PRISMA RVD Short Range Camera Performance optimization.

Cooperative mode operations.

Desing parameters and constants:
Natrual constants:

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

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

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

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

Lens system:

$Dsr := 0.002m$ Effective lens entrance aperture

$EFL := 0.020m$ 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:

$DIMmin := 0.1m$ Minimum distance between LEDs in a group

$DIMmax := 0.6m$ Maximum distance between LEDs in a group

$DIMdoc := 0.14m$ Maximum distance between LEDs in docking group

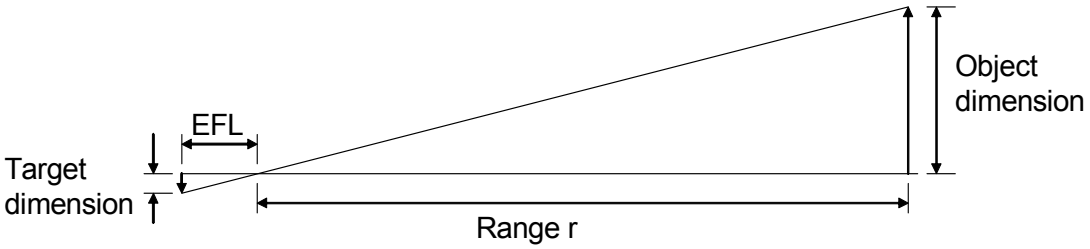
$ILED := 180 \cdot 10^{-3} A$ Pulse current for LED

$alphaLED := 0.01 \frac{W}{}$ Light yield factor for LED in pulsed operation

$lambdaLED := 735 \cdot 10^{-9} m$ Centre wavelenght for LED

$LEDfwhm := 130deg$	Full width half maximum of light cone of LED
$pqLED := 1 \cdot 10^{-3} s$	Pulse length step size
$Adirecttarget := 0.02 \cdot 0.8 m^2$	Typical area of target in direct sunlight
$Aalbedotarget := 0.3 \cdot 0.8 m^2$	Typical area of target in Earth albedo light
$albedoTarget := 0.2$	Average albedo of target
$EarthAlbedo := 0.2$	Earth albedo reflected power at Target orbit
$Tsz := 0.005 m$	Diameter of optical stimulator LED (illuminated spot size of lens)
$ROIsz := 20$	Size in pixels of centroid region for LEDs

Resolution and FOV:



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

$$rSRmin := \frac{DIMmax}{2} \cdot \frac{EFL}{\left(\frac{CCDw}{2}\right)} \qquad rSRmin = 1.856\,m$$

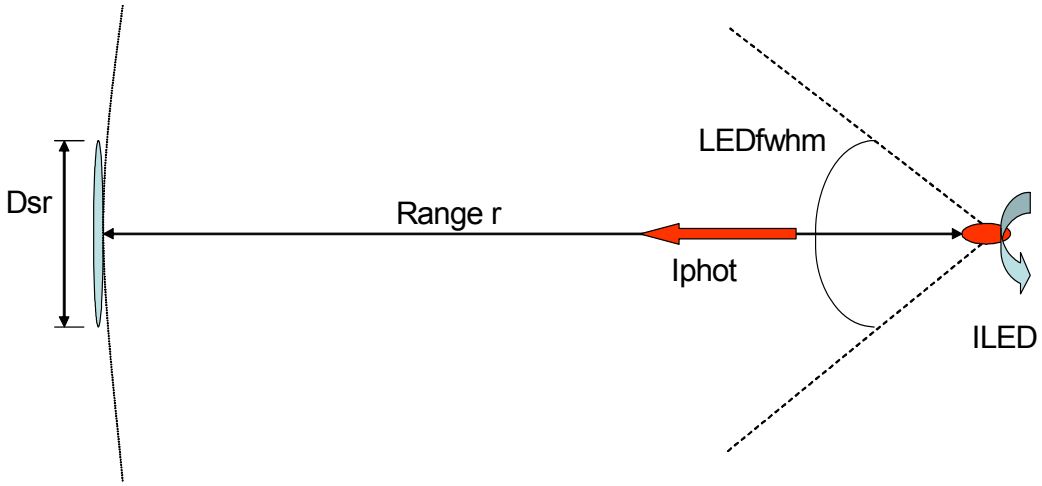
Minimum distance at which the full docking pattern may be observed in one image:

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

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

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

Photon housekeeping:



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

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

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

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

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

$nphotCCD_{i,j} := \left[\frac{\left[\pi \cdot \left(\frac{Dsr}{2}\right)^2\right]}{saLED \cdot \left(r_i\right)^2}\right] \cdot n0_j$ 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 $nsmin = 3.163 \times 10^3$

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

$S2FW := \frac{nsmax}{CCDfw}$ Signal to full well capacity $S2FW = 2.824$

Noise photons from target.

$c1 := 2 \cdot h \cdot c^2$ 1'st radiation constant per solid angle $c1 = 0 \frac{m^4 \cdot kg}{s^3}$

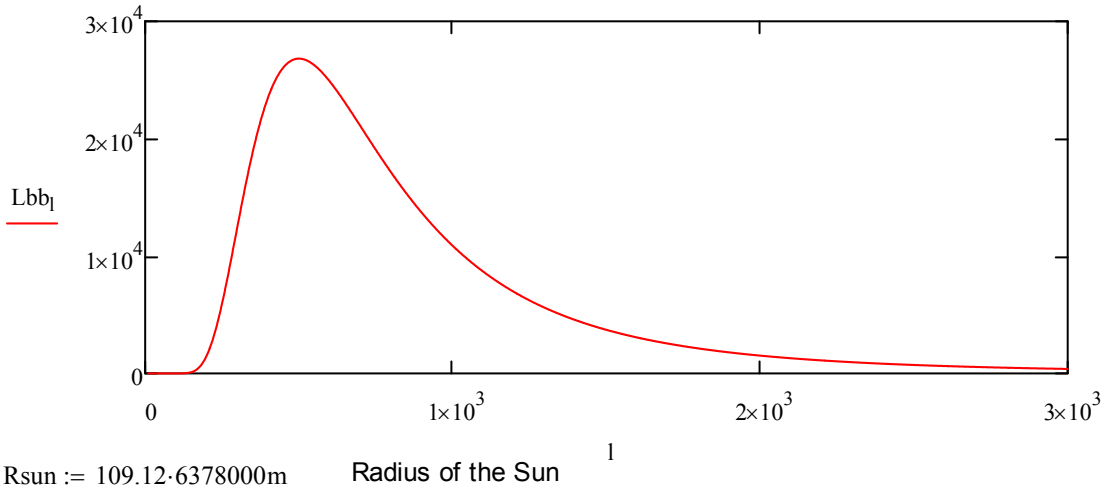
$c2 := h \cdot \frac{c}{k}$ 2'nd radiation constant $c2 = 0.014\ m \cdot K$

$l := 10 .. 3000$

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

$T := 5800K$

$Lbb_l := \frac{10^{-9} \cdot c1}{(\lambda_l)^5 \cdot \left(e^{\frac{c2}{\lambda_l \cdot T}} - 1\right)}$ Spectral radiance of a black body radiator $Lbb_{1000} = 1.087 \times 10^4 \frac{kg}{m \cdot s}$



$Rsun := 109.12 \cdot 6378000 m$ Radius of the Sun

$Lsun_l := Lbb_l \cdot Rsun^2 \cdot \pi$ Spectral Radiance of full Sun $Lsun_{1000} = 1.654 \times 10^{22}$

$Rs := 1 \cdot 150000000000 m$ Distance Target to Sun

$ERs_l := \frac{Lsun_l}{Rs^2}$ Sp. Irradiance at Rs distance from Sun $ERs_{1000} = 0.735 \frac{kg}{m \cdot s^3}$

