PRISMA RVD Short Range Camera Performance optimization.

Cooperative mode operations.

Desing parameters and constants:

Natrual constants:

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

$h := 6.62621\cdot 10^{-34} J\cdot s$	Planck's constant
$c := 3\cdot 10^{8} \frac{m}{s}$	Velocity of Light
$k := 1.380621\cdot 10^{-23}\cdot \frac{J}{K}$	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:

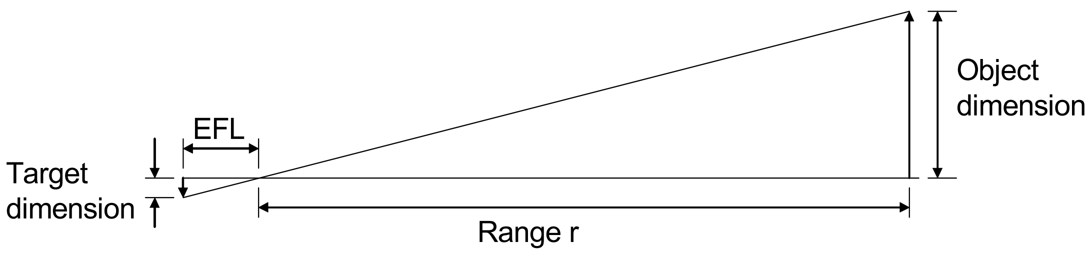
$pCCDw := 8.6\cdot 10^{-6} m$	Pixel size in wide direction
$pCCDn := 8.3\cdot 10^{-6} m$	Pixel size in narrow direction
$nCCDw := 752$	Pixel in wide direction
$nCCDn := 2\cdot 290$	Pixel in narrow direction
$CCDw := nCCDw\cdot pCCDw$	Size in wide direction
$CCDn := nCCDn\cdot pCCDn$	Size in narrow direction
$CCDqe := 0.35$	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
$alphaLED := 0.01 \frac{W}{A}$	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
$Adirecttarget := 0.02 \cdot 0.8m^2$	Typical area of target in direct sunlight
$Aalbedotarget := 0.3 \cdot 0.8m^2$	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
$Tsz := 0.005m$	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:

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

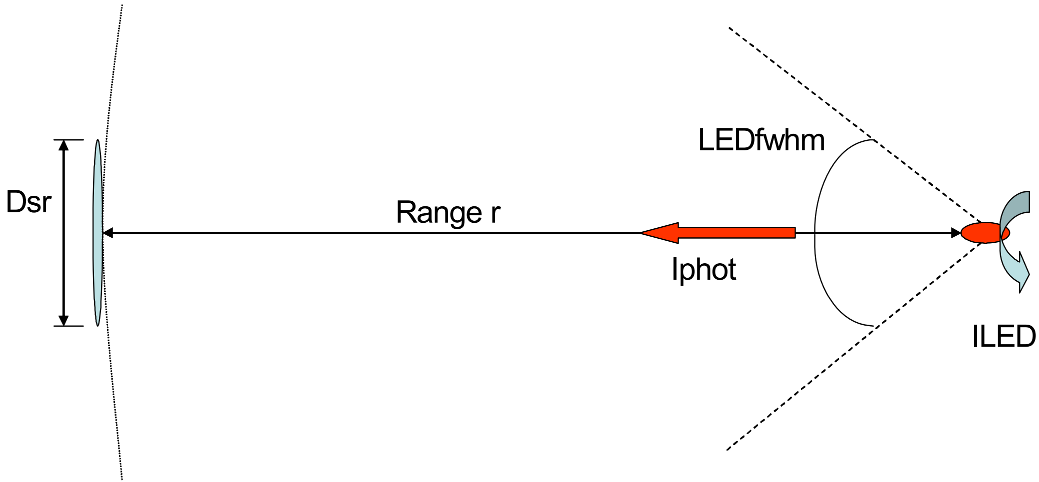
Minimum distance at which the full docking pattern may be observed in one image:

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

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	
$i := 0 .. 99 \quad r_i := (i+1)m$	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	$n0_1 = 6.655 \times 10^{12}$
$nphotCCD_{i,j} := \left[\frac{\left[\pi \cdot \left(\frac{Dsr}{2}\right)^2\right]}{saLED \cdot (r_i)^2}\right] \cdot n0_j$	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 $c1 = 0 \frac{m^4 \cdot kg}{s^3}$

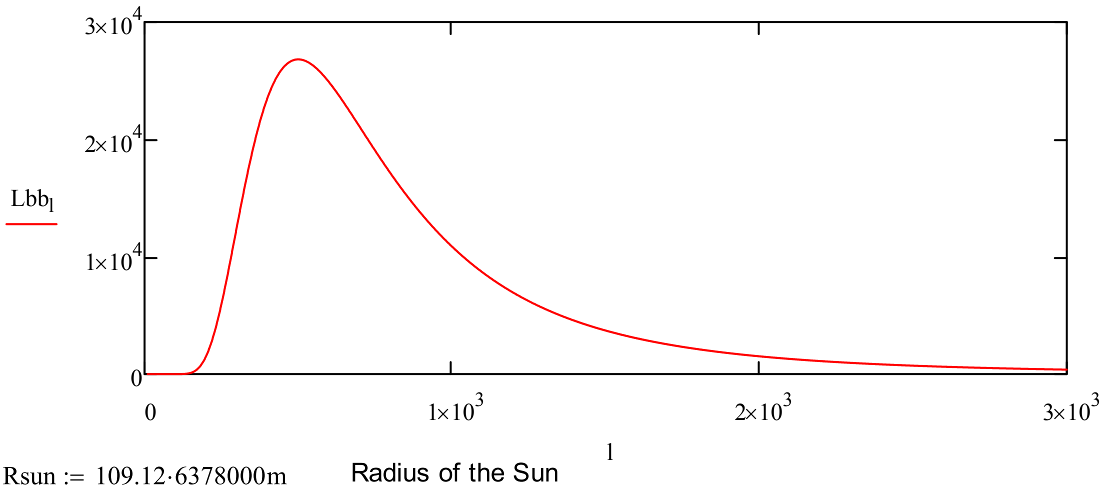
$c2 := h \cdot \frac{c}{k}$ 2'nd radiation constant $c2 = 0.014\, m \cdot K$

$l := 10 .. 3000$

$\lambda_l := \left(1 \cdot 10^{-9}\right) m$

$T := 5800K$

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



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

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

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

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

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

$BWERs := \sum_{i = 735-25}^{735+25} \left(ERs_i \cdot 1m\right)$ 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 $neCCD_{0,16} = 3.163 \times 1$

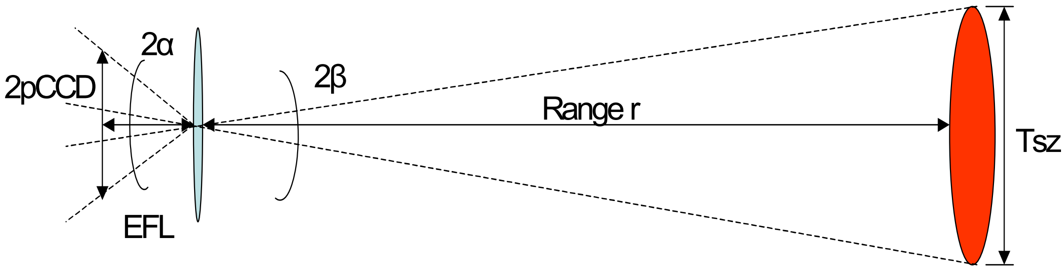
max range min pulse $neCCD_{99,1} = 197.686$

$nsnmax := nenCCD_{1,1}$ 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 $RatioSn = 294.118$

