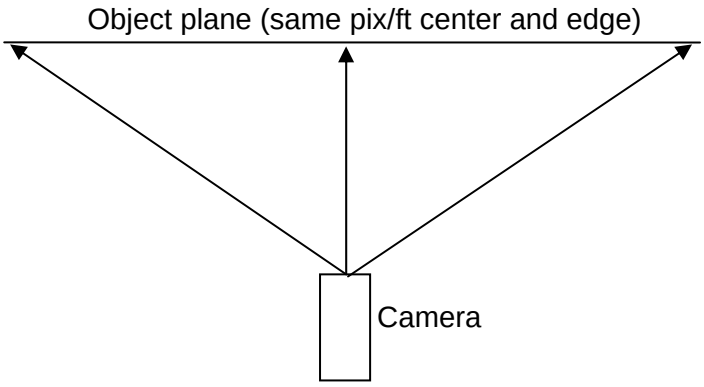
Lens Resolution with Linear Optical Technology™

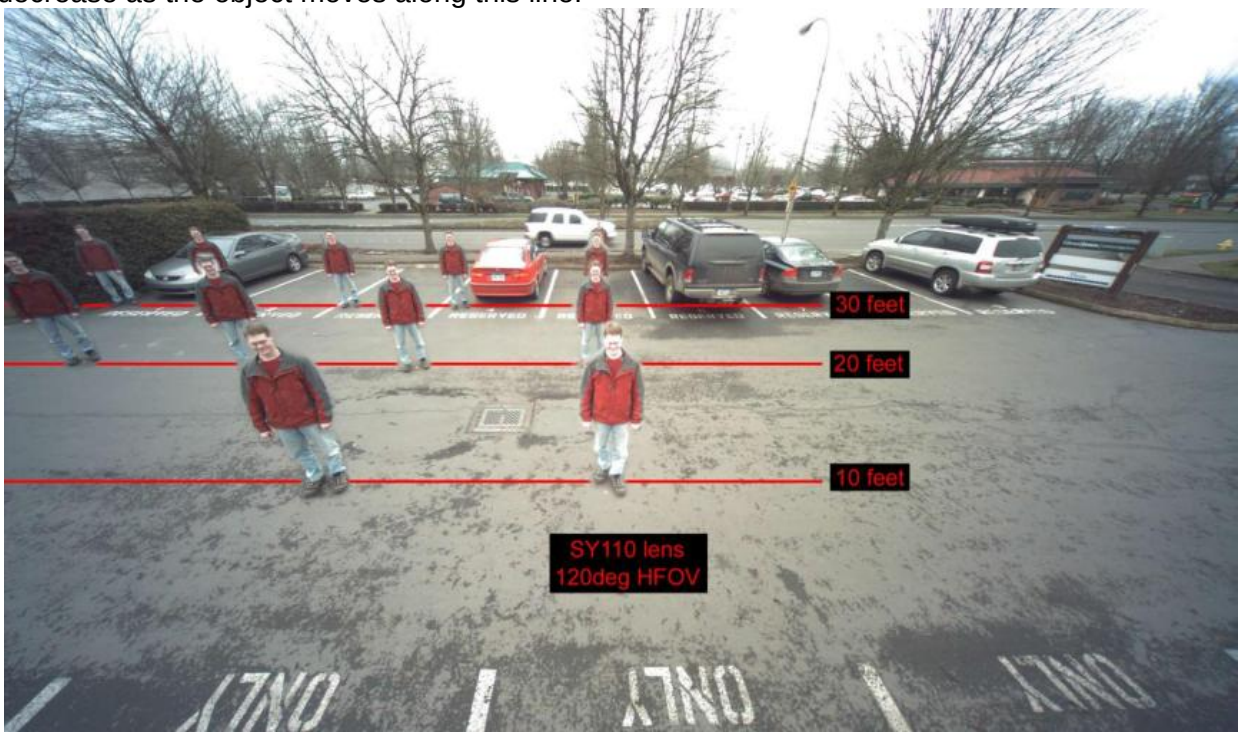
Rectilinear lenses, like those made for the security industry by Theia Technologies, keep straight lines in the real world straight on the image sensor. This creates an effect called 3D stretching or lean-over in which objects at the image edge seem to be stretched because they are being "flattened" onto a plane along the tangent angle from the lens. The wider the field of view (for rectilinear lenses), the more noticeable this effect. There is an additional benefit in increased resolution at the edges of the image because of 3D stretching.

Objects in a plane

With a rectilinear lens, for objects all in the same plane perpendicular to the camera, the resolution is the same at the center and edge, even though the objects at the edges are much farther away from the camera. This is shown in the diagram below.