$Etotal := \sum_{735+25} ERs \cdot 1m$ Irradiance at Rs distance from Sun $Etotal = 1.35 \times 10^3 \frac{kg}{s^3}$

$BWERs := \sum_{i=735-25} (ERs_i \cdot 1m)$ Power in pass band of lens $BWERs = 67.784 \frac{kg}{s^3}$

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

Luminous power reflected towards SRcam

$WBWsun = 0.868\ W$

$ss := 0 .. 299$ Electronic shutter steps

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

$$nnoise_{ss} := \frac{WBWsun \cdot ts_{ss}}{h \cdot \frac{c}{lambdaLED}}$$

Noise photons per shutter time $nnoise_0 = 3.208 \times 10^{15}$

$$nphotnoiseCCD_{i,ss} := \left[\frac{\left[\pi \cdot \left(\frac{Dsr}{2}\right)^2\right]}{2\pi \cdot (r_i)^2}\right] \cdot nnoise_{ss}$$

Number of noise photons per pulse to Lens

Number of noise electrons registered by CCD per LED and pulse

$nenCCD_{i,ss} := nphotnoiseCCD_{i,ss} \cdot CCDqe \cdot alphaLens$

min range max pulse $neCCD_{0,16} = 3.163 \times 1$

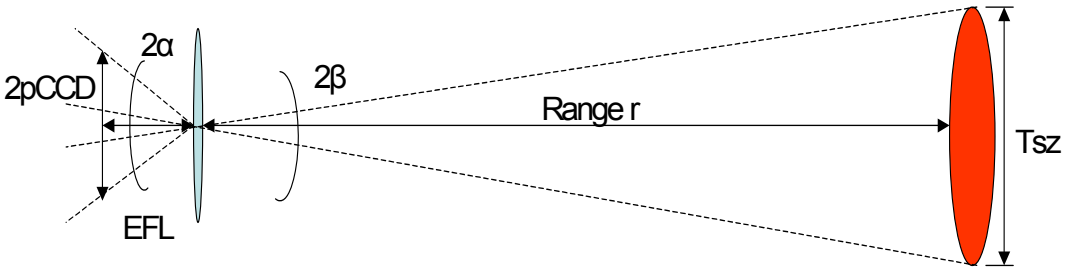
max range min pulse $neCCD_{99,1} = 197.686$

$nsnmax := nenCCD_{1,1}$ Signal at close operations $nsnmax = 2.751 \times 10$

$nsnmin := nenCCD_{99,16}$ Signal at far operations $nsnmin = 9.353 \times 10$

$RatioSn := \frac{nsnmax}{nsnmin}$ Signal ratio max to min $RatioSn = 294.118$

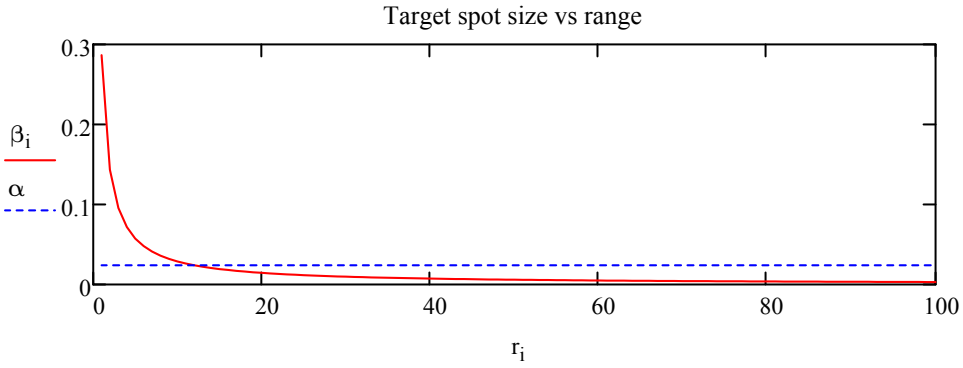
Pixel size vis-a-vis target spot size:



$$\alpha := \operatorname{atan}\left(\frac{pCCDn}{EFL}\right)\cdot r2d$$ Pixel angular size $\alpha = 0.024$

