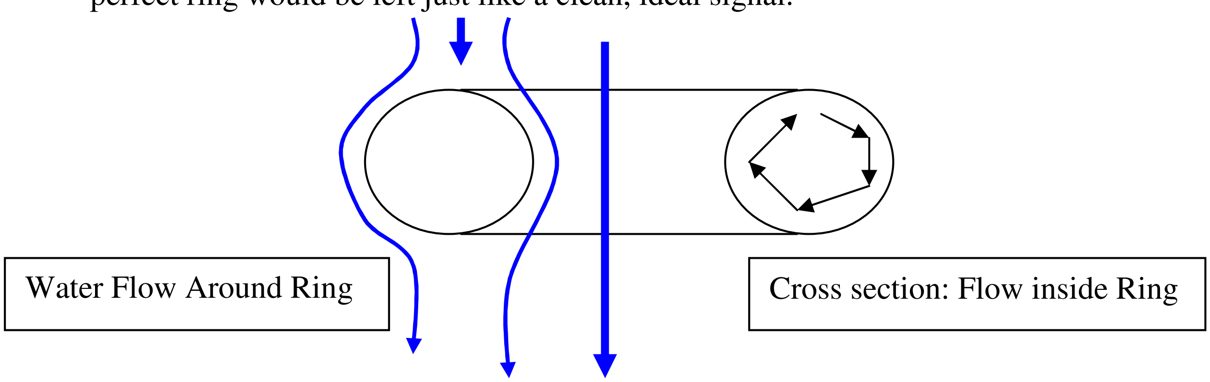
The intent of this image is to capture a fluid flow in the form of an air ring rising from the depths of water much like the rings dolphins produce out of their blowholes. This bubble ring was produced by a SCUBA diver in a dimly lit shallow pool and photographed on its un-inhibited trip to the surface. The production of rings without excess tiny bubbles is nearly impossible with a traditional scuba system but all efforts were made to minimize the interaction of these outliers. They appear in the final image as backscatter, a very real obstacle in the underwater photographic realm.

Bubble rings are produced by forcing a rapidly moving short burst of a gas through a small, ideally contracting circular or oval orifice, in this case my lungs provided air with a rapid exhaling movement through my lips which were in plane with the surface of the pool. Lying on my back on the bottom of the pool at the Kensington Apartments, this placed the origin of the bubble at a depth of approximately nine feet. As the bubble rises its volume increases which results in the expansion of the rings diameter at astonishing rate. The rings thickness also increases to a point but then starts decreasing until reaching a roughly constant thickness at which point the reducing pressure results in only an increasing diameter to allow for the increased volume. The bubble is driven by an Archimedes force to the surface (ring volume*ring gas density*gravitational constant) and resisted by a drag force, which is proportional to the projected frontal area, which can be seen in this image. This drag force follows Stokes Law much like a small spherical bubble does however the surface area changes are based on both the thickness of the vortex ring, the diameter of the ring and these in turn are dependant on depth, liquid pressure, the rings gas pressure and gas density. Therefore a simple equation for the drag on a vortex ring in fluid is not possible and is beyond the scope of this report. Inside the air vortex ring the air is circulating revolving around its thickness. There does not appear to be any spin motion of the air as seen in the following cross section. I speculate that the Reynolds number for this interaction inside the ring (for the air flow only) is just inside the linear range and that the boundary layer flow of the water and air, while mostly in a linear direction has a Reynolds number just in the mixed flow range as seen in the slight deformations in the rings shape from a perfect ring. I base this on the fact that the ring shape is constantly changing just a little but like noise in an electronic reading if these small deformations were averaged out or removed a perfect ring would be left just like a clean, ideal signal.




The photographic technique used was relatively simple. A digital still camera placed in a waterproof housing with high optical glass port was held by the diver who produced the ring at the bottom of the pool and then used to capture the image. A specialty underwater strobe was used via hard cable sync. Adjustments on the digital file to maximize the effect of the image are slightly more complex. Using Apple's Aperture photo program, the exposure was artificially increased, as was the contrast, and brightness of the image. From there the luminosity level was increased slightly on all color channels making the shadows, mids, and highlights slightly more pronounced. The downside to these modifications is the pronounced increase in backscatter and other elements in the outliers of the photo. The result is a twilight-esque, almost outer space like mood.

A Canon DSLR 10D set to 100 ISO fixed with a Sigma 50 mm macro lens captured this image from inside a Subal C10 underwater housing with the FP75 flat port mounted to the bayonet. A Sea & Sea YS 120 strobe was cable synced and set at 1/2 power and placed on aluminum arm approximately 2 feet to the left and otherwise in plane with the port front provided the illumination for the image. The image was shot at f21.9 at 180$^{th}$ of a second. The ring at this point was at approximate depth of three feet and had a thickness of approximately 1.5" and a diameter of 32" Additional information is provided in the following table taken from the EXIF sidecar data.

This image is by far not my best work, lack of a disposable tripod, other swimmers in the pool, a VERY limited quantity of air available, and a flickering ceiling florescent light made this a very difficult shot to capture. Additionally the failure of my secondary fill strobe (a DTTL) prior to this shoot made these variations virtually impossible to accommodate for in real time. This image however does convey what blowing rings at a much greater depth (deeper then 100 feet salt water) looks like to a diver. The rings produced rarely travel on their own but generally have a slew of small, slower companions. Ocean conditions always provide an equivalent amount of backscatter from sediment, plankton and other suspended particles and this adds to the, albeit faked, realism of the image.

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| Image Date | 9/22/07 8:32 PM MST |
| Camera Model | Canon EOS 10D |
| Serial Number | 620312005 |
| Shutter Speed | 1/180th second |
| Aperture | f21.9 |
| Exposure Bias | 0ev |
| Focal Length | 50mm |
| ISO Speed Rating | ISO 100 |
| Aspect Ratio | 3:02 |
| Orientation | Landscape |
| Depth | 16-bit |
| Color Profile | Adobe RGB 1998 |