PRISMA RVD Short Range Camera Performance optimization.

Cooperative mode operations.

Desing parameters and constants:
Natrual constants:

$$r2d := \frac{180}{\pi}$$

$$h := 6.6262 \cdot 10^{-34} J \cdot s \qquad \text{Planck's constant}$$

$$c := 3 \cdot 10^{8} \frac{m}{s} \qquad \text{Velocity of Light}$$

$$k := 1.38062 \cdot 10^{-23} \cdot \frac{J}{K} \qquad \text{Boltzmann's constant}$$

Lens system:

$Dsr := 0.002 m$	Effective lens entrance aperture
$EFL := 0.020 m$	Effective focal length
$alphaLens := 0.98$	Pass band efficiency of lens system
$BWfilter := 50 \cdot 10^{-9} m$	Bandwidth of lens colour filter

CCD Constants:

$pCCDw := 8.6 \cdot 10^{-6} m$	Pixel size in wide direction
$pCCDn := 8.3 \cdot 10^{-6} m$	Pixel size in narrow direction
$nCCDw := 752$	Pixel in wide direction
$nCCDn := 2 \cdot 290$	Pixel in narrow direction
$CCDw := nCCDw \cdot pCCDw$	Size in wide direction
$CCDn := nCCDn \cdot pCCDn$	Size in narrow direction
$CCDqe := 0.35$	CCD quantum efficiency at lambda wavelength
$CCDpq := 10^{-3} s$	Electronic shutter granularity
$CCDfw := 175000$	Full well capacity per pixel

Target parameters:

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$DIMmin := 0.1 m$	Minimum distance between LEDs in a group
$DIMmax := 0.6 m$	Maximum distance between LEDs in a group
$DIMdoc := 0.14 m$	Maximum distance between LEDs in docking group
$ILED := 180 \cdot 10^{-3} A$	Pulse current for LED
$alphaLED := 0.01 \frac{W}{}$	Light yield factor for LED in pulsed operation
$lambdaLED := 735 \cdot 10^{-9} m$	Centre wavelenght for LED

$\text{LEDfwhm} := 130\deg$ Full width half maximum of light cone of LED

$\text{pqLED} := 1 \cdot 10^{-3} \text{s}$ Pulse length step size

$\text{Adirecttarget} := 0.02 \cdot 0.8 \text{m}^2$ Typical area of target in direct sunlight

$\text{Aalbedotarget} := 0.3 \cdot 0.8 \text{m}^2$ Typical area of target in Earth albedo light

$\text{albedoTarget} := 0.2$ Average albedo of target

$\text{EarthAlbedo} := 0.2$ Earth albedo reflected power at Target orbit

$\text{Tsz} := 0.005 \text{m}$ Diameter of optical stimulator LED (illuminated spot size of lens)

$\text{ROIsz} := 20$ Size in pixels of centroid region for LEDs

Resolution and FOV:
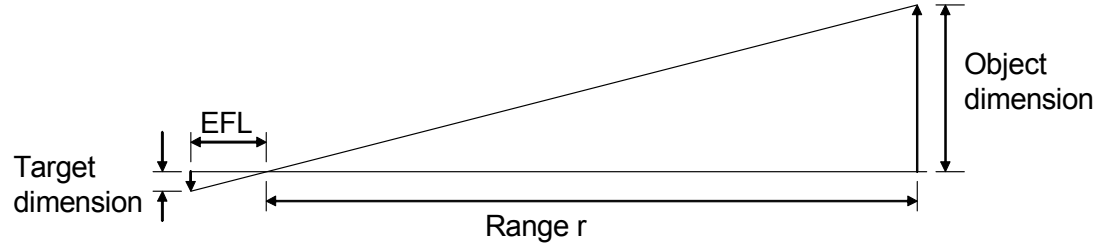
Minimum distance at which a full pattern may be observed in one image:

$$rSRmin := \frac{DIMmax}{2} \cdot \frac{EFL}{\left(\dfrac{CCDw}{2}\right)} \qquad rSRmin = 1.856 \text{ m}$$
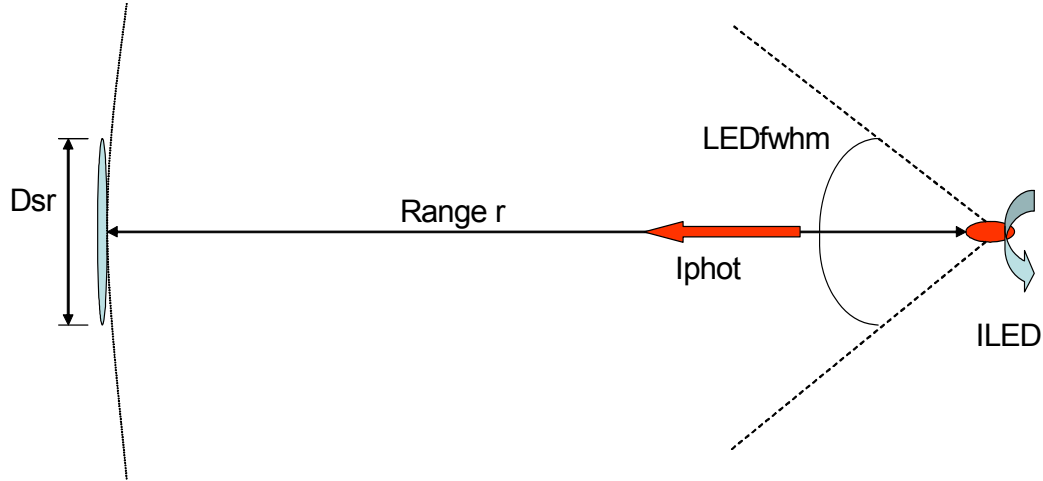
Minimum distance at which the full docking pattern may be observed in one image:

$$rSRDOCmin := 0.5 \cdot DIMdoc \cdot \frac{EFL}{\left(\dfrac{CCDw}{2}\right)} \qquad rSRDOCmin = 0.433 \text{ m}$$

Maximum distance at which the pattern may still be resolved in an image:

$$rSRmax := DIMmin \cdot \frac{EFL}{(3 \cdot pCCDn)} \qquad rSRmax = 80.321 \text{ m}$$

Photon housekeeping:

$j := 1 .. 16$ Target pulse length step factor

$i := 0 .. 99$ $r_i := (i + 1)m$ Range in meters

$Wlum_j := ILED \cdot alphaLED \cdot pqLED \cdot j$ Luminous energy per pulse $Wlum_1 = 1.8 \times 10^{-6} J$

$saLED := 2 \cdot \pi \cdot \left(1 - \cos\left(\dfrac{LEDfwhm}{2} \right) \right)$ Solid angle illuminated by LED $saLED = 3.628$

$n0_j := \dfrac{Wlum_j}{h \cdot \dfrac{c}{lambdaLED}}$ Photons per LED pulse $n0_1 = 6.655 \times 10^{12}$

$nphotCCD_{i,j} := \left[\dfrac{\left[\pi \cdot \left(\dfrac{Dsr}{2} \right)^2 \right]}{saLED \cdot \left(r_i \right)^2} \right] \cdot n0_j$ Number of LED photons per pulse to Lens

Number of electrons registered by CCD per LED and pulse

$neCCD_{i,j} := nphotCCD_{i,j} \cdot CCDqe \cdot alphaLens$ min range max pulse $neCCD_{0,16} = 3.163 \times 1$

                                                 max range min pulse $neCCD_{99,1} = 197.686$

$nsmax := neCCD_{1,1}$ Signal at close operations $nsmax = 4.942 \times 10^5$

$nsmin := neCCD_{99,16}$ Signal at far operations $nsmin = 3.163 \times 10^3$

$RatioS := \dfrac{nsmax}{nsmin}$ Signal ratio max to min $RatioS = 156.25$

$$\text{S2FW} := \frac{\text{nsmax}}{\text{CCDfw}}$$

Signal to full well capacity

$$\text{S2FW} = 2.824$$

Noise photons from target.

