

## Glossary of terms for Macro Photography

<b>Achromatic lens</b>	A lens that brings at least two wavelengths (typically red and blue) into focus in the same plane, thereby limiting the effects of chromatic and spherical aberration
<b>Airy disk and Airy pattern</b>	Descriptions of the best focused spot of light that a perfect lens with a circular aperture can make, limited by the diffraction of light
<b>Angle of view (AOV)</b>	The angular extent of a given scene that is imaged by a camera
<b>Aperture control filter</b>	An adapter that fits on the rear of a reversed lens to manually control the aperture
<b>Astigmatism</b>	Light rays that propagate in two perpendicular planes have different foci
<b>Asymmetric lens</b>	A lens where the aperture appears to have different dimensions when viewed from the front and from the back
<b>Bellows</b>	A pleated light-tight extensible part in a camera between the film plane and the lens
<b>Circle of confusion (CoC)</b>	The optical spot caused by a cone of light rays from a lens not coming to a perfect focus when imaging a point source (also known as a disk of confusion)
<b>Close focus distance</b>	See <b>minimum focus distance</b>
<b>Close-up lens</b>	A single or multi-element lens that fits on the filter thread of a primary lens to increase magnification
<b>Close-up photography</b>	Images taken close to the subject typically with magnifications of ~0.1X to ~1X
<b>Coma or comatic aberration</b>	A lens aberration due to imperfections in a lens, or other components, that results in off-axis point sources appearing to have a tail (coma) similar to a comet
<b>Chromatic aberration (or colour/purple fringing)</b>	An optical effect when a lens is unable to bring all wavelengths of colour to the same focal plane, and/or when wavelengths of different colours are focused at different positions in the focal plane. It gives rise to "fringes" of color along boundaries that separate dark and bright parts of an image
<b>Crop factor</b>	The ratio of the dimensions of a camera's sensor compared to a reference format, usually the 35 mm film format (in which the diagonal of the image sensor is 43.3 mm)
<b>Depth-of-field (DOF)</b>	The distance between the nearest and farthest objects in a scene that appear acceptably sharp in an image
<b>Depth map method (DMap)</b>	A method use to reconstruct a series of images in focus stacking
<b>Diffraction</b>	The process by which a beam of light is spread out as a result of passing through a narrow aperture or across an edge, typically accompanied by interference between the wave forms produced
<b>Diffraction limited aperture</b>	The aperture where diffraction begins to visibly negatively affect the sharpness of the image at the pixel level
<b>Diopter</b>	A unit of measurement of the optical power of a lens or curved mirror, which is equal to the reciprocal of the focal length measured in meters
<b>Effective f-number</b>	The change in the f-number in macro lenses at higher magnifications
<b>Entrance pupil of lens</b>	The image of the aperture stop as seen from the object side of the lens. It defines the cone of light accepted by the optic
<b>Extension (distance)</b>	The distance that an extension tube or bellow moves the lens away from the sensor
<b>Extension tube (or ring)</b>	A tube with no optical elements that moves the lens further away from the image plane. An extension tube increases lens magnification by an amount equal to the extension distance divided by the lens focal length.
<b>Extreme macro photography</b>	Images taken with magnifications higher than 1X to ~15X
<b>Far distance</b>	The furthest distance from a camera that is in acceptable focus
<b>Field curvature</b>	Field curvature is due to the curved nature of the optical elements in a lens, which project the image in a curved manner, rather than flat, i.e., a flat object only appears sharp at certain parts of the frame, instead of being uniformly sharp across the frame.
<b>Focal length of lens</b>	The distance from the film plane (or sensor) to the lens' optical center, when focused at infinity, i.e., the distance over which initially collimated rays are brought to a focus.
<b>Focal plane</b>	The plane that is perpendicular to the axis of a lens or mirror that passes through the focal point.