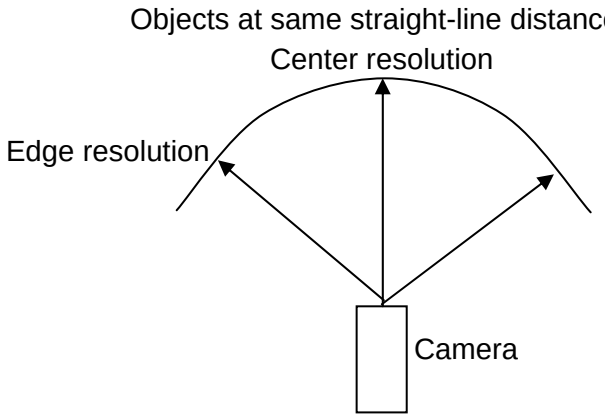


For example, if you need 20 pixels per foot and are using a 5MPix camera, the camera would be 37 feet away from an object in the center of the image (using the SY110 lens). As the object moves in a straight line as shown by the "object plane" in the diagram above, the resolution will remain 20 pixels per foot even though the object is getting farther from the camera. This is shown in the composite image below as well. The resolution of all other wide angle lenses will decrease as the object moves along this line.



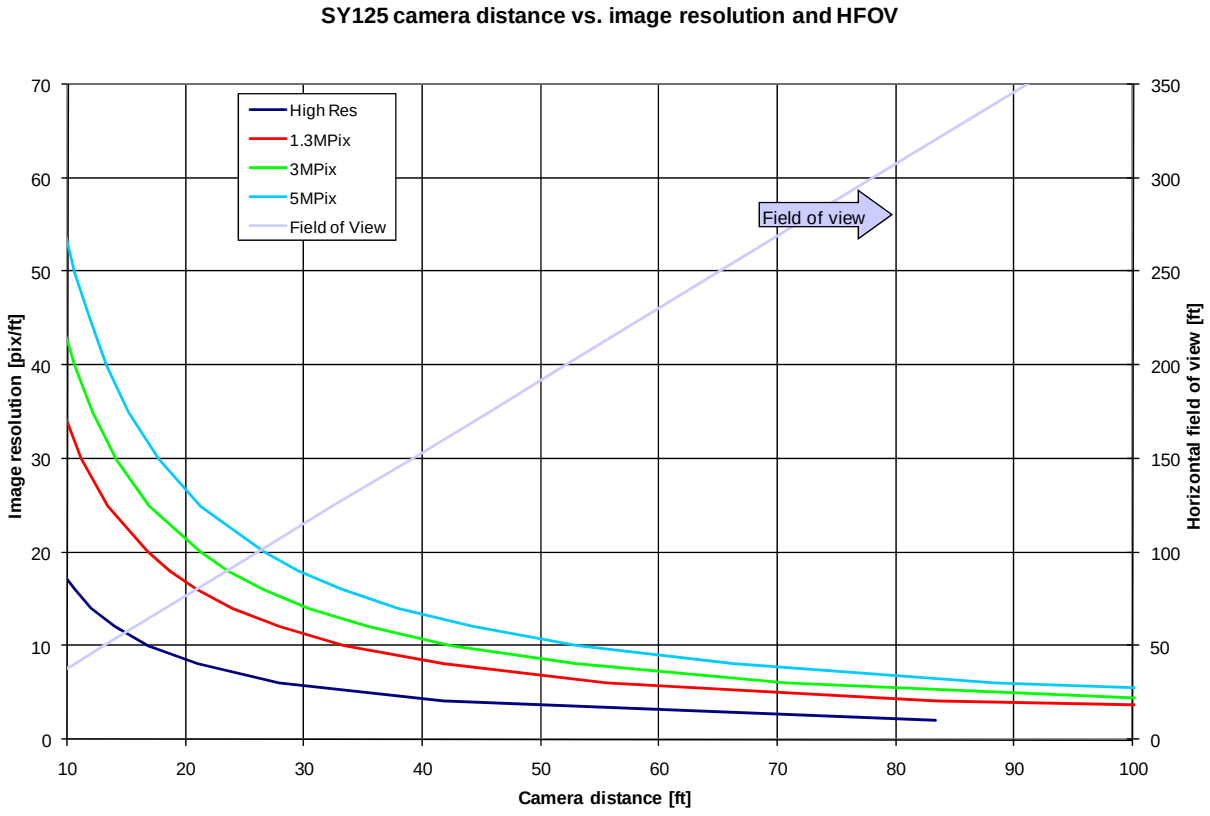
Objects in a circle

With a rectilinear lens, resolution of objects in a circle with the camera at the center is a little more complicated. Resolution at the edge of the image as a function of straight-line distance is greater than the resolution at the center of the image at the same straight-line distance. This is shown in the diagram below.