$$c1 := 2 \cdot h \cdot c^2$$

1'st radiation constant per solid angle

$$c1 = 0 \; \frac{m^4 \cdot kg}{s^3}$$

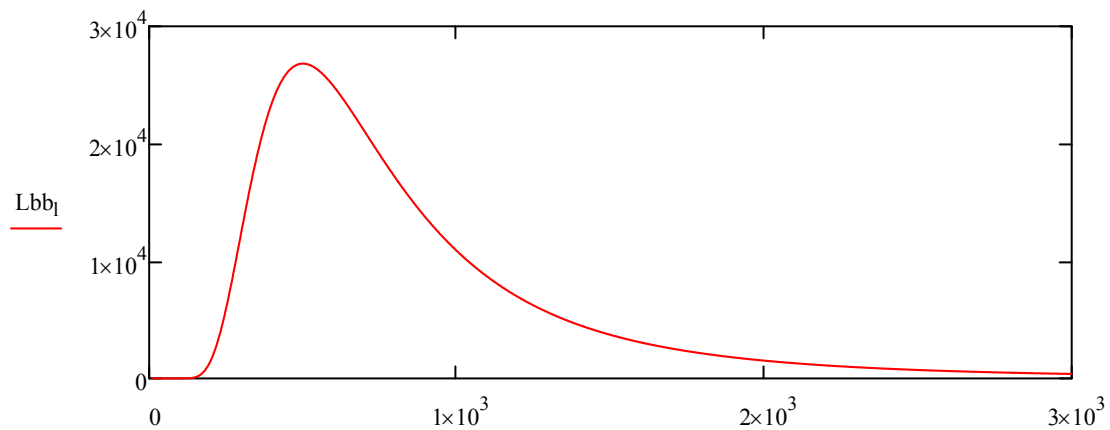$$c2 := h \cdot \frac{c}{k}$$

2'nd radiation constant

$$c2 = 0.014 \, m \cdot K$$

$$l := 10 .. 3000$$

$$\lambda_l := \left(l \cdot 10^{-9}\right) m$$

$$T := 5800 K$$

$$\text{Lbb}_l := \frac{10^{-9} \cdot c1}{\left(\lambda_l\right)^5 \cdot \left(e^{\left(\frac{c2}{\lambda_l \cdot T}\right)} - 1\right)}$$

Spectral radiance of a black body radiator

$$\text{Lbb}_{1000} = 1.087 \times 10^4 \; \frac{kg}{m \cdot s}$$

$$\text{Rsun} := 109.12 \cdot 6378000 \, m$$

Radius of the Sun

$$\text{Lsun}_l := \text{Lbb}_l \cdot \text{Rsun}^2 \cdot \pi$$

Spectral Radiance of full Sun

$$\text{Lsun}_{1000} = 1.654 \times 10^{22}$$

$$\text{Rs} := 1 \cdot 150000000000 \, m$$

Distance Target to Sun

$$\text{ERs}_l := \frac{\text{Lsun}_l}{\text{Rs}^2}$$

Sp. Irradiance at Rs distance from Sun

$$\text{ERs}_{1000} = 0.735 \; \frac{kg}{m \cdot s^3}$$

$$\text{Etotal} := \sum \text{ERs} \cdot 1 m$$

Irradiance at Rs distance from Sun

$$\text{Etotal} = 1.35 \times 10^3 \; \frac{kg}{s^3}$$

$$\text{BWERs} := \sum_{i = 735-25}^{735+25} \left(\text{ERs}_i \cdot 1 m\right)$$

Power in pass band of lens

$$\text{BWERs} = 67.784 \; \frac{kg}{s^3}$$

$$\text{WBWsun} := \text{BWERs} \cdot \text{albedoTarget} \cdot (\text{Adirecttarget} + \text{EarthAlbedo} \cdot \text{Aalbedotarget})$$

Luminous power reflected towards SRcam

$$\text{WBWsun} = 0.868 \text{ W}$$

ss := 0 .. 299   Electronic shutter steps

$$ts_{ss} := (1 + ss) \cdot \text{CCDpq}$$ Shutter time $$ts_0 = 1 \times 10^{-3} \text{ s}$$

$$\text{nnoise}_{ss} := \frac{\text{WBWsun} \cdot ts_{ss}}{h \cdot \dfrac{c}{\text{lambdaLED}}}$$ Noise photons per shutter time $$\text{nnoise}_0 = 3.208 \times 10^{15}$$

$$\text{nphotnoiseCCD}_{i, ss} := \left[\frac{\left[\pi \cdot \left(\dfrac{\text{Dsr}}{2} \right)^2 \right]}{2\pi \cdot \left(r_i \right)^2} \right] \cdot \text{nnoise}_{ss}$$ Number of noise photons per pulse to Lens