<b>Focal length multiplier (FLM)</b>	See <b>crop factor</b>
<b>Focus banding</b>	Out-of-focus bands observed in a focus stacked image when the step size between frames is too small
<b>Focus stacking or blending</b>	A method to increase the <i>depth of field</i> by combining a series of images taken at either different focus settings or at a fixed focus and at different camera-to-subject distances, and then combining the resulting images with software
<b>Focusing rail</b>	Focusing rails move the camera smoothly in relation to the subject to allow precise camera-to-subject focusing or lateral positioning
<b>f-number or f-stop</b>	The ratio of the lens's focal length to the diameter of the entrance pupil
<b>Guide number for flash</b>	The product of the maximum flash-to-subject distance and the f-number of the lens that will correctly expose film/sensor with the specified ISO sensitivity.
<b>Halos</b>	Out-of-focus bands around the edges of features in a reconstructed stacked image, etc.
<b>Hyperfocal distance</b>	The closest distance at which a lens can be focused while keeping objects at distances from half of the hyperfocal distance to infinity acceptably sharp.
<b>Image circle</b>	The surface of the camera's sensor which is exposed by the optics in a uniform way without significant vignetting in the marginal areas
<b>Infinity objective</b>	An infinity objective is a microscope lens that forms a virtual image at infinity
<b>Light emitting diode (LED)</b>	A high intensity light source that can provide continuous or flashed illumination
<b>ISO sensitivity</b>	A standard specified by the International Organization for Standardization in ISO 12232:2006 to measure the camera's ability to capture light.
<b>Macro</b>	Images taken with a magnification of 1X (or full size) , i.e., the size of the object is reproduced at the same size on the <i>camera's sensor or film</i>
<b>Macro coupler</b>	An adapter used to couple a reversed lens to a primary lens
<b>Magnification</b>	The size of the image compared to the size of the subject
<b>Minimum focus distance</b>	The minimum distance that a lens will properly focus on the subject
<b>Near distance</b>	The closest distance from a camera that is in acceptable focus
<b>Nodal plane of lens or more correctly the entrance pupil</b>	The point at which the rays entering the lens converge (or the centre of perspective of the lens or the apparent pupil)
<b>Optic</b>	A lens or other optical component in an optical instrument
<b>Overlap</b>	The amount of duplication required between consecutive frames in an image stack or panoramic sequence to ensure a seamless reconstruction of the final image
<b>Parfocal lens</b>	A lens that maintains focus when its focal length changes
<b>Photomicroscopy</b>	images taken with a variety of microscopes at magnifications between ~10X and >1,000,000X
<b>Prime or fixed focal length lens</b>	A photographic lens whose focal length is fixed
<b>Primary lens</b>	The lens attached directly to the camera
<b>Pyramid method (PMax)</b>	A method use to reconstruct a series of images in focus stacking
<b>Refraction</b>	The change in the direction of propagation of a (light) wave due to a change in its transmission medium
<b>Reversing ring adapter</b>	An adapter that allows a primary lens to be attached to the camera in the reverse orientation, i.e., the front on the lens is attached to the camera body
<b>Reversed lens</b>	A primary lens that is attached to the camera in reversed orientation
<b>Ring light</b>	A flash or white LED lights that surrounds the lens to provide even illumination
<b>Sensor</b>	Electro-optical sensors are electronic detectors that convert light, or a change in light, into an electronic signal used in cameras and other devices
<b>Sensor pixel pitch</b>	The linear distance from the center of a pixel to the center of an adjacent pixel in the camera's digital sensor, usually measured in microns (millionths on a meter)
<b>Shortening of focal length</b>	The change in focal length in macro lenses with focus distance or in zoom lenses with focal length
<b>Spherical aberration</b>	An optical effect observed in a lens (or mirror) that occurs due to the increased refraction of light rays striking a lens near its edge compared to those striking nearer

	the centre.
<b>Stacked lenses</b>	A reversed lens attached to a primary lens with a macro coupler
<b>Stackshot™</b>	A commercial computer-controlled automatic macro focusing rail
<b>Step size for focus stacking</b>	The camera-to-subject distance step moved or the change in focus distance between images in a focus stack
<b>Substack slabbing</b>	A small section of a stack of images in a focus stack used to optimize the reconstruction of fine details
<b>Teleconverter</b>	A secondary lens which is mounted between the camera and a primary lens that act as a diverging lens to enlarge the central part of an image
<b>Vignetting</b>	The reduction of an image's brightness or saturation at the periphery of the image compared to the center.
<b>Tube (or telan) lens</b>	A simple primary lens used with an infinity objective
<b>Working distance</b>	The distance from the front of the lens to the subject
<b>Zoom lens</b>	A lens in which the focal length (and angle of view can be varied

### **Books by the author**

**Australia:** <http://www.blurb.com/books/4397105-australia>

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**Botswana:** <http://blur.by/1sV5tW6>

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Circle of confusion for particular cameras: [http://www.dofmaster.com/digital\\_coc.html](http://www.dofmaster.com/digital_coc.html)

Crop factors: <https://photographylife.com/sensor-crop-factors-and-equivalence>  
<https://photographylife.com/sensor-size-perspective-and-depth-of-field>

Details on Nikon Lenses: <http://www.naturfotograf.com/> then open lenses

Camera sensor parameters: <http://www.digicamdb.com/>

Astigmatism and field curvature: <http://toothwalker.org/optics/astigmatism.html>

Raynox close-up lenses: <http://www.raynox.co.jp/english/digital/egdigital.html>

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Lume Cube: <https://www.lumecube.com/>

Nikon R1 flash system: <http://www.nikonusa.com/en/nikon-products/product/flushes/r1-wireless-close-up-speedlight-system.html>

Introduction to flash: <http://strobist.blogspot.com/>

Topaz labs plug-ins: <https://www.topazlabs.com/>

### Camera Control:

Helicon Remote: <http://www.heliconsoft.com/heliconsoft-products/helicon-remote/>

Camranger: <http://camranger.com/macro-focusstacking/>

ControlMyNikon: <http://www.controlmynikon.com/>

digiCamcontrol: <http://digicamcontrol.com/>

Stackshot macro focusing rail: <https://www.cognisys-inc.com/products/stackshot/stackshot.php>

### Focus stacking software:

Helicon Focus: <http://www.heliconsoft.com/heliconsoft-products/helicon-focus/>

Zerene Stacker <http://zerenesystems.com/cms/stacker>

Photoshop DOF blending: <https://helpx.adobe.com/photoshop/using/combine-images-auto-blend-layers.html>

Photomicroscopy: [http://www.microscopy-uk.org.uk/mag/artmar10/history\\_photomicrography\\_ed3.pdf](http://www.microscopy-uk.org.uk/mag/artmar10/history_photomicrography_ed3.pdf)

Camera teardowns and repair tips: <http://www.fixyourcamera.org>