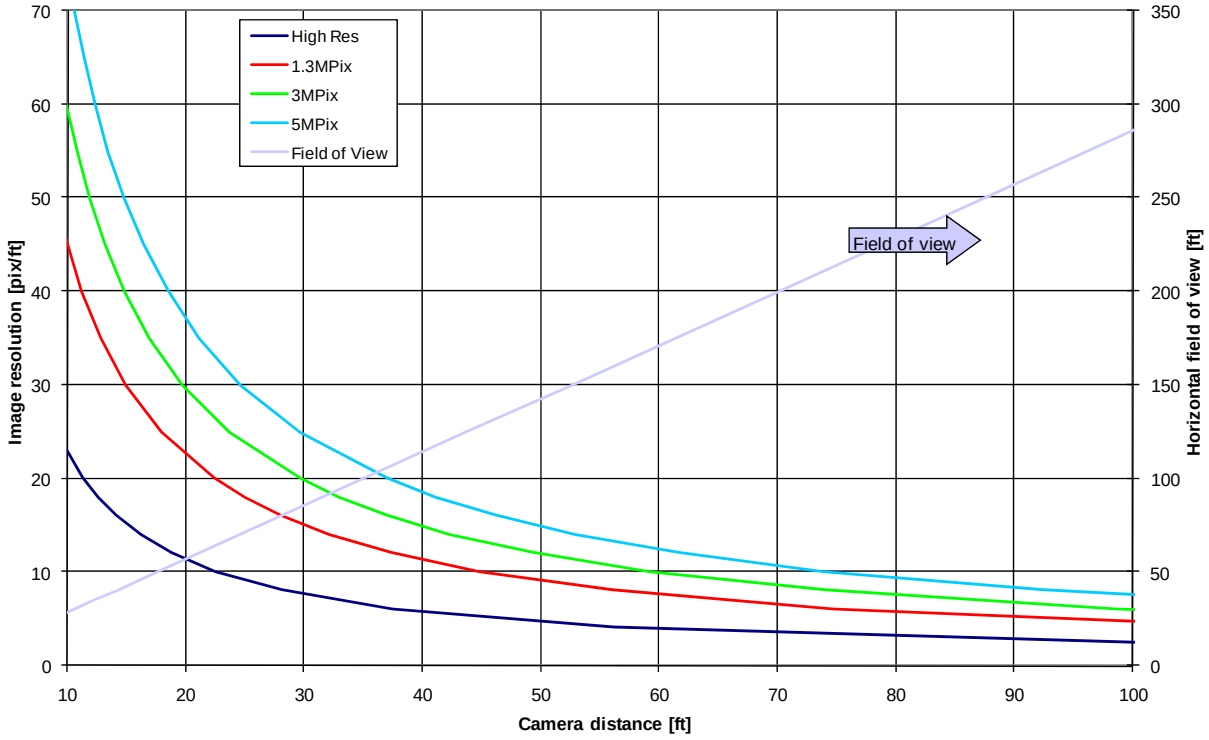


For example, if you need 20 pixels per foot at the image center and are using a 5MPix camera with the SY110 lens, the camera should be 37 feet away. As the object moves in an arc maintaining the 37 feet to the camera, the resolution will increase towards the edge (i.e. the object will cover more pixels in the image, thus appearing to stretch) reaching a maximum of 35 pixels per foot.

Theia Lenses Resolution Performance



SY110 camera distance vs. image resolution and HFOV



Resolution calculation

This formula is used to calculate the image resolution in pixels per foot for a given camera resolution and camera distance. These formulas calculate the horizontal field of view, the lens focal length, and the resolution at the image center as reflected in the above graphs.

Equation	Example
$lens\_angle = 2 * \arctan\left(\frac{image\_width}{2 * dist}\right)$	Image width is 80 feet Distance to subject is 23 feet $120^0 = 2 * \arctan\left(\frac{80'}{2 * 23'}\right)$
$focal\_length = \frac{chip\_width}{2 * \tan\left(\frac{lens\_angle}{2}\right)}$	5Mpix chip width $1.66mm = \frac{5.76mm}{2 * \tan\left(\frac{120^0}{2}\right)}$
$resolution = \frac{\#\ pixels_{horiz}}{2 * dist * \tan\left(\frac{lens\_angle}{2}\right)}$	#pixels for 5 Mpix chip $32\,pixels/\ ft = \frac{2560\,pixels}{2 * 23' * \tan\left(\frac{120^0}{2}\right)}$
	Result for 5Mpix camera and SY110 lens: **120° wide at 23 feet = 32 pix/foot for a 1.66mm focal length**

Resolution will be in pixels per foot if you specify the distance to the image in feet (in pixels per meter if you use a distance in meters).

Lens	**SY110**			
Camera	1.3MPix	2MPix*	3MPix*	5MPix
Chip size	1/3”	1/2”	1/2”	1/2.5”
Chip_width	4.8mm	6.4mm	6.4mm	5.76mm
# pixels$_{horiz}$	1280	1600	2048	2560
HFOV$_{max}$	110°	126°	126°	120°

Lens	**SY125**			
Camera	1.3MPix	2MPix*	3MPix*	5MPix
Chip size	1/3”	1/2”	1/2”	1/2.5”
Chip_width	4.8mm	6.4mm	6.4mm	5.76mm
# pixels$_{horiz}$	1280	1600	2048	2560
HFOV$_{max}$	125°	140°	140°	135°

*2MPix and 3MPix cameras (with 1/2” chips) will show dark corners.

The edge resolution is related to the center resolution by the cosine of the maximum HFOV angle.

Equation	**Example**
$edge\_resolution = \frac{center\_resolution}{\cos\left(\frac{lens\_angle_{\max}}{2}\right)}$	Edge resolution for SY110 lens $64\,pixels/\,ft = \frac{32\,pixels/\,ft}{\cos\left(\frac{120^o}{2}\right)}$

For any further explanation please contact Theia Technologies:

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