a negative power lens, the camera lens will not perform the same as on land and a positive supplementary lens is needed to compensate for the negative effect of the dome.

Supplementary lenses

The power of this supplementary lens will depend on the curvature of the dome and, to a lesser extent, it's position in relation to the land lens.

The dome correction port is unfortunately not perfect and there are two main defects.

The first is curvature of field. This has the effect of rendering the subject in the centre of the picture being in focus while those at the edge are out of focus. This is most severe with wide angle lenses behind small diameter domes and it may be so severe that the edges can not be brought into focus, whatever aperture is used.

Using a positive supplementary lens of the correct power attached to the front of the land lens

will reduce this defect but will not entirely flatten the curvature of field. Using a small aperture will reduce the out of focus effect of curvature by increasing depth of field.

Reflections

The second defect is one of reflections. Internal reflections on the inside of the dome often take the form of an inverted image of the surface or bright object (eg the sun) outside the picture area. Great care should be taken to provide an efficient lenshood and masking the unused parts of the dome surface will help. Reflecting surfaces inside the dome should also be blacked out i.e. lens markings and any chromed camera/lens parts.

For optimum results the dome/supplementary lens/camera lens positioning is important. The housing design may limit this possibility but let's look at the combination in a perfect world.

Assuming that the wall thickness of the dome is substantially the same over its entire surface, the internal diameter of the dome needs to be determined. From that information the power of the positive supplementary lens can be calculated.

The formula is as follows: f = 2d or 4r where f=focal length of the dome, d=diameter and r=radius. So for a dome with a 20cm diameter, it's focal length will be 2x20=f40cm (or 400mm) and it will have a negative power. To compensate for that negative power a positive supplementary lens of f40cm is needed.

These supplementary (close up) lenses are often expressed in diopters. To find the power in diopters, divide the focal length in cms into 100. i.e a lens f40cms will be 100/40=2.5 dioptres.

Fortunately most quality housing manufacturers let you know what strength of dioptre is needed for their domes and all you have to do is purchase this and screw it onto the front of your land lens.

Lens positioning

The water/dome/supplementary lens will be a-focal (at optimum) when the supplementary lens is positioned at the centre of curvature of the dome (in strict theory this is not absolutely correct but is accurate enough in practice). It is important that the optical axis of the dome and the supplementary are accurately lined up and ideally should be fixed with the camera's lens located as close as possible to the supplementary.

In practice, when wide angle lenses are used with small focus travel the supplentary lens can be fitted to the filter threads of the camera lens and in this case it should be arranged so that the supplementary lens is in the correct position in relation to the dome when the lens is set at infinity.

In order to retain the full focusing range of your lens underwater, the lens must be able to focus on the virtual image of infinity when the land lens is set to infinity (this is an important point which most manufacturers don't point out). The optical effect of a dome underwater is to move the image of infinity to a virtual position 4x the radius of the dome from the supplementary dioptre lens. In practice this is much closer than infinity would be on land so a dioptre lens needs to be fitted to the front of the camera lens to counteract for the power of the dome.Some manufacturers say that as long as your lens can focus on the virtual image of infinity (i.e. with the land lens focused at minimum focus or thereabouts) then all will be well. Strictly speaking this is not true. It means you will be able to focus on infinity underwater but how much closer you can focus will depend on the close focusing capabilities of your lens. Check this out with the manufacturer/ supplier to make sure.

As we have seen with fixed focal length lenses behind domes, the dioptre/dome positioning must remain fixed in relation to eachother and as long as the zoom lens being used is not the 'push pull' design (which would move back and forward too much), then a zoom lens can be used behind a dome port.

Reality

All of the above is theoretically fact but in reality it may not always be possible to obtain theoretical perfection. For example, the dome you are using may not be a perfect hemisphere or the lens position in relation to the dome may not be correct.

In these cases the following alterations will take place.

If the dome section is not a full hemisphere with the lens being too far into the hemisphere of the dome (because to provide a full hemisphere would not be practical within the housing design) the resulting position of the lens will reduce its angle of coverage and you will need a slightly stronger dioptre lens to focus on virtual infinity.

This is a typical situation with most modern manufacturers as they try to produce more and more compact designs and only use a smaller section of the dome rather than the full hemisphere. However these manufacturers usually provide a full hemisphere dome which corrects the limitation at a greater cost in terms of both size and finance.

If the dome is hemispherical but the land lens is set back from the centre this will result in an increase in angle and introduction of poorer geometric correction as well the need for a slightly less powerful dioptre lens. However, this situation is unlikely to occur in most housings designs.

So there you have it! For some reason the theories of domes have never been fully described so we hope this has helped.

If, after you read this, you become paranoid about dome curvature/lens position relationships, don't get too concerned as the practical limitations of housing design will almost invariably result in some form of compromise between perfect positioning and the practical size of the end product and lastly, a slightly wrong dome curvature/lens position is nearly always far more acceptable than a flat port!

Peter Scoones

pjscoones@aol.com

Peter has been designing, building and using housings for over 45 years in both the amateur and commercial world. He has worked as a BBC cameraman for over 20 years on series such as ReefWatch, SeaTrek and more recently The Blue Planet. He has developed new cameras such as the "Polecam" to get new shots underwater and has just completed the production of two High definition video housings for the BBC which are being used to film their latest underwater series.

Peter Rowlands

peter@uwpmag.com

Peter Rowlands is Peter Rowlands