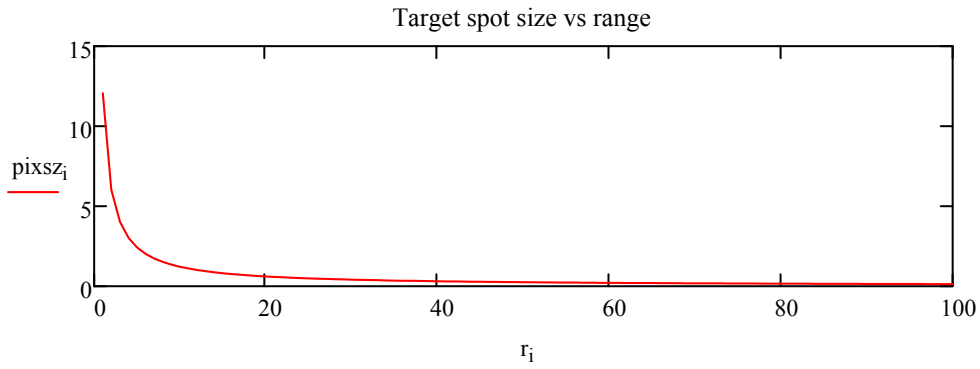
$3600\cdot\alpha = 85.6$

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

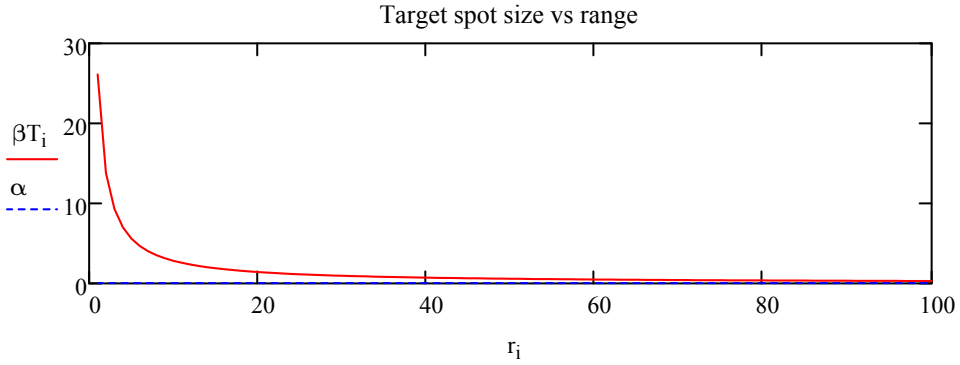


$$rc := Tsz\cdot\frac{EFL}{pCCDn}$$ Size match distance $rc = 12.048\,m$

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

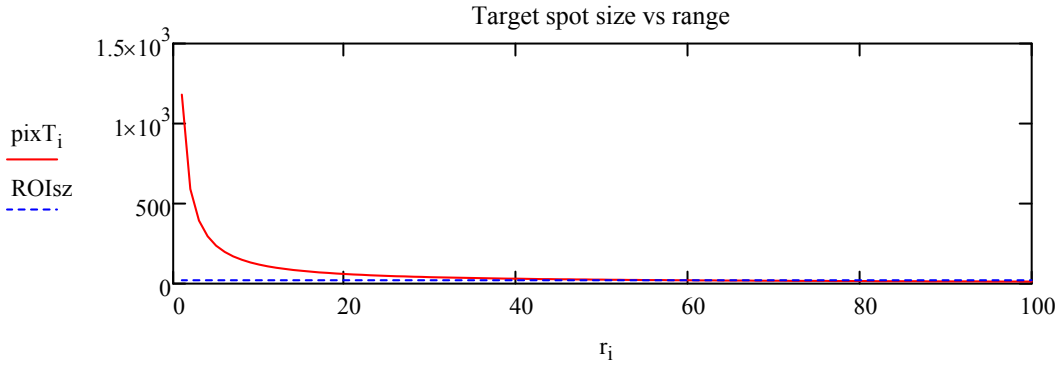


$$\beta T_i := \operatorname{atan}\left(\frac{Aalbedotarget^{0.5}}{r_i}\right)\cdot r2d$$ Target body size