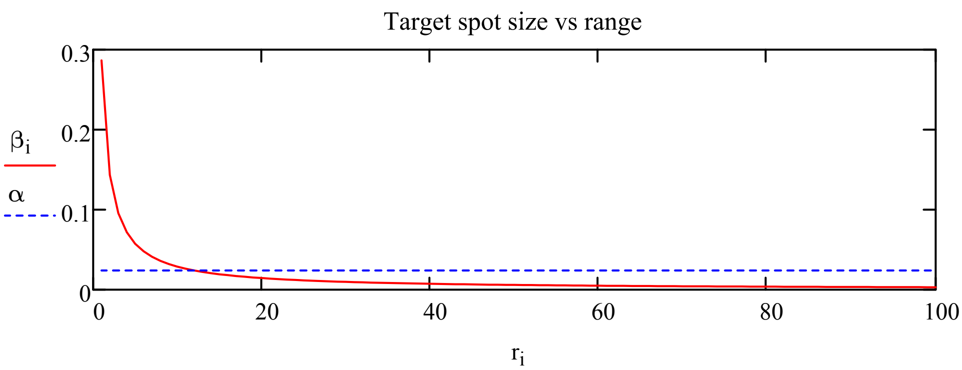
Pixel size vis-a-vis target spot size:



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

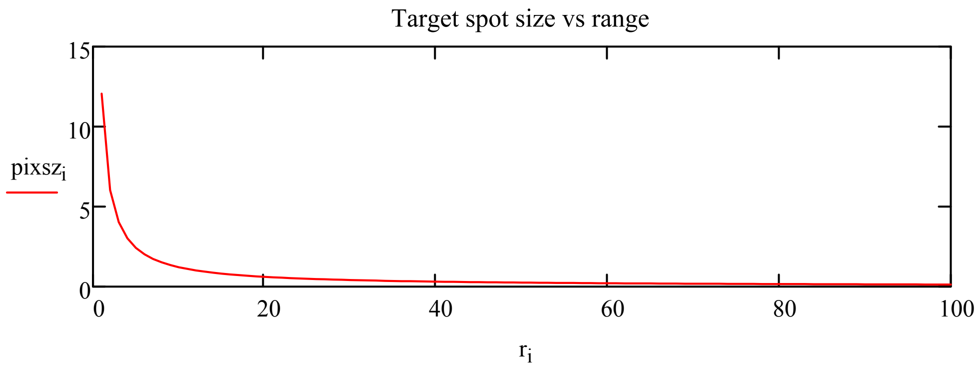
$3600\cdot\alpha = 85.6$

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

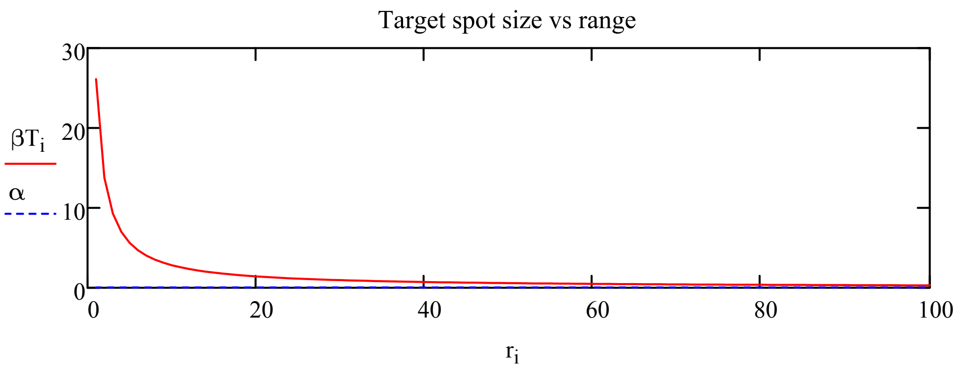


$$rc := Tsz\cdot\frac{EFL}{pCCDn}$$ Size match distance $rc = 12.048\,\mathrm{m}$