Number of noise electrons registered by CCD per LED and pulse

$$\text{nenCCD}_{i, ss} := \text{nphotnoiseCCD}_{i, ss} \cdot \text{CCDqe} \cdot \text{alphaLens}$$

	min range max pulse	$\text{neCCD}_{0, 16} = 3.163 \times 1$
	max range min pulse	$\text{neCCD}_{99, 1} = 197.686$
$\text{nsnmax} := \text{nenCCD}_{1, 1}$	Signal at close operations	$\text{nsnmax} = 2.751 \times 10$
$\text{nsnmin} := \text{nenCCD}_{99, 16}$	Signal at far operations	$\text{nsnmin} = 9.353 \times 10$
$\text{RatioSn} := \dfrac{\text{nsnmax}}{\text{nsnmin}}$	Signal ratio max to min	$\text{RatioSn} = 294.118$

Pixel size vis-a-vis target spot size:
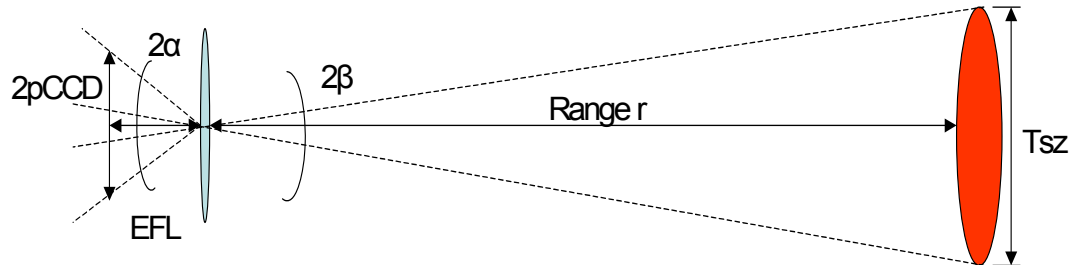
$$\alpha := \operatorname{atan}\left(\frac{pCCDn}{EFL}\right) \cdot r2d \qquad \text{Pixel angular size}$$
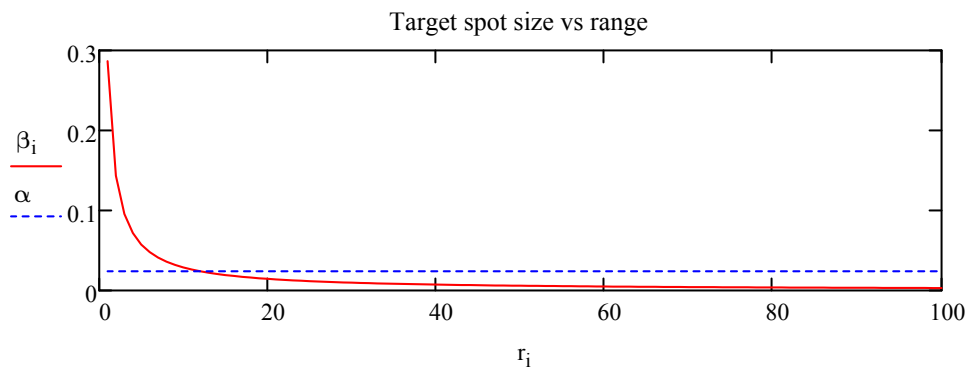
$\alpha = 0.024$