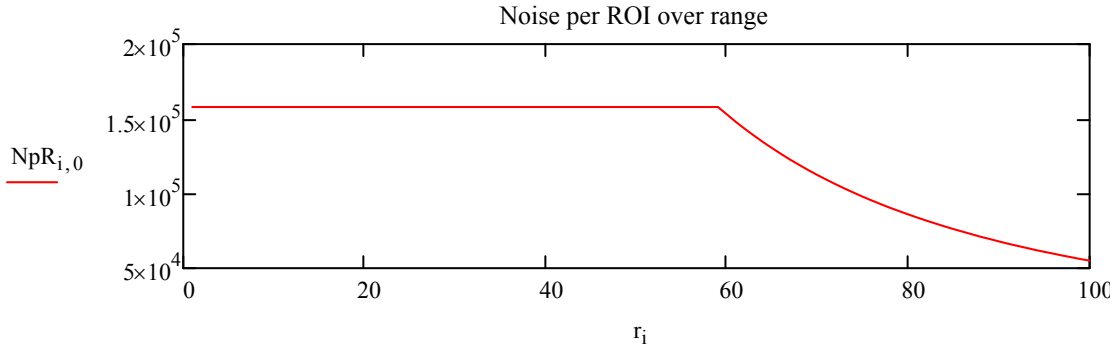
$$rc := Aalbedotarget^{0.5}\cdot\frac{EFL}{pCCDn}$$ Size match distance $rc = 1.18\times 10^{3}\,m$

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

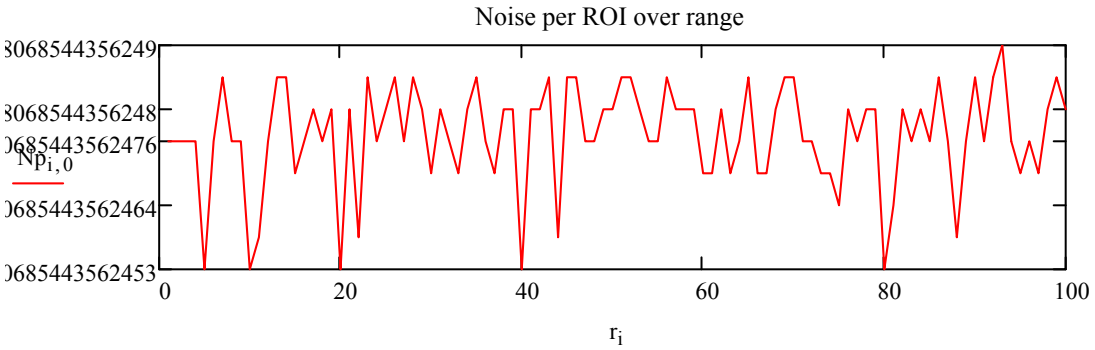


$$rcT := Aalbedotarget^{0.5}\cdot\frac{EFL}{ROIsz\cdot pCCDn}$$ Size match distance $rcT = 59.024\,m$

