DOME PORTS Why they Work (or don't)!

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Have you ever wondered why it is considered best to use a dome port with a wide-angle lens? After all, flat ports are much cheaper, and can be bought for many lenses, so why bother with an expensive and sometimes vulnerable dome port? Well, the maximum theoretical angle of view that it is possible using a flat port is 96 degrees, and in practice it is much less (and no, I'm not going into the complex optical theory of why - see details of the book at the end if you must know). In fact, the accepted cut-off focal length of the lens usable with a flat port is reckoned to be 35mm (on the 35mm format).

Any shorter focal length generally requires a dome port, and to get the best out of a dome port, it is essential to choose the right one and use it correctly. So for those of you with technical longings here follows the reasoning. For everyone else, there's the information on the effects of using ports that correctly match the lens in use, or otherwise, further on.

The theory goes like this. Firstly, for a dome port to work properly it has to be positioned correctly in relation to the camera lens. Without going into the optical theory, the bottom line is that the position of the 'entrance pupil' (this is the position of the lens aperture stop as viewed from the object space - roughly the image of the lens diaphragm when viewed from in front of the lens) of the camera lens needs to be coincident with the centre of curvature of the dome being used. In other words the 'entrance pupil' should be in the centre of the sphere of which the dome is a part. Now obviously, the manufacturer of a lens knows the position of the 'entrance pupil', but such data is not always all that easily obtained. (Some manufacturers, such as Zeiss, publish full lens optical information on the Web try www.zeiss.de). But not all manufacturers do.

So we have a seemingly straightforward enough piece of optical information, but one which is difficult to use in practice simply due to problems of obtaining such data. If we assume that such information is available, or better still, has been obtained by a reputable port manufacturer (like Subal), then buying a port for a specific lens should mean correct alignment has been already sorted out. So what other optical reasons are there for buying a correctly matched port?

Wreck: This shot is crisp throughout as f/11 was used at 17mm on the Nikon 17~35 AFS Zoom, again behind Subal's fisheye port. (The "Carnatic", Red Sea)

Well a dome port acts as a concave lens. Underwater, this will produce a 'virtual' image of a subject. (A 'virtual' image is one which has the optical property of appearing to be where it is not! It is possible to calculate where it seems to be, but as it doesn't actually exist there; it is virtual!).

Optical theory can be used to show that subjects at infinity produce 'virtual' images at a distance of 3r from the surface of the dome (where r is the radius of the dome). This means that the 'virtual' image of an object at infinity lies on a spherical surface of a diameter equal to 4r. As this resulting 'virtual' image is not planar (it isn't flat!), accordingly, there are problems when trying to focus it onto a flat film plane, as only flat subjects can be imaged onto a flat surface. To make matters worse we tend to focus on the centre of this image (where it is furthest from the film) so the images corners (nearest to the film) are often closer than depth of field allows to be maintained in focus. The bottom line is that the corners of a wide-angle underwater photograph are all too often very out of focus!!!

There are solutions, and one is rather elegant. The reduction in the apparent subject distance caused by the negative lens property of the dome (infinity is now at 4r) may be cancelled out by use of the positive supplementary (close-up) lens. The calculation of the strength of the supplementary lens needed is as follows:

Dioptric power of the supplementary lens = 1000/4r where r is the radius of the dome. (The focal length of the lens in use does not enter into the calculation).

So for a dome of say 160mm in diameter (this information can also be

Reef: The top of this picture contains little detail so defocusing is not problematic, but in the bottom fine detail is affected and is not at all sharp. Taken with Nikons 17-35 AFS Zoom at 17mm and at f/8 using Subal's fisheye port.
(Haska Island, Outer Hebrides).

tricky to find out), the supplementary lens to be used should be 1000/4 x 80 = +3.125 dioptres. In practice a +4 dioptre lens is often used as infinity is not available underwater (!) and a +4 will usually work very effectively, although it may be worth experimenting with +3 as this may give better distance focus.

Optical correction produced by a supplementary lens may also help by introducing reversed 'field curvature' to somewhat negate the spherical curvature produced by the dome. (It can induce curvature of the 'virtual' image in the opposite direction to the curvature produced by the dome port). This happens 'best' or 'most' if a 'poor' supplementary lens is used (one with a flat rear and curved front as opposed to a 'better' corrected lens with both surfaces curved). The best (apochromat) supplementary lenses probably are 'optically' better but don't induce the reversed curvature which is so useful.

As the curved image is not entirely flattened by a supplementary positive lens, it is still preferable to use lenses behind their dome ports at smallish apertures (often f/8 or f/11 as a minimum), in order to try and place the 'virtual' image within the depth of field. If doing this, it may be worth trying to focus slightly in front of the image being photographed as this is the farthest away part of the 'virtual' image, and depth of field extends in front and behind the area being focussed on.

The practical outcome of all this is as follows. In practice the situation shifts slightly due to the physical problems of housing some lenses

Lenses from 35mm upwards can be used with flat ports as the aberrations, distortions and reflections induced towards the edges of the image are no longer too problematic with lenses of this focal length and higher. (Note though that the angle of view of lenses used behind a flat port is reduced by about 1/3). Such lenses can be used behind dome ports though, but curvature of the image will be a problem at wider apertures.

Lenses from 20-35mm can be used behind relatively compact dome ports (with supplementary lenses) and some (say 24 and 28mm) can utilise the same port as their entrance pupils are similar in relation to the physical characteristics of the port (the difference is insignificant). 20mm lenses are compact enough to enable a supplementary lens to be easily fitted and good correction can be achieved at modest apertures of as low as f/5.6 in some circumstances. Problems occur beyond about 20mm (this isn't set in stone!), when larger supplementary lenses, and more significant image curvature mean that progressively smaller apertures are required to sharpen up ever more defocused corners.

Zooms are a real problem. Traditionally, many have spanned the crossover from dome to flat port, and many have not focused very close meaning that they were of limited use behind dome ports in very clear water. A further problem is that of a shift in the position of the entrance pupil as the lens was zoomed, meaning that best correction could only exist at one focal length.

Today things are changing, with wide-angle zooms working through internal zooming and focusing as well as being able to focus quite close too. Large diameter supplementary lenses will fit on some, such as Nikon's 17~35 AFS lens, which results in very acceptable correction is achieved throughout the zoom range, and a very versatile if somewhat bulky set-up. Interestingly Subal state that their fisheye dome port is 160mm in diameter. They recommend an extension ring to be fitted between it and the housing body (to place the dome in the best position), for the 17-35 and a supplementary lens of +3 dioptres (I use a +4 with excellent results). Nevertheless, this zoom does not quite match a fixed focal length lens in terms of absolute quality.

Physical requirements inevitably mean that most ultrawide-angle lenses tend to need large diameter dome ports. Ultrawide-angle lenses have their own problems, as often a supplementary lens cannot be attached, as this is physically impossible. Many produce images, which exhibit badly out-of-focus corners (plenty of examples exist in bookso and magazines), and only the use of very small apertures really helps at all.

The most successful ultrawides commonly used underwater are fisheye lenses. Fisheye lenses are the exception as their dramatic depth of field can enable sharpness throughout the picture. They are extensively used but care has to be taken if an obviously straight line appears in the picture, as it is usually imaged as a curve by the fisheye lens to some degree, unless it passes through thecentre of the picture.

For anyone wishing to read more about underwater lens theory, may I refer them to Sidney F Ray's superb book "Scientific Photography and Applied Imaging" (Focal Press ISBN 0 240 51323 1) where chapter 30 will prove fascinating!

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