$3600 \cdot \alpha = 85.6$

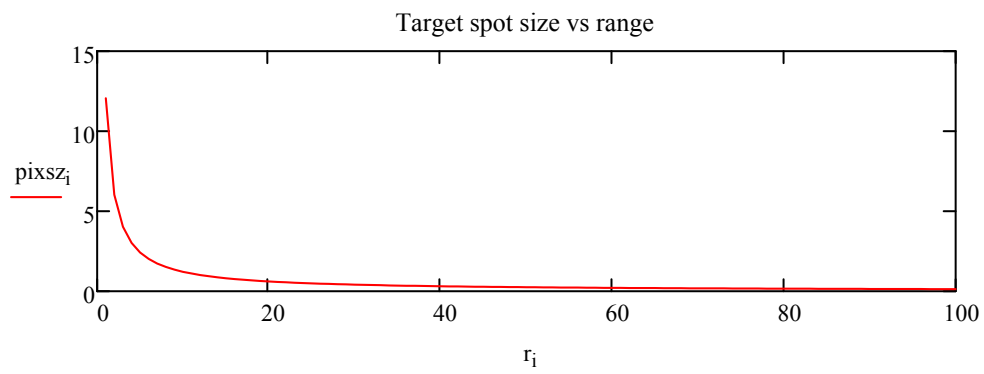$$\beta_i := \operatorname{atan}\left(\frac{Tsz}{r_i}\right) \cdot r2d \qquad \text{Target spot size}$$

Target spot size vs range

$$rc := Tsz \cdot \frac{EFL}{pCCDn} \qquad \text{Size match distance} \qquad rc = 12.048 \, m$$

$$pixsz_i := \frac{EFL \cdot Tsz}{pCCDn \cdot r_i} \qquad \text{Spot size in number of pixels}$$

Target spot size vs range

$$\beta T_i := atan\left(\frac{Aalbedotarget^{0.5}}{r_i}\right) \cdot r2d \quad \text{Target body size}$$

Target spot size vs range
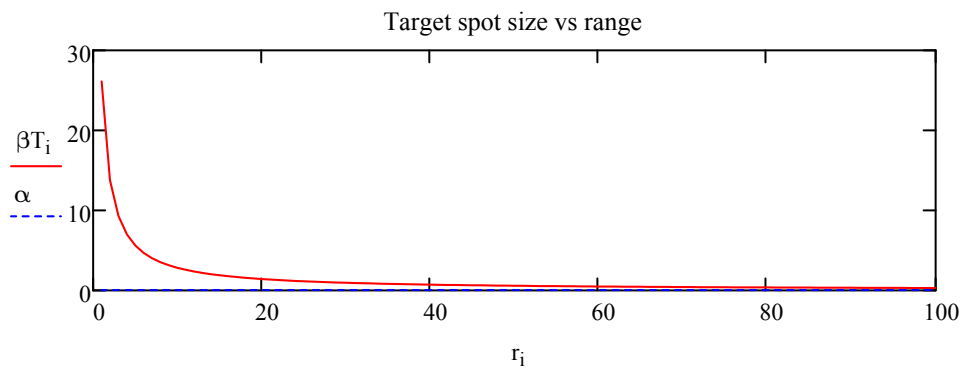
$$rc := Aalbedotarget^{0.5} \cdot \frac{EFL}{pCCDn} \quad \text{Size match distance} \qquad rc = 1.18 \times 10^3 \, m$$

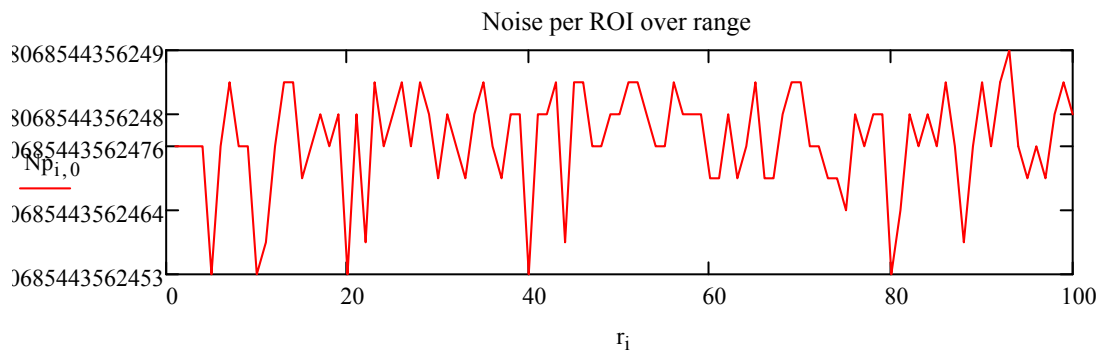$$pixT_i := \frac{EFL \cdot Aalbedotarget^{0.5}}{pCCDn \cdot r_i} \quad \text{Spot size in number of pixels}$$