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

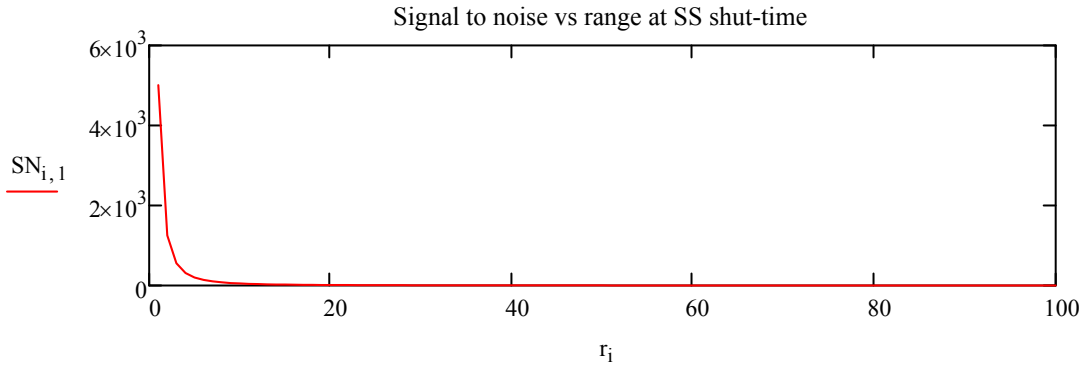


$$Np_{i,ss} := \text{if}\left[r_i < rc, nenCCD_{i,ss}\cdot\left(\frac{1}{pixT_i}\right)^2, nenCCD_{i,ss}\right]$$ Noise per pixel



$SS := 0$

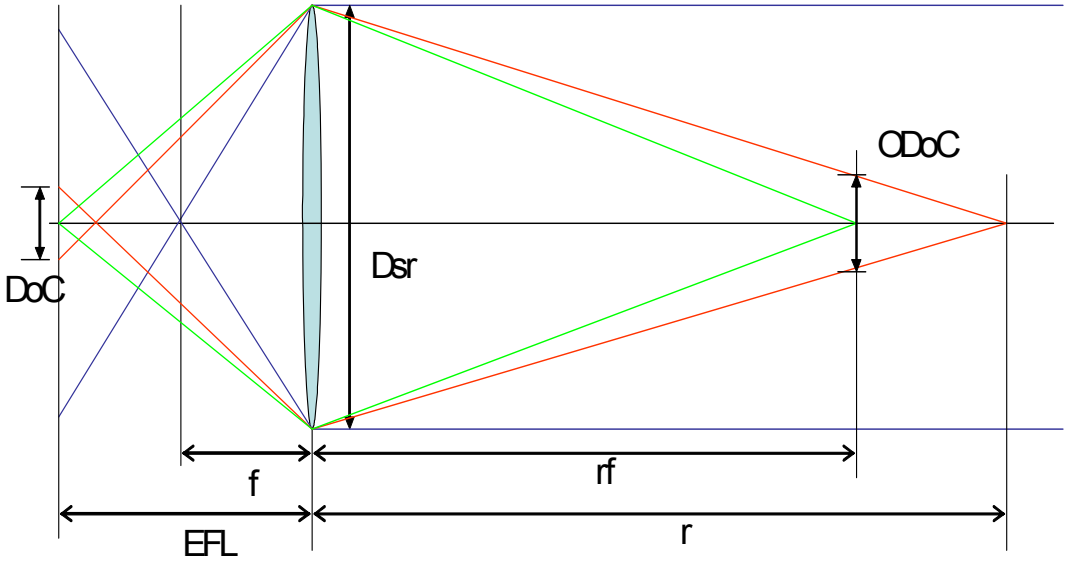
$$SN_{i,j} := \frac{neCCD_{i,j}}{Np_{i,SS}}$$ Signal to noise ratio centre pixel to background pixel at SS shuttertime