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

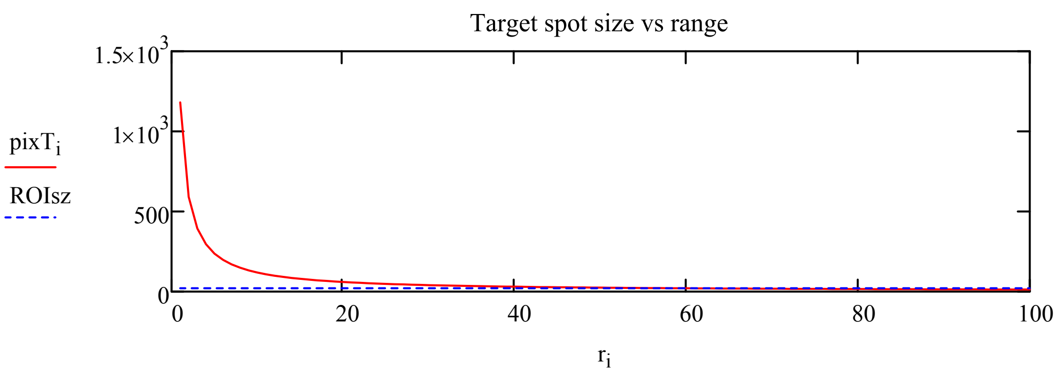


$$\beta T_i := \operatorname{atan}\left(\frac{\text{Aalbedotarget}^{0.5}}{r_i}\right)\cdot r2d$$ Target body size



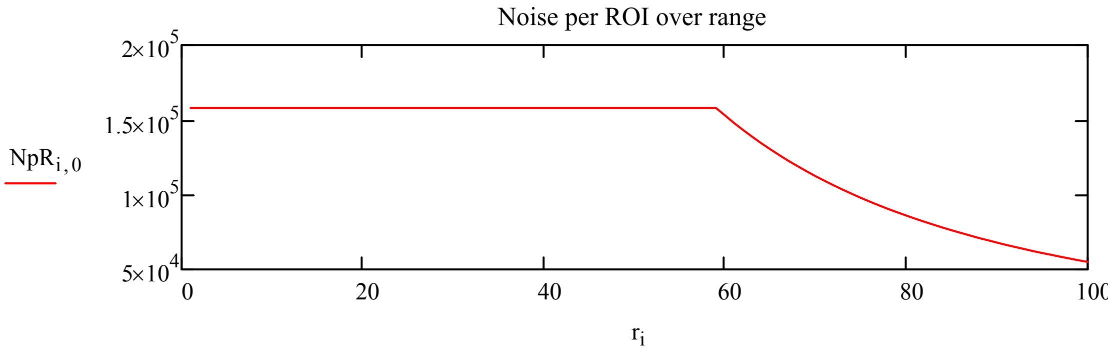
$$rc := \text{Aalbedotarget}^{0.5}\cdot\frac{\text{EFL}}{\text{pCCDn}}$$ Size match distance $rc = 1.18\times 10^{3}\,\text{m}$

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

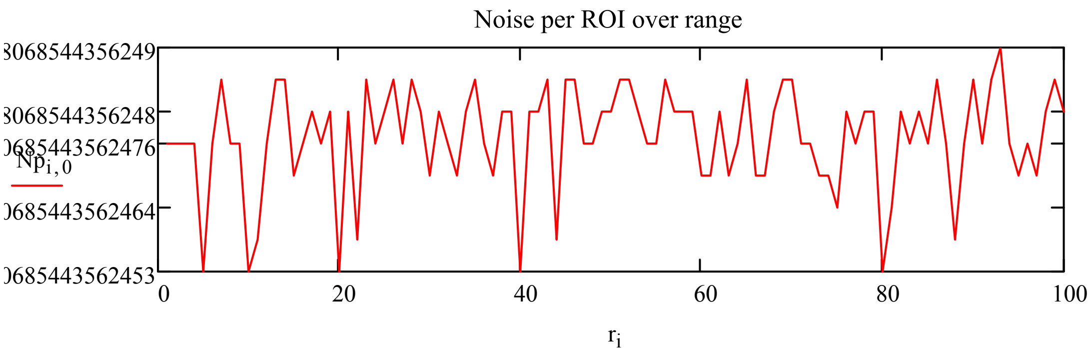


$$rcT := \text{Aalbedotarget}^{0.5}\cdot\frac{\text{EFL}}{\text{ROIsz}\cdot\text{pCCDn}}$$ Size match distance $rcT = 59.024\,\text{m}$