Target spot size vs range
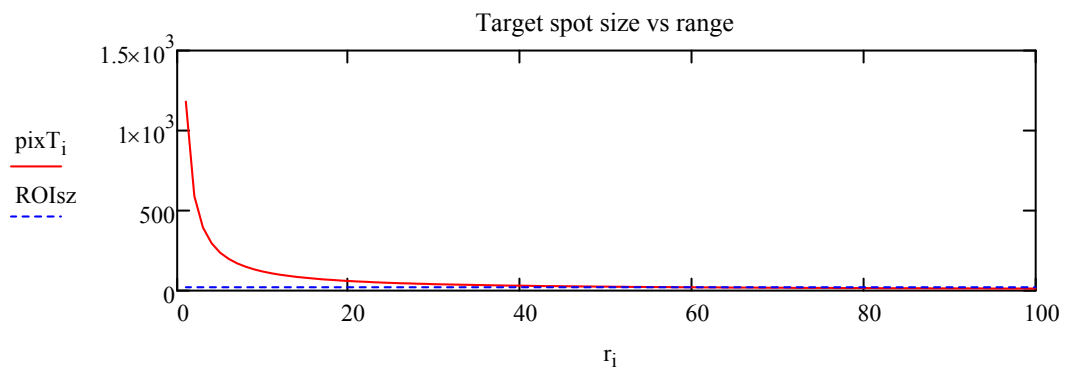
$$rcT := Aalbedotarget^{0.5} \cdot \frac{EFL}{ROIsz \cdot pCCDn} \quad \text{Size match distance} \quad rcT = 59.024 \, m$$

$$NpR_{i,ss} := if\left[r_i < rcT, nenCCD_{i,ss} \cdot \left(\frac{ROIsz}{pixT_i}\right)^2, nenCCD_{i,ss}\right]$$ Noise per ROI
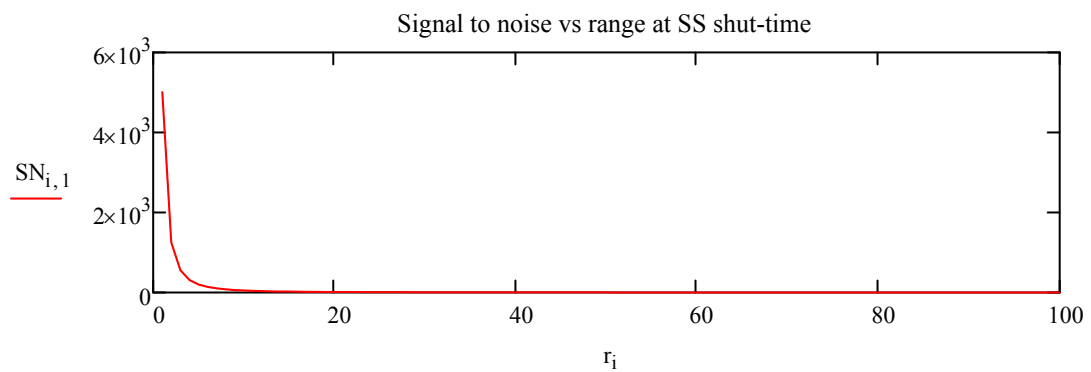
Noise per ROI over range
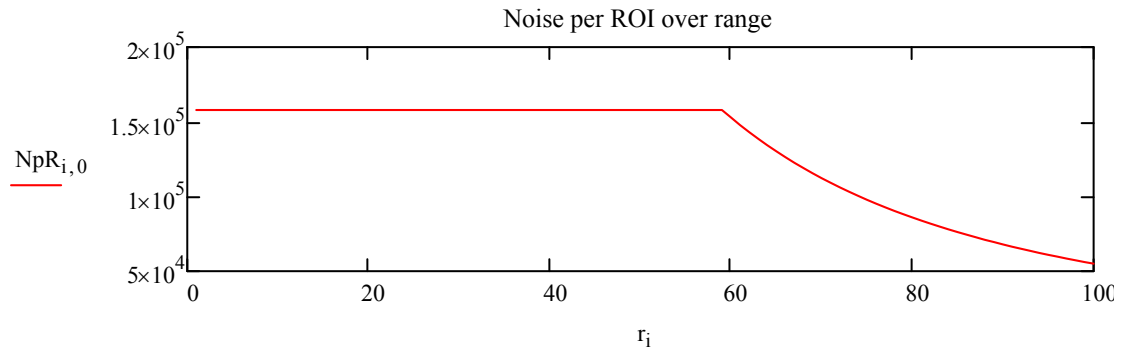
$$Np_{i,ss} := if\left[r_i < rc, nenCCD_{i,ss} \cdot \left(\frac{1}{pixT_i}\right)^2, nenCCD_{i,ss}\right]$$ Noise per pixel