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

$neCCD_{99,1} = 197.686$

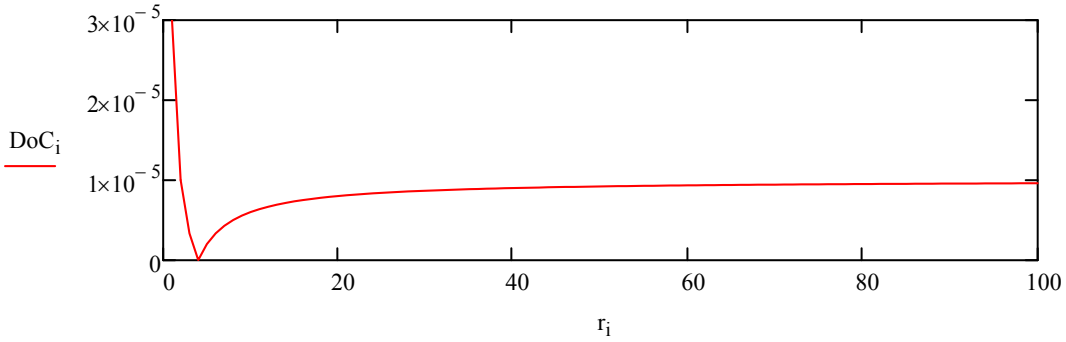
Focal lenght and sharpess depth:



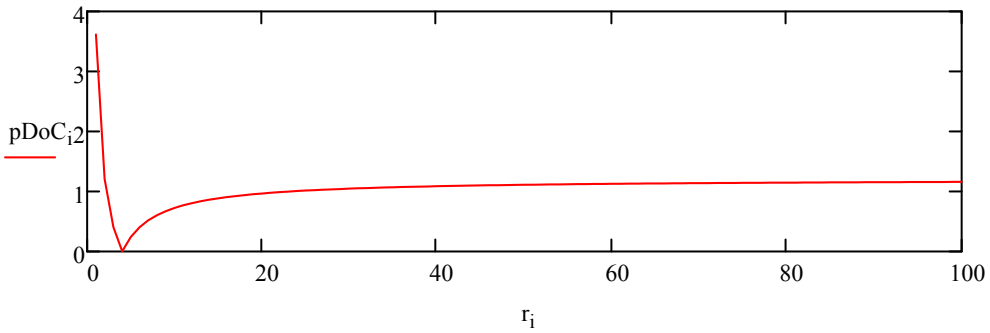
$rf := 4m$ Chosen focal length of system

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

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



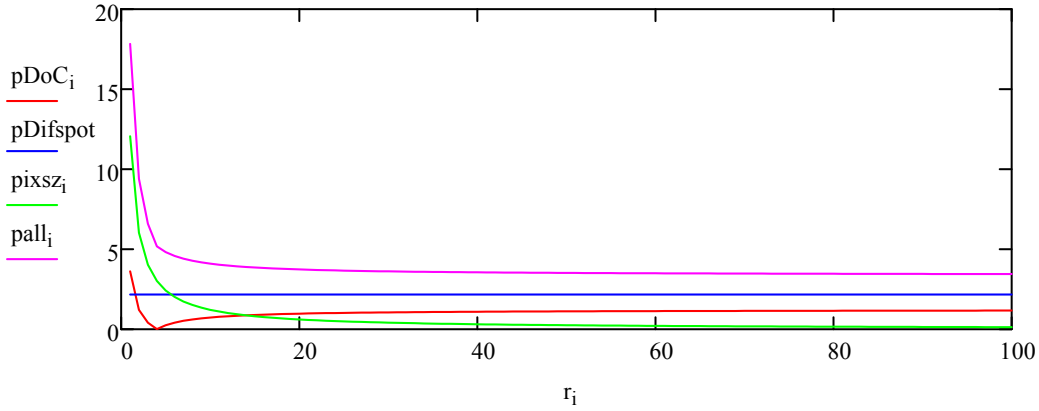
$$pDoC_i := \frac{DoC_i}{pCCDn}$$ Diameter of confusion in pixels



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

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

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


pDoC_i
pDifspot
pixsz_i
pall_i
20
15
10
5
0
0
20
40
60
80
100
r_i

0^7

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

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

0^{7}

^{8}

5

)

1