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

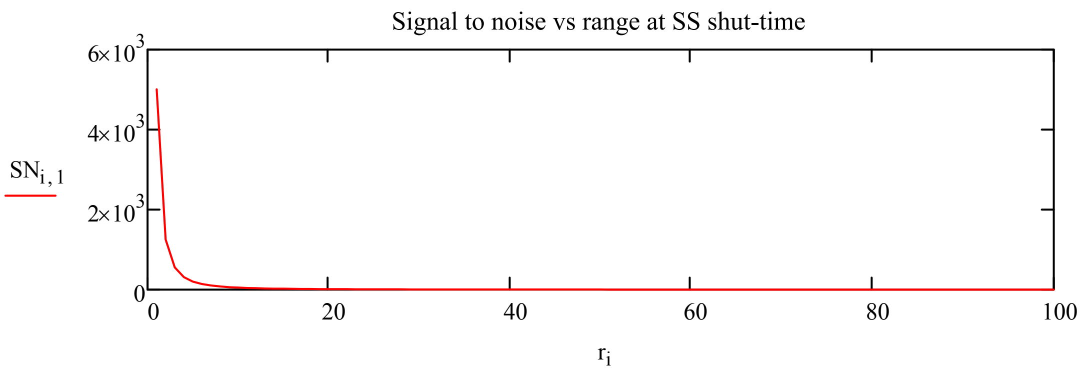


$Np_{i,ss} := \mathrm{if}\left[r_i < rc, nenCCD_{i,ss} \cdot \left(\frac{1}{pixT_i}\right)^2, nenCCD_{i,ss}\right]$ Noise per pixel



$SS := 0$

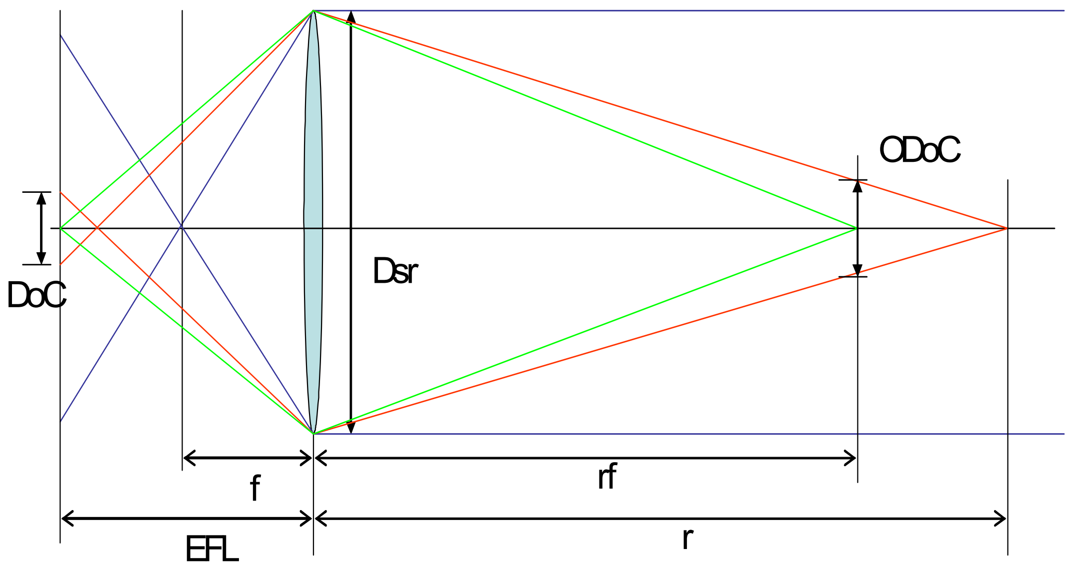
$SN_{i,j} := \frac{neCCD_{i,j}}{Np_{i,SS}}$ Signal to noise ratio centre pixel to background pixel at SS shuttertime



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

$neCCD_{99,1} = 197.686$

Focal lenght and sharpess depth:



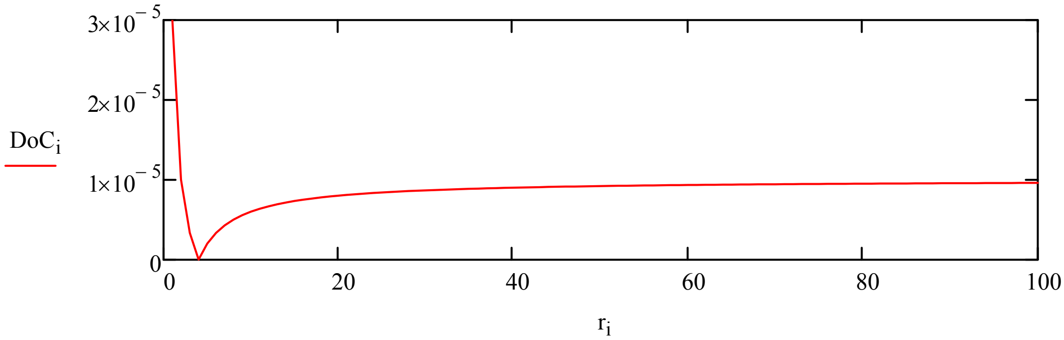
$rf := 4m$ Chosen focal length of system

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

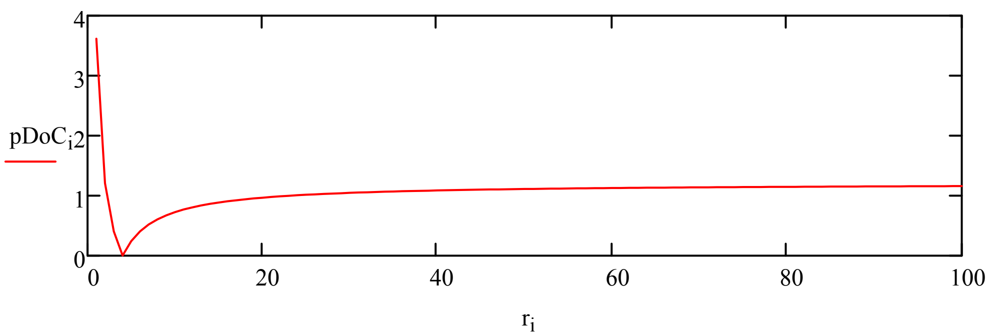
$f = 0.02\,m$

$$DoC_i := Dsr \cdot \frac{\left|r_i - rf\right|}{r_i} \cdot \frac{f}{rf - f}$$ Diameter of confusion

$DoC_{10} = 6.364 \times 10^{-6}\,m$



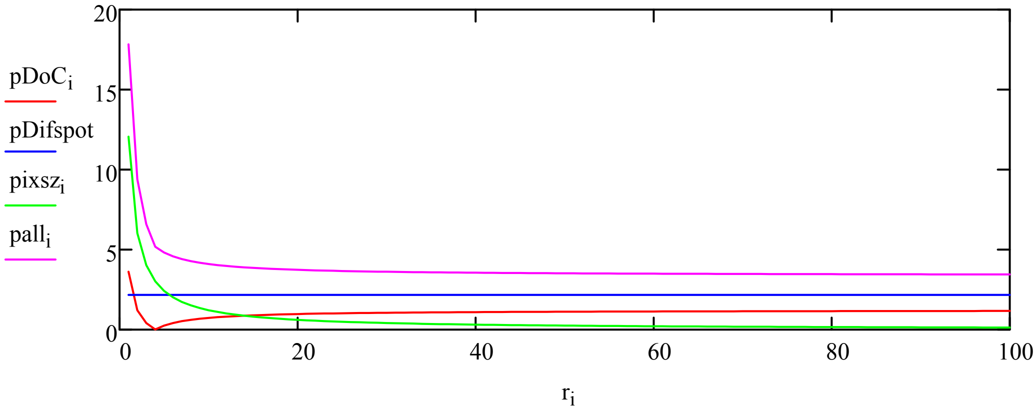
$pDoC_i := \frac{DoC_i}{pCCDn}$ Diameter of confusion in pixels



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

$pDifspot := \frac{Difspot}{pCCDn}$ 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