Noise per ROI over range

$$SS := 0$$

$$SN_{i,j} := \frac{neCCD_{i,j}}{Np_{i,SS}}$$ Signal to noise ratio centre pixel to background pixel at SS shuttertime

Signal to noise vs range at SS shut-time
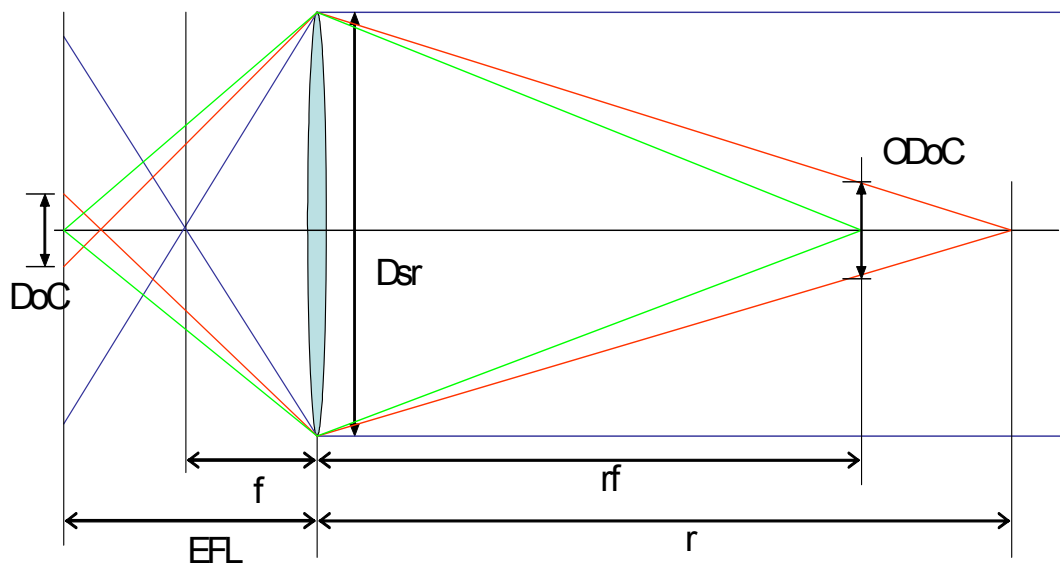

$$SNmr := SN_{99,1}$$ S/N at max range and min pulse time $$SNmr = 0.501$$

$$neCCD_{99,1} = 197.686$$

Focal lenght and sharpess depth:
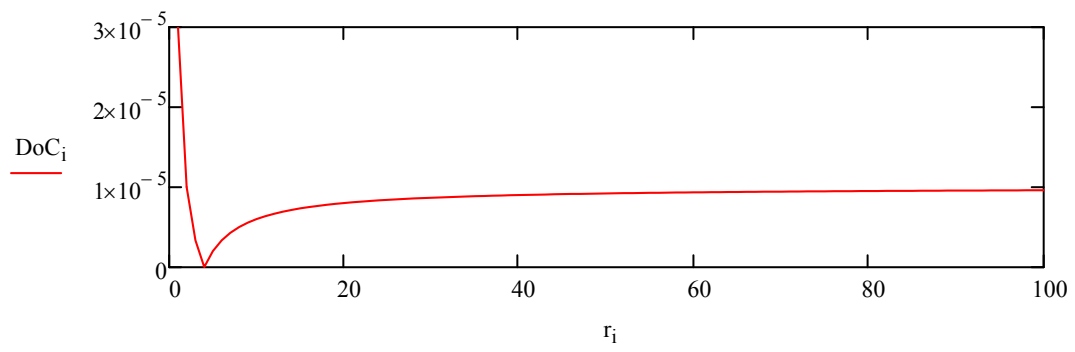

rf := 4m   Chosen focal length of system

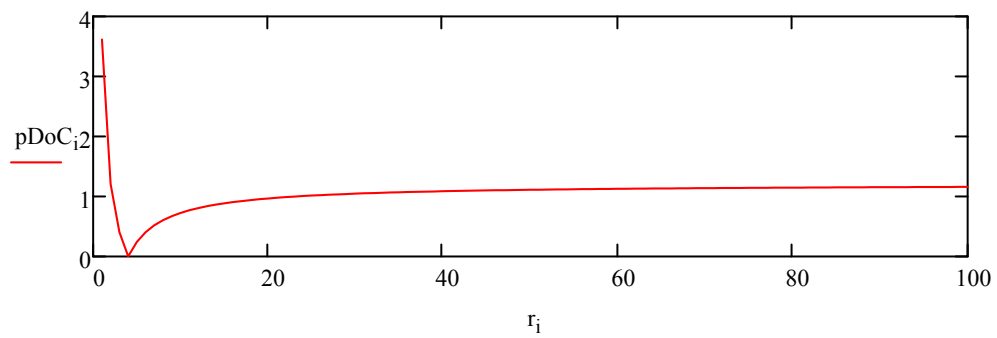$$f := \frac{1}{\left(\frac{1}{rf} + \frac{1}{EFL}\right)}$$ focal lenght of lens $f = 0.02\,m$

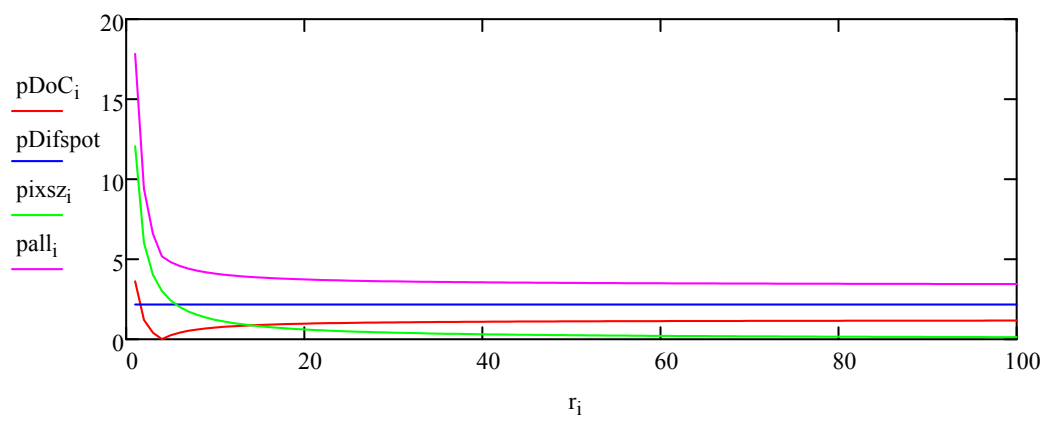$$DoC_i := Dsr \cdot \frac{|r_i - rf|}{r_i} \cdot \frac{f}{rf - f}$$ Diameter of confusion $DoC_{10} = 6.364 \times 10^{-6}\,m$

$$pDoC_i := \frac{DoC_i}{pCCDn}$$

Diameter of confusion in pixels

$$Difspot := 2EFL \cdot \tan\left(1.22 \cdot \frac{lambdaLED}{Dsr}\right)$$ Diffraction spot size on CCD $Difspot = 1.793 \times 10^{-5}$ n

$$pDifspot := \frac{Difspot}{pCCDn}$$ Diffraction spot in pix on CCD $pDifspot = 2.161$

$$pall_i := pDoC_i + pDifspot + pixsz_i$$

0^7

$$\frac{g}{s^3}$$

$$\frac{m \cdot kg}{s^3}$$

0^